PNNL-27831

Pacific Northwest NATIONAL LABORATORY

Pacific Northwest National Laboratory Annual Site Environmental Report for Calendar Year 2017

September 2018

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U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
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Pacific Northwest National Laboratory
Richland, Washington 99352

Pacific Northwest National Laboratory
Annual Site Environmental Report for 2017
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- ☐ To learn general information about PNNL
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- ☐ Other: ______________________________

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EXECUTIVE SUMMARY

Pacific Northwest National Laboratory (PNNL), one of the U.S. Department of Energy (DOE) Office of Science's 10 national laboratories, provides innovative science and technology development in the areas of energy and the environment, fundamental and computational science, and national security. DOE's Pacific Northwest Site Office is responsible for oversight of PNNL.

This report provides a synopsis of ongoing environmental management performance and compliance activities conducted during 2017 to meet the requirements of DOE Order 231.1B, *Environmental, Safety and Health Reporting*, and DOE Order 458.1, *Radiation Protection of the Public and the Environment*, assuring that the public is informed of any event that could adversely affect the health and safety of the public, site staff, or the environment. The report addresses the operations that occur on the PNNL Richland Campus in Richland, Washington, and at the PNNL Marine Sciences Laboratory (MSL) near Sequim, Washington. It describes the location of and background for each facility; addresses compliance with all applicable DOE, federal, state, and local regulations and site-specific permits; documents environmental monitoring efforts and their status; presents potential radiation doses to staff and the public in the surrounding areas; and describes DOE-required data quality assurance methods used for data verification.

Compliance with Federal, State, and Local Laws and Regulations in 2017

PNNL is subject to many federal, state, and local environmental laws, regulations, guidance decrees, DOE requirements, and Executive Orders as well as site-specific permits. Detailed requirements are integrated into all PNNL projects by means of environmental compliance representatives assigned to assess and assist with each project. PNNL continued to exhibit an excellent compliance record in 2017. No violation notices were received from any regulatory agency, required reports were submitted, necessary reviews and permits for research and support activities were obtained, and all sitewide permits were current. Detailed information regarding 2017 compliance may be found in Section 2.0.

Environmental Sustainability Performance

PNNL's environmental management system (EMS) has been certified to meet the requirements of the International Standards Organization (ISO) 14001 standards since 2002, demonstrating commitment to safe and sustainable operations, and satisfying the requirements of DOE Order 436.1, *Departmental Sustainability*. The EMS is integrated into PNNL's Integrated Safety Management Program, which assures that staff are aware of project scope, risks/hazards, and controls available to address functions, processes, and procedures used to plan and perform work safely. PNNL is dedicated to responsible planning for and management of resources that could be affected by facility operations and exhibits excellent environmental sustainability performance in disciplines including energy and water conservation and sustainable building design, assuming a leadership position in planning for a cleaner future. See Section 3.0 for further details concerning environmental and sustainability performance.

Environmental Monitoring and Dose Assessment

PNNL monitors air and water quality to assure compliance with all federal, state, and local regulatory requirements.

Air Emissions. Airborne emissions from PNNL facilities are monitored to assess the effectiveness of emission treatment and control systems as well as pollution management practices. The Benton Clean Air Agency implements and enforces most federal and state requirements on the PNNL Richland Campus, and the Olympic Region Clean Air Agency implements and enforces most federal and state requirements at MSL. There were no unplanned releases of regulated substances or substances of concern from PNNL facilities in 2017 (Sections 2.4, 4.2, and 5.2).

Liquid Effluent Monitoring. Liquid effluent discharges from PNNL Richland Campus operations are monitored under permits issued by the City of Richland. Process wastewater from MSL is treated at an onsite wastewater treatment plant prior to being discharged to Sequim Bay under a permit issued by the Washington State Department of Ecology. In 2017, there were no unplanned releases of regulated pollutants or contaminated wastewater from PNNL facilities (Sections 2.5.1, 4.1, and 5.1).

Radiological Release of Property. PNNL uses the pre-approved guideline limits derived from guidance in DOE Order 458.1, Chg 3, *Radiation Protection of the Public and the Environment*, when releasing property potentially contaminated with residual radioactive material. No property with detectable residual radioactivity above authorized levels was released from PNNL in 2017 (Section 4.3).

Radiation Protection of Biota. Potential media exposure pathways (air, soil, water, and food) were considered in conjunction with particulate radioactive contamination of air pathways. Calculated dose rates for 2017 were well below dose rate limits for aquatic, terrestrial, and riparian animals and plants for both the PNNL Richland Campus and MSL (Section 4.4).

Environmental Radiological Monitoring. No radiological releases to the environment exceeded permitted limits in 2017.

Radioactive particulates in ambient air are monitored using a particulate air-sampling network located at the PNNL Richland Campus. In 2017, there was no indication that any PNNL activities increased the ambient air concentrations at the air-sampling locations. Maximum exposed individual (MEI) exposure to radionuclide air emissions resulted in a dose estimate of 2.3×10^{-5} mrem (2.3×10^{-7} mSv).

In 2017, within the 80 km (50 mi) radius of the PNNL Richland Campus, the collective dose from radionuclide air emissions that originated from the Campus was 1.6×10^{-4} person-rem (1.6×10^{-6} person-Sv). The PNNL Richland Campus MEI location was 0.70 km (0.43 mi) south-southeast of the Physical Sciences Facility 3410 Building (Section 4.2.1).

The MSL MEI location was 0.19 km (0.12 mi) west of the MSL-5 facility. The dose to the MEI from site emissions was 1.6×10^{-4} mrem (1.6×10^{-6} mSv) (Section 4.2.2). The 80 km (50 mi) collective dose for MSL emissions was 1.8×10^{-4} person-rem (1.8×10^{-6} person-Sv).

The total dose to either the PNNL Richland Campus or MSL MEI is well below the federal and state standard of 10 mrem/yr (0.1 mSv/yr).

Environmental Nonradiological Program Information. PNNL nonradiological air emissions are below levels requiring stack monitoring; compliance is achieved by conforming to permit conditions (Section 5.0).

Natural and Cultural Resource Management

Protection and management of cultural and biological resources on PNNL lands is implemented through internal cultural and biological resource protection procedures, which are updated annually to reflect relevant changes in applicable laws and regulations and compliance methods. The *Pacific Northwest Site Office Cultural and Biological Resources Management Plan* provides guidance relative to protecting and managing biological and cultural resources at PNNL.

Groundwater Protection

Groundwater under the PNNL Richland Campus is monitored routinely through seven groundwater monitoring wells and four heat pump production wells. Results are reported monthly to the Washington State Department of Ecology. PNNL is in compliance with all permit sampling requirements (Section 6.0).

Quality Assurance

Comprehensive quality assurance programs, which include various quality control practices and methods of verifying data, are maintained by monitoring and surveillance projects to assure data quality (Section 7.0).

ACKNOWLEDGMENTS

Compilation of the Pacific Northwest National Laboratory Annual Site Environmental Report involved the collaboration and expertise of numerous PNNL staff. Principal contributors and their subject matter specialties included the following:

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EA Raney	Groundwater Protection, Liquid Effluent Monitoring
JM Becker	Ecology and Biological Resources
KD Hand	Biological Resources, Noxious Weed Control
EP Kennedy	Cultural and Historic Resources
JL Mendez	Cultural and Historic Resources
MD Ellefson	Permitting, Regulations, Statutes
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KM Meier	Quality Control and Assurance
JA Stephens	Radiation Protection
CJ Duchsherer	Nonradiological Air Effluents
MJ Parker	Publications Design
SK Ennor	Copy Editing
SF Snyder	Peer Review

ACRONYMS AND ABBREVIATIONS

°C	degrees Celsius
°F	degrees Fahrenheit
µg/L	microgram(s) per liter
µS/cm	microsiemen(s) per centimeter
µSv	microsievert(s)
ac	acre(s)
A.D.	Anno Domini
ALARA	as low as reasonably achievable
ASME	American Society of Mechanical Engineers
ASO	Analytical Support Operations (laboratory)
Battelle	Battelle Memorial Institute
BCAA	Benton Clean Air Agency
B.P.	Before Present
BPA	Bonneville Power Administration
Bq	bequerel(s)
BSF	Biological Sciences Facility
Btu	British thermal unit(s)
C&D	construction and demolition
ca.	circa (approximately)
CAA	*Clean Air Act*
CBRMP	Cultural and Biological Resources Management Plan
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CFR	Code of Federal Regulations
Ci	curie(s)
cm	centimeter(s)
CSF	Computational Sciences Facility
CWA	*Clean Water Act*
CY	calendar year
CZMA	*Coastal Zone Management Act of 1972*
d	day(s)
DOE	U.S. Department of Energy
DOE-RL	DOE-Richland Operations Office
DOE-SC	DOE Office of Science
dpm	disintegrations per minute
DQO	data quality objective
ECM	energy and water conservation measure
ED	effective dose
EDE	effective dose equivalent

EDL	Engineering Development Laboratory
EISA	*Energy Independence and Security Act of 2007*
EM	effluent management
EMP	Environmental Management Plan
EMS	environmental management system
EMSL	William R. Wiley Environmental Molecular Sciences Laboratory
EO	Executive Order
EPEAT	Electronic Product Environmental Assessment Tool
EPA	U.S. Environmental Protection Agency
EPCRA	*Emergency Planning and Community Right-to-Know Act of 1986*
ERP	Environmental Research Permitting
ESA	*Endangered Species Act of 1973*
FEMA	Federal Emergency Management Agency
FR	*Federal Register*
ft	foot (feet)
ft^2	square foot (feet)
ft^3	cubic foot (feet)
FY	fiscal year
g	gram(s)
gal	gallon(s)
GBq	gigabecquerel(s)
GEL	General Engineering Laboratories
GGE	gallon gas equivalent
GHG	greenhouse gas
GPCL	General Purpose Chemistry Laboratory
gpd	gallon(s) per day
gpm	gallon(s) per minute
GRI	Global Reporting Initiative
GSA	General Services Administration
Gy	gray(s)
ha	hectare(s)
HDI	How Do I….?
HPSB	high-performance sustainable building
in.	inch(es)
ISO	International Organization for Standardization
kg	kilogram(s)
km	kilometer(s)
km^2	square kilometer(s)
kW	kilowatt(s)
L	liter(s)
L/min	liter(s) per minute
lb	pound(s)
LNM	Local Notice to Mariners
LSL2	Life Sciences Laboratory 2
m	meter(s)
m^2	square meter(s)
m^3	cubic meter(s)
m/s	meter(s) per second
MAPEP	Mixed-Analyte Performance Evaluation Program
MDL	method detection limit
MEI	maximum exposed individual
mg	milligram(s)
mg/L	milligram(s) per liter
mGy/d	milligray(s) per day
mi	mile(s)
mi^2	square mile(s)
min	minute(s)
MMPA	*Marine Mammal Protection Act of 1972*
MoU	Memorandum of Understanding
mph	mile(s) per hour
mrem	millirem
mrem/yr	millirem per year
MSFCMA	*Magnuson-Stevens Fishery Conservation and Management Act*
MSL	Marine Sciences Laboratory

mSv	millisievert(s)
mSv/yr	millisievert(s) per year
NA	not applicable
ND	nondetectable
NEPA	*National Environmental Policy Act of 1969*
NESHAP	National Emission Standards for Hazardous Air Pollutants
NMFS	National Marine Fisheries Service
NPDES	National Pollutant Discharge Elimination System
NQA	nuclear quality assurance
NRHP	National Register of Historic Places
OAR	Oregon Administrative Rules
ORCAA	Olympic Region Clean Air Agency
PATON	permit and/or private aid to navigation
PCB	polychlorinated biphenyl
pCi/m^3	picocurie(s) per cubic meter
pCi/mL	picocurie(s) per milliliter
PIC-5	Potential Impact Category 5
PNL	Pacific Northwest Laboratory
PNNL	Pacific Northwest National Laboratory
PNSO	Pacific Northwest Site Office
PSF	Physical Sciences Facility
PSL	Physical Sciences Laboratory
QAP	quality assurance plan
QC	quality control
R&D	research and development
RAEL	radioactive air emission license
RCRA	*Resource Conservation and Recovery Act of 1976*
RHA	*Rivers and Harbors Appropriations Act of 1899*
RTL	Research Technology Laboratory
RCW	Revised Code of Washington
s	second(s)
SEPA	*State Environmental Policy Act*
SHPO	State Historic Preservation Officer
SMA	*Shoreline Management Act of 1971*
Sv	sievert(s)
TRIDEC	Tri-Cities Economic Development Council
USACE	U.S. Army Corps of Engineers
U.S.C.	U.S. Code
USCG	U.S. Coast Guard
USFWS	U.S. Fish and Wildlife Service
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WDOH	Washington State Department of Health
yr	year(s)

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1.0 INTRODUCTION

This report was prepared to satisfy the requirements of U.S. Department of Energy (DOE) Order 231.1B Admin Chg 1 (2012), *Environment, Safety and Health Reporting*, and DOE Order 458.1, Admin Chg 3 (2013) *Radiation Protection of the Public and the Environment*, by providing a synopsis of calendar year (CY) 2017 information related to environmental management performance and compliance efforts at Pacific Northwest National Laboratory (PNNL).

PNNL, one of 10 DOE Office of Science (DOE-SC) national laboratories, provides innovative science and technology solutions in energy and environment, fundamental and computational science, and national security disciplines. Operated by Battelle Memorial Institute (Battelle) under contract to DOE-SC's Pacific Northwest Site Office (PNSO), PNNL performs work for a diverse set of clients, including the National Nuclear Security Administration, U.S. Department of Homeland Security, U.S. Nuclear Regulatory Commission, U.S. Environmental Protection Agency (EPA), DOE Office of Environmental Management, and other federal agencies, as well as private industry. PNSO is responsible for program implementation, acquisition management, and laboratory stewardship at PNNL. Through its oversight role, PNSO manages the safe and efficient operation of PNNL while enabling the pursuit of visionary research and development (R&D) in support of complex national energy and environmental missions.

As the primary document for reporting PNNL annual site environmental and operating performance, this report provides environmental and monitoring information to Native American tribes, public officials, regulatory agencies, other interested groups, and the public. It summarizes site compliance with federal, state, and local environmental laws, regulations, policies, directives, permits, and Orders, and provides environmental management performance benchmarks and their status.

After the context-setting background information provided in this Introduction, ensuing chapters present a summary of PNNL's 2017 record of operational activities related to the site environment with regard to compliance with governmental statutes, Orders, and guidance; environmental management and sustainability; environmental monitoring and radiological dose assessment; the nonradiological and groundwater protection programs; and the quality assurance of these programs.

To assist readers, Appendix A lists information including scientific notation, units of measure, unit conversions, and radionuclide and chemical information. Appendix B presents a glossary of terms. Appendices C and D, respectively, contain lists of plant and animal species found on the PNNL Richland Campus and at PNNL's Marine Sciences Laboratory (MSL) property near Sequim, Washington.

1.1 Location

JP Duncan

PNNL includes facilities at the PNNL Richland Campus in Richland, Washington, and at MSL near Sequim, Washington (Figure 1.1). Environmental activities at other locations are also included if they are under PNNL's responsibility (e.g., a permitted waste storage

Figure 1.1. Locations of the PNNL Richland Campus and PNNL Marine Sciences Laboratory in Washington State

and treatment unit on the Hanford Site). In addition, PNNL conducts research at satellite offices in various other locations, including Seattle, Washington, and Portland, Oregon, as well as in various offsite field locations.

1.1.1 PNNL Richland Campus

The PNNL Richland Campus covers approximately 269 ha (664 ac) and is located in Benton County in southeastern Washington State, 275 km (171 mi) east-northeast of Portland, Oregon, 270 km (168 mi) southeast of Seattle, Washington, and 200 km (124 mi) southwest of Spokane, Washington. It is located at the northern boundary of the City of Richland, south of the DOE-Richland Operations Office's (DOE-RL's) Hanford Site 300 Area, and east of approximately 664 ha (1641 ac) of Hanford Site land that was transferred to the Tri-City Economic Development Council (TRIDEC) (DOE-RL 2015a). TRIDEC transferred the land to the City of Richland, Port of Benton, and Energy Northwest for economic development (Tangent 2017). PNNL also leases facilities located on private land and on the campus of Washington State University–Tri-Cities (Figure 1.2).

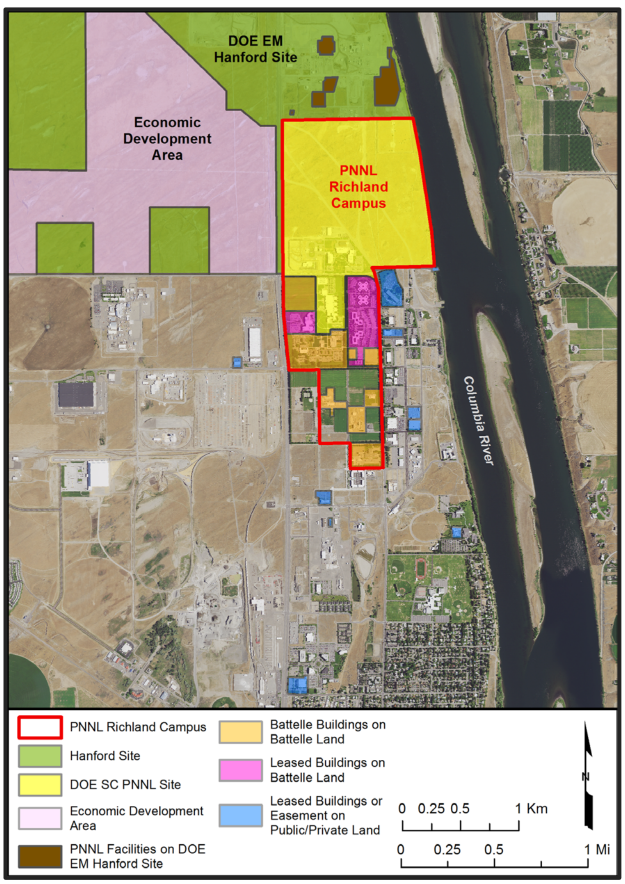


Figure 1.2. Pacific Northwest National Laboratory Richland Campus and Surrounding Area

The area immediately south of the PNNL Richland Campus includes public and privately owned land, currently envisioned to be developed with office, laboratory, residential, and retail space as part of the Tri-Cities Research District.

1.1.2 PNNL Marine Sciences Laboratory

MSL is located at the mouth of Sequim Bay, near the town of Sequim on the northern portion of the Olympic Peninsula in Clallam County, Washington. The Battelle Land–Sequim area encompasses 60.7 ha (149 ac) of uplands and tidelands, about 3 ha (7.4 ac) of which have been developed for research operations (Figure 1.3). The developed areas include MSL facilities, an innovative seawater treatment system, research docks, and outdoor experimental tanks and ponds. Research scientists and engineers at MSL perform R&D in marine sciences, sustainable energy, climate change, biofouling/ biocorrosion, intelligence, national security, and homeland security operations. DOE has exclusive use of about 36 ha (89 ac) of Battelle Land-Sequim, including the MSL facilities (Figure 1.3). All MSL operations are consolidated under PNSO oversight.

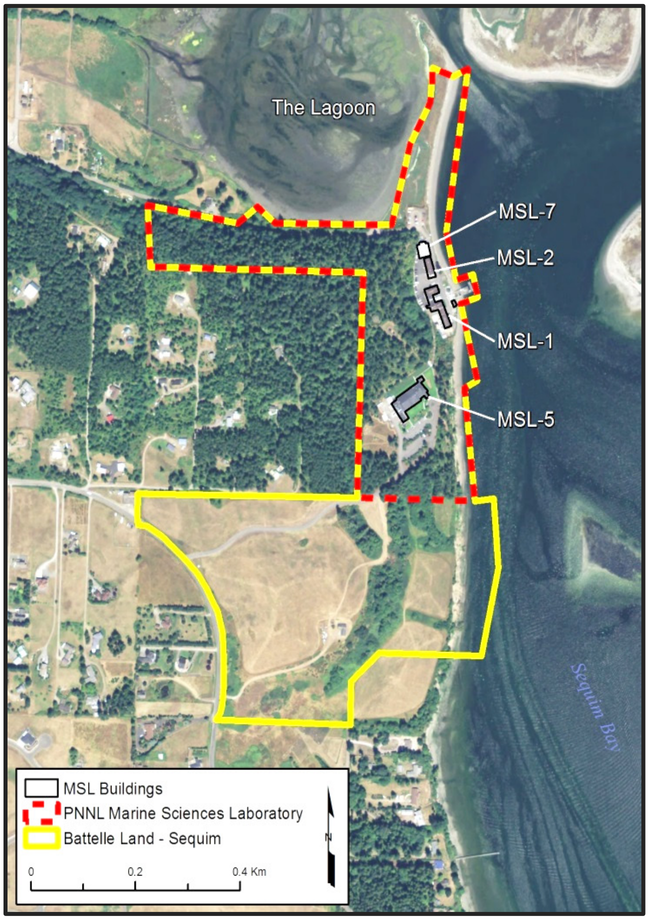


Figure 1.3. Battelle Land–Sequim Encompassing the PNNL Marine Sciences Laboratory Facilities and Surrounding Environment

1.2 Background and Mission

JP Duncan

1.2.1 PNNL Richland Campus

In January 1965, Battelle was awarded the Pacific Northwest Laboratory (PNL) contract to operate the Hanford Site laboratories. In addition, Battelle invested its own funds to construct facilities to conduct non-Hanford Site research to promote R&D in the Pacific Northwest. In the late 1970s, research expanded to include energy, health, environment, and national security ventures. PNL contributed to areas including robotics, environmental monitoring, material coatings, veterinary medicine, and the formation of new plastics. In 1995, PNL was renamed Pacific Northwest National Laboratory. Over the years, PNNL researchers have developed versatile technologies, earning numerous R&D 100 awards, Federal Laboratory Consortium awards, Innovation awards, and patents for their R&D work and contributions.

PNNL is operated by Battelle for DOE-SC's PNSO, which was established in 2003. PNSO is responsible for overseeing all PNNL activities and for monitoring the Laboratory's compliance with applicable laws, policies, and DOE Orders. Research facilities on the PNNL Richland Campus include the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL), the Engineering Development Laboratory (EDL), Physical Sciences Laboratory (PSL), Life Sciences Laboratory 2 (LSL2), Biological Sciences Facility/Computational Sciences Facility (BSF/CSF), and the Physical Sciences Facility (PSF) complex. The PSF complex includes the Systems Engineering Building for energy research; the Materials and Science Technology Laboratory for the development and analysis of high-performance materials for energy, construction, and transportation technologies and systems; and the Radiation Detection Laboratory and Ultra-Trace Laboratory for the development of radiation detection methodologies.

The Radiation Portal Monitoring Test Track and Large Detector Laboratory were designed to develop and test radiation detection technologies for border entry points and national and homeland security research projects. Research at the EDL is focused on national security, with particular emphasis on electromagnetics /radiography, optics/infrared spectroscopy, and acoustics/ultrasonics. PSL and LSL2 are general purpose research facilities. BSF is occupied by the Biological Sciences Division, which performs systems biology research and develops technologies focused on how cells, cell communities, and organisms sense and respond to their environment; and the Earth Systems Science Division, which develops comprehensive monitoring programs and performs environmental and biotechnology research. CSF research includes the development of visual analytics technologies, cyber analytics, and critical infrastructure assessment and protection. The General Purpose Chemistry Laboratory (GPCL), built to high-performance and sustainable building (HPSB) guidelines, houses 10 laboratories and supports several DOE missions, including energy storage. Additional laboratory and office buildings are currently under construction, also employing HPSB guidelines.

1.2.2 PNNL Marine Sciences Laboratory

In 1967, Battelle acquired acreage on Sequim Bay on the Strait of Juan de Fuca in Washington's Puget Sound near the City of Sequim. As part of Battelle's commitment to developing research facilities to benefit the region and serve the environment, the Marine Research Laboratory near Sequim was constructed to provide laboratories for marine-related work involving biology, physiology, histology, chemistry, physics, and engineering. In 1973, the Marine Research Laboratory opened; it was later renamed Marine Research Operations and is now referred to as MSL.

In October 2012, the PNNL operating contract was revised, giving DOE exclusive use of MSL and consolidating operations under PNSO oversight. Currently, researchers at MSL provide innovative science and technology solutions critical to the nation's energy, environmental, and security future. Capabilities are based on expertise in environmental chemistry, water and ecosystem modeling, remote sensing, remediation technology research, environmental sensors, ecotoxicology, biotechnology, and national and homeland security. In addition, the facility contains an innovative seawater treatment system that treats up to 200 gallons per minute of sea water to remove chemical and biological impurities before returning the water to Sequim Bay. Research efforts include the development of sustainable renewable energy from the nearshore and ocean environments and understanding and mitigating the long-term impacts of human activities, including climate change, on marine resources.

1.3 Demographics

JP Duncan

The PNNL Richland Campus is located in Benton County, Washington, south of the Hanford Site, in an area that is primarily flat, semi-arid, and restricted from public access. Residents north and east of Hanford Site generally live on farms or in farming communities. Residents south, southwest, and west of the PNNL Richland Campus live in the urban communities of Richland, Kennewick, Pasco, and West Richland.

In 2017, an estimated 198,200 people lived in Benton County and 92,100 people lived in adjacent Franklin County, increases of 13.1% and 17.9%, respectively, over 2010 figures (USCB 2018a). During 2017, Benton and Franklin Counties accounted for 3.9% of Washington's population. Based on U.S. Census population data, the population within an 80 km (50 mi) radius of the PNNL Richland Campus is estimated to be about 432,000. This population estimate is used to calculate the radiation dose to the general public (Section 4.2).

MSL is located in Clallam County, Washington, an area of approximately 4,500 km^2 (1,740 mi^2) on the

Olympic Peninsula in the northwestern corner of Washington State. An estimated 75,500 people lived in Clallam County in 2017, an increase of approximately 5.7% over 2010 figures and equivalent to approximately 1% of Washington's population (USCB 2018b). Sequim, the nearest population center to MSL, had a population of 7,108 people in 2017 (USCB 2018b). An estimated 2,349,100 people live within an 80 km (50 mi) radius of MSL; 1,986,300 in the United States (85%) and 362,800 in Canada (15%) (Zuljevic et al. 2016).

1.4 Environmental Setting – PNNL Richland Campus

JP Duncan

The PNNL Richland Campus occupies land that has had varying degrees of previous disturbance, the severity and duration of which are exhibited to some extent by the current vegetation. Upland areas with lower levels of prior disturbance largely support native shrub-steppe vegetation, while more heavily disturbed uplands support more invasive, non-native vegetation.

Other areas have undergone complete habitat conversion and contain facilities that have landscaping and xeriscaping. The Columbia River riparian zone within the PNNL Richland Campus area is largely undisturbed and supports both native and non-native vegetation.

1.4.1 Geology and Soils

The PNNL Richland Campus lies above a gentle syncline formed by the intersection of the Yakima Fold Belt and the gently west-dipping Palouse Slope. The uppermost basalt flow belongs to the Ice Harbor Member of the Saddle Mountains Basalt. The overlying sediment layers are relatively thin, consisting of Ringold Formation and Hanford formation sediments. These sediment layers are predominantly coarse sandy alluvial deposits mantled by windblown sand. A generalized suprabasalt stratigraphic column showing what underlies the PNNL Richland Campus is shown in Figure 1.4. The stratigraphic column for the upper Ringold Formation and the Hanford formation is based on information obtained from the drilling of 11 boreholes within the footprint of the BSF/CSF on the PNNL Richland Campus (Freedman et al. 2010).

Additional stratigraphic information was obtained from previously existing geologic logs for nearby irrigation wells, water-supply wells, monitoring wells, and characterization boreholes associated with environmental remediation activities. The uppermost geologic unit in the study area is the Hanford formation—a highly permeable mixture of sand and gravel that was deposited by Ice Age floods during the late Pleistocene period. These poorly sorted and unconsolidated sediments generally cover a wide range of sizes, from boulder-sized gravel to sand, silt, and clay. Late Miocene- to Pliocene-age sediments of the Ringold Formation underlie the Hanford formation. The Ringold Formation is texturally and structurally distinct from the overlying Hanford formation and displays lower hydraulic conductivity. The Ringold Formation contains sands, gravels, and muds that are typically more consolidated and less permeable than those in the Hanford formation. The basalt underlying the Ringold Formation has a very low vertical hydraulic conductivity, and forms an aquitard between the base of the unconfined aquifer and the confined aquifers within the basalt formations.

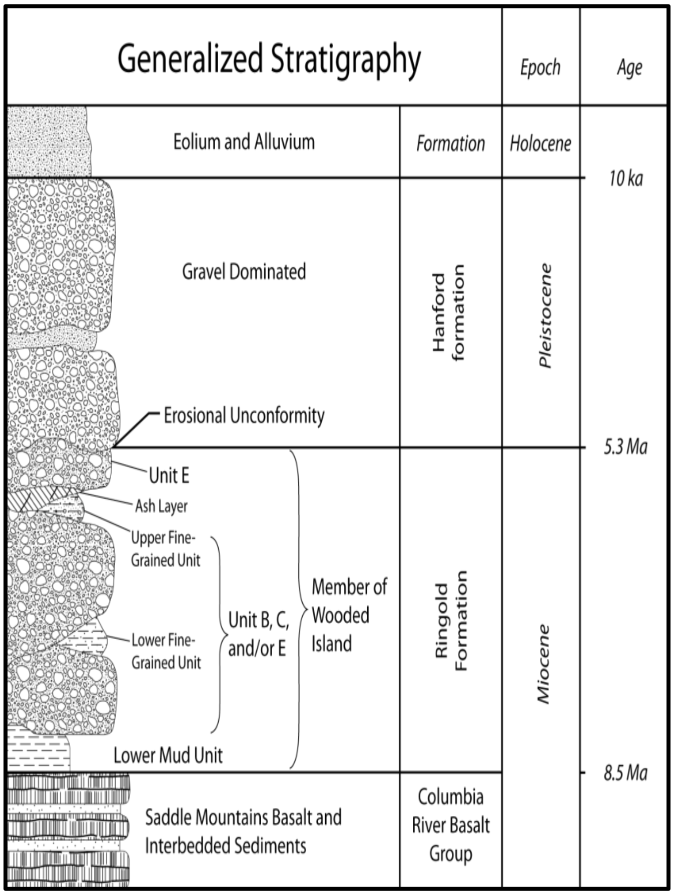


Figure 1.4. Generalized Stratigraphic Column Depicting the Stratigraphy Underlying the PNNL Richland Campus (modified from Reidel et al. 1992; Thorne et al. 1993; Lindsey 1995; Williams et al. 2000; DOE-RL 2002; and Williams et al. 2007)

1.4.2 Hydrology

The general direction of groundwater flow under the PNNL Richland Campus is toward the east-northeast from the Yakima River to the Columbia River (Figure 1.5). The northeasterly flow direction is likely influenced by the City of Richland recharge ponds, upgradient irrigation, and the Yakima River. In addition, the 300 Area of the Hanford Site has been shown to be a convergence zone for groundwater flow (Peterson et al. 2005), which may also contribute to the local gradient of the PNNL Richland Campus.

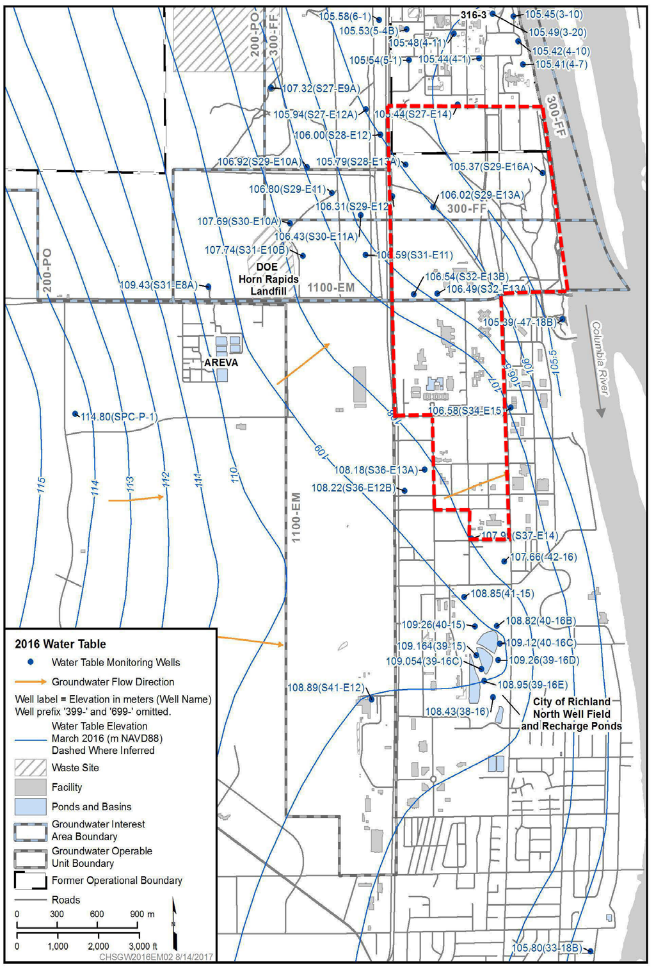


Figure 1.5. Water Table Elevations (m) in 2016 (modified from DOE-RL 2017a). Groundwater flow direction is normal to the water table contour lines. The approximate PNNL Richland Campus is outlined in red.

Field data collected on and around the PNNL Richland Campus indicate that the unconfined aquifer is predominantly in the Ringold Formation; however, depending on the water table elevation, the aquifer may inundate portions of the Hanford formation. The vadose zone consists of unsaturated sediments between the ground surface and the water table. This zone occurs predominantly within sandy gravel, gravelly sand, and silty, sandy gravel of the Hanford formation (Newcomer 2007). In some areas, the Ringold Formation extends above the water table into the lower part of the vadose zone. Below the PNNL Richland Campus, the vadose zone is about 15 m (49 ft) thick; its thickness generally decreases with proximity to the Columbia River, as the ground surface slopes toward the river.

1.4.3 Flooding

While large Columbia River floods have occurred in the past, the likelihood of recurrence of large-scale flooding has been reduced by the construction of dams on the Columbia River. The largest flood on record for the Columbia River occurred in 1894 and had an estimated peak discharge of 21,000 m^3/s (742,000 ft^3/s) at the Hanford Site; the largest recent flood took place in 1948 and had an estimated peak discharge of 20,000 m^3/s (700,000 ft^3/s) (Duncan 2007). Exceptionally high runoff during the spring of 1996 resulted in a maximum discharge of nearly 11,750 m^3/s (415,000 ft^3/s) (Duncan 2007). The flood plain associated with the 1894 flood has been modeled based on topographic cross sections of the river; no portion of the PNNL Richland Campus was within this area.

The probable maximum flood has an unspecified, but very large return period (generally much greater than 500 years). Based on modeling conducted in 1976, the Hanford Site would be unaffected by the probable maximum flood on the Columbia River, a discharge of about 39,600 m^3/s (1.4 million ft^3/s) (Duncan 2007). A flood of this magnitude would result in a water-surface elevation of 119 m (390 ft) at the Columbia Generating Station, located about 12 km

(7.5 mi) north of the PNNL Richland Campus (Energy Northwest 2011). The standard project flood, a flood that would occur during the combination of the harshest meteorological and hydrological conditions, has an unspecified return period, usually greater than several hundred years (Linsley et al. 1992). The regulated standard project flood used by the U.S. Army Corps of Engineers for the Columbia Generating Station is 16,100 m^3/s (570,000 ft^3/s) (Energy Northwest 2011). The 100-year regulated flood discharge for the Columbia River along the northern boundary of the Hanford Site is estimated to be 12,500 m^3/s (440,000 ft^3/s) (Duncan 2007); corresponding discharge at the PNNL Richland Campus would be somewhat larger. The Federal Emergency Management Agency (FEMA) floodplain maps extend only to the southern boundary of the PNNL Campus (FEMA 1984). However, FEMA maps suggest that the PNNL Campus, with a ground-surface elevation of about 122 m (400 ft), would be unaffected by a 100-year flood.

1.4.4 Climate and Meteorology

Temperature, precipitation, and wind across the Columbia River Basin are affected by mountain barriers. The rain-shadow effect of the Cascade Range, west of Yakima, influences the climate at the PNNL Richland Campus. North of the PNNL Richland Campus, the Rocky Mountains and ranges in southern British Columbia protect the region from severe, cold polar air masses moving southward across Canada and the winter storms associated with them. The Hanford Meteorological Station operates an array of remote meteorological towers across the Hanford Site. One tower (300 Area, Station 11) is located in the vicinity of the PNNL Richland Campus. The Hanford Meteorological Station conducts meteorological monitoring to support Hanford Site operations, emergency preparedness and response, and atmospheric dispersion calculations for dose assessments. Normal monthly average temperatures on the Hanford Site range from a low of –0.5°C (31.1°F) in December to a high of 25.1°C (77.1°F) in July (DOE 2018). The maximum high temperature in 2017 was 41.7°C (107°F); the minimum was -21.7°C (-7°F). The average annual temperature at the Hanford Site in 2017 was 11.8°C (53°F), 0.2°C below the 30-year average (1981–2010) of 12°C (53.6°F) (DOE 2018). The normal annual relative humidity at the Hanford Meteorology Station is 55.3%; humidity is highest during winter, when it averages approximately 77%, and lowest during summer, when it averages 36.5% (DOE-RL 2017b). Precipitation for 2017 was 26% above average (DOE 2018), which is 17.3 cm (6.81 in.) at the Hanford Meteorological Station. Most precipitation occurs during late autumn and winter; the majority of the annual total for 2017, 21.8 cm (8.60 in.), occurred during January to April and October to November.

Winds from the northwestern quadrant are the most common during winter and summer. During spring and fall, the frequency of southwesterly winds increases, with corresponding decreases in the northwesterly flow (Poston et al. 2011). Monthly average wind speeds are lowest during winter months, averaging about 3 m/s (7 mph), and highest during summer, averaging about 4 m/s (9 mph). Wind speeds well above average are usually associated with southwesterly winds. However, summertime drainage winds are generally northwesterly and frequently exceed 13 m/s (30 mph) (Poston et al. 2011).

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 at the Hanford Site during summer (Poston et al. 2011). Less favorable conditions may occur when wind speed is light and the mixing layer is shallow. These conditions are most common during winter, when moderate to extremely stable stratification exists (approximately 66% of the time).

Occasionally (primarily during winter), poor dispersion conditions, associated with stagnant air in stationary high-pressure systems, occur for extended periods. Fog has been recorded during every month of the year at the Hanford Meteorology Station; however, fog occurs mostly from November through February. Additional visibility reductions can occur in the form of windblown dust; the region has averaged four dust storms per year for the entire period of record (1945–2017).

1.4.5 Ecology

JM Becker

The PNNL Richland Campus is located in the lowest and most arid portion of the Columbia Plateau Ecoregion (LandScope Washington 2018; EPA 2013)—the largest ecoregion in Washington, which is bordered by the Cascade Range to the west and the Blue and Rocky Mountains to the east (WWHCWG 2012–2015). The semi-arid climate of the Columbia Plateau supports native shrub-steppe vegetation, an estimated 60% of which has been converted to agriculture, and the remainder has been largely fragmented and degraded by historic land use (mostly livestock grazing) (USFWS 2013a; WWHCWG 2012–2015). A notable exception is the Hanford Site, which is adjacent to and just north of the PNNL Richland Campus (Figure 1.2); it has been protected from agricultural use and development for more than 70 years. The portion of the PNNL Richland Campus north of Horn Rapids Road (Figure 1.6) was formerly part of the Hanford Site before being assigned to the DOE-SC. Thus, since 1943, this area had been protected from agricultural use and development prior to transfer. It is still dominated by native shrub-steppe vegetation and thus retains much of its native biodiversity and community structure (Figure 1.6). The portion of the PNNL Richland Campus south of Horn Rapids Road has been developed to various extents and consists of a mosaic of maintained landscapes, fallow agricultural fields, and previously disturbed, early-successional habitats (Figure 1.6).

Plant communities are classified based on the dominant overstory (shrubs) and understory (grasses and forbs) species (Figure 1.6). Shrub-steppe plant communities north of Horn Rapids Road include those dominated by climax shrubs such as big sagebrush (*Artemisia tridentata*) and antelope bitterbrush (*Purshia tridentata*), which are indicative of relatively little prior disturbance. Communities dominated by subclimax shrubs, such as rubber rabbitbrush (*Ericameria nauseosa*), green rabbitbrush (*Chrysothamnus viscidiflorus*), or snow buckwheat (*Eriogonum niveum*), are generally indicative of some prior disturbance. Plant communities dominated by non-native cheatgrass (*Bromus tectorum*) are indicative of more extensive or more recent disturbance (e.g., mechanical disturbance or fire). The more mature and undisturbed shrub-steppe communities generally support greater plant species diversity.

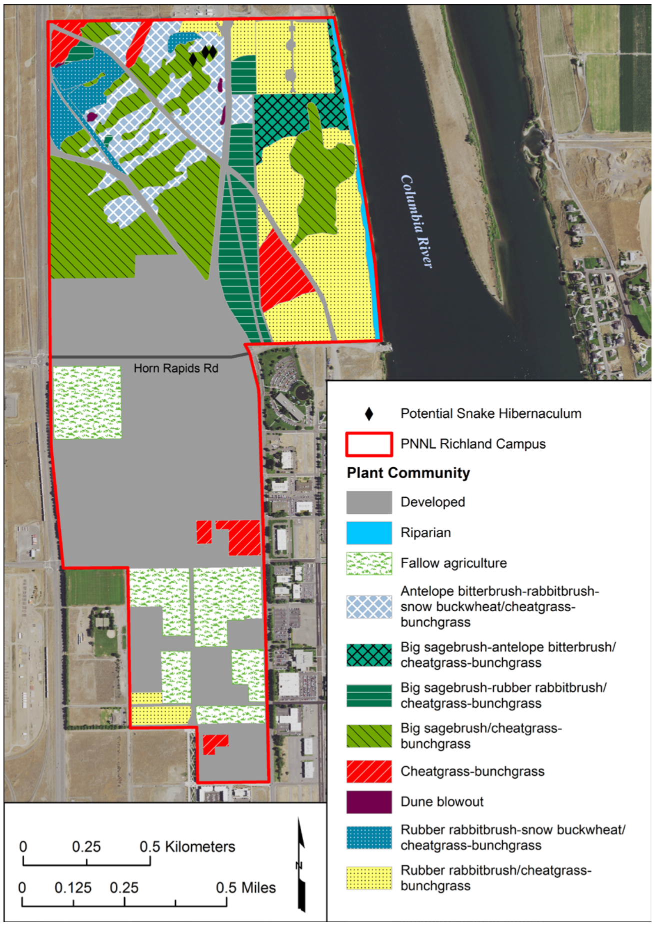


Figure 1.6. Habitat Polygons Located on the PNNL Richland Campus

The southwest-to-northeast trending fingerlike mosaic of bitterbrush and sagebrush communities (Figure 1.6) is indicative of the direction of prevailing wind gusts (Hoitink et al. 2005) that shift loose soils into superficial swales and ridges. The bitterbrush communities tend to occur in the sandier areas, while sagebrush communities tend to occur on the loamier areas. The above shrub communities include native perennial bunchgrasses; the communities where they are more prevalent are indicated in Figure 1.6. The most common perennial bunchgrass is Sandberg's bluegrass (*Poa secunda*); however, several stands of needle-and-thread grass (*Hesperostipa comata*) dominate swales, and Indian ricegrass (*Achnathrum hymenoides*) is represented in several swales containing antelope bitterbrush. Snow buckwheat is prevalent in most big sagebrush, bitterbrush, and rabbitbrush communities (Figure 1.6), and cheatgrass is prevalent in all upland plant communities.

Common native forb species in the plant communities north of Horn Rapids Road include Carey's balsamroot (*Balsamorhiza careyana*), longleaf phlox (*Phlox longifolia*), common yarrow (*Achillea millefolium*), pale evening primrose (*Oenothera pallida*), lemon scurfpea (*Psoralidium lanceolatum*), fiddleneck (*Amsinckia spp.*), and turpentine wavewing (*Pteryxia terebinthina*).

Common non-native forbs across the PNNL Richland Campus include tumble mustard (*Sisymbrium altissimum*), Russian thistle (*Salsola kali*), redstem stork's bill (*Erodium cicutarium*), and several species listed as Class B or Class C noxious weeds, classified as such by the state of Washington (WAC 16-750-011 and WAC 16-750-015, respectively). Common Class B noxious weeds include diffuse knapweed (*Centaurea diffusa*), rush skeletonweed (*Chondrilla juncea*), Russian knapweed (*Acroptilon repens*), burningbush (*Bassia scoparia*), puncturevine (*Tribulus terrestris*), and yellow starthistle (*Centaurea solstitialis*). Common Class C noxious weeds include field bindweed (*Convolvulus arvensis*) and Russian olive (*Elaeagnus angustifolia*).

Shrub-steppe plant communities north of Horn Rapids Road support a variety of wildlife, including coyote (*Canis latrans*), American badger (*Taxidea taxus*), mule deer (*Odocoileus hemionus*), and northern pocket gopher (*Thomomys talpoides*). Migratory bird species that have been observed and likely nest in the shrub-steppe plant communities include, but are not limited to, ground-nesting birds such as mourning dove (*Zenaida macroura*), horned lark (*Eremophila alpestris*), and western meadowlark (*Sturnella neglecta*), and shrub-nesting birds such as lark sparrow (*Chondestes grammacus*). Long-billed curlews (*Numenius americanus*) have been observed north of Horn Rapids Road, but to date are known to nest only on the nearby Hanford Site (Cranna and Nugent 2017). The more mature and undisturbed a shrub-steppe community is, the more valuable it generally is to wildlife (e.g., a greater abundance of mature sagebrush and other native plant species supports a more diverse assemblage of wildlife) (Dobler et al. 1996).

Three potential snake hibernacula composed of partially buried rubble exist south of the 300 Area (Figure 1.6). These may be suitable for snake species common in south-central Washington such as the western rattlesnake (*Crotalus viridis*) (Fitzner and Gray 1991), as well as some that are rare in the ecoregion and thus are of concern to the state, such as the striped whipsnake (*Masticophis taeniatus*) (Table 1.1) (WDFW 2018a), which is known to occur in the vicinity of the PNNL Richland Campus (WNHP et al. 2009). The potential hibernacula were surveyed in 2017 and no snake activity was observed.

In addition to shrub-steppe upland communities, a riparian community exists along the Columbia River shoreline north of Horn Rapids Road (Figure 1.6). The riparian community is limited to a narrow band of multilayered trees, shrubs, and herbaceous species. Common tree species include Siberian elm (*Ulmus pumila*), white mulberry (*Morus alba*), poplars (*Populus* spp.), and tree-of-heaven (*Ailanthus altissima*) and Russian olive, both of which are Class C noxious weeds. Narrowleaf willow (*Salix exigua*) and Wood's rose (*Rosa woodsii*) are common shrub species. Common herbaceous species include common St. Johnswort (*Hypericum perforatum*), Himalayan blackberry (*Rubus armeniacus*), and reed canarygrass (*Phalaris arundinacea*), all of which are Class C noxious weeds, as well as Atkinson's tickseed (*Coreopsis tinctoria var. atkinsoniana*), rough cocklebur (*Xanthium strumarium*), and chicory (*Cichorium intybus*).

Riparian habitats support a diverse assemblage of wildlife. A number of migratory bird species, including eastern kingbird (*Tyrannus tyrannus*), red-winged blackbird (*Agelaius phoeniceus*), and Bullock's oriole (*Icterus bullockii*), use riparian trees and shrubs as nesting habitat. The great-horned owl (*Bubo virginianus*), a year-round resident, also nests in riparian trees. Osprey (*Pandion haliaetus*) have been observed perching on utility poles in the uplands north of Horn Rapids Road, but are not known to nest there; they forage in the nearby Columbia River. The shoreline is frequented by wading birds such as the great blue heron (*Ardea herodias*), black-crowned night heron (*Nycticorax nycticorax*), and great egret (*Ardea alba*), and shorebirds such as the spotted sandpiper (*Actitis macularius*), but these species are not known to nest there. However, heron rookeries occur along the Columbia River north of the 300 Area. The river is used by a variety of waterfowl during winter and the island habitats are used for nesting. The most common waterfowl include the Canada goose (*Branta canadensis*) and mallard (*Anas platyrhynchos*) (USFWS 2013b). Many migratory bird species use the riparian habitats for resting and feeding during spring and fall migration.

The developed areas south of Horn Rapids Road include facilities surrounded by landscaped vegetation consisting of planted lawn grass and ornamental trees and shrubs, interspersed with fallow agricultural fields (alfalfa and pasture grass) and early-successional habitats (Figure 1.6). The facilities and landscaped vegetation provide suitable nesting habitat for approximately 25 avian species that are common in similar environments throughout the ecoregion. These include birds of prey that nest in trees (e.g., great-horned owl); other non-perching birds that nest in trees (e.g., Eurasian collared dove [*Streptopelia decaocto*]), on buildings (e.g., rock pigeon [*Columba livia*]), or on the ground (e.g., killdeer [*Charadrius vociferus*], California quail [*Callipepla californica*], mourning dove); and perching birds that nest in trees (e.g., black-billed magpie [*Pica hudsonia*], American robin [*Turdus migratorius*], American crow [*Corvus brachyrhynchos*], American goldfinch [*Spinus tristis*]), in shrubbery (e.g., Brewer's blackbird [*Euphagus cyanocephalus*]), or on human structures (e.g., European starling [*Sturnus vulgaris*], house sparrow [*Passer domesticus*], western kingbird [*Tyrannus verticalis*]).

Table 1.1. Wildlife, Fish, and Plant Species of Conservation Concern Known to Occur or That Potentially Occur near the PNNL Richland Campus

Common Name	Genus and Species	Federal Status[(a)]	State Status[(b)]
Wildlife			
American white pelican	*Pelecanus erythrorhynchos*		Threatened
Bald eagle	*Haliaeetus leucocephalus*	Species of Concern	
Black-tailed jackrabbit	*Lepus californicus*		Candidate
Burrowing owl	*Athene cunicularia*		Candidate
Loggerhead shrike	*Lanius ludovicianus*		Candidate
Northern sagebrush lizard	*Sceloporus graciosus*		Candidate
Sagebrush sparrow	*Artemisiospiza nevadensis*		Candidate
Striped whipsnake	*Masticophis taeniatus*		Candidate
Townsend ground squirrel	*Urocitellus townsendii townsendii*		Candidate
Fish			
Upper Columbia River spring Chinook salmon	*Oncorhynchus tshawytscha*	Endangered	Candidate
Upper Columbia River steelhead	*Oncorhynchus mykiss*	Threatened	Candidate
Plants			
Awned halfchaff sedge	*Lipocarpha aristulata*		Threatened
Beaked spike-rush	*Eleocharis rostellata*		Sensitive
Canadian St. Johnswort	*Hypericum majus*		Sensitive
Columbian yellowcress	*Rorippa columbiae*		Threatened
Grand redstem	*Ammania robusta*		Threatened
Great Basin gilia	*Aliciella leptomeria*		Threatened
Loeflingia	*Loeflingia squarrosa*		Threatened
Lowland toothcup	*Rotala ramosior*		Sensitive
Rosy pussypaws	*Calyptridium roseum*		Threatened
Suksdorf monkeyflower	*Erythranthe suksdorfii*		Sensitive

Sources: WDFW (2018a) and WNHP (2018)

(a) Federal species of concern are those that may be in need of conservation actions, ranging from monitoring of populations and habitat to listing the species as federally threatened or endangered. Federal species of concern receive no legal protection and the classification does not imply that the species is being considered for listing as threatened or endangered (USFWS 2018).

(b) Candidate animal species are those fish and wildlife species that the Washington Department of Fish and Wildlife will review for possible listing as endangered, threatened, or sensitive (WDFW 2018a). Threatened plant species are those that are likely to become endangered within the near future in Washington if the factors contributing to their population decline or habitat loss continue. Endangered plant species are in danger of becoming extinct or extirpated from the state of Washington. Sensitive species those that are vulnerable or declining and could become endangered or threatened in the state without active management or removal of threats (WNHP 2018).

The early-successional habitats south of Horn Rapids Road are degraded remnants of shrub-steppe habitat, which support primarily cheatgrass and rubber rabbitbrush (Figure 1.6). Many of the Class B and C noxious weeds noted above also occur in the early-successional habitats south of Horn Rapids Road. The ground-nesting avian species noted above may nest in early-successional habitats, on the margins of fallow agricultural fields, and in adjacent non-vegetated areas.

Mammal species that may use the early-successional habitats and fallow agricultural fields include those noted above that also use the area north of Horn Rapids Road. Mammals that use landscaped areas include eastern gray squirrel (*Sciurus carolinensis*), eastern fox squirrel (*Sciurus niger*), and Nuttall's cottontail (*Sylvilagus nutalli*). The eastern gray squirrel and eastern fox squirrel were introduced to Washington State from the eastern United States and occur in many urban and developed areas (WDFW 2004). Nuttall's cottontail is common in the Columbia Plateau Ecoregion and typically inhabits the perimeter area of PNNL facilities adjacent to or near areas of natural vegetation.

The Hanford Reach of the Columbia River supports a diverse fish and invertebrate community. It is used as a spawning and migration corridor by anadromous salmonids, including fall Chinook salmon (*Oncorhynchus tshawytscha*), *Endangered Species Act*-listed Upper Columbia River spring Chinook salmon (70 FR 37160) and Upper Columbia River steelhead (*Oncorhynchus mykiss*) (74 FR 42605) (Table 1.1), and summer Chinook, coho (*Oncorhynchus kisutch*), and sockeye (*Oncorhynchus nerka*) salmon. The Columbia River constitutes critical habitat for Upper Columbia River spring Chinook salmon (70 FR 52630) and Upper Columbia River steelhead (70 FR 52630), and essential fish habitat for Upper Columbia River spring Chinook salmon and fall Chinook salmon. Steelhead use this habitat for juvenile rearing, juvenile migration, growth and development to adulthood, adult migration, and spawning. Functions of this habitat for Upper Columbia River spring Chinook salmon include juvenile rearing and juvenile and adult migration (DOE-RL 2015b). Fall Chinook salmon use the habitat for spawning, juvenile rearing, and juvenile and adult migration. The habitat is used by summer Chinook salmon, coho, and sockeye for juvenile and adult migration. The primary invertebrate fauna include caddisfly (Trichoptera) and chironomid larvae, crayfish (*Pacifasticus leniusculus towbridgii*), and western floaters (*Anodonta kennerlyi*) (Mueller et al. 2011).

Federal and state-listed wildlife and plant species known to occur or that potentially occur on or near the PNNL Richland Campus were identified using sources from the Washington Department of Fish and Wildlife (WDFW 2018a) and Washington Natural Heritage Program (WNHP 2018) and are listed in Table 1.1. The bald eagle (*Haliaeetus leucocephalus*), American white pelican (*Pelecanus erythrorhynchos*), sagebrush sparrow (*Artemisiospiza nevadensis*), and black-tailed jackrabbit (*Lepus californicus*) were observed between 2009 and 2017 north of Horn Rapids Road (see Appendix C).

A wintering population of bald eagles occupies the Hanford Reach annually from approximately mid-November through mid-March (Cranna 2017a). During that time period, eagles may perch in trees and forage in the riparian area of the PNNL Richland Campus. Bald eagles are known to nest along the river on the Hanford Site (Cranna 2017a), but do not nest on the PNNL Richland Campus. American white pelicans have been observed foraging along the Columbia River shoreline of the PNNL Richland Campus, but are not known to nest there. The sagebrush sparrow, a sagebrush-obligate species (WDFW 2018b) dependent upon mature shrub-steppe habitat (Vander Haegen et al. 2000), may nest north of Horn Rapids Road. Black-tailed jackrabbits occupy shrub-steppe habitat and are known to occur in the uplands of the PNNL Richland Campus and nearby on the Hanford Site (Grzyb 2016; Grzyb et al. 2016).

A single burrowing owl (*Athene cunicularia*) was observed north of Horn Rapids Road in 2006, but nesting was not observed (DOE-PNSO 2007a) and the species has not been observed since that time; however, the species does nest on the Hanford Site (Wilde et al. 2017). Townsend's ground squirrel (*Urocitellus townsendii townsendii*) is known to occur just north of the PNNL Richland Campus in the southern periphery of the Hanford Site 300 Area (Cranna and Nugent 2016). No reptiles, including the northern sagebrush lizard (*Sceloporus graciosus*), were observed during reptile surveys conducted near the 300 Area of the Hanford Site in 2015 (Cranna 2107b). However, the gopher snake (*Pituophis catenifer*) was observed during general field surveys of the PNNL Richland Campus north of Horn Rapids Road between 2009 and 2017 (Appendix C). The loggerhead shrike has been observed at locations on the Hanford Site (Wilde 2017), but was not observed on the PNNL Richland Campus north of Horn Rapids Road between 2009 and 2017 (Appendix C). Although the sagebrush lizard and loggerhead shrike were not observed previously, they could occur north of Horn Rapids Road based on the availability of suitable habitat.

Four relatively stable sand dune blowouts and mature shrub areas with relatively open sand (Figure 1.6) provide potentially suitable habitat for several species of rare spring ephemeral annual forbs, including Great Basin gilia (*Aliciella leptomeria*), loeflingia (*Loeflingia squarrosa*), rosy pussypaws (*Calyptridium roseum*), and Suksdorf monkeyflower (*Erythranthe suksdorfii*) (Table 1.1) (WNHP 2018). However, none of these species were observed between 2009 and 2017 in the uplands north of Horn Rapids Road (Appendix C).

The riparian community provides potentially suitable habitat for Columbia yellowcress (*Rorippa columbiae*), lowland toothcup (*Rotala ramosior*), awned halfchaff sedge (*Lipocarpha aristulata*), grand redstem (*Ammania robusta*), Canadian St. John's-wort (*Hypericum majus*), and beaked spike-rush (*Eleocharis rostellata*) (Sackschewsky et al. 2014; WNHP 2018). Columbia yellowcress is known to occur in the riparian zone in the 300 Area of the Hanford Site, located just north of the PNNL Richland Campus. The other five species occur in the riparian area along the Hanford Reach of the Columbia River north of the 300 Area. However, none of these species were observed in 2015 or 2017 in the riparian area of the PNNL Richland Campus (Appendix C).

Priority habitats are those habitat types or elements that have unique or significant value to a diverse assemblage of species. Both the shrub-steppe and riparian habitats described previously are listed by the WDFW as priority habitats for the state and are considered to be priorities for management and conservation (WDFW 2016).

1.5 Environmental Setting – PNNL Marine Sciences Laboratory Vicinity

JP Duncan

Battelle Land−Sequim is located on Sequim Bay in Puget Sound and consists of forests, sandy beach shoreline, a bluff line, and developed areas with roads and structures (Figure 1.3). MSL facilities include buildings on the shoreline as well as structures approximately 27 m (89 ft) higher in elevation on a bluff overlooking the ocean.

The geology immediately underlying MSL is composed of glacial till from the Vashon glaciations that occurred 10,000 to 15,000 years ago. This glacial till sits atop several alternating layers of coarse- and fine-grained units, and ultimately bedrock around 305 m (1,000 ft) below ground surface. This layered stratigraphy results in several confined aquifers below the region as well as the uppermost unconfined aquifer. The aquifer units (both confined and unconfined) consist primarily of coarse-grained sand and gravel, while the confining units generally consist of fine-grained silt and clay deposits, but may contain discontinuous lenses of water-bearing sand and gravel (Thomas et al. 1999). The unconfined aquifer is nominally 9 m (30 ft) below ground surface under most of the MSL, and it moves in a northeasterly direction toward Sequim Bay.

Daily meteorological data are collected at the MSL weather station. The region is positioned in the rain shadow of the Olympic Mountains, so it receives less than 38 cm (15 in.) of rainfall annually despite its coastal location. The area experiences cool, wet winters and warm, dry summers; average monthly temperatures in 2017 ranged from 3.8°C to 16.2°C (38.8°F to 61.1°F). The annual average temperature in 2017 was 10.4°C (50.7°F); maximum temperature was 27.2°C (81.0°F) and minimum was -4.3°C (24.3°F). The annual relative humidity at MSL was 85.2% in 2017; humidity was highest during fall, averaging approximately 88%, and lowest during summer, when it averaged 82.5%. Regional winds are primarily from the west and northwest; however, the local topography of Battelle Land–Sequim also has localized wind patterns from the southeast and east. Wind speed averaged 1.3 m/s (2.9 mph) in 2017 at MSL; peak wind speed, 18.8 m/s (42.0 mph), occurred in the fall.

1.5.1 Ecology

JM Becker

The MSL (Figure 1.3) lies in the Olympic Rain Shadow subdivision of the Puget Lowland Ecoregion, a north-south depression between the Olympic Peninsula and western slopes of the Cascade Mountains that flanks the coastline of Puget Sound, and features many islands, peninsulas, and bays (LandScope Washington 2018; EPA 2013). Timber harvesting and cultivation have fragmented the original vegetation of the Puget Lowland that once consisted of coniferous forest and expanses of prairie-oak woodland (WWF 2018). Today, second-growth coniferous forest and agricultural fields occupy much of the ecoregion's glacial moraines, outwash plains, floodplains, and terraces (EPA 2013; LandScope Washington 2018). These patterns of disturbance have influenced the development of the current vegetation and cover types at MSL (Figure 1.7) and surrounding areas that consist largely of second-growth mixed coniferous and deciduous forest and agricultural fields, with adjacent areas of beach, feeder bluffs (i.e., eroding bluffs) (some of exceptional quality), and spit habitat along Sequim Bay (Clallam County 2017).

The uplands located on the about 36 ha (89 ac) that immediately surround the MSL facilities consist of the following general cover types: mixed conifer forest and field/meadow, bluff, spit, and developed areas (Figure 1.7). Species observed during several biological surveys of MSL are listed in Appendix D.

Mixed coniferous forest at MSL begins above the ordinary high-water mark of Sequim Bay (except for along the MSL spit) and extends west of the facilities and along Washington Harbor Road (Figure 1.7). Dominant tree species include Douglas fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), and western red cedar (*Thuja plicata*). Other common tree species include Pacific madrone (*Arbutus menziesii*), bigleaf maple (*Acer macrophyllum*), red alder (*Alnus rubra*), and grand fir (*Abies grandis*). Subcanopy tree species include Indian plum (*Oemleria cerasiformis*) and non-native English holly (*Ilex aquifolium*). Common shrub species include salal (*Gaultheria shallon*), hollyleaved barberry (*Mahonia aquifolium*), Cascade barberry (*M. nervosa*), dwarf rose (*Rosa gymnocarpa*), California blackberry (*Rubus ursinus*), Himalayan blackberry (*Rubus armeniacus*), oceanspray (*Holodiscus discolor*), redflower currant (*Ribes sanguineum*), vine maple (*Acer circinatum*), common snowberry (*Symphoricarpos albus*), and Scotch broom (*Cytisus scoparius*), a Washington State Class B noxious weed (WNWCB 2018). Common fern species include western swordfern (*Polystichum munitum*) and western bracken fern (*Pteridium aquilinum*).

Spit habitat is located in the northeastern portion of the MSL site. It includes the area situated just to the west (along the east margin of the lagoon) and just to the east (tidal zone) of the Sequim Bay ordinary high-water mark (Figure 1.7). The west side of the spit includes estuarine and marine wetlands. The portion of the spit located west of the ordinary high-water mark was surveyed in May 2015. Dense mats of Virginia glasswort (*Salicornia depressa*) and saltgrass (*Distichlis spicata*) occur closest to the lagoon, while dense stands of Puget Sound gum weed (*Grindelia integrifolia*) and common yarrow (*Achillea millefolium*) occur just upgradient of the lagoon.

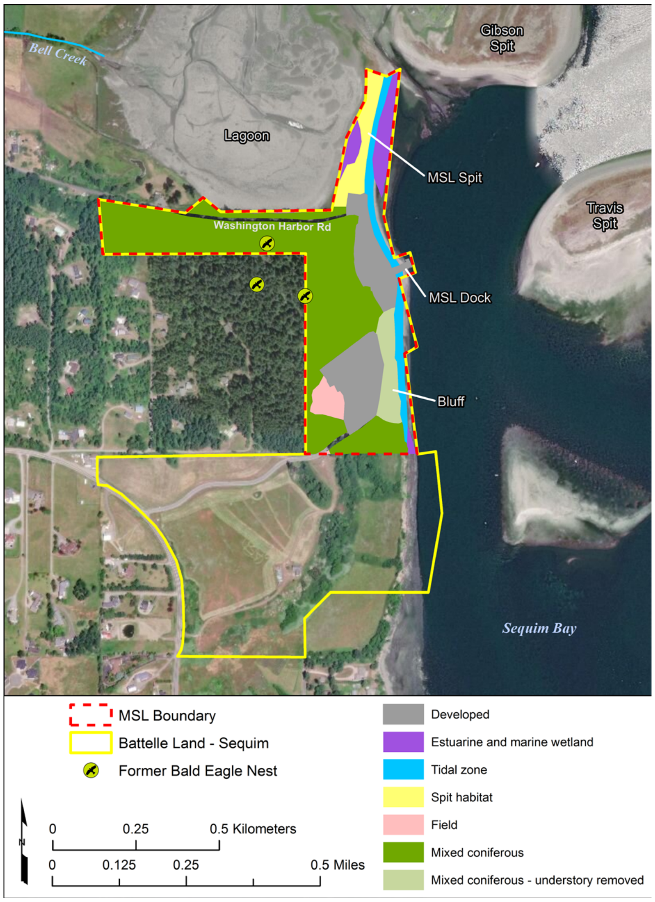


Figure 1.7. Plant Communities and Locations of Former Bald Eagle Nests at MSL

The combined acreage of wetland types within the MSL property is about 2.6 ha (6.5 ac); 2 ha (4.9 ac) are estuarine/marine wetlands, 0.5 ha (1.3 ac) are estuarine subtidal deepwater habitat, and 0.13 ha (0.33 ac) is riverine wetland. The relatively undisturbed nearshore areas of Puget Sound and the open coast are listed by the WDFW as a priority habitat for the state (WDFW 2016), and are therefore considered to be a priority for management and conservation (Clallam County 2017). The shore habitat (marine riparian zone) of such areas, including that which lies adjacent to MSL (Figure 1.7), extends inland from the ordinary high-water mark to the portion of the terrestrial landscape that it is influenced by or directly influences the aquatic ecosystem. Cliffs above 7.6 m (25 ft) in height and below 1,524 m

(5,000 ft) elevation are considered priority habitat features in the state, and include feeder bluffs adjacent to MSL, which are an important source of sediments that form and sustain beaches (WDFW 2016).

The nearshore and open-water environment of Sequim Bay provides potential habitat to various aquatic and terrestrial species, most notably federally listed threatened species such as the bull trout (*Salvelinus confluentus*) (64 FR 58910), Puget Sound Chinook salmon (70 FR 37160), Hood Canal summer-run chum salmon (*Oncorhynchus keta*) (70 FR 37160), and Puget Sound steelhead (72 FR 26722). Sequim Bay is designated critical habitat for bull trout (75 FR 63898), Puget Sound Chinook salmon, and Hood Canal summer-run chum salmon (70 FR 52630). Sequim Bay also provides potential habitat for the federally threatened North American green sturgeon (*Acipenser medirostris*) (NMFS 2018; 71 FR 17757), Pacific eulachon (Columbia River smelt; *Thaleichthys pacificus*) (NMFS 2017; 75 FR 13012), yelloweye rockfish (*Sebastes ruberrimus*) (75 FR 22276; 82 FR 7711), and marbled murrelet (*Brachyramphus marmoratus*) (75 FR 3424), as well as federally endangered Puget Sound bocaccio (*Sebastes paucispinis*) (75 FR 22276). The northern half of Sequim Bay contains designated nearshore and deepwater critical habitat for yelloweye rockfish and bocaccio (79 FR 68041). Critical habitat for the marbled murrelet occurs at the southwest end of Sequim Bay about 6 km (3.7 mi) south of MSL (61 FR 26256; 81 FR 51348). The nearshore environment of Sequim Bay is also spawning habitat for forage fish species such as Pacific sand lance (*Ammodytes hexapterus*) and surf smelt (*Hypomesus pretiosus*) (WDFW 2018c).

Common mammal species in the Puget Lowland ecoregion include raccoon (*Procyon lotor*), mink (*Mustela vison*), coyote, and black-tailed deer (*Odocoileus hemionus*) (WWF 2018). These species likely are also common in the MSL vicinity (Appendix D). Harbor seals (*Phoca vitulina*) are also common in the vicinity of the MSL. Klapot Point on the southwest tip of Travis Spit, located in Sequim Bay about 0.4 km (0.25 mi) from MSL (Figure 1.7), provides a haulout area for harbor seals.

Avian species found in the MSL vicinity are representative of the rich bird diversity of the northern Olympic Peninsula (Olympic Peninsula Audubon Society 2017). The groups represented and some of their most common species include waterfowl such as the bufflehead (*Bucephala albeola*); birds of prey such as the bald eagle; seabirds such as the Olympic gull (*Larus glaucescens x occidentalis*); upland game birds such as the mourning dove; colonial nesting waterbirds such as the great blue heron; woodpeckers such as the downy woodpecker (*Picoides pubescens*); and a variety of perching birds. Approximately 80 avian species have been observed at MSL (Appendix D).

Six salamander and five frog and toad species are known to occur in the MSL vicinity, the most common being the rough-skinned newt (*Taricha granulosa*) and Pacific tree frog (*Pseudacris regilla*) (Dungeness River Audubon Center 2015). Three snake and one lizard species also occur in the MSL vicinity, the most common of which are the common garter snake (*Thamnophis sirtalis*) and northwestern garter snake (*Thamnophis ordinoides*) (Dungeness River Audubon Center 2015).

Six animal species of conservation concern are known to occur or potentially occur at or near MSL facilities (Table 1.2). The bald eagle (Figure 1.7), peregrine falcon (*Falco peregrinus*), and western toad (*Anaxyrus boreas*) are known to occur on MSL property (Appendix D). Taylor's checkerspot butterfly (*Euphydryas editha taylori*) (78 FR 61451) and sand-verbena moth (*Copablepharon fuscum*) potentially occur in the vicinity of MSL, based on the availability of suitable habitat. Suitable habitat for Taylor's checkerspot butterfly consists of short-statured

Table 1.2. Animal Species of Conservation Concern Known to Occur or that Potentially Occur at and in the Vicinity of the PNNL Marine Sciences Laboratory

Common Name	Genus and Species	Federal Status[(a)]	State Status[(b)]
Bald eagle	*Haliaeetus leucocephalus*	Species of Concern	
Brandt's cormorant	*Phalacrocorax penicillatus*		Candidate
Peregrine falcon	*Falco peregrinus*	Species of Concern	
Sand-verbena moth	*Copablepharon fuscum*		Candidate
Taylor's checkerspot butterfly	*Euphydryas editha taylori*	Endangered	Endangered
Western toad	*Anaxyrus boreas*		Candidate

Source: WDFW (2018a)

(a) Endangered Speies are those in danger of extinction throughout all or a significant portion of their range. Species of concern are those that may be in need of conservation actions that could range from monitoring of populations and habitat to listing them as federally threatened or endangered. Federal species of concern receive no legal protection and the classification does not imply that the species is being considered for listing as threatened or endangered (USFWS 2018).

(b) Endangered species are those that are native to the state of Washington and are seriously threatened with extinction throughout all or a significant portion of their range within the state (WAC 232-12-297). Candidate species are those that WDFW will review for possible listing as endangered, threatened, or sensitive.

vegetation communities with specific larval and adult food resources (78 FR 61451; Potter 2016). Designated critical habitat for Taylor's checkerspot butterfly occurs approximately 5 km (3 mi) north of MSL (78 FR 61505). Suitable habitat for sand-verbena moth consists of coastal sand dunes and spit habitat containing coastal sand verbena (*Abronia latifolia*), the species' only host plant (Canada 2018). Coastal sand verbena occurs on the MSL spit and on nearby Travis Spit (Figure 1.7). Brandt's cormorant (*Phalacrocorax penicillatus*) may use the beaches and waters of Sequim Bay and the lagoon located just north of MSL.

1.6 Cultural Setting – PNNL Richland Campus

JL Mendez

The archaeological record of the Mid-Columbia Basin bears evidence of more than 8,000 years of human occupation. Regional development of hydroelectric dams, highways, commercial and residential real estate, and agriculture have obscured or destroyed much of the archaeological record. Despite continual development in the region, places within the Columbia Basin still remain largely undisturbed, including portions of the PNNL Richland Campus. Because the arid climate provides favorable environmental conditions for preservation of materials that might otherwise decay more quickly, evidence of past human behavior may be present within these undisturbed areas. The history of the Mid-Columbia Basin includes three distinct periods of human occupation: the Pre-Contact period, the Euro-American period, and the Manhattan Project period.

1.6.1 Pre-Contact Period

Archaeological investigations conducted on the Columbia Plateau enabled the creation of a cultural chronology dating back to the end of the Pleistocene (about 11,000 years Before Present [B.P.]). Table 1.3 summarizes the pre-contact cultural sequence for the PNNL Richland Campus area.

Table 1.3. Pre-Contact Cultural Sequence for the PNNL Richland Campus Region

Cultural Period	Years Before Present	Site Types	Architecture	Subsistence
General Columbia Plateau				
Windust Phase	11,000–8,000	Rock shelters, caves, game processing sites, lithic reduction sites; isolated lithic tools. Examples include Marmes Rockshelter, Bernard Creek, Lind Coulee, Kirkwood Bar, Deep Gully, Granite Point, Fivemile Rapids, and Bobs Point.	Rock shelters and caves; open habitation sites. No evidence of constructed dwellings or storage features.	Large mammals supplemented with small mammals and fish. Toolset: Windust, Clovis, Folsom, and Scottsbluff Points; contracting stemmed points and/or lanceolate points; cobble tools.
Mid-Columbia Region – Vantage Area				
Cascade/ Vantage Phase	8,000–4,500	Lithic scatters, quarry sites, resource processing sites, temporary camps.	Rock shelters and caves; open habitation sites.	Mobile, opportunistic foragers subsisting on fish, mussels, seeds, and mammals. Basalt leaf-shaped Cascade and stemmed projectile points, ovate knives, edge-ground cobble tools, microblades, hammerstones, core tools, and scrapers.
Frenchman Springs Period	4,500–2,500	Habitation sites along major rivers, confluences, tributaries, canyons, and rapids. Lithic scatters, quarry sites, resource processing sites, seasonal rounds of upland to lowland travel for resource procurement; seasonal camps.	House dwellings, including semi-subterranean.	As earlier, but with increased use of upland resources, seeds, and roots. Groundstone and cobble tools, mortars, pestles, contracting stemmed, corner-notched, and stemmed projectile points, hopper mortar bases and pestles, knives, scrapers, and gravers. Wider tool material variety.
	I 2,500–1,200	Habitation sites at major rivers, confluences, tributaries, canyons, and rapids. Lithic scatters, quarry sites, resource processing sites, seasonal round camps. Ideological and spiritual sites.	Pithouses with wall benches.	Reliance on riverine resources, fish, and botanicals; basal-notched and corner-notched projectile points (most corner-notched); variety of tools including groundstone, scrapers, lanceolate, and pentagonal knives, net weights, cobble tools, drills, etc.
Cayuse Phase	II 1,200–900	Same as Cayuse Phase I.	Pithouses without wall benches.	Same as Cayuse Phase I.
	III 900–250	Increased mobility and hunting ability due to horse introduction. Large village habitation sites along rivers, seasonal round camps. Same site types as Cayuse Phases I & II.	Pit longhouse village sites.	Decrease in corner-notched points, increase in stemmed and side-notched projectile points, fine pressure flaked tools. Increase in trade goods.

Sources: Swanson (1962); Nelson (1969); Green (1975); Rice (1980); Galm et al. (1981); Thoms et al. (1983); Benson et al. (1989); Walker (1998); Morgan et al. (2001); Sharpe and Marceau (2001).

1.6.2 Ethnographic Period

Ethnographically, the Sahaptin-speaking Cayuse, Walla Walla, Palouse, Nez Perce, Umatilla, Wanapum, and Yakama used the area. During this period, local residents relied on a pattern of seasonal rounds that included semi-permanent residences in villages along major waterways during the winter months. With the arrival of spring, small groups living in temporary camps traveled into the canyons and river valleys to gather roots. Seasonal camps were used in the inland areas during the spring and early summer months. By late summer or early fall, seasonal rounds focused on ripening berries in the mountains. It was this time of the year when the acquisition of food came to an end and families returned to the winter villages (Chatters 1980; Galm et al. 1981; Bard and McClintock 1996; Dickson 1999).

1.6.3 Euro-American Period

The Lewis and Clark expedition of 1805 began the Euro-American exploration and settlement of the region. Explorers sought trade items from Native Americans and trade routes were established. Gold miners, livestock producers, and homesteaders soon followed. By the 1860s, the discovery of gold north and east of the mid-Columbia region resulted in an influx of miners traveling through the area. Ringold, White Bluffs, and Wahluke were stops along the transportation routes used by miners and the supporting industry. Numerous features created by Euro-Americans and Chinese that remain along the shoreline of the Hanford Reach are believed to be related to gold mining (Sharpe 2000). The mining industry created a demand for beef, and the Columbia Basin was ideal for livestock production.

An increase in Euro-American settlement began in eastern Washington in the late 1800s. The initial permanent settlement of non-Indians in the area began slowly with livestock producers. Pasture was abundant and free for the taking. Ranchers relied on the abundant bunchgrass and open rangeland to graze thousands of cattle and later sheep and horses. The open range lasted from the 1880s to ca. 1910, when homesteaders settled the area and plowed the rangeland to plant crops. However, livestock remained an important economic commodity for the area's agricultural producers. Cattle became confined by fences, while sheep pastured on the remaining open range of Rattlesnake Mountain and Horse Heaven Hills (Fridlund 1985). Agricultural producers gradually replaced the open-range livestock operations that had dominated the area in the latter part of the 1800s and early 1900s.

Homesteaders removed unwanted sagebrush and bunchgrass and plowed the land. The *Homestead Act of 1862* (12 Stat. 392, ch. 75) enabled individuals 21 years of age or older to legally own land if they were willing to live on and develop the land (DOE-RL 1997). Circa 1900, homesteaders moved west, traveling by railroad to the Columbia Basin area.

Local transportation systems were very limited at the turn of the century; many of the Hanford area settlers arrived by river transportation. Steamboats and ferries were the primary transportation systems on the Columbia River during the homesteading era (Sharpe 2001). Residents of the new agricultural towns of Hanford and White Bluffs as well as the small communities of Allard-Vernita, Wahluke, and Fruitvale, relied almost exclusively on river transportation during the early development of the area.

The southern Columbia Basin area was unique because it produced ripe agricultural crops and orchard fruit 2 to 3 weeks ahead of surrounding areas, resulting in higher profits to local farmers. In the early

1900s, dryland wheat and livestock were the primary agricultural commodities in Benton County. As farming increased, water resources other than rainfall were needed to produce higher crop yields. Many irrigation projects began; most were privately and insufficiently funded. Land speculators began constructing large-scale irrigation canals to supply water to thousands of acres in the White Bluffs, Hanford, Fruitvale, Vernita, and Richland areas (Sharpe 1999). However, poor economic conditions associated with the Great Depression of the 1930s created economic hardship for local residents. The hardship continued until the government took over the area under the *First War Powers Act of 1941* (50 U.S.C. App. 601 *et seq.*) (Marceau et al. 2003).

1.6.4 Manhattan Project Era

In 1942, the area around Hanford, Washington, was selected by the federal government as one of the three principal Manhattan Project sites. Occupying portions of Grant, Franklin, and Benton Counties, the Hanford Site was created to support the United States' plutonium-production effort during World War II. Plutonium production, chemical separation, and R&D focused on process improvements were the primary activities during the Manhattan Project as well as the subsequent Cold War Era. The industrial components of the Manhattan Project and Cold War Era are still located in discrete areas throughout the site. Reactors in the 100 Areas were used to irradiate uranium fuel to produce plutonium. Plutonium was extracted from irradiated fuel at the chemical separation facilities in the 200 Areas. The uranium fuel was manufactured in the 300 Area, prior to being delivered to the reactors in the 100 Areas for use in advanced power plants. The 600 Area is a broad expanse between the production areas that contained infrastructure such as roads and rail systems that served the entire site. The 700 Area was the administration area in Richland (Marceau et al. 2003).

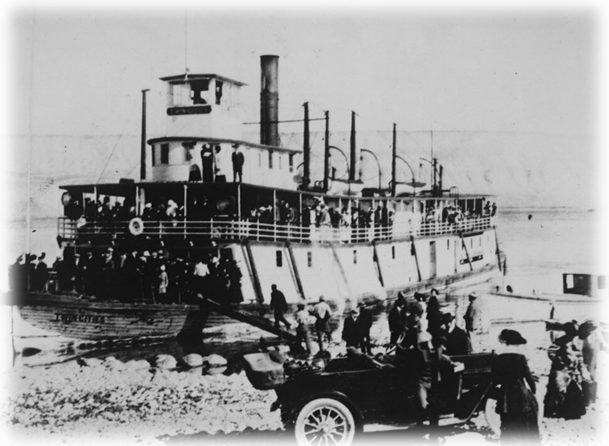
1.7 Cultural Setting – PNNL Marine Sciences Laboratory Vicinity

JL Mendez

Evidence of the earliest settlement of the northwest coast is sparse in the archaeological record. Early sites from the northern northwest coast suggest the presence of coastal populations as early as 10,000 B.P. (Ackerman et al. 1985). These early sites contain lithic assemblages made up of bifaces, scrapers, and microblades similar to those known from Alaskan tool traditions. Sites dating to the earliest occupation of the region often contain assemblages of sea mammal bones. Early components of the Namu site on the central British Columbia coast provide evidence of heavy reliance on salmon, herring, and shellfish. The richness of these resources may have supported semi-sedentary winter occupation of the site as early as 7,000 B.P. (Cannon 1991).

As the Holocene era progressed and the climate of the region warmed, salmon and the human populations that subsisted on them could move into upland areas and places away from the coasts that were previously inaccessible. As the Canadian Cordilleran glacier retreated, Puget Sound was created and new interior coastal territories opened up (Schalk 1988). By about 5,000 B.P., it seems that consumption of shellfish began to play a dominant role in regional subsistence patterns. The abundance of shellfish, salmon, and other wild resources in the region formed the basis of an economic and subsistence pattern that was exceptionally stable. This stability is what allowed for the development of the classic complex hunter/fisher/gatherer societies that persisted into the 18th century (Fagan 2001).

Starting in the middle prehistoric period, the diverse groups of the northwest coast began to participate in a more homogeneous regional social system. This spread of ideas and cultural traits is thought to have been facilitated by widespread regional trade networks (Croes 1989). During this middle period (between 3,800 B.P. and A.D. 500), complex cultural mechanisms developed among societies of the northwest coast. Chief among these developments was the accumulation of resource surpluses and the emergence of social ranking. A rich material culture developed during this period that included elaborate ceremonial goods and new artistic traditions (Ames and Maschner 1999).



During the late pre-contact period (A.D. 500 until the ethnographic period), the classic complex hunter-fisher-gatherer societies of the region grew and flourished on the northwest coast. This trend toward more complex societies included hallmarks such as increased population density, heavy reliance on stored food and other resources, and architectural styles that included plank houses and fortified villages (Fagan 2001). Social mechanisms such as social stratification, redistribution of resources, and political networks were part of the culture that emerged in the region.

1.7.1 Ethnographic Period

MSL is located within the Central Coast Salish Culture Area, which includes the southern end of the Strait of Georgia, most of the Strait of Juan de Fuca, the lower Frasier Valley, and other nearby areas. This area includes parts of present-day British Columbia and Washington State. Five traditional languages were spoken throughout the area: Squamish, Halkomelem, Nooksack, Northern Straits, and Klallam (Suttles 1991). Speakers of the Klallam language are native to the northern Olympic Peninsula, between the Hoko River and Port Discovery Bay. According to early ethnographic data, there were 13 Klallam winter villages in this region—all but one was located on saltwater shores (Schalk 1988).

Fishing for salmon and other anadromous fish was a major component of the subsistence pattern within the Central Coast Salish Culture Area. Anadromous species native to the region include five species of salmon (Chinook, coho, sockeye, chum, and pink [*O. gorbuscha*]), steelhead and cutthroat trout, and Dolly Varden (*Salvelinus malma*; Schalk 1988). In marine settings, a reef net consisting of a rectangular net suspended between canoes was used to catch salmon. In freshwater settings, fishing gear included harpoons, leisters, gaff hooks, four-pronged spears, dip nets, basket traps, weirs, and trawl lines (Suttles 1991). In addition to salmon, saltwater fish such as halibut, herring, lingcod, and flounder were caught. The relatively calm sandy beaches and highly productive estuarine conditions of the eastern portion of the Strait of Juan de Fuca supported large populations of invertebrates such as the little neck clam, butter clam, horse clam, and the basket cockle (Schalk 1988).

The Klallam-speaking people were one of the few groups in the region to practice whaling; whales were only hunted opportunistically, when spotted from shore (Schalk 1988). Klallam whalers used harpoons to hunt whales from canoes (Suttles 1991). On land, Salish hunters trapped, drove, and stalked deer as a main source of terrestrial game. Other game species included elk, black bear, mountain goat, and beaver, as well as many species of waterfowl. Ethnographic data suggest that hunting among the Klallam was limited to a small number of specialized hunters who hunted in the mountains, and that terrestrial game played a relatively small role in the overall subsistence pattern (Schalk 1988). Women gathered at least 40 different edible plants including sprouts, stems, bulbs, roots, berries, fruits, and nuts. Other gathered resources included marine mollusks such as mussels, clams, and cockles, as well as sea urchins, crabs, and barnacles (Suttles 1991).

Woodworking was an important aspect of Salish technology, and wooden items hold an important place in the material culture in this area. A variety of tools, including both chipped and ground stone, were produced for this purpose. Traditional wooden objects produced by Salish cultures included house posts, beams, planks, canoes, various boxes, dugout dishes, tools, and weapons, as well as ceremonial paraphernalia (Suttles 1991). Cordage was made using a range of plant and animal fibers including cedar bark, willow bark, sinew, kelp, and hide. These materials were used to manufacture a wide range of products including nets, towels, cradle mattresses, skirts, mats, and different types of containers and baskets. A unique weaving tradition was practiced by groups in the Central Coast Salish Culture Area that used mountain goat wool, waterfowl down, fireweed cotton, and the fur of a now extinct breed of dog (Suttles 1991).

Most travel in the region was by canoe. Central Coast Salish groups manufactured different styles of dugout canoes for various purposes including saltwater fishing, freshwater fishing, transportation, and war (Suttles 1991). Winter village sites were located on the water in areas where canoes could be beached. Villages often consisted of one or more rows of plank houses paralleling the shore. Houses were constructed on a post and beam framework, with plank walls and shed roofs (Suttles 1991).

One important aspect of Central Coast Salish society was the practice of ritual feasts and gift-giving events known as potlatches. The potlatch was a practice that marked an important event or a change in an individual's status (Suttles 1991; Fagan 2001). A typical potlatch included members from several or all of the houses of a village preparing a feast and giving large quantities of accumulated wealth and gifts to guests from neighboring villages. The redistribution of accumulated goods was important for establishing and reinforcing status or fame. Direct reciprocity was not expected, but elaborate gift-giving rituals were seen as an investment in securing relationships and support networks between villages and neighbors (Suttles 1991).

1.7.2 Historic Period

The earliest Euro-American settlement in Clallam County and the Sequim area (in the 1850s) was known as Whiskey Flat; it was located on the cliffs above the Strait of Juan de Fuca (Morgan 1996). In 1852 the town of Dungeness was started at Whiskey Flats. By the end of the nineteenth century, the settlement of New Dungeness had grown and the county courthouse was moved to Port Angeles. At this time, the Sequim area was a developing agricultural area. The Sequim Prairie irrigation ditch was completed in 1896, which allowed for expanded farming in the area (Morgan 1996).

In 1907, the Bugge Clam Cannery was established at what is the current MSL site. A fire destroyed the plant in 1929, but the facility was rebuilt and operated until 1967. In 1967, Battelle hired John Graham and Company, a prominent architecture firm in Seattle, to design a master plan for a marine research laboratory to be located near Sequim, Washington, on 48.6 ha (120 ac) at the mouth of Sequim Bay on the Strait of Juan de Fuca, which Battelle had acquired the previous year (Battelle-Northwest 1967). The laboratory near Sequim was intended to "provide facilities for research projects which require ocean waters or oceanic environments" (Battelle-Northwest 1967).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Offer Described As Outstanding; Objectives Met

Tri-City Growth Seen

Chance Seen As Challenge

Tri-City Herald

2.0 COMPLIANCE SUMMARY

Operations at PNNL are conducted in compliance with all applicable federal, state, and local environmental laws, regulations, and guidance; presidential Executive Orders; and DOE Orders, directives, policies, and guidance. PNNL endeavors to conduct operations in a sustainable manner that is protective of the environment. Table 2.1 summarizes PNNL's compliance, and subsequent subsections provide brief descriptions of each statute or regulation.

2.1 Sustainability and Environmental Management System

JP Duncan

The DOE-Battelle Prime Contract for the management and operation of PNNL (DOE-PNSO 2017a) incorporates applicable requirements from DOE Order 436.1, *Departmental Sustainability*, including associated performance goals, objectives, and systems. This Order and related Executive Orders are briefly discussed in the following sections.

2.1.1 DOE Order 436.1, *Departmental Sustainability*

DOE Order 436.1 was approved on May 2, 2011. The purpose of this Order is to

> "…1) ensure the Department carries out its missions in a sustainable manner that addresses national energy security and global environmental challenges, and advances sustainable, efficient and reliable energy for the future,
>
> 2) institute wholesale cultural change to factor sustainability and greenhouse gas (GHG) reductions into all DOE corporate management decisions, and
>
> 3) ensure DOE achieves the sustainability goals established in its Strategic Sustainability Performance Plan pursuant to applicable laws, regulations and Executive Orders (EO[s]), related performance scorecards, and sustainability initiatives…."

PNNL has incorporated these requirements through modifications to the DOE-Battelle Prime Contract, which include the development of a site sustainability plan (e.g., DOE 2017), incorporation of sustainable acquisition requirements into applicable processes, and the development of an EMS that is certified to meet the requirements of the International Organization for Standardization (ISO) 14001:2015 standards.

The PNNL *FY 2018 Site Sustainability Plan* (DOE 2017) identifies the status and accomplishments of sustainability projects related to DOE's sustainability goals. Prepared and submitted to DOE annually, the PNNL site sustainability plan includes Pollution Prevention Program activities, accomplishments, and continuous improvement opportunities. Section 3.0 provides further information concerning PNNL's EMS and the status of PNNL's sustainability goals.

2.1.2 Executive Order 13693, "Planning for Federal Sustainability in the Next Decade"

Executive Order 13693 of March 19, 2015 (80 FR 15871), strengthens policies for federal agencies to increase energy efficiency and environmental performance. The Order revokes Executive Order 13423 of January 24, 2007, "Strengthening Federal Environmental, Energy, and Transportation Management" (72 FR 3919), and Executive Order 13514 of October 5, 2009, "Federal Leadership in Environmental, Energy, and Economic Performance" (74 FR 52117), which require increased federal sustainability and GHG emission reductions beyond those established by the earlier authorities.

Table 2.1. Status of Federal and State Environmental Laws and Regulations Applicable to PNNL, 2017

Statute/Regulation	What It Covers	2017 Status
Federal		
Environmental Safety and Health Reporting		
DOE Order 231.1B, *Environment, Safety, and Health Reporting*	Requires the gathering, analysis, and reporting of information about environmental safety and health issues	PNNL monitors and conveys information via reports, emails, LabWeb News articles, and staff meetings. The Pacific Northwest National Laboratory (PNNL) Annual Site Environmental Report is a requirement of this Order.
Air Quality and Protection		
Clean Air Act	Air quality including emissions from facilities and unmonitored sources.	PNNL conducted operations under permits issued by the Washington State Department of Health, Washington State Department of Ecology, Benton Clean Air Agency, and Olympic Region Clean Air Agency. No events were reported for emissions of regulated substances to the air or substances of concern. Radioactive air emissions were more than 10,000 times lower than the regulatory standard of 10 mrem/yr (0.1 mSv/yr) at both the PNNL Richland Campus and the Marine Sciences Laboratory (MSL).
Cultural Resources		
American Indian Religious Freedom Act; *Antiquities Act of 1906*; *Archeological and Historic Preservation Act of 1974*; *Archaeological Resources Protection Act of 1979*; *National Historic Preservation Act of 1966*; and *Native American Graves Protection and Repatriation Act of 1990*	Preservation and protection of cultural resources.	Five *National Historic Preservation Act* Section 106 cultural resource reviews were conducted for PNNL projects. No cultural/historical resource compliance issues were identified. In addition, 27 projects were reviewed by cultural resource staff to assure that they were covered by previously conducted Section 106 cultural resource reviews.
Hazardous Materials and Waste Management		
Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)	Sites already contaminated by hazardous materials.	PNNL is not part of any Hanford CERCLA operable unit and had no continuous releases.

Statute/Regulation	What It Covers	2017 Status
Emergency Planning and Community Right-to-Know Act of 1986	The public's right to information about hazardous materials in the community and the establishment of emergency planning procedures.	PNNL submitted two Tier Two reports, providing information concerning potential hazards. PNNL was not required to submit a Toxic Release Inventory Report.
Federal Facility Compliance Act of 1992	Amends the *Resource Conservation and Recovery Act of 1976* (RCRA) and CERCLA and requires new mixed waste reporting requirements.	PNNL provided information as part of the Hanford Site Mixed Waste Land Disposal Restrictions Summary Reports pursuant to Tri-Party Agreement Milestone M-26.
Federal Insecticide, Fungicide, and Rodenticide Act	Storage and use of pesticides.	Licensed PNNL staff or certified commercial applicators were used to purchase, store, and apply pesticides on the PNNL Richland Campus and at MSL.
Resource Conservation and Recovery Act of 1976 (RCRA)	Tracking hazardous waste from generator to treatment, storage, or disposal (referred to as cradle-to-grave management).	PNNL is responsible for one RCRA-permitted storage and treatment unit. Washington State Department of Ecology personnel inspected two PNNL facilities; no noncompliances were identified. There are no RCRA permits applicable to MSL.
Superfund Amendments and Reauthorization Act of 1986	Amends and reauthorizes CERCLA.	PNNL Richland Campus areas near the Hanford Site have been evaluated and require no further action. Groundwater near the PNNL Richland Campus is monitored for Hanford Site contaminant migration. No contamination was identified at MSL that would require response under CERCLA or the *Superfund Amendments and Reauthorization Act*.
Toxic Substances Control Act	Hazardous chemical regulation and tracking; primarily polychlorinated biphenyls (PCBs).	PNNL contributed to the 2016 PCB annual document log report for the Hanford Site and 2016 PCB annual report; both were submitted to the U.S. Environmental Protection Agency as required.
Environment and Wildlife		
Bald and Golden Eagle Protection Act	Protection of bald and golden eagles.	Biological resource reviews provided assurance that proposed actions did not adversely affect bald or golden eagles.

Statute/Regulation	What It Covers	2017 Status
Coastal Zone Management Act of 1972	Encourages the development of coastal zone management plans to preserve, protect, and enhance natural coastal resources and the wildlife using coastal habitats.	PNNL considers coastal resources and the fish and wildlife that use those habitats when evaluating proposed actions. No federal consistency determinations were acquired by PNNL.
Endangered Species Act of 1973 (ESA)	Threatened and endangered plant and animal species.	No endangered or threatened species were observed during biological field surveys of the PNNL Richland Campus. Five ESA authorizations were acquired and several no effect determinations were made for offsite scientific research studies.
Forest Service Organic Administration Act of 1897	Protection and administration of U.S. Forest Service lands.	One special use permit was acquired for an offsite scientific research study.
Magnuson–Stevens Fishery Conservation and Management Act	Essential fish habitat.	Four essential fish habitat authorizations were acquired and several no effect determinations were made for offsite scientific research studies.
Marine Mammal Protection Act of 1972	All marine mammals.	Two *Marine Mammal Protection Act* authorizations were acquired and several no effect determinations were made for offsite scientific research studies.
Migratory Bird Treaty Act	Migratory birds or their feathers, nests, or eggs.	A number of migratory birds were observed during the biological field survey of the PNNL Richland Campus and the lands encompassing MSL. PNNL biologists resolved about 30 inquiries concerning migratory birds on the PNNL Richland Campus and at MSL.
National Environmental Policy Act of 1969 (NEPA)	Environmental impact statements, environmental assessments, and categorical exclusions for federal projects that have the potential to affect the quality of the human environment.	PNNL environmental compliance representatives and NEPA staff conducted 1,042 NEPA reviews during CY 2017 for research and support activities. The U.S. Department of Energy (DOE)-Richland Operations Office approved nine generic categorical exclusions; ten were revised and approved by the Pacific Northwest Site Office.
National Park Service Organic Act	Management of national park and national monument lands.	No scientific research and collecting permits were acquired for offsite studies.

Statute/Regulation	What It Covers	2017 Status
National Wildlife Refuge System Administration Act of 1966	Allows the U.S. Fish and Wildlife Service to issue permits for scientific research within national wildlife refuges.	One special use permit was acquired for an offsite scientific research study.
Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990	Prevents the spread of nonindigenous aquatic nuisance species to non-infested waters.	An aquatic invasive plant and animal species interception program has been developed and implemented by PNNL.
Rivers and Harbors Appropriation Act of 1899	Prohibits obstruction or alteration of navigable waters.	No Section 10 permits were acquired in 2017 for offsite scientific research.
Executive Order 11988, "Floodplain Management"	Requires federal agencies to evaluate the potential effects of any actions within a floodplain.	No activities were performed during 2017 that required a floodplain evaluation.
Executive Order 11990, "Protection of Wetlands"	Requires federal agencies to minimize the loss or degradation of wetlands and to preserve and enhance their natural and beneficial values.	One offsite activity was performed during 2017 that required a wetland evaluation.
Energy Independence		
Energy Independence and Security Act of 2007 (EISA)	Shifting the United States to greater energy independence and security and promoting energy efficiency, conservation, and savings.	PNNL evaluated three buildings under EISA energy and water evaluation requirements in FY 2017. PNNL also implemented stormwater management practices to promote water drainage and reduce runoff.
DOE Order 436.1, *Departmental Sustainability*	Implementation of requirements to include the preparation of a site sustainability plan and an environmental management system (EMS)	PNNL has developed and implements a site sustainability plan that incorporates the annual status and strategy for achieving the goals and objectives of DOE Order 436.1. PNNL has a fully integrated EMS that is certified to meet International Organization for Standardization (ISO) 14001:2015 standards.

Statute/Regulation	What It Covers	2017 Status
Executive Order 13693, "Planning for Federal Sustainability in the Next Decade"	Establishes goals and requirements in the areas of greenhouse gas reduction and promotes sustainable buildings, clean and renewable energy, water use efficiency and management, fleet management, sustainable acquisition, pollution prevention and waste reduction, energy performance contracts, and electronic stewardship.	PNNL produced the *Pacific Northwest National Laboratory FY 2018 Site Sustainability Plan*, which focuses on the goals and requirements of Executive Order 13693.
Radiation Protection		
DOE Order 435.1, *Radioactive Waste Management*	Establishes requirements for managing high-level waste, transuranic waste, low-level waste, and mixed wastes.	PNNL's Radioactive Waste Management Basis Program identifies and implements radioactive waste-management controls through internal workflows and procedures.
DOE Order 458.1, *Radiation Protection of the Public and the Environment*	Requirements related to radiation protection of the public and the environment, including estimating radiological dose.	PNNL implements programs to assure that facilities, emissions, effluents, and wastes are protective of the public, workers, and the environment.
Atomic Energy Act of 1954	Management of low-level and mixed low-level wastes and radioactive materials.	PNNL's Radiation Protection Management and Operation Program includes safeguarding and monitoring radioactive materials through work controls, dosimetry, bioassay, and safety information.
Water Quality and Protection		
Clean Water Act	Includes point-source discharges to United States surface waters and indirect discharges to sewer systems, as well as the discharge of dredged or fill material into U.S. waters and/or wetlands.	PNNL conducted operations under permits issued by the Washington State Department of Ecology and the City of Richland. MSL operated under a National Pollutant Discharge Elimination System permit issued by the Washington State Department of Ecology. Two Nationwide Permits were acquired for offsite scientific research studies.

Statute/Regulation	What It Covers	2017 Status
Safe Drinking Water Act of 1974	Drinking water systems.	The PNNL Richland Campus receives all drinking water for use in laboratory and nonlaboratory spaces from the City of Richland. The City is responsible for meeting water-quality standards under the *Safe Drinking Water Act of 1974*. At MSL, water is provided exclusively from onsite wells and PNNL is considered the water purveyor.
Washington State		
Hazardous Waste Management Act of 1976	Safe planning, regulation, control, and management of hazardous waste.	PNNL manages hazardous wastes in a safe and responsible manner. Inventories and storage methods are regulated, and reports are submitted as required.
Revised Code of Washington Chapter 17.10	Control of noxious weeds.	PNNL implements an invasive terrestrial plant species control program.
State Environmental Policy Act (SEPA)	Identifies environmental impacts of state and local decisions and gives agencies the authority to deny a proposal when adverse environmental impacts are identified.	PNNL environmental compliance representatives and staff review research and support activities, completing SEPA checklists as required.
Shoreline Management Act of 1971	Shoreline use, environmental protection, and public access.	One Shoreline Conditional Use Permit was obtained for an offsite scientific research study.
Washington Clean Air Act	Implements and supplements the federal *Clean Air Act*, overseeing air quality.	PNNL operated under permits issued by the Washington State Department of Health, Washington State Department of Ecology, Benton Clean Air Agency, and Olympic Region Clean Air Agency. No events were reported for air emissions of regulated substances or substances of concern.
Washington Pesticide Application Act	Control of pesticide application and use to protect public health and welfare.	Licensed PNNL staff or certified commercial applicators are used to apply pesticides.
Washington Pesticide Control Act	Proper use and control of pesticides.	Licensed PNNL staff or certified commercial applicators are used to apply pesticides.

Executive Order 13693 (80 FR 15871) establishes new goals and requirements for GHG emissions reductions and reporting; increased renewable energy generation and use of renewable energy sources; green building performance for new buildings and increased performance compliance in existing buildings; reduction in potable and nonpotable water use; installation of green infrastructure for stormwater and wastewater management; increased fleet performance and sustainable work-related travel practices including electric vehicles, telecommuting and teleconferencing, and carpooling and public transportation; electronics stewardship; and pollution prevention and waste diversion. In addition, Executive Order 13693 requires the development and implementation of an annual strategic sustainability performance plan. PNNL has developed detailed plans and milestones for achieving site-specific energy efficiency objectives and goals as directed by Executive Order 13693; details are available in Section 3.0.

2.2 *Energy Independence and Security Act of 2007*

JP Duncan

The *Energy Independence and Security Act of 2007* (EISA) (42 U.S.C. § 17001) was enacted "to move the United States toward greater energy independence and security." It promotes the production of clean, renewable fuels, R&D of biofuels, improved vehicle technology, energy savings through improved standards including those for appliances and lighting, improved energy savings in buildings and industry, the reduction of stormwater runoff and water conservation and protection, the development and extension of new technologies (including solar, geothermal, marine and hydrokinetic, and energy storage), carbon capture and sequestration research, and energy transportation and infrastructure provisions. In fiscal year (FY) 2017, PNNL completed evaluations for three buildings subject to EISA Section 432 continuous (4-year cycle) comprehensive energy and water requirements. To date, over 64% of PNNL buildings have met the criteria for DOE Federal Energy Management Program Guiding Principles for high-performance sustainable buildings (HPSBs), far exceeding the 2025 goal of 17% (DOE 2017). In addition, PNNL began construction of a science and technology event center designed to HPSB guidelines.

Whole-building metering for electricity, natural gas, and water have been completed for all viable buildings, enabling facility system analyses, as needed. Stormwater management practices are implemented to promote water drainage and reduce runoff (see Section 2.5.2). Also, a 125 kW photovoltaic array continued operation in 2017, contributing to onsite energy generation, and together with a solar water heater, additional small photovoltaic arrays on monitoring stations, and renewable energy certificate purchases provided 30.4% of the PNNL electricity consumption from renewables (DOE 2017). Further details are available in Section 3.0.

2.3 *National Environmental Policy Act of 1969*

MR Sackschewsky

The *National Environmental Policy Act of 1969* (NEPA) (42 U.S.C. § 4321 *et seq.*) was enacted to assure that potential environmental impacts, as well as technical factors and costs, are considered during federal agency decision-making. The PNNL NEPA Compliance Program supports Laboratory compliance with NEPA and the Washington *State Environmental*

Policy Act (SEPA) (Revised Code of Washington [RCW] 43.21C, as amended). Program activities include preparing sitewide and activity-specific categorical exclusions, environmental assessments, and Washington SEPA checklists. NEPA reviews of PNNL activities are conducted by both PNSO and DOE-RL NEPA compliance staff. The DOE office responsible for concurring with and approving the NEPA documentation depends on the proposed project location and source of funding. NEPA compliance is verified through assessments conducted by PNNL and DOE.

PNNL environmental compliance representatives and NEPA staff conducted 1,042 NEPA reviews during CY 2017 for research and support activities (698 Electronic Prep and Risk System reviews, 322 EMSL user proposals, and 22 facility-modification permits). NEPA staff reviewed the Electronic Prep and Risk reviews to verify that potential project environmental impacts were adequately considered, and NEPA (and as appropriate, SEPA) coverage was correctly applied. In nearly every case, activities were adequately addressed in previously approved NEPA documentation, such as generic categorical exclusions, environmental assessments, environmental impact statements, and supplement analyses. When there was no adequate previously approved documentation, PNNL staff prepared additional NEPA documentation, such as project-specific categorical exclusions for approval by DOE.

PNSO published no environmental impact statements during 2017. PNSO published one environmental assessment, *Pacific Northwest National Laboratory Richland Campus Future Development* (DOE/EA-2025; DOE-PNSO 2017b).

Categorical exclusions represent an effective and necessary means of addressing activities that 1) clearly fit within a class of actions that DOE has determined do not individually or cumulatively have a significant effect on the environment, 2) do not possess extraordinary circumstances that may affect the environment, and 3) are not "connected" to other actions that may have potentially significant impacts. A single determination for a generic categorical exclusion is allowed for recurring activities undertaken during a specified time period.

There were no new PNSO-approved generic categorical exclusions in 2017. A total of 15 generic categorical exclusions have been previously approved by PNSO to cover PNNL research and operations activities; 10 were revised and renewed in 2017. When projects clearly are within the definition of a categorical exclusion, but a generic categorical exclusion is not applicable, a project- or activity-specific categorical exclusion is prepared. There was one activity-specific PNSO–approved categorical exclusion in 2017, covering acquisition and operation of a new aircraft for the Atmospheric Radiation Monitoring Program. A list of all PNSO-approved categorical exclusions is available at http://science.energy.gov/pnso/nepa-documents/categorical-exclusion-determinations/.

A total of nine PNNL-related generic categorical exclusions were approved by DOE-RL in 2017, covering areas such as routine maintenance, small-scale R&D, site characterization, construction of small structures, environmental monitoring, use of nanoscale materials, and biomedical research. These activities are relevant to PNNL projects conducted in facilities located in the 300 Area of the Hanford Site and field work occurring on the Hanford Site; the list of DOE-RL-approved categorical exclusions is available at http://www.hanford.gov/page.cfm/CategoricalExclusions.

2.4 Air Quality

JM Barnett

Federal regulations that apply to air quality at the PNNL Richland Campus and MSL site and the permits necessary to maintain compliance are discussed in this section.

2.4.1 *Clean Air Act*

The *Clean Air Act* (42 U.S.C. § 7401 *et seq.*) is administered by EPA. It regulates air emissions from stationary and mobile sources, both criteria and hazardous air pollutants. The Act authorized EPA to establish National Ambient Air Quality Standards for the protection of public health and welfare. The establishment of these pollutant standards was combined with state implementation plans to facilitate attainment of the standards. The *Washington Clean Air Act* (RCW 70.94), which implements and supplements the federal law, has been revised periodically to keep pace with changes at the federal level. The Washington State Department of Ecology is responsible for developing most statewide air-quality rules, and enforces Title 40 of the *Code of Federal Regulations* Part 52 (40 CFR Part 52), 40 CFR Part 60, 40 CFR Part 61, 40 CFR Part 63, 40 CFR Part 68, 40 CFR Part 82, and 40 CFR Part 98, as well as the state requirements in WAC 173-400, WAC 173-441, WAC 173-460, and WAC 173-480.

The Benton Clean Air Agency (BCAA) implements and enforces most federal and state requirements on the PNNL Richland Campus through BCAA Regulation 1 (BCAA 2017). Requirements applicable to the PNNL Richland Campus include Article 4, "General Standards for Particulate Matter," Article 5, "Outdoor Burning," Article 8, "Asbestos," Article 9, "Source Registration," and Article 10, "Fees and Charges." The Olympic Region Clean Air Agency (ORCAA) implements and enforces most federal and state requirements at MSL through ORCAA Regulations (ORCAA 2016). Requirements applicable to MSL include Regulation 4, "Registration," Regulation 6, "Required Permits," Regulation 7, "Prohibitions," and Regulation 8, "Performance Standards."

2.4.2 *Clean Air Act Amendments of 1990* and the National Emissions Standards for Hazardous Air Pollutants

Section 112 of the *Clean Air Act* addresses emissions of hazardous air pollutants. The *Clean Air Act Amendments of 1990* revised Section 112 to require standards for major and certain specific stationary source types. The amendments also revised the National Emissions Standards for Hazardous Air Pollutants (NESHAP) regulations (40 CFR Part 61, Subpart H) that govern emissions of radionuclides from DOE facilities. These regulations address the measurement of point-source emissions, but incorporate fugitive emissions with regard to complying with established regulations for radioactive air emissions, including standards, monitoring provisions, and annual reporting requirements. The NESHAP regulations cover all pollutants not regulated by the National Ambient Air Quality Standards that are classified as hazardous. PNNL is in compliance with all NESHAP requirements at both the PNNL Richland Campus and MSL.

2.4.3 Radioactive Emissions

Federal regulations in 40 CFR Part 61, Subpart H, require the measurement and reporting of radionuclides emitted from DOE facilities and the resulting maximum public dose from those emissions. These regulations impose a standard of 10 mrem/yr (0.1 mSv/yr) effective dose equivalent (EDE), which is not to be exceeded. Washington State adopted the 40 CFR Part 61 standard in its regulations (WAC 246-247) that require the calculation and reporting of the EDE to the maximum exposed individual (MEI) from point-source emissions and from radon and fugitive source emissions. While the

WAC 246-247 receptor location considers whether an individual resides or abides at the evaluated location, an additional assessment is performed for the location with maximum offsite nuclide air concentrations whether or not the reside/abide criterion is met (WAC 173-480).

On the PNNL Richland Campus, PSF, the Research Technology Laboratory (RTL), and LSL2 have the potential to emit radionuclides.[1] Radioactive emission point sources at the PNNL Richland Campus are actively ventilated stacks that use electrically powered exhausters and from which emissions are discharged under controlled conditions. The sources are major, minor, and fugitive emissions units. In addition, several PNNL Richland Campus sitewide radioactive air permits, commonly called Potential Impact Category 5 (PIC-5) permits (PNNL 2012), were used to assign dose from very low potential emissions sources associated with campus-wide operations. The low-level radioactive sources permitted under PIC-5 include emissions for instrument and operational checks, nondispersible radioactive materials, volumetrically released radioactive materials, and certain facilities restoration activities.

Details regarding ambient air, stack emissions monitoring, and PIC-5 permit programs for the PNNL Richland Campus and MSL are reported annually. Richland Campus data for 2017 are available in the *PNNL Richland Campus Radionuclide Air Emissions Report for Calendar Year 2017* (Snyder et al. 2018). MSL has two nonpoint minor emission units that have the potential to emit radionuclides. Radioactive air emissions results for MSL are available in the *Marine Sciences Laboratory Radionuclide Air Emissions Report for Calendar Year 2017* (Snyder and Barnett 2018). During CY 2017, the PNNL Richland Campus and MSL maintained compliance with state and federal regulations and with issued air emissions permits, as described below. In particular, radioactive air emissions were more than 10,000 times lower than the regulatory standard of 10 mrem/yr (0.1 mSv/yr) EDE for the period at each facility.

2.4.4 Air Permits

PNNL has several permits that control airborne emissions from facilities within the PNNL Richland Campus boundary. These include the radioactive air emission license (RAEL) issued by the Washington State Department of Health (WDOH; RAEL–005). WDOH renewed the RAEL–005 on June 17, 2015; WDOH RAELs are renewed every 5 years. The nonradiological approval orders issued by the BCAA are listed below:

- Environmental Molecular Sciences Laboratory (Order of Approval No. RO 2012-0009)
- Life Sciences Laboratory 2 (Order of Approval No. 2007-0006, Rev. 1; and Order of Approval No. 2016-0008)
- Physical Sciences Facility (Order of Approval No. 2007-0013, Rev. 1)
- Richland North Building Support (Order of Approval No. 2012-0017)
- Richland North Research (Order of Approval No. 2012-0016).

MSL has two air permits for airborne emissions: the RAEL issued by the WDOH (RAEL–014) and the nonradiological regulatory order issued by the ORCAA (Order of Approval 13NOI968).

[1] As a group of research buildings, the PSF expects to host changing types of research over time. Research at the RTL has ended and the facility is scheduled for demolition. The LSL2 has no new or planned radiological operations other than the removal of radiologically contaminated ductwork from past operations.

2.5 Water Quality and Protection

EA Raney and TW Moon

Federal regulations that apply to water quality at the PNNL Richland Campus and MSL are discussed in this section, which addresses wastewater, drinking water, and stormwater regulations and permitting processes.

2.5.1 *Clean Water Act*

The *Clean Water Act* (33 U.S.C. § 1251 *et seq.*) establishes the basic structure for regulating discharges of pollutants into the waters of the United States as well as quality standards for surface waters. The basis of the *Clean Water Act* was enacted in 1948 and was called the *Federal Water Pollution Control Act*. Significantly reorganized and expanded with amendments in 1972, it became the commonly known as the *Clean Water Act*. Under the *Clean Water Act*, the EPA has implemented pollution control programs such as setting wastewater standards for industry and implementing water-quality standards for all contaminants in surface waters. The *Clean Water Act* made it unlawful to discharge any pollutant from a point source into navigable waters unless a permit is obtained. The EPA's National Pollutant Discharge Elimination System (NPDES) permit program controls these point-source discharges. Point sources are discrete conveyances such as pipes or manmade ditches. Industrial, municipal, and other facilities must obtain permits if their discharges go directly to surface waters. The EPA delegated responsibility for the Washington State NPDES permit program to the Washington State Department of Ecology in August 1989.

The Washington State Department of Ecology has issued Permit No. WA0020419 to the City of Richland for discharges from its Publicly Owned Treatment Works to the Columbia River. To assure that it meets its NPDES permit conditions, the City of Richland issues industrial wastewater discharge permits to industrial users that discharge process wastewater to the City of Richland sanitary sewer system, as codified in Richland Municipal Code Chapter 17.30.

On the PNNL Richland Campus, the discharge of process wastewater to the City of Richland sanitary sewer system is governed by three City of Richland industrial wastewater discharge permits. Industrial wastewater discharge permit CR-IU001 regulates discharges from facilities on the PNNL Richland Campus and leased facilities, and requires monitoring at one discharge point, Outfall CS-001. Permit CR-IU005 regulates discharges from EMSL to Outfall 001. Permit CR-IU011 regulates process wastewater discharged from PSF. All process wastewater from PSF is monitored at a single compliance point (Outfall PS-001). All waste streams regulated by these permits are reviewed by PNNL staff and evaluated for compliance with the applicable permit prior to discharge.

Process wastewater from MSL facilities is discharged directly to Sequim Bay under the authorization of Washington State Department of Ecology NPDES Permit No. WA0040649, after treatment by an onsite wastewater treatment system. This permit was reissued in 2017. The wastewater treatment system consists of particulate filters, ultra-violet lamps, and granulated activated carbon. All waste streams regulated by this permit are reviewed by PNNL staff and evaluated for compliance prior to discharge.

2.5.2 Stormwater Management

Stormwater on the PNNL Richland Campus is primarily managed via underground injection control wells and grassy swales. The underground injection control wells are registered with the Washington State

Department of Ecology as required by WAC 173-218. Best management practices are used to minimize pollution in stormwater. These practices include storing chemicals inside or under cover when possible to prevent contact with stormwater, routinely sweeping and cleaning parking lots, promptly notifying and cleaning up spills, and conducting good housekeeping.

Stormwater at MSL is managed via a stormwater drain system that includes grated drain boxes for paved areas and a trench that drains to an infiltration pond. Drain boxes provide simple oil separation through the use of a submerged discharge outlet. In addition, two drain boxes in the boat storage yard and in the wastewater treatment system area contain multimedia filtration (sedimentation chamber, oil adsorbent, and granular activated carbon adsorbent). The infiltration pond is an engineered stormwater collection basin with an overflow trench.

Stormwater discharges from the PNNL Richland Campus and MSL are not subject to federal or state NPDES stormwater regulations. However, stormwater management practices that promote water drainage and reduce runoff as outlined under EISA Section 438 are considered and implemented as part of PNNL sustainability practices (DOE 2017). The registrations of underground injection wells for stormwater and injection of ground-source heat pump return flow water (see Section 6.0) have been completed as required by *Safe Drinking Water Act of 1974*.

2.5.3 *Safe Drinking Water Act of 1974*

The *Safe Drinking Water Act of 1974* (42 U.S.C. § 300f *et seq.*) is the main federal law that assures the quality of drinking water in the United States. Under the Act, the EPA sets standards for drinking water quality and oversees the states, localities, and water suppliers who implement those standards. The *Safe Drinking Water Act of 1974* was originally passed by Congress to protect public health by regulating the nation's public drinking water supply. The law was amended in 1986 and 1996, and requires many actions to protect drinking water and its sources—rivers, lakes, reservoirs, springs, and groundwater wells.

The Act focuses on all waters actually or potentially designated for use as drinking water, whether from aboveground or underground sources. The Act authorizes the EPA to establish minimum standards to protect tap water, and requires all owners or operators of public water systems to comply with these primary (health-related) standards. State governments, which can be approved to implement these rules for EPA, also encourage attainment of secondary standards.[2] Under the *Safe Drinking Water Act of 1974*, EPA also established minimum standards for state programs to protect underground sources of drinking water from endangerment by underground injection of fluids.

[2] Secondary standards are established to give operators of public water systems guidance about removing contaminants that may cause the water to appear cloudy or colored, or to taste or smell bad, even though the water is actually safe to drink.

The PNNL Richland Campus receives all drinking water for uses in laboratory and nonlaboratory spaces from the City of Richland drinking water supply, and is not subject to the *Safe Drinking Water Act of 1974*.

Water for MSL facilities is provided exclusively from Battelle Land–Sequim onsite wells. PNNL is considered the water purveyor, and is responsible for all monitoring and sampling of the drinking water distribution system. All drinking water parameters sampled met compliance requirements.

2.6 Environmental Restoration and Waste Management

MD Ellefson

This section describes PNNL activities conducted to protect the environment through the proper management of waste.

2.6.1 Tri-Party Agreement

The "Hanford Federal Facility Agreement and Consent Order" (also known as the Tri-Party Agreement [Ecology et al. 1989]) is an agreement among the Washington State Department of Ecology, EPA, and DOE (the Tri-Party Agreement agencies) to achieve compliance on the Hanford Site with the treatment, storage, and disposal unit regulations and corrective action provisions of the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) (42 U.S.C. § 9601 *et seq.*) and the *Resource Conservation and Recovery Act of 1976* (RCRA) (42 U.S.C. § 6901 *et seq.* and 42 U.S.C. § 6927(c) *et seq.*). The Tri-Party Agreement is an interagency agreement (also known as a federal facility agreement) under Section 120 of CERCLA, a corrective action order under RCRA, and a consent order under the Washington State *Hazardous Waste Management Act of 1976* (RCW 70.105). The Agreement 1) defines RCRA and CERCLA cleanup commitments, 2) establishes responsibilities, 3) provides a basis for budgeting, and 4) reflects a concerted goal to achieve regulatory compliance and remediation with enforceable milestones.

The Tri-Party Agreement is available on the DOE Hanford Site website at http://www.hanford.gov/?page=81. Printed copies of the Tri-Party Agreement, which is current as of August 17, 2017, are publicly available at DOE's Public Reading Room, located in the Washington State University Tri-Cities Consolidated Information Center, 2770 University Drive, Richland, Washington, and at public reading rooms in Seattle and Spokane, Washington, and Portland, Oregon.

Under the Tri-Party Agreement, Hanford waste sites were grouped into "operable units" based on geographic proximity or similarity of waste-disposal history. The PNNL Richland Campus is not part of any Hanford Site CERCLA operable unit or subject to any cleanup action under the Tri-Party Agreement. PNNL maintains administrative controls similar to those at adjacent uncontaminated portions of the Hanford Site 300 Area; e.g., access control and groundwater use restrictions. PNNL provides information to DOE-RL and its contractors with regard to the facilities it occupies on the Hanford Site to support the preparation of the annual land disposal restrictions report required by the Tri-Party Agreement M-26 milestone series. Some wells located on the PNNL Richland Campus are monitored by Hanford Site contractors as part of the regional groundwater monitoring network. Sampling data are available in the *Hanford Site Groundwater Monitoring Report for 2016* (DOE-RL 2017a).

The Tri-Party Agreement does not apply to MSL.

2.6.2 *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*

CERCLA was promulgated to address response, compensation, and liability for past releases or potential releases of hazardous substances, pollutants, and contaminants to the environment. CERCLA was amended by the *Superfund Amendments and Reauthorization Act of 1986* (42 U.S.C. § 9601 *et seq.*), which made several important changes and additions, including clarification that federal facilities are subject to the same provisions of CERCLA as any nongovernmental entity. Executive Order 12580 of January 23, 1987, "Superfund Implementation" (52 FR 2923), directs that DOE, as the lead agency, must conduct CERCLA response actions (i.e., removal and remedial actions). Such actions would be subject to oversight by EPA and/or the Washington State Department of Ecology.

Two Hanford 300 Area operable units, listed on the National Priorities List on November 3, 1989, are located near the PNNL Richland Campus.

A portion of the PNNL Richland Campus located north of Horn Rapids Road was investigated as part of the Hanford 300-FF-2 Operable Unit in the late 1990s. Site characterization efforts found vestiges of petroleum hydrocarbons, irrigation canals, and recent debris (windblown garbage, porcelain china, battery cores, cans, and glass). After a site evaluation, EPA issued a CERCLA Final Record of Decision (EPA and DOE-RL 2013) that concluded that PNNL Richland Campus areas north of Horn Rapids Road require no further remedial action under CERCLA.

Groundwater under the northern portion of the PNNL Richland Campus is routinely monitored for contaminants migrating from Hanford Site contamination plumes as well as nitrates migrating from offsite locations. See Section 6.0 for further information concerning groundwater monitoring on the PNNL Richland Campus.

No MSL facilities require action under CERCLA guidelines.

2.6.3 Washington State Dangerous Waste/Hazardous Substance Reportable Releases to the Environment

The Washington State Dangerous Waste Regulations (WAC 173-303-145) require that spills or non-permitted discharges of dangerous waste or hazardous substances to the environment be reported to the Washington State Department of Ecology. This requirement applies to discharges to soil, surface water, groundwater, or air when such discharges threaten human health or the environment, regardless of the quantity of the dangerous waste or hazardous substance released.

During CY 2017, no spills or non-permitted discharges that posed a threat to human health or the environment occurred at the PNNL Richland Campus or MSL. Minor spills were cleaned up immediately and disposed of in accordance with applicable requirements.

2.6.4 *Resource Conservation and Recovery Act of 1976*

RCRA was enacted to protect human health and the environment through cradle-to-grave management of hazardous waste from its generation through treatment, storage, and disposal. The Washington State Department of Ecology has the authority to enforce RCRA requirements in the state under WAC 173-303, "Dangerous Waste Regulations."

PNNL, in cooperation with DOE-RL, operates one RCRA-permitted storage and treatment unit group—the 325 Hazardous Waste Treatment Units. This unit group is located in the Radiochemical Processing Laboratory in the Hanford 300 Area, and is permitted as part of the Hanford Facility RCRA Permit. The Hanford Facility RCRA Permit expired on September 27, 2004. However, DOE and PNNL continue to operate in compliance with the expired permit until the permit is reissued, as authorized by WAC 173-303-806(7) and the Washington State Department of Ecology. The Hanford RCRA Permit may be viewed at https://fortress.wa.gov/ecy/nwp/permitting/hdwp/rev/8c/index.html.

With the exception of the 325 Hazardous Waste Treatment Units, PNNL Richland Campus and MSL facilities operate under the generator requirements of WAC 173-303. During CY 2017, PNNL facilities followed the generator requirements for waste management and shipped nonradioactive waste to offsite facilities for proper disposal.

RCRA and WAC 173-360 also include requirements for the proper management of underground storage tanks. Battelle administers two underground storage tanks for the storage of diesel fuel for backup generators on the PNNL Richland Campus in Richland—a 20,000-gallon tank and a 500-gallon tank. The tanks are routinely monitored and no problems were observed in CY 2017. No underground tanks are used at MSL.

Washington State Department of Ecology and EPA personnel inspected two PNNL facilities (the 325 Hazardous Waste Treatment Units and MSL) for RCRA compliance in 2017. Inspection reports for these two inspections found no noncompliances.

2.6.5 *Federal Facility Compliance Act of 1992*

The *Federal Facility Compliance Act of 1992* (42 U.S.C. 6939c and 6961), enacted by Congress on October 6, 1992, amended Section 6001 of RCRA to specify that the United States 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 also given authority to conduct inspections of federal facilities to enforce compliance with state hazardous waste programs. A portion of the Act also requires DOE to provide mixed waste information to EPA and the states. PNNL provides this information as part of the *Hanford Site Mixed Waste Land Disposal Restrictions Summary Report* pursuant to Tri-Party Agreement Milestone M-26 (DOE-RL 2015c).

2.6.6 *Toxic Substances Control Act*

Requirements of the *Toxic Substances Control Act* (15 U.S.C. § 2601 *et seq.*) that apply to PNNL primarily involve regulation of polychlorinated biphenyls (PCBs). Federal regulations for PCB use, storage, and disposal are provided in 40 CFR Part 761, "Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions." PCB wastes at PNNL are stored and/or disposed of in accordance with this regulation; however, some radioactive PCB waste must be transferred to extended storage at the Hanford Site, pending the development of adequate treatment and disposal technologies and capacities.

The *2016 Hanford Site Polychlorinated Biphenyl Annual Document Log* (DOE-RL 2017c) and the *2016 Hanford Site Polychlorinated Biphenyl Annual Report* (DOE-RL 2017d) were produced in 2017 and describe the PCB waste-management and disposal activities occurring on the Hanford Site, including PNNL Richland Campus activities related to PCBs. The Annual Report is provided to EPA as required by 40 CFR 761.180. MSL did not generate enough PCB waste to require reporting under 40 CFR 761.180 in 2017.

2.6.7 *Federal Insecticide, Fungicide, and Rodenticide Act*

The *Federal Insecticide, Fungicide, and Rodenticide Act* (7 U.S.C. § 136 *et seq.*) is administered by EPA. Washington State Department of Agriculture rules implementing the Act requirements include the

Washington Pesticide Control Act (RCW 15.58), the *Washington Pesticide Application Act* (RCW 17.21), and rules related to general pesticide use codified in WAC 16-228, "General Pesticide Rules." In 2017, commercial pesticides used at the PNNL Richland Campus and at MSL were managed in accordance with these rules and applied either by licensed PNNL staff or by a licensed commercial applicator.

2.6.8 *Emergency Planning and Community Right-to-Know Act of 1986*

The *Emergency Planning and Community Right-to-Know Act of 1986* (EPCRA) (42 U.S.C. § 11001 *et seq.*) requires each state to establish an emergency response commission and local emergency planning committees, and develop a process for gathering and distributing information about hazardous chemicals present in local facilities. These local emergency planning committees develop emergency plans for local planning districts. Facilities that produce, use, release, or store toxic or hazardous substances in quantities above threshold levels must submit information about the chemicals to local emergency planning committees.

EPCRA has four major provisions: emergency planning, emergency release notification, hazardous chemical inventory reporting, and toxic chemical release inventory reporting. Each provision requires reporting when thresholds are exceeded (Table 2.2).

PNNL EPCRA reporting combines the quantities of chemicals in the Hanford 300 Area facilities that PNNL occupies and those present in PNNL Richland Campus facilities.

PNNL electronically submitted a Tier Two report to the Washington State Emergency Response Commission, Benton County Emergency Management, and the Richland Fire Department on January 17, 2018. The report provided updated inventories of urea, diesel fuel, and lead-acid batteries (which contain sulfuric acid, an extremely hazardous substance)—the only chemicals exceeding the combined reporting threshold at the PNNL Richland Campus during CY 2017. Battelle also filed a Tier Two report to the Washington State Emergency Response Commission, Clallam County Emergency Management, and Clallam Fire District 3 on January 17, 2018 for diesel fuel stored at MSL—the only hazardous substance stored in excess of reporting thresholds. Diesel fuel is used to power generators during electrical service interruptions.

Neither the PNNL Richland Campus nor MSL was required to submit a Toxic Release Inventory Report for 2017, because no releases of Toxic Release Inventory chemicals occurred in excess of reporting thresholds.

Table 2.3 provides an overview of PNNL reporting under EPCRA for CY 2017.

Table 2.2. Provisions of the *Emergency Planning and Community Right-to-Know Act of 1986*

Section	CFR Section	Reporting Criteria	Due Date	Agencies Receiving Report
302	40 CFR Part 355: Emergency Planning	The presence of an extremely hazardous substance in a quantity equal to or greater than the threshold planning quantity at any one time.	Within 60 days of threshold planning quantity exceedance.	SERC; LEPC
302	40 CFR Part 355: Emergency Planning	Change occurring at a facility that is relevant to emergency planning.	Within 30 days after the change has occurred.	LEPC
304	40 CFR Part 355: Emergency Release Notification	Release of an extremely hazardous substance or a CERCLA hazardous substance in a quantity equal to or greater than the reportable quantity.	Initial notification: immediate (within 15 minutes of knowledge of reportable release). Written follow-up within 14 days of the release.	SERC; LEPC
311	40 CFR Part 370: Reporting Requirements – Material Safety Data Sheet Reporting	The presence at any one time at a facility of an OSHA hazardous chemical in a quantity equal to or greater than 4,500 kg (10,000 lb) or an extremely hazardous substance in a quantity equal to or greater than the threshold planning quantity or 230 kg (500 lb), whichever is less.	Revised list of chemicals due within 3 months of a chemical exceeding a threshold.	SERC; LEPC; local fire departments
312	40 CFR Part 370: Reporting Requirements – Tier Two Report	The presence at any one time at a facility of an OSHA hazardous chemical in a quantity equal to or greater than 4,500 kg (10,000 lb), or an extremely hazardous substance in a quantity equal to or greater than the threshold planning quantity or 230 kg (500 lb), whichever is less.	Annually by March 1.	SERC; LEPC; local fire departments
313	40 CFR Part 372: Reporting Requirements – Toxic Release Inventory Report	Manufacture, processing, or use at a facility of any listed Toxic Release Inventory chemical in excess of its threshold amount during the course of a calendar year. Thresholds are 11,300 kg (25,000 lb) for manufactured or processed chemicals or 4,500 kg (10,000 lb) for chemicals otherwise used, except for persistent, bio-accumulative, toxic chemicals, which have thresholds of 45 kg (100 lb) or less.	Annually by July 1.	EPA; SERC

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*; CFR = *Code of Federal Regulations*; EPA = U.S. Environmental Protection Agency; LEPC = Local Emergency Planning Committee; OSHA = Occupational Safety and Health Administration; SERC = State Emergency Response Commission.

Table 2.3. *Emergency Planning and Community Right-to-Know Act of 1986* Compliance Reporting, 2017

Section	Description of Reporting	Reporting Status	Notes
302	Emergency planning notifications	Not required	No changes to previously reported inventories of sulfuric acid and no new extremely hazardous substances managed in excess of thresholds.
304	Extremely hazardous substance release notification	Not required	No releases occurred.
311	Material Safety Data Sheet	Yes	No changes to previously reported inventories.
312	Chemical inventory	Yes	The CY 2017 Tier Two reports for the PNNL Richland Campus and MSL were submitted to the Washington State Department of Ecology, the LEPC, and the local fire department on January 17, 2018.
313	Toxic release inventory	Not required	No releases were greater than the reporting threshold requirement.

CY = calendar year; LEPC = Local Emergency Planning Committee; MSL = PNNL Marine Sciences Laboratory; PNNL = Pacific Northwest National Laboratory.

2.7 Natural and Cultural Resources

JM Becker

The *Pacific Northwest Site Office Cultural and Biological Resources Management Plan* (CBRMP; DOE-PNSO 2015) provides direction and guidance related to protecting and managing biological and cultural resources on the PNNL Richland Campus in accordance with applicable laws and regulations. The CBRMP was developed as a requirement of DOE Policy 141.1, "Department of Energy Management of Cultural Resources," to provide for the protection and management of cultural and biological resources, identify impacts of unauthorized public use on prehistoric sites, identify actions that will protect sensitive sites, and provide details of annual monitoring activities to identify potential impacts. The CBRMP is implemented by application of PNNL's internal cultural and biological resource protection procedures, which are updated annually to reflect relevant changes in applicable laws and regulations and compliance methods.

PNNL conducts field research for which environmental permits are required, oftentimes at locations throughout the Pacific Northwest other than the PNNL Richland Campus or MSL. The Environmental Research Permitting (ERP) program was established in 2016 to centralize the acquisition of permits and authorizations in compliance with laws and regulations applicable to PNNL research projects. The ERP program also maintains a searchable permit database and tracks reporting requirements. The Environmental Permitting Information Center is the information repository and database for environmental permits.

The following sections describe the laws and regulations applicable to biological and cultural resources on the PNNL Richland Campus, at MSL, and at offsite research locations, as well as PNNL activities conducted to protect and manage biological and cultural resources, including environmental permitting for research projects.

2.7.1 Biological Resources

JM Becker and KD Hand

A number of federal and state laws, EOs, regulations, and related memoranda contain requirements for protecting biological resources both on the PNNL Richland Campus, at MSL, and at offsite locations where PNNL research projects are conducted. This section and Table 2.4 summarize the requirements and catalog PNNL's compliance activities related to biological resources in 2017.

Federal Statutes and Regulations

The *Endangered Species Act of 1973* (16 U.S.C. § 1531 *et seq.*) contains requirements for the designation and protection of wildlife, fish, plant, and invertebrate species that are in danger of becoming extinct due to natural or manmade factors and the conservation of the habitats upon which they depend. Under Section 7(a)(2) of the Act, federal agencies are required to evaluate actions that they perform, fund, or permit to determine whether they would affect any species listed as endangered or threatened or impact designated critical habitat. Consultation with the U.S. Fish and Wildlife Service (USFWS) and/or the National Marine Fisheries Service (NMFS) are required if the action may affect listed species or critical habitat. The biological resource review process and consultation with USFWS and/or NMFS are the primary means by which PNNL determines whether any listed species or critical habitat may be affected by a proposed action. For actions that are found to not affect listed species or critical habitat an internal PNNL no effects memorandum is prepared.

The *Migratory Bird Treaty Act* (16 U.S.C. § 703 *et seq.*) makes it illegal to take, capture, or kill any migratory bird, or to take any part, nest, or egg of any such birds. A Department of the Interior Office of the Solicitor Memorandum (M-37050 issued in December 2017 [DOI 2017]) clarified that the MBTA applies to purposeful actions, not to actions that result from otherwise lawful activities (incidental take). PNNL projects that have a potential to affect avian species listed under the Act use the PNNL biological resource review process as described in the CBRMP (DOE-PNSO 2015) and implemented by PNNL's internal biological resource protection procedures to protect migratory birds. In 2017, PNNL biologists resolved about 30 inquiries concerning migratory birds on the PNNL Richland Campus and at MSL, and installed deterrents in areas of habitual nesting to avoid potential impacts on active bird nests.

The *Bald and Golden Eagle Protection Act* (16 U.S.C. § 688 *et seq.*) prohibits anyone without a permit from disturbing, wounding, killing, harassing, or taking bald eagles or golden eagles (*Aquila chrysaetos*), alive or dead, including their parts, nests, or eggs. The Act also applies to impacts made around previously used nest sites, if, upon an eagle's return, normal breeding, feeding, or sheltering habits are influenced negatively. The PNNL biological resource review process provides assurance that a proposed action will not adversely affect bald or golden eagles. Mitigation includes performing work according to the spatial and timing restrictions established for seasonal use locations, such as nest sites and communal night roosts (see Sections 1.4.5 and 1.5.1), in applicable jurisdictional management plans for the species.

The *Magnuson–Stevens Fishery Conservation and Management Act* (16 U.S.C. § 1801 *et seq.*) is the primary law governing marine fisheries management in the United States. It provides a national program for the conservation and management of U.S. fishery resources in order to prevent overfishing, rebuild overfished stocks, assure conservation, and facilitate long-term protection of essential fish habitats (waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity). Under Section 305(b)(2) of the Act, federal agencies must consult with the NMFS about any action that might adversely affect essential fish habitat. An internal no effects memorandum is prepared for actions that are found to not affect essential fish habitat. The PNNL biological resource review process and consultation with NMFS are the primary means by which PNNL determines whether any essential fish habitat may be affected by a proposed action.

Table 2.4. Environmental Research Permits Obtained in 2017 for PNNL Research Activities

Issuer and Permit Type	Regulatory Driver[a]	Number of Permits
Clallam County		
Shoreline Substantial Development Permit Exemption	SMA	1
National Marine Fisheries Service		
ESA Section 7 Consultation	ESA	1
ESA Section 7/MSFCMA Essential Fish Habitat Consultation	ESA, MSFCMA	2
ESA Section 7/MSFCMA Essential Fish Habitat/MMPA Consultation	ESA, MSFCMA, MMPA	2
Federal Columbia River Power System Biological Opinion – Determination of Take	ESA	2
Willamette Biological Opinion – Determination of Take	ESA	3
National Park Service		
Scientific Research and Collecting Permit	NPSOA, CFR	3
Oregon Department of Fish and Wildlife		
Fish Transport Permit	OAR	1
In-Water Work Window Variance	OAR	1
Scientific Taking Permit – Fish	OAR	5
Oregon Department of State Lands		
Removal/Fill Permit Exemption	OAR	1
Short-Term Access Agreement	OAR	1
Olympic Region Clean Air Agency		
Non-rad Air Approval Order	CAA	1
PNNL for DOE-PNSO		
No Effects Determination (ESA/EFH/MMPA)	ESA, MSFCMA, MMPA	1
No Effects Determination (ESA/MMPA)	ESA, MMPA	3
Private Landowner		
Property Access	NA	1
U.S. Army Corps of Engineers		
Civil Works Permit	CFR	1
Nationwide Permit 5 – Scientific Measurement Devices	RHA, CWA	2
RHA Section 10 – Work in Navigable Waters	RHA, CWA	1
U.S. Coast Guard		
Private Aids to Navigation – Local Notice to Mariners	CFR	2
U.S. Fish and Wildlife Service		
ESA Section 7 Consultation	ESA	4
Special Use Permit	NWRSAA, CFR	1
U.S. Forest Service		
Special Use Permit	FSOA, CFR	1
Washington Department of Ecology		
CZMA Consistency Certification	CZMA	1
Washington Department of Fish and Wildlife		
Fish Transport Permit	WAC	3
Hydraulic Project Approval	WAC	1
Scientific Collection Permit	WAC	3

Issuer and Permit Type	Regulatory Driver[a]	Number of Permits
Washington Department of Natural Resources		
Aquatic Lands Right of Entry License	WAC	1
Total		50

CAA = *Clean Air Act*; CFR = Code of Federal Regulations; CWA = *Clean Water Act*; CZMA = *Coastal Zone Management Act of 1972*; ESA = *Endangered Species Act of 1973*; FSOA = *Forest Service Organic Administration Act of 1897*; MMPA = *Marine Mammal Protection Act of 1972*; MSFCMA = *Magnuson-Stevens Fishery Conservation and Management Act*; NPSOA = *National Park Service Organic Act*; NWRSAA = *National Wildlife Refuge System Administration Act of 1966*; OAR = Oregon Administrative Rules; RHA = *Rivers and Harbors Appropriation Act of 1899*; SMA = *Shoreline Management Act of 1971*; WAC = *Washington Administrative Code*.

The *Marine Mammal Protection Act of 1972* (16 U.S.C. § 1361 *et seq.*) provides a program for the protection of all marine mammals based on some species or stocks being in danger of extinction or depletion due to human activities. The purpose of the Act is to assure that actions that may affect marine mammal species or stocks do not cause them to fall below their optimum sustainable population levels. Consultation with the NMFS is required if an action may affect any marine mammal species. The biological resource review process and consultation with NMFS are the primary means by which PNNL determines whether marine mammal species may be affected by a proposed action. An internal no effects memorandum is prepared for actions that are found to not affect marine mammal species.

The *Rivers and Harbors Appropriation Act of 1899* (RHA; 33 U.S.C. § 403 *et seq.*) is the oldest federal environmental law in the United States. Section 10 of the Act prohibits the creation of any obstruction, excavation, or fill within a navigable waterway without a permit, including but not limited to the building of any wharfs, piers, jetties, or other structures. Authorization for issuing permits under both RHA Section 10 and *Clean Water Act* Section 404 (Section 2.5.1) is delegated to the U.S. Army Corps of Engineers (USACE), within the Department of the Army. One of several permit types may be issued depending on the type of use and the project's impacts on navigable waters. The USACE has established a system of Nationwide Permits to streamline permitting certain activities known to have minimal impacts. Nationwide Permits are often acquired for PNNL research projects. PNNL evaluates the need for Department of the Army permits for each project as part of its biological resource review process and corresponds with USACE under the auspices of its ERP program.

The *Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990* (16 U.S.C. § 4701 *et seq.*) provides for the development and execution of environmentally sound control methods that prevent the unintentional introduction and dispersal of nonindigenous aquatic nuisance species into waters of the United States. PNNL has developed and implements an aquatic invasive plant and animal species interception program to comply with this Act. The program details mechanisms for controlling nuisance species on aquatic equipment used in affected waters, to prevent accidental introduction of those species into uninfested waters.

Executive Order 11990 of May 24, 1977, "Protection of Wetlands" (42 FR 26961), requires federal agencies to minimize the destruction, loss, or degradation of wetlands on federal lands, and to preserve and enhance the natural and beneficial values of wetlands on federal lands. The Order does not apply to non-federal property. The Order states that federal agencies should avoid undertaking or providing assistance for new construction located in wetlands unless the agency finds 1) that there is no practicable alternative to such construction, and 2) that the proposed action includes all practicable measures to minimize harm to wetlands that may result from such use. Compliance with this Order, as well as the wetland provisions of the *Clean Water Act* (Section 2.5.1), is achieved through the biological resource review process at PNNL.

Executive Order 11988 of May 24, 1977, "Floodplain Management" (42 FR 26951), requires federal agencies to evaluate the potential effects of any actions within a floodplain to minimize any direct or indirect impacts on the floodplain's natural and beneficial values. Floodplain management and consequences of flood hazards need to be considered when developing water- and land-use plans, as well as alternatives to floodplain use. Compliance with this Order is achieved through the biological resource review process at PNNL.

Executive Order 13112 of February 3, 1999,"Invasive Species" (64 FR 6183), establishes a National Invasive Species Council to oversee implementation of the Order and requires federal agencies to identify actions that may affect the status of invasive species; prevent introduction of invasive species; detect, respond to, monitor, and control populations of invasive species; provide for restoration of native species and habitats in ecosystems that have been invaded; and conduct research and public outreach to control and prevent the introduction of invasive species. See Section 2.7.1.1 for a description of the PNNL noxious weed control program.

Executive Order 13186 of January 10, 2001, "Responsibilities of Federal Agencies to Protect Migratory Birds" (66 FR 3853), requires agencies to avoid or minimize the adverse impact of their actions on migratory birds and to assure that environmental analyses under NEPA evaluate the effects of proposed federal actions on such species. A Memorandum of Understanding (MoU) between DOE and the USFWS (DOE and USFWS 2013) regarding implementation of Executive Order 11386, identifies specific areas in which enhanced collaboration between DOE and the USFWS will substantially contribute to the conservation and management of migratory birds and their habitats. PNNL projects that have a potential to affect avian species or their habitat comply with this Executive Order and MoU by using the PNNL biological resource review process described in the CBRMP (DOE-PNSO 2015). The Order and MoU are implemented by PNNL's internal biological resource protection procedures.

The *Coastal Zone Management Act of 1972* (16 U.S.C. § 1451 *et seq*.) establishes two national programs, the National Coastal Zone Management Program and the National Estuarine Research Reserve System, and is administered by the National Oceanic and Atmospheric Administration Office of Ocean and Coastal Resource Management. The Act encourages and provides for federal assistance to states and/or Native American tribes to voluntarily develop a coastal zone management program to preserve, protect, develop, and where possible, restore or enhance valuable natural coastal resources such as wetlands, floodplains, estuaries, beaches, dunes, barrier islands, and coral reefs, as well as the fish and wildlife using those habitats. The Act considers ecological, cultural, historical, and aesthetic values, need for compatible economic development, and the siting of major facilities in or adjacent to areas of existing development. The Act outlines a national estuarine research reserve system, which serves as a field laboratory to promote greater understanding of estuaries and anthropogenic impacts on them. The *Coastal Zone Act Reauthorization Amendments of 1990* include Section 6217, which calls upon states and/or Native American tribes with federally approved coastal zone management programs to develop coastal nonpoint pollution control programs to improve, safeguard, and restore the quality of coastal waters. Section 6217 is administered jointly by EPA and the National Oceanic and Atmospheric Administration. PNNL maintains compliance with this Act through its biological resource review process and its ERP program.

The U.S. Coast Guard (USCG) administers 33 CFR Part 66, "Navigation and Navigable Waters, Private Aids to Navigation." For the safe navigation of watercraft, the installation of a fixed structure or floating object in any navigable water of the United States requires review by the USCG to determine whether a permit and/or private aid to navigation (a buoy, light, or daybeacon owned and maintained by a private organization or individual [PATON]) is necessary. The USCG also publishes a Local Notice to Mariners (LNM) weekly, which provides location information about structures to facilitate navigational safety in marine environments. Permits, PATONs, and LNMs allow research projects to be located in navigable waters without posing undue hazard to watercraft. PNNL maintains compliance with these regulations through its ERP program.

The *Forest Service Organic Administration Act of 1897* (formally titled the *Sundry Civil Appropriations Act of 1897*, but commonly called the *Forest Service Organic Act*) specified the purpose for establishing forest reserves and their administration and protection. The U.S. Forest Service, within the U.S. Department of Agriculture, administers the use of national forests, including for scientific research, under 36 CFR Part 251. Uses such as scientific research and specimen collecting are deemed "special uses" and require a permit. PNNL maintains compliance with these regulations through its ERP program.

The *National Park Service Organic Act* established the National Park Service in 1916 to oversee management of national parks and monuments. The National Park Service, within the U.S. Department of the Interior, administers the use of such lands under Chapter 1 of 36 CFR, which governs parks, forests, and public property. A Scientific Research and Collecting Permit is required for activities pertaining to natural resources that involve fieldwork, specimen collection, or that may potentially disturb resources or visitors. PNNL maintains compliance with these regulations through its ERP program.

The *National Wildlife Refuge System Administration Act of 1966* formally established the National Wildlife Refuge System and provided administration and management directives under the jurisdiction of the USFWS. The USFWS, in accordance with 50 CFR, issues permits for uses, including scientific research, deemed compatible with the purposes of specific refuge areas. PNNL maintains compliance with these regulations through its ERP program.

The *Columbia River Gorge National Scenic Area Act* (16 U.S.C. § 544 *et seq.*) was enacted to protect and enhance the scenic, recreational, and natural resources and to support the economy of the Columbia River Gorge. The Act is implemented through a Gorge Management Plan (CRGC 2011) overseen by the U.S. Forest Service and an Oregon-Washington bi-state Columbia River Gorge Commission. The U.S. Forest Service is responsible for conducting a consistency review for any proposed projects that are to be located within designated management areas. PNNL maintains compliance with this Act through its ERP program.

State Statutes and Regulations

PNNL conducts biological research studies at locations throughout the Northwest and must also comply with applicable state and local statutes, regulations, and directives at those sites. Principal relevant rulings are summarized in the following paragraphs.

The Washington State *Shoreline Management Act of 1971* (RCW 90.58, as amended) establishes policy for shoreline use and environmental protection along shorelines that includes rivers and streams with a mean annual flow greater than 0.6 m^3/s (21 ft^3/s), which includes the Columbia River in Benton and Franklin Counties. The shoreline jurisdiction extends 61 m (200 ft) landward of these waters, and includes associated wetlands, floodways, and up to 61 m (200 ft) of floodway-contiguous floodplains. The Act requires that preferred shoreline uses be consistent with the control of pollution and the prevention of damage to the natural environment, and requires protection of natural resources, including the land, vegetation, wildlife, water, and aquatic life from adverse effects. County Shoreline Master Programs (Ecology 2018) implement the policies of the Washington State *Shoreline Management Act of 1971* at the local level and establish a shoreline-specific combined comprehensive plan, zoning ordinance, and development permit system. PNNL maintains compliance with the Act by complying with the provisions of County Shoreline Master Programs through PNNL's ERP program.

Several chapters and sections of the Washington Administrative Code (WAC) govern activities that affect fish and wildlife or their habitat, and aquatic lands in the state of Washington. WAC 220-200-150 requires a Scientific Collection Permit from the WDFW for the collection of fish, shellfish, wildlife, or nests of birds for research purposes, as well as a Fish Transport Permit for transport of fish or the viable eggs/gametes of fish into or through Washington. WAC 220-660 requires a Hydraulic Project Approval from the WDFW for construction or projects that will use, divert, obstruct, or change the natural flow or bed of any waters of the state (see RCW 77.55). WAC 332-30 governs the use of state-owned aquatic lands and outlines necessary use authorizations from the Washington State Department of Natural Resources. PNNL maintains compliance with these regulations through its ERP program.

PNNL regularly conducts research activities in the state of Oregon and must comply with state regulations involving fish and wildlife or their habitat, and aquatic lands as governed by the Oregon Administrative Rules (OARs). OAR 635-007 and OAR 635-043 direct the administration of Scientific Taking Permits for fish and for wildlife, respectively, under the jurisdiction of the Oregon Department of Fish and Wildlife. OAR 141-082 governs the use of state-owned submerged land and OAR 141-089 governs removal/fill activities within waters of the state under the jurisdiction of the Oregon Department of State Lands. PNNL maintains compliance with these regulations for research activities through its ERP program.

PNNL Programs

Programs and activities performed to assure compliance with the preceding biological resource statutes and drivers are discussed in the following paragraphs.

PNSO prepared the CBRMP (DOE-PNSO 2015) in response to the direction and guidance provided in DOE Policy 141.1, "Department of Energy Management of Cultural Resources," relative to protecting and managing cultural and biological resources. The plan provides direction on the requirements for annual surveys and monitoring for species of concern, review of project activities for environmental impacts, and identification and control of invasive species. The CBRMP is implemented by application of PNNL's internal cultural and biological resource protection procedures.

As stipulated in the CBRMP (DOE-PNSO 2015), projects involving soil or vegetation disturbance or work outdoors are routinely evaluated to determine their potential to affect biological resources prior to implementation. Forty-one biological resource reviews were conducted for PNNL projects in CY 2017—27 on the Richland Campus and 14 at MSL or for MSL-related projects.

Potential project impacts were evaluated for plant or animal species protected under the *Endangered Species Act of 1973*, species proposed or candidates for such protection, and species of concern; species listed by the state of Washington as threatened, endangered, sensitive, candidate, or monitor; Washington State priority habitats; and bird species protected under the *Migratory Bird Treaty Act* and *Bald and Golden Eagle Protection Act*. No projects violated related federal or state laws, regulations, or conservation priority guidance.

Staff ecologists performed pedestrian and visual reconnaissance surveys of biological resources found on the undeveloped portions of the PNNL Richland Campus from April through July 2017, which included the riparian zone adjacent to the Columbia River. The primary objective of the field surveys was to determine the occurrence of the plant and animal species and habitats of interest for project-specific biological resource reviews. Lists of plant and animal species identified on the undeveloped portions of the PNNL Richland Campus from 2009 to 2017, and at MSL from 2013 to 2015 (except for avian surveys, which were also conducted in 2016 and 2017) and their status are provided in Appendix C and Appendix D, respectively.

2.7.1.1 Noxious Weed Control

KD Hand

Several plant species listed as Class B and Class C noxious weeds have been identified on the PNNL Campus (Larson and Downs 2009; Duncan et al. 2014, 2015, 2016, 2017). Class B noxious weeds are species designated for control where they are not yet widespread, to prevent new infestations (WNWCB 2018). Class C noxious weeds are already widespread and each county determines what level of control is required. On the PNNL Richland Campus, Class B species include diffuse knapweed, rush skeletonweed, Russian knapweed, burningbush, puncturevine, and yellow starthistle. Class C species include field bindweed, Russian olive, tree-of-heaven, common St. Johnswort, Himalayan blackberry, baby's breath (*Gypsophila paniculata*), broadleaf pepperweed (*Lepidium latifoium*), common groundsel (*Senecio vulgaris*), and reed canarygrass (Appendix C). The Class B and Class C noxious weeds listed above are all classified as such by the state of Washington (WAC 16-750-011 and 16-750-015, respectively).

Figure 2.1. Hand-Spraying Herbicides on Individual Noxious Weeds

Since 2010, PNNL Facilities and Operations staff possessing pesticide applicator licenses, in coordination with staff ecologists, have been using hand-spraying methods (spot-spraying of individual weeds within the surveyed/traversed area) to control populations of Class B noxious weeds in upland areas of natural vegetation on the PNNL Richland Campus. The hand-spraying method was chosen because of its minimal impact on other vegetation (Figure 2.1). The herbicide used is Milestone™ (along with water conditioner, drift control agent, surfactant, and blue dye for visibility). Most areas require spraying over two or more years to eradicate perennial weeds that are not completely killed or that germinate from seeds in the soil.

Diffuse knapweed occurs sporadically throughout areas of natural vegetation on the PNNL Richland Campus. In 2012, seed-eating weevils (*Larinus minutus*) were observed parasitizing numerous plants (Duncan et al. 2013). The weevils were not purposely introduced by PNNL staff, but did appear to reduce the spread of the plants for a period of time, so diffuse knapweed was not targeted for spraying between 2012 and 2015. In 2016, increased occurrences of diffuse knapweed were noted and herbicide treatments were resumed.

Russian knapweed can form dense stands where water is adequate. There are no approved biocontrol agents, but application of Milestone™ when the plant is blooming and beginning to produce seeds has been shown to be effective (Duncan et al. 2013). Two large patches and scattered individual plants of Russian knapweed were identified on the PNNL Richland Campus in 2017. Individual plants were treated when encountered during spraying events, but limited availability of authorized herbicide applicators precluded treatment of the larger regions.

Burningbush is known to occur within and along access roads north of Horn Rapids Road. The only practical way of treating the long linear strips of dense burningbush is by boom or hand-spraying from a vehicle-mounted tank. Fire hazard restrictions, which reduced access, as well as limited staff availability prevented the treatment of burningbush in 2017.

Rush skeletonweed occurs throughout areas of natural vegetation and is most prevalent in previously disturbed areas or along road edges. It spreads by seed and by root, forming dense stands if left unchecked. After seven years of herbicide treatments in the area north of Horn Rapids Road (excluding newly acquired land at the extreme north end), most of the dense populations of rush skeletonweed have been greatly reduced, leaving only scattered individuals and small clusters. Results from a post-treatment assessment in 2016 indicate that spraying is effective in reducing the abundance of rush skeletonweed, but continued monitoring and treatment is necessary because of the rhizomatous nature of the plant and its ability to re-grow from the root system.

Yellow starthistle is an annual or biennial plant that reproduces by seed. Several small patches were identified on the PNNL Richland Campus in 2017. Because it is primarily an annual plant, removing the seed source is an effective control. Treatment in 2017 included extracting individual plants or hand-spraying them when encountered.

The primary target species of the treatment program on the PNNL Richland Campus in 2017 was rush skeletonweed, though diffuse knapweed, yellow starthistle, and individual occurrences of Russian knapweed were treated opportunistically, as described above. In 2017, the program focused on two areas that had not been previously treated. The first area of emphasis consisted of small fields of natural vegetation and associated road edges located along 4th and 5th Streets near the south end of the

PNNL Richland Campus. The other was the approximately 35-ha (86-ac) area of former Hanford Site land transferred to DOE-PNSO in December 2016. This area, located at the north end of the PNNL Richland Campus, contained several large areas of dense rush skeletonweed and Russian knapweed, as well as scattered individual plants and small patches of various weed species throughout. Hand-spraying was conducted on four days between June 1 and June 29, 2017 (Figure 2.2).

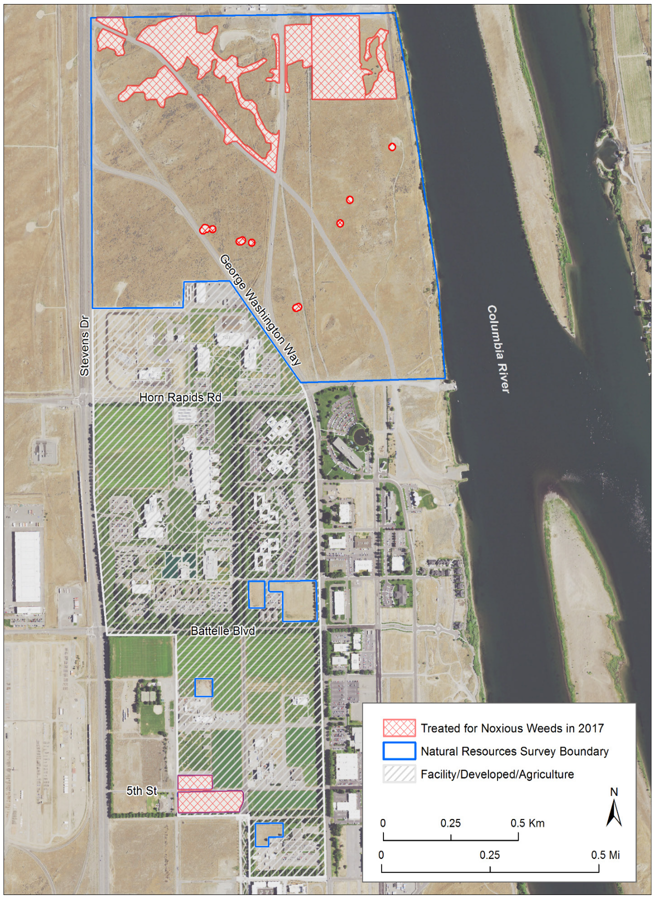

Figure 2.2. Areas Treated for Noxious Weeds on the PNNL Richland Campus in 2017

2.7.1.2 Habitat Mitigation

MR Sackschewsky

In 2013, PNNL began development in support of Phase 2 construction of the PSF. The initial land clearing for this development phase resulted in the loss of approximately 6.6 ha (16.3 ac) of mature sagebrush steppe habitat. As stipulated in the mitigation action plan prepared for this activity (DOE-PNSO 2013), this habitat loss needed to be mitigated. PNNL performed compensatory mitigation for this habitat loss by working with the National Fish and Wildlife Foundation and the USFWS to establish replacement habitat on the Fitzner-Eberhardt Arid Lands Ecology Reserve, which is part of the Hanford Reach National Monument. The USFWS coordinated the planting of 112,158 shrub seedlings in three plots over approximately 321 ha (794 ac) in early December 2016. Approximately three-quarters of the shrub seedlings were big sagebrush, and the balance consisted of antelope bitterbrush, winterfat (*Krascheninnikovia lanata*), snow buckwheat, green rabbitbrush, gray rabbitbrush, spiny hopsage (*Grayia spinosa*), and purple sage (*Salvia dorrii*). Twenty-four monitoring transects were established in the spring of 2017 and the number of plants by species (composing greater than 1% of the total number of seedlings planted in 2016) was counted; survival will be assessed in spring 2018, 2020, and 2022.

2.7.2 Cultural Resources

EP Kennedy and JL Mendez

A number of federal Acts and Orders provide the framework for protection of cultural resources on the PNNL Richland Campus and at MSL. This section summarizes the requirements and catalogs PNNL's compliance activities in 2017.

The *National Historic Preservation Act of 1966* (54 U.S.C. § 300101 *et seq.*) and its amendments established historic preservation as a national policy and define it as the protection, rehabilitation, restoration, and reconstruction of districts, sites, buildings, structures, and objects that are significant in American history, architecture, archaeology, or engineering. The Act also expanded the National Register of Historic Places (NRHP) listing to include resources of state and local significance, and it established the Advisory Council on Historic Preservation as an independent federal agency. As a result of Public Law 113-287 (enacted on December 19, 2014), the *National Historic Preservation Act of 1966* (NHPA) was repealed from 16 U.S.C. § 470 *et seq.*, and reenacted in 54 U.S.C. § 300101 *et seq.*, *Historic Preservation Programs*. Section 106 of the NHPA specifically requires federal agencies to consider the impact of federally funded, permitted projects or projects occurring on federally managed lands on cultural resources that are eligible for listing or listed in the NRHP. At PNNL the cultural resources review process supports compliance with NHPA Section 106.

The *Antiquities Act of 1906* (54 U.S.C. § 320301–320303 and 18 U.S.C. § 1866(b)) provided for the protection of historic and prehistoric remains and structures on federal lands. It established a permit system for conducting scientific archaeological investigations and established criminal penalties and fines to manage looting and vandalism of archaeological sites on public lands. By the 1970s, the penalties were no longer commensurate with the severity of the offenses, and in 1974 the Ninth Circuit Court of Appeals proclaimed the Act to be unconstitutionally vague. In response, Congress enacted the *Archaeological Resources Protection Act of 1979* (16 U.S.C. § 470aa). As a result of Public Law 113-287 (enacted on December 19, 2014), the *Antiquities Act of 1906* was repealed from 16 U.S.C. § 431–433 and reenacted in 54 U.S.C. § 320301–320303, *Monuments, Ruins, and Objects of Antiquity*, and 18 U.S.C. § 1866(b), *Historic, Archeologic, or Prehistoric, Items and Antiquities*.

The *Archaeological Resources Protection Act of 1979* (16 U.S.C. § 470aa-mm) provides for the protection of archaeological resources and sites on federal and tribal lands. It also describes the conditions required preceding the issuance of a permit to excavate or remove any archaeological resource, the curation and record requirements for resource removal or excavation, and the penalties for convicted violators. At PNNL, the annual site monitoring activities support compliance with the *Archaeological Resources Protection Act of 1979*.

The *Native American Graves Protection and Repatriation Act of 1990* (25 U.S.C. § 3001 *et seq.*) established a means for Native Americans to request the return of human remains and other sensitive cultural articles held by federal agencies. It also contains provisions regarding the requirement to inventory any remains and associated funerary objects, the intentional excavation of remains or cultural items, and the illegal trafficking of those items.

The *American Indian Religious Freedom Act* (42 U.S.C. § 1996 *et seq.*) was established in 1978 for the protection and preservation of the traditional religious ceremonial rights and cultural practices of American Indians. These rights include access to sacred sites, repatriation of sacred items held in museums, and freedom to worship through traditional ceremonies. The Act also required governmental agencies not to interfere with Native American religious practices and to accommodate access to and use of religious sites to the extent that the use is practicable and consistent with an agency's essential functions. Because the *American Indian Religious Freedom Act* could not enforce its provisions, the *American Indian Religious Freedom Act Amendments of 1994* were established to provide for the management of federal lands "in a manner that does not undermine or frustrate traditional Native American religions or religious practices" (103 HR 4155).

The *Archeological and Historic Preservation Act of 1974* (54 U.S.C. § 312501–312508) provides for the preservation of historical American sites, buildings, objects, and antiquities of national significance. It also imparts the preservation of historical and archaeological data (including relics and specimens), which might otherwise be irreparably lost or destroyed, and requires preservation of significant historical and archaeological data affected by any federal or federally related land modification activity. As a result of Public Law 113-287 (enacted on December 19, 2014), the *Archeological and Historic Preservation Act of 1974* was repealed from 16 U.S.C. § 469–469c-2 and reenacted in 54 U.S.C. § 312501–312508, *Preservation of Historical and Archaeological Data*.

Executive Order 11593 of May 15, 1971, "Protection and Enhancement of the Cultural Environment" (36 FR 8921), requires federal agencies to inventory their cultural resources and establish policies and procedures to assure the protection, restoration, and maintenance of any sites, structures, or objects of historical, architectural, or archaeological significance.

Executive Order 13007 of May 29, 1996, "Indian Sacred Sites" (61 FR 26771), directs federal agencies to accommodate access to and ceremonial use of Indian sacred sites and to avoid adversely affecting the physical integrity of these sites. Where appropriate, agencies shall maintain the confidentiality of sacred sites.

Executive Order 13175 of November 6, 2000, "Consultation and Coordination with Indian Tribal Governments" (65 FR 67249), directs federal agencies to develop a process for assuring meaningful tribal input when developing regulatory policies that have tribal implications and to consult with tribal authorities.

Executive Order 13287 of March 3, 2003, "Preserve America" (68 FR 10635), directs federal agencies to increase their knowledge of historic resources in their care, enhance the management of these assets, and seek partnerships with state, tribal, and local governments to make more informed and efficient use of those resources.

DOE Policy 141.1, "Department of Energy Management of Cultural Resources," assures that DOE maintains a program that reflects the spirit and intent of cultural resource legal mandates. Two specific goals are to

- assure that DOE programs and field elements integrate cultural resources management into their missions and activities, and
- raise the level of awareness within DOE concerning the importance of the Department's cultural resource-related legal and trust responsibilities.

The purpose of DOE Order 144.1, Admin Chg 1, *Department of Energy American Indian Tribal Government Interactions and Policy*, is to communicate the departmental, programmatic, and field responsibilities for interacting with American Indian Governments and to communicate DOE's *American Indian and Alaska Native Tribal Government Policy*, including its guiding principles and implementation framework.

In consultation with tribal consulting parties and in response to the direction and guidance provided in DOE Policy 141.1, "Department of Energy Management of Cultural Resources," DOE Order 144.1, Admin Chg 1, *Department of Energy American Indian Tribal Government Interactions Policy*, DOE Order 436.1, *Departmental Sustainability*, and DOE Order 430.1B, Chg 2, *Real Property and Asset Management*, DOE-PNSO revised its CBRMP in 2015 (DOE-PNSO 2015). The CBRMP provides direction and guidance for the protection and long-term stewardship of cultural and biological resources on PNSO-managed lands in accordance with federal and state laws.

2.7.2.1 Cultural Resources Reviews

In accordance with NHPA Section 106 requirements (54 U.S.C. § 300101 *et seq.*), cultural resources reviews are conducted for all federal undertakings to identify their potential to affect cultural resources. If an undertaking is determined to be the type of activity that does not have the potential to affect historic properties (assuming such historic properties are present), the agency has no further obligations under NHPA Section 106. Six PNNL projects in 2017 were reviewed and determined to have No Potential to Cause Effect on historic properties as defined by 36 CFR 800.3(1): four in the Sequim Bay vicinity, one on the PNNL Richland Campus, and one offsite. If the undertaking is determined to be the type of activity that has the potential to affect historic properties, the Section 106 process is initiated. The Section 106 review process results in one of three findings: 1) No Historic Properties Affected, 2) No Adverse Effect on Historic Properties, or 3) an Adverse Effect on Historic Properties. Five Section 106 cultural resource reviews were conducted (and completed) for PNNL projects in 2017: two on the PNNL Richland Campus, two on the Hanford Site, and one on the PNNL MSL site. One of these reviews resulted in a finding of No Historic Properties Affected, while four resulted in a finding of No Adverse Effect on Historic Properties. In addition to these Section 106 reviews, 27 projects were reviewed by cultural resources staff to assure that the project activities were covered by previously conducted Section 106 cultural resource reviews.

2.7.2.2 Section 110 Activities

To assure that important cultural resources are protected on the PNNL Richland Campus and in accordance with NHPA Section 110 and the *Archaeological Resources Protection Act*, the CBRMP (DOE-PNSO 2015) requires annual monitoring of three NRHP eligible properties to identify potential threats and recommend appropriate actions, if necessary. As stipulated in the CBRMP, trip results are analyzed and reported to consulting American Indian tribes and the Washington State Historic Preservation Office. The annual cultural resources monitoring trip was conducted on October 10, 2017. Monitoring was conducted by the PNNL cultural resources contractor CH2M HILL, with the participation of PNSO, PNNL, and tribal cultural resources staff. Photographs and field notes were taken at set points for each archaeological site to assess the site condition and identify potential changes to the site caused by human or natural causes. In addition, information was collected and added to file records to update the current knowledge of the sites.

No previously unrecorded impacts at any of the three sites were identified during the 2017 monitoring trip. Evidence of disturbance activities at the three sites appeared to be mostly related to past manmade disturbances. Most of the erosional and manmade impacts (roads, construction related impacts, etc.) appeared to be stabilizing, natural vegetation was thriving, and the overall condition was improving. In addition, native grasses and shrubs were found to be thriving in revegetation plots located within one of the sites. These areas will continue to be monitored.

2.7.2.3 Inventories, Identification, and Evaluation Activities

A total of 43 ha (105 ac) was surveyed for archaeological and architectural resources during an NHPA Section 106 project-specific survey in 2017. This survey occurred on the PNNL Richland Campus, included subsurface shovel testing excavations, and was associated with the ongoing NHPA Section 106 cultural resources review (and associated NEPA environmental assessment) for the PNNL Richland Campus Future Development project. Two archaeological sites were recorded that have not been evaluated for their eligibility for inclusion in the NRHP. Seven architectural resources and the PNNL Richland Campus Historic District were determined to be eligible for inclusion in the NRHP. Six architectural resources and one historical period road were recommended as being not eligible for inclusion in the NRHP.

2.7.2.4 Consultation and Public Involvement

PNSO routinely consults with various SHPOs, American Indian tribes, and other interested parties about NHPA Section 106 activities. PNSO consulted with 11 American Indian tribes and the Washington SHPO with respect to NHPA Section 106 activities in 2017.

Tribal consultation and involvement at the PNNL Richland Campus and adjacent Hanford Site is focused on five American Indian tribes that have historical ties to the area. As such, PNSO routinely consults with the Confederated Tribes and Bands of the Yakama Nation, the Confederated Tribes of the Umatilla Indian Reservation, The Nez Perce Tribe, the Wanapum, and the Confederated Tribes of the Colville Reservation. In addition to NHPA Section 106 consultations, PNSO held three meetings in 2017 with Tribal Cultural Resources staff. Discussions centered around cultural resources reviews on the PNNL Richland Campus and overviews of program tasks (such as a summary of NHPA Section 110 activities, etc.). In addition several meetings were held to discuss NHPA Section 106 agreement documents being developed as part of the ongoing NHPA Section 106 Review for the PNNL Richland Campus Future Development project.

Tribal consultation and involvement at MSL is focused on six American Indian tribes that have historical ties to the MSL site, including the Makah Indian Tribe of the Makah Indian Reservation, the Jamestown S'Klallam Tribe of Washington, the Lower Elwha Klallam Tribe, the Port Gamble Indian Community of the Port Gamble Reservation, the Hoh Indian Tribe of the Hoh Indian Reservation, and the Quileute Nation. These tribes are consulted about the protection of biological, natural, and cultural resources related to MSL. In addition to NHPA Section 106 consultations, PNSO held one meeting with the Jamestown S'Kallam and discussed ongoing and future projects occurring at the MSL.

In addition to tribal consultation, PNSO consulted with interested parties and the public regarding the ongoing NHPA Section 106 review and associated NEPA environmental analysis for the Richland Campus Future Development project.

2.8 Radiation Protection

JA Stephens

PNNL is subject to the radiation protection statutes and regulations designed to protect the health and safety of the public, the workforce, and the environment.

2.8.1 DOE Order 458.1, *Radiation Protection of the Public and the Environment*

During the reporting period of this annual site environmental report, PNNL was working under the requirements of DOE Order 458.1, issued in February 2011 with changes in March 2011 (Admin Chg 1), June 2011 (Chg 2), and January 2013 (Admin Chg 3). Section 2.d (As Low As Reasonably Achievable [ALARA]), Section 2.g (Control and Management of Radionuclides from DOE Activities in Liquid Discharges), and Section 2.k (Release and Clearance of Property) of DOE Order 458.1 were added to PNNL's contract with PNSO in July 2011, and were fully implemented on September 1, 2012.

Section 2.d of DOE Order 458.1 requires each contractor to establish an environmental ALARA process to control and manage radiological activities so that doses to the public and releases to the environment are kept ALARA (Figure 2.3). The ALARA process must be applied to the design or modification of facilities and to the conduct of radiological work activities.

Section 2.g of DOE Order 458.1 requires each contractor to establish and implement procedures and practices related to control and management of radionuclides from DOE activities in liquid discharges.

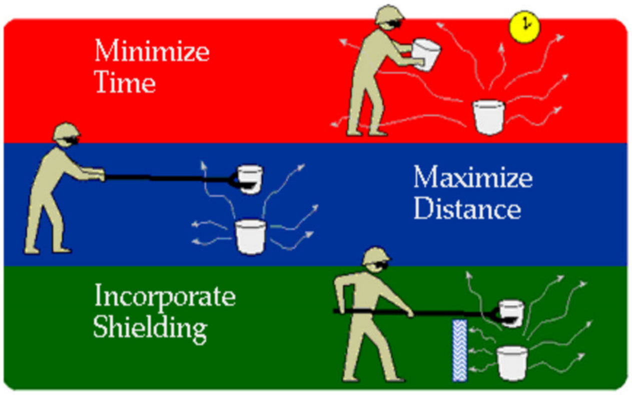

Figure 2.3. Elements of the As Low As Reasonably Achievable (ALARA) Principle

Section 2.k of DOE Order 458.1 provides the requirements with which each contractor must comply when releasing property that potentially contains residual radioactivity. Dose constraints for the public are established based on the type of property (i.e., personal property and real property). Requirements for releasing property based on process knowledge, radiological surveys, or a combination of both are provided. The process of obtaining pre-approved release limits and activity-specific release limits for releasing property is also described in the Order. The public is required to be notified annually of property released from contractor facilities.

PNNL radiation protection procedures implement Sections 2.d and 2.k of DOE Order 458.1. Procedures include guidance on the environmental ALARA program, the use of process knowledge and historical knowledge when releasing property, the preparation and approval of requests for authorized limits, and the preparation of an annual site environmental report. A description of PNNL programs that implement these sections of the Order is found in Section 4.3 of this report.

No property with detectable residual radioactivity above guideline limits was released in 2017.

A description of how PNNL complies with the liquid discharge requirements in Section 2.g of DOE Order 458.1 is found in Section 4.1 of this report.

2.8.2 DOE Order 435.1, *Radioactive Waste Management*

The purpose of DOE Order 435.1 is to establish requirements for assuring DOE radioactive waste is managed in a manner that is protective of workers public health and safety, and the environment. The Order takes a cradle-to-grave approach to managing waste and includes requirements for waste generation, storage, treatment, disposal, and post-closure monitoring of facilities.

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

- 10 CFR Part 835, "Occupational Radiation Protection"
- DOE Order 440.1B, Chg 2, *Worker Protection Program for DOE (Including the National Nuclear Security Administration) Federal Employees*
- DOE Order 458.1, Admin Chg 3, *Radiation Protection of the Public and the Environment.*

DOE Order 435.1 establishes requirements for the management of high-level waste, transuranic waste, and low-level waste. It also covers mixed waste (i.e., high-level waste, transuranic waste, or low-level waste that also contain chemically hazardous constituents). DOE Order 435.1 (approved in 1999) superseded a previous set of requirements (DOE Order 5820.2A, dated September 26, 1988) for managing radioactive waste. DOE Order 435.1, Chg 1, approved in 2001, includes minor revisions to the original Order and was formally certified again in 2007.

PNNL's Radioactive Waste Management Basis Program identifies the hazards associated with radioactive waste management at PNNL along with their potential impacts. Controls for the protection of the public, workers, and the environment are also presented. Controls are implemented through internal PNNL workflows and waste-management procedures.

2.8.3 *Atomic Energy Act of 1954*

The *Atomic Energy Act of 1954* (42 U.S.C. § 2011 *et seq.*) was promulgated to assure the proper management of radioactive materials. Through the Act, DOE regulates the control of radioactive materials under its authority, including the treatment, storage, and disposal of low-level radioactive waste from its operations, and establishes radiation protection standards for itself and its contractors. Accordingly, DOE promulgated a series of regulations (e.g., 10 CFR Part 820, 10 CFR Part 830, and 10 CFR Part 835) and directives (e.g., DOE Order 435.1, Chg 1 [Section 2.8.2] and DOE Order 458.1, Admin Chg 3 [Section 2.8.1]) to protect public health and the environment from potential risks associated with radioactive materials. PNNL complies with the *Atomic Energy Act of 1954* through its Radiation Protection Management and Operation Program and Radioactive Waste Management Basis Program.

2.9 Major Environmental Issues and Actions

MD Ellefson

Releases of radioactive and regulated materials to the environment are reported to DOE and other federal, state, and/or local agencies as required by law. The specific agencies notified depend on the type and amount of material released, and the location of each release event. This section describes releases to the environment that occurred at PNNL during CY 2017.

2.9.1 Continuous Release Reporting

A continuous release is a hazardous release exceeding reporting thresholds under CERCLA regulations (40 CFR 302.8) that is "continuous" and "stable in quantity and rate" for which reduced reporting requirements apply. There were no continuous releases on the PNNL Richland Campus or at MSL in 2017.

2.9.2 DOE Order 232.2A, *Occurrence Reporting and Processing of Operations Information*

DOE Order 232.2A, requires the reporting of incidents that could adversely affect the public or workers, the environment, or the mission that occur at DOE sites and/or during DOE operations. Releases requiring regulatory agency notification (Section 2.9.3) and receipt of formal or informal regulator correspondence alleging violations (Section 2.6) are required to be reported to DOE through the reporting system. PNNL reports all incidents to DOE as required.

2.9.3 Unplanned Releases

No environmentally significant releases occurred at PNNL in 2017.

2.10 Summary of Permits

MD Ellefson

Table 2.5 summarizes air, liquid, and hazardous waste permits for the PNNL Richland Campus and MSL during 2017. Project-specific permits are also acquired but are not reflected in the table because they are usually of limited term and scope.

Table 2.5. PNNL Air, Liquid, and Hazardous Waste Permits, 2017

Issuer	Permit #	Location(s) Regulated	Activity(ies) Regulated	Expiration Date[(a)]
Air Emissions				
Washington State Department of Health	FF-01[(b)]	PNNL-occupied locations on Hanford Site	Radioactive air emissions	12/31/2017
Washington Department of Health	RAEL-005	PNNL Richland Campus	Radioactive air emissions	6/17/2020
Washington Department of Health	RAEL-014	PNNL Marine Sciences Laboratory	Radioactive air emissions	10/1/2017
Washington State Department of Ecology	00-05-006, Renewal 2, Revision A	PNNL-occupied locations on Hanford Site	Radioactive and nonradioactive air emissions	3/31/2018
Benton Clean Air Agency	Order 2007-0013, Rev. 1	Physical Science Facility	Nonradioactive air emissions	None
Benton Clean Air Agency	Order 2012-0017	PNNL Richland Campus – Building Operations	Nonradioactive air emissions	None
Benton Clean Air Agency	RO 2012-0009	W.R. Wiley Environmental Molecular Sciences Laboratory – Building Operations	Nonradioactive air emissions	None
Benton Clean Air Agency	Order 2012-0016	PNNL Richland Campus – R&D Pilot Scale Processes and Field Experiments	Nonradioactive air emissions	None
Benton Clean Air Agency	Order 2007-0006, Rev. 1	Life Sciences Laboratory II – Building Operations	Nonradioactive air emissions	None
Benton Clean Air Agency	Order 2016-0008	Life Sciences Laboratory II – Halogenated Solvent Degreaser Operations	Nonradioactive air emissions	None
Washington State Department of Ecology	Order 02NWP-001	300 Area Standby Generators (Radiochemical Processing Laboratory & 331 Buildings)	Nonradioactive air emissions	None
Olympic Region Clean Air Agency	Order of Approval 13NOI968	PNNL Marine Sciences Laboratory Standby Generators	Nonradioactive air emissions	None
Liquid Effluents[(c)]				
City of Richland	CR-IU001	PNNL Richland Campus	Liquid effluent discharges to city sewer	4/1/2020

Issuer	Permit #	Location(s) Regulated	Activity(ies) Regulated	Expiration Date[a]
City of Richland	CR-IU005	W.R. Wiley Environmental and Molecular Sciences Laboratory	Liquid effluent discharges to city sewer	8/21/2022
City of Richland	CR-IU011	Physical Sciences Facility (new buildings north of Horn Rapids Road)	Liquid effluent discharges to city sewer	3/3/2018
City of Richland	CR-IU010[b]	PNNL-occupied locations on the Hanford Site	Liquid effluent discharges to city sewer	11/30/2021
Washington State Department of Ecology	ST 4511[b]	PNNL-occupied locations in Hanford Site 300 Area	Discharge of wastewater from maintenance, construction, and hydro testing activities; allows for cooling water, condensate, and industrial stormwater discharges to ground	12/31/2019
Washington State Department of Ecology	ST-9274	Biological Sciences Facility and Computational Sciences Facility	Reinjection of well water used in ground-source heat pump	6/6/2020
Washington State Department of Ecology	WA0040649	PNNL Marine Sciences Laboratory	Treated liquid effluent discharges to Sequim Bay	11/30/2022
Hazardous Waste				
Washington State Department of Ecology	WA7890008967	325 Hazardous Waste Treatment Units (located in the 300 Area)	Treatment and storage of dangerous waste (primarily mixed waste)	9/27/2004

(a) Expired permits generally remain in force while renewal applications are processed by the issuing agency.
(b) Permit issued to DOE-Richland Operations Office and/or its contractor(s); PNNL (Pacific Northwest National Laboratory) is obligated to comply with these permits through an operating agreement between the DOE-Richland Operations Office and Pacific Northwest Site Office.
(c) PNNL also conducts activities in leased facilities that have wastewater permits issued to the owner. These permits are not listed here, but compliance-related impacts from PNNL activities are included in this report.

3.0 ENVIRONMENTAL MANAGEMENT SYSTEM

J Su-Coker

PNNL has a mature, robust EMS that has been certified to meet the requirements of ISO 14001 standards since 2002. The EMS is integrated into PNNL's Integrated Safety Management Program, which assures that staff are aware of project scope, risks/hazards, and controls available to address functions, processes, and procedures used to plan and perform work safely. The outcome of the integration is the accomplishment of PNNL missions while protecting the worker, the public, and the environment.

Management at PNNL periodically assesses environmental performance from a programmatic perspective to determine whether issues require attention and to facilitate the identification and communication of best management practices. PNNL management also routinely evaluates progress on key environmental improvement projects.

The EMS is audited annually to verify that it is operating as intended and in conformance with ISO 14001 standards. In early 2017, PNNL successfully transitioned its EMS to the latest ISO 14001:2015 Standards (Figure 3.1).

In addition, the 2017 EMS performance data submitted to the Federal Facilities Environmental Stewardship & Compliance Assistance Center received a "Green" score for the EMS performance metrics listed below.

- Environmental aspects were identified or re-evaluated using an established procedure and updated as appropriate.
- Measurable environmental goals, objectives, and targets were identified, reviewed, and updated as appropriate.
- Operational controls were documented to address significant environmental aspects consistent with objectives, and targets were fully implemented.
- Environmental training procedures were established to assure that training requirements for individual competence and responsibility were identified, carried out, monitored, tracked, recorded, and refreshed as appropriate to maintain competence.
- EMS requirements were included in all appropriate contracts, and contractors fulfilled defined roles and specified responsibilities.
- EMS audit/evaluation procedures were established, audits were conducted, and nonconformities were addressed or corrected.

NSF ISR

Certificate of Registration

This certifies that the Environmental Management System of

Battelle - Pacific Northwest Division

Pacific Northwest National Laboratory
902 Battelle Boulevard
Mail Stop J2-25
Richland, Washington, 99354, United States

has been assessed by NSF-ISR and found to be in conformance to the following standard(s):

ISO 14001:2015

Scope of Registration:
Pacific Northwest National Laboratory, operated by Battelle for the U.S. Department of Energy: Research and development activities and associated facilities operations

Certificate Number: 6Z781-EM1
Certificate Issue Date: 02-FEB-2017
Registration Date: 26-JAN-2017
Expiration Date *: 25-JAN-2020

Carl Blazik,
Director, Technical
Operations & Business Units,
NSF-ISR, Ltd.

NSF International Strategic Registrations
789 North Dixboro Road, Ann Arbor, Michigan 48105 | (888) NSF-9000 | www.nsf-isr.org

Figure 3.1. Certificate of Registration for PNNL Conformance with ISO-14001:2015 Standards

- Senior leadership review of the EMS was conducted and management responded to recommendations for continual improvement.

PNNL examines its operations to determine which categories of environmental impacts (referred to as "aspects" in the ISO 14001 standards) have the greatest potential to occur, and therefore, require consideration and control through the EMS process. PNNL performs annual environmental aspect and impact analyses, including risk analysis and work evaluations, to assure regulatory requirements and any concerns of the public or other interested parties are addressed. The 11 most significant aspects and the EMS controls used to minimize the potential impacts of each aspect are as follows:

- **Chemical Use and Storage**. As a research laboratory, PNNL has many buildings in which chemicals/biological materials are used and/or stored for research operations and maintenance activities. Controls used to avoid potential hazards include training, inventory control procedures, approvals prior to requisitioning, and work procedures for chemical/biological material use, including adequate safety requirements. PNNL implements a "ChemAgain" program, which redistributes surplus chemicals internally in an effort to reduce PNNL's chemical waste.
- **Biological Material Use and Storage.** As a research laboratory, PNNL has many buildings in which biological materials are used and/or stored for research activities. Controls used to avoid potential hazards include training and work procedures for biological material use, including adequate safety requirements.
- **Regulated Waste Generation.** The use of chemical and radioactive materials creates waste streams that may be regulated as dangerous waste, radioactive waste, or both dangerous and radioactive (mixed) waste. Wastes within these categories are subject to the regulations of the Washington State Department of Ecology (for dangerous and mixed waste) and DOE (for radioactive and mixed waste). In addition to the controls imposed by these requirements, PNNL seeks to reduce generated wastes. Projects are regularly reviewed and procedures are scrutinized to minimize the production of regulated wastes. Any generated waste may be treated to be made less hazardous or nonhazardous for proper disposal.
- **Radioactive Material Use and Storage.** Research at PNNL may involve the use of radioactive materials. All radioactive materials are labeled and controlled. Controls include restricted access to radiation areas and special training requirements for staff requiring access.

- **Emissions to Air.** Potential air emissions are evaluated and permits are obtained when required. Active controls for the management of chemicals, radioactive materials, and regulated wastes seek to minimize PNNL air emissions. Sources of air emissions include boilers, diesel generators, vehicle exhaust, R&D activities, and facility and grounds maintenance and operations.

- **Effluents to Water**. PNNL seeks to minimize liquid discharges to the environment. Discharges include laboratory drain water to sewer systems and stormwater to dry wells in parking lots, which are regulated by state and local permits and/or regulations. Discharges are evaluated to assure they conform with regulations and permits.
- **Energy Use.** Using energy judiciously is a prime objective at PNNL. Energy reduction goals are established and activities to reduce energy consumption are implemented.
- **Solid Waste Generation.** The use of office products, electronics, and equipment, along with construction, demolition, and normal maintenance activities, create nonregulated solid waste streams. Reduction or elimination of environmental hazards, conservation of environmental resources, and maximization of operational sustainability are achieved through the incorporation of electronic stewardship practices, reuse of materials, and operation of recycling programs.
- **Fuel Usage.** PNNL seeks to minimize the use of petroleum-based fuels by purchasing vehicles that use alternative fuels, such as ethanol-85, and by acquiring high-fuel–efficiency vehicles, including hybrid and all-electric vehicles. PNNL has also acquired electric vehicles for on-campus transportation and has installed solar-powered electric vehicle charging stations across the Richland Campus. In addition, PNNL was instrumental in obtaining the first biofuel service station in Richland, Washington, and when appropriate, uses bio-diesel to fuel generators.

- **Physical Interaction with the Environment**. Some PNNL projects are performed outdoors in direct contact with the environment. These projects include facility construction, maintenance, and modifications, as well as occasional R&D activities. Work proposed to be performed outdoors is reviewed to minimize potential impacts and assure the protection of workers, the public, and environmental resources.
- **Water Use.** PNNL recognizes the value of water in the eastern Washington environment. PNNL maintains water-use reduction goals and implements actions to reduce water consumption.

The benefits of implementing a well-performing EMS include enabling upfront planning to incorporate sustainability and pollution prevention opportunities, early identification of environmental requirements to avoid project delays, high-level integration with existing programs to improve efficiency, reduced operational costs, and enhanced public recognition as a "good neighbor."

PNNL has been using a multi-disciplinary Sustainability Core Team as a best practice to drive continuous improvement in its sustainability environmental performance and to enable an integrated approach in managing the environmental aspects and impacts. The Sustainability Core Team is a diverse, authorized working group composed of key EMS program leads and managers. Core Team members are held accountable for the successful execution of PNNL's sustainability goals and targets.

3.1 Sustainability Goals and Targets

Executive Order 13514 of October 5, 2009, "Federal Leadership in Environmental, Energy, and Economic Performance" (74 FR 52117), established sustainability goals for federal agencies and focused on improving their environmental, energy, and economic performance. Executive Order 13693 of March 19, 2015, "Planning for Federal Sustainability in the Next Decade" (80 FR 15871), revoked and superseded Executive Order 13514, establishing new sustainability goals with numerical targets for federal agencies.

PNNL's comprehensive and diverse approach meets the principles of Executive Order 13693 requirements. Details about PNNL's plan to advance DOE's sustainability mission are captured in the PNNL *FY 2018 Site Sustainability Plan* (DOE 2017). The plan contains the annual status and strategy for achieving long-term goals in the areas of GHG reduction, sustainable buildings, clean and renewable energy, water use efficiency and management, fleet management, sustainable acquisition, pollution prevention and waste reduction, energy performance contracts, electronic stewardship, and climate change resilience.

Each sustainability goal, PNNL's performance status, and planned actions are detailed in Table 3.1.

3.2 Accomplishments, Awards, and Recognition

In FY 2017, PNNL received the 2017 Achievement Award from the Association of Washington Business for achievements in science, technology, engineering, and mathematics education. The award recognizes businesses that have excelled in creating, implementing, or supporting high-caliber education and/or workforce development systems aligned with closing the employment gap.

PNNL achieved several sustainability milestones in FY 2017, as highlighted below. Figure 3.2 provides an "At a Glance" view of key environmental sustainability accomplishments.

- Utility Energy Services Contract

  Working toward the performance contracting goals outlined in the *FY 2018 Site Sustainability Plan* (DOE 2017), PNNL solicited interest from utility providers in partnering on a Utility Energy Services Contract (UESC). This type of arrangement uses outside energy management services to perform energy and water evaluations at PNNL, recommend energy and water conservation measures (ECMs), and provide funding by way of low-interest loans and incentives to implement projects that are life cycle cost effective. PNNL solicited interest from serving utilities and selected Bonneville Power Administration (BPA) to provide a customized UESC program based on their energy management services offerings, experience, and qualifications. Engineers from BPA began to evaluate both laboratory and office facilities at PNNL in FY 2017 and will continue in FY 2018 to identify potential ECM projects for implementation.

- Single-Stream Recycling Prompts Cultural Shift

  Single-stream recycling was implemented campus-wide in FY 2017. Moving to single-stream recycling was an important step in sustaining and exceeding the waste diversion goal. Prior to using single-stream recycling, a suite of recycling bins were scattered throughout each facility to support the collection of common recyclable materials (mixed paper, plastic, aluminum, tin, and glass). Staff found the old "multi-stream" version of recycling confusing and it often resulted in recyclables being placed in the wrong bin or in the trash. Single-stream recycling was initiated to streamline the recycling process, by eliminating the need for users to sort their recyclables and to optimize bin placement. Single-stream recycling has not only vastly improved staff recycling participation, it has also changed the perception of recycling. Based on the positive feedback, recycling has moved from being a confusing chore to an easy task.

Table 3.1. Status of PNNL Sustainability Goals through FY 2017 and Targets for FY 2018

DOE Goal	FY 2017 Performance Status	FY 2018 Plans
Multiple Categories		
50% Scope 1 & 2 greenhouse gas (GHG) emissions reduction by FY 2025 from a FY 2008 baseline.	Interim Target: -25% Current Performance: -18.1%	Continue Renewable Energy Certificate (REC) purchases for near-term GHG reduction goal and implement energy conservation measures where cost effective.
25% Scope 3 GHG emissions reduction by FY 2025 from a FY 2008 baseline.	Interim Target: -9% Current Performance: -3.8%	Continue promoting telework and use of video conferencing to reduce travel; encourage staff through bus and carpool promotions and incentives.
Energy Management		
25% energy intensity (Btu per gross square foot) reduction in goal-subject buildings by FY 2025 from a FY 2015 baseline.	Interim Target: -5% Current Performance: 8.5%	Pursue funding for large, high-impact projects through the Utility Energy Services Contract with Bonneville Power Administration.
Energy Independence and Security Act of 2007 (EISA) Section 432 continuous (4-year cycle) energy and water evaluations.	Completed energy and water evaluations on Buildings 3410, 3420, and 3430 in FY 2017 to stay compliant with EISA Section 432.	Perform energy and water evaluation on Building 325 in FY 2018.
Meter all individual buildings for electricity, natural gas, steam and water where cost effective and appropriate.	All individual buildings metered for electricity, natural gas, steam, and water where cost effective and appropriate.	Improve building performance through data analysis.
Water Management		
36% potable water intensity (gallons per gross square foot) reduction by FY 2025 from a FY 2007 baseline.	Interim Target: -20% Current Performance: -77.2%	Continue to implement reduction opportunities for site water management.
30% water consumption (gal) reduction of industrial, landscaping, and agricultural water by FY 2025 from a FY 2010 baseline.	FY 2011 Baseline: 176,248,000 gal FY 2017 Actual: 173,280,000 gal Interim Target: -14% Current Performance: -1.7%	Continue to implement reduction opportunities for site water management.
Waste Management		
Divert at least 50% of non-hazardous solid waste, excluding construction and demolition (C&D) debris.	Interim Target: 50% Current Performance: 60.1%	Continue to expand nitrile glove recycling program; continue conducting assessments to identify waste reduction opportunities.

DOE Goal	FY 2017 Performance Status	FY 2018 Plans
Divert at least 50% of C&D materials and debris.	Interim Target: 50% Current Performance: 88.4%	Continue monitoring C&D recycling performance and raising awareness about waste diversion requirements.
Fleet Management		
30% reduction in fleet-wide per-mile GHG emissions reduction by FY 2025 from a FY 2014 baseline.	Interim Target: -4% Current Performance: 1.4%	Continue to look at optimizing routes traveled by vehicles and consolidating deliveries where applicable. Staff will continue to be provided education on the importance of avoiding extra idling time, speed control, and combining trips with other staff members when feasible.
20% reduction in annual petroleum consumption by FY 2015 relative to a FY 2005 baseline; maintain 20% reduction thereafter.	Interim Target: -20% Current Performance: -10.1%	Education will continue for vehicle custodians regarding the importance of avoiding extra idling time, speed control, combining trips with other staff members when feasible
10% increase in annual alternative fuel consumption by FY 2015 relative to a FY 2005 baseline; maintain 10% increase thereafter.	Interim Target: 10% Current Performance: 0%	Continue periodic checks on the local availability of bio-diesel fuel. As older vehicles are replaced, PNNL will continue to work with the General Services Administration (GSA) to determine if an alternative fuel vehicle or fully electric vehicle is an option for vehicle replacement.
75% of light-duty vehicle acquisitions must consist of alternative fuel vehicles.	77% of PNNL acquisitions during FY 2017 were alternative fuel vehicles.	PNNL will continue to work closely with GSA to assure that all applicable PNNL vehicle orders are for alternatively fueled vehicles.
50% of passenger vehicle acquisitions consist of zero-emission or plug-in hybrid electric vehicles by FY 2025.	No passenger vehicle acquisitions were made in FY 2017.	Continue to work closely with GSA to acquire zero-emission or plug-in hybrid vehicles for all newly acquired passenger vehicles.

DOE Goal	FY 2017 Performance Status	FY 2018 Plans
Clean and Renewable Energy		
"Clean Energy" requires that the percentage of an agency's total electric and thermal energy accounted for by renewable and alternative energy shall be not less than 25% by FY 2025 and each year thereafter.	Interim Target: 10% Current Performance: 21%	Continue to meet the clean energy goal through onsite generation and RECs.
"Renewable Electric Energy" requires that renewable electric energy account for not less than 30% of a total agency electric consumption by FY 2025 and each year thereafter.	Interim Target: 10% Current Performance: 30.4%	Continue to meet the clean energy goal through onsite generation and RECs.
Green Buildings		
At least 17% (by building count) of existing buildings greater than 5,000 gross square feet to be compliant with the revised Guiding Principles for HPSB by FY 2025, with progress to 100% thereafter.	Interim Target: 15% Current Performance: 64.3%	Continue trending toward 100% of facilities meeting HPSB guidelines.
Net Zero Buildings: 1% of the site's existing buildings above 5,000 gross square feet are intended to be energy, waste, or water net zero buildings by FY 2025.	Continued to participate in DOE effort to establish guidance on Net Zero building requirements.	Continue to work with the Net Zero community on guidance development.
Net Zero Buildings: All new buildings (>5,000 gross square ft) entering the planning process are designed to achieve energy net zero beginning in FY 2020.	Continued to participate in the DOE effort to establish guidance on Net Zero building requirements.	Continue to work with the Net Zero community on guidance development.
Increase regional and local planning coordination and involvement.	Collaborated with City of Richland Energy Services on new buildings at PNNL.	Continue partnering with regional and local groups to obtain Site Sustainability Plan goals.
Acquisition and Procurement		
Promote sustainable acquisition and procurement to the maximum extent practicable, ensuring bio-preferred and bio-based provisions and clauses are included in 95% of applicable contracts.	Interim Target: 95% Current Performance: 100%	Continue being proactive with sustainable acquisitions.

DOE Goal	FY 2017 Performance Status	FY 2018 Plans
Measures, Funding, and Training		
Annual targets for performance contracting are to be implemented in FY 2017 and annually thereafter as part of the planning of Section 14 of Executive Order 13693.	Selected Bonneville Power Administration is to provide a customized UESC program. Began energy and water evaluations.	Continue performing energy and water evaluations, and review energy conservations measure projects proposed by the UESC contractor.
Electronic Stewardship		
Purchases – 95% of eligible acquisitions each year are Electronic Product Environmental Assessment Tool (EPEAT)-registered products.	Interim Target: 95% Current Performance: 96.3%	Continue to purchase EPEAT-registered products when available.
Power management – 100% of eligible PCs, laptops, and monitors have power management enabled.	Interim Target: 100% Current Performance: 100%	Continue to implement power management features on initial setup.
Automatic duplexing – 100% of eligible computers and imaging equipment have automatic duplexing enabled.	Interim Target: 100% Current Performance: 93.9%	Continue to use duplex printing as the default configuration.
End of Life – 100% of used electronics are reused or recycled using environmentally sound disposition options each year.	Interim Target: 100% Current Performance: 100%	Continue to reuse and recycle electronics.
Data Center Efficiency – Establish a power usage effectiveness target in the range of 1.2–1.4 for new data centers and less than 1.5 for existing data centers.	The normalized (weighted by Information Technology Load) power usage effectiveness across the PNNL Campus is 1.42 for FY 2017.	Continue performing energy assessments and profiling of data centers.
Organizational Resilience		
Discuss overall integration of climate resilience in emergency response, workforce, and operations procedures and protocols.	Climate resilience is integrated into response and operations through a Climate Resilience Action Plan.	The climate resiliency planning team will continue to meet to assure we have followed up on our commitments to improve PNNL's resiliency, review metrics that could indicate changes in our vulnerability, and determine the need to revise plans and procedures.

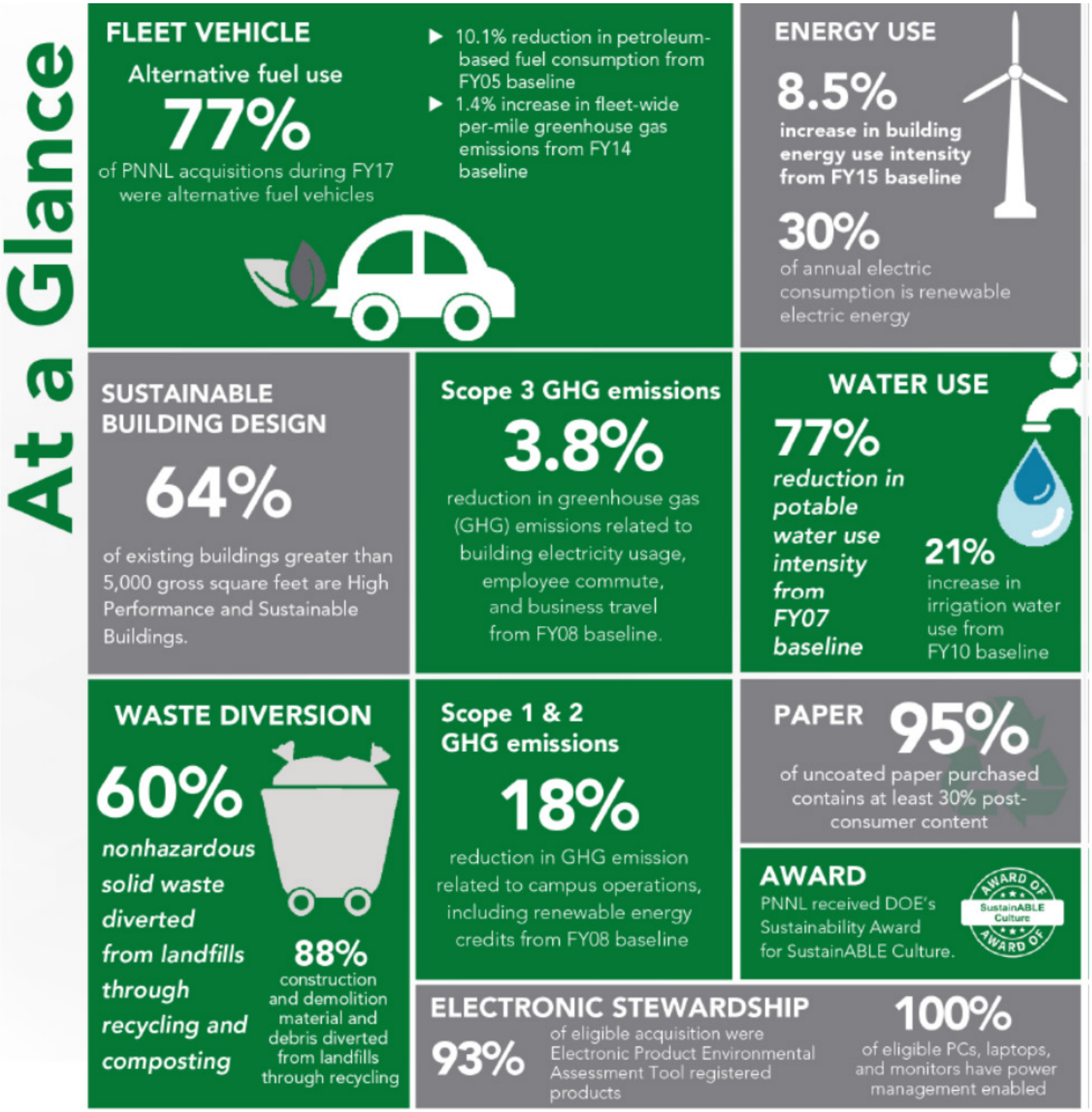

Figure 3.2. Summary of Key Environmental Sustainability Accomplishments

- Guiding Principles for Sustainable Construction

  In FY 2017, PNNL finished the certification process for a recently completed HPSB (high-performance and sustainable building), the GPCL (General Purpose Chemistry Laboratory), using the Guiding Principles for Sustainable Construction. The GPCL included sustainable design elements such as a heating, ventilation, and air conditioning system that uses advanced controls and incorporates energy recovery in both the heating and cooling seasons, low-flow plumbing fixtures, light-emitting diode lighting, and water-efficient landscaping. With the addition of this building, more than 60% of applicable PNNL buildings comply with the Guiding Principles, far exceeding the 17% goal by 2025. Recently, PNNL completed the HPSB certification on another new facility, the Engineering Analysis Building, and a new collaboration center designed to meet the Guiding Principles was under construction on the PNNL Richand Campus in 2017.

4.0 RADIOLOGICAL ENVIRONMENTAL MONITORING AND DOSE ASSESSMENT

This section describes the environmental monitoring programs for radiological constituents and the associated estimated dose assessments for the PNNL Richland Campus and MSL.

4.1 Liquid Radiological Discharges and Doses

TW Moon

PNNL prohibits the discharge of liquid waste streams that contain radiological material to sanitary sewer systems, the ground, or surface water. Wastewater in PNNL facilities is expected to be free of radioactive materials, but may have the potential for contamination in the event of a failure of an engineered barrier or administrative control. In facilities in which wastewater generated in radiologically controlled areas has the potential to become contaminated, it is discharged to retention tanks. After each retention tank is filled, it is isolated and its contents are analyzed for radiological components. The results of the analyses are compared to screening limits in WAC 246-221-190, "Disposal by Release into Sanitary Sewerage Systems." If the analytical results indicate that the concentrations of radiological components in the wastewater are below the screening criteria, the wastewater is released to the City of Richland's sanitary sewer system. If the analytical results indicate that the concentrations of radiological components in the wastewater are above the screening criteria, the wastewater is transported to a waste treatment facility. These wastes may be transferred and discharged to a treatment facility authorized or permitted to receive radiological material. Further evaluation is then performed to determine the source of the radiological component in the discharge.

The City of Richland may authorize the discharge of individual waste streams that contain radiological material to the sewer system. As described in Section 4.1.1, there is currently only one authorized discharge of a liquid waste stream containing radiological material to the City of Richland sanitary sewer.

4.1.1 Annual Report for DOE Order 458.1

This report has been prepared in accordance with DOE Order 458.1 (4)(g)(8)(a)(7), which requires that the contractor prepare and provide a report that describes and summarizes discharges of liquids containing radionuclides from DOE activities into non-federally owned sanitary sewers. PNNL has one waste stream that has the potential for radionuclides that is approved for discharge to the City of Richland's sanitary sewer system. This waste stream is associated with fume hood washdown operations in PSF.

On November 2, 2010, the City of Richland authorized the release of "…very low levels of volumetrically released radioactive material." These volumetrically released radioactive materials can be handled without concern for measurable contamination and without radiological postings or labeling pursuant to 10 CFR Part 835.

The total amount of radioactive material used in each fume hood is very small. Each washdown is estimated to be 190 L (50 gal). The worst-case concentration of radioactivity in each washdown is estimated to be 7.1×10^{-7} pCi/L.

In 2017, the fume hoods were washed down an estimated total of 27 times. The screening criteria, as referenced in the City of Richland's Industrial Wastewater Discharge Permit CR-IU011 for PSF, are based on WAC 246-221-190, Appendix A, Table III. The screening limits for each washdown are 20 pCi/L for gross alpha activity and 100 pCi/L for beta/gamma activity. If all activity in each washdown is conservatively presumed to be alpha activity, the concentration of radioactive material is more than a million times less than the screening limit. This affirms that the washdowns are negligible in terms of the screening limits for discharge to the City of Richland's sewer systems.

4.2 Radiological Discharges and Doses from Air

JM Barnett

Radionuclide air emissions are routinely sampled and tracked at the PNNL Richland Campus and at MSL. Regulatory compliance reporting and monitoring results are reported in an annual air emission report for each location (Snyder et al. 2018; Snyder and Barnett 2018). CY 2017 data are summarized in the following sections.

The federal regulatory standard for a maximum dose to any member of the public is 10 mrem/yr EDE. The standard is set forth in 40 CFR Part 61, Subpart H, and applies to radionuclide air emissions other than radon from DOE facilities.

Washington State has adopted the federal dose standard of 10 mrem/yr EDE in WAC 246-247-040(1). In addition to the maximum dose attributable to radionuclides emitted from point sources, WAC 246-247-060(6) requires that the dose to the MEI include doses attributable to fugitive emissions, radon, and nonroutine events.

4.2.1 Radiological Discharges and Doses from Air – PNNL Richland Campus

Operations are registered with the state of Washington under RAEL–005. For CY 2017, the PNNL Richland Campus MEI location was 0.70 km (0.43 mi) south-southeast of the PSF 3410 Building. Table 4.1 lists the relative contributions of each nuclide to the MEI dose. During CY 2017, the RTL Complex was decomissioned, vacated, and prepared for demolition.

There were no nonroutine emissions from the PNNL Richland Campus in CY 2017. Emissions were determined from both sampling and, for non-sampled emissions, by the 40 CFR Part 61, Appendix D method. The CAP88-PC Version 4 code was used for estimating dose. The dose of 2.3×10^{-5} mrem (2.3×10^{-7} mSv) effective dose is more than 10,000 times smaller than the 10 mrem/yr WAC 246-247 compliance standard. This dose is many orders of magnitude below the average annual individual background dose of 310 mrem (3.1 mSv) from natural terrestrial and cosmic radiation and inhalation of naturally occurring radon (NCRP 2009). The maximum modeled air concentration for CY 2017 is the same as that for the MEI.

The estimated regional collective dose from PNNL's Richland Campus air emissions in CY 2017 was estimated using CAP88-PC Version 4. Population exposure to radionuclide air emissions considers site-specific meteorology and population distributions. The population consists of approximately 432,000 people residing within an 80 km (50 mi) radius of the Hanford Site 300 Area (Hamilton and Snyder 2011), with one adjustment to add 640 residents in the sector that accounts for the two phases of apartment units constructed and occupied southwest of the RTL Complex. The close proximity of the Hanford Site 300 Area and relatively rural region within 80 km (50 mi) of the PNNL Richland Campus permits the Hanford Site 300 Area 80 km (50 mi) population estimate to be applicable. Pathways evaluated for population exposure include inhalation, air submersion, ground shine, and consumption of food. The CY 2017 total collective dose from radionuclide air emissions estimated from nuclides that originated from the PNNL Richland Campus was 1.6×10^{-4} person-rem (1.6×10^{-6} person-Sv).

No operations from the storage and disposal of radium-bearing material that result in radon emissions are conducted at the PNNL Richland Campus; therefore, 40 CFR Part 61, Subpart Q, does not apply to PNNL Richland Campus operations. In addition, no uranium milling or uranium ore processing activities are conducted at the PNNL Richland Campus; therefore, 40 CFR Part 61, Subpart T, does not apply to PNNL Richland Campus operations.

Table 4.1. PNNL Richland Campus Emissions and Dose Contributions by Radionuclide, 2017 (Snyder et al. 2018)

Radionuclide	Releases (Ci)	Campus MEI Dose (mrem EDE)	% of Total EDE
Hydrogen-3 (tritium)	1.2×10^{-4}	1.6×10^{-8}	<1%
Cobalt-60	3.3×10^{-8}	9.2×10^{-8}	<1%
Strontium-89	9.5×10^{-11}	8.3×10^{-10}	<1%
Strontium-90	6.3×10^{-11}	6.5×10^{-9}	<1%
Yttrium-88	1.3×10^{-9}	7.9×10^{-10}	<1%
Yttrium-91	1.1×10^{-8}	6.8×10^{-10}	<1%
Zirconium-95	1.1×10^{-8}	2.5×10^{-9}	<1%
Niobium-94	1.1×10^{-11}	4.1×10^{-10}	<1%
Tecnicium-99	4.4×10^{-11}	3.3×10^{-11}	<1%
Ruthenium-103	7.6×10^{-9}	4.4×10^{-10}	<1%
Tellurium-132	2.8×10^{-8}	6.8×10^{-10}	<1%
Iodine-131	2.1×10^{-8}	4.0×10^{-8}	<1%
Xenon-127	5.5×10^{-13}	2.9×10^{-17}	<1%
Xenon-131m	8.5×10^{-8}	5.5×10^{-13}	<1%
Xenon-133	1.0×10^{-4}	6.4×10^{-10}	<1%
Xenon-133m	3.3×10^{-9}	6.6×10^{-14}	<1%
Xenon-135	1.0×10^{-6}	5.2×10^{-11}	<1%
Cesium-137	1.4×10^{-6}	5.3×10^{-6}	23%
Barium-140	3.6×10^{-8}	3.4×10^{-9}	<1%
Lanthanum-140	3.9×10^{-8}	5.2×10^{-10}	<1%
Cerium-141	1.7×10^{-8}	3.5×10^{-10}	<1%
Cerium-144	2.2×10^{-9}	6.7×10^{-10}	<1%
Praseodynium-143	3.6×10^{-8}	4.4×10^{-10}	<1%
Europium-152	6.0×10^{-10}	5.4×10^{-9}	<1%
Lutetium-177	3.9×10^{-8}	4.5×10^{-8}	<1%
Lead-210	1.6×10^{-10}	2.9×10^{-9}	<1%
Radium-226	1.2×10^{-9}	7.9×10^{-8}	<1%
Thorium-232	1.5×10^{-13}	5.3×10^{-12}	<1%
Uranium-233/234	1.6×10^{-9}	1.1×10^{-8}	<1%
Uranium-235	1.2×10^{-10}	1.6×10^{-9}	<1%
Uranium-238	1.7×10^{-11}	6.5×10^{-11}	<1%
Plutonium-238	1.4×10^{-9}	4.9×10^{-8}	<1%
Plutonium-239/240	3.8×10^{-7}	1.5×10^{-5}	64%
Americum-241	7.1×10^{-9}	4.8×10^{-7}	2%
Americum-243	6.6×10^{-9}	2.2×10^{-7}	1%
Curium-243/244	1.1×10^{-9}	2.8×10^{-8}	<1%
Californium-252	1.6×10^{-11}	3.4×10^{-10}	<1%
All other nuclides	1.9×10^{-7}	2.9×10^{-9}	<1%
PIC-5 emissions – VRRM	NA	9.4×10^{-7}(a)	4%
PIC-5 emissions – Facilities Restoration	NA	8.4×10^{-7}(a)	4%
PIC-5 emissions – NDRM	NA	6.6×10^{-8}(a)	<1%
PIC-5 emissions – LLS	1.2×10^{-7}	6.0×10^{-12}(a)	<1%
Total	2.4×10^{-4} Ci	2.3 × 10-5 mrem EDE	100%

(a) The PIC-5 emission doses are assigned based on permit value except for the LLS, which is assigned based on calculatons from actual emissions.

To convert Ci to GBq, multiply Ci by 37. To convert mrem to mSv, multiply mrem by 0.01.

LLS = low level sources; NA = not applicable; NDRM = nondispersible radioactive material; VRRM = volumetrically released radioactive material.

4.2.2 Radiological Discharges and Doses from Air – PNNL Marine Sciences Laboratory

MSL operations for the two nonpoint-source minor emission units associated with MSL-1 and MSL-5 facilities (Figure 1.3) are registered with the state of Washington under RAEL–014. For CY 2017, the MSL MEI location was 0.19 km (0.12 mi) west of MSL-5, which is a hypothetical boundary receptor (and also the location of the maximum modeled air concentration). Radiological operations at MSL facilities emit very low levels of radioactive materials.

Table 4.2 lists the relative contributions to the MEI dose. The 40 CFR Part 61, Appendix D method was used to determine the routine emissions from MSL in CY 2017. There were no unplanned emissions from the site during the year. The COMPLY Code (a computerized screening tool for evaluating radiation exposure from atmospheric releases of radionuclides) Version 1.7 (Level 4) was used for estimating dose (EPA 1989). The dose to the MSL MEI was 1.6×10^{-4} mrem (1.6×10^{-6} mSv) EDE. This dose is many orders of magnitude below the average annual individual background dose from natural terrestrial and cosmic radiation and inhalation of naturally occurring radon.

Collective dose was determined for the estimated 2.35 million people who live within 80 km (50 mi) of MSL; about 362,000 of them reside in Canada (Zuljevic et al. 2016). Victoria, British Columbia, is the only major Canadian city within 80 km (50 mi) of MSL and is more than 32 km (20 mi) from MSL. The maximum collective dose was determined assuming the total CY 2017 MSL curies released dispersed in the single direction resulting in the maximum collective dose. This direction was determined to be toward the west, which only contains U.S. populations. The MEI dose was multiplied by a population-weighted air concentration for a collective dose of 1.8×10^{-4} person-rem (1.8×10^{-6} person-Sv). If the release were dispersed only to the maximum Canadian sector (north-northwest), the maximum estimated Canadian collective dose would be 7.2×10^{-5} person-rem (7.2×10^{-7} person-Sv).

No storage or disposal of radium-bearing materials occurs at MSL; therefore, 40 CFR Part 61, Subpart Q, does not apply to MSL operations. No uranium mill tailings or ore disposal activities have been conducted at MSL; therefore, 40 CFR Part 61, Subpart T, does not apply to MSL operations.

4.3 Release of Property Having Residual Radioactive Material

JA Stephens

Principal requirements for the release of DOE property having residual radioactivity are set forth in DOE Order 458.1, Admin Chg 3, *Radiation Protection of the Public and the Environment*. These requirements are designed to assure the following:

- Property is evaluated, radiologically characterized, and—where appropriate—decontaminated before it is released.
- The level of residual radioactivity in property to be released is as near background levels as is reasonably practicable, as determined using DOE's ALARA process requirements, and it meets DOE-authorized limits.
- All property releases are appropriately certified, verified, documented, and reported; public participation needs are addressed; and processes are in place to appropriately maintain records.

Property as defined in DOE Order 458.1 consists of real property (i.e., land and structures), personal property, and material and equipment. PNNL has two paths for releasing property to the public: 1) pre-approved surface contamination guidelines for releasing property potentially contaminated on the surface, and 2) pre-approved volumetric release limits for releasing small-volume research samples. A summary of the two release paths is provided in the following sections. No property with detectable residual radioactivity above DOE-authorized levels was released from PNNL during CY 2017.

Table 4.2. Marine Sciences Laboratory Emissions and Dose Contributions, 2017 (Snyder and Barnett 2018)

Radionuclide	Releases[(a)] (Ci)	Dose to MEI (mrem EDE)	Percent of Total EDE (Percent)
Hydrogen-3 (tritium)	7.0×10^{-11}	2.8×10^{-13}	<1%
Carbon-14	2.5×10^{-13}	3.7×10^{-13}	<1%
Potassium-40	1.1×10^{-11}	3.6×10^{-9}	<1%
Iron-55	3.5×10^{-14}	1.4×10^{-14}	<1%
Cobalt-57	9.5×10^{-15}	4.5×10^{-14}	<1%
Cobalt-60	1.2×10^{-13}	5.2×10^{-11}	<1%
Strontium-90	2.3×10^{-12}	4.8×10^{-10}	<1%
Technetium-99	3.0×10^{-10}	9.8×10^{-9}	<1%
Ruthenium-106	1.2×10^{-12}	1.6×10^{-11}	<1%
Antimony-125	1.5×10^{-12}	7.7×10^{-11}	<1%
Iodine-125	1.0×10^{-6}	8.5×10^{-5}	52%
Iodine-129	2.4×10^{-15}	3.1×10^{-12}	<1%
Cesium-134	9.4×10^{-12}	1.8×10^{-9}	<1%
Cesium-137	1.1×10^{-10}	5.1×10^{-8}	<1%
Europium-152	6.2×10^{-14}	2.8×10^{-11}	<1%
Europium-154	1.5×10^{-13}	5.2×10^{-11}	<1%
Europium-155	1.8×10^{-14}	2.4×10^{-13}	<1%
Lead-210	1.3×10^{-13}	1.4×10^{-10}	<1%
Polonium-208	7.0×10^{-10}	7.7×10^{-7}	<1%
Polonium-209	1.4×10^{-11}	1.5×10^{-8}	<1%
Radium-226	5.7×10^{-13}	1.7×10^{-9}	<1%
Radium-228	5.0×10^{-14}	2.9×10^{-11}	<1%
Thorium-228	4.0×10^{-13}	3.5×10^{-9}	<1%
Thorium-230	1.5×10^{-13}	1.3×10^{-9}	<1%
Thorium-232	5.4×10^{-13}	2.3×10^{-8}	<1%
Uranium-233	6.7×10^{-15}	2.4×10^{-11}	<1%
Uranium-234	1.2×10^{-8}	4.1×10^{-5}	25%
Uranium-235	5.4×10^{-10}	1.9×10^{-6}	1%
Uranium-238	1.2×10^{-8}	3.6×10^{-5}	22%
Plutonium-238	8.2×10^{-14}	8.5×10^{-10}	<1%
Plutonium-239	3.8×10^{-13}	4.2×10^{-9}	<1%
Plutonium-240	3.7×10^{-13}	4.2×10^{-9}	<1%
Plutonium-241	4.7×10^{-14}	1.0×10^{-11}	<1%
Americium-241	4.3×10^{-13}	5.1×10^{-9}	<1%
Total	1.0×10^{-6}	1.6×10^{-4}	100%

(a) Emissions based on 40 CFR Part 61, Appendix D methods.
To convert Ci to GBq, multiply Ci by 37; to convert from mrem to μSv, multiply mrem by 10.

4.3.1 Property Potentially Contaminated on the Surface

PNNL uses the previously approved surface activity guideline limits (Table 4.3) derived from guidance in DOE Order 458.1 when releasing property potentially contaminated on the surface. As part of research activities conducted in PNNL facilities, PNNL releases hundreds of items of personal property annually for excess to the general public, including office equipment, office furniture, labware, and research equipment. The PNNL Radiation Protection organization has a documented process for releasing items based on process knowledge, radiological surveys, or a combination of both. No property with detectable residual radioactivity above the pre-approved surface activity guidelines was released from PNNL during CY 2017.

In 2013, in accordance with PNNL Prime Contract Section J, Appendix J, paragraph eight (DOE-PNSO 2017a), PNNL (Battelle) initiated a survey program with an objective to release five Battelle Memorial Institute-owned buildings for unrestricted use. These facilities include the EDL, PSL, and LSL2 on the PNNL Richland Campus, and the MSL-1 and MSL-5 facilities at MSL.

In September 2017, PNNL received authorization from PNSO to release EDL, PSL, and LSL2 for unrestricted use. MSL-1 and MSL-5 are scheduled to achieve unrestricted use status by September 30, 2019. Program activities completed during CY 2017 included the release of EDL, PSL, and LSL2, and the radiological surveys of MSL-1 and MSL-5.

In addition to the release of five Battelle Memorial Institute-owned buildings for unrestricted use, in CY 2017, work commenced on decommissioning RTL. The RTL facility was not released and demolished materials were shipped as waste to the Environmental Restoration Disposal Facility on the Hanford Site. The decommissioning of RTL is scheduled to be completed by September 30, 2018.

4.3.2 Property Potentially Contaminated in Volume

PNNL uses pre-approved volumetric release limits when releasing small-volume research samples and wastewater potentially contaminated in volume (Table 4.4). DOE approved these release limits in response to an authorized limits request submitted by PNNL in 2000 and 2007 (DOE-RL 2001; DOE-PNSO 2007b). During CY 2017, PNNL released hundreds of liquid research samples with a total volume on the order of 1,095 L (289 gal) using the pre-approved release limits in Table 4.4. The liquid samples were not released to the public, but were used by staff without radiological controls in PNNL facilities. When disposed of, the samples were treated as radioactive waste.

4.4 Radiation Protection of Biota

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DOE Order 458.1 (Admin Chg 3) indicates that DOE sites establish procedures and practices to protect biota. PNNL has adopted dose rate limits of 1 rad/d (10 mGy/d) for aquatic animals and terrestrial plants and 0.1 rad/d (1 mGy/d) for riparian and terrestrial animals for the demonstration of the protection of biota (DOE 2002). These limits are applied equally to the PNNL Richland Campus and MSL.

Table 4.3. Pre-Approved Surface Activity Guideline Limits

Radionuclides	Allowable Total Residual Surface Contamination Limits (dpm/100 cm^2)		
	Removable	Total	
		Average	Maximum
Uranium-natural, uranium-235, uranium-238, and associated decay products	1,000	5,000	15,000
Transuranic elements,[a] radium-226, radium-228, thorium-230, thorium-228, protactinium-231, actinium-227, iodine-125, iodine-129	20	100	300
Natural thorium, thorium-232, strontium-90, radium-223, radium-224, uranium-232, iodine-126, iodine-131, iodine-133	200	1,000	3,000
Beta/gamma-emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except strontium-90 and others noted above	1,000	5,000	15,000
Select hard-to-detect radionuclides (carbon-14, iron-55, nickel-59, nickel-63, selenium-79, technetium-99, palladium-107, and europium-155)	10,000	50,000	150,000
Tritium organic compounds; surfaces contaminated with tritium gas, tritiated water vapor, and metal tritide aerosols	10,000	Not applicable	Not applicable

(a) All transuranic elements except plutonium-241, which is treated as a beta/gamma-emitter.
dpm = disintegrations per minute.

Table 4.4. Pre-Approved Volumetric Release Limits

Radionuclide Groups	Volumetric Release Limit (pCi/mL)
Transuranic elements, iodine-125, iodine-129, radium-226, actinium-227, radium-228, thorium-228, thorium-230, protactinium-231, polonium-208, polonium-209, polonium 210	1
Natural thorium, thorium-232	3
Strontium-90, iodine-126, iodine-131, iodine-133, radium 223, radium-224, uranium-232	9
Natural uranium, uranium-233, uranium-235, uranium-238	30
Beta/gamma-emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except strontium-90 and others noted in the rows above	45
Tritium	450

4.4.1 Radiation Protection of Biota – PNNL Richland Campus

Environmental media pathways were evaluated during the development of the PNNL Richland Campus data quality objectives (DQOs) in support of radiological emissions monitoring (Snyder et al. 2017). Potential media exposure pathways such as air, soil, water, and food were considered in conjunction with both gaseous and particulate radioactive contamination of the air pathway. The DQO process determined that only the air pathway necessitates monitoring (there are no radiological emissions via liquid pathways or directly to contaminated land areas). It also determined that the extremely small amount of emissions would be impossible to differentiate from background levels in nearby locations such as the Columbia River and food sources. While these measures are used primarily to demonstrate protection of the public, they also adequately demonstrate protection of biota. Therefore, biota monitoring for radionuclides both near and far from the PNNL Richland Campus is not conducted.

Routine operations were conducted on the PNNL Richland Campus during CY 2017—there were no unplanned radiological emissions. The resultant external dose rates were less than 8.6×10^{-4} rad/d (8.6×10^{-3} mGy/d) from contaminated water to aquatic animals and terrestrial plants and less than 7.6×10^{-3} rad/d (7.6×10^{-2} mGy/d) from contaminated soil to riparian and terrestrial animals (Table 4.5). These conservative dose rates are well below dose rate limits, which are based on the PNNL-reported total particulate radionuclide emissions for CY 2017 (Snyder et al. 2018). Assumptions are that all the particulate radioactive material is concentrated into either 1 m^3 (35 ft^3) of contaminated water or 1 m^2 (10.8 ft^2) of contaminated soil with a soil density of 224 kg m^2 (14 lb/ft^2) to a depth of 15 cm (6 in.) (Napier 2006). The screening-level dose coefficients used are found in DOE-STD-1153-2002, Module 3 (DOE 2002). The resulting water and soil concentrations are very conservative and used for basic screening and simplicity of calculation for comparison to the adopted biota dose rate limits.

4.4.2 Radiation Protection of Biota – PNNL Marine Sciences Laboratory

Environmental media pathways were evaluated during the development of MSL's DQOs in support of radiological emissions monitoring. Potential media exposure pathways such as air, soil, water, and food were considered in conjunction with potential releases of radioactive contamination to the air pathway. The DQO process determined that, because of the low probability of potential air emissions and the absence of radiological emissions via liquid pathways or directly to land areas, no environmental monitoring would be required. Because emission levels at MSL are very low, it would be impossible to differentiate actual emissions from background levels in nearby locations such as Sequim Bay and those from food sources (Barnett et al. 2012a). Reported emissions from MSL are conservatively estimated, because neither environmental surveillance nor stack sampling is required. These conservatively estimated emissions are also adequate to demonstrate protection of the public and of biota; therefore, biota monitoring for radionuclides both near and distant from MSL is not conducted.

Routine operations were conducted at MSL facilities during CY 2017—there were no unplanned radiological emissions. The external dose rates for operations in CY 2017 were less than 6.7×10^{-5} rad/d (6.7×10^{-4} mGy/d) from contaminated water to aquatic animals and terrestrial plants and less than 5.9×10^{-4} rad/d (5.9×10^{-3} mGy/d) from contaminated soil to riparian and terrestrial animals (Table 4.6). These conservative dose rates are well below dose rate limits, which are based on the PNNL-reported total particulate radionuclide emissions for CY 2017 (Snyder and Barnett 2018). Assumptions are that all the particulate radioactive material is concentrated into either 1 m^3 (35 ft^3) of contaminated water or 1 m^2 (10.8 ft^2) of contaminated soil with a soil density of 224 kg/m^2 (14 lb/ft^2) to a depth of 15 cm (6 in.) (Napier 2006). The screening-level dose coefficients used are found in DOE-STD-1153-2002, Module 3 (DOE 2002). The resulting water and soil concentrations are very conservative and used for basic screening and the simplicity of calculation for comparison to the adopted biota dose rate limits.

Table 4.5. Screening-Level Dose Rates to Aquatic and Terrestrial Biota for the PNNL Richland Campus, 2017

Nuclide(a)	Particulate Emissions[a] (Bq/yr)	Screening-Level Dose Coefficient for Exposure to Aquatic Animals to Contaminated Water[b] (Gy/yr per Bq/m3)	Screening-Level Dose Coefficient for Exposure to Terrestrial Biota to Contaminated Soil[b] (Gy/yr per Bq/kg)	Radionuclide Concentration in 1 m3 Water[c] (Bq/m3)	Radionuclide Concentration in 1 m2 Soil[d] (Bq/kg)	Dose Rate for Aquatic Animals (mGy/d)	Dose Rate for Terrestrial Biota (mGy/d)
gross alpha	1.4×10^{4}	6.8×10^{-9}	1.4×10^{-5}	1.4×10^{4}	6.1×10^{1}	2.6×10^{-4}	2.3×10^{-3}
gross beta	4.8×10^{4}	6.6×10^{-9}	1.3×10^{-5}	4.8×10^{4}	2.1×10^{2}	8.7×10^{-4}	7.6×10^{-3}
Cobalt-60	1.2×10^{3}	6.6×10^{-9}	1.3×10^{-5}	1.2×10^{3}	5.5×10^{0}	2.2×10^{-5}	1.9×10^{-4}
Strontium-89	3.5×10^{2}	6.6×10^{-9}	1.3×10^{-5}	3.5×10^{2}	1.6×10^{0}	6.4×10^{-6}	5.6×10^{-5}
Strontium-90	5.6×10^{1}	2.8×10^{-9}	5.7×10^{-6}	5.6×10^{1}	2.5×10^{-1}	4.3×10^{-7}	3.9×10^{-6}
Yttrium-88	4.8×10^{1}	6.6×10^{-9}	1.3×10^{-5}	4.8×10^{1}	2.1×10^{-1}	8.7×10^{-7}	7.6×10^{-6}
Yrrtium-91	3.7×10^{2}	6.6×10^{-9}	1.3×10^{-5}	3.7×10^{2}	1.7×10^{0}	6.7×10^{-6}	5.9×10^{-5}
Zirconium-95	4.1×10^{2}	4.2×10^{-9}	8.4×10^{-6}	4.1×10^{2}	1.8×10^{0}	4.7×10^{-6}	4.2×10^{-5}
Niobium-94	4.1×10^{-1}	4.3×10^{-9}	8.6×10^{-6}	4.1×10^{-1}	1.8×10^{-3}	4.8×10^{-9}	4.3×10^{-8}
Technetium-99	1.6×10^{0}	2.1×10^{-10}	4.3×10^{-7}	1.6×10^{0}	7.3×10^{-3}	9.4×10^{-10}	8.6×10^{-9}
Ruthenium-103	2.8×10^{2}	6.6×10^{-9}	1.3×10^{-5}	2.8×10^{2}	1.3×10^{0}	5.1×10^{-6}	4.5×10^{-5}
Tellurium-132	1.0×10^{3}	6.6×10^{-9}	1.3×10^{-5}	1.0×10^{3}	4.6×10^{0}	1.9×10^{-5}	1.6×10^{-4}
Iodine-131	7.8×10^{2}	1.4×10^{-9}	2.9×10^{-6}	7.8×10^{2}	3.5×10^{0}	3.0×10^{-6}	2.8×10^{-5}
Cesium-137	1.1×10^{3}	2.0×10^{-9}	4.0×10^{-6}	1.1×10^{3}	5.1×10^{0}	6.3×10^{-6}	5.6×10^{-5}
Barium-140	1.3×10^{3}	6.6×10^{-9}	1.3×10^{-5}	1.3×10^{3}	5.9×10^{0}	2.4×10^{-5}	2.1×10^{-4}
Lanthanum-140	1.4×10^{3}	6.6×10^{-9}	1.3×10^{-5}	1.4×10^{3}	6.4×10^{0}	2.6×10^{-5}	2.3×10^{-4}
Cerium-141	6.3×10^{2}	6.6×10^{-9}	1.3×10^{-5}	6.3×10^{2}	2.8×10^{0}	1.1×10^{-5}	1.0×10^{-4}
Cerium-144	8.1×10^{1}	3.4×10^{-9}	6.8×10^{-6}	8.1×10^{1}	3.6×10^{-1}	7.6×10^{-7}	6.8×10^{-6}
Praseodynium-143	1.3×10^{3}	6.6×10^{-9}	1.3×10^{-5}	1.3×10^{3}	5.9×10^{0}	2.4×10^{-5}	2.1×10^{-4}
Europium-152	2.2×10^{1}	6.6×10^{-9}	1.3×10^{-5}	2.2×10^{1}	9.9×10^{-2}	4.0×10^{-7}	3.5×10^{-6}
Lutetium-177	4.1×10^{5}	6.6×10^{-9}	1.3×10^{-5}	4.1×10^{5}	1.8×10^{3}	7.4×10^{-3}	6.5×10^{-2}
Lead-210	5.9×10^{0}	1.1×10^{-9}	2.2×10^{-6}	5.9×10^{0}	2.6×10^{-2}	1.8×10^{-8}	1.6×10^{-7}
Radium-226	4.4×10^{1}	6.8×10^{-9}	1.4×10^{-5}	4.4×10^{1}	2.0×10^{-1}	8.3×10^{-7}	7.6×10^{-6}
Thorium-232	5.6×10^{-3}	3.0×10^{-11}	6.1×10^{-8}	5.6×10^{-3}	2.5×10^{-5}	4.6×10^{-13}	4.1×10^{-12}
Uranium-233/234	5.9×10^{1}	3.2×10^{-11}	6.5×10^{-8}	5.9×10^{1}	2.6×10^{-1}	5.2×10^{-9}	4.7×10^{-8}
Uranium-235	4.4×10^{0}	9.4×10^{-10}	1.8×10^{-6}	4.4×10^{0}	2.0×10^{-2}	1.1×10^{-8}	9.8×10^{-8}
Uranium-238	6.7×10^{-1}	2.3×10^{-9}	4.6×10^{-6}	6.7×10^{-1}	3.0×10^{-3}	4.2×10^{-9}	3.7×10^{-8}
Plutonium-238	5.2×10^{1}	2.5×10^{-11}	5.0×10^{-8}	5.2×10^{1}	2.3×10^{-1}	3.5×10^{-9}	3.2×10^{-8}
Plutonium-239/240	3.0×10^{2}	2.5×10^{-11}	4.9×10^{-8}	3.0×10^{2}	1.4×10^{0}	2.1×10^{-8}	1.8×10^{-7}
Americium-241	2.6×10^{2}	1.4×10^{-10}	2.9×10^{-7}	2.6×10^{2}	1.2×10^{0}	1.0×10^{-7}	9.3×10^{-7}
Americium-243	2.4×10^{2}	1.3×10^{-9}	2.5×10^{-6}	2.4×10^{2}	1.1×10^{0}	8.7×10^{-7}	7.5×10^{-6}
Curium-243/244	4.1×10^{1}	6.4×10^{-10}	1.3×10^{-6}	4.1×10^{1}	1.8×10^{-1}	7.1×10^{-8}	6.5×10^{-7}
Californium-252	5.9×10^{-1}	6.8×10^{-9}	1.4×10^{-5}	5.9×10^{-1}	2.6×10^{-3}	1.1×10^{-8}	1.0×10^{-7}
					Total	8.6×10^{-3}	7.6×10^{-2}

(a) Data from Table 2.4 of Snyder et al. (2018).
(b) Data from DOE (2002). In cases in which a specific dose rate factor was not available, the radium-226 value was used as a conservative alpha surrogate and the cobalt-60 value was used as a conservative beta surrogate.
(c) The conservative dose rate is assumed to be from 1 m^3 (35 ft^3) of contaminated water.
(d) The conservative dose rate is assumed to be from 1 m^2 (10.8 ft^2) of contaminated soil with a soil density of 224 kg/m^2 (14 lb/ft^2) to a depth of 15 cm (6 in.) (Napier 2006).
Conversion factors: 1 Ci = 3.7 × 1010 Bq; 1 Gy = 100 rad.

Table 4.6. Screening-Level Dose Rates to Aquatic and Terrestrial Biota for the PNNL Marine Sciences Laboratory, 2017

Nuclide[(a)]	Particulate Emissions[(a)] (Bq/yr)	Screening-Level Dose Coefficient for Exposure to Aquatic Animals to Contaminated Water[(b)] (Gy/yr per Bq/m³)	Screening-Level Dose Coefficient for Exposure to Terrestrial Biota to Contaminated Soil[(b)] (Gy/yr per Bq/kg)	Radionuclide Concentration in 1 m³ Water[(c)] (Bq/m³)	Radionuclide Concentration in 1 m² Soil[(d)] (Bq/kg)	Dose Rate for Aquatic Animals (mGy/d)	Dose Rate for Terrestrial Biota (mGy/d)
Potassium-40	4.1×10^{-1}	6.6×10^{-9}	1.3×10^{-5}	4.1×10^{-1}	1.8×10^{-3}	7.4×10^{-9}	6.5×10^{-8}
Iron-55	1.3×10^{-3}	6.6×10^{-9}	1.3×10^{-5}	1.3×10^{-3}	5.8×10^{-6}	2.3×10^{-11}	2.1×10^{-10}
Cobalt-57	3.5×10^{-4}	6.6×10^{-9}	1.3×10^{-5}	3.5×10^{-4}	1.6×10^{-6}	6.4×10^{-12}	5.6×10^{-11}
Cobalt-60	4.4×10^{-3}	6.6×10^{-9}	1.3×10^{-5}	4.4×10^{-3}	2.0×10^{-5}	8.0×10^{-11}	7.1×10^{-10}
Strontium-90	8.5×10^{-2}	2.8×10^{-9}	5.7×10^{-6}	8.5×10^{-2}	3.8×10^{-4}	6.5×10^{-10}	5.9×10^{-9}
Technetium-99	1.1×10^{1}	2.1×10^{-10}	4.3×10^{-7}	1.1×10^{1}	5.0×10^{-2}	6.4×10^{-9}	5.8×10^{-8}
Ruthenium-106	4.4×10^{-2}	6.6×10^{-9}	1.3×10^{-5}	4.4×10^{-2}	2.0×10^{-4}	8.0×10^{-10}	7.1×10^{-9}
Antimony-125	5.6×10^{-2}	6.6×10^{-9}	1.3×10^{-5}	5.6×10^{-2}	2.5×10^{-4}	1.0×10^{-9}	8.8×10^{-9}
Iodine-125	3.7×10^{4}	6.6×10^{-9}	1.3×10^{-5}	3.7×10^{4}	1.7×10^{2}	6.7×10^{-4}	5.9×10^{-3}
Iodine-129	9.0×10^{-5}	2.0×10^{-10}	4.0×10^{-7}	9.0×10^{-5}	4.0×10^{-7}	4.9×10^{-14}	4.4×10^{-13}
Cesium-134	3.5×10^{-1}	4.3×10^{-9}	8.7×10^{-6}	3.5×10^{-1}	1.6×10^{-3}	4.1×10^{-9}	3.7×10^{-8}
Cesium-137	4.1×10^{0}	2.0×10^{-9}	4.0×10^{-6}	4.1×10^{0}	1.8×10^{-2}	2.2×10^{-8}	2.0×10^{-7}
Europium-152	2.3×10^{-3}	6.6×10^{-9}	1.3×10^{-5}	2.3×10^{-3}	1.0×10^{-5}	4.1×10^{-11}	3.6×10^{-10}
Europium-154	5.6×10^{-3}	3.8×10^{-9}	7.7×10^{-6}	5.6×10^{-3}	2.5×10^{-5}	5.8×10^{-11}	5.2×10^{-10}
Europium-155	6.7×10^{-4}	3.1×10^{-10}	6.2×10^{-7}	6.7×10^{-4}	3.0×10^{-6}	5.7×10^{-13}	5.1×10^{-12}
Lead-210	4.8×10^{-3}	1.1×10^{-9}	2.2×10^{-6}	4.8×10^{-3}	2.1×10^{-5}	1.4×10^{-11}	1.3×10^{-10}
Polonium-208	2.6×10^{1}	6.6×10^{-9}	1.3×10^{-5}	2.6×10^{1}	1.2×10^{-1}	4.7×10^{-7}	4.1×10^{-6}
Polonium-209	5.2×10^{-1}	6.6×10^{-9}	1.3×10^{-5}	5.2×10^{-1}	2.3×10^{-3}	9.4×10^{-9}	8.2×10^{-8}
Radium-226	2.1×10^{-2}	6.8×10^{-9}	1.4×10^{-5}	2.1×10^{-2}	9.4×10^{-5}	3.9×10^{-10}	3.6×10^{-9}
Radium-228	1.9×10^{-3}	3.4×10^{-9}	6.9×10^{-6}	1.9×10^{-3}	8.3×10^{-6}	1.7×10^{-11}	1.6×10^{-10}
Thorium-228	1.5×10^{-2}	6.1×10^{-9}	1.2×10^{-5}	1.5×10^{-2}	6.6×10^{-5}	2.5×10^{-10}	2.2×10^{-9}
Thorium-230	5.6×10^{-3}	3.6×10^{-11}	7.2×10^{-8}	5.6×10^{-3}	2.5×10^{-5}	5.5×10^{-13}	4.9×10^{-12}
Thorium-232	2.0×10^{-2}	3.0×10^{-11}	6.1×10^{-8}	2.0×10^{-2}	8.9×10^{-5}	1.6×10^{-12}	1.5×10^{-11}
Uranium-233	2.5×10^{-4}	9.3×10^{-12}	1.9×10^{-8}	2.5×10^{-4}	1.1×10^{-6}	6.3×10^{-15}	5.8×10^{-14}
Uranium-234	4.4×10^{2}	3.2×10^{-11}	6.5×10^{-8}	4.4×10^{2}	2.0×10^{0}	3.9×10^{-8}	3.5×10^{-7}
Uranium-235	2.0×10^{1}	9.4×10^{-10}	1.8×10^{-6}	2.0×10^{1}	8.9×10^{-2}	5.1×10^{-8}	4.4×10^{-7}
Uranium-238	4.4×10^{2}	2.3×10^{-9}	4.6×10^{-6}	4.4×10^{2}	2.0×10^{0}	2.8×10^{-6}	2.5×10^{-5}
Plutonium-238	3.0×10^{-3}	2.5×10^{-11}	5.0×10^{-8}	3.0×10^{-3}	1.4×10^{-5}	2.1×10^{-13}	1.9×10^{-12}
Plutonium-239	1.4×10^{-2}	1.4×10^{-11}	2.8×10^{-8}	1.4×10^{-2}	6.3×10^{-5}	5.4×10^{-13}	4.8×10^{-12}
Plutonium-240	1.4×10^{-2}	2.5×10^{-11}	4.9×10^{-8}	1.4×10^{-2}	6.1×10^{-5}	9.4×10^{-13}	8.2×10^{-12}
Plutonium-241	1.7×10^{-3}	1.3×10^{-11}	2.6×10^{-8}	1.7×10^{-3}	7.8×10^{-6}	6.2×10^{-14}	5.5×10^{-13}
Americium-241	1.6×10^{-2}	1.4×10^{-10}	2.9×10^{-7}	1.6×10^{-2}	7.1×10^{-5}	6.1×10^{-12}	5.6×10^{-11}
				Total		6.7×10^{-4}	5.9×10^{-3}

(a) Data from Table 2.1 of Snyder and Barnett (2018).

(b) Data from DOE (2002). In cases in which a specific dose rate factor was not available, the radium-226 value was used as a conservative alpha surrogate and the cobalt-60 value was used as a conservative beta surrogate.

(c) The conservative dose rate is assumed to be from 1 m³ (35 ft³) of contaminated water.

(d) The conservative dose rate is assumed to be from 1 m² (10.8 ft²) of contaminated soil with a soil density of 224 kg/m² (14 lb/ft²) to a depth of 15 cm (6 in.) (Napier 2006).

Conversion factors: 1 Ci = 3.7 × 1,010 Bq; 1 Gy = 100 rad.

4.5 Unplanned Radiological Releases

JM Barnett

No radiological releases to the environment exceeded permitted limits at the PNNL Richland Campus or MSL in 2017.

4.6 Environmental Radiological Monitoring

JM Barnett

The DOE Handbook, *Environmental Radiological Effluent Monitoring and Environmental Surveillance*, provides information about basic program implementation requirements and activities (DOE-HDBK-1216-2015; DOE 2015). In addition, the WDOH may require an operator of any emission unit to conduct ambient air monitoring or other testing as necessary to demonstrate compliance with the WAC 246-247 standard; such requirements for a program would be included in the operator's license. The environmental radiological monitoring activities conducted by PNNL for both the PNNL Richland Campus and MSL are included in this report.

4.6.1 Environmental Radiological Monitoring – PNNL Richland Campus

A particulate air-sampling (environmental surveillance) network was established in 2010 to monitor radioactive particulates in ambient air near the PNNL Richland Campus as stipulated by WDOH in RAEL 005. As a result of changes in DOE-permitted operations in 2012, the air-sampling network was re-evaluated (Barnett et al. 2012b). The air-sampling network was re-evaluated again in 2017, because the Campus expanded to the north by 35 ha (85.6 ac) (Snyder et al. 2017). The current particulate air-sampling network consists of four Campus samplers—PNL-1, PNL-2, PNL-3, and PNL-4—and one background sampler—PNL-5 (Figure 4.1)—and co-located ambient external dose monitors.

During CY 2017, the collection of air samples occurred at all sampling stations and included the sampling and analysis for airborne particulate radionuclides. Particulate air samples are routinely analyzed for gross alpha activity and gross beta activity. Semi-annually, filters are composited for specific radionuclide analysis. The required composite analyses include cobalt-60, uranium-233,[1] plutonium-238 and plutonium-239/240, americium-241 and americium-243, and curium-244.[2] Monitoring of ambient levels of external dose is done with aluminum oxide dosimeters read by optically stimulated luminescence; there is a 5 mrem (50 µSv) minimum detection level for these dosimeters and two control dosimeters are used in conjunction with the deployed ones.

No PNNL activities resulted in increased ambient air concentrations at the air-sampling locations in CY 2017 (Table 4.7). The gross alpha and gross beta results were comparable to background levels. All nuclide-specific results were less than the values in 40 CFR Part 61, Appendix E, Table 2 (2011), and there was no indication of elevated levels of monitored particulate radionuclides near the PNNL Richland Campus. The lack of overall detectable concentrations supports the results of stack effluent monitoring, and demonstrates that emissions from the PNNL Richland Campus are low, and have minimal potential for dose to members of the public.

Quarterly monitoring of ambient levels of external dose from beta, gamma, and X-ray sources at the five particulate air-sampling stations during 2017 was conducted (Table 4.8). Results were normalized to a 91-day monitoring period in accordance with ANSI/HPS N13.37 (ANSI/HPS 2014).

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[1] Only uranium-233 is required, but it is reported as uranium-233/234 because the naturally occurring uranium-234 emission peak overlaps with uranium-233.

[2] Only curium-244 is required, but it is reported as curium-243/244 because the curium-243 emission peak overlaps with curium-244.

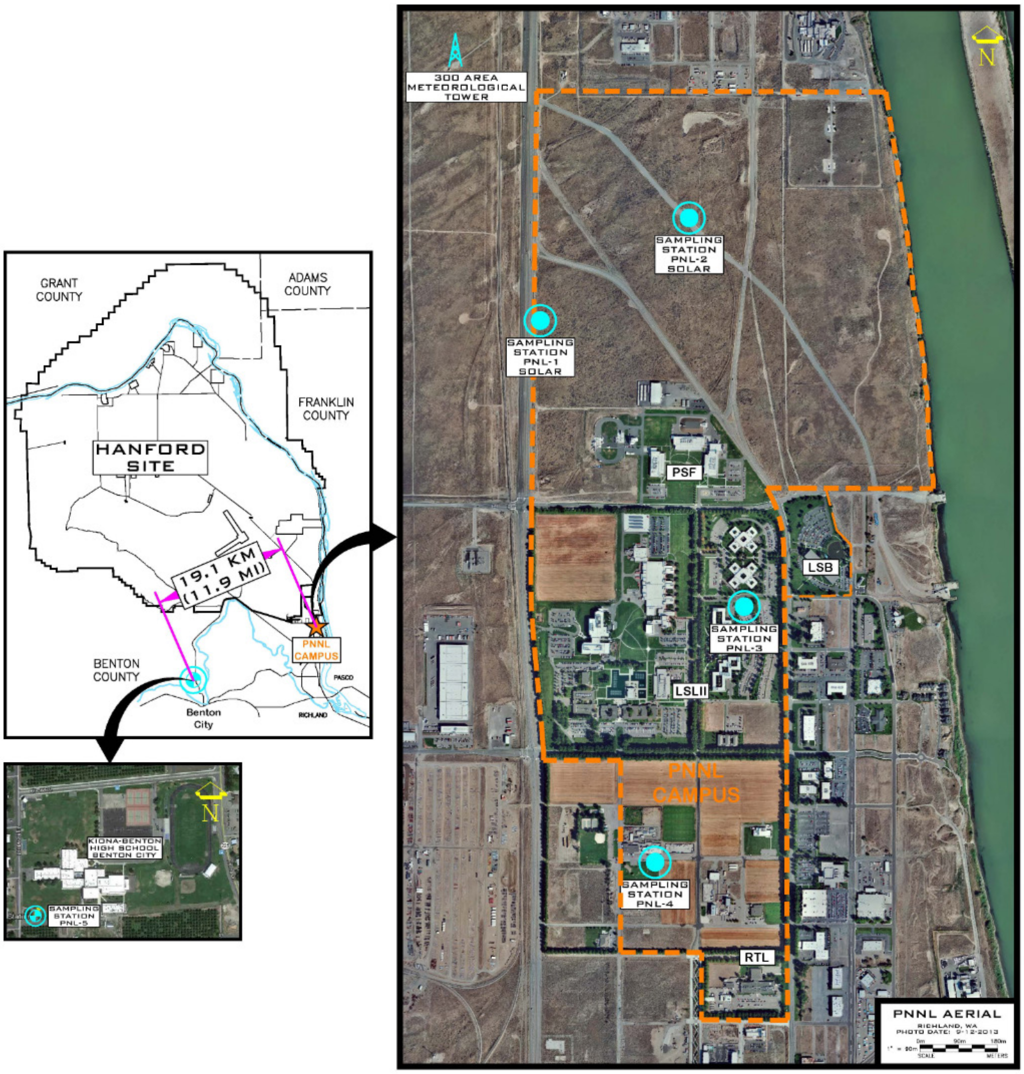

Figure 4.1. Air Surveillance Station Locations for the PNNL Richland Campus (based on Snyder et al. 2018)

Table 4.7. Summary of 2017 Air-Sampling Results for the PNNL Richand Campus (Snyder et al. 2018)

Nuclide	Location[a]	No. of Samples Analyzed	No. of Detections	Value[b] ± 2σ (pCi/m³)		
Gross alpha	PNL-1	25	16	7.1×10^{-4}	±	2.0×10^{-3}
	PNL-2	26	18	8.3×10^{-4}	±	2.5×10^{-3}
	PNL-3	25	16	6.9×10^{-4}	±	1.8×10^{-3}
	PNL-4	24	17	8.4×10^{-4}	±	2.2×10^{-3}
	PNL-5	25	15	6.2×10^{-4}	±	1.7×10^{-3}
Gross beta	PNL-1	25	25	1.7×10^{-2}	±	6.4×10^{-3}
	PNL-2	26	26	1.9×10^{-2}	±	7.2×10^{-3}
	PNL-3	25	25	1.6×10^{-2}	±	5.5×10^{-3}
	PNL-4	24	24	1.5×10^{-2}	±	5.6×10^{-3}
	PNL-5	25	25	1.4×10^{-2}	±	5.1×10^{-3}

Nuclide	Location[a]	No. of Samples Analyzed	No. of Detections	Value[b] ± 2σ (pCi/m³)		
Cobalt-60	PNL-1	2	0	-4.4×10^{-5}	±	3.3×10^{-4}
	PNL-2	2	0	3.1×10^{-5}	±	4.0×10^{-4}
	PNL-3	2	0	5.2×10^{-5}	±	2.4×10^{-4}
	PNL-4	2	0	-1.2×10^{-4}	±	4.1×10^{-4}
	PNL-5	2	0	4.5×10^{-5}	±	3.0×10^{-4}
Cesium-137	PNL-1	2	0	8.6×10^{-5}	±	2.9×10^{-4}
	PNL-2	2	0	1.6×10^{-4}	±	4.3×10^{-4}
	PNL-3	2	0	9.0×10^{-5}	±	2.8×10^{-4}
	PNL-4	2	0	1.0×10^{-4}	±	5.0×10^{-4}
	PNL-5	2	0	-1.0×10^{-4}	±	3.2×10^{-4}
Uranium-233/234	PNL-1	2	2	5.3×10^{-5}	±	3.4×10^{-5}
	PNL-2	2	2	5.0×10^{-5}	±	2.6×10^{-5}
	PNL-3	2	2	5.2×10^{-5}	±	2.7×10^{-5}
	PNL-4	2	2	4.3×10^{-5}	±	2.0×10^{-5}
	PNL-5	2	2	5.3×10^{-5}	±	2.4×10^{-5}
Plutonium-238	PNL-1	2	0	1.5×10^{-6}	±	4.5×10^{-6}
	PNL-2	2	1	2.2×10^{-6}	±	4.1×10^{-6}
	PNL-3	2	0	1.5×10^{-6}	±	3.5×10^{-6}
	PNL-4	2	0	2.4×10^{-7}	±	2.2×10^{-6}
	PNL-5	2	0	5.7×10^{-7}	±	2.8×10^{-6}
Plutonium-239/240	PNL-1	2	0	-6.4×10^{-7}	±	5.4×10^{-6}
	PNL-2	2	0	7.9×10^{-7}	±	3.4×10^{-6}
	PNL-3	2	1	9.9×10^{-7}	±	2.2×10^{-6}
	PNL-4	2	0	6.3×10^{-7}	±	4.3×10^{-6}
	PNL-5	2	0	4.4×10^{-7}	±	3.0×10^{-6}
Americium-241	PNL-1	2	0	2.0×10^{-6}	±	1.5×10^{-5}
	PNL-2	2	0	2.2×10^{-6}	±	1.1×10^{-5}
	PNL-3	2	0	2.4×10^{-6}	±	9.5×10^{-6}
	PNL-4	2	0	2.2×10^{-6}	±	1.1×10^{-5}
	PNL-5	2	0	2.6×10^{-7}	±	7.8×10^{-6}
Americium-243	PNL-1	2	0	1.1×10^{-6}	±	7.1×10^{-6}
	PNL-2	2	0	1.5×10^{-6}	±	1.2×10^{-5}
	PNL-3	2	0	-1.4×10^{-6}	±	1.1×10^{-5}
	PNL-4	2	0	-1.9×10^{-6}	±	8.3×10^{-6}
	PNL-5	2	0	3.6×10^{-6}	±	8.2×10^{-6}
Curium-243/244	PNL-1	2	0	-1.5×10^{-6}	±	7.9×10^{-6}
	PNL-2	2	0	3.5×10^{-8}	±	5.9×10^{-6}
	PNL-3	2	0	1.4×10^{-6}	±	1.1×10^{-5}
	PNL-4	2	0	4.2×10^{-7}	±	4.4×10^{-6}
	PNL-5	2	0	3.1×10^{-7}	±	4.9×10^{-6}

(a) Refer to Figure 4.1 for PNL-1, PNL-2, PNL-3, PNL-4, and PNL-5 locations.
(b) The value is the average of samples collected throughout the year.
To convert pCi/m³ to Bq/m³, multiply pCi by 0.037.

Table 4.8. Summary of 2017 Reported Ambient External Dose Results for the PNNL Richland Campus (Snyder et al. 2018)

2017 Quarter	PNL-1[a]	PNL-2[a]	PNL-3[a] (mrem)	PNL-4[a]	PNL-5[a, b]
Q1	34	31	28	31	34
Q2	24	27	27	26	25
Q3	31	27	29	29	33
Q4	25	24	26	24	26
Annual Total	**114**	**109**	**110**	**110**	**118**

(a) Refer to Figure 4.1 for the physical location.
(b) PNL-5 is the background station; no background value results were subtracted from the perimeter station results (PNL-1 through PNL-4).
To convert mrem to μSv, multiply mrem by 10.

No current PNNL Richland Campus radioactive air emissions include significant quantities of external dose contributors. For CY 2017, the total background ambient external dose result of 118 mrem (1,180 μSv) was higher than any of the perimeter stations.

In addition to the boundary and background station ambient external dose monitoring discussed above, the PNNL Radiation Protection organization performs semi-annual external dose rate surveys and direct contamination surveys of the ground within 6 m (20 ft) of PNNL buildings that contain radiological areas. For CY 2017, survey results were at background levels in areas that could be occupied by the public.

4.6.2 Environmental Radiological Monitoring – PNNL Marine Sciences Laboratory

Emissions at MSL are low, the radionuclide inventory is relatively small, and radiological impact estimates are well below regulatory limits, even when highly over-estimating assumptions are applied (Barnett et al. 2012a). The emissions at MSL have historically met requirements for dose limit compliance based on estimates derived using the COMPLY Code (EPA 1989). COMPLY is applicable to sites that have low levels of releases (i.e., releases that result in an MEI dose below the minor emissions unit limit of 0.1 mrem/yr [1 μSv/yr; Barnett et al. 2012a]). For this reason, particulate air-sampling is not required at MSL.

The PNNL Radiation Protection organization performs semi-annual external dose rate surveys at MSL-5 exterior door locations. For CY 2017, survey results were at background levels in areas that could be occupied by the public.

4.7 Future Radiological Monitoring

JM Barnett

In 2017, a renewal application was submitted for the MSL RAEL-014. The renewal will result in a single, MSL sitewide fugitive emission unit, thereby eliminating specific building emission units and reducing the permit complexity. A re-evaluation of the MSL for environmental surveillance will be conducted in 2018.

5.0 ENVIRONMENTAL NONRADIOLOGICAL PROGRAM INFORMATION

The Effluent Management Group within the PNNL Environmental Protection and Regulatory Programs Division establishes or provides reference to already established discharge limits for toxic and radiological effluents to air and water. Specific effluent management services include establishing monitoring and sampling programs to characterize effluents from PNNL facilities including those at MSL, verifying compliance with effluent standards and controls, assisting facility operations, and monitoring compliance with air and water permits.

The Effluent Management Group provides the interface between regulatory agencies and PNNL to prepare and submit required environmental permitting documentation, and reports spills and releases to regulatory agencies. A detailed description of the responsibilities assigned to the Effluent Management Group and interactions with other PNNL organizations is provided in the internal *Pacific Northwest National Laboratory Effluent Management Quality Assurance Plan* (Ballinger and Beus 2016). The ALARA principle is applied to effluent activities to minimize the potential effects of emissions on the public and the environment.

5.1 Liquid Effluent Monitoring

EA Raney and TW Moon

Wastewater from the PNNL Richland Campus is discharged directly to the City of Richland's Publicly Owned Treatment Works. Wastewater discharges are regulated by the City of Richland under three industrial wastewater discharge permits. All waste streams regulated by these permits are reviewed by PNNL staff and evaluated relative to compliance with the applicable permit prior to their discharge. Sampling and monitoring of these waste streams are done in accordance with the permits, and results are reported as required to the City of Richland.

Process wastewater from MSL is discharged to an onsite wastewater treatment plant and then directly discharged to Sequim Bay under the authorization of Washington State Department of Ecology NPDES Permit No. WA0040649. This permit identifies effluent limitations and monitoring requirements for this facility. Monitoring data required by the NPDES permit for 2017 are listed in Table 5.1. One grab sample was taken each month from Outfall 008 and analyzed for the parameters identified in Table 5.1. All parameters met the NPDES permit effluent limitations. There were no regulated discharges from Outfall 007 during this time period. Almost all parameters were measured at concentrations below the Method Reporting Limit.

Table 5.1. PNNL Marine Sciences Laboratory 2017 NPDES Monitoring Results for Outfall 008[a]

Parameter	Total Samples	Quantity Found Below Method Reporting Limit	Method Reporting Limit[b]	Maximum Value
Maximum flow (gpd)		NA	NA	62,500
Chlorine, total residual (µg/L)	12	12	50	<50
Ammonia (µg/L)	2	1	50	118
Antimony (µg/L)	2	2	0.5	<0.5
Arsenic (µg/L)	2	2	5	<5
Beryllium (µg/L)	2	2	0.2	<0.2
Cadmium (µg/L)	2	2	0.2	<0.2
Chromium (µg/L)	2	1	2	15.2
Copper (µg/L)	12	3	1	60.2
Lead (µg/L)	12	8	0.2	2.4
Mercury (µg/L)	2	2	0.2	<0.2
Nickel (µg/L)	2	0	2	3.3
Selenium (µg/L)	2	2	10	<10
Silver (µg/L)	2	1	0.2	0.69
Thallium (µg/L)	2	2	0.2	<0.2
Zinc (µg/L)	12	5	5	40
pH[c]	12	NA	NA	7.9

(a) There were no regulated discharges from Outfall 007 during this time period.
(b) The highest Method Reporting Limit reported for all months is listed.
(c) pH limits of 6–9 standard units are specified in the current permit.
gpd = gallons per day; NA = not applicable; µg/L = micrograms per liter.

5.2 Air Effluent

JM Barnett and CJ Duchsherer

While PNNL is not a large source of nonradiological air emissions, past and present emissions include GHGs, ozone-depleting substances (primarily refrigerants), hazardous air pollutants, and criteria air pollutants. The air effluent program does not monitor any stacks for nonradiological constituents, and compliance is assured by complying with regulatory standards for equipment and permit conditions. Complying typically involves activities such as using clean fuels and monitoring fuel use, adhering to required operating hours for boilers and diesel engines, and adhering to maintenance and operating requirements. Permit applications contain emission estimates based on vendor data (e.g., emission rate/hour), so monitoring of run time or fuel use is an acceptable method of determining permit compliance. In addition, reviews of research and facility construction/renovation projects are conducted to maintain compliance with all applicable requirements.

Nonradiological atmospheric effluent is tracked and reported according to standards established by the Global Reporting Initiative (GRI) (Table 5.2). The GRI is a non-profit organization that promotes economic, environmental, and social sustainability by providing companies and organizations with a comprehensive sustainability reporting framework that is extensively used around the world. PNNL's approach to reducing ozone-depleting substances includes administrative controls implemented through procedures for maintenance, repair, and disposal, as well as minimizing procurement of Class I ozone-depleting substances for new and replacement refrigeration systems.

Table 5.2. PNNL Richland Campus Nonradiological Atmospheric Emissions for 2017 Reported in Accordance with the Global Reporting Initiative (GRI) Standards

GRI Indicator	Indicator Title	2017 Emissions	Units
EN15	Direct greenhouse gas emissions	12,145	metric tons of carbon dioxide equivalent
EN16	Energy indirect greenhouse gas emissions	39,042	metric tons of carbon dioxide equivalent
EN17	Other relevant indirect greenhouse gas emissions	23,215	metric tons of carbon dioxide equivalent
EN20	Ozone-depleting substance R12	0.000028	metric tons
	Ozone-depleting substance R22	0.00996	metric tons
	Ozone-depleting substance R123	0.00218	metric tons
	Ozone-depleting substance 403B	0	metric tons
	Ozone-depleting substance 414B	0	metric tons
	Ozone-depleting substance 502	0	metric tons
	Emissions of ozone-depleting substances in CFC-11 Equivalent	0.0122	metric tons
EN21	Nitrogen oxides	4,439	kilograms
	Sulfur dioxide	40	kilograms
	Volatile organic compounds	814	kilograms
	Hazardous air pollutants	300	kilograms
	Particulate matter	545	kilograms
	Carbon monoxide	6,980	kilograms

To convert metric tons to U.S. tons multiply by 1.1.
To convert kilograms to pounds multiply by 2.2.

6.0 GROUNDWATER PROTECTION PROGRAM

EA Raney and TW Moon

Groundwater under the PNNL Richland Campus is monitored routinely through seven groundwater monitoring wells. Monitoring of the groundwater under the PNNL Richland Campus was initiated under the direction of the Washington State Department of Ecology through temporary State Waste Discharge Permit ST-9274 for the BSF/CSF ground-source heat pump. Pursuant to the permit, groundwater is primarily monitored for temperature, pH, dissolved oxygen, conductivity, turbidity, and total dissolved solids. Groundwater is also analyzed for other parameters that are associated with underlying contamination plumes. These include nitrate, tritium, uranium, and trichloroethylene.

The BSF/CSF uses a novel technology for heating and cooling the buildings that relies on a ground-source heat pump. Water is pumped from four extraction wells, passed through a non-contact heat exchanger, and returned to the aquifer through four injection wells. In February 2011, the Washington State Department of Ecology issued a water right for the nonconsumptive use of groundwater for the ground-source heat pump, allowing the withdrawal and use of groundwater by the four extraction wells at flow rates up to 7,200 L/min (1,900 gpm) and requiring injection of the water back to the aquifer.

Because the water is re-injected back into the ground, the Washington State Department of Ecology issued temporary State Waste Discharge Permit ST-9274 to have the groundwater monitored for temperature changes and potential influence on pollutants from underground contamination plumes. Sampling and monitoring focus on contaminants, including uranium, tritium, nitrate, and trichloroethylene found in regional contaminant plumes that might be drawn toward the ground-source heat pump during groundwater withdrawal, and on potential increases in the temperature of groundwater that will reach the Columbia River. The groundwater is sampled and analyzed in accordance with the sampling and analysis plan for the ground-source heat pump (Fritz and Moon 2010). The discharge permit requires sampling and analysis of seven groundwater monitoring wells that are downgradient from the injection site in addition to the extraction and injection wells. Three of the monitoring wells located on the PNNL Richland Campus are existing wells previously associated with the Hanford Site monitoring network. The other four monitoring wells were constructed and developed in accordance with the sampling and analysis plan (Fritz and Moon 2010). The sampling data are reported monthly to the Washington State Department of Ecology. Table 6.1 provides a summary of the monitoring results for the BSF/CSF ground-source heat pump for 2017. PNNL is in compliance with all sampling and monitoring requirements of the discharge permit, and results show no concern with respect to the ground-source heat pump water affecting movement of the contaminant plumes. No other groundwater sampling at either the PNNL Richland Campus or MSL is required for environmental compliance.

Table 6.1. Biological Sciences Facility/Computational Sciences Facility Ground-Source Heat Pump Monitoring Results, 2017

Parameter	Number of Samples Analyzed	Quantity Found Below Method Reporting Limit	Method Reporting Limit	Minimum Reported Value	Maximum Reported Value
Injection Wells					
Flow (gpm)	NA	NA	NA	0	916
Temperature (°C)	NA	NA	NA	17.2	27.7
pH (pH units)	4	NA	NA	7.2	7.5
Dissolved oxygen (mg/L)	4	NA	NA	6.8	7.4
Conductivity (µS/cm)	4	NA	NA	642	796
Turbidity (NTU)	2	2	0.2	<0.2	0.2
Total dissolved solids (mg/L)	2	0	10	506	535
Nitrate-nitrite (mg/L)	2	0	0.5	18.1	23.0
Uranium (µg/L)	2	0	0.02	5.9	7.0
Tritium (pCi/L)	2	2	1,000	ND	ND
Trichloroethylene (µg/L)	2	2	5	ND	ND
Monitoring Wells Downgradient of the Injection Wells					
Temperature (°C)	NA	NA	NA	16.0	18.9
pH (pH units)	28	NA	NA	7.1	7.6
Dissolved oxygen (mg/L)	28	NA	NA	6.3	9.4
Conductivity (µS/cm)	28	NA	NA	638	3620
Turbidity (NTU)	14	8	0.2	<0.2	0.77
Total dissolved solids (mg/L)	14	0	10	476	1440
Nitrate-nitrite (mg/L)	14	0	0.5	14.5	19.9
Uranium (µg/L)	14	0	0.02	4.4	13.1
Tritium (pCi/L)	14	14	1,000	ND	ND
Trichloroethylene (µg/L)	14	14	5	ND	ND

gpm = gallons per minute; NA = not applicable; ND = nondetectable; NTU = nephelometric turbidity unit; µS = microsiemens.

7.0 QUALITY ASSURANCE

KM Meier

The PNNL Quality Assurance (QA) Program is based on the requirements defined in DOE Order 414.1D, *Quality Assurance*, and 10 CFR Part 830, *Energy/ Nuclear Safety Management*, Subpart A, "Quality Assurance Requirements." PNNL has chosen to implement the following consensus standards in a graded approach:

- ASME NQA-1-2000, *Quality Assurance Requirements for Nuclear Facility Applications*, Part I, "Requirements for Quality Assurance Programs for Nuclear Facilities" (ASME 2001)
- ASME NQA-1-2000, Part II, Subpart 2.7, "Quality Assurance Requirements for Computer Software for Nuclear Facility Applications," including problem reporting and corrective action (ASME 2001)
- ASME NQA-1-2000, Part IV, Subpart 4.2, "Guidance on Graded Application of Quality Assurance (QA) for Nuclear-Related Research and Development" (ASME 2001).

The PNNL *Quality Assurance Program Description/ Quality Management M&O Program Description* describes the Laboratory-level QA program that applies to all work performed by PNNL. Laboratory-level procedures for implementing the QA requirements described in the standards identified above are deployed through PNNL's web-based "How Do I…?" (HDI) system, a standards-based system for managing and deploying requirements and procedures to PNNL staff.

7.1 Environmental Monitoring Program

Environmental sampling and monitoring activities were performed under PNNL's Environmental Management Program. These activities included sampling of water, wastewater, radiological air emissions, ambient air, and ambient external dose. Sampling is conducted by the Effluent Management Group or its delegates under the *Pacific Northwest National Laboratory Effluent Management Quality Assurance Plan (EM QAP)*, EM-QA-01 (Ballinger and Beus 2016), and the related quality requirements documents that describe the specific QA elements applicable to each activity (see Table 7.1).

The EM QAP addresses the requirements in DOE Order 414.1D and the guidance in EPA QA/G-5 (EPA 2002). The related quality requirements documents were approved by the PNNL QA organization that monitors compliance. Work performed through contracts or statements of work, including sample analyses, must meet the same QA requirements as those specified in the QA documents. Potential suppliers of items and services that could have an impact on quality (e.g., analytical services, calibration services, providers of Reference Standard Material), were evaluated before contracts were awarded.

Radiological environmental monitoring activities for the PNNL Operations in Richland and Sequim were determined using the DQO process described in the EPA *Guidance on Systematic Planning Using the Data Quality Objectives Process* (EPA 2006) and were documented in the latest revisions, Snyder et al. 2017 and Barnett et al. 2012a, respectively. The DQO process provides a standard working tool for project managers and planners to develop DQOs for determining the type, quantity, and quality of data needed to reach defensible decisions or make credible estimates; Snyder et al. 2017 resulted in determining and documenting the environmental sampling and monitoring requirements necessary to comply with applicable regulations at PNNL Richland Campus and PNNL MSL. As determined in the DQO for the Richland Campus (Snyder et al. 2017), PNNL has established an environmental surveillance program that samples particulate radionuclides in air. The Environmental Management Plan (EMP) (Snyder et al. 2011) with its attachments—the *Sampling and Analysis Plan*, *Data Management Plan*, and *Dose Assessment Guidance*—provides a comprehensive approach to environmental monitoring of PNNL operations. A similar DQO process was performed for the PNNL MSL in Sequim, Washington (Barnett et al. 2012a), where it was decided that air emissions are so low that environmental monitoring currently is not required. Potential MSL radioactive air emissions are permitted under the current radioactive air emissions license, and compliance is demonstrated through calculated emission rates.

Table 7.1. Effluent Management Quality Assurance Requirements Documents

Document Title
Effluent Management Quality Assurance Plan (EM-QA-01)
Quality Requirements for Air Chemical Emissions Management
Quality Requirements for Biological Sciences Facility/Computational Sciences Facility (BSF/CSF) Ground Source Heat Pump Monitoring to State Waste Discharge Permit ST-9274
Quality Requirements for Facility Effluent Management Planning
Quality Requirements for Industrial Wastewater Discharge Permit Sampling and Monitoring for the PNNL Campus (CR-IU001), Environmental Molecular Sciences Laboratory (CR-IU005), and Physical Sciences Facility (CR-IU011)
Quality Requirements for Marine Sciences Laboratory Monitoring to National Pollutant Discharge Elimination System Permit WA 0040649
Quality Requirements for Radionuclide Air Emissions Sampling and Monitoring
Quality Requirements for Radionuclide Air Environmental Surveillance Monitoring

In 2017, an ambient external dose surveillance program was performed at the five particulate air monitoring stations on the PNNL Richland Campus. The program will establish baseline ambient external dose levels at the perimeter and background sampling stations, because PNNL Richland Campus currently has no significant quantities of external dose contributors. Monitoring is done using aluminum oxide dosimeters read by optically stimulated luminescence. Details and results can be reviewed in the *PNNL Richland Campus Radionuclide Air Emissions Report for Calendar Year 2017* (Snyder et al. 2018).

Water and wastewater sampling and monitoring at the PNNL Richland Campus were performed to meet requirements in permits issued by the City of Richland for discharges to the sewer and by the Washington State Department of Ecology for discharges to the ground. At MSL, water and wastewater sampling and monitoring are performed to comply with NPDES and Group A Drinking Water permits. QA requirements for these activities have been integrated into the EM QAP (Ballinger and Beus 2016) and related QA documents (see Table 7.1), and include specific requirements such as sampling locations, quality objective criteria, analytical methods, and detection limits.

7.2 Sample Collection Quality Assurance

Samples were collected by personnel trained to conduct environmental sampling according to approved and documented procedures. Sampling protocols include use of appropriate sampling methods and equipment, a defined sampling frequency, specified sampling locations, and protocols for sample handling (which may include storage, packaging, and shipping) to maintain sample integrity. Chain-of-custody processes were used to track the transfer of samples from the point of collection to the analytical laboratory. Quality assurance program requirements are integrated into the statement of work for subcontracted analytical laboratories and include analyses of laboratory method blanks to evaluate sources of contamination, analyses of laboratory duplicates to evaluate method precision, and analyses of laboratory control samples/blank spike samples and possibly matrix spikes and/or surrogates to assess accuracy. A description of these quality control (QC) terms is given in Table 7.2.

In August and September 2017, due to heavy smoke in the air from wildfires, particulate air sampling in several cases was reduced from two-week to one-week samples.

Water and wastewater samples are analyzed using EPA-approved methods or methods specified by the regulatory agency. Some samples are required to be analyzed in the field at the time of sample collection because of short holding time limits. These analyses (e.g., pH, conductivity, dissolved oxygen) are performed using controlled procedures to meet QC acceptance criteria, thereby demonstrating compliance with method requirements.

Table 7.2. Quality Control Terms

Quality Control Type	Description
Laboratory method blank	Control sample containing no analyte of interest; used to monitor for bias or contamination introduced during processing and analysis in the laboratory.
Duplicate	Field Duplicate: An additional sample collected as closely as possible at the same time and location to measure sources of error from field sampling activities when compared to laboratory duplicate precision results. (PNNL did not sample field duplicates.) Laboratory Duplicate: An additional aliquot or split sample from the same sample that is analyzed by the laboratory to measure analytical precision.
Matrix spike or surrogate samples	An aliquot of actual sample spiked with a known concentration of target analytes and processed in the same manner as the sample; used to determine the extent to which matrix bias or interferences affect the results when compared to a blank spike result. Instead of target analytes, surrogates analytes can be used. These are similar compounds that behave analytically like the target analyte in the specific analytical process.
Blank spike or reagent spike samples	A known concentration of target analyte added to the sample matrix or the reagents used to process the sample prior to analysis. Blank or reagent spike samples are used to determine the accuracy associated with measuring a specific analyte by a specific method.
Laboratory control samples (LCSs)	A certified reference material or a prepared sample (created from an analyte-free sample matrix spiked with a known amount of analyte), which may be carried through the preparation and analysis procedures as if it were a sample or inserted at various points in sample processing to identify sources of error/contamination. The recovery of the target analytes in the LCS is used to indicate process or method error and may be useful in assessing accuracy, and if repeated measures are made to estimate precision.

7.3 Quality Assurance Analytical Results

The following laboratories conducted the analyses of environmental samples (i.e., stack air emissions, ambient air, water, and wastewater) from the PNNL Richland Campus and MSL during 2017:

- Radiological air emission filter samples were analyzed by PNNL's Analytical Support Operations (ASO) laboratory in the Radiochemical Processing Laboratory.
- Ambient air samples were analyzed for radioactivity by General Engineering Laboratories (GEL), LLC, Charleston, South Carolina.
- Environmental dosimeters were read out using optically stimulated luminescence technology by Landauer®, Glenwood, Illinois.
- Water and wastewater samples were analyzed by
  - ALS Environmental, Kelso, Washington;
  - Benton-Franklin Health District Laboratory, Kennewick, Washington;
  - an in-house MSL accredited laboratory; and
  - Spectra Laboratories, Port Orchard, Washington.

Analyses were performed according to a statement of work or contract, which described the activities necessary to assure that the analysis results were of high and verifiable quality. These activities included calibrating and performance testing of analytical equipment; implementing a QA program; maintaining analytical and support equipment and facilities; handling, protecting, and analyzing samples; checking data traceability, validity, and quality; recording all analytical data; participating in the analysis of performance evaluation programs; and communicating and reporting to the Effluent

Management Group. Each analytical data package is validated prior to using and reporting data. In all cases where quality issues were identified that resulted in invalid data (e.g., missed hold times; laboratory blanks, spikes, or duplicates do not meet QC criteria), the issue was documented and corrective actions were taken.

In 2017, the ASO laboratory and GEL analyzed all airborne filter samples for radioactivity according to the criteria in their respective statements of work and contracts. Both laboratories participated in a QA program that included internal QC measurements to provide estimates of precision and accuracy of the data. Both laboratories also participated in the Mixed-Analyte Performance Evaluation Program (MAPEP) intercomparison program, which provides an evaluation of laboratory performance. MAPEP provides samples of environmental media, including air filter samples, containing specific amounts of one or more radionuclide unknown to the participating laboratory. After analysis, the results were evaluated against a stated reference value and acceptance range.

- In 2017, GEL participated in two MAPEP studies (MAPEP 36 and 37); 100% of air filter results for radiological analysis were within acceptable or acceptable with warning (strontium-90 only) control limits. GEL is audited annually by the DOE Consolidated Audit Program, which provides added confidence in the data reported by the laboratory.
- In 2017, the ASO laboratory participated in MAPEP Study 37; results for the filter sample were reported on November 15, 2017, to fulfill an ASO requirement to participate in annual radiochemistry performance testing. Alpha Energy Analysis was used to obtain results for the filter sample for Am-241, Pu-238, Pu-239/240, U-234/233, and U-238. Liquid scintillation counting was used to obtain results for the filter sample for Sr-90. Gamma Energy Analysis was used to obtain results for the filter sample for Cs-134, Cs-137, Co-57, Co-60, Mn-54, and Zn-65. All filter sample results were acceptable; no flags were applied.

The analytical laboratories contracted to analyze airborne filter samples prepared and analyzed QC samples (e.g., blanks, spiked samples, and sample duplicate pairs), as required in the contract and statement of work. The ASO laboratory analyzed a blank and an instrument control sample against known standards for each batch of routine samples analyzed for alpha and beta activity. In addition, a spiked sample and a blank were included with each batch of composite analyses and analyzed for specific isotopes in addition to alpha and beta activity. Similar QC samples were analyzed by GEL. The QC samples indicated that the sample batches had no measurable contamination from sample preparation activities, and no issues were identified in the sample preparation process.

ALS Environmental, the Benton-Franklin Health District Laboratory, Spectra Laboratories, and an in-house laboratory at MSL analyzed all water and wastewater samples from the PNNL Richland Campus and MSL during 2017. All analytical laboratories are accredited by the Washington State Department of Ecology (C544, H408, C575, C1003, and C560, respectively) for the analysis of water and wastewater samples. To receive accreditation, a laboratory must implement a quality assurance plan, perform periodic proficiency testing, and be periodically inspected by the Washington State Department of Ecology to assure that it is operating within regulatory and QA requirements. Each time a laboratory is selected to perform analyses for PNNL, the PNNL Acquisition Quality Support Services evaluate whether the lab is either accredited or currently listed on PNNL's Evaluated Supplier List. ALS Environmental and the in-house MSL laboratory are also accredited by the National Environmental Laboratory Accreditation Conference Institute, which requires adherence to a uniform and robust laboratory program that has been implemented consistently nationwide. All wastewater analyses are performed using approved *Clean Water Act* methods specified by EPA in "Guidelines Establishing Test Procedures for the Analysis of Pollutants" (40 CFR Part 136).

Quality assurance and QC requirements in the contract with PNNL for wastewater analyses include the measurement or assessment of sample accuracy, precision, reliability, representativeness, completeness, and comparability. These measurements are reviewed for each analytical data package to verify that the data are valid. Analytical methods, method detection limits, holding times, sample containers, and preservation must meet 40 CFR Part 136 requirements and are verified for each sample collected. All of the analytical methods, MDLs, and holding times were met in 2017 for samples submitted by PNNL. If analytical methods, MDLs, or holding times are not met, PNNL does not use the results and resamples, if possible.

7.4 Data Management and Calculations

Quality assurance is integrated into data management processes and calculations through the EM QAP and related QA documents, the EMP Data Management Plan, and staff procedures; parameters for dose calculations are documented as a component of the EMP. Software QA processes are used to verify the accuracy of databases used for analytical results. Procedures identify the process for developing, testing, maintaining, and using spreadsheets to perform calculations that support or relate to a regulatory compliance, permit, or safety requirement; procedures also contain the basis for parameters and methods used in estimating environmental releases as well as checklists used to verify and validate analytical results. For 2017, the processes for managing data and calculations were followed.

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APPENDIX A

HELPFUL INFORMATION

APPENDIX A

HELPFUL INFORMATION

The following information is provided to assist readers in understanding this report. Included here is information about scientific notation, units of measurement, radioactivity units, radiological dose units, chemical and elemental nomenclature, and greater than or less than symbols. Definitions of technical terms can be found in Appendix B.

A.1 Scientific Notation

Scientific notation is used to express very large or very small numbers. For example, the number 1 billion can be written as 1,000,000,000 or, by using scientific or E notation, written as 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 the 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.

A.2 Units of Measurement

The primary units of measurement used in this report follow the International System of Units and are metric, though U.S. standard measurements are also provided. Table A.1 summarizes and defines the terms and corresponding symbols (metric and non-metric). A conversion table is also provided in Table A.2.

A.3 Radioactivity Units

Much of this report deals with 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 A.3). The curie is the basic unit used to describe the amount of activity present, and activities are generally expressed in terms of curies per mass or volume (e.g., picocuries per liter). One curie is equivalent to 37 billion disintegrations per second or is a quantity of any radionuclide that decays at the rate of 37 billion disintegrations per second. One becquerel is equivalent to one disintegration per second. Nuclear disintegrations produce spontaneous emissions of alpha or beta particles, gamma radiation, or combinations of these. Figure A.1 includes selected conversions from curies to becquerels.

Table A.1. Names and Symbols for Units of Measure

Symbol	Name	Symbol	Name
Temperature		**Concentration**	
°C	degree Celsius	ppb	parts per billion
°F	degree Fahrenheit	ppm	parts per million
Time		ppmv	parts per million by volume
d	day	**Length**	
hr	hour	cm	centimeter (1 × 10^{-2} m)
min	minute	ft	foot
sec	second	in.	inch
yr	year	km	kilometer (1 × 10^{3} m)
Rate		m	meter
cfs (or ft^3/sec)	cubic feet per second	mi	mile
cpm	counts per minute	mm	millimeter (1 × 10^{-3} m)
gpm	gallon per minute	µm	micrometer (1 × 10^{-6} m)
mph	mile per hour	**Area**	
mR/hr	milliroentgen per hour	ha	hectare (1 × 10^{4} m^2)
mrem/yr	millirem per year	km^2	square kilometer
Volume		mi^2	square mile
cm^3	cubic centimeter	ft^2	square foot
ft^3	cubic foot	**Mass**	
gal	gallon	g	gram
L	liter	kg	kilogram (1 × 10^{3} g)
m^3	cubic meter	mg	milligram (1 × 10^{-3} g)
mL	milliliter (1 × 10^{-3} L)	µg	microgram (1 × 10^{-6} g)
yd^3	cubic yard	lb	pound

Table A.2. Conversion Table

Multiply	By	To Obtain	Multiply	By	To Obtain
cm	0.394	in.	in.	2.54	cm
m	3.28	ft	ft	0.305	m
km	0.621	mi	mi	1.61	km
kg	2.205	lb	lb	0.454	kg
L	0.2642	gal	gal	3.785	L
m^2	10.76	ft^2	ft^2	0.093	m^2
ha	2.47	acres	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	10^9	pCi/L	pCi/L	10^{-9}	µCi/mL
Ci/m^3	10^{12}	pCi/m^3	pCi/m^3	10^{-12}	Ci/m^3
mCi/cm^3	10^{15}	pCi/m^3	pCi/m^3	10^{-15}	mCi/cm^3
nCi/m^2	1.0	mCi/km^2	mCi/km^2	1.0	nCi/m^2
Ci	3.7×10^{10}	Bq	Bq	2.7×10^{-11}	Ci
pCi	0.037	Bq	Bq	27	pCi
rad	0.01	Gy	Gy	100	rad
rem	0.01	Sv	Sv	100	rem
ppm	1,000	ppb	ppb	0.001	ppm
°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

Table A.3. Names and Symbols for Units of Radioactivity

Symbol	Name	Symbol	Name
Ci	curie	Bq	becquerel
mCi	millicurie (1×10^{-3} Ci)	kBq	kilobecquerel (1×10^{3} Bq)
µCi	microcurie (1×10^{-6} Ci)	mBq	millibecquerel (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)		

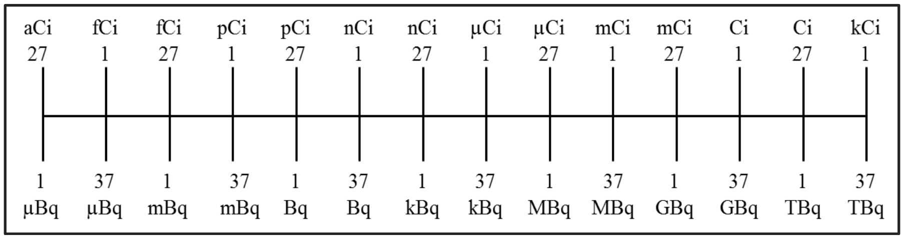

Figure A.1. Conversions for Radioactivity Units

A.4 Radiological Dose Units

Radiological dose in this report is usually written in terms of EDE and reported numerically in units of millirem (mrem), with the metric units millisievert (mSv) or microsievert (μSv) following in parentheses or footnoted. The EDE and effective dose (ED) units can be considered equivalent for the purposes of this report and reflect the units calculated by the software used.

Millirem (millisievert) is a unit of measurement that relates a given amount of absorbed radiation energy to its biological effectiveness or risk (to humans). For perspective, a dose of 0.01 mrem (1 mSv) would have a biological effect roughly the same as that received from 1 day's exposure to natural background radiation. An acute (short-term) dose to the whole body of 100 rem (1 Sv) would likely cause temporary radiation sickness in some exposed individuals. An acute dose of over 500 rem (5 Sv) 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 300 mrem (3 mSv). Medical and dental x-rays and air travel add to this total. Figure A.2 includes selected conversions from rem to sievert.

Also used in this report is the term rad, with the corresponding International System of Units, gray (Gy), in parentheses 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 Figure A.2 can also be used to convert grays to rads.

The names and symbols for units of radiation dose used in this report are listed in Table A.4.

Additional information about radiation and dose terminology can be found in APPENDIX B. A list of the radionuclides discussed in this report, their symbols, and their half-lives are included in Table A.5.

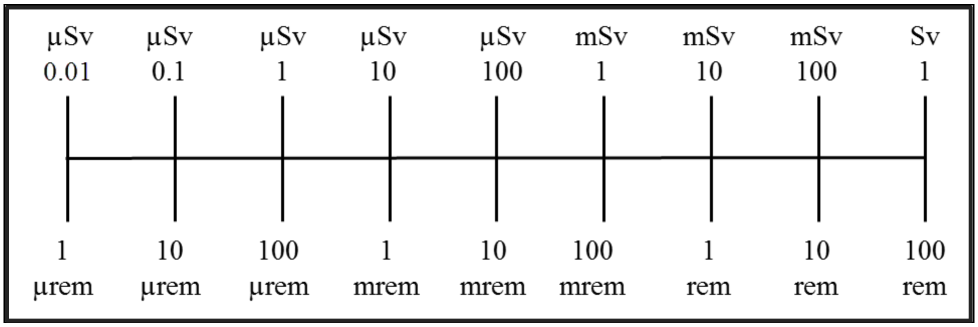

Figure A.2. Conversions for Radiological Dose Units

Table A.4. Names and Symbols for Units of Radiation Dose or Exposure

Symbol	Name
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)
Gy	gray (100 rad)
mGy	milligray (1 x 10^{-3} Gy)

Table A.5. Radionuclides and Their Half-Lives[a]

Symbol	Radionuclide	Half-Life	Symbol	Radionuclide	Half-Life
^{3}H	tritium	12.35 yr	^{140}Ba	barium-140	12.75 d
^{7}Be	beryllium-7	53.3 d	^{152}Eu	europium-152	13.33 yr
^{14}C	carbon-14	5,730 yr	^{154}Eu	europium-154	8.8 yr
^{24}Na	sodium-24	14.96 h	^{155}Eu	europium-155	4.96 yr
^{40}K	potassium-40	1.28×10^{9} yr	^{177}Lu	lutetium-177	6.65 d
^{37}Ar	argon-37	35.01 d	^{208}Po	polonium-208	2.90 yr
^{39}Ar	argon-39	269 yr	^{210}Pb	lead-210	22.3 yr
^{51}Cr	chromium-51	27.70 d	^{212}Pb	lead-212	10.64 h
^{54}Mn	manganese-54	312.5 d	^{220}Rn	radon-220	55.6 sec
^{55}Fe	iron-55	2.7 yr	^{222}Rn	radon-222	3.82 d
^{59}Fe	iron-59	44.53 d	^{226}Ra	radium-226	1600 yr
^{59}Ni	nickel-59	7.5×10^{4} yr	^{228}Ra	radium-228	5.75 yr
^{57}Co	cobalt-57	272 d	^{228}Th	thorium-228	1.91 yr
^{60}Co	cobalt-60	5.27 yr	^{229}Th	thorium-229	7340 yr
^{63}Ni	nickel-63	96 yr	^{230}Th	thorium-230	7.54×10^{4} yr
^{65}Zn	zinc-65	243.9 d	^{232}Th	thorium-232	1.41×10^{10} yr
^{82}Br	bromine-82	35.3 h	U or uranium	natural uranium	$\sim 4.5 \times 10^{9}$[b]
^{85}Kr	krypton-85	10.72 yr	^{233}U	uranium-233	1.59×10^{5} yr
^{89}Sr	strontium-89	50.53 d	^{234}U	uranium-234	2.45×10^{5} yr
^{90}Sr	strontium-90	29.12 yr	^{235}U	uranium-235	7.04×10^{8} yr
^{88}Y	yttrium-88	106.7 d	^{238}U	uranium-238	4.47×10^{9} yr
^{90}Y	yttrium-90	64.0 h	^{236}Np	neptunium-236	1.54×10^{5} yr
^{95}Zr	zirconium-95	63.98 d	^{237}Np	neptunium-237	2.14×10^{6} yr
^{99}Tc	technetium-99	2.13×10^{5} yr	^{238}Pu	plutonium-238	87.74 yr
^{103}Ru	ruthenium-103	39.28 d	^{239}Pu	plutonium-239	2.41×10^{4} yr
^{106}Ru	ruthenium-106	368.2 d	^{240}Pu	plutonium-240	6.54×10^{3} yr
^{109}Cd	cadmium-109	462.6 d	^{241}Pu	plutonium-241	14.4 yr
^{113}Sn	tin-113	115.1 d	^{242}Pu	plutonium-242	3.76×10^{5} yr
^{125}Sb	antimony-125	2.77 yr	^{244}Pu	plutonium-244	8.0×10^{7} yr
^{129}I	iodine-129	1.57×10^{7} yr	^{241}Am	americium-241	432.2 yr
^{131}I	iodine-131	8.04 d	^{243}Am	americium-243	7,380 yr
^{132}I	iodine-132	2.30 h	^{243}Cm	curium-243	28.5 yr
^{133}Xe	xenon-133	5.24 d	^{244}Cm	curium-244	18.11 yr
^{134}Cs	cesium-134	2.06 yr	^{245}Cm	curium-245	8,500 yr
^{137}Cs	cesium-137	30.0 yr	^{250}Cf	californium-250	13.08 yr
^{137m}Ba	barium-137m	2.55 min	^{252}Cf	californium-252	2.645 yr

(a) From EPA 402-R-99-001 (EPA 1999) and Table of Nuclides at http://atom.kaeri.re.kr/nuchart/.

(b) Natural uranium is a mixture dominated by uranium-238.

APPENDIX B

GLOSSARY

APPENDIX B

GLOSSARY

This glossary contains selected words and phrases used in this report that may not be familiar to readers. Words appearing in *italic* type within a definition are also defined in this glossary.

alpha particle – A positively charged particle composed of two protons and two neutrons ejected spontaneously from the nuclei of some *radionuclides* during radioactive decay. It has low penetrating power and short range. The most energetic alpha particle will generally fail to penetrate the skin, but is hazardous when introduced into the body.

aquifer – Underground sediment or rock that stores and/or transmits water.

background radiation – *Radiation* in the natural environment, including cosmic rays from space and *radiation* from naturally occurring radioactive elements in the air, in the earth, and in human bodies. It also includes *radiation* from global fallout from historical atmospheric nuclear weapons testing. In the United States, the average person receives approximately 300 *millirem* of background radiation per year.

Battelle Land–Sequim – Battelle privately owned land and supporting infrastructure (pump houses, access roads, parking lots, docks, etc.) located near Sequim, Washington, and associated with the PNNL Marine Sciences Laboratory area.

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) released from a nucleus during radioactive *decay*. At high enough intensities, some beta particles may cause skin burns and may be harmful if they enter the body. Beta particles are easily stopped by a thin sheet of metal or plastic.

Categorical Exclusion – A class of *actions* that DOE has determined are not likely to have significant environmental impacts under normal circumstances, and for which an environmental assessment or environmental impact statement is not normally needed. These are listed at 10 CFR Part 1021 Appendix D.

collective dose – Sum of the total effective dose equivalent for individuals composing a defined population. Collective dose units are *person-rem* or *person-sievert*.

composite sample – Sample formed by combining 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.

curie (Ci) – A unit of *radioactivity* equal to 37 billion (3.7×10^{10}) nuclear transformations per second (*becquerels*).

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 nonradioactive (stable). They are informally referred to as daughter products or progeny. See *radioactivity*.

dispersion – Process whereby *effluents* or *emissions* are spread or mixed when they are transported by *groundwater*, surface water, or air.

dose rate – The rate at which a dose is delivered over time (e.g., *millirem* per hour [mrem/h]).

effective dose equivalent (EDE) – Dose unit qualifier to indicate wholebody risk from ionizing radiation exposure. Calculated as the sum of critical human-tissue doses weighted for total heatlh risk. Total health risk includes the risk of fatal and non-fatal cancers, severe hereditary effects, and relative length of life lost.

effluent – Liquid material released from a facility.

effluent monitoring – Sampling or measuring specific liquid *effluent* streams for the presence of pollutants.

emission – Gaseous stream released from a facility.

exposure – The interaction of an organism with a physical agent (e.g., *radiation*) or a chemical agent (e.g., arsenic) of interest. Also used as a term for quantifying x- and *gamma-radiation* fields.

fission – The splitting or breaking apart of a nucleus into at least two other nuclei, accompanied by the release of a relatively large amount of energy.

gamma radiation – High-energy electromagnetic *radiation* (photons) originating in the nucleus of decaying *radionuclides*. Gamma radiation is substantially more penetrating than *alpha* or *beta emissions*, but comparatively the energy is not as readily absorbed.

grab sample – A short-duration sample (e.g., air, water, and soil) that is grabbed from the collection site.

gray (Gy) – Unit of absorbed dose in the International System of Units equal to the absorption of 1 joule per kilogram. The common unit of absorbed dose, the *rad*, is equal to 0.01 Gy.

groundwater – Subsurface water that is in the pores of sand and gravel or in the cracks of fractured rock.

high-level waste – Highly radioactive waste material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains *fission* products and other *radioisotopes* in sufficient concentrations to require permanent isolation.

irradiation – *Exposure* to *radiation*.

isotopes – *Nuclides* of the same chemical element with the same number of protons but a different number of neutrons.

low-level waste – Radioactive waste that is not high-level radioactive waste, spent nuclear fuel, *transuranic waste*, byproduct material, or naturally occurring radioactive material.

maximum exposed individual – A hypothetical member of the public residing near the PNNL Richland Campus or MSL who, by virtue of location and living habits, would reasonably receive the highest possible *radiation* dose from radioactive materials originating from the site.

method reporting limit – The lowest amount of analyte in a sample that can be quantitatively determined with the stated acceptable precision and accuracy under controlled laboratory conditions.

millirem – A unit of *radiation dose* that is equal to one one-thousandth (1/1000) of a *rem*.

minimum detectable activity – The smallest amount or concentration of a chemical or radioactive material that can be reliably detected in a sample.

mitigation – Prevention or reduction of expected *risks* to workers, the public, or the environment.

mixed waste – A U.S. Environmental Protection Agency or state-designated dangerous, extremely hazardous, or acutely hazardous waste that contains both a nonradioactive hazardous component and a radioactive component.

monitoring – As defined in DOE Order 458.1, Admin Chg 3, the collection and analysis of samples or measurements of liquid *effluent* and gaseous *emissions* for purposes of characterizing and quantifying contaminants, assessing *radiation exposure* to the public, and demonstrating compliance with regulatory standards.

nuclide – A particular combination of neutrons and protons. A *radionuclide* is a radioactive nuclide.

operable unit – A discrete area for which an incremental step can be taken toward comprehensively addressing site problems. The cleanup of a site can be divided into a number of operable units, depending on the complexity of the problems associated with the site.

outfall – End of a drain or pipe that carries wastewater or other *effluent* into a ditch, pond, or river.

person-rem or **person-sievert (person-Sv)** – Unit of *collective dose.* 1 person-Sv = 100 person-rem.

plutonium – A heavy, radioactive, metallic element of several possible *isotopes*. One important *isotope* is plutonium-239, which is produced after a specific neutron reaction with uranium-238. Routine analysis cannot distinguish between the plutonium-239 and plutonium-240 *isotopes*; hence, the term plutonium-239/240 is used in this report to indicate the presence of one or both of these *isotopes* in the analytical results.

PNNL Richland Campus – Includes a mix of federal and private land and facility ownership.

PNNL Marine Sciences Laboratory – Referred to as MSL, it consists of DOE-contracted elements on *Battelle Land–Sequim*.

quality assurance – Actions that provide confidence that an item or process meets or exceeds a user's requirements and expectations.

quality control – All actions necessary to control and verify the features and characteristics of a material, process, product, or service meet specified requirements. Quality control is an element of *quality assurance*.

rad – The unit of absorbed dose. 1 rad = 0.01 gray (Gy).

radiation – The energy emitted in the form of photons or energetic *alpha* and *beta particles* subsequent to radioactive decay. 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.

radionuclide – An atom that has a particular number of protons (Z), a particular number of neutrons (A), and a particular atomic weight (N = Z + A) that happens to emit *radiation*. Carbon-14 is a radionuclide but carbon-12, which is not radioactive, is referred to simply as a *nuclide*.

rem – The unit of *effective dose equivalent*. 1 rem = 0.01 sievert (Sv).

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.

shrub-steppe – A drought-resistant shrub and grassland ecosystem.

sievert (Sv) – The unit of *effective dose equivalent* and its variants in the International System of Units. The common unit for *effective dose equivalent* and its variants, the *rem*, is equal to 0.01 Sv.

surveillance – As defined in DOE Order 458.1, Admin 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 assessing effects, if any, on the local environment.

transuranic element – An element with an atomic number greater than 92 (92 is the atomic number of uranium).

transuranic waste – Waste containing more than 100 nanocuries (10^{-9} *curies*) per gram of alpha-emitting transuranic isotopes that have half-lives greater than 20 years.

tritium – The heaviest radioactive isotope of hydrogen (hydrogen-3) with a 12.3-year half-life.

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.

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.

water table – The top of the *unconfined aquifer*.

APPENDIX C

PLANT AND ANIMAL SPECIES FOUND ON THE UNDEVELOPED PORTIONS AND RIPARIAN AREA OF THE PNNL RICHLAND CAMPUS, 2009–2017

APPENDIX C

PLANT AND ANIMAL SPECIES FOUND ON THE UNDEVELOPED UPLAND PORTIONS AND IN THE RIPARIAN AREA OF THE PNNL RICHLAND CAMPUS, 2009–2017

Table C.1. Plant Species Observed on the Undeveloped Upland Portions of the PNNL Richland Campus, 2009–2017

Species Name[a]	Common Name[a]	State Status	Federal Status	Noxious Weed Class[b]
Achillea millefolium	common yarrow			
Achnatherum hymenoides	Indian ricegrass			
Acroptilon repens	hardheads			B
Agoseris heterophylla	annual mountain dandelion			
Agropyron cristatum	crested wheatgrass			
Agropyron dasytachyum	thickspike wheatgrass			
Ailanthus altissima	tree-of-heaven			C
Allium schoenoprasum	wild chives			
Amaranthus albus	prostrate pigweed			
Ambrosia acanthicarpa	flatspine bur ragweed			
Amsinckia lycopsoides	tarweed fiddleneck			
Amsinckia tessellata	bristly fiddleneck			
Artemisia campestris	field sagewort			
Artemisia dracunculus	tarragon			
Artemisia lindleyana	Columbia river mugwort			
Artemisia tridentata	big sagebrush			
Asclepias speciosa	showy milkweed			
Asparagus officinalis	garden asparagus			
Astragalus caricinus	buckwheat milkvetch			
Balsamorhiza careyana	Carey's balsamroot			
Bassia scoparia	burningbush			B
Bromus tectorum	cheatgrass			
Cardaria draba	whitetop			
Centaurea diffusa	diffuse knapweed			B
Centaurea solstitialis	yellow starthistle			B
Chaenactis douglasii	hoary false yarrow			
Chamaesyce serpyllifolia	thymeleaf sandmat			
Chenopodium album	lambsquarters			
Chenopodium leptophyllum	narrowleaf goosefoot			
Chenopodium rubrum	red goosefoot			
Chondrilla juncea	rush skeletonweed			B

Species Name[a]	Common Name[a]	State Status	Federal Status	Noxious Weed Class[b]
Chorispora tenella	crossflower			
Chrysothamnus viscidiflorus	green rabbitbrush			
Cichorium intybus	chicory			
Cirsium sp.	thistle			
Clematis ligusticifolia	western white clematis			
Comandra umbellata	bastard toadflax			
Convolvulus arvensis	field bind weed			C
Conyza canadensis	Canadian horseweed			
Coreopsis tinctoria var. *atkinsoniana*	Columbia tickseed			
Crepis atribarba	slender hawksbeard			
Cryptantha circumscissa	cushion cryptantha			
Cryptantha flaccida	weak-stemmed cryptantha			
Cryptantha fendleri	Fendler's cryptantha			
Cryptantha pterocarya	winged cryptantha			
Dalea ornata	Blue Mountain prairie clover			
Delphinium nuttallianum	twolobe larkspur			
Descurainia pinnata	western tansymustard			
Descurainia sophia	herb sophia			
Draba verna	spring draba			
Elaeagnus angustifolia	Russian olive			C
Eleocharis sp.	spikerush			
Elymus elymoides	squirreltail			
Elymus lanceolatus	thickspike wheatgrass			
Epilobium brachycarpum	tall willowherb			
Equisetum sp.	horsetail			
Ericameria nauseosa	rubber rabbitbrush			
Erigeron filifolius	threadleaf fleabane			
Eriogonum niveum	snow buckwheat			
Eriogonum vimineum	broom buckwheat			
Erodium cicutarium	redstem stork's bill			
Erysimum asperum	western wallflower			
Fritillaria pudica	yellow bell			
Gaillardia aristata	blanketflower			
Gilia sinuata	rosy gilia			
Gilia sp.	gilia			
Gratiola neglecta	American hedge-hyssop			
Grayia spinosa	spiny hopsage			
Grindelia columbiana	Columbia River gumweed			
Gypsophila paniculata	baby's breath			C
Hesperostipa comata	needle and thread			

Species Name[a]	Common Name[a]	State Status	Federal Status	Noxious Weed Class[b]
Holosteum umbellatum	jagged chickweed			
Hordeum jubatum	foxtail barley			
Hymenopappus filifolius	fineleaf hymenopappus			
Hypericum perforatum	common St. Johnswort			C
Iris missouriensis	Rocky Mountain iris			
Juniperus sp.	juniper			
Koeleria macrantha	prairie junegrass			
Krascheninnikovia lanata	winterfat			
Lactuca serriola	prickly lettuce			
Lagophylla rammosissima	branched lagophylla			
Lamium amplexicaule	henbit deadnettle			
Layia glandulosa	whitedaisy tidytips			
Lepidium densiflorum	common pepperweed			
Lepidium latifolium	broadleaf pepperweed			B
Lepidium perfoliatum	clasping pepperweed			
Leptodactylon pungens	prickly phlox			
Leymus cinereus	basin wildrye			
Logfia arvensis	field fluffweed			
Lomatium macrocarpum	bigseed biscuitroot			
Machaeranthera canescens	hoary tansyaster			
Malus pumila	apple			
Medicago sativa	alfalfa			
Melilotus officianalis	sweetclover			
Mentzelia albicaulis	whitestem stickleaf			
Microsteris gracilis	slender phlox			
Morus alba	white mulberry			
Narcissus sp.	daffodil			
Oenothera pallida	pale evening primrose			
Opuntia polyacantha	plains pricklypear			
Orobanche corymbosa	flat-top broomrape			
Phacelia hastata	silverleaf phacelia			
Phacelia linearis	threadleaf scorpionweed			
Phalaris arundinacea	reed canarygrass			C
Phlox longifolia	longleaf phlox			
Plantago lanceolata	narrowleaf plantain			
Plantago patigonica	woolly plantain			
Plectritis macrocera	longhorn plectritis			
Poa bulbosa	bulbous bluegrass			
Poa secunda	Sandberg bluegrass			
Polemonium micranthum	annual Jacob’s ladder			

Species Name[a]	Common Name[a]	State Status	Federal Status	Noxious Weed Class[b]
Polygonum convolvulus	climbing bindweed			
Plantago patigonica	woolly plantain			
Prunus virginiana	chokecherry			
Pseudognaphalium stramineum	cottonbatting plant			
Pseudoroegneria spicata	bluebunch wheatgrass			
Psoralidium lanceolatum	lemon scurfpea			
Pteryxia terebinthina	turpentine wavewing			
Purshia tridentata	antelope bitterbrush			
Ribes aureum	golden currant			
Ribes sp.	currant			
Robinia pseudoacacia	black locust			
Rosa woodsii	Woods' rose			
Rubus armeniacus	Himalayan blackberry			C
Rumex salicifolius	willow dock			
Rumex venosus	veiny dock			
Salix exigua	narrowleaf willow			
Salsola kali	Russian thistle			
Senecio vulgaris	common groundsel			C
Sisymbrium altissimum	tall tumblemustard			
Solidago canadensis	Canada goldenrod			
Solanum dulcamara	climbing nightshade			
Solanum triflorum	cutleaf nightshade			
Sphaeralcea munroana	Munro's globemallow			
Sporobolus cryptandrus	sand dropseed			
Stephanomeria paniculata	tufted wirelettuce			
Taraxacum officinale	common dandelion			
Tragopogon dubius	yellow salsify			
Tribulus terrestris	puncturevine			B
Triteleia douglasii	Douglas' clusterlily			
Triteleia grandiflora	Douglas clusterlily			
Ulmus pumila	Siberian elm			
Ulmus americana	American elm			
Verbascum thapsus	common mullein			
Vulpia microstachys	small sixweeks			
Vulpia octoflora	sixweeks fescue			
Vulpia sp.	fescue			
Zigadenus venenosus	meadow death camas			

(a) Nomenclature according to USDA (2018), Natural Resource Conservation Service Plants Database. http://plants.usda.gov/java/nameSearch

(b) Noxious Weed Class: B = Prevent spread and contain or reduce existing populations; C = Weeds widespread, control methods available but not normally required.

Table C.2. Bird Species Observed on the Undeveloped Upland Portions of the PNNL Richland Campus, 2009–2017

Species Name	Common Name	State Status	Federal Status
Artemisiospiza nevadensis	sagebrush sparrow	Candidate	
Anas platyrhynchos	mallard		
Asio flammeus	short-eared owl		
Branta canadensis	Canada goose		
Buteo jamaicensis	red-tailed hawk		
Buteo swainsoni	Swainson's hawk		
Callipepla californica	California quail		
Carpodacus mexicanus	house finch		
Carduelis tristis	American goldfinch		
Charadrius vociferus	killdeer		
Chordeiles minor	common nighthawk		
Chondestes grammacus	lark sparrow		
Circus cyaneus	northern harrier		
Colaptes auratus	northern flicker		
Columbus livia	rock pigeon		
Corvus brachyrhynchos	American crow		
Corvus corax	common raven		
Eremophila alpestris	horned lark		
Haliaeetus leucocephalus	bald eagle		Species of Concern
Hirundo pyrrhonota	cliff swallow		
Hirundo rustica	barn swallow		
Icterus bullockii	Bullock's oriole		
Numenius americanus	long-billed curlew		
Pandion haliaetus	osprey		
Passer domesticus	house sparrow		
Phasianus colchicus	ring-necked pheasant		
Pica pica	black-billed magpie		
Riparia riparia	bank swallow		
Sturnella neglecta	western meadowlark		
Sturnus vulgaris	European starling		
Tachycineta thalassina	violet-green swallow		
Turdus migratorius	American robin		
Tyrannus verticalis	western kingbird		
Zenaida macroura	mourning dove		
Zonotrichia leucophrys	white-crowned sparrow		

Table C.3. Mammal Species Observed on the Undeveloped Upland Portions of the PNNL Richland Campus, 2009–2017

Species Name	Common Name	State Status	Federal Status
Canis latrans	coyote		
Castor canadensis	beaver		
Erithizon dorsatum	porcupine		
Lepus californicus	black-tailed jackrabbit	Candidate	
Odocoileus hemionus	mule deer		
Perognathus parvus	Great Basin pocket mouse		
Sylvilagus nutalli	mountain cottontail		
Taxidea taxus	badger		
Thomomys talpoides	northern pocket gopher		

Table C.4. Plant Species Observed in the Riparian Area of the PNNL Richland Campus in 2015 and 2017

Species Name[a]	Common Name[a]	State Status	Federal Status	Noxious Weed Class[b]
Achillea millefolium	common yarrow			
Achnatherum hymenoides	Indian ricegrass			
Acroptilon repens	hardheads			B
Agropyron cristatum	crested wheatgrass			
Ailanthus altissima	tree-of-heaven			C
Allium schoenoprasum	wild chives			
Ambrosia acanthicarpa	flatspine bur ragweed			
Amsinckia lycopsoides	tarweed fiddleneck			
Apocynum cannabinum	Indianhemp			
Artemisia campestris	field sagewort			
Artemisia dracunculus	tarragon			
Artemisia lindleyana	Columbia River wormwood			
Artemisia ludoviciana	white sagebrush			
Artemisia tridentata	big sagebrush			
Asclepias speciosa	showy milkweed			
Asparagus officinalis	garden asparagus			
Bromus tectorum	cheatgrass			
Cardaria draba	whitetop			
Centaurea diffusa	diffuse knapweed			B
Chamaesyce serpyllifolia	thymeleaf sandmat			
Chondrilla juncea	rush skeletonweed			B
Cirsium arvense	Canada thistle			

Species Name[a]	Common Name[a]	State Status	Federal Status	Noxious Weed Class[b]
Clematis ligusticifolia	western white clematis			
Convolvulus arvensis	field bind weed			C
Conyza canadensis	Canadian horseweed			
Coreopsis tinctoria var. *atkinsoniana*	Atkinson's tickseed			
Descurainia pinnata	western tnasymustard			
Descurainia sophia	herb sophia			
Eleocharis palustris	common spikerush			
Elymus lanceolatus	thickspike wheatgrass			
Equisetum sp.	horsetail			
Ericameria nauseosa	rubber rabbitbrush			
Ericameria teretifolia	green rabbitbrush			
Eriogonum niveum	snow buckwheat			
Eriogonum sp.	buckwheat			
Gaillardia aristata	blanketflower			
Galium sp.	bedstraw			
Hesperostipa comata	needle and thread			
Hypericum perforatum	common St. Johnswort			C
Iris missouriensis	Rocky Mountain iris			
Krascheninnikovia lanata	winterfat			
Lactuca serriola	prickly lettuce			
Lepidium densiflorum	common pepperweed			
Lepidium perfoliatum	clasping pepperweed			
Lotus unifoliatus	American bird's-foot trefoil			
Lupinus sericeus	silky lupine			
Machaeranthera canescens	hoary tansyaster			
Medicago sativa	alfalfa			
Melilotus officinalis	sweetclover			
Morus alba	white mulberry			
Oenothera pallida	pale evening primrose			
Parthenocissus quinquefolia	Virginia creeper			
Phalaris arundinacea	reed canarygrass			C
Plantago lanceolata	narrowleaf plantain			
Plantago patigonica	woolly plantain			
Poa bulbosa	bulbous bluegrass			
Poa compressa	Canada bluegrass			
Poa secunda	Sandberg bluegrass			
Prunus virginiana	chokecherry			

Species Name[a]	Common Name[a]	State Status	Federal Status	Noxious Weed Class[b]
Psoralidium lanceolatum	lemon scurfpea			
Purshia tridentata	antelope bitterbrush			
Rhus glabra	smooth sumac			
Ribes aureum	golden currant			
Robinia pseudoacacia	black locust			
Rosa woodsii	Woods' rose			
Rubus armeniacus	Himalayan blackberry			C
Rumex crispus	curly dock			
Rumex patienta	patience dock			
Rumex salicifolius	willow dock			
Rumex venosus	veiny dock			
Salix exigua	narrowleaf willow			
Salsola kali	Russian thistle			
Sisymbrium altissimum	tall tumblemustard			
Solidago canadensis	Canada goldenrod			
Solanum dulcamara	climbing nightshade			
Sphaeralcea munroana	Munro's globemallow			
Sporobolus cryptandrus	sand dropseed			
Stephanomeria paniculata	tufted wirelettuce			
Taraxacum officinale	common dandelion			
Tragopogon dubius	yellow salsify			
Ulmus americana	American elm			
Verbascum thapsus	common mullein			
Vicia cracca	bird vetch			
Xanthium strumarium	rough cocklbur			

(a) Nomenclature according to the U.S. Department of Agriculture (USDA 2018), Natural Resource Conservation Service Plants Database. http://plants.usda.gov/java/

(b) Noxious Weed Class B = Prevent spread and contain or reduce existing populations; Noxious Weed Class C = Weeds widespread, control methods available but not normally required.

Table C.5. Bird Species Observed in the Riparian Area of the PNNL Richland Campus in 2015 and 2017

Species Name	Common Name	State Status	Federal Status
Actitis macularius	spotted sandpiper		
Agelaius phoeniceus	red-winged blackbird		
Anas platyrhynchos	mallard		
Ardea herodias	great blue heron		
Branta canadensis	Canada goose		
Bubo virginianus	great-horned owl		
Calidris bairdii	Baird's sandpiper		
Calidris mauri	western sandpiper		
Callipepla californica	California quail		
Ardea alba	great egret		
Columba livia	rock pigeon		
Corvus corax	common raven		
Icterus bullockii	Bullock's oriole		
Larus californicus	California gull		
Megaceryle alcyon	belted kingfisher		
Melospiza lincolnii	Lincoln's sparrow		
Melospiza melodia	song sparrow		
Mergus merganser	common merganser		
Nycticorax nycticorax	black-crowned night heron		
Pandion halaetus	osprey		
Pelecanus erythrorhynchos	American white pelican	Threatened	
Phalacrocorax auritus	double-crested cormorant		
Pica pica	black-billed magpie		
Riparia riparia	bank swallow		
Sturnus vulgaris	European starling		
Tyrannus tyrannus	eastern kingbird		
Turdus migratorius	American robin		
Zenaida macroura	mourning dove		

Table C.6. Mammal Species Observed in the Riparian Area of the PNNL Richland Campus in 2015 and 2017

Species Name	Common Name	State Status	Federal Status
Canis latrans	coyote		
Castor canadensis	American beaver		
Erithizon dorsatum	porcupine		
Odocoileus hemionus	mule deer		
Sciurus niger	eastern fox squirrel		

APPENDIX D

PLANT AND ANIMAL SPECIES OBSERVED DURING ANNUAL SURVEYS ON AND IN THE VICINITY OF THE PNNL MARINE SCIENCES LABORATORY LANDS

APPENDIX D

PLANT AND ANIMAL SPECIES OBSERVED DURING ANNUAL SURVEYS ON AND IN THE VICINITY OF THE PNNL MARINE SCIENCES LABORATORY LANDS

Table D.1. Plant Species Observed on PNNL Marine Sciences Laboratory Lands, 2013–2015

Species Name[(a)]	Common Name[(a)]	State Status	Federal Status	Noxious Weed Class[(b)]
Abies grandis	grand fir			
Abronia latifolia	coastal sand verbena			
Acer circinatum	vine maple			
Acer glabrum	Rocky Mountain maple			
Acer macrophyllum	bigleaf maple			
Achillea millefolium	common yarrow			
Alnus rubra	red alder			
Ambrosia chamissonis	silver bur ragweed			
Amelanchier alnifolia	Saskatoon serviceberry			
Arbutus menziesii	Pacific madrone			
Arctostaphylos uva-ursi	kinnikinnick			
Artemisia suksdorfii	coastal wormwood			
Argentina anserina	silverweed cinquefoil			
Avena sp.	oat			
Bellis perennis	lawndaisy			
Blechnum spicant	deer fern			
Brassica rapa	field mustard			
Cakile edentula	American searocket			
Carex sp.	sedge			
Castilleja hispida	harsh Indian paintbrush			
Centaurea cyanus	garden cornflower			
Cerastium spp.	mouse-ear chickweed			
Chamerion angustifolium	fireweed			
Chenopodium album	lambsquarters			
Cirsium arvense	Canada thistle			C
Cirsium spp.	thistle			
Claytonia perfoliata	miner's lettuce			
Conium maculatum	poison hemlock			B
Cornus sericea	redosier dogwood			

Species Name[a]	Common Name[a]	State Status	Federal Status	Noxious Weed Class[b]
Corylus cornuta var. *californica*	California hazelnut			
Crataegus monogyna	oneseed hawthorn			C
Cytisus scoparius	Scotch broom			B
Dactylis glomerata	orchardgrass			
Dipsacus fullonum	Fuller's teasel			C
Distichlis spicata	saltgrass			
Draba verna	spring draba			
Elymus glaucus	blue wildrye			
Equisetum hyemale	scouring-rush horsetail			
Equisetum spp.	horsetail			
Erodium cicutarium	redstem stork's bill			
Eschscholzia californica	California poppy			
Fragaria virginiana	Virginia strawberry			
Fritillaria affinis	checker lily			
Galium aparine	stickywilly			
Gaultheria shallon	salal			
Geranium molle	dovefoot geranium			
Grindelia integrifolia	Puget Sound gumweed			
Heracleum maximum	common cow-parsnip			
Holodiscus discolor	oceanspray			
Hypochaeris radicata	hairy cat's ear			C
Ilex aquifolium	English holly			M
Juncus sp.	rush			
Lathyrus japonicus	beach pea			
Lathyrus polyphyllus	leafy pea			
Leucanthemum vulgare	oxeye daisy			C
Lomatium nudicaule	barestem biscuitroot			
Lonicera ciliosa	orange honeysuckle			
Lysichiton americanus	American skunkcabbage			
Mahonia aquifolium	hollyleaved barberry			
Mahonia nervosa	Cascade barberry			
Maianthemum dilatatum	false lily of the valley			
Maianthemum racemosum ssp. *amplexicaule*	feathery false lily of the valley			
Medicago lupulina	black medick			
Mimulus guttatus	seep monkeyflower			

Species Name[a]	Common Name[a]	State Status	Federal Status	Noxious Weed Class[b]
Mycelis muralis	Wall-lettuce			
Myosotis sp.	forget-me-not			
Oemleria cerasiformis	Indian plum			
Osmorhiza berteroi	sweetcicely			
Petasites frigidus	arctic sweet coltsfoot			
Physocarpus capitatus	Pacific ninebark			
Plantago lanceolata	narrowleaf plantain			
Plantago major	common plantain			
Plantago maritima	goose tongue			
Plectritis congesta	shortspur seablush			
Polystichum munitum	western swordfern			
Populus balsamifera ssp. *trichocarpa*	black cottonwood			
Pseudotsuga menziesii	Douglas fir			
Pteridium aquilinum	western brackenfern			
Ranunculus repens	creeping buttercup			
Ranunculus uncinatus	woodland buttercup			
Ribes sanguineum	redflower currant			
Rosa gymnocarpa	dwarf rose			
Rosa nutkana	Nootka rose			
Rubus armeniacus	Himalayan blackberry			C
Rubus leucodermis	whitebark raspberry			
Rubus parviflorus	thimbleberry			
Rubus ursinus	California blackberry			
Rumex acetosella	common sheep sorrel			
Rumex crispus	curly dock			
Rumex aquaticus	western dock			
Salicornia depressa	Virginia glasswort			
Salix spp.	willow			
Sambucus racemosa	red elderberry			
Senecio sylvaticus	woodland ragwort			
Spiraea douglasii	rose spirea			
Symphoricarpos albus	common snowberry			
Taraxacum officinale	common dandelion			
Tellima grandiflora	bigflower tellima			
Thuja plicata	western red cedar			
Tolmiea menziesii	youth on age			

Species Name[a]	Common Name[a]	State Status	Federal Status	Noxious Weed Class[b]
Trientalis borealis	starflower			
Trifolium latifolium	twin clover			
Trifolium pratense	red clover			
Trifolium repens	white clover			
Triglochin maritima	seaside arrowgrass			
Tsuga heterophylla	western hemlock			
Urtica dioica	stinging nettle			
Vicia americana	American vetch			
Vicia nigricans	black vetch			
Vicia sativa	garden vetch			
Vicia sp.	vetch			

(a) Nomenclature according to USDA (2017), Natural Resource Conservation Service Plants Database. http://plants.usda.gov/java.

(b) Noxious Weed Class: B = Prevent spread and contain or reduce existing populations; C = Weeds widespread, control methods available but not normally required; M = Monitor list.

Table D.2. Bird Species Observed on and in the Vicinity of the PNNL Marine Sciences Laboratory Lands, 2013–2017

Species Name	Common Name	State Status	Federal Status
Accipiter cooperii	Cooper's hawk		
Agelaius phoeniceus	red-winged blackbird		
Anas platyrhynchos	mallard		
Anthus rubescens	American pipit		
Ardea herodias	great blue heron		
Branta canadensis	Canada goose		
Bubo virginianus	great-horned owl		
Bucephala albeola	bufflehead		
Bucephala clangula	common goldeneye		
Buteo jamaicensis	red-tailed hawk		
Callipepla californica	California quail		
Calypte anna	Anna's hummingbird		
Cardellina pusilla	Wilson's warbler		
Carduelis tristis	American goldfinch		
Carpodacus mexicanus	house finch		
Cathartes aura	turkey vulture		
Catharus ustulatus	Swainson's thrush		
Charadrius vociferus	killdeer		

Species Name	Common Name	State Status	Federal Status
Cepphus columba	pigeon guillemot		
Cerorhinca monocerata	rhinoceros auklet		
Certhia americana	brown creeper		
Chamaea fasciata	wrentit		
Circus cyaneus	northern harrier		
Cistothorus palustris	marsh wren		
Coccothraustes vespertinus	evening grosbeak		
Colaptes auratus	northern flicker		
Columba livia	rock dove (pigeon)		
Corvus brachyrhynchos	American crow		
Corvus corax	common raven		
Cyanocitta stelleri	Steller's jay		
Dendroica townsendii	Townsend's warbler		
Empidonax alnorum	willow flycatcher		
Empidonax difficilis	Pacific-slope flycatcher		
Empidonax hammondii	Hammond's flycatcher		
Euphagus cyanocephalus	Brewer's blackbird		
Falco peregrinus	peregrine falcon		Species of Concern
Haliaeetus leucocephalus	bald eagle		Species of Concern
Hirundo rustica	barn swallow		
Histrionicus histrionicus	harlequin duck		
Junco hyemalis	dark-eyed junco		
Larus glaucescens	glaucus-winged gull		
Larus glaucescens x L. occidentalis	Olympic gull		
Larus occidentalis	western gull		
Larus spp.	gull		
Megaceryle alcyon	belted kingfisher		
Melanitta perspicillata	surf scoter		
Melospiza melodia	song sparrow		
Mergus serrator	red-breasted merganser		
Molothrus ater	brown-headed cowbird		
Oreothlypis celata	orange-crowned warbler		
Parus atricapillus	black-capped chickadee		
Parus gambeli	mountain chickadee		
Parus rufescens	chestnut-backed chickadee		
Passerculus sandwichensis	savannah sparrow		
Passerella iliaca	fox sparrow		
Patagioenas fasciata	band-tailed pigeon		

Species Name	Common Name	State Status	Federal Status
Petrochelidon pyrrhonota	cliff swallow		
Phalacrocorax auritus	double-crested cormorant		
Phalacrocorax pelagicus	pelagic cormorant		
Phalacrocorax penicillatus	Brant's cormorant	Candidate	
Pheucticus melanocephalus	black-headed grosbeak		
Picoides pubescens	downy woodpecker		
Picoides villosus	hairy woodpecker		
Pipilo maculatus	spotted towhee		
Piranga ludoviciana	western tanager		
Podilymbus podiceps	pied-billed grebe		
Poecile atricapillus	black-capped chickadee		
Poecile rufescens	chestnut-backed chickadee		
Psaltriparus minimus	bushtit		
Regulus calendula	ruby-crowned kinglet		
Regulus satrapa	golden-crowned kinglet		
Selasphorus rufus	rufous hummingbird		
Setophaga coronata	yellow-rumped warbler		
Sitta canadensis	red-breasted nuthatch		
Sphyrapicus ruber	red-breasted sapsucker		
Spinus tristis	American goldfinch		
Stelgidopteryx serripennis	northern rough-winged swallow		
Sterna caspia	Caspian tern		
Strix varia	barred owl		
Sturnus vulgaris	European starling		
Tachycineta bicolor	tree swallow		
Tachycineta thalassina	violet-green swallow		
Thryomanes bewickii	Bewick's wren		
Troglodytes pacificus	Pacific wren		
Turdus migratorius	American robin		
Zenaida macroura	mourning dove		
Zonotrichia leucophrys	white-crowned sparrow		

Table D.3. Other Vertebrate Species Observed on PNNL Marine Sciences Laboratory Lands, 2013–2015

Species Name	Common Name	State Status	Federal Status
Anaxyrus boreas	western toad	Candidate	
Canis latrans	coyote		
Odocoileus hemionus	black-tailed deer		
Rana aurora	northern red-legged frog		
Sorex sp.	shrew		
Tamiasciurus douglasii	Douglas squirrel		
Taricha granulosa	rough-skinned newt		

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