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**Pacific Northwest  
National Laboratory**

Operated by Battelle for the  
U.S. Department of Energy

**Hanford Site  
National Environmental  
Policy Act (NEPA)  
Characterization**

D. A. Neitzel, Editor

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September 2005



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under Contract DE-AC05-76RL01830

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Richland, Washington 99352

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# Preface

This document describes the U.S. Department of Energy's (DOE) Hanford Site environment. It is updated each year and is intended to provide a consistent description of the Hanford Site environment for the many environmental documents being prepared by DOE contractors concerning the National Environmental Policy Act (NEPA). No statements about significance or environmental consequences are provided. This year's report is the seventeenth revision of the original document published in 1988 and is (until replaced by the eighteenth revision) the only version that is relevant for use in the preparation of Hanford NEPA, State Environmental Policy Act (SEPA), and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) documents.

The two chapters included in this document (Chapters 4 and 6) are numbered to correspond to the chapters where such information is typically presented in environmental impact statements (EISs) and other Hanford Site NEPA or CERCLA documentation. Chapter 4.0 (Affected Environment) describes Hanford Site climate and meteorology; air quality; geology; hydrology; ecology; cultural, archaeological, and historical resources; socioeconomics; noise; and occupational health and safety. Sources for extensive tabular data related to these topics are provided in the chapter. Most subjects are divided into a general description of the characteristics of the Hanford Site, followed by site-specific information, where available, of the 100, 200, 300, and other areas. This division allows the reader to go directly to those sections of particular interest. When specific information on each of these separate areas is not complete or available, the general Hanford Site description should be used.

Chapter 6.0 (Statutory and Regulatory Requirements) describes federal and state laws and regulations, DOE directives and permits, and presidential executive orders that are applicable to the NEPA documents prepared for Hanford Site activities. Information in Chapter 6 of this document can be adapted and supplemented with specific information for a chapter covering statutory and regulatory requirements in an environmental assessment or environmental impact statement.

When preparing environmental assessments and EISs, authors should also be cognizant of the document titled *Recommendations for the Preparation of Environmental Assessments and Environmental Impact Statements* published by the DOE Office of NEPA Oversight (DOE 2004). Additional guidance on preparing DOE NEPA documents can be found at <http://tis.eh.doe.gov/nepa/guidance.html>.

Any interested individual seeking baseline data on the Hanford Site and its past activities may also use the information contained in this document to evaluate projected activities and their impacts.

For this 2005 revision, the following sections of the document were reviewed by the authors and updated with the best available information through May 2005:

- Climate and Meteorology
- Air Quality
- Geology – Seismicity section only
- Hydrology – Flow charts for the Columbia and Yakima rivers only
- Ecology – Threatened and Endangered Species subsection only
- Socioeconomics
- Occupational Safety
- All of Chapter 6.

Pacific Northwest National Laboratory (PNNL) staff prepared individual sections of this document, with input from other Hanford Site contractors. More detailed data are available from reference sources cited or from the authors. The following personnel are responsible for the various sections of this document and can be contacted with questions:

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A copy of the document is available, upon request, from Duane A. Neitzel at (509) 376-0602. The document is also available electronically at <http://www.pnl.gov/nepa>.

## Acknowledgments

As the editor of Revision 17, I hope you find this document useful in preparing Hanford Site NEPA documents or as a useful source of information about the Hanford environment. Many people are responsible for the years of work that went into preparing this description of the Hanford Site. The authors of the individual sections took great care to accurately describe their work. PNNL, DOE, and other Hanford contractor personnel reviewed the document. Their comments and suggestions are important to preparing Revision 17. This year's reviewers include Kathy Rhoads, Paul Dunigan, Amanda Stegen, Robin Durham, Kenneth Gano, Roger Ovink, Regan Weeks, Thomas Marceau, Katherine Cort, and Theresa Gilbride. Special thanks go to Paul Dunigan and Annabelle Rodriguez with DOE for their help and support. Most importantly, I thank Joanne Duncan for all her work in making sure Revision 17 was completed on time and presented in a way that is useful to everyone needing an up-to-date description of the Hanford environment. Joanne Duncan also maintains an electronic copy of the document throughout the year.

D. A. Neitzel

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## Acronyms, Abbreviations, and Symbols

AADT	Annual average daily traffic
AAS	Associate in applied science
ACL	Administrative Control Level
AEA	Atomic Energy Act
AMH	Advance Med Hanford
ARAR	Applicable or Relevant and Appropriate Requirements
ARPA	Archaeological Resources Protection Act
BCAA	Benton Clean Air Authority
BCRFD	Benton County Rural Fire Department
BFCOG	Benton Franklin Council of Governments
BFT	Benton Franklin Transit
BLS	Bureau of Labor Statistics
BNI	Bechtel National Inc.
BNSF	Burlington Northern and Santa Fe Railway
BPA	Bonneville Power Administration
CAA	Clean Air Act
CBC	Columbia Basin College
CCP	Comprehensive Conservation Plan
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
Corps	U.S. Army Corps of Engineers
CREHST	Columbia River Exhibition of History, Science and Technology
CWA	Clean Water Act
dB	Decibels
dBA	A-weighted sound level
DCG	Derived concentration guides
DOC	U.S. Department of Commerce
DOE	U.S. Department of Energy
DOE-ORP	U.S. Department of Energy, Office of River Protection
DOE/RL	U.S. Department of Energy, Richland Operations Office
DOH	Washington State Department of Health
DOI	U.S. Department of the Interior
DOL	U.S. Department of Labor
DWS	Drinking water standards
E/Q	Atmospheric dispersion estimates
EA	Environmental assessment
EC	Environmental concern
Ecology	Washington State Department of Ecology
EDNA	Environmental designation for noise abatement
EIS	Environmental Impact Statement
EJ	Environmental justice
EMC	Ecological Monitoring and Compliance
EMT	Emergency medical technician
EO	Environmental Objections
E.O.	Executive Order

## Acronyms, Abbreviations, and Symbols (cont'd.)

EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-To-Know Act
ESA	Endangered Species Act
ESU	Evolutionary significant units
EU	Environmentally unsatisfactory
FEMA	Federal Emergency Management Agency
FFTF	Fast Flux Test Facility
FR	Federal Register
FY	Fiscal Year
GENII	Generation II Model for Environmental Dose Calculations
GIS	Geographic Information System
HABS	Historic American Buildings Survey
HAER	Historic American Engineering Record
HAMMER	Hazardous Materials Management and Emergency Response
HCP-EIS	Hanford Comprehensive Land-Use Plan Environmental Impact Statement
HCRL	Hanford Cultural Resources Laboratory
HEHF	Hanford Environmental Health Foundation
Historic District	Hanford Site Manhattan Project and Cold War Era Historic District
HMS	Hanford Meteorology Station
Hz	Hertz
I	Interstate
kWh	Kilowatt-hour
$L_{eq}$	Equivalent sound level
LIGO	Laser Interferometer Gravitational Wave Observatory
LLC	Limited Liability Corporation
LLWPA	Low-Level Radioactive Waste Policy Act
LMEA	Labor Market and Economic Analysis
LO	Lack of objections
LOS	Level of service
LWC	Lost workday cases
LWD	Lost workdays
MCL	Maximum contaminant levels
MEI	Maximally exposed individual
MMI	Modified Mercalli intensity
MW	Megawatt
NAAQS	National Ambient Air Quality Standards
National Register	National Register of Historic Places
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NHPA	National Historic Preservation Act
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NPR	New Production Reactor
NRC	U.S. Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act
NWPPA	Northwest Public Power Association
OFM	Office of Financial Management (Washington State)

## Acronyms, Abbreviations, and Symbols (cont'd.)

ORP	Office of River Protection (Department of Energy)
OSHA	Occupational Safety and Health Administration
OTED	Washington State Office of Trade and Economic Development
PCB	Polychlorinated biphenyls
PFP	Plutonium Finishing Plant
PL	Public law
PM <sub>2.5</sub>	Particulate matter (2.5 µm or less)
PM <sub>10</sub>	Particulate matter (10 µm or less)
PNNL	Pacific Northwest National Laboratory
PSD	Prevention of significant deterioration
PUREX	Plutonium-uranium extraction
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
REIS	Regional Economic Information System
RL	Richland Operations Office (Department of Energy)
RM	River mile
ROD	Record of Decision
SALDS	State-approved land disposal structure
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SEPA	State Environmental Policy Act (Washington)
SESP	Surface Environmental Surveillance Project
SIP	State Implementation Plan
SR	State route
TCH	Tri-City Herald
TCP	Traditional Cultural Place
TEDE	Total effective dose equivalent
TEDF	Treated Effluent Disposal Facility
TRC	Total recordable cases
Tri-Cities	Kennewick, Pasco, and Richland, Washington
Tri-Party Agreement	Hanford Federal Facility Agreement and Consent Order
TSCA	Toxic Substances Control Act
TSD	Treatment, storage, and/or disposal
UO <sub>3</sub>	Uranium trioxide
USC	United States Code
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WAC	Washington Administrative Code
WDFW	Washington State Department of Fish and Wildlife
WNP	Washington nuclear plant
WSU-TC	Washington State University, Tri-Cities
X/Q'	Atmospheric dispersion coefficient

## Acronyms, Abbreviations, and Symbols (cont'd.)

### Names and Symbols for Units of Measure, Radioactivity, Time, and Mathematical Terms

<p style="text-align: center;"><b><u>Length</u></b></p> cm centimeter ft foot in. inch km kilometer m meter mi mile mm millimeter	<p style="text-align: center;"><b><u>Area</u></b></p> km <sup>2</sup> square kilometer mi <sup>2</sup> square mile ac acre ha hectare	<p style="text-align: center;"><b><u>Volume</u></b></p> m <sup>3</sup> cubic meter gal gallon L liter	<p style="text-align: center;"><b><u>Time/Speed</u></b></p> s second hr hour yr year mph miles per hour m/s meters per second
<p style="text-align: center;"><b><u>Radioactivity/ Radiation Dose</u></b></p> Ci curie pCi picocurie mrem millirem Bq becquerel Sv sievert Gy gray	<p style="text-align: center;"><b><u>Temperature</u></b></p> °C degrees Celsius °F degrees Fahrenheit	<p style="text-align: center;"><b><u>Mathematical</u></b></p> < less than > greater than ≤ less than or equal to ≥ greater than or equal to ~ approximately avg average max maximum min minimum	<p style="text-align: center;"><b><u>Mass</u></b></p> g gram kg kilogram mg milligram μg microgram
	<p style="text-align: center;"><b><u>Chemical</u></b></p> M molar		<p style="text-align: center;"><b><u>Concentration</u></b></p> ppm parts per million

## Glossary

**Ambient air.** Any unconfined portion of the atmosphere: open air, surrounding air.

**Anisotropic.** The condition in which hydraulic properties of an aquifer are not equal when measured in all directions.

**Anticline.** A fold in rocks that brings rocks up from depth, forming a ridge or arch-like structure. The rocks in the center of an anticline are the older rocks.

**Aquatic ecosystem.** Ecological system containing species that live in water.

**Aquifer.** A water-bearing, geologic formation below the surface of the earth that can supply water for a well or spring.

**Atmospheric dispersion.** The transport and diffusion of gases and particles within the atmosphere.

**Benthic organism.** A form of aquatic plant or animal life that is found on or near the bottom of a stream, lake or ocean.

**Biomass.** All of the living material in a given area; often refers to vegetation.

**Biota.** Living organisms.

**Clastic dike.** An intrusion of sediment forced into fractures in rock or sediments.

**Ecoregion.** Areas where the geology, vegetation, land use, and topography are similar, and where similar groups of organisms might be expected to live.

**Evaporation.** The process by which liquid water is converted into a gaseous state.

**Evapotranspiration.** Combined loss of water to the atmosphere via the processes of evaporation and transpiration.

**Groundwater.** Water that occurs below the Earth's surface. It is found within the pores of sand and gravel or the cracks of fractured rock beneath the land and is invisible to the naked eye.

**Habitat.** The place where an organism lives or is expected to occur; habitat type is a grouping of similar habitats.

**Meteoric Water.** Groundwater derived primarily from precipitation.

**Plankton.** Small or microscopic organisms, including algae and protozoans, that float or drift in great numbers in water, especially at or near the surface, and serve as food for fish and other larger organisms.

**Plant community.** A habitat description based on the dominant plant species present.

**Pre-contact.** The period prior to the arrival of European explorers and settlers.

**Redds.** Nests fish make in gravel and/or small cobble in the riverbed to lay their eggs.

**Riparian areas.** Vegetated areas found on each side of streams and rivers.

**Rough fish.** Species of fish that are neither sport fish nor important food fish.

**Shrub-steppe.** A plant community characterized by a dominant shrub and grasslands that has hot dry summers, cold winters and little rainfall

**Syncline.** A fold in rocks in which the layers are bowed downward, resulting in a valley or bowl-shaped structure. The younger rocks are toward the center of a syncline.

**Transpiration.** The process of water loss from plants.

**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.

**Vadose zone.** The hydrogeologic region between the surface of the land and the water table.

**Water table.** Theoretical surface represented by the elevation of water surfaces in wells penetrating only a short distance into the unconfined aquifer.

**Wetlands.** Lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface.

**Zooplankton.** Animal constituent of plankton; mainly small crustaceans and fish larvae.

# Table of Contents

Preface .....	iii
Acknowledgments .....	v
Acronyms, Abbreviations, and Symbols .....	vii
Glossary .....	xi
4.0 Affected Environment .....	4.1
Introduction .....	4.1
4.1. Climate and Meteorology .....	4.5
4.1.1 Wind .....	4.8
4.1.2 Temperature and Humidity .....	4.12
4.1.3 Precipitation .....	4.12
4.1.4 Fog and Visibility .....	4.13
4.1.5 Severe Weather .....	4.13
4.2. Air Quality .....	4.15
4.2.1 Atmospheric Dispersion .....	4.15
4.2.2 Nonradiological Air Quality .....	4.16
4.2.2.1 Prevention of Significant Deterioration .....	4.17
4.2.2.2 Emissions of Nonradiological Pollutants .....	4.17
4.2.2.3 Offsite Monitoring .....	4.17
4.2.2.4 Background Monitoring .....	4.19
4.2.2.5 Onsite Monitoring .....	4.20
4.2.3 Radiological Air Quality .....	4.21
4.2.3.1 Radiological Emissions .....	4.21
4.2.3.2 Dose Assessments .....	4.21
4.2.3.3 Environmental Monitoring .....	4.23
4.3. Geology .....	4.25
4.3.1 Physical and Structural Characteristics .....	4.27
4.3.2 Strata and Structure of Sediment and Rock .....	4.30
4.3.2.1 Columbia River Basalt Group .....	4.30
4.3.2.2 Ellensburg Formation .....	4.30
4.3.2.3 Hanford Formation, Cold Creek Unit, and Ringold Formation .....	4.30
4.3.2.4 Clastic Dikes .....	4.32
4.3.2.5 100 Areas Strata and Structure .....	4.33
4.3.2.6 200 Areas Strata and Structure .....	4.33
4.3.2.7 300 Area Strata and Structure .....	4.33
4.3.3 Surface Soil .....	4.34
4.3.4 Seismicity .....	4.36
4.4. Hydrology .....	4.43
4.4.1 Surface Water .....	4.43
4.4.1.1 Columbia River .....	4.43

4.4.1.2	Water Quality of the Columbia River .....	4.45
4.4.1.3	Yakima River .....	4.48
4.4.1.4	Springs and Streams .....	4.48
4.4.1.5	Columbia Riverbank Springs .....	4.48
4.4.1.6	Runoff and Net Infiltration.....	4.50
4.4.1.7	Flooding .....	4.50
4.4.1.8	Non-Riverine Surface Water.....	4.55
4.4.2	Hanford Site Vadose Zone .....	4.58
4.4.2.1	Vadose Zone Contamination.....	4.59
4.4.3	Hanford Site Groundwater.....	4.60
4.4.3.1	Basalt-Confined Aquifer System.....	4.60
4.4.3.2	Unconfined Aquifer System.....	4.61
4.4.3.3	Limitations of Hydrogeologic Information .....	4.63
4.4.3.4	Groundwater Travel Times .....	4.63
4.4.3.5	Groundwater East and North of the Columbia River .....	4.64
4.4.4	Groundwater Quality .....	4.64
4.4.5	100 Area Hydrology .....	4.66
4.4.6	200 Areas Hydrology.....	4.66
4.4.7	300 Area Hydrology .....	4.72
4.4.8	Richland North Area Hydrology .....	4.72
4.5.	Ecology.....	4.73
4.5.1	Terrestrial Ecology .....	4.73
4.5.1.1	Vegetation .....	4.74
4.5.1.2	Wildlife .....	4.83
4.5.2	Aquatic Ecology .....	4.86
4.5.2.1	Columbia River .....	4.86
4.5.2.2	Spring Streams .....	4.90
4.5.2.3	Temporary Water Bodies .....	4.91
4.5.3	Threatened and Endangered Species .....	4.91
4.6.	Cultural, Archaeological, and Historical Resources.....	4.99
4.6.1	Native American Cultural Landscape.....	4.102
4.6.1.1	Archaeological Resources .....	4.103
4.6.1.2	Traditional Cultural Places.....	4.103
4.6.2	Early Settlers/Farming Landscape.....	4.104
4.6.2.1	Archaeological Resources .....	4.104
4.6.2.2	Traditional Cultural Places.....	4.106
4.6.2.3	Buildings and Structures .....	4.106
4.6.3	Manhattan Project and Cold War Cultural Landscape .....	4.106
4.6.3.1	Archaeological Resources .....	4.107
4.6.3.2	Buildings and Structures .....	4.107
4.6.4	Site Areas.....	4.108
4.6.4.1	100 Areas.....	4.108
4.6.4.2	200 Areas.....	4.112
4.6.4.3	300 Area .....	4.114
4.6.4.4	400 Area .....	4.115
4.6.4.5	600 Area .....	4.115
4.6.4.6	700 Area .....	4.117

4.7.	Socioeconomics .....	4.119
4.7.1	Local Economy .....	4.119
4.7.1.1	DOE Contractors (Hanford) .....	4.119
4.7.1.2	Energy Northwest .....	4.121
4.7.1.3	Agriculture .....	4.121
4.7.1.4	Other Major Employers .....	4.122
4.7.1.5	Tourism .....	4.122
4.7.1.6	Retirees .....	4.122
4.7.2	Employment and Income .....	4.123
4.7.3	Demography .....	4.124
4.7.4	Environmental Justice .....	4.125
4.7.5	Housing .....	4.131
4.7.6	Transportation .....	4.131
4.7.7	Educational Services .....	4.133
4.7.8	Health Care and Human Services .....	4.134
4.7.9	Police and Fire Protection .....	4.135
4.7.10	Parks and Recreation .....	4.136
4.7.11	Utilities .....	4.136
4.7.12	Land Use .....	4.138
4.8.	Visual Resources .....	4.147
4.9.	Noise .....	4.149
4.9.1	Background Information .....	4.149
4.9.2	Environmental Noise Regulations .....	4.149
4.9.3	Hanford Site Sound Levels .....	4.150
4.9.3.1	Skagit/Hanford Data .....	4.150
4.9.3.2	Basalt Waste Isolation Project (BWIP) Data .....	4.150
4.9.3.3	New Production Reactor (NPR) EIS .....	4.152
4.9.3.4	Noise Levels of Hanford Field Activities .....	4.153
4.10.	Occupational Health and Safety .....	4.155
4.10.1	Industrial Illness and Injury Experience at the Hanford Site .....	4.155
4.10.2	Occupational Radiation Exposure at the Hanford Site .....	4.158
	References .....	4.161
	Appendix A - Atmospheric Dispersion Tables .....	A.1
	Appendix B - Hanford Site Species Lists .....	B.1
	Appendix C - Vegetation Maps .....	C.1
6.0	Statutory and Regulatory Requirements .....	6.1
	Introduction .....	6.2
	Federal and State Environmental Laws .....	6.3
	Citation of Laws and Regulations .....	6.3

Specific Federal Laws Cited in the CEQ Regulations.....	6.3
6.1 Federal Environmental Laws.....	6.5
6.2 Federal and State Environmental Regulations .....	6.7
6.2.1 Air Quality.....	6.7
6.2.2 Water Quality .....	6.8
6.2.3 Hazardous Waste Management .....	6.10
6.2.4 Species Protection .....	6.11
6.2.5 Historic and Cultural Resource Preservation.....	6.11
6.2.6 Land Use.....	6.12
6.2.7 Other.....	6.13
6.3 Executive Orders .....	6.15
6.4 DOE Directives .....	6.17
6.5 Treaties, Statutes, and Policies Relating to Indian Tribes of the Hanford Region .....	6.19
6.6 Permits.....	6.21
References .....	6.23

## Figures

<b>Figure 4.0-1.</b>	U.S. Department of Energy's Hanford Site, Washington.....	4.2
<b>Figure 4.1-1.</b>	Hanford Meteorological Monitoring Network, Hanford Site, Washington.....	4.6
<b>Figure 4.1-2.</b>	Wind Roses at the 9.1 m (30 ft) Level of the Hanford Meteorological Monitoring Network, Washington, 1982 through 2004.....	4.9
<b>Figure 4.1-3.</b>	Wind Roses at the 60 m (197 ft) Level of the Hanford Meteorological Monitoring Network, Washington, 1986 through 2004.....	4.11
<b>Figure 4.2-1.</b>	24-hr Average Concentrations for Particulate Matter with a Diameter of 10 $\mu$ m or less at the Hanford Meteorological Station, Washington, 2004 .....	4.20
<b>Figure 4.3-1.</b>	Geologic Elements of the Pasco Basin Portion of the Columbia Basin, Washington.....	4.26
<b>Figure 4.3-2.</b>	White Bluffs at the Hanford Site, Washington, Display River and Lake Deposits Left from the Ancestral Columbia River .....	4.27
<b>Figure 4.3-3.</b>	Conceptualization of an Ice-Age Flood in the Vicinity of the Hanford Site, Washington, which Occurred Intermittently between 18,000-13,000 years ago.....	4.28
<b>Figure 4.3-4.</b>	Physical and Structural Geology of the Hanford Site, Washington.....	4.29
<b>Figure 4.3-5.</b>	Strata of Rocks and Sediment at the Hanford Site, Washington .....	4.31
<b>Figure 4.3-6.</b>	Map of Soil Types at the Hanford Site, Washington .....	4.35
<b>Figure 4.3-7.</b>	Historical Earthquake Activity of the Columbia Basin, Washington, and Surrounding Areas between 1890 and 1970 with a Modified Mercalli Intensity V or larger and/or a magnitude 4 or larger. ....	4.38
<b>Figure 4.3-8.</b>	Earthquake Activity of the Columbia Basin, Washington, and Surrounding Areas as Measured by Seismographs between 1970 and 2005 with Richter magnitudes of 3 or larger. ....	4.40
<b>Figure 4.4-1.</b>	Surface Water Features on the Hanford Site, Washington, including Rivers, Ponds, Major Springs, and Ephemeral Streams.....	4.44
<b>Figure 4.4-2.</b>	Average Daily Flow for the Hanford Reach, Columbia River, Washington, from January 1994 through April 2005 .....	4.45
<b>Figure 4.4-3.</b>	Average Daily Flow for the Columbia River during Calendar Year 2004 .....	4.46
<b>Figure 4.4-4.</b>	Surface Water and Sediment Monitoring Locations, Hanford Site, Washington .....	4.47
<b>Figure 4.4-5.</b>	Average Daily Flow for the Yakima River, Washington, from 1994 through April 2005 .....	4.49

<b>Figure 4.4-6.</b>	Locations of Principal Dams within the Columbia Plateau, Washington and Oregon .....	4.51
<b>Figure 4.4-7.</b>	Flood Area on the Hanford Site, Washington, during the 1894 Flood Based on Modeled Topographic Cross Sections .....	4.52
<b>Figure 4.4-8.</b>	Flood Area for the Probable Maximum Flood on the Hanford Site, Washington, as Determined by the Upper Limit of Precipitation and Maximum Runoff .....	4.54
<b>Figure 4.4-9.</b>	Flood Area from a 100-Year Flood of the Yakima River near the Hanford Site, Washington .....	4.56
<b>Figure 4.4-10.</b>	Extent of Probable Maximum Flood in Cold Creek Area, Hanford Site, Washington, delineated using the U.S. Army Corps of Engineers' HEC-2 Water Surface Profiles model.....	4.57
<b>Figure 4.4-11.</b>	Water Table Elevations in Meters and Inferred Groundwater Flow Directions for the Unconfined Aquifer at Hanford, Washington, March 2003 .....	4.62
<b>Figure 4.4-12.</b>	Distribution of Radionuclides in Groundwater on the Hanford Site, Washington, at Concentrations above the Maximum Contaminant Level or Interim Drinking Water Standard during Fiscal Year 2003.....	4.69
<b>Figure 4.4-13.</b>	Distribution of Hazardous Chemicals in Groundwater on the Hanford Site, Washington, at Concentrations above the Maximum Contaminant Level or Interim Drinking Water Standard during Fiscal Year 2003 .....	4.70
<b>Figure 4.5-1.</b>	Distribution of Vegetation Types and Areas on the Hanford Site, Washington, before the Year 2000 Fire .....	4.76
<b>Figure 4.5-2.</b>	Area of Hanford Site, Washington, Burned as a Result of the June 27 to July 2, 2000, Wildfire .....	4.80
<b>Figure 4.5-3.</b>	Columbia River Islands in the Vicinity of the Hanford Site, Washington.....	4.82
<b>Figure 4.5.4.</b>	Fall Chinook Salmon Spawning Areas in Hanford Reach Area of the Columbia River, Washington .....	4.89
<b>Figure 4.6-1.</b>	Areas Surveyed for Cultural Resources on the Hanford Site, Washington .....	4.100
<b>Figure 4.6-2.</b>	Map of the Hanford Site, Washington, showing towns, ferries and prominent features associated with the Early Settlers landscape .....	4.105
<b>Figure 4.7-1.</b>	Hanford Site, Washington, and Surrounding Communities .....	4.120
<b>Figure 4.7-2.</b>	Location of Minority Populations Near the Hanford Site, Washington, based on 2000 Census.....	4.129
<b>Figure 4.7-3.</b>	Location of Low-Income Populations Near the Hanford Site, Washington, based on 2000 Census.....	4.130

<b>Figure 4.7-4.</b>	DOE's Preferred Alternative for Land Use on the Hanford Site, Washington.....	4.139
<b>Figure 4.7-5.</b>	Geographic Study Areas for the Hanford Site, Washington.....	4.141
<b>Figure 4.8-1.</b>	Viewshed from Gable Mountain on the Hanford Site, Washington.....	4.148
<b>Figure 4.9-1.</b>	Location of Background Noise Measurements Collected for the Basalt Waste Isolation Project, Hanford Site, Washington.....	4.151
<b>Figure 4.10-1.</b>	Occupational Injury and Illness Total Recordable Case Rates at the Hanford Site, Washington, Compared to Department of Energy and Private Industry.....	4.156
<b>Figure 4.10-2.</b>	Average Measureable Dose (mrem/yr) to Hanford Site, Washington, 1999-2003.....	4.159
<b>Figure 4.10-3.</b>	Collective Operational Dose (person-mrem/yr) at the Hanford Site, Washington, 1999-2003.....	4.159
<b>Figure C-1.</b>	Vegetation/Land Coverage Map for the 100-B/C Area, Hanford Site, Washington, during 2004.....	C.3
<b>Figure C-2.</b>	Vegetation/Land Coverage Map for the 100-D Area, Hanford Site, Washington, during 2004.....	C.4
<b>Figure C-3.</b>	Vegetation/Land Coverage Map for the White Bluffs Boat Launch Vicinity, Hanford Site, Washington, during 2004.....	C.5
<b>Figure C-4.</b>	Vegetation/Land Coverage Map for the 100-F Area, Hanford Site, Washington, during 2004.....	C.6
<b>Figure C-5.</b>	Vegetation/Land Coverage Map for the 100-H Area, Hanford Site, Washington, during 2004.....	C.7
<b>Figure C-6.</b>	Vegetation/Land Coverage Map for the 100-K Area, Hanford Site, Washington, during 2004.....	C.8
<b>Figure C-7.</b>	Vegetation/Land Coverage Map for the 100-N Area, Hanford Site, Washington, during 2004.....	C.9
<b>Figure C-8.</b>	Vegetation/Land Coverage Map for the Hanford Townsite Vicinity, Hanford Site, Washington, during 2004.....	C.10
<b>Figure C-9.</b>	Vegetation/Land Coverage Map for the 300 Area, Hanford Site, Washington, during 2004.....	C.11
<b>Figure C-10.</b>	Vegetation/Land Coverage Map for the 200-East Area, Hanford Site, Washington, during 2004.....	C.12
<b>Figure C-11.</b>	Vegetation/Land Coverage Map for the 200-West Area, Hanford Site, Washington, during 2004.....	C.13

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## Tables

<b>Table 4.1-1.</b>	Station Numbers, Names, and Meteorological Data Measured at each Station in the Hanford Meteorological Monitoring Network, Washington.....	4.7
<b>Table 4.1-2.</b>	Monthly and Annual Wind Related Data Collected at 15-m (50-ft) Level, 1945 through 2004, Hanford Meteorology Station, Washington .....	4.10
<b>Table 4.1-3.</b>	Number of Days with Peak Gusts above Specific Thresholds at 15-m (50-ft) Level, 1945 through 2004, Hanford Meteorology Station, Washington.....	4.10
<b>Table 4.1-4.</b>	Number of Days with Fog by Season, Hanford Site, Washington .....	4.13
<b>Table 4.1-5.</b>	Estimate of the Probability of Extreme Winds Associated with Tornadoes Striking a Point at Hanford, Washington .....	4.14
<b>Table 4.1-6.</b>	Estimates of Extreme Winds at the Hanford Site, Washington.....	4.14
<b>Table 4.2-1.</b>	Percent Probabilities for Extended Periods of Surface-Based Inversions, Hanford Site, Washington .....	4.16
<b>Table 4.2-2.</b>	U.S. Environmental Protection Agency (EPA) and Washington State Ambient Air Quality Standards .....	4.18
<b>Table 4.2-3.</b>	Nonradioactive Constituents Discharged to the Atmosphere during 2004, Hanford Site, Washington .....	4.19
<b>Table 4.2-4.</b>	Radionuclides Discharged to the Atmosphere at the Hanford Site, Washington, 2004.....	4.22
<b>Table 4.4-1.</b>	Regulatory Drinking Water Standards for Groundwater.....	4.50
<b>Table 4.4-2.</b>	Maximum Concentrations of Selected Groundwater Contaminants during Fiscal Year 2003 .....	4.67
<b>Table 4.5.1.</b>	Federal or Washington State Threatened and Endangered Species on the Hanford Site.....	4.92
<b>Table 4.5-2.</b>	Washington State Candidate and Sensitive Animal Species on the Hanford Site.....	4.95
<b>Table 4.5-3.</b>	Washington State Plant Species of Concern on the Hanford Site .....	4.96
<b>Table 4.6-1.</b>	Historic Buildings, Archaeological Sites, and Districts Listed in the National Register of Historic Places on the Hanford Site, Washington .....	4.101
<b>Table 4.6-2.</b>	Historic Buildings, Archaeological Sites, and Districts Determined Eligible for Listing in the National Register of Historic Places on the Hanford Site, Washington .....	4.101

<b>Table 4.6-3.</b>	Archaeological Sites and Districts Listed in the Washington Heritage Register on the Hanford Site, Washington .....	4.102
<b>Table 4.7-1.</b>	Federal Government Transfer Payments in Benton County and Franklin County, Washington, 2003.....	4.123
<b>Table 4.7-2.</b>	Nonagricultural Wage and Salary Workers in Benton County and Franklin County, Washington, 2003 and 2004 .....	4.124
<b>Table 4.7-3.</b>	Population Estimates and Percentages by Race and Hispanic Origin by County in Washington State and Within the 80-km (50 mi) Radius of Hanford as Determined by the 2000 Census.....	4.126
<b>Table 4.7-4.</b>	Year 2004 Population Estimates and Percentages by Race and Hispanic Origin by County in Washington State.....	4.127
<b>Table 4.7-5.</b>	Police Personnel in the Tri-Cities, Washington, 2004.....	4.135
<b>Table 4.7-6.</b>	Fire Protection Personnel in the Tri-Cities, Washington, 2004.....	4.136
<b>Table 4.7-7.</b>	Examples of Physical Recreational Facilities Available in the Tri-Cities, Washington.....	4.137
<b>Table 4.7-8.</b>	Definitions and Descriptions of DOE's Preferred Alternative Land Use Designations for the Hanford Site, Washington.....	4.140
<b>Table 4.7-9.</b>	Key Areas of the Hanford Site, Washington, Outgranted/Released to Date .....	4.145
<b>Table 4.9-1.</b>	Applicable State Noise Limitations for the Hanford Site, Washington, Based on Source and Receptor EDNA Designation .....	4.150
<b>Table 4.9-2.</b>	Estimated Noise Resulting from Automobile Traffic at Hanford, Washington, with the New Production Reactor Environmental Impact Statement .....	4.152
<b>Table 4.9-3.</b>	Noise Levels Propagated from Construction Activities .....	4.153
<b>Table 4.10-1.</b>	Occupational Injury and Illness Incidence Rates, and Fatality Counts for Department of Energy Facilities and Private Industry .....	4.157
<b>Table 4.10-2.</b>	Radiation Exposure Data for the Hanford Site, Washington, 1999-2003 .....	4.160
<b>Table A1.</b>	Joint Frequency Distributions of Atmospheric Stability, Wind Speed, and Transport Direction for the 100 Area at 9.1 m (30 ft) above Ground Level, Hanford Site, Washington. ....	A.5
<b>Table A2.</b>	Joint Frequency Distributions of Atmospheric Stability, Wind Speed, and Transport Direction for the 100 Area at 60 m (197 ft) above Ground Level, Hanford Site, Washington .....	A.6

<b>Table A3.</b>	Joint Frequency Distributions of Atmospheric Stability, Wind Speed, and Transport Direction for the 200 Areas at 9.1 m (30 ft) above Ground Level, Hanford Site, Washington. ....	A.7
<b>Table A4.</b>	Joint Frequency Distributions of Atmospheric Stability, Wind Speed, and Transport Direction for the 200 Areas at 60 m (197 ft) above Ground Level, Hanford Site, Washington. ....	A.8
<b>Table A5.</b>	Joint Frequency Distributions of Atmospheric Stability, Wind Speed, and Transport Direction for the 300 Area at 9.1 m (30 ft) above Ground Level, Hanford Site, Washington. Based on 1983-2002 data from the 300 Area instrumented tower. ....	A.9
<b>Table A6.</b>	Joint Frequency Distributions of Atmospheric Stability, Wind Speed, and Transport Direction for the 300 Area at 60 m (197 ft) above Ground Level, Hanford Site, Washington. ....	A.10
<b>Table A7.</b>	Joint Frequency Distributions of Atmospheric Stability, Wind Speed, and Transport Direction for the 400 Area at 9.1 m (30 ft) above Ground Level, Hanford Site, Washington. ....	A.11
<b>Table A8.</b>	Joint Frequency Distributions of Atmospheric Stability, Wind Speed, and Transport Direction for the 400 Area at 60 m (197 ft) above Ground Level, Hanford Site, Washington. ....	A.12
<b>Table A9.</b>	$X/Q'$ Values ( $s\ m^{-3}$ ) for Chronic Ground-Level Releases from 100-N Area Based on 1983 through 2002 Meteorological Information, Hanford Site, Washington .....	A.13
<b>Table A10.</b>	$X/Q'$ Values ( $s\ m^{-3}$ ) for Chronic 60-m Stack Releases from 100-N Area Based on 1986 through 2002 Meteorological Information, Hanford Site, Washington .....	A.13
<b>Table A11.</b>	$X/Q'$ Values ( $s\ m^{-3}$ ) for Chronic Ground-Level Releases from 200 Areas Based on 1983 through 2002 Meteorological Information, Hanford Site, Washington .....	A.14
<b>Table A12.</b>	$X/Q'$ Values ( $s\ m^{-3}$ ) for Chronic 60-m Stack Releases from 200 Areas Based on 1983 through 2002 Meteorological Information, Hanford Site, Washington .....	A.14
<b>Table A13.</b>	$X/Q'$ Values ( $s\ m^{-3}$ ) for Chronic Ground-Level Releases from 300 Area Based on 1983 through 2002 Meteorological Information, Hanford Site, Washington .....	A.15
<b>Table A14.</b>	$X/Q'$ Values ( $s\ m^{-3}$ ) for Chronic 60-m Stack Releases from 300 Area Based on 1986 through 2002 Meteorological Information, Hanford Site, Washington .....	A.15
<b>Table A15.</b>	$X/Q'$ Values ( $s\ m^{-3}$ ) for Chronic Ground-Level Releases from 400 Area Based on 1983 through 2002 Meteorological Information, Hanford Site, Washington .....	A.16
<b>Table A16.</b>	$X/Q'$ Values ( $s\ m^{-3}$ ) for Chronic 60-m Stack Releases from 400 Area Based on 1986 through 2002 Meteorological Information, Hanford Site, Washington .....	A.16

<b>Table A17.</b>	95th Percentile E/Q Values ( $s\ m^{-3}$ ) for Acute Ground Level Releases from 100-N Area Based on 1983 through 2002 Meteorological Information, Hanford Site, Washington.....	A.17
<b>Table A18.</b>	95th Percentile E/Q Values ( $s\ m^{-3}$ ) for Acute 60-m Stack Releases from 100-N Area Based on 1986 through 2002 Meteorological Information, Hanford Site, Washington.....	A.17
<b>Table A19.</b>	95th Percentile E/Q Values ( $s\ m^{-3}$ ) for Acute Ground-Level Releases from 200 Areas Based on 1983 through 2002 Meteorological Information, Hanford Site, Washington.....	A.18
<b>Table A20.</b>	95th Percentile E/Q Values ( $s\ m^{-3}$ ) for Acute 60-m Stack Releases from 200 Areas Based on 1983 through 2002 Meteorological Information, Hanford Site, Washington.....	A.18
<b>Table A21.</b>	95th Percentile E/Q Values ( $s\ m^{-3}$ ) for Acute Ground-Level Releases from 300 Area Based on 1983 through 2002 Meteorological Information, Hanford Site, Washington.....	A.19
<b>Table A22.</b>	95th Percentile E/Q Values ( $s\ m^{-3}$ ) for Acute 60-m Stack Releases from 300 Area Based on 1986 through 2002 Meteorological Information, Hanford Site, Washington.....	A.19
<b>Table A23.</b>	95th Percentile E/Q Values ( $s\ m^{-3}$ ) for Acute Ground-Level Releases from 400 Area Based on 1983 through 2002 Meteorological Information, Hanford Site, Washington.....	A.20
<b>Table A24.</b>	95th Percentile E/Q Values ( $s\ m^{-3}$ ) for Acute 60-m Stack Releases from 400 Area Based on 1986 through 2002 Meteorological Information, Hanford Site, Washington.....	A.20
<b>Table B-1.</b>	Common Vascular Plants on the Hanford Site, Washington.....	B.3
<b>Table B-2.</b>	Mammals that Have Been Observed on the Hanford Site, Washington.....	B.6
<b>Table B-3.</b>	Common Bird Species Known to Occur on the Hanford Site, Washington.....	B.8
<b>Table B-4.</b>	Reptiles and Amphibians Found on the Hanford Site, Washington.....	B.13
<b>Table B-5.</b>	Fish Species in the Hanford Reach, Washington, Region of the Columbia River.....	B.14

## 4.0 Affected Environment

### Introduction

*A.L. Bunn*

The U.S. Department of Energy (DOE) Hanford Site lies within the semiarid Pasco Basin of the Columbia Plateau in south central Washington State (Figure 4.0-1). The Hanford Site occupies an area of about 1517 km<sup>2</sup> (about 586 mi<sup>2</sup>)<sup>(a)</sup> north of the confluence of the Yakima River with the Columbia River. The Hanford Site is about 50 km (30 mi) north to south and 40 km (24 mi) east to west. This land, with restricted public access, provides a buffer for the smaller areas currently used for storage of nuclear materials, waste treatment, and waste storage and/or disposal. The Columbia River flows through the northern part of the Hanford Site and, turning south, forms part of the Site's eastern boundary. The Yakima River runs near the southern boundary of the Hanford Site and joins the Columbia River at the city of Richland, which bounds the Hanford Site on the southeast. Rattlesnake Mountain, Yakima Ridge, and Umtanum Ridge form the southwestern and western boundaries. Saddle Mountain forms the northern boundary of the Hanford Site. Two small east-west ridges, Gable Butte and Gable Mountain, rise above the plateau of the central part of the Hanford Site. Adjoining lands to the west, north, and east are principally range and agricultural land. The cities of Kennewick, Pasco, and Richland (the Tri-Cities), and the city of West Richland constitute the nearest population centers and are located south-southeast of the Hanford Site.

The Hanford Site was established in 1943 to produce plutonium for nuclear weapons; it was the first nuclear production facility in the world. The U.S. Army Corps of Engineers selected the Hanford Site because it was remote from major populated areas and had ample electrical power from Grand Coulee Dam, a functional railroad, clean water available from the Columbia River, and plenty of sand and gravel available onsite for construction. The Hanford Site was divided into a number of operational areas (e.g., 100, 200, 300, and 400 Areas) (DOE 1998a, b).

From the early 1940s to the present, most research and development activities were carried out in the 300 Area located just north of Richland. The 300 Area was also the location of nuclear fuel fabrication. Nuclear fuel in the form of pipe-like cylinders (fuel slugs) was fabricated from purified uranium shipped in from offsite production facilities. The fabricated fuel slugs were shipped by rail from the 300 Area to the nuclear reactors in the 100 Area, located at the northern portion of the Site on the shore of the Columbia River, where up to nine nuclear reactors were in operation. The first eight reactors were constructed between 1944 and 1955. The ninth reactor, N Reactor, was completed in 1963. The irradiated fuel produced in the 100 Area reactors was transported by rail to the 200 Areas, where the plutonium was recovered.

The 200 East and 200 West Areas are located on a plateau about 11 and 8 km (7 and 5 mi), respectively, south of the Columbia River. These areas housed facilities called separations plants that received and dissolved irradiated fuel and then separated out the plutonium. Wastes were neutralized and stored in large underground tanks. Wastes containing fission products, activation products, and nitrate

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(a) This figure is based on the newest geographical information system (GIS) interpolation of the Hanford Site legal boundary. Historically, the Site area was reported as 1450 km<sup>2</sup> (560 mi<sup>2</sup>), calculated by the addition of sections and subunits based on surveys from the 1800s. Included in the Site is 36.42 km<sup>2</sup> (14.1 mi<sup>2</sup>) of Columbia River surface water and 2.6 km<sup>2</sup> (1 mi<sup>2</sup>) of Washington State land (DOE 1999a).

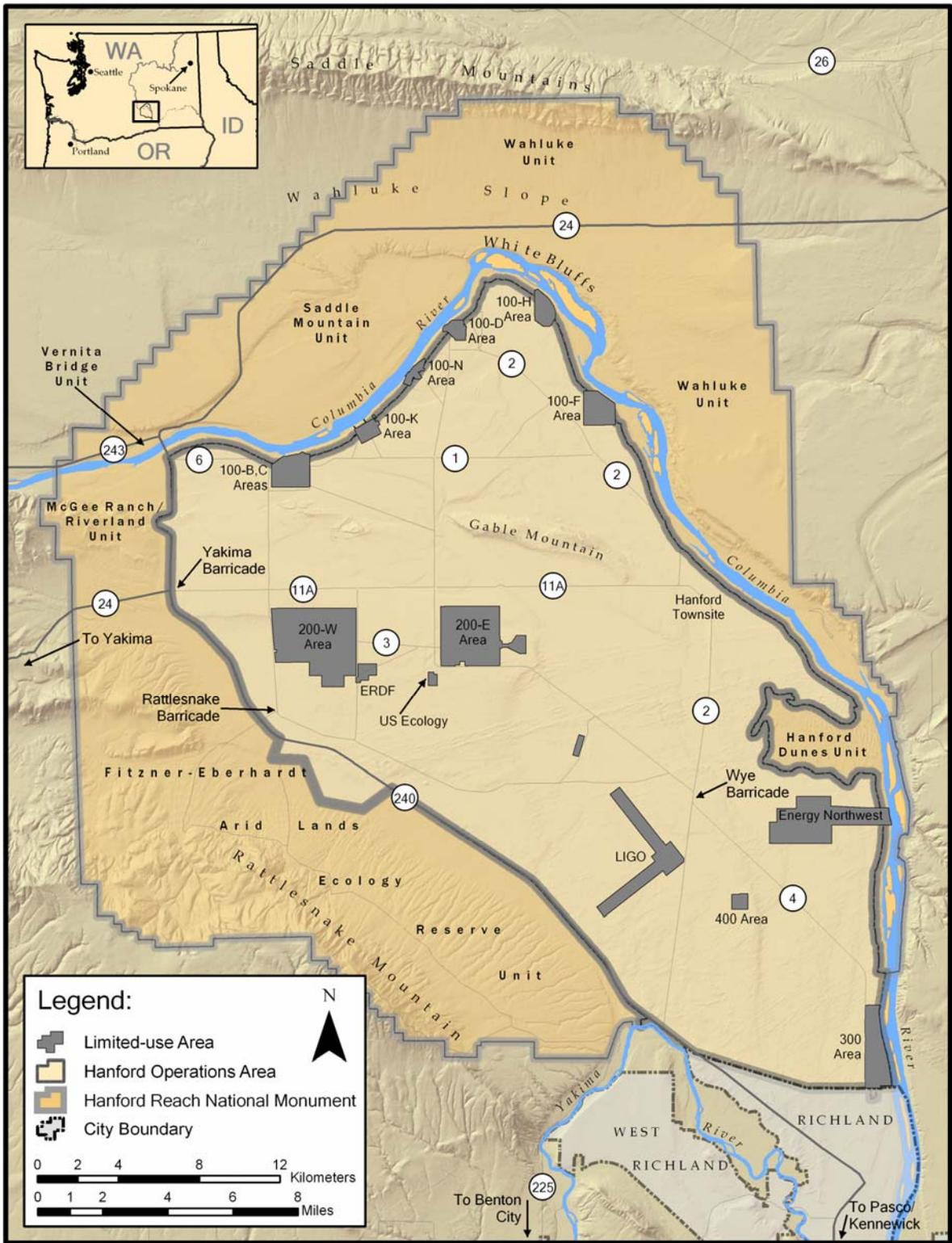


Figure 4.0-1. U.S. Department of Energy's Hanford Site, Washington

were discharged to cribs. Low-level wastes and cooling water from the plants were distributed by open ditch to surface ponds for evaporation and percolation into the ground.

Other areas on the Hanford Site include the 400 and 600 Areas. The Fast Flux Test Facility (FFTF) located in the 400 Area was a special nuclear reactor designed to test various types of nuclear fuel, produce medical and industrial isotopes, and conduct cooperative international research. The facility operated for about ten years and has been shut down since 1993. The 600 Area includes all the land between the designated areas of the Site.

The 700 and 1100 Areas, near north Richland, provided Hanford Site support services. The 700 Area was the original location for administrative activities for the Hanford Site, and was located where the Federal Building is located today (DOE 1997a). The 1100 Area was the location of general stores and transportation maintenance facilities for the Hanford Site. Operations at the transportation maintenance facility resulted in ground contamination from several chemicals, oils, and greases. The 1100 Area was located about 1.8 km (1.1 mi) west of the Columbia River and contiguous to the 600 Area. In September 1996, the 1100 Area was declared remediated and the Environmental Protection Agency issued a delisting from the National Priorities List (DOE 1998a). No radioactive waste was discharged to the ground in the 1100 Area. Most of the 1100 Area has been incorporated into the city of Richland and is no longer a part of the Hanford Site (DOE 2002a).

At the Hanford Site several areas, totaling 665 km<sup>2</sup> (257 mi<sup>2</sup>), have been set aside for special uses. The Fitzner-Eberhardt Arid Lands Ecology Reserve Unit, used for ecological research, was established in 1967 on land between the southern boundary of the Hanford Site and State Route 240. On the north end of the site is the Saddle Mountain National Wildlife Refuge Unit. Operations and activities on the Hanford Site, not under the auspices of DOE include a commercial power production reactor by Energy Northwest (near the 400 Area); a scientific observatory for measuring gravity waves at extremely tiny levels, called the Laser Interferometer Gravitational Wave Observatory (LIGO) project (near the 400 Area); and a commercial low-level radioactive waste burial ground at a site leased and licensed by the State of Washington and operated by U.S. Ecology (near the 200 Areas). Offsite, but near the southern boundary of the Hanford Site in North Richland, Framatome ANP (an AREVA and Siemens company) operates a commercial nuclear fuel fabrication facility and Pacific EcoSolutions LLC operates a low-level radioactive waste decontamination, super-compaction, and packaging disposal facility.

The Hanford Site encompasses more than 2700 waste management units and groundwater contamination plumes. These waste sites have been grouped into 74 operable units. Each operable unit has complementary characteristics such as geography, waste content, type of facility, and relationship of contaminant plumes. The grouping into operable units allows for economies of scale to reduce the cost and number of characterization investigations and remedial actions required to complete environmental cleanup (WHC 1989). The 74 operable units are located in four areas: 17 in the 100 Area, 51 in the 200 Areas, two in the 300 Area, and four in the former 1100 Area (DOE 2002a). Those persons contemplating National Environmental Policy Act (NEPA)-related activities on the Hanford Site should be aware of the existence and location of the operable units. Detailed information concerning the operable units and current maps showing the locations of the operable units can be obtained from *Hanford Site Waste Management Units Report* (DOE 2002a).

A portion of the Hanford Site was designated the Hanford Reach National Monument (65 FR 37253) during 2000. As established, the Monument totals 792.6 km<sup>2</sup> (306 mi<sup>2</sup>) and includes Fitzner-Eberhardt Arid Lands Ecology Reserve Unit, Saddle Mountain Wildlife Refuge Unit, McGee Ranch/Riverlands Unit, and land 0.40 km (0.25 mi) inland from the mean high-water mark on the south and west shores of the 82 km (51 mi) long Hanford Reach of the Columbia River. It also includes the federally owned islands in the Hanford Reach and the sand dune area northwest of the Energy Northwest Site. This

designation establishes the protection and management of the lands within the region of the monument. Also, a letter from President Clinton to the Secretary of Energy directs the Secretary of Energy to consult with the Secretary of the Interior regarding the incorporation of additional Hanford Site lands into the Monument as the land is remediated. The U.S. Fish and Wildlife Service (USFWS) is the lead agency in producing a Comprehensive Conservation Plan (CCP) Environmental Impact Statement (EIS) for management of the Hanford Reach National Monument.

## 4.1. Climate and Meteorology

*D.J. Hoitink*

The Hanford Site lies within the semiarid shrub-steppe Pasco Basin of the Columbia Plateau in south-central Washington State. The region's climate is greatly influenced by the Pacific Ocean and the Cascade Mountain Range to the west, and other mountain ranges to the north and east. The Pacific Ocean moderates temperatures throughout the Pacific Northwest, and the Cascade Range generates a rain shadow that limits rain and snowfall in the eastern half of Washington State. The Cascade Range also serves as a source of cold air drainage, which has a considerable effect on the wind regime on the Hanford Site. Mountain ranges to the north and east of the region shield the area from the severe winter storms and frigid air masses that move southward across Canada.

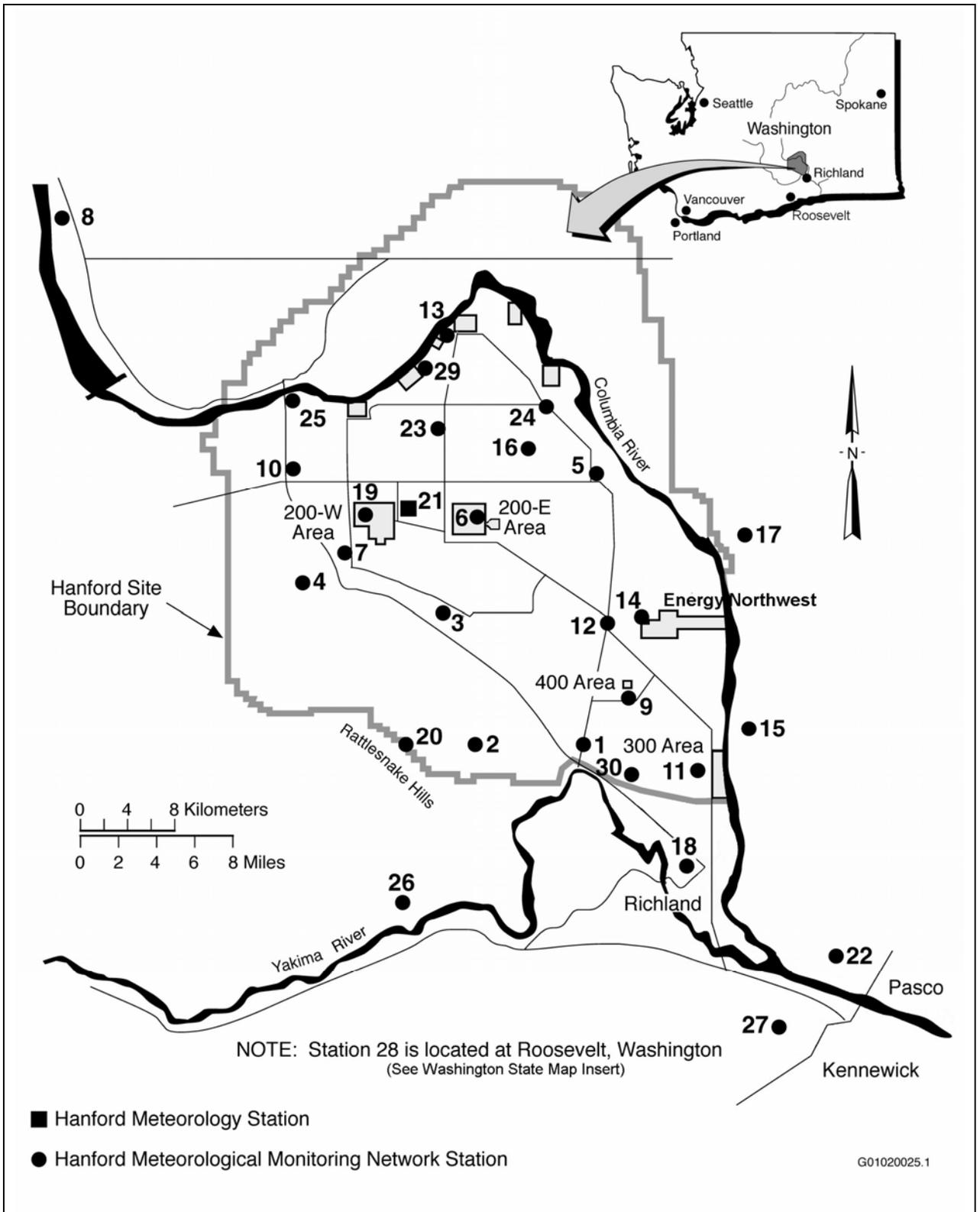
Climatological data for the Hanford Site are compiled at the Hanford Meteorology Station (HMS), which is located on the Hanford Site's Central Plateau, just outside the northeast corner of the 200 West Area and about 4 km (3 mi) west of the 200 East Area. Meteorological measurements have been made at the HMS since late 1944. Before the HMS was established, local meteorological observations were made at the Old Hanford Townsite (1912 through late 1943) and in Richland (1943-1944). A climatological summary for Hanford is provided in Hoitink et al. (2005).<sup>(a)</sup>

Data from the HMS capture the general climatic conditions for the region and describe the specific climate of Hanford's Central Plateau. The size of the Hanford Site and its topography give rise to substantial spatial variations in wind, precipitation, temperature, and other meteorological characteristics. This is observed for the differences in the annual distribution of wind direction and speed measured at the HMS and at the 300 Area. To characterize meteorological differences accurately across the Hanford Site, the HMS operates a network of monitoring stations. These stations, which currently number 30, are situated throughout the Site and in neighboring areas (Figure 4.1-1). A 124-m (408-ft) instrumented meteorological tower operates at the HMS. A 61-m (200-ft) instrumented tower operates at each of the 100-N, 300, and 400 area meteorology-monitoring sites. Most of the other network stations use instrumented towers with heights of about 9.1 m (30 ft). The data collected at each tower vary with at least three variables collected at all towers and up to seven collected at some (Table 4.1-1). Data are collected and processed at each station, and information is transmitted to the HMS every 15 minutes. This monitoring network has been in full operation since the early 1980s.

For the following descriptions in this section the seasons are defined as follows: winter, December through February; spring, March through May; summer, June through August; and autumn, September through November.

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(a) Hanford climatological data summaries have been updated annually since 1995. Earlier climatological reports that have been cited extensively include Glantz et al. (1990) and Stone et al. (1983).



**Figure 4.1-1.** Hanford Meteorological Monitoring Network, Hanford Site, Washington

**Table 4.1-1.** Station Numbers, Names, and Meteorological Data Measured at each Station in the Hanford Meteorological Monitoring Network, in Washington State

Site Number	Site Name	Meteorological Data		
1	Prosser Barricade	WS, WD, T, P		
2	Emergency Operations Center	WS, WD, T, P		
3	Army Loop Road	WS, WD, T, P		
4	Rattlesnake Springs	WS, WD, T, P		
5	Edna Railroad Crossing	WS, WD, T		
6	200 East Area	WS, WD, T, P, AP		
7	200 West Area	WS, WD, T, P		
8	Beverly, Washington	WS, WD, T, P		
9	Fast Flux Test Facility (61 m or 200 ft)	WS, WD, T, TD, DP, P, AP		
10	Yakima Barricade	WS, WD, T, P, AP		
11	300 Area (61 m or 200 ft)	WS, WD, T, TD, DP, P, AP		
12	Wye Barricade	WS, WD, T, P		
13	100-N Area (61 m or 200 ft)	WS, WD, T, TD, DP, P, AP		
14	Energy Northwest	WS, WD, T, P		
15	Franklin County	WS, WD, T		
16	Gable Mountain	WS, WD, T		
17	Ringold, Washington	WS, WD, T, P		
18	Richland Airport	WS, WD, T, AP		
19	Plutonium Finishing Plant	WS, WD, T, AP		
20	Rattlesnake Mountain	WS, WD, T, P		
21	Hanford Meteorology Station (124 m or 408 ft)	WS, WD, T, P, DP, AP		
22	Tri-Cities Airport	WS, WD, T, P		
23	Gable West	WS, WD, T		
24	100-F Area	WS, WD, T, P		
25	Vernita Bridge	WS, WD, T		
26	Benton City, Washington	WS, WD, T, P		
27	Vista	WS, WD, T, P		
28 <sup>(a)</sup>	Roosevelt, Washington	WS, WD, T, P, AP		
29	100-K Area	WS, WD, T, P, AP		
30	Hazardous Material Management and Emergency Response Training Center	WS, WD, T		
<p><b>Legend:</b></p> <table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border-right: 1px solid black; padding-right: 10px;">                     AP - Atmospheric Pressure                      DP - Dew Point Temperature                      P - Precipitation                      T - Temperature                 </td> <td style="width: 50%; padding-left: 10px;">                     TD - Temperature Difference (between 10-m and 60-m Tower Levels)                      WD - Wind Direction                      WS - Wind Speed                 </td> </tr> </table> <p>(a) Roosevelt is located on the Columbia River 57 mi west/southwest of the Hanford Site.</p>			AP - Atmospheric Pressure DP - Dew Point Temperature P - Precipitation T - Temperature	TD - Temperature Difference (between 10-m and 60-m Tower Levels) WD - Wind Direction WS - Wind Speed
AP - Atmospheric Pressure DP - Dew Point Temperature P - Precipitation T - Temperature	TD - Temperature Difference (between 10-m and 60-m Tower Levels) WD - Wind Direction WS - Wind Speed			

### 4.1.1 Wind

Wind data at the HMS are collected 2.1 m (7 ft) above the ground and at the 15.2-, 61.0-, and 121.9-m (50-, 200-, and 400-ft) levels on the 124-m (408-ft) tower. Each of the three 61-m (200-ft) towers has wind-measuring instrumentation at the 10-, 25-, and 60-m (33-, 82-, and 197-ft) levels. The short towers measure winds 9.1 m (30 ft) above ground level.

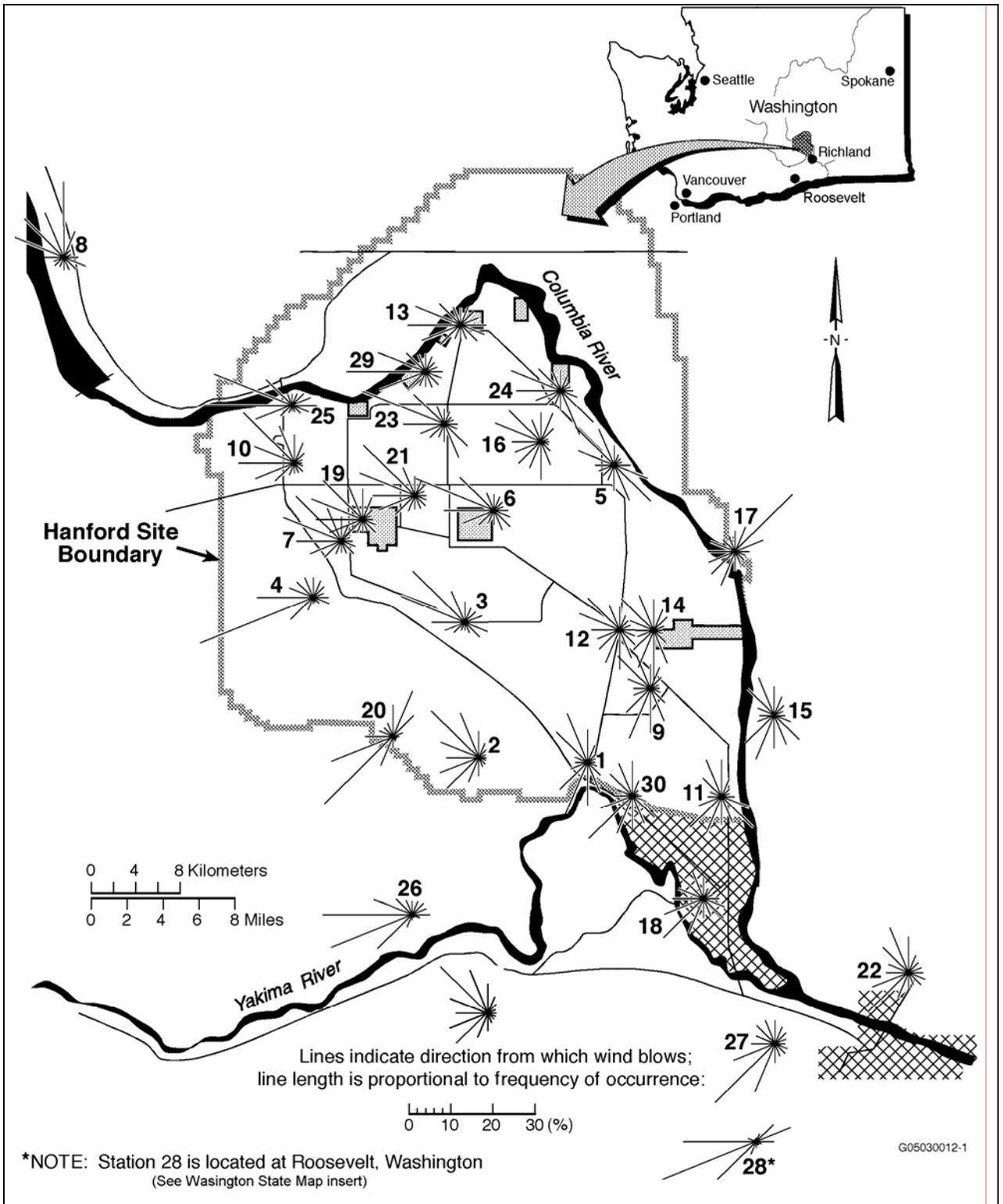
The prevailing surface winds on Hanford's Central Plateau are from the northwest (Figure 4.1-2), and occur most frequently during the winter and summer. Winds from the southwest also have a high frequency of occurrence on the Central Plateau. During the spring and fall, there is an increase in the frequency of winds from the southwest and a corresponding decrease in winds from the northwest.

In the southeastern portion of the Hanford Site (including the 300 [Station 11] and 400 [Station 9] Areas), the prevailing wind direction near the surface is from the southwest during most months; winds from the northwest are much less common (Figure 4.1-2). In the 100 Area and along the Columbia River, local winds are strongly influenced by the topography near the river. At the 100-K (Station 29) and 100-N (Station 13) Areas, the prevailing wind direction is from the west. At the 100-F (Station 24) Area and near the Old Hanford Townsite (Edna Railroad crossing [Station 5]), winds often have a northwesterly or southeasterly component.

Stations that are relatively close together can exhibit significant differences in wind patterns. For example, the stations at Rattlesnake Springs (Station 4) and the 200 West Area (Station 7) are separated only by about 5 km (3 mi), yet the wind patterns at the two stations are very different (Figure 4.1-2). Care should be taken when assessing the appropriateness of the wind data used in estimating environmental impacts. When possible, wind data from the closest representative station should be used for estimating local dispersion conditions.

Monthly and annual joint-frequency distributions of wind direction versus wind speed for the HMS are reported in Hoitink et al. (2005). Monthly average wind speeds 15.2 m (50 ft) above the ground are lower during the winter months, averaging 2.7 to 3.1 m/s (6 to 7 mph), and faster during the spring and summer, averaging 3.6 to 4.0 m/s (8 to 9 mph) (Table 4.1-2). The fastest wind speeds at the HMS are usually associated with flow from the southwest (Table 4.1-2). However, the summertime drainage winds from the northwest frequently exceed speeds of 13 m/s (30 mph). The maximum speed of the drainage winds (and their frequency of occurrence) tends to decrease as one moves toward the southeast across the Hanford Site. The HMS averages 156 days per year with peak wind gusts greater than or equal to 11 m/s (25 mph) (ranging from a low of about 7 in December to high of nearly 20 in June and July), and 57 days with peak gusts greater than or equal to 16 m/s (35 mph) (from a low of about 3 days in September and October to a high of about 6 days during the months of April through July) (Table 4.1-3).

Surface features have less influence on winds aloft than on winds near the surface. However, substantial spatial variations are found in the wind distributions across Hanford 60 m (197 ft) above ground level (Figure 4.1-3). For releases at greater heights, the most representative data may come from the closest representative 61-m (200-ft) tower rather than the nearest 9.1-m (30-ft) tower.



**Figure 4.1-2.** Wind Roses at the 9.1 m (30 ft) Level of the Hanford Meteorological Monitoring Network, Washington, 1982 through 2004 (after Hoitink et al. 2005)

**Table 4.1-2.** Monthly and Annual Wind-Related Data Collected at the 15-m (50-ft) Level, 1945 through 2004, Hanford Meteorology Station, Washington (Hoitink et al. 2005)

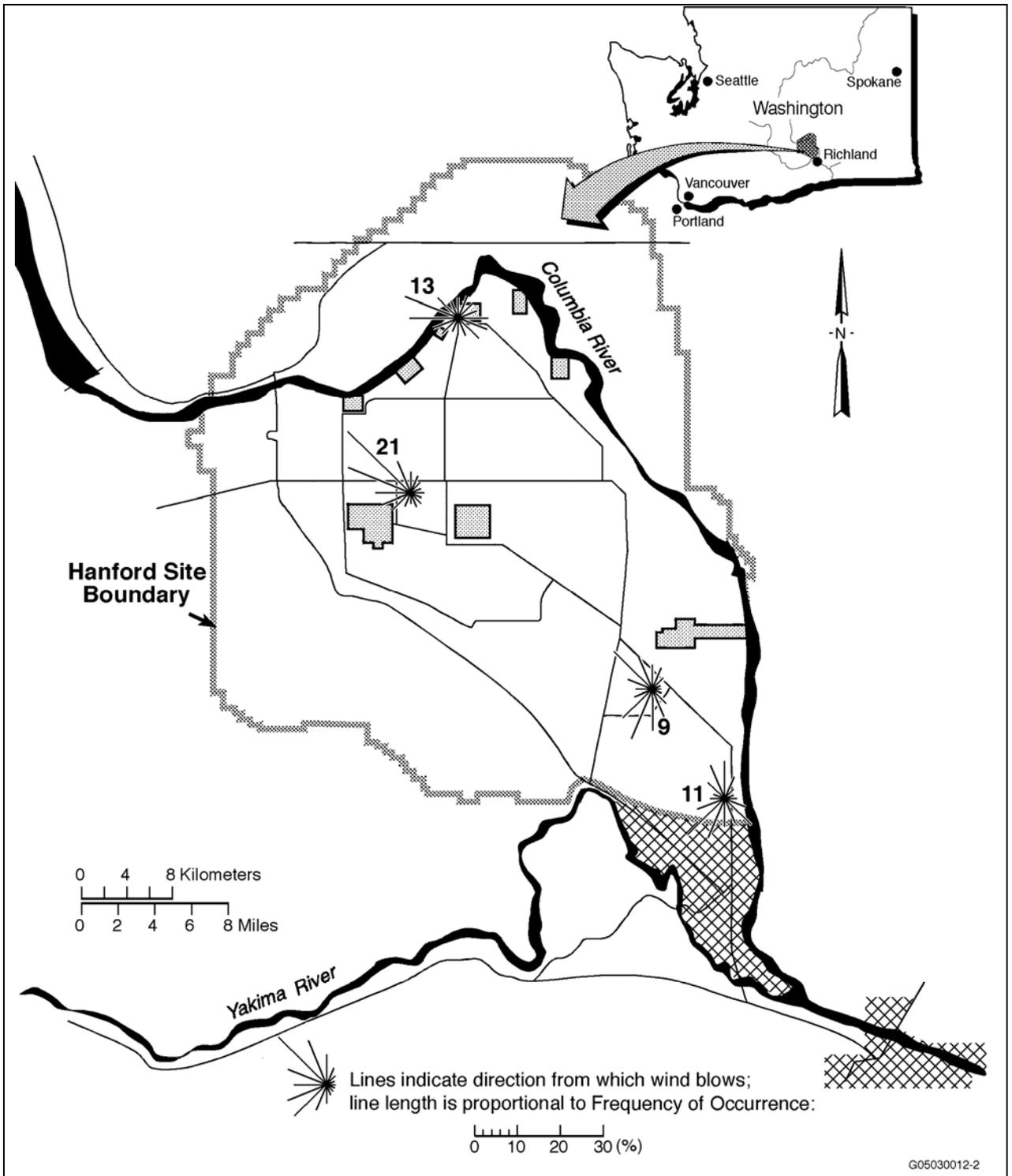
Month	Prevailing Direction	Average Speed (mph) <sup>(a)</sup>	Highest Average (mph)	Year	Lowest Average (mph)	Year	Speed (mph)	Direction	Year
January	NW	6.3	10.3	1972	2.9	1985	80	SW	1972
February	NW	7.0	11.1	1999	4.6	1963	65	SSW	1999 <sup>(b)</sup>
March	WNW	8.2	10.7	1977 <sup>(b)</sup>	5.9	1958	70	SW	1956
April	WNW	8.8	11.1	1972 <sup>(b)</sup>	7.4	1989 <sup>(b)</sup>	73	SSW	1972
May	WNW	8.8	10.7	1983	5.8	1957	71	SSW	1948
June	NW	9.1	10.7	1983 <sup>(b)</sup>	7.7	1950 <sup>(b)</sup>	72	SW	1957
July	NW	8.6	10.7	1983	6.8	1955	69	WSW	1979
August	WNW	8.0	9.5	1996	6.0	1956	66	SW	1961
September	WNW	7.4	9.2	1961	5.4	1957	65	SSW	1953
October	NW	6.6	9.1	1946	4.4	1952	72	SW	1997
November	NW	6.4	10.0	1990	2.9	1956	67	WSW	1993
December	NW	6.0	8.3	1968	3.3	1985	71	SW	1955
Annual	NW	7.6	8.8	1999	6.2	1989	80	SW	1972

(a) 1 mph = 1.61 km/hr or 0.447 m/s  
(b) Most recent of multiple occurrences

**Table 4.1-3.** Number of Days with Peak Gusts above Specific Thresholds at the 15-m (50-ft) Level, 1945 through 2004, Hanford Meteorology Station, Washington (Hoitink et al. 2005)

Month	Days with Peak Gusts $\geq 11$ m/s (25 mph)					Days with Peak Gusts $\geq 16$ m/s (35 mph)				
	Avg	Max	Year	Min	Year	Avg	Max	Year	Min	Year
January	7.6	21	1953	0	1985 <sup>(a)</sup>	4.0	14	1953	0	1985 <sup>(a)</sup>
February	8.5	17	1976 <sup>(a)</sup>	2	2004 <sup>(a)</sup>	3.7	14	1976	0	2004 <sup>(a)</sup>
March	13.2	21	1977	4	1992	5.5	14	1997	0	1992
April	16.9	26	1954	8	1946	6.2	12	1972	1	1967
May	18.8	26	1978	9	1945	6.2	13	2002	0	1957
June	19.7	26	1963	11	1950 <sup>(a)</sup>	6.4	12	2002 <sup>(a)</sup>	1	1982
July	19.6	26	1995	11	1955	5.6	11	1994 <sup>(a)</sup>	1	1982 <sup>(a)</sup>
August	15.9	24	2000	7	1945	4.2	12	1996	0	1978 <sup>(a)</sup>
September	11.4	17	2002 <sup>(a)</sup>	7	1975 <sup>(a)</sup>	3.4	7	2003 <sup>(a)</sup>	0	1975
October	9.1	19	2003	3	1987 <sup>(a)</sup>	3.3	11	1997	0	1993 <sup>(a)</sup>
November	8.3	16	1990	0	1979	3.8	10	1998	0	1997 <sup>(a)</sup>
December	7.4	15	1968	0	1985	4.2	11	1957	0	1985 <sup>(a)</sup>
Annual	156.4	192	1999	123	1952	56.6	86	2002	31	1978

(a) Most recent of multiple occurrences



**Figure 4.1-3.** Wind Roses at the 60-m (197-ft) Level of the Hanford Meteorological Monitoring Network, Washington, 1986 through 2004 (Hoitink et al. 2005)

## 4.1.2 Temperature and Humidity

The 124-m (408-ft) tower at the HMS has temperature-measuring instrumentation at the following levels: 0.9, 9.1, 15.2, 30.5, 61.0, 76.2, 91.4, and 121.9 m (3, 30, 50, 100, 200, 250, 300, and 400 ft). The three 61-m (200-ft) towers have temperature-measuring instrumentation at the 2, 10, and 60 m (approximately 6.5, 33, and 197 ft) levels. Temperatures are measured at the 2-m (6.5-ft) level on the 9-m (30-ft) towers. Relative humidity/dew point temperature measurements are made at the HMS and at the three 61-m (200-ft) tower locations.

Monthly averages and extremes of temperature, dew point, and humidity are presented in Hoitink et al. (2005). Based on data collected from 1946 through 2004, the average monthly temperatures at the HMS range from a low of  $-0.7^{\circ}\text{C}$  ( $31^{\circ}\text{F}$ ) in January to a high of  $24.7^{\circ}\text{C}$  ( $76^{\circ}\text{F}$ ) in July. The highest winter monthly average temperature was  $6.9^{\circ}\text{C}$  ( $44^{\circ}\text{F}$ ) in February 1958 and February 1991, and the lowest average monthly temperature was  $-11.1^{\circ}\text{C}$  ( $12^{\circ}\text{F}$ ) in January 1950. The highest monthly average temperature was  $27.9^{\circ}\text{C}$  ( $82^{\circ}\text{F}$ ) in July 1985 and the lowest summer monthly average temperature was  $17.2^{\circ}\text{C}$  ( $63^{\circ}\text{F}$ ) in June 1953.

Daily maximum temperatures at the HMS vary from an average of  $2^{\circ}\text{C}$  ( $35^{\circ}\text{F}$ ) in late December and early January to  $36^{\circ}\text{C}$  ( $96^{\circ}\text{F}$ ) in late July. There are, on average, 52 days during the summer months with maximum temperatures greater than or equal to  $32^{\circ}\text{C}$  ( $90^{\circ}\text{F}$ ) and 12 days with maxima greater than or equal to  $38^{\circ}\text{C}$  ( $100^{\circ}\text{F}$ ). The largest number of consecutive days on record with maximum daily temperatures greater than or equal to  $32^{\circ}\text{C}$  ( $90^{\circ}\text{F}$ ) is 32 days. The record maximum temperature,  $45^{\circ}\text{C}$  ( $113^{\circ}\text{F}$ ) occurred at the HMS on July 13, 2002 and August 4, 1961.

From mid-November through early March, the average daily minimum temperature is below freezing; the daily minimum in late December and early January is  $-6^{\circ}\text{C}$  ( $21^{\circ}\text{F}$ ). On average, the daily minimum temperature of less than or equal to  $-18^{\circ}\text{C}$  (approximately  $0^{\circ}\text{F}$ ) occurs only 3 days per year; however, only about one winter in two experiences such low temperatures. The greatest number of consecutive days on record with minimum daily temperatures of less than or equal to  $-18^{\circ}\text{C}$  ( $0^{\circ}\text{F}$ ) is 11 days. The record minimum temperature,  $-31^{\circ}\text{C}$  ( $-23^{\circ}\text{F}$ ) occurred on both February 1 and 3, 1950.

The annual average relative humidity at the HMS is 55 percent. It is highest during the winter months, averaging about 76 percent, and lowest during the summer, averaging about 36 percent. The annual average dewpoint temperature at the HMS is  $1^{\circ}\text{C}$  ( $34^{\circ}\text{F}$ ). In the winter, the dewpoint temperature averages about  $-3^{\circ}\text{C}$  ( $27^{\circ}\text{F}$ ), and in the summer it averages about  $6^{\circ}\text{C}$  ( $43^{\circ}\text{F}$ ).

## 4.1.3 Precipitation

Average annual precipitation at the HMS is 17 cm (6.8 in.). During 1995, the wettest year on record, 31.3 cm (12.3 in.) of precipitation was measured; during 1976, the driest year, only 7.6 cm (3 in.) was measured. The wettest season on record was the winter of 1996-1997 with 14.1 cm (5.4 in.) of precipitation; the driest season was the summer of 1973, when only 0.1 cm (0.03 in.) of precipitation was measured. Most precipitation occurs during the late autumn and winter, with more than half of the annual amount occurring from November through February. Days with greater than 1.3 cm (0.50 in.) precipitation occur on average less than one time each year.

Average snowfall ranges from 0.25 cm (0.1 in.) during October to a maximum of 13.2 cm (5.2 in.) during December and decreases to 1.3 cm (0.5 in.) during March. The record monthly snowfall of 59.4 cm (23.4 in.) occurred during January 1950. The seasonal record snowfall of 142.5 cm (56.1 in.)

occurred during the winter of 1992-1993. Snowfall accounts for about 38 percent of all precipitation from December through February.

#### 4.1.4 Fog and Visibility

Fog has been recorded during every month of the year at the HMS; however, 89 percent of the occurrences are from November through February, with less than 3 percent from April through September (Table 4.1-4). The average number of days per year with fog (visibility less than or equal to 9.6 km [6 mi]) is 48, while those with dense fog (visibility less than or equal to 0.4 km [0.25 mi]) number 25. The greatest number of days with fog was 84 days during 1985–1986, and the least was 22 during 1948–1949. The greatest number of days with dense fog was 42 during 1950–1951, and the least was 9 during 1948–1949. The greatest persistence of fog was 114 hours (December 1985) and the greatest persistence of dense fog was 47 hours (December 1957).

Other phenomena causing restrictions to visibility (i.e., visibility less than 9.6 km [6 mi]) include dust, blowing dust, and smoke from field burning. There are few such days; an average of 5 days per year have dust or blowing dust, and less than 1 day per year, on average, has reduced visibility from smoke.

**Table 4.1-4.** Number of Days with Fog by Season, Hanford Site, Washington

Category	Winter	Spring	Summer	Autumn	Total
fog	32	3	≤1	12	48
dense fog	17	1	≤1	7	25

#### 4.1.5 Severe Weather

Concerns about severe weather usually center on hurricanes, tornadoes, and thunderstorms. Fortunately, Washington does not experience hurricanes; tornadoes are infrequent and generally small in the northwestern portion of the United States. The National Climatic Data Center maintains a database that provides information on the incidence of tornados reported in each county in the United States. This database can be accessed via the Internet at: <http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms>.

This database reports that in the ten counties closest to the Hanford Site (Benton, Franklin, Grant, Adams, Yakima, Klickitat, Kittitas, and Walla Walla counties in Washington and Umatilla and Morrow counties in Oregon), there have been only 24 tornadoes recorded from 1950 through November 2004. Of these, 17 tornadoes had maximum wind speeds estimated to be in the range of 18 to 32 m/s (40 to 72 mph), four had maximum wind speeds in the range of 33 to 50 m/s (73 to 112 mph), and three had maximum wind speeds in the range of 51 to 71 m/s (113 to 157 mph). There were no deaths or substantial property damage (in excess of \$50,000) associated with any of these tornadoes.

Ramsdell and Andrews (1986) report that for the 5° block centered at 117.5° west longitude and 47.5° north latitude (where the Hanford Site is located), the expected path length of a tornado is 7.6 km (5 mi), the expected width is 95 m (312 ft), and the expected area is about 1.5 km<sup>2</sup> (1 mi<sup>2</sup>). The estimated probability of a tornado striking a point on the Hanford Site is 9.6 x 10<sup>-6</sup>/yr (Ramsdell and Andrews 1986). The probabilities of extreme winds associated with tornadoes striking a point can be estimated using the distribution of tornado intensities for the region (Table 4.1-5).

**Table 4.1-5.** Estimate of the Probability of Extreme Winds Associated with Tornadoes Striking a Point at Hanford, Washington (after Ramsdell and Andrews 1986)

Wind Speed		Probability Per Year
(m/s)	(mph)	
28	62	$2.6 \times 10^{-6}$
56	124	$6.5 \times 10^{-7}$
83	186	$1.6 \times 10^{-7}$
111	249	$3.9 \times 10^{-8}$

The average occurrence of thunderstorms in the vicinity of the HMS is ten per year. They are most frequent during the summer; however, they have occurred in every month. Thunderstorms can generate high-speed winds and hail. Using the National Weather Service criteria for classifying a thunderstorm as “severe” (i.e., hail with a diameter greater than or equal to 19 mm [3/4 in.] or wind gusts greater than or equal to 25.9 m/s [58 mph]), only 1.9 percent of all thunderstorm events surveyed at the HMS have been “severe” storms, and all met the criteria based on their wind gusts. High-speed winds at Hanford are more commonly associated with strong cold frontal passages. In rare cases, intense low-pressure systems can generate winds of near hurricane force (Table 4.1-6).

**Table 4.1-6.** Estimates of Extreme Winds at the Hanford Site, Washington (Hoitink et al. 2005)

Return Period (yr)	<u>Peak Gusts</u>			
	15.2 m (50 ft) above Ground		61 m (200 ft) above Ground	
	(m/s)	(mph)	(m/s)	(mph)
2	27	60	30	67
10	32	71	36	80
100	38	85	43	96
1000	44	98	50	111

## 4.2. Air Quality

*B.G. Fritz*

A variety of atmospheric monitoring is done on and around the Hanford Site, allowing a relatively detailed analysis of air quality. The primary air pollutant of concern for the Hanford Site is radiological contamination. Radiological contamination becomes airborne as a result of stack emissions, diffuse emissions, and resuspension of contaminated material from the ground. Dust is another air quality parameter of particular interest on and around the Hanford Site. Although the dust (or particulate matter) concentrations are generally low, the local environment results in periodic windblown dust storms, raising the interest in particulate matter concentrations. Emissions of other nonradiological gaseous compounds are measured, but due to the low regional concentrations, these compounds are generally of less concern. The following sections summarize the ambient air monitoring programs and emissions measurements that occur, and provide a general synopsis of regional air quality.

### 4.2.1 Atmospheric Dispersion

Atmospheric dispersion is a function of wind speed, duration and direction of wind, intensity of atmospheric turbulence, and mixing depth. Atmospheric turbulence is not directly measured at the Hanford Site; instead, the impact of turbulence on atmospheric dispersion is characterized using atmospheric stability. Atmospheric stability describes the thermal stratification or vertical temperature structure of the atmosphere. Generally, six or seven different classes of atmospheric stability are used to describe the atmosphere. These classes range from extremely unstable (when atmospheric turbulence is greatest) to extremely stable (when atmospheric mixing is at a minimum). When the atmosphere is unstable, pollutants can rapidly diffuse through a large volume of the atmosphere. When the atmosphere is stable, pollutants will diffuse much more slowly in a vertical direction. Horizontal dispersion may be limited during stable conditions; however, plumes may also fan out horizontally during stable conditions, particularly when the wind speed is low. Most major pollutant incidents have been associated with stable conditions when inversions can trap pollutants near the ground.

Conditions likely to increase dispersion are most common in the summer when neutral and unstable stratification exists, about 56 percent of the time (Stone et al. 1983). Conditions less likely to promote dispersion are most common during the winter when moderately to extremely stable stratification exists, about 66 percent of the time (Stone et al. 1983). Less-favorable conditions also occur periodically for surface and low-level releases in all seasons from about sunset to about an hour after sunrise as a result of ground-based temperature inversions and shallow mixing layers. Occasionally, there are extended periods of poor dispersion conditions associated with stagnant air in stationary high-pressure systems. These instances tend to occur during the winter months (Stone et al. 1983).

Stone et al. (1972) estimated the probability of extended periods of poor dispersion conditions. The probability of an inversion once established persisting more than 12 hours varies from a low of about 10 percent in May and June to a high of about 64 percent in September and October. These probabilities decrease rapidly for durations of more than 12 hours and are associated with extended surface-based inversions (Table 4.2-1).

Many simple dispersion models use the joint frequency distribution of atmospheric stability, wind speed, and wind direction to compute diffusion factors for both chronic and acute releases. Joint frequency distributions for atmospheric stability, wind speed, and transport direction have been estimated for the data collected at the 100-N, 200, 300, and 400 Areas from two release heights (9.1 m and

**Table 4.2-1.** Percent Probabilities for Extended Periods of Surface-Based Inversions, Hanford Site, Washington (after Stone et al. 1972)

Months	Inversion Duration		
	12-hr	24-hr	48-hr
January-February	54.0	2.5	0.28
March-April	50.0	<0.1	<0.1
May-June	10.0	<0.1	<0.1
July-August	18.0	<0.1	<0.1
September-October	64.0	0.11	<0.1
November-December	50.0	1.2	0.13

60 m [30 ft and 197 ft]) (Tables A1 through A8, Appendix A). For each station, the joint frequency distributions were determined using wind measurements and calculated stability.

The annual sector-average atmospheric dispersion coefficient ( $X/Q'$ ) where  $X$  is the air concentration ( $C_i/m^3$ ) and  $Q'$  is the emission rate ( $C_i/s$ ) were estimated for ground level and 60 m (197 ft) releases (Tables A9 through A16, Appendix A). The 95 percent centerline atmospheric dispersion estimates ( $E/Q'$ ) for the four major Hanford operating areas (100, 200, 300, and 400 Areas) were estimated from atmospheric data (Tables A17 through A24, Appendix A). These dispersion factors are presented as a function of direction and distance from the release point and are based on meteorological data collected during the years 1983 through 2002.

#### 4.2.2 Nonradiological Air Quality

The Clean Air Act (CAA) is the basis for federal regulation of air quality in the United States (42 USC 7401). The CAA was first passed during 1967 and was comprehensively amended in 1970, 1977, and 1990. Section 108 of the CAA calls for the U.S. Environmental Protection Agency (EPA) to promulgate a list of air pollutants that are emitted by numerous or diverse sources and whose presence in the atmosphere may reasonably be expected to endanger public health or welfare. In response to this mandate, EPA has issued regulations in 40 CFR 50 setting national ambient air quality standards. These standards are not directly enforceable, but other enforceable regulations are based on these standards. The states have primary responsibility for ensuring that their air quality meets the national ambient air quality standards through implementation plans that are approved by EPA. Areas that meet ambient air quality standards are said to be “in attainment.” Areas that fail to meet one or more ambient air standards are designated as “nonattainment areas.” The CAA also establishes a permitting program for construction or modification of large sources of air pollutants in both attainment and nonattainment areas and an operating permit program.

Section 176 of the CAA states that federal agencies are not to engage in, support in any way, provide financial assistance for, license, permit, or approve any activity that does not conform to an applicable state implementation plan. The DOE has guidance (DOE 2000) on how to apply the CAA conformity requirements and associated EPA regulations in a NEPA document and how to coordinate the CAA and NEPA public participation requirements.

Ambient air quality standards define levels of air quality that are necessary, with an adequate margin of safety, to protect the public health (primary standards) and the public welfare (secondary standards). “Ambient air” is that portion of the atmosphere, external to buildings, to which the general public has access (40 CFR 50.1). EPA has issued ambient air standards for sulfur oxides (measured as sulfur dioxide), nitrogen dioxide, carbon monoxide, lead, ozone, and PM<sub>10</sub>, which is an air pollutant consisting of small particles with an aerodynamic diameter less than or equal to 10 µm. The standards specify the maximum pollutant concentrations and frequencies of occurrence that are allowed for specific averaging periods. The averaging periods vary from 1 hour to 1 year, depending on the pollutant.

State and local governments have the authority to impose standards for ambient air quality that are stricter than the national standards (Table 4.2-2). Washington State has established more stringent standards for sulfur dioxide. In addition, Washington has established standards for total suspended particulates (WAC 173-470) and fluorides (WAC 173-481) that are not covered by national standards. The state standards for carbon monoxide, nitrogen dioxide, PM<sub>10</sub>, and lead are identical to the national standards. Benton County and the Hanford Site are “in attainment” for all standards outlined in Table 4.2-2.

On July 18, 1997, EPA issued new air quality standards for particulate matter with a diameter of 2.5 µm or less (PM<sub>2.5</sub>) and an 8-hour ozone standard. Decisions on violations of the new particulate matter and ozone standard were delayed for 5 to 8 years to give states time to set up monitoring networks and obtain 3 years of data (Ecology 1997).

#### **4.2.2.1 Prevention of Significant Deterioration**

Prevention of significant deterioration permits are issued to large sources of pollutants subject to ambient air standards in attainment areas. The Plutonium-Uranium Extraction (PUREX) and Uranium Trioxide (UO<sub>3</sub>) facilities were issued a prevention of significant deterioration permit for nitrogen oxide emissions during 1980. These facilities were permanently shut down in the late 1980s and deactivated in the 1990s. None of the currently operating Hanford facilities have nonradiological emissions of sufficient magnitude to warrant consideration under prevention of significant deterioration regulations.

#### **4.2.2.2 Emissions of Nonradiological Pollutants**

Nonradiological pollutants are mainly emitted from power-generating and chemical-processing facilities in the 200 and 300 Areas on the Hanford Site (Table 4.2-3). The 100, 400, and 600 Areas do not have any nonradiological emission sources of concern (Poston et al. 2005).

#### **4.2.2.3 Offsite Monitoring**

During 1998, the Washington State Department of Ecology (Ecology) conducted offsite monitoring near the Hanford Site for PM<sub>10</sub> (Ecology 1999, 2000). PM<sub>10</sub> was monitored at one location in Benton County, the Tri-Tech Vocational Center near the Hanford network’s Vista Field meteorological monitoring site in Kennewick. The Benton Clean Air Authority currently conducts particulate monitoring at Tri-Tech Vocational Center to demonstrate compliance with EPA and Washington State standards (Table 4.2-2). During 2004, the maximum measured PM<sub>10</sub> concentration was 91 µg/m<sup>3</sup>, and the second highest measured concentration was 85 µg/m<sup>3</sup> (EPA 2005). The annual average PM<sub>10</sub> concentration reported for Benton County was 22 µg/m<sup>3</sup> (EPA 2005). The maximum measured PM<sub>2.5</sub> concentration for Benton County during 2004 was 48 µg/m<sup>3</sup>, and the 2004 annual average PM<sub>2.5</sub> concentration was 7.6 µg/m<sup>3</sup> (EPA 2005). These 2004 measured concentrations were less than EPA and Washington State standards.

**Table 4.2-2.** U.S. Environmental Protection Agency (EPA) and Washington State Ambient Air Quality Standards <sup>(a)</sup>

Pollutant	EPA Primary	EPA Secondary	Washington State
<b>Total Suspended Particulates</b>			
annual geometric mean	NS <sup>(b)</sup>	NS	60 µg/m <sup>3</sup>
24-hr average	NS	NS	150 µg/m <sup>3</sup>
<b>PM<sub>10</sub></b> <sup>(c)</sup>			
annual arithmetic mean	50 µg/m <sup>3</sup>	50 µg/m <sup>3</sup>	50 µg/m <sup>3</sup>
24-hr average	150 µg/m <sup>3</sup>	150 µg/m <sup>3</sup>	150 µg/m <sup>3</sup>
<b>PM<sub>2.5</sub></b> <sup>(d)</sup>			
annual arithmetic mean	15 µg/m <sup>3</sup>	15 µg/m <sup>3</sup>	NS
24-hr average	65 µg/m <sup>3</sup>	65 µg/m <sup>3</sup>	
<b>Sulfur Dioxide</b>			
annual average	0.03 ppm (≅80 µg/m <sup>3</sup> )	NS	0.02 ppm (≅50 µg/m <sup>3</sup> )
24-hr average	0.14 ppm (≅365µg/m <sup>3</sup> )	NS	0.10 ppm (≅260 µg/m <sup>3</sup> )
3-hr average	NS	0.50 ppm (≅1.3 mg/m <sup>3</sup> )	NS
1-hr average	NS	NS	0.40 ppm (≅1.0 mg/m <sup>3</sup> ) <sup>(e)</sup>
<b>Carbon Monoxide</b>			
8-hr average	9 ppm (≅10 mg/m <sup>3</sup> )	9 ppm (≅10 mg/m <sup>3</sup> )	9 ppm (≅10 mg/m <sup>3</sup> )
1-hr average	35 ppm (≅40 mg/m <sup>3</sup> )	35 ppm (≅40 mg/m <sup>3</sup> )	35 ppm (≅40 mg/m <sup>3</sup> )
<b>Ozone</b>			
8-hr average	0.08 ppm (~157 µg/m <sup>3</sup> )	0.08 ppm (~157 µg/m <sup>3</sup> )	NS
1-hr average	0.12 ppm (≅235 µg/m <sup>3</sup> )	0.12 ppm (≅235 µg/m <sup>3</sup> )	0.12 ppm (≅235 µg/m <sup>3</sup> )
<b>Nitrogen Dioxide</b>			
annual average	0.053 ppm (≅100 µg/m <sup>3</sup> )	0.053 ppm (≅100 µg/m <sup>3</sup> )	0.053 ppm (≅100 µg/m <sup>3</sup> )
<b>Lead</b>			
quarterly average	1.5 µg/m <sup>3</sup>	1.5 µg/m <sup>3</sup>	1.5 µg/m <sup>3</sup>
<b>Fluorides</b>			
12-hr average	NS	NS	3.7 µg/m <sup>3</sup>
24-hr average			2.9 µg/m <sup>3</sup>
7 day average			1.7 µg/m <sup>3</sup>
30 day average			0.84 µg/m <sup>3</sup>
Abbreviations: ppm = parts per million; µg/m <sup>3</sup> = micrograms per cubic meter; mg/m <sup>3</sup> = milligrams per cubic meter.			
(a) Source: 40 CFR 50 and WAC 173-470 – 173-481. Annual standards are never to be exceeded; short-term standards are not to be exceeded more than once per year unless otherwise noted. Particulate pollutants are in micrograms per cubic meter. Gaseous pollutants are in parts per million and equivalent micrograms (or milligrams) per cubic meter.			
(b) NS = no standard.			
(c) PM <sub>10</sub> - small particles in the air with an aerodynamic diameter less than or equal to 10 micrometers.			
(d) PM <sub>2.5</sub> - small particles in the air with an aerodynamic diameter less than or equal to 2.5 micrometers. Currently the PM <sub>2.5</sub> standard is not enforced by the EPA.			
(e) 0.25 ppm not to be exceeded more than twice in any 7 consecutive days.			

**Table 4.2-3.** Nonradioactive Constituents Discharged to the Atmosphere during 2004, Hanford Site, Washington (Poston et al. 2005)

<b>Constituent</b>	<b>Release, kg (lb)</b>
particulate matter	5,000 (11,000)
nitrogen oxides	11,000 (25,000)
sulfur oxides	2,700 (6,000)
carbon monoxide	16,000 (34,000)
lead	0.44 (1.0)
volatile organic compounds <sup>(a,b)</sup>	11,000 (25,000)
ammonia <sup>(c)</sup>	13,000 (28,000)
other toxic air pollutants <sup>(d)</sup>	6,800 (15,000)
<p>(a) The estimate of volatile organic compound emissions does not include emissions from certain laboratory operations.</p> <p>(b) Produced from burning fossil fuel for steam and electrical generators, calculated estimates from the 200 East and 200 West Area tank farms, and the 242-A Evaporator, and the 200 Area Effluent Treatment Facility.</p> <p>(c) Estimated ammonia releases are from the 200 East and 200 West Area tank farms, the 242-A Evaporator, and the 200 Area Effluent Treatment Facility.</p> <p>(d) Releases are a composite of calculated estimates of toxic air pollutants, excluding ammonia, from the 200 East and 200 West Area tank farms, the 242-A Evaporator, and the 200 Area Effluent Treatment Facility.</p>	

#### 4.2.2.4 Background Monitoring

During the last 10 years, carbon monoxide, sulfur dioxide, and nitrogen dioxide have been monitored periodically in communities and commercial areas south-southeast of Hanford. These urban measurements are typically used to estimate the maximum background pollutant concentrations for the Hanford Site because of the lack of specific onsite monitoring.

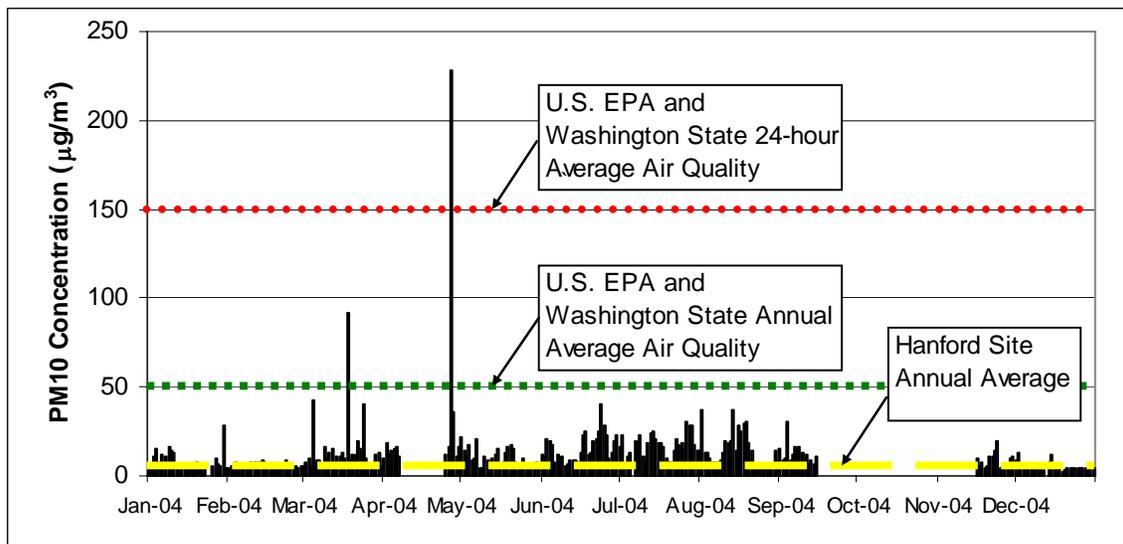
Particulate concentrations can reach relatively high levels in eastern Washington because of exceptional natural events (i.e., dust storms and large brushfires) that occur in the region. During June 1996, EPA adopted the policy that allows dust storms to be treated as uncontrollable natural events (EPA 1996). This means that EPA will not designate areas affected by dust storms as nonattainment. However, states are required to develop and implement a natural events action plan.

Areas that require more strict controls on air quality impacts are regions that have been determined to be nonattainment areas by the EPA. Federal Class I areas include certain national parks and wilderness areas. Actions on the Hanford Site are unlikely to have any effect on these types of areas. The nearest nonattainment area to the Hanford Site is the Wallula area (located approximately 30 km [20 mi] southeast of the Site), which is a nonattainment area for PM<sub>10</sub> (40 CFR 81.348, 66 FR 9663). The major source of PM<sub>10</sub> in the Wallula area is from windblown dust. In making the nonattainment determination, EPA found that even if some of the data from the Wallula monitoring site are considered uncontrollable natural events and excluded from consideration in determining the air quality status of the area, the remaining data still show that the Wallula area has not attained the PM<sub>10</sub> national ambient air quality standard (66 FR 9663). The non-attainment status is under review, and may change sometime during 2005.

The nearest Federal Class I areas to the Hanford Site are Mount Rainer National Park, 160 km (100 mi) west of the Site; Goat Rocks Wilderness Area, approximately 145 km (90 mi) west of the Site; Mount Adams Wilderness Area, approximately 150 km (95 mi) southwest of the Site; and Alpine Lakes Wilderness Area, approximately 175 km (110 mi) northwest of the Site (40 CFR 81.434). Operations at the Hanford Site should have no discernable effects on these areas because of their distance from the Site and because topography and prevailing winds tend to prevent Hanford emissions from reaching these Class I areas.

#### 4.2.2.5 Onsite Monitoring

Monitoring of particulate matter mass concentrations in air on the Hanford Site began during February 2001.  $PM_{10}$  data have been collected at the HMS since February 2001, while  $PM_{2.5}$  data collection began during October 2001. The observed annual average  $PM_{10}$  concentration at the HMS during 2004 was  $12 \mu\text{g}/\text{m}^3$ . Daily average  $PM_{10}$  concentrations on the Hanford Site were greater than the EPA standard on two days (Figure 4.2-1). The Benton Clean Air Authority (BCAA) conducts air monitoring that is responsible for determining Benton County's compliance with the EPA National Ambient Air Quality Standards (NAAQS), so concentrations on the Hanford Site that are higher than the EPA standard for  $PM_{10}$  are not considered for determining compliance with the EPA NAAQS. All of the elevated  $PM_{10}$  concentrations observed on the Hanford Site during 2004 were associated with high winds. The measured annual average  $PM_{2.5}$  concentration at the HMS during 2004 was  $6.5 \mu\text{g}/\text{m}^3$ , while the highest 24-hr average concentration observed was  $21 \mu\text{g}/\text{m}^3$ . Both of these concentrations were less than EPA standards of  $15 \mu\text{g}/\text{m}^3$  and  $65 \mu\text{g}/\text{m}^3$ , respectively (Table 4.2-2). The annual average particulate matter concentrations observed on the Hanford Site were less than the concentrations measured by the BCAA in Kennewick, Washington.



**Figure 4.2-1.** 24-hr Average Concentrations for Particulate Matter with a Diameter of  $10 \mu\text{m}$  or less at the Hanford Meteorological Station, Washington, 2004

## 4.2.3 Radiological Air Quality

Airborne effluents that may contain radioactive constituents are continually monitored at the Hanford Site. Samples are analyzed for gross alpha and gross beta activity as well as selected radionuclides. Radioactive emissions during 2004 originated in the 100, 200, 300, and 400 Areas. 100 Area emissions originated from the K Basins (irradiated fuel stored in two water-filled storage basins) and the Cold Vacuum Drying Facility, where fuel from the K Basins was prepared for storage. The 200 Area emissions originated from the PUREX Plant, the Waste Encapsulation and Storage Facility, the Plutonium Finishing Plant, T Plant, 222-S Laboratory, underground storage tanks, and waste evaporators. Emissions from the 300 Area originated from the 324 Waste Technology Engineering Laboratory, 325 Radiochemical Processing Laboratory, 327 Post-Irradiation Laboratory, and 340 Vault and Tanks; 400 Area emissions originated at the Fast Flux Test Facility (FFTF) and Maintenance and Storage Facility (Rokkan *et al.* 2005).

### 4.2.3.1 Radiological Emissions

Standards for emissions of radionuclides from DOE facilities have been established by EPA (40 CFR 61) and Washington State (WAC 173-480 and WAC 246-247). Emissions may not exceed quantities that would result in a dose of 10 mrem in a year to a maximally exposed individual (MEI) of the public. Dose to an MEI is calculated through computer modeling that uses radiological emissions to the atmosphere as one input parameter (Table 4.2-4).

### 4.2.3.2 Dose Assessments

Each year dose assessments are conducted to determine doses from Hanford emissions. Different assessments are done to comply with various regulations. A hypothetical MEI dose with contributions from all potential pathways is calculated to satisfy the requirements of DOE Order 5400.5 (DOE 1993). This dose estimate is made to ensure that no member of the public receives a dose exceeding 100 mrem (1000  $\mu$ Sv) per year. Similarly, several dose estimates are made to satisfy the requirements of the Clean Air Act, which stipulates that no member of the public can receive an annual inhalation dose that exceeds 10 mrem (100  $\mu$ Sv).

The annual dose to the Hanford Site maximally exposed individual is estimated using a computer code generated at Pacific Northwest National Laboratory (Napier *et al.* 1998). It estimates dose based on exposure from all potential pathways. For 2004, this MEI dose was calculated to be 0.014 mrem (0.14  $\mu$ Sv) per year (Poston *et al.* 2005). The MEI was modeled to reside at the Sagemoor location in Franklin County, just across the Columbia River from the 300 Area.

The Clean Air Act requires the implementation of an EPA approved dispersion model to be used in order to estimate dose based on measured stack emissions. For the Hanford Site, the annual dose to an offsite MEI from air emissions in 2004 was calculated to be 0.0022 mrem (0.022  $\mu$ Sv) (Poston *et al.* 2005). Based on guidance from EPA Region 10 and the Washington State Department of Health, a dose to a non-DOE worker on the Hanford Site from Hanford emissions was also calculated. This dose was estimated to be 0.0019 mrem (0.019  $\mu$ Sv) per year to an employee of the LIGO facility (Poston *et al.* 2005). Finally, using environmental measurements at the Hanford Site perimeter and CAP-88 dispersion results, a dose to an offsite member of the public from diffuse and fugitive sources is calculated. For 2004, this dose was calculated to be 0.031 mrem (0.31  $\mu$ Sv) per year at the Ringold Sampling location (Poston *et al.* 2005).

**Table 4.2-4.** Radionuclides Discharged to the Atmosphere at the Hanford Site, Washington, 2004  
(Rokkan et al. 2005)

Radionuclide	Releases, Ci <sup>(a)</sup>					
	100 Areas	200 East Area	200 West Area	300 Area	400 Area	Total
<sup>3</sup> H (as HT) <sup>(b)</sup>	NM	NM	NM	1.8 E+00	NM	1.8 E+00
<sup>3</sup> H (as HTO) <sup>(c)</sup>	NM	NM	NM	6.0 E+00	3.6 E-01	6.4 E+00
<sup>60</sup> Co	ND	ND	ND	ND	NM	ND
<sup>85</sup> Kr	NM	NM	NM	2.0 E-04	NM	2.0 E-04
<sup>90</sup> Sr	2.5 E-05 <sup>(d)</sup>	4.8 E-05 <sup>(d)</sup>	6.3 E-05 <sup>(d)</sup>	1.6 E-05 <sup>(d)</sup>	NM	1.4 E-04 <sup>(d)</sup>
<sup>106</sup> Ru	ND	ND	ND	ND	NM	ND
<sup>129</sup> I	NM	1.9 E-03	NM	NM	NM	1.9 E-03
<sup>137</sup> Cs	4.7 E-08	2.0 E-05	4.3 E-06	1.2 E-05 <sup>(e)</sup>	1.2 E-05 <sup>(f)</sup>	3.9 E-05 <sup>(e,f)</sup>
<sup>220</sup> Rn	NM	NM	NM	8.9 E+01 <sup>(g)</sup>	NM	8.9 E+01 <sup>(g)</sup>
<sup>222</sup> Rn	NM	NM	NM	5.8 E-10	NM	5.8 E-10
<sup>234</sup> U	NM	NM	NM	ND	NM	ND
<sup>235</sup> U	NM	NM	NM	ND	NM	ND
<sup>238</sup> U	NM	NM	NM	ND	NM	ND
<sup>232</sup> Th	NM	NM	NM	ND	NM	ND
<sup>238</sup> Pu	2.8 E-06	ND	1.2 E-06	1.1 E-08	NM	4.0 E-06
<sup>239/240</sup> Pu	1.9 E-05 <sup>(h)</sup>	1.7 E-06 <sup>(g)</sup>	6.7 E-05 <sup>(h)</sup>	2.7 E-07 <sup>(h)</sup>	1.4 E-07 <sup>(h)</sup>	8.8 E-05 <sup>(h)</sup>
<sup>241</sup> Pu	1.6 E-04	ND	5.3 E-05	ND	NM	2.1 E-04
<sup>241</sup> Am	1.5 E-05	1.3 E-06	1.1 E-05	8.3 E-08 <sup>(i)</sup>	NM	2.7 E-05
<sup>243</sup> Am	NM	NM	NM	9.0 E-10 <sup>(i)</sup>	NM	9.0 E-10

- (a) 1 Ci = 1 curie = 3.7 E+10 becquerels (Bq); ND = not detected (i.e., either the radionuclide was not detected in any sample during the year or the average of all the measurements for that given radionuclide or type of radioactivity made during the year was below background levels); NM = not measured.
- (b) HT = tritium in the form of incondensable gas.
- (c) HTO = tritium in the form of condensable water vapor.
- (d) This release value includes gross beta data, assumed to be <sup>90</sup>Sr in dose calculations.
- (e) For dose modeling, this value had added to it the value of 9.2 E-06 Ci of gross beta activity, assumed to be <sup>137</sup>Cs in dose calculations.
- (f) This release value derives entirely from FFTF gross beta data, assumed to be <sup>137</sup>Cs in dose calculations.
- (g) Calculated release based on inventory and project process.
- (h) This release value includes gross alpha data, assumed to be <sup>239/240</sup>Pu in dose calculations.
- (i) For dose modeling, this value had added to it the value of 7.8 E-07 Ci of gross alpha, assumed to be <sup>241</sup>Am in dose calculations.

#### **4.2.3.3 Environmental Monitoring**

Both the Surface Environmental Surveillance Project (SESP) and the near-facility environmental monitoring project conduct Hanford Site environmental monitoring. The SESP conducts monitoring at locations across the Hanford Site, as well as at upwind and downwind locations. The near-facility monitoring project primarily collects samples near known effluent sources. Summaries of the 2004 monitoring data from both of these projects are available in the annual Hanford Site Environmental Report (Poston et al. 2005). The spatial coverage of these two monitoring networks is sufficient to identify some Hanford sources. However, the amount of radiological materials in air is so small that there is no difference between upwind and downwind samples for most radionuclides. Atmospheric dispersion reduces Hanford atmospheric emissions to background levels before those emissions leave the site (Poston et al. 2005).

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### 4.3. Geology

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The Hanford Site contains all the main geologic characteristics of the Columbia Basin (DOE 1988). The Columbia Basin is the area bounded by the Cascade Range to the west, the Rocky Mountains to the northeast, and the Blue Mountains to the southeast (Figure 4.3-1). Four major geologic processes occurring over millions of years formed the soil, rocks, and geologic features (ridges and valleys) in the Columbia Basin and therefore the Hanford Site. The area was flooded with numerous basaltic lava flows between 17 and 6 million years ago, as tectonic forces folded the basalt. In this landscape, the ancestral Columbia River flowed across the area leaving behind layers of sediment called the Ringold Formation. Between 1-2 million and 12,000 years ago the area was inundated by a series of Ice-Age floods (including the Missoula floods), which deposited more sediment in what is referred to informally as the Hanford formation.

**Lava Flows.** Lava flows erupted over a period of time from 17 to 6 million years ago. Under the Hanford Site, basaltic lava deposits (Columbia River Basalt Group) are over 4 km (13,000 ft) thick (Reidel and Hooper 1989), spreading over portions of Idaho, Oregon, and Washington. The Columbia Basin encloses the Columbia River Basalt Group. A depression in the south-central part of the Columbia Basin is referred to as the Pasco Basin. The Pasco Basin is bounded by the Saddle Mountains to the north, Naneum Ridge to the west, Rattlesnake Hills to the south, and the Palouse Slope to the east—generally the area north and east of where the Snake River flows into the Columbia River. Geographically, the ridges surrounding the Hanford Site and vicinity define the Pasco Basin, which contains Ringold Formation sediment from the ancestral Columbia River and sediment deposited by the Ice-Age floods.

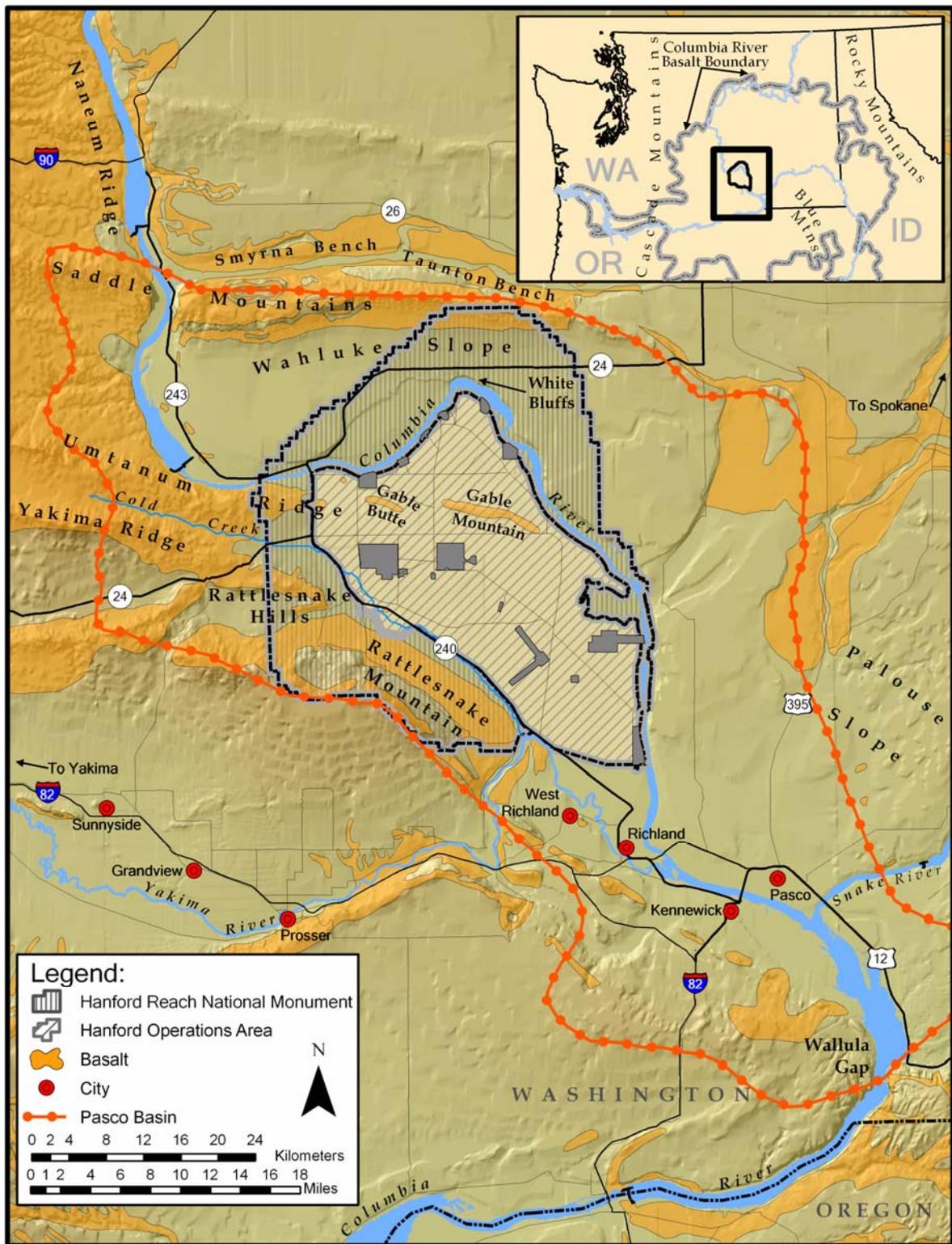
**Crustal Folding.** During and after the eruption of the lava flows, the Earth's tectonic forces buckled and folded the basalt in the western Columbia Basin into generally east-west trending, long, narrow ridges (anticlines) and intervening valleys (synclines). Collectively, this is identified as the Yakima Fold Belt.

**Ancestral Columbia River Deposits.** The Columbia River within the Pasco Basin changed its course over the past 15 million years, depositing gravel, sand, silt, and clay (Tallman et al. 1981, Fecht *et al.* 1987, DOE 1988, Reidel et al. 1994, Lindsey 1996). Uplifting basalt ridges diverted the course of the Columbia River from a southerly direction (toward Goldendale) to the east (toward Wallula Gap) and left behind the sediment called the Ringold Formation (Fecht et al. 1987). Later regional uplift associated with the Cascade Mountains caused the river to cut through its own earlier deposits (the Ringold Formation) exposing the White Bluffs (Figure 4.3-2). The Columbia River continues to erode the White Bluffs. Groundwater seepage from irrigation along the bluffs also makes them unstable. Consequently, the White Bluffs are landsliding and sloughing into the Columbia River along the shoreline (Hays and Schuster 1987, USBR 2002).

**Ice-Age Floods.** The Ice-Age floods began as early as 2.5 million years ago (Bjornstad et al. 2001) with the most recent occurring 18,000 to 12,000 years ago. During the freezes and thaws that occurred in the Ice-Age, an ice dam across the Clark Fork River along the Montana-Idaho border formed and failed many times, each time releasing a wall of water that surged southwest through the Columbia Basin, inundating the area that is now the Hanford Site. As the water moved across eastern Washington, it eroded the basalt, forming channels of barren rocky land referred to as the Channeled Scabland. At other localities the water deposited bars of gravel and sand. The waste management facilities in the 200 Areas

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(a) Technical contact person



**Figure 4.3-1.** Geologic Elements of the Pasco Basin Portion of the Columbia Basin, Washington



**Figure 4.3-2.** White Bluffs at the Hanford Site, Washington, Display River and Lake Deposits Left from the Ancestral Columbia River

of the Hanford Site are located on one prominent flood bar of sand and gravel, the Cold Creek bar (Bretz et al. 1956, DOE 1988). Where the waters back-flooded up tributary valleys, they left behind deposits of sand and silt known as the Touchet Beds. Touchet Bed silt deposits lie beneath the southern/central plateau of the Hanford Site.

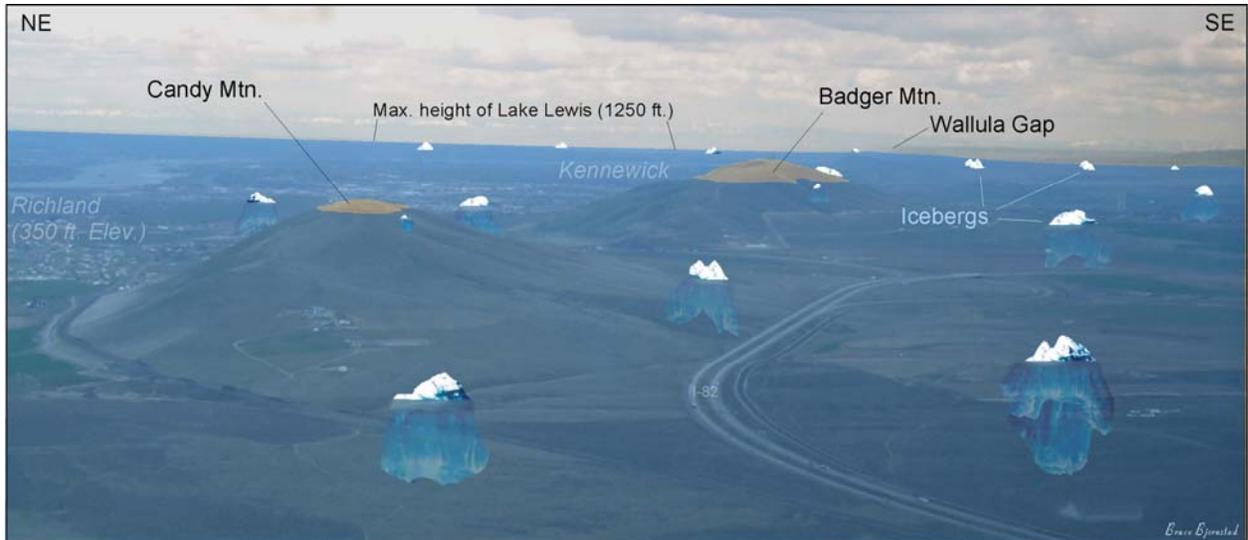
During the largest Ice-Age floods, most of the southern Pasco Basin was under water (Figure 4.3-3). Ice-Age floods became hydraulically dammed behind Wallula Gap, forming Lake Lewis, which probably lasted a week or less. The largest and most frequent floods came from glacial Lake Missoula in northwestern Montana. Other floods probably escaped down-valley from glacial lakes Clark and Columbia along the northern margin of the Columbia Plateau (Waitt 1980, Baker and Bunker 1985) or down the Snake River from glacial Lake Bonneville (Malde 1968, O'Connor 1993) or from subglacial outbursts (Shaw et al. 1999).

Since the end of the Ice-Age floods, winds have reworked the deposits of sand and silt, shifting them into dune sands in the lower elevations and loess (windblown fine sand and silt) around the margins of the Pasco Basin. Anchoring vegetation has stabilized many sand dunes. Where human activity has disturbed this vegetation, dunes have been reactivated. Most recently, many dunes were reactivated by the removal of vegetation resulting from the June-July 2000 fire at the Hanford Site.

The Hanford Site today is a composite of what the lava flows, earth's tectonic forces, river changes, and Ice-Age floods of long ago left behind and the winds since then have reshaped. The resulting landmass elements that affect and are affected by activities at the Hanford Site are its physical and structural characteristics, and the strata and structure of its rocks.

### **4.3.1 Physical and Structural Characteristics**

The physical characteristics of the Hanford Site include the mountains, valleys, and riverbeds. These are the landmarks that usually have recognizable names on topographical maps. The structural geology of the Hanford Site demonstrates pressure effects on the landmass, which have produced many of the landmarks (Figure 4.3-4). The Earth's internal forces continually push and press the landmass into a



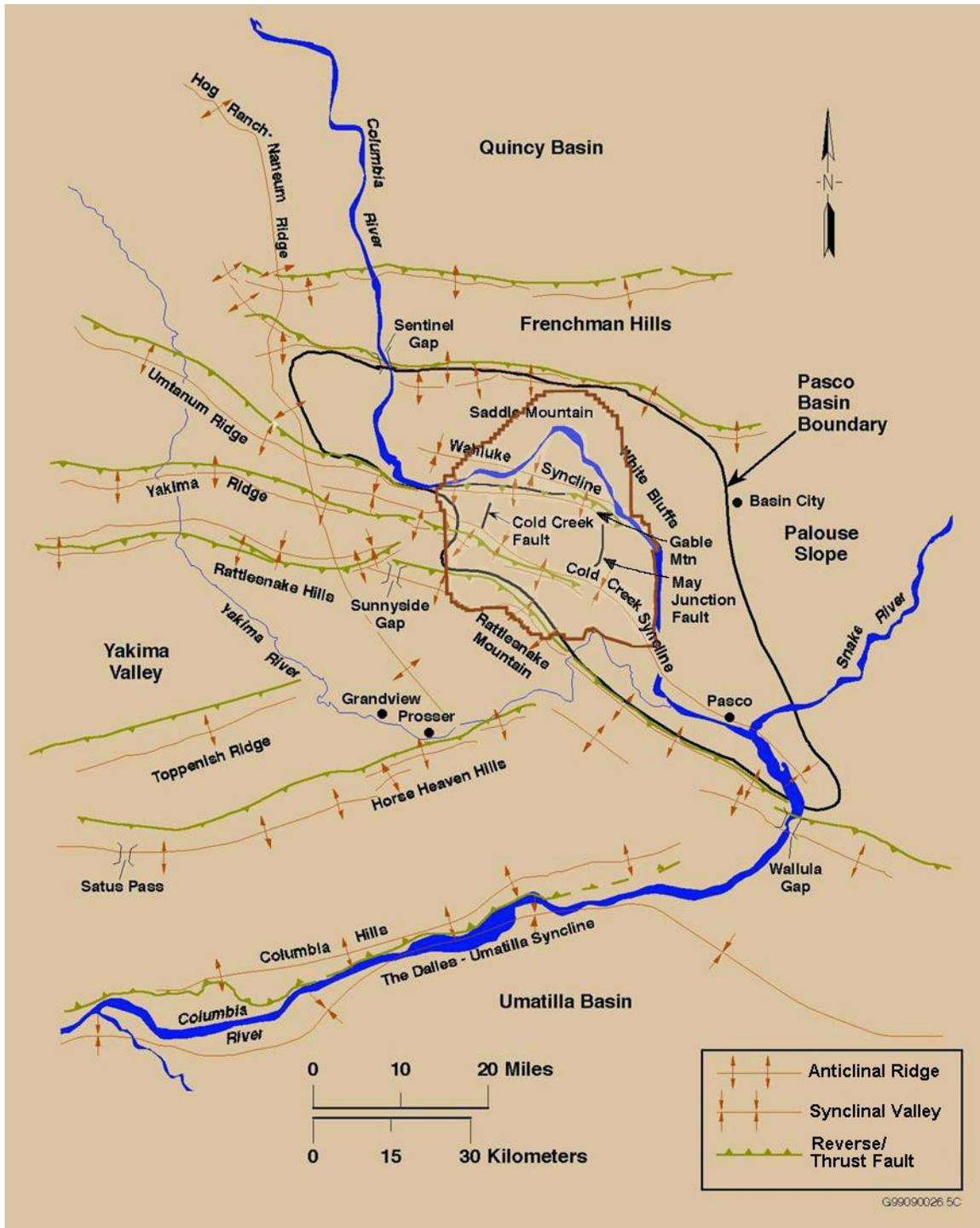
**Figure 4.3-3.** Conceptualization of an Ice-Age Flood in the Vicinity of the Hanford Site, Washington, which Occurred Intermittently between 18,000-13,000 years ago

variety of shapes: ridges (anticlines) and valleys (synclines) and associated faults. Unlike the physical characteristics which define the landscape, structural geology defines the fabric of a landmass.

The fabric of the Hanford Site is defined by the Palouse Slope and Yakima Fold Belt (DOE 1988). The underlying basalt of the Palouse Slope dips toward the central Columbia Basin and exhibits some structural deformation. A wedge of Columbia River basalt underlies the Palouse Slope thinning gradually toward the east and north and lapping onto the adjacent highlands. The Yakima Fold Belt is the name collectively given to all the ridges formed from the folded basaltic lava flows that are found within the central and western parts of the Columbia Basin (DOE 1988).

The main ridges and valleys on the Hanford Site area are as follows:

- Saddle Mountains form the ridge that is the northern boundary of the Pasco Basin and Hanford Site. The Saddle Mountains are an east-west ridge about 110 km (68 mi) long and 5 km (3 mi) wide.
- Wahluke Slope is on the north side of the Columbia River. The Wahluke Slope is a portion of the synclinal valley of basalt between the Saddle Mountains and Umtanum Ridge.
- Umtanum Ridge makes up the southern boundary of the Wahluke Syncline. Gable Butte and Gable Mountain are the parts of this ridge that lie between the 100 and 200 Areas. Gable Butte and Gable Mountain are folded layers of rock that are the high points along the Umtanum anticlinal ridge, which is buried in places by the Ringold Formation and Hanford formation. The valley north of the Umtanum Ridge is the Wahluke Syncline and the valley south is Cold Creek.
- Rattlesnake Hills, southwest of the Hanford Site, are also the result of folded rock layers. Rattlesnake Mountain, the highest of the Rattlesnake Hills, reaches an elevation of 1110 m (3660 ft) above mean sea level, the highest elevation in the area.



**Figure 4-3.4.** Physical and Structural Geology of the Hanford Site, Washington (Hartshorn *et al.* 2002)

- Cold Creek is a valley of rock and sediment that lies between Umtanum Ridge and Yakima Ridge. Yakima Ridge is one of the anticlinal ridges of the Yakima Fold Belt. The Cold Creek bar, a deposit of Ice-Age flood sediment, lies in this area.

### **4.3.2 Strata and Structure of Sediment and Rock**

The strata and structure of the sediment and rocks (Figure 4.3-5) are important characteristics of the Hanford Site (DOE 1988).

#### **4.3.2.1 Columbia River Basalt Group**

The bedrock of the Hanford Site is basalt. Beneath the Hanford Site lay a minimum of 100 basalt flows with a maximum combined thickness of more than 4 km (13,000 ft) (DOE 1988), all part of the Columbia River Basalt Group.

To organize the many basalt deposits into a consistent nomenclature, geologists have named and grouped them based on their physical and chemical properties. The basalt deposit closest to the surface at the Hanford Site, and therefore most often referred to, is Saddle Mountains Basalt (Figure 4.3-5). Saddle Mountains Basalt consists of ten distinct basaltic lava deposits (members). The most recent basalt flow underlying most of the Hanford Site is the Elephant Mountain Member of the Saddle Mountains Basalt. A younger basalt flow, the Ice Harbor Member, is found in the southern portion of the site near the 300 Area (DOE 1988).

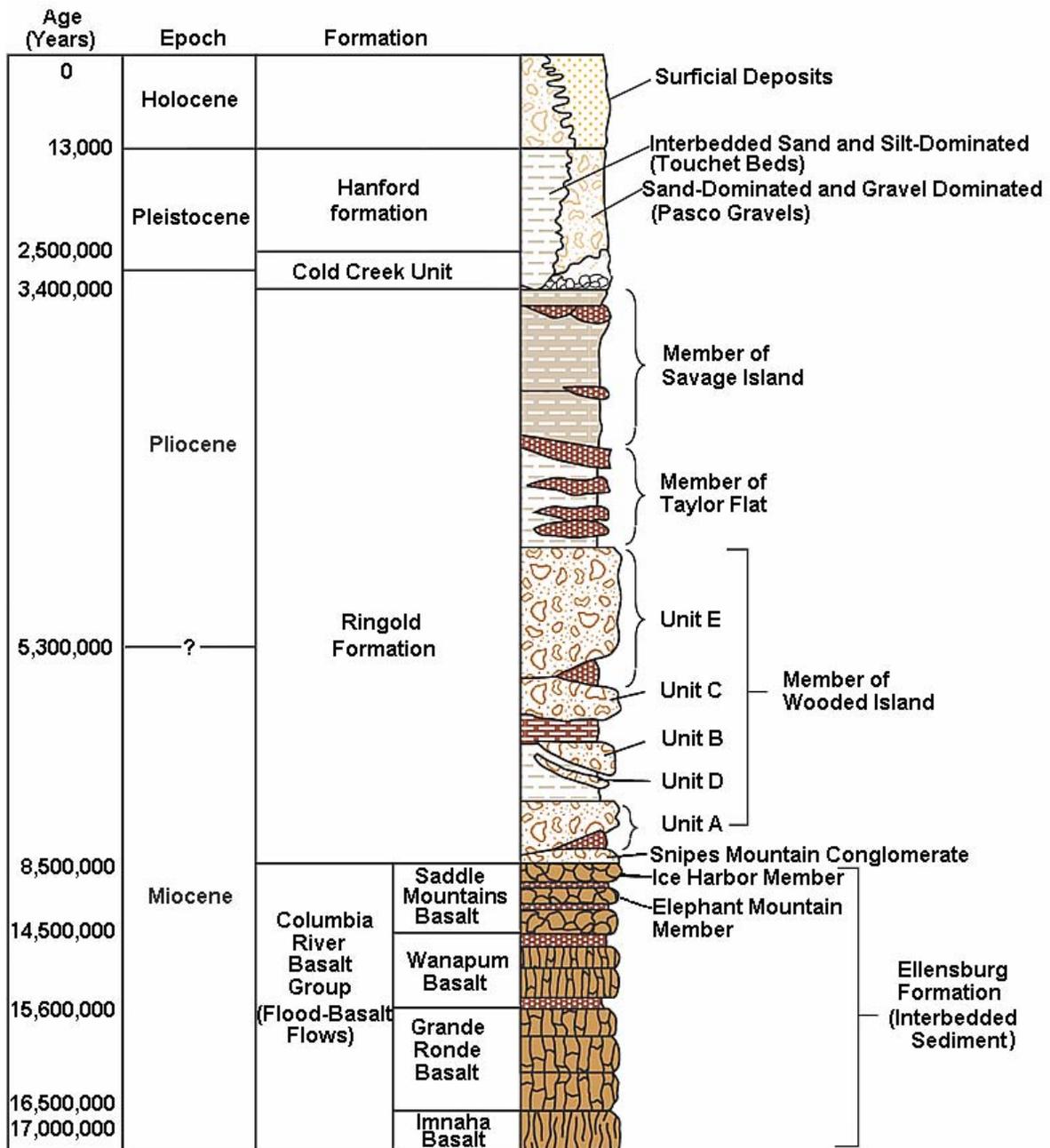
In addition to basalt, the Hanford Site has sedimentary formations. Some of the sediment at the Hanford Site is found between the basaltic lavas and is called the Ellensburg Formation. The majority of the sediment is above the basalt with the Ringold Formation overlain by the Cold Creek unit, and topped with the Hanford formation (Figure 4.3-5). Understanding the formations, along with clastic dikes and the soil of the Hanford Site, contributes to our understanding of how, for example, contaminants might travel in the 100, 200, and 300 Areas.

#### **4.3.2.2 Ellensburg Formation**

The Ellensburg Formation is the sediment found interbedded with the Columbia River Basalt Group. The Ellensburg Formation formed as early as 17 million years ago, although the youngest portion on the Hanford Site may have formed as recently as 8 million years ago (DOE 1988). The Ellensburg Formation was created when volcanic rock and sediment from uplands surrounding the Columbia Plateau interfingering with the basalt of the Columbia River Basalt Group (Swanson et al. 1979a, b). The thickest accumulations of the Ellensburg Formation lie along the western margin of the Columbia Basin. While deposition along the western margin was primarily from volcanic debris flows and related stream and sheet floods, no volcanic debris flows have been identified at the Hanford Site (Reidel *et al.* 1994). Volcanic ash known as tuff is the dominant material in the Hanford Site portion of the Ellensburg Formation. The Ellensburg Formation is commonly exposed between basalt flows along the ridges of the Yakima Fold Belt.

#### **4.3.2.3 Hanford Formation, Cold Creek Unit, and Ringold Formation**

Sediments overlying basalt in the Pasco Basin and Hanford Site include the Ringold Formation, Cold Creek unit, and the Hanford formation. These formations are primarily exposed in the lower elevation areas around the Hanford Site, including White Bluffs.



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Figure 4.3-5. Strata of Rocks and Sediment at the Hanford Site, Washington

**Ringold Formation.** The Ringold Formation formed between 8.5 and about 3.0 million years ago and consists of gravel, sand, silt, and clay deposited across portions of the Columbia Basin by the ancestral Columbia River (Tallman et al. 1981, DOE 1988, Lindsey 1996). For detailed descriptions of the Ringold Formation see DOE (1988) and Lindsey (1995, 1996). Although exposures of the Ringold Formation are limited to White Bluffs within the central Pasco Basin and to Smyrna and Taunton Benches along the Saddle Mountains north of the Pasco Basin, extensive data on the Ringold Formation are available from boreholes. The Ringold Formation at the Hanford Site is up to 185 m (600 ft) thick. Erosion removed the upper 300 feet of the Ringold Formation over most of the Hanford Site. Along White Bluffs, the Ringold Formation is up to 285 m (900 ft) thick (DOE 1988).

**Cold Creek unit.** The Cold Creek unit (DOE 2002b) includes all material underlying the Hanford formation, overlying the Ringold Formation in the vicinity of 200 West, and may extend over most of the central Pasco Basin. The Cold Creek unit distinguishes itself from the Hanford and Ringold formations because it was formed when the Ringold Formation was eroding and relatively little was being deposited at the Hanford Site. This subunit is found locally in the subsurface of the Cold Creek synclinal valley. Distribution of the Cold Creek unit depends in part on erosion and weathering of the underlying Ringold Formation and post-depositional erosion by the Ice-Age floods (Slate 1996). The thickness of the Cold Creek deposit ranges from 0-20 m (0-66 ft). Locally, the Cold Creek unit contains very hard rock that formed during soil development as precipitation evaporated and left behind minerals forming what geologists call caliche or hardpan. This layer can influence contaminant migration by slowing its rate of downward movement and potentially diverting contaminants laterally (Slate 1996). The thin, fine-grained layers in the Hanford formation also cause lateral migration (Serne *et al.* 2002).

**Hanford formation.** The Hanford formation is the informal name for the strata that lie on top of Cold Creek unit above the Ringold Formation. The Ice-Age floods inundated the Hanford Site a number of times beginning as early as 1-2 million years ago (Bjornstad *et al.* 2001). The last major flood sequence occurred about 12,000 years ago. When the Ice-Age floodwaters entered the Pasco Basin, they quickly became impounded behind Wallula Gap, which was too restrictive for the volume of water involved. Floodwaters formed a temporary lake with shorelines up to 381 m (1250 ft) in elevation. The lake only lasted a few days (O'Connor and Baker 1992). After the floodwater receded, the Hanford formation deposits were left in the low-lying areas over most of the Hanford Site.

On the Hanford Site the Hanford formation is thickest in the vicinity of the 200 Areas where it is up to 100 m (300 ft) thick (DOE 2002b). Gravel, sand, and silt (Touchet Beds) dominate the Hanford formation (Reidel et al. 1992). The different sediment types of the Hanford formation commonly interfinger laterally. The relative proportion of each sediment type at any given location is related to its distance from main high-energy flows at the time of deposition (DOE 2002b). Generally, gravel was deposited in the center of the Pasco Basin, while finer grained sand and silt were deposited along the margins of the basin.

#### 4.3.2.4 Clastic Dikes

Clastic dikes are fissures filled with sand, silt, clay, and coarser debris. They are commonly associated with, but not restricted to, Ice-Age flood deposits in the Columbia Basin. Many dikes occur as sharp-walled, near-vertical tabular bodies filled with multiple layers of unconsolidated sediment. Thin clay/silt linings separate the margins of dikes and internal layers (Fecht *et al.* 1999). Dikes vary in width from less than 1 mm (0.039 in.) to greater than 2 m (6.5 ft). Vertical extents range from less than 1 m (3 ft) to greater than 50 m (164 ft) with a large number greater than 20 m (65 ft) (Fecht et al. 1999).

Clastic dikes are complex natural structures that may facilitate or retard the migration of contaminants. Where large leaks have occurred, clastic dikes may also act as barriers, limiting the extensive lateral spreading of contaminants caused by horizontal layers of Hanford sediment (Murray *et al.* 2002, 2003; Ward *et al.* 2002a, b).

#### **4.3.2.5 100 Areas Strata and Structure**

The 100 Areas are located along the Columbia River in the northern portion of the Hanford Site (Figure 4.0-1). With the exception of the 100-B/C Area, the 100 Areas lie on the north limb of the Wahluke synclinal valley. The 100-B/C Area lies over the axis of the synclinal valley. The top of the basalt in the 100 Areas ranges in elevation from 46 m (150 ft) near the 100-H Area to -64 m (-210 ft) below sea level near the 100-B/C Area. The Ringold Formation and Hanford formation occur throughout this area. The Cold Creek unit deposits have not been identified in the 100 Areas.

The Ringold Formation shows a marked west-to-east variation in the 100 Areas (Lindsey 1992). The main channel of the ancestral Columbia River flowed along Umtanum Ridge and through the 100-B/C and 100-K Areas before turning south to flow along Gable Mountain and/or through the Gable Mountain-Gable Butte gap. This main channel deposited coarse-grained sand and gravel of the Ringold Formation. Farther to the north and east, however, the Ringold sediment is gradually dominated by the fine-grained silt deposits and associated ancient soil with the 100-H Area showing almost no gravel.

#### **4.3.2.6 200 Areas Strata and Structure**

The geology in the 200 West Area is notably different from that in the 200 East Area even though they are separated by a distance of only 6 km (4 mi) (DOE 1988) (Figure 4.0-1). The 200 West Area has sections containing all three formations including most of the Ringold Formation as well as the Cold Creek unit and the Hanford formation (DOE 1988).

In the 200 East Area, some Ringold Formation is present in the southern portion but has been completely eroded in the northern part. On the north side of the 200 East Area, the Hanford formation rests directly on the basalt, and no Ringold sediment is present. Erosion by the ancestral Columbia River and Ice-Age flooding are believed to have removed the Ringold Formation from this area. Material of questionable origin overlies basalt within the B-BX-BY Waste Management Area, the location of the B, BX, and BY tank farms where radioactive wastes are stored in underground tanks (Wood *et al.* 2000). This material may be equivalent or partially equivalent to the Cold Creek unit or it may represent the earliest ice-age flood deposits overlain by a locally thick sequence of fine-grained non-flood deposits. This unit is referred to informally as Hanford-Cold Creek deposits.

#### **4.3.2.7 300 Area Strata and Structure**

The 300 Area is located in the southeastern portion of the Hanford Site (Figure 4.0-1). The 300 Area lies next to the Columbia River and sits on the Hanford formation, which in turn overlies the Ringold Formation and Columbia River Basalt Group. The Columbia River Basalt Group and Ringold Formation beneath the 300 Area are folded into the Cold Creek synclinal valley that lies near the intersection of the Yakima Fold Belt and the un-deformed Palouse Slope (Figure 4.3-3) (DOE 1988). The uppermost basalt flows belong to the Elephant Mountain Member over most of the Hanford Site, but near the 300 Area younger flows belonging to the Ice Harbor Member of the Saddle Mountains Basalt are present, causing the overlying sediment layers to be relatively thin (Schalla *et al.* 1988). Both Ringold Formation and Hanford formation sediment is found in the 300 Area.

### 4.3.3 Surface Soil

Hajek (1966)<sup>(a)</sup> describes 15 different surface soil types on the Hanford Site, varying from sand to silty and sandy loam (Figure 4.3-6). Classifications including land use are also given in Hajek (1966).

Soil types found on the Hanford Site include the following:

**Ritzville Silt Loam.** Ritzville silt loam, a dark-colored silt loam soil, is found midway up the slopes of the Rattlesnake Hills. It was formed under bunch grass from silty wind-laid deposits mixed with small amounts of volcanic ash. Characteristically greater than 150 cm (60 in.) deep, Ritzville silt loam may be separated by bedrock that occurs between 75 and 150 cm (30 and 60 in.).

**Rupert Sand.** Rupert sand, brown-to grayish-brown coarse sand grading to dark grayish-brown at a depth of 90 cm (35 in.), is one of the most extensive soil types on the Hanford Site. Rupert sand developed under grass, sagebrush, and hopsage in coarse sandy alluvial deposits that were mantled by wind-blown sand and formed hummocky terraces and dune-like ridges.

**Hezel Sand.** Hezel sand, similar to Rupert sands, is laminated grayish-brown strongly calcareous silt loam subsoil usually encountered within 100 cm (39 in.) of the surface. When found as surface soil it is very dark brown. Hezel sand was formed in wind-blown sands that mantled lake-laid sediment.

**Koehler Sand.** Koehler sand is similar to other sandy soil found on the Hanford Site, differing in that it mantles a lime-silica cemented hardpan layer. It was developed in a wind-blown sand mantle and exhibits a very dark grayish-brown surface layer and is somewhat darker than Rupert sand. Its calcareous subsoil is usually dark grayish-brown at about 45 cm (18 in.).

**Burbank Loamy Sand.** Burbank loamy sand is a dark-colored, coarse-textured soil underlain by gravel. Its surface soil is usually about 40 cm (16 in.) thick but may be as much as 75 cm (30 in.) thick. The gravel content of its subsoil ranges from 20 percent to 80 percent.

**Ephrata Sandy Loam.** Ephrata sandy loam is found on level topography on the Hanford Site. Its surface is darkly colored and its subsoil is dark grayish-brown medium-textured soil underlain by gravelly material that may continue for many feet.

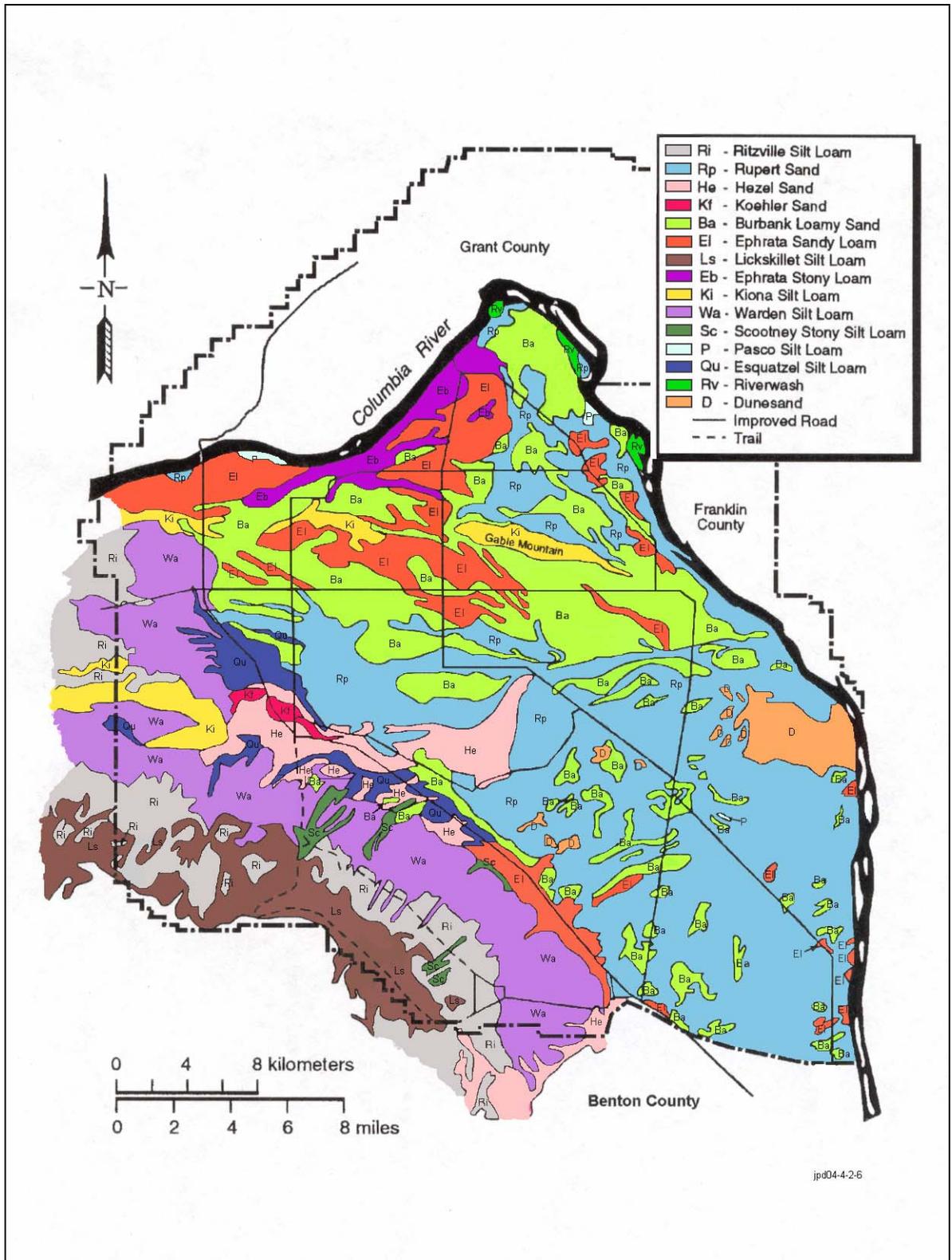
**Lickskillet Silt Loam.** Lickskillet silt loam occupies the ridge slopes of Rattlesnake Hills and slopes greater than 765 m (2509 ft) elevation. It is similar to Kiona silt loam except the surface soil is darker. Lickskillet silt loam is shallow over basalt bedrock and exhibits numerous basalt fragments throughout the profile.

**Ephrata Stony Loam.** Ephrata stony loam is similar to Ephrata sandy loam. It differs in that many large hummocky ridges are made up of debris released from melting glaciers. Areas of Ephrata stony loam located between hummocks contain many boulders several feet in diameter.

**Pasco Silt Loam.** Pasco silt loam is poorly drained very dark grayish-brown soil formed in recent alluvial material. Its subsoil is variable, consisting of stratified layers. Only small areas of Pasco silt loam are found on the Hanford Site, located in low areas adjacent to the Columbia River.

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(a) The soil classifications given in Hajek (1966) have not been updated to reflect current reinterpretations of soil classifications. Until the surface soil on the Hanford Site is resurveyed, the descriptions presented in Hajek (1966) will continue to be used.



**Figure 4.3-6.** Map of Soil Types at the Hanford Site, Washington (based on Hajek 1966)

**Kiona Silt Loam.** Kiona silt loam occupies steep slopes and ridges. Its surface soil is very dark grayish-brown, is about 10 cm (4 in.) thick, and has dark-brown subsoil containing basalt fragments 30 cm (12 in.) and larger in diameter. Many basalt fragments are found in its surface layer and basalt rock outcrops are often present. Kiona silt loam is a shallow stony soil normally occurring in association with Ritzville and Warden soil.

**Warden Silt Loam.** Warden silt loam is dark grayish-brown soil with a surface layer usually 23 cm (9 in.) thick. Its silt loam subsoil becomes strongly calcareous at about 50 cm (20 in.) and becomes lighter colored. Granitic boulders are found in many areas. Warden silt loam is usually greater than 150 cm (60 in.) deep.

**Scootney Stony Silt Loam.** Scootney stony silt loam developed along the north slope of the Rattlesnake Hills and is usually confined to floors of narrow draws or small fan-shaped areas where draws open onto plains. It is severely eroded with numerous basaltic boulders and fragments exposed and surface soil is usually dark grayish-brown grading to grayish-brown within the subsoil.

**Esquatzel Silt Loam.** Esquatzel silt loam is a deep dark-brown soil formed in recent alluvium derived from loess and lake sediment. Its subsoil grades to dark grayish-brown in many areas, but the color and texture of the subsoil are variable because of the stratified nature of the alluvial deposits.

**Riverwash.** Riverwash is wet, periodically flooded areas of sand, gravel, and boulder deposits that make up overflowed islands in the Columbia River and adjacent land.

**Dunesand.** Dunesand is a miscellaneous land type that consists of hills or ridges of sand-sized particles drifted and piled up by wind. They are either actively shifted or so recently fixed or stabilized that no soil layers have developed.

#### 4.3.4 Seismicity

The historic record of earthquakes in the Pacific Northwest dates from about 1840. The early part of this record is based on newspaper reports of human perception of shaking and structural damage as classified using the Modified Mercalli Intensity (MMI) scale; the early record is probably incomplete because the region was sparsely populated. The historical record appears to be complete since 1905 for MMI V and since 1890 for MMI VI (Rohay 1989). Seismograph networks did not start providing earthquake locations and magnitudes of earthquakes in the Pacific Northwest until about 1960. A comprehensive network of seismic stations that provides accurate locating information for most earthquakes of magnitude greater than 2.5 was installed in eastern Washington during 1969. DOE (1988) provides a summary of the seismicity of the Pacific Northwest, a detailed review of the seismicity in the Columbia Plateau region and the Hanford Site, and a description of the seismic networks used to collect the data.

Large earthquakes (magnitude  $M$  greater than or equal to 7) in the Pacific Northwest have occurred near Puget Sound, Washington, and near the Rocky Mountains in eastern Idaho and western Montana. Two large earthquakes occurred beneath Vancouver Island. The first occurred during 1918 and had a maximum MMI VII (estimated magnitude  $M$  7.0). The second earthquake occurred in 1946 and had a maximum MMI VII (over a wider area) and magnitude  $M$  7.3. The depth of these early, large earthquakes beneath Vancouver Island is uncertain. Another large earthquake occurred at a depth of 53 km (33 mi) near Olympia, Washington, in 1949 that had a maximum MMI VIII and a magnitude  $M$  equal 7.1. A smaller ( $M$  6.5), deep (63 km [39 mi]) earthquake occurred during 1965 between Seattle and

Tacoma. These events may all be related to deformation within the subducting Juan de Fuca Plate at depth beneath the Vancouver Island/Puget Sound region.

Two large events occurred on the eastern boundary of the Pacific Northwest, in the Rocky Mountains. These were the 1959 Hebgen Lake earthquake in western Montana, which had a Richter magnitude of 7.5 and an MMI X, and the 1983 Borah Peak earthquake in eastern Idaho, which had a Richter magnitude of 7.3 and an MMI IX.

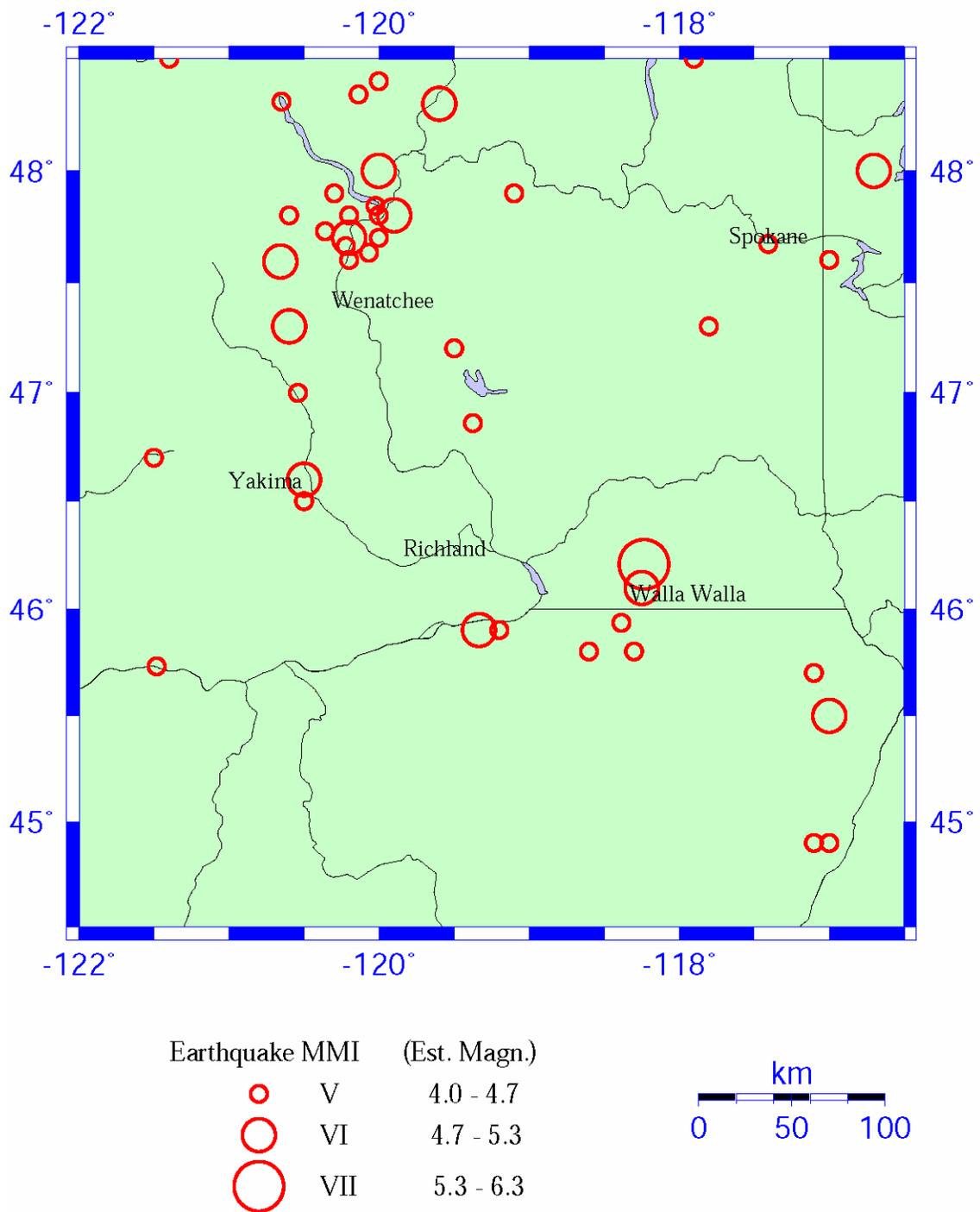
Closer to the Hanford Site, a significant, large earthquake of uncertain location occurred in north-central Washington in 1872. This event had an estimated maximum MMI ranging from VIII to IX and an estimated Richter magnitude of approximately 7.4. The distribution of intensities suggests a location within a broad region between Lake Chelan, Washington, and the British Columbia border. Evidence of landslides near Lake Chelan suggests a location near there. A recent study indicates that the maximum MMI for this event was VIII and its magnitude was 6.8, with a location at the south end of Lake Chelan (Bakun *et al.* 2002).

On February 28, 2001, there was a moderate (M less than 7), deep earthquake near Olympia in Puget Sound called the Nisqually earthquake. This earthquake occurred at a depth of 52 km (32 mi) and had a magnitude of 6.8; reported ground-shaking effects reached MMI VIII. This event is similar to those in 1949 and 1965 described above. The Nisqually earthquake was recorded by a network of strong motion accelerographs at the Hanford Site. Peak horizontal accelerations measured from 0.0016 to 0.0055g (1g is the acceleration of gravity). These levels of ground shaking are considerably less than design and evaluation values (PNNL Seismic Monitoring Team 2001).

The seismicity of the Columbia Plateau, as determined by the rate of earthquakes per area and the historical magnitude of these events, is relatively low compared with other regions of the Pacific Northwest, the Puget Sound, and western Montana/eastern Idaho. The largest known earthquake in the Columbia Plateau occurred in 1936 near Milton-Freewater, Oregon. This earthquake had a Richter magnitude of 5.75 and a maximum MMI of VII, and it was followed by a number of aftershocks indicating a northeast-trending fault plane. Bakun *et al.* (2002) concluded that the magnitude of this earthquake was a lower value of 5.35.

Other earthquakes with Richter magnitudes greater than or equal to 5 and/or MMIs of VI occurred along the boundaries of the Columbia Plateau in a cluster near Lake Chelan in 1872 and extended into the northern Cascade Range, northern Idaho and Washington, and along the boundary between the western Columbia Plateau and the Cascade Range. Three MMI VI earthquakes have occurred within the Columbia Plateau, including one in the Milton-Freewater, Oregon region in 1921; one near Yakima, Washington, in 1892; and one near Umatilla, Oregon, in 1893 (Figure 4.3-7). In the central portion of the Columbia Plateau, the largest earthquakes near the Hanford Site are two that occurred during 1918 and 1973. These two events were magnitude 4.4 and intensity V and were located north of the Hanford Site near Othello.

Earthquakes often occur in spatial and temporal clusters in the central Columbia Plateau and are termed “earthquake swarms.” The region north and east of the Hanford Site is a region of concentrated earthquake swarm activity, but earthquake swarms have also occurred in several locations within the Hanford Site. The frequency of earthquakes in a swarm tends to gradually increase and decay with no one outstanding large event within the sequence. Roughly 90 percent of the earthquakes in swarms have Richter magnitudes of 2 or less. These earthquake swarms are generally shallow; 75 percent of the events are at depths less than 4 km (2.5 mi). However, several recent swarm sequences have occurred at greater depths (PNNL Seismic Monitoring Team 2003). Each earthquake swarm typically lasts several weeks to



**Figure 4.3-7.** Historical Earthquake Activity of the Columbia Basin, Washington and Surrounding Areas. All earthquakes between 1890 and 1970 with a Modified Mercalli Intensity V or larger and/or a magnitude 4 or larger are shown (Rohay 1989).

months, consists of several to 100 or more earthquakes, and is clustered in an area 5 to 10 km (3 to 6 mi) in lateral dimension. Often, the longest dimension of the swarm area is in an east-west direction. However, detailed locations of swarm earthquakes indicate that the events occur on fault planes of variable orientation and not on a single throughgoing fault plane.

Earthquakes in the central Columbia Plateau also occur to depths of about 30 km (18.6 mi). These deeper earthquakes are less clustered and occur more often as isolated events. Based on seismic refraction surveys in the region, the shallow earthquake swarms occur in the Columbia River basalts and the deeper earthquakes occur in crustal layers below the basalts.

The spatial pattern of seismicity in the central Columbia Plateau suggests an association of the shallow swarm activity with the east-west oriented Saddle Mountain anticline. However, this association is complex, and the earthquakes do not delineate a throughgoing fault plane that would be consistent with the faulting observed on this structure.

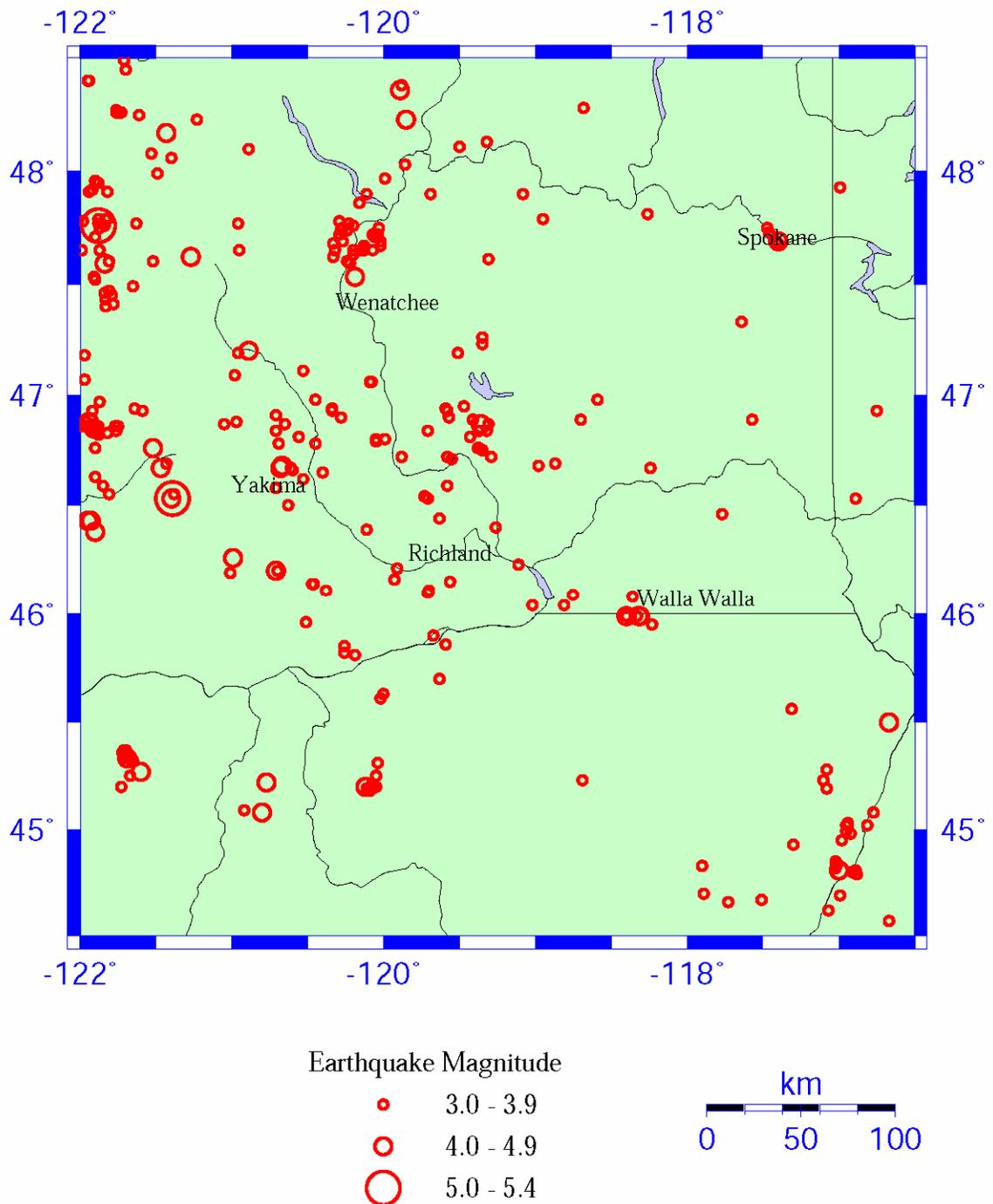
Earthquake focal mechanisms in the central Columbia Plateau generally indicate reverse faulting on east-west planes, consistent with a north-south-directed maximum compressive stress and with the formation of the east-west oriented anticlinal folds of the Yakima Fold Belt (Rohay 1987; 2003). However, earthquake focal mechanisms indicate faulting on a variety of fault plane orientations.

Earthquake focal mechanisms along the western margin of the Columbia Plateau also indicate north-south compression, but here the minimum compressive stress is oriented east to west, resulting in strike-slip faulting (Rohay 1987). Geologic studies indicate an increased component of strike-slip faulting in the western portion of the Yakima Fold Belt. Earthquake focal mechanisms in the Milton-Freewater region to the southeast indicate a different stress field, one with maximum compression directed east-west instead of north-south.

Estimates for earthquake potential of structures and zones in the central Columbia Plateau have been developed during the licensing of nuclear power plants at the Hanford Site. In reviewing the operating license application for the Washington Public Power Supply System Washington Nuclear Plant (WNP)-2 (now Energy Northwest Columbia Generating Station), the U.S. Nuclear Regulatory Commission (NRC) concluded that four earthquake sources should be considered for seismic design: the Rattlesnake-Wallula alignment, Gable Mountain, a floating earthquake in the tectonic province, and a swarm area (NRC 1982).

For the Rattlesnake-Wallula alignment, which passes along the southwest boundary of the Hanford Site, the NRC estimated a maximum Richter magnitude of 6.5; for Gable Mountain, an east-west structure that passes through the northern portion of the Hanford Site, a maximum Richter magnitude of 5.0 was estimated. These estimates were based on the inferred sense of slip, the fault length, and/or the fault area. The floating earthquake for the tectonic province was developed from the largest event located in the Columbia Plateau, the Richter magnitude 5.75 Milton-Freewater earthquake. The maximum swarm earthquake for the Columbia Generating Station seismic design was a Richter magnitude 4.0 event based on the maximum swarm earthquake in 1973 (Figure 4.3-8). (The NRC concluded that the actual magnitude of this event was smaller than previously estimated.)

Probabilistic seismic hazard analyses have been used to determine the seismic ground motions expected from multiple earthquake sources, and these are used to design or evaluate facilities on the Hanford Site. The most recent Hanford Site-specific hazard analysis (Geomatrix 1994, 1996) estimated that 0.10g horizontal acceleration would be experienced on average every 500 years (or with a 10 percent



**Figure 4.3-8.** Earthquake Activity of the Columbia Basin, Washington, and Surrounding Areas as Measured by Seismographs. All earthquakes between 1970 and 2005 with Richter magnitudes of 3 or larger are shown (ANSS 2005).

chance every 50 years). This study also estimated that 0.2 g would be experienced on average every 2500 years (or with a 2 percent chance in 50 years). These estimates are in approximate agreement with the results of national seismic hazard maps produced by the U.S. Geological Survey (USGS 1996, 2002a). A site-specific ground response model for the Waste Treatment Plant being constructed at the Hanford Site (Rohay and Reidel 2005) increased ground motions for the design basis of this facility by up to 40 percent to include greater conservatism.

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## 4.4. Hydrology

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Characterization of hydrology at the Hanford Site includes surface water, the vadose zone, and groundwater. The vadose zone is the unsaturated or partially saturated region between the ground surface and the saturated zone. Water in the vadose zone is called soil moisture. Groundwater refers to water within the saturated zone. Permeable saturated units in the subsurface are called aquifers.

### 4.4.1 Surface Water

Surface water at Hanford includes the Columbia River, springs, and ponds. Intermittent surface streams, such as Cold Creek, may also contain water after large precipitation or snowmelt events. In addition, the Yakima River flows along a short section of the southern boundary of the Hanford Site (Figure 4.4-1), and there is surface water associated with irrigation east and north of the Site.

#### 4.4.1.1 Columbia River

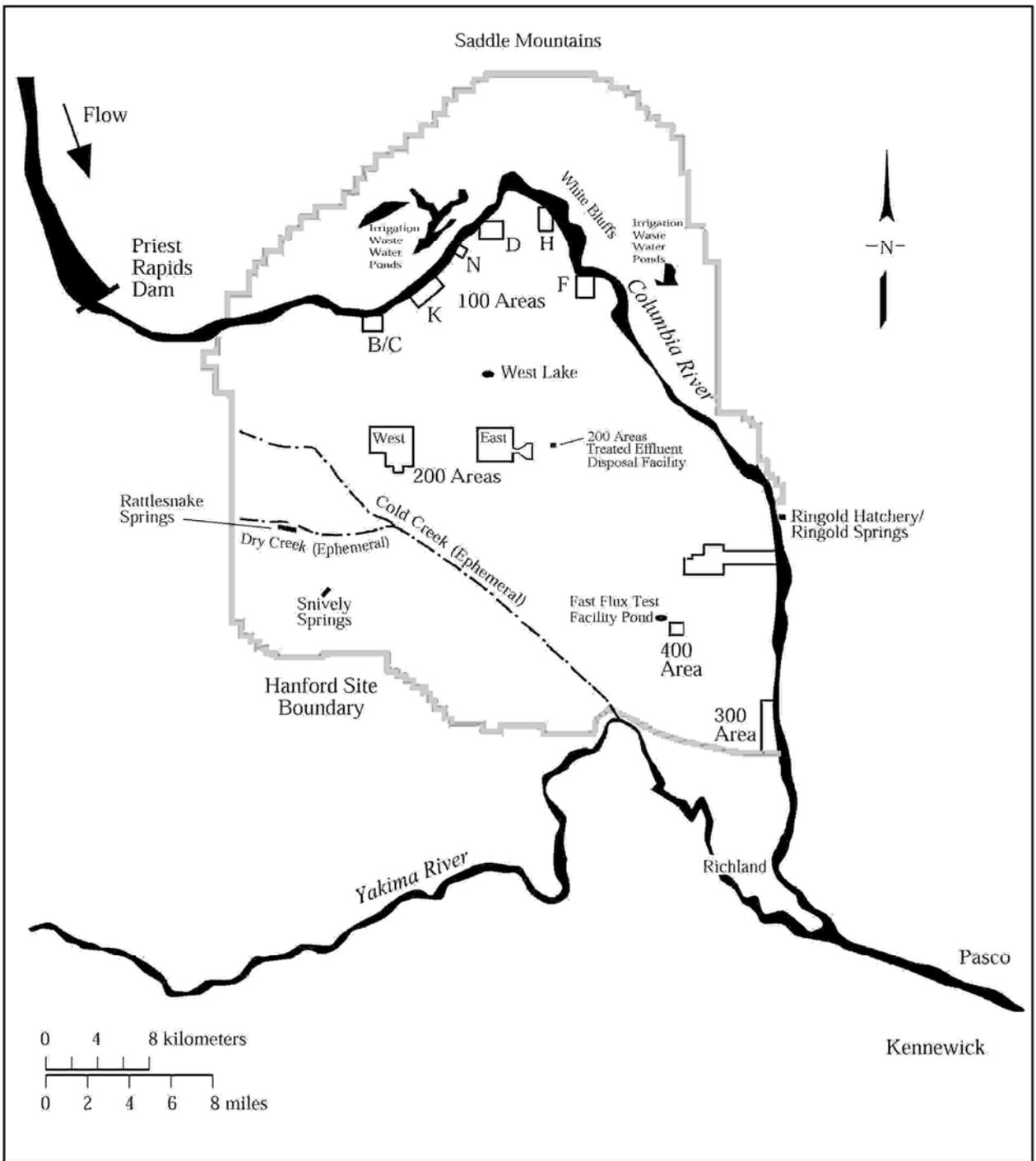
The Columbia River is the second largest river in the contiguous United States in terms of total flow and is the dominant surface-water body on the Hanford Site. The original selection of the Hanford Site for plutonium production and processing was based, in part, on the abundant water provided by the Columbia River. The existence of the Hanford Site has precluded development of this section of the river for hydroelectric production and barge transportation.

Originating in the Canadian Rockies of southeastern British Columbia, Canada, the Columbia River drains a total area of approximately 680,000 km<sup>2</sup> (262,480 mi<sup>2</sup>) en route to the Pacific Ocean. Most of the Columbia River is impounded by 11 dams within the United States: 7 upstream and 4 downstream of the Hanford Site. Priest Rapids is the nearest upstream dam, and McNary is the nearest downstream dam. Lake Wallula, the impoundment created by McNary Dam, extends upstream past Richland, Washington, to the southern part of the Hanford Site. Except for the Columbia River estuary, the only unimpounded stretch of the river in the United States is the Hanford Reach, which extends from Priest Rapids Dam downstream approximately 82 km (51 mi) to Lake Wallula, north of Richland. The Hanford Reach of the Columbia River was recently incorporated into the land area established as the Hanford Reach National Monument.

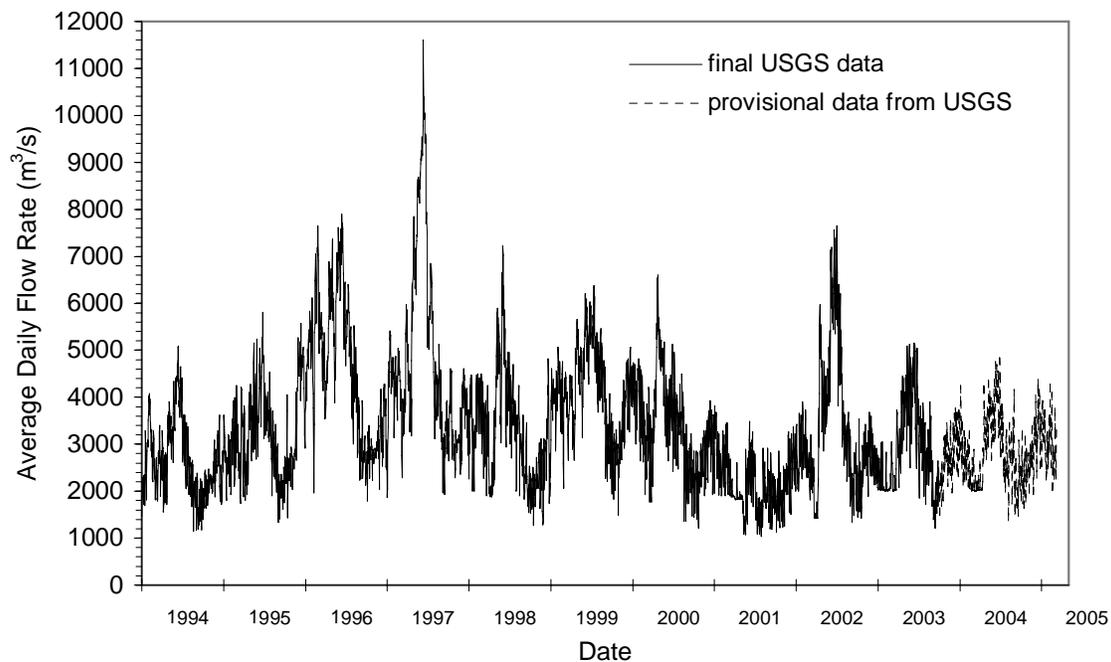
Flows through the Hanford Reach fluctuate significantly and are controlled primarily by releases from three upstream storage dams: Grand Coulee in the United States, and Mica and Keenleyside in Canada. Flows in the Hanford Reach are directly affected by releases from Priest Rapids Dam; however, Priest Rapids operates as a run-of-the-river dam rather than a storage dam. Flows are controlled for purposes of power generation and to promote salmon egg and embryo survival.<sup>(a)</sup> Columbia River flow rates near Priest Rapids during the 83-year period from 1917 to 2000 averaged nearly 3360 m<sup>3</sup>/s (120,000 ft<sup>3</sup>/s). Daily average flows during this period ranged from 570 to 19,500 m<sup>3</sup>/s (20,000 to 690,000 ft<sup>3</sup>/s). The lowest and highest flows occurred before the construction of upstream dams. During the 10-year period from 1991 through 2000, the average flow rate was also about 3360 m<sup>3</sup>/s (120,000 ft<sup>3</sup>/s). Daily average flows through the Hanford Reach for 1994 through April 2005 are plotted in Figure 4.4-2. Storage dams on tributaries of the Columbia River also affect flows.

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(a) The Vernita Bar Agreement (signed June 16, 1988 by the U.S. Department of Energy, federal and state agencies, Tribal governments, and public utility districts in Grant, Chelan, and Douglas counties) was created to prevent redds (salmon nests) from being left high and dry when river flows fluctuate to meet peak power demands.



**Figure 4.4-1.** Surface Water Features on the Hanford Site, Washington, including Rivers, Ponds, Major Springs, and Ephemeral Streams



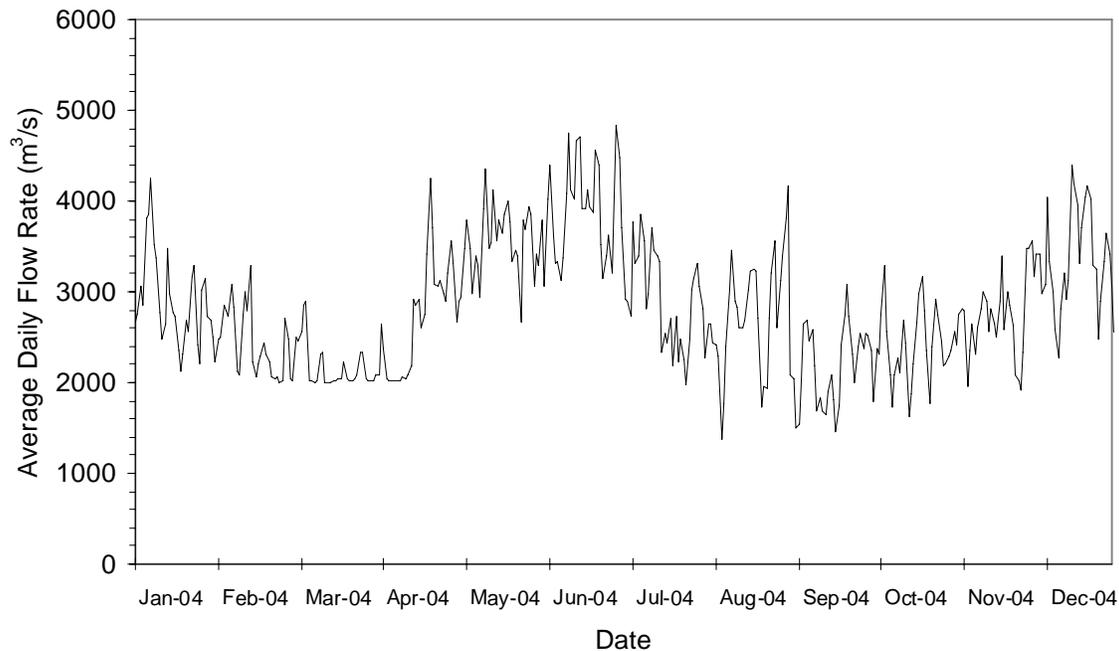
**Figure 4.4-2.** Average Daily Flow for the Hanford Reach, Columbia River, Washington, from January 1994 through April 2005 (data from USGS 2005, provisional data not yet reviewed and subject to change) ( $1 \text{ m}^3/\text{s} = 35.3 \text{ ft}^3/\text{s}$ )

During 1996 and 1997, exceptionally high spring runoff resulted from larger than normal snowpacks. The highest daily average flow rate during 1997 was nearly  $11,750 \text{ m}^3/\text{s}$  ( $415,000 \text{ ft}^3/\text{s}$ ) (USGS 2005). Peak daily average flow during 2004 was  $4842 \text{ m}^3/\text{s}$  ( $171,000 \text{ ft}^3/\text{s}$ ) (Figure 4.4-3). Columbia River flows typically peak from April through June during spring runoff from snowmelt and are lowest from September through October. As a result of daily discharge fluctuations from upstream dams, the depth of the river varies over a short time period. River stage changes of up to 3 m (10 ft) during a 24-hr period may occur along the Hanford Reach (Poston et al. 2003). The width of the river varies from approximately 300 m (1000 ft) to 1000 m (3300 ft) within the Hanford Reach. The width also varies with the flow rate, which causes repeated wetting and drying of an area along the shoreline.

The primary uses of the Columbia River include the production of hydroelectric power, irrigation of cropland in the Columbia Basin, and transportation of materials by barge. The Hanford Reach is the upstream limit of barge traffic on the mainstem Columbia River. Barges are used to transport reactor vessels from decommissioned nuclear submarines to Hanford for disposal. Several communities along the Columbia River rely on the river as their source of drinking water. The Columbia River is also used as a source of both drinking water and industrial water for several Hanford Site facilities (Poston et al. 2003). In addition, the Columbia River is used extensively for recreation, including fishing, hunting, boating, sailing, water-skiing, diving, and swimming.

#### 4.4.1.2 Water Quality of the Columbia River

The water quality of the Columbia River from Grand Coulee Dam to the Washington-Oregon border, which includes the Hanford Reach, has been designated as Class A, Excellent (WAC 173-201A) by Washington State (Poston et al. 2003). Class A waters are suitable for essentially all uses, including raw

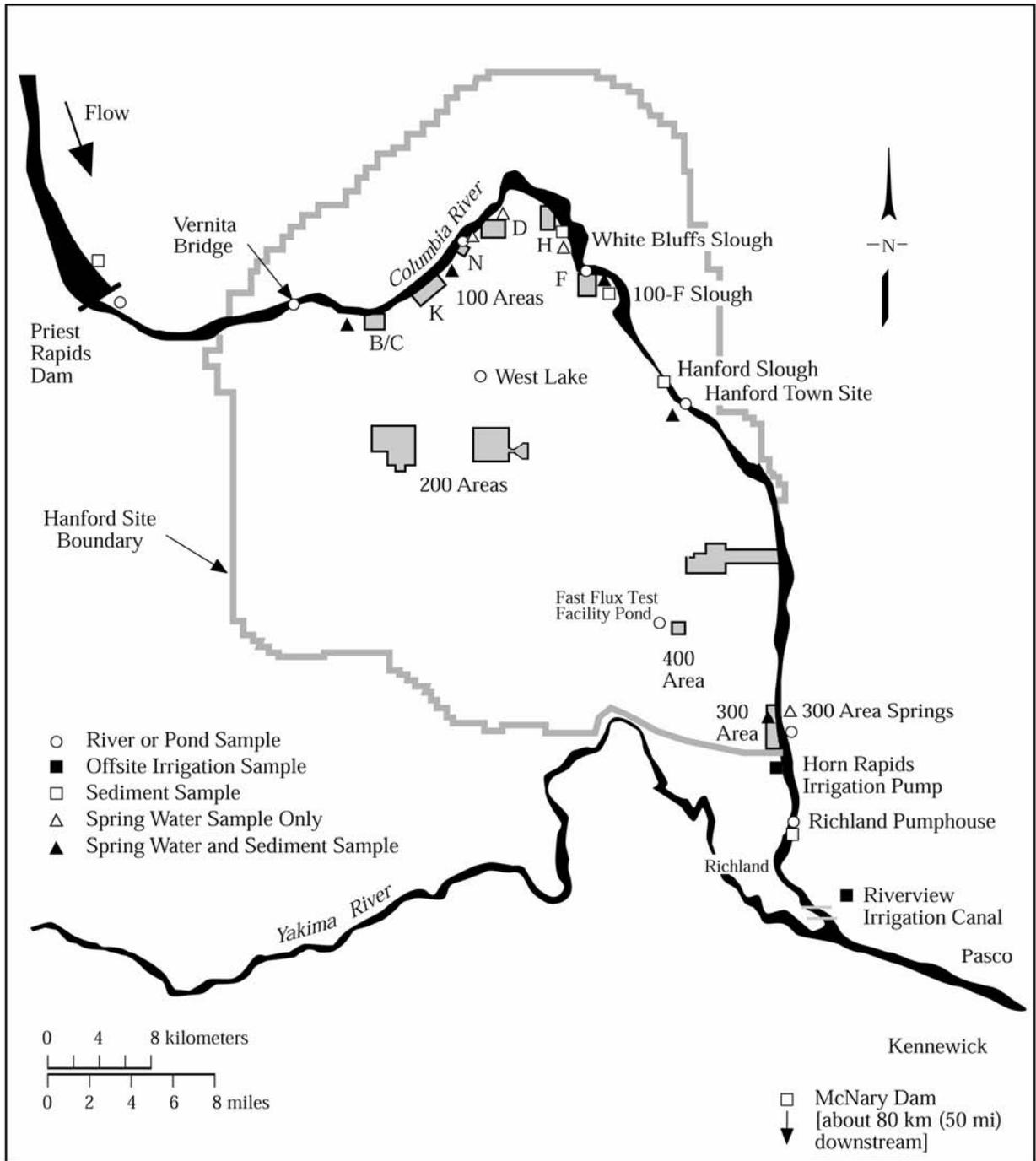


**Figure 4.4-3.** Average Daily Flow for the Columbia River During Calendar Year 2004 (data from USGS 2005, provisional data not yet reviewed and subject to change) (1 m<sup>3</sup>/s = 35.3 ft<sup>3</sup>/s)

drinking water, recreation, and wildlife habitat. State and federal drinking water standards apply to the Columbia River (Section 6.2.2).

During 2002, the USGS measured several water quality parameters at Vernita Bridge, upstream of Hanford Site operations areas, and at the Richland pumphouse, which is downstream of the Hanford Site (Figure 4.4-4). Total dissolved solids measured near the Hanford Site during 2002 ranged from 71 to 99 mg/L, and total dissolved nitrogen ranged from 0.16 to 0.37 mg/L. Dissolved oxygen ranged from 10 to 14 mg/L and pH was 7.7 to 8.2. There were no statistically significant differences between upstream and downstream samples for these parameters (Poston et al. 2003).

PNNL measured both radiological and nonradiological constituents in Columbia River water during 2002 as part of a continuing environmental monitoring program (Poston et al. 2003). Cumulative water samples are collected at Priest Rapids Dam and at the Richland pumphouse (Figure 4.4-4). Additional samples were taken at transects of the river and at near-shore locations at the Vernita Bridge, 100-F Area, 100-N Area, the Hanford Townsite, and the 300 Area. These water samples were collected at frequencies varying from quarterly to annually. Results are presented in Bisping (2003) and summarized in Poston et al. (2003). These data show a statistical increase in tritium, nitrate, uranium, and iodine-129 along the Hanford Reach. All these constituents are known to be entering the river from contaminated groundwater beneath the Hanford Site (Section 4.4.3). Measurements of strontium-90 at the Richland pumphouse were not statistically higher than those at the Vernita Bridge even though strontium-90 is known to enter the river through groundwater inflow at 100-N Area. Measurements of tritium along transects showed higher concentrations near the shoreline relative to mid-river for samples from the 100-N Area, the Hanford Townsite, the 300 Area, and the Richland pumphouse.



**Figure 4.4-4.** Surface Water and Sediment Monitoring Locations, Hanford Site, Washington (Poston et al. 2003)

Other sources of pollutants entering the river are irrigation return flows and groundwater seepage associated with irrigated agriculture. The USGS (1995) documented nitrate groundwater contamination in Franklin County, which also seeps into the river along the Hanford Reach. However, in spite of pollutants introduced from both the Hanford Site and other sources, dilution in the river results in contaminant concentrations that are below drinking water standards (Poston et al. 2003).

#### **4.4.1.3 Yakima River**

The Yakima River follows a portion of the southwestern boundary of the Hanford Site and has much lower flows than the Columbia River. The average flow, based on 70 years of daily flow records (USGS 2005), is about  $100 \text{ m}^3/\text{s}$  ( $3530 \text{ ft}^3/\text{s}$ ), with an average monthly maximum of  $497 \text{ m}^3/\text{s}$  ( $17,550 \text{ ft}^3/\text{s}$ ) and minimum of  $4.6 \text{ m}^3/\text{s}$  ( $165 \text{ ft}^3/\text{s}$ ). Exceptionally high flows were observed during 1996 and 1997 (Figure 4.4-5). The highest average daily flow rate during 1996 was nearly  $1300 \text{ m}^3/\text{s}$  ( $45,900 \text{ ft}^3/\text{s}$ ). Average daily flow during 2000 was  $89.9 \text{ m}^3/\text{s}$  ( $3176 \text{ ft}^3/\text{s}$ ). Average daily flow during 2004 was  $73 \text{ m}^3/\text{s}$  ( $2580 \text{ ft}^3/\text{s}$ ) (USGS 2005). The Yakima River System drains surface runoff from approximately one-third of the Hanford Site. Groundwater is expected to flow from the Yakima River into the aquifer underlying the Site rather than from the aquifer into the river because, based on well water-level measurements, the elevation of the river surface is higher than the adjacent water table (Thorne et al. 1994). Therefore, groundwater contaminants from the Hanford Site do not reach the Yakima River.

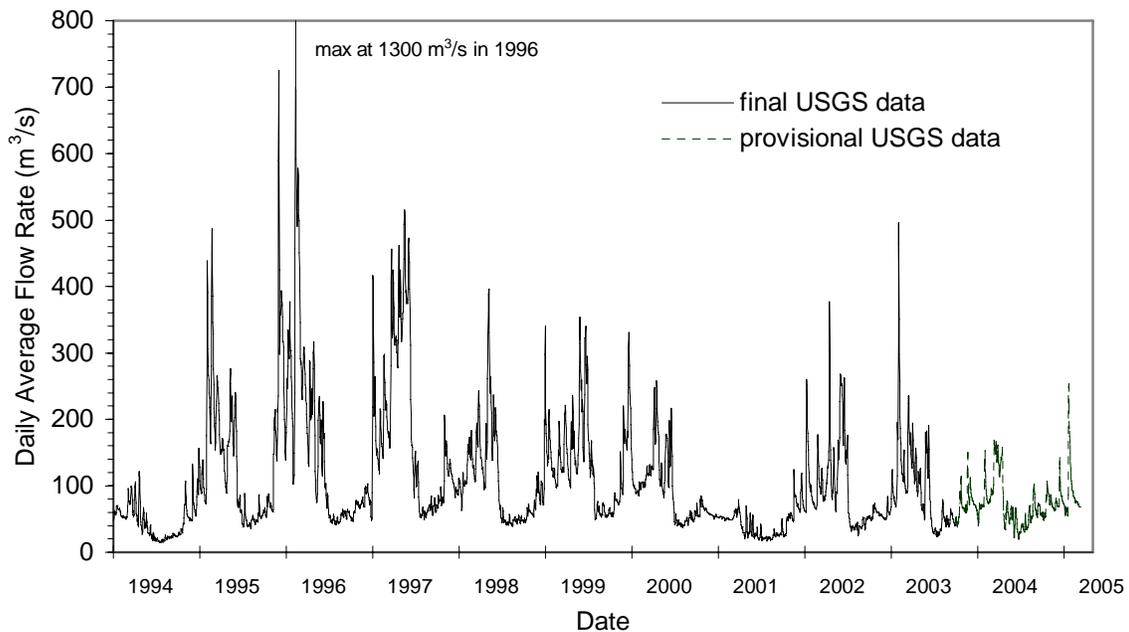
#### **4.4.1.4 Springs and Streams**

Springs are found on the slopes of the Rattlesnake Hills along the western edge of the Hanford Site (DOE 1988). There is also an alkaline spring at the east end of Umtanum Ridge (Hall 1998). Rattlesnake and Snively springs form small surface streams. Water discharged from Rattlesnake Springs flows in Dry Creek for about 3 km (1.6 mi) before disappearing into the ground (Figure 4.4-1). Cold Creek and its tributary, Dry Creek, are ephemeral streams within the Yakima River drainage system in the southwestern portion of the Hanford Site. These streams drain areas to the west of the Hanford Site and cross the southwestern part of the Site toward the Yakima River. When surface flow occurs, it infiltrates rapidly and disappears into the surface sediments in the western part of the Site. The quality of water in these springs and streams varies depending on the source. However, they are upgradient of Hanford waste sites and groundwater contamination plumes.

#### **4.4.1.5 Columbia Riverbank Springs**

Riverbank springs were documented along the Hanford Reach long before Hanford operations began (Jenkins 1922). During the early 1980s, researchers identified 115 springs along the Benton County shoreline of the Hanford Reach (McCormack and Carlile 1984). Seepage occurs both below the river surface and on the exposed riverbank, particularly at low-river stage. Riverbank springs flow intermittently, apparently influenced primarily by changes in river level. In many areas, water flows from the river into the aquifer at high river stage and then returns to the river at low river stage. This “bank-storage” phenomenon has been modeled numerically for the 100-H Area (Peterson and Connelly 2001).

In areas of contaminated groundwater, riverbank springs are also generally contaminated. However, the concentrations in seeping water along the riverbank may be lower than groundwater because of the bank-storage phenomenon. Contaminants have been detected in near shore samples downstream from riverbank springs (Poston et al. 2003). Riverbank springs are monitored for radionuclides at the 100-N Area, the Hanford Townsite, and the 300 Area (Figure 4.4-4). Hanford-origin contaminants occur in some of these springs (Peterson and Johnson 1992, Poston et al. 2003). Detected radionuclides include strontium-90, technetium-99, iodine-129, uranium-234, -235, and -238, and tritium. Other detected



**Figure 4.4-5.** Average Daily Flow for the Yakima River, Washington, from 1994 through April 2005 (data from USGS 2005, provisional data not yet reviewed and subject to change) ( $1 \text{ m}^3/\text{s} = 35.3 \text{ ft}^3/\text{s}$ )

contaminants include arsenic, chromium, chloride, fluoride, nitrate, and sulfate. Volatile organic compounds were below detection limits. Results for riverbank spring samples analyses are listed in Bisping (2003) and summarized in Poston et al. (2003). For a listing of the regulatory standards for groundwater, refer to Table 4.4-1.

The highest strontium-90 concentration detected in riverbank springs during 2002 was 3.3 pCi/L (0.12 Bq/L) at the 100-N Area. A spring in this area previously had a reported strontium-90 concentration higher than 1000 pCi/L (37.34 Bq/L). However, because of decreased groundwater elevations, no flow has been observed at this spring during the past six years (Poston et al. 2003). Tritium concentrations in riverbank springs varied widely with location. The highest tritium concentration detected in riverbank springs during 2002 was 58,000 pCi/L (2,100 Bq/L) at the Hanford Townsite. The highest iodine-129 concentration of 0.19 pCi/L (0.007 Bq/L) was also found in a Hanford Townsite spring. Concentrations of radionuclides including tritium, technetium-99, and iodine-129 in riverbank springs near the Hanford Townsite have generally been increasing since 1994. This is an area where a major groundwater plume from the 200 East Area intercepts the river. However, tritium concentration has declined since 1997. This decline may be due to the effects of radioactive decay and/or less wastewater disposal, which would cause the groundwater tritium plume to move at a slower velocity.

**Table 4.4-1.** Regulatory Drinking Water Standards for Groundwater

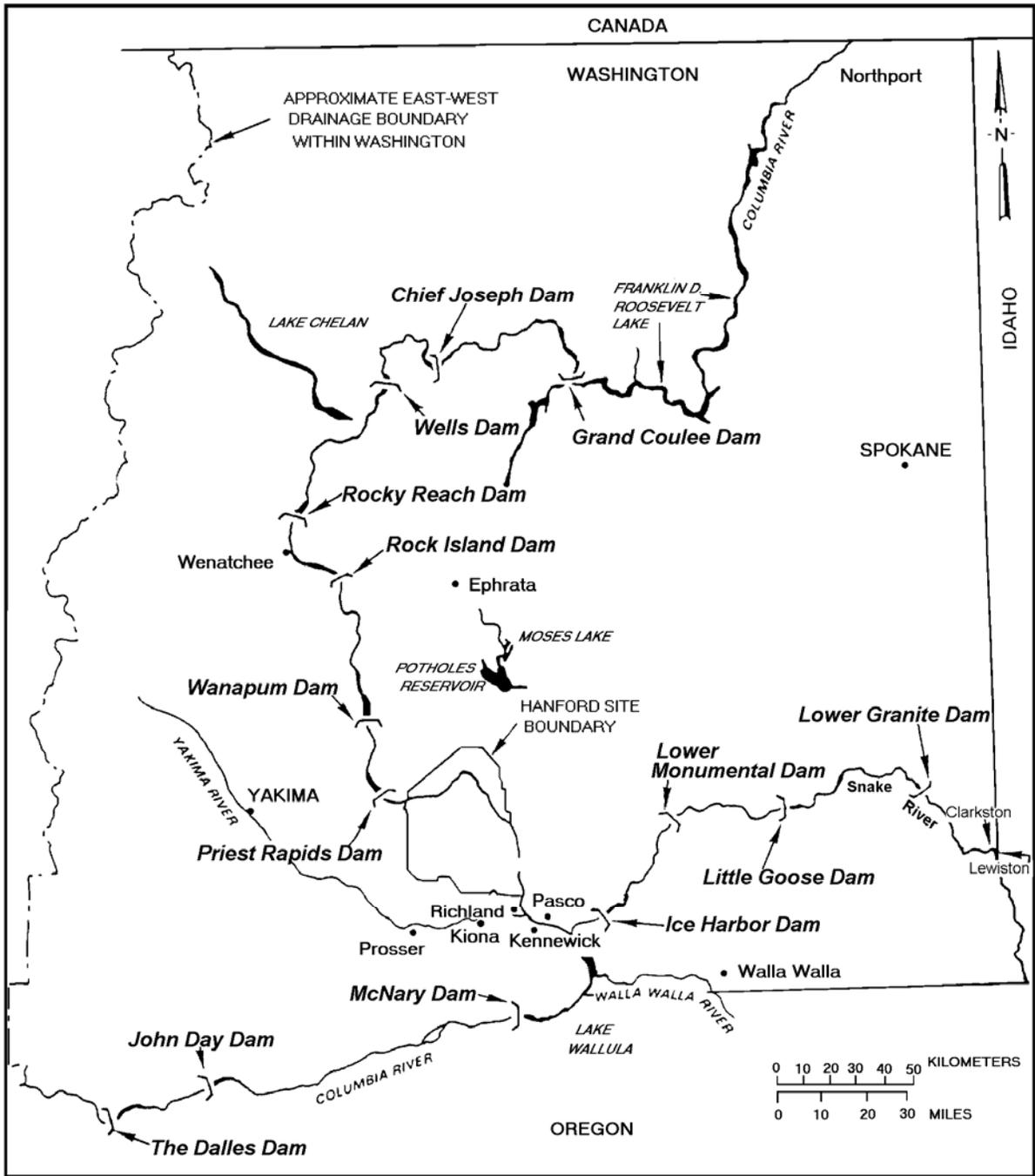
<b>Contaminant, Units</b>	<b>Drinking Water Standard</b>	<b>Contaminant, Units</b>	<b>Drinking Water Standard</b>
arsenic (filtered), µg/L	10	gross beta, pCi/L	50
cadmium (filtered), µg/L	5	iodine-129, pCi/L	1
carbon tetrachloride, µg/L	5	nickel (filtered), µg/L	100
carbon-14, pCi/L	2,000	nitrate, mg/L	45
cesium-137, pCi/L	200	nitrite, mg/L	3.3
chloroform, µg/L	100	plutonium-239/240, pCi/L	not applicable
chromium (dissolved), µg/L	100	strontium-90, pCi/L	8
cis-1,2-dichloroethene, µg/L	70	technetium-99, pCi/L	900
cobalt-60, pCi/L	100	trichloroethene, µg/L	5
cyanide, µg/L	200	tritium, pCi/L	20,000
fluoride, mg/L	4	uranium, µg/L	30
gross alpha, pCi/L	15		

#### 4.4.1.6 Runoff and Net Infiltration

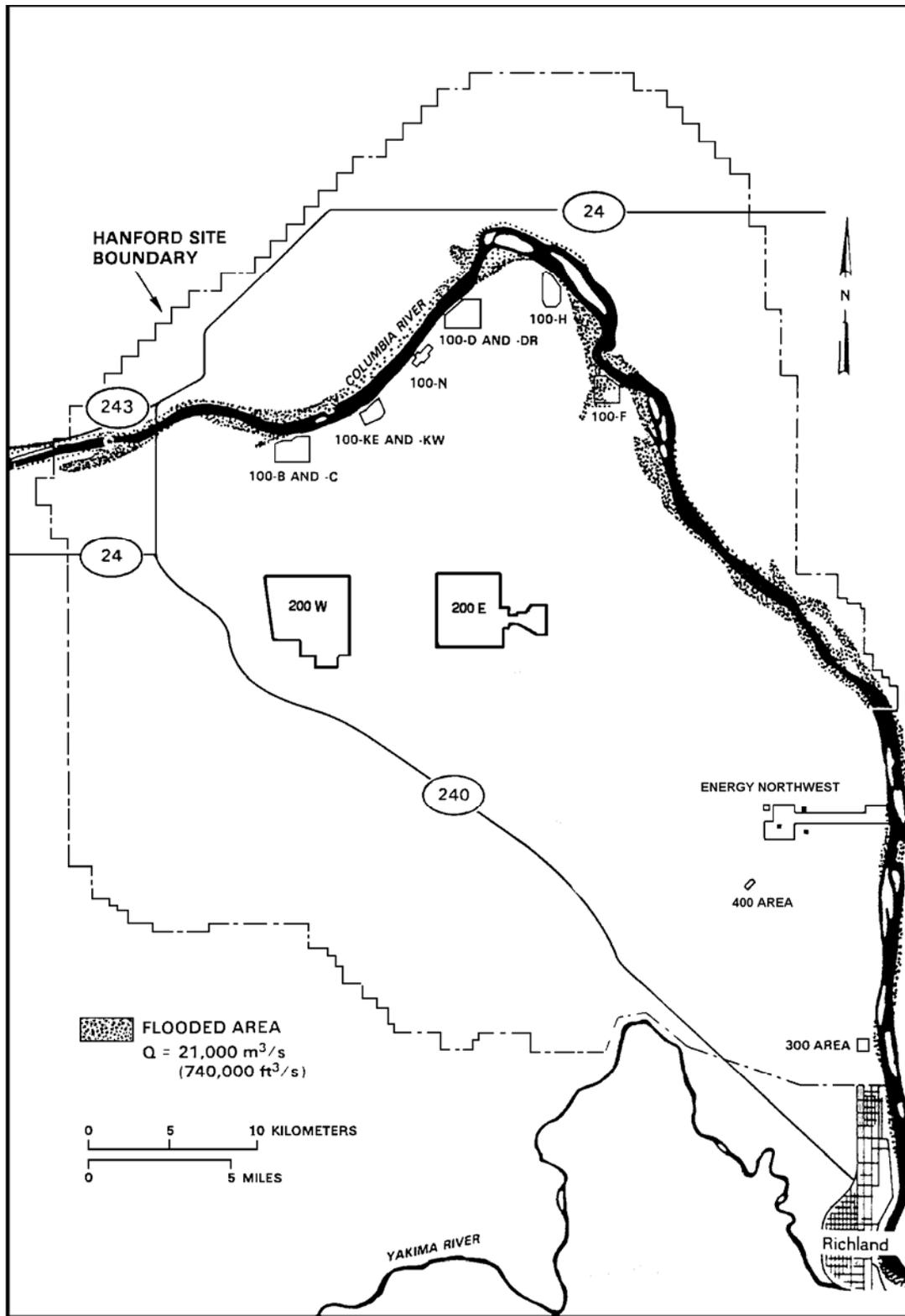
Total estimated precipitation over the Pasco Basin is about  $9 \times 10^8 \text{ m}^3$  ( $3.2 \times 10^{10} \text{ ft}^3$ ) annually (DOE 1988). This was calculated by multiplying the average annual precipitation averaged over the Pasco Basin by the  $4900 \text{ km}^2$  ( $1900 \text{ mi}^2$ ) basin area. Precipitation varies both spatially and temporally with higher amounts generally falling at higher elevations. Annual precipitation measured at the HMS has varied from 7.6 cm (3 in.) to 31.3 cm (12.3 in.) since 1945. Most precipitation occurs during the late autumn and winter, with more than half of the annual amount occurring from November through February. Mean annual runoff from the Pasco Basin is estimated at  $3.1 \times 10^7 \text{ m}^3/\text{yr}$  ( $1.1 \times 10^9 \text{ ft}^3/\text{yr}$ ), or approximately 3 percent of the total precipitation (DOE 1988). Most of the remaining precipitation is lost through evapotranspiration; however, a portion of the precipitation that infiltrates the soil is not lost to evaporation or transpiration and eventually recharges the groundwater flow system. The amount of recharge varies spatially based primarily on soil texture and vegetation (Gee et al. 1992, Fayer and Walters 1995). Recharge also varies temporally with the majority occurring in the winter and spring. There is some evidence that the most significant recharge events are associated with rapid melting of relatively large snowpacks, which may only occur a few times in a decade (Fayer and Szecsody 2004).

#### 4.4.1.7 Flooding

Large Columbia River floods have occurred in the past (DOE 1987), but the likelihood of recurrence of large-scale flooding has been reduced by the construction of several flood control/water-storage dams upstream of the Hanford Site (Figure 4.4-6). Major floods on the Columbia River are typically the result of rapid melting of the winter snowpack over a wide area augmented by above-normal precipitation. The maximum historical flood on record occurred June 7, 1894, with a peak discharge at the Hanford Site of  $21,000 \text{ m}^3/\text{s}$  ( $742,000 \text{ ft}^3/\text{s}$ ). The floodplain associated with the 1894 flood was modeled based on topographic crosssections of the river channel (ERDA 1976) (Figure 4.4-7). The largest recent flood



**Figure 4.4-6.** Locations of Principal Dams within the Columbia Plateau, Washington and Oregon (DOE 1988)



**Figure 4.4-7.** Flood Area on the Hanford Site, Washington, during the 1894 Flood Based on Modeled Topographic Cross Sections (DOE 1986)

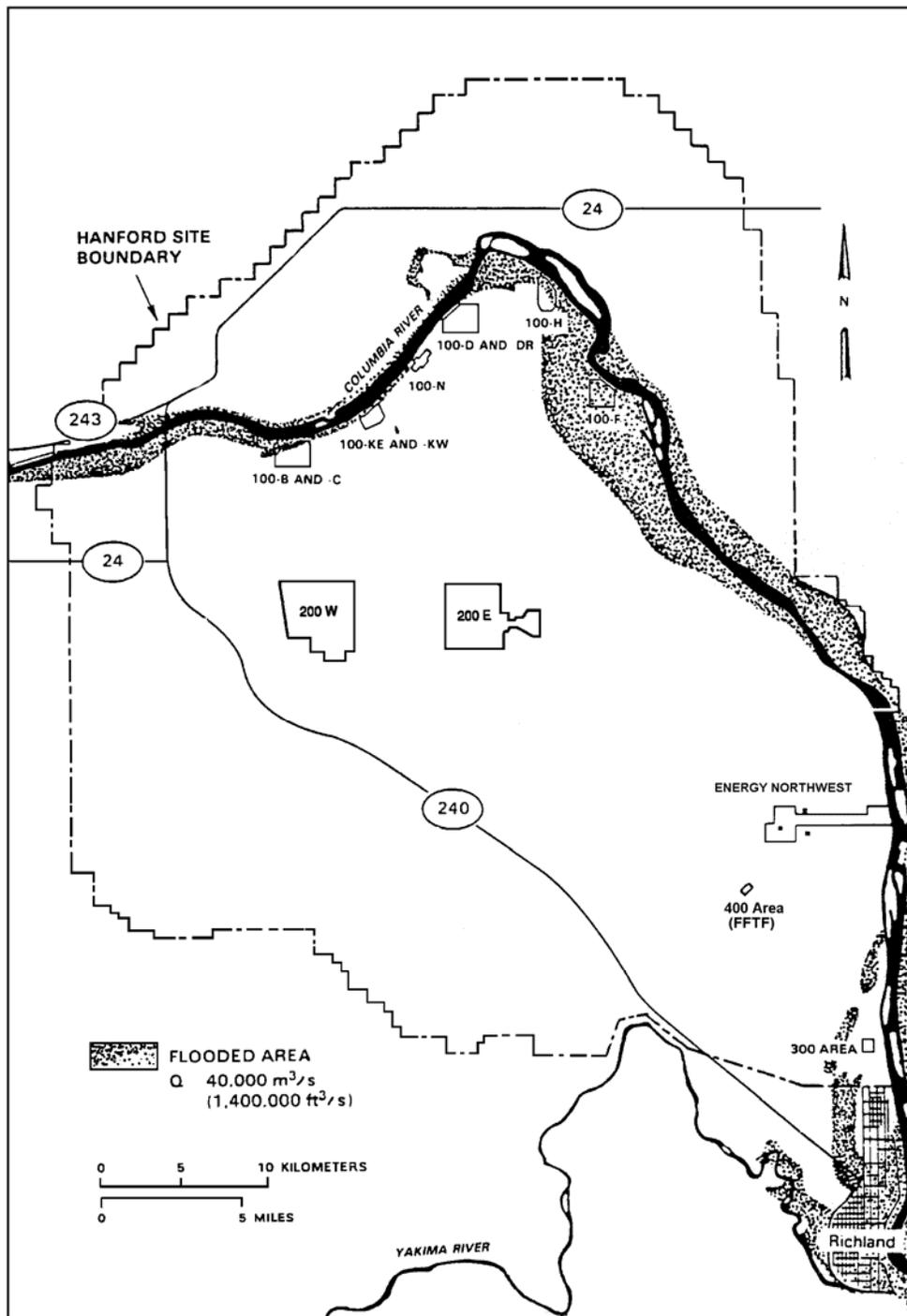
took place during 1948 with an observed peak discharge of 20,000 m<sup>3</sup>/s (700,000 ft<sup>3</sup>/s) at the Hanford Site. The exceptionally high runoff during the spring of 1996 resulted in a maximum discharge of nearly 11,750 m<sup>3</sup>/s (415,000 ft<sup>3</sup>/s) (USGS 2002b). There are no Federal Emergency Management Agency (FEMA) floodplain maps for the Hanford Reach of the Columbia River. FEMA only maps developing areas, and the Hanford Reach has been specifically excluded because the adjacent land is primarily under federal control.

Evaluation of flood potential is conducted in part through the concept of the probable maximum flood, which is determined from the upper limit of precipitation falling on a drainage area and other hydrologic factors such as antecedent moisture conditions, snowmelt, and tributary conditions that could result in maximum runoff. The probable maximum flood for the Columbia River downstream of Priest Rapids Dam has been calculated to be 40,000 m<sup>3</sup>/s (1.4 million ft<sup>3</sup>/s) and is greater than the 500-year flood (Figure 4.4-8). This flood would inundate parts of the 100 Area adjacent to the Columbia River, but the central portion of the Hanford Site would remain unaffected (DOE 1986).

The U.S. Army Corps of Engineers (Corps) (1989) has derived the Standard Project Flood with both regulated and unregulated peak discharges given for the Columbia River downstream of Priest Rapids Dam. Frequency curves for both unregulated and regulated peak discharges are also given for the same portion of the Columbia River. The regulated Standard Project Flood for this part of the river is given as 15,200 m<sup>3</sup>/s (54,000 ft<sup>3</sup>/s) and the 100-year regulated flood as 12,400 m<sup>3</sup>/s (440,000 ft<sup>3</sup>/s) (DOE 1998c). Impacts to the Hanford Site are negligible and would be less than the probable maximum flood (Figure 4.4-8).

Potential dam failures on the Columbia River have been evaluated. Upstream failures could arise from a number of causes, with the magnitude of the resulting flood depending on the degree of breaching at the dam. The Corps evaluated a number of scenarios on the effects of failures of Grand Coulee Dam, assuming flow conditions of 11,000 m<sup>3</sup>/s (400,000 ft<sup>3</sup>/s). For emergency planning, they hypothesized that 25 and 50 percent breaches, the “instantaneous” disappearance of 25 or 50 percent of the center section of the dam, could result from the detonation of explosives. The discharge or floodwave resulting from such an instantaneous 50 percent breach at the outfall of the Grand Coulee Dam was determined to be 600,000 m<sup>3</sup>/s (21 million ft<sup>3</sup>/s). In addition to the areas inundated by the probable maximum flood (Figure 4.4-8), the remainder of the 100 Area, the 300 Area, and nearly all of Richland would be flooded (DOE 1986, ERDA 1976). No determinations were made for failures of dams upstream, for associated failures downstream of Grand Coulee or for breaches greater than 50 percent of Grand Coulee Dam. The 50 percent scenario was believed to represent the largest realistically conceivable flow resulting from either a natural or human-induced breach (DOE 1986). It was also assumed that a scenario such as the 50 percent breach would occur only as the result of direct explosive detonation, and not because of a natural event such as an earthquake, and that even a 50 percent breach under these conditions would indicate an emergency situation in which there might be other overriding major concerns.

The possibility of a landslide resulting in river blockage and flooding along the Columbia River has been examined for an area bordering the east side of the river upstream of the city of Richland. The possible landslide area considered was the 75-m- (250-ft-) high bluff generally known as White Bluffs. Calculations were made for an 8 x 10<sup>5</sup> m<sup>3</sup> (1 x 10<sup>6</sup> yd<sup>3</sup>) landslide volume with a concurrent flood flow of 17,000 m<sup>3</sup>/s (600,000 ft<sup>3</sup>/s) (a 200-year flood), resulting in a floodwave crest elevation of 122 m (400 ft) above mean sea level. Areas inundated upstream of such a landslide event would be similar to those occurring during the probable maximum flood (DOE 1986).



**Figure 4.4-8.** Flood Area for the Probable Maximum Flood on the Hanford Site, Washington, as Determined by the Upper Limit of Precipitation and Maximum Runoff (DOE 1986)

There have been fewer than 20 major floods on the Yakima River since 1862 (DOE 1986). The most severe occurred during November 1906, December 1933, May 1948, and February 1996; discharge magnitudes at Kiona, Washington, were 1870 m<sup>3</sup>/s (66,000 ft<sup>3</sup>/s), 1900 m<sup>3</sup>/s (67,000 ft<sup>3</sup>/s), 1050 m<sup>3</sup>/s (37,000 ft<sup>3</sup>/s), and 1300 m<sup>3</sup>/s (45,900 ft<sup>3</sup>/s), respectively. The average flow of the Yakima River is 104 m<sup>3</sup>/s (165 ft<sup>3</sup>/s), and the average monthly maximum is 490 m<sup>3</sup>/s (17,500 ft<sup>3</sup>/s). The recurrence intervals for the 1933 and 1948 floods are estimated at 170 and 33 years, respectively. The development of irrigation reservoirs within the Yakima River Basin has considerably reduced the flood potential of the river. The southern border of the Hanford Site could be susceptible to a 100-year flood on the Yakima River (Figure 4.4-9).

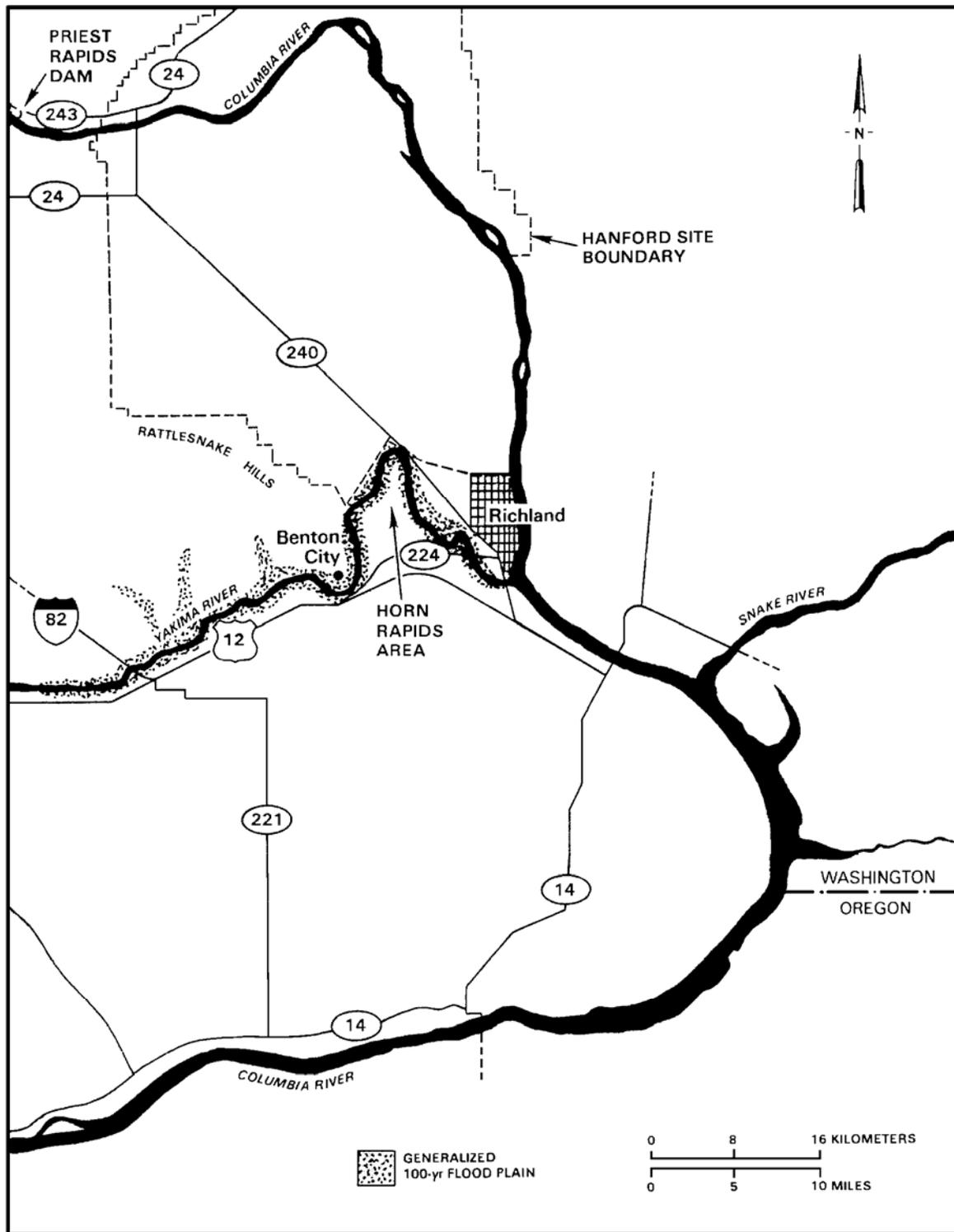
During 1980, a flood risk analysis of Cold Creek was conducted as part of the characterization of a basaltic geologic repository for high-level radioactive waste. Such design work is usually done according to the criteria of Standard Project Flood or probable maximum flood, rather than the worst-case or 100-year flood scenario. Therefore, in lieu of 100- and 500-year floodplain studies, a probable maximum flood evaluation was performed based on a large rainfall or combined rainfall/snowmelt event in the Cold Creek and Dry Creek watershed (Skaggs and Walters 1981). The probable maximum flood discharge rate for the lower Cold Creek Valley was 2265 m<sup>3</sup>/s (80,000 ft<sup>3</sup>/s) compared to 564 m<sup>3</sup>/s (19,900 ft<sup>3</sup>/s) for the 100-year flood. Modeling indicated that State Route (SR) 240 along the Site's southwestern and western areas would not be usable (Figure 4.4-10).

#### **4.4.1.8 Non-Riverine Surface Water**

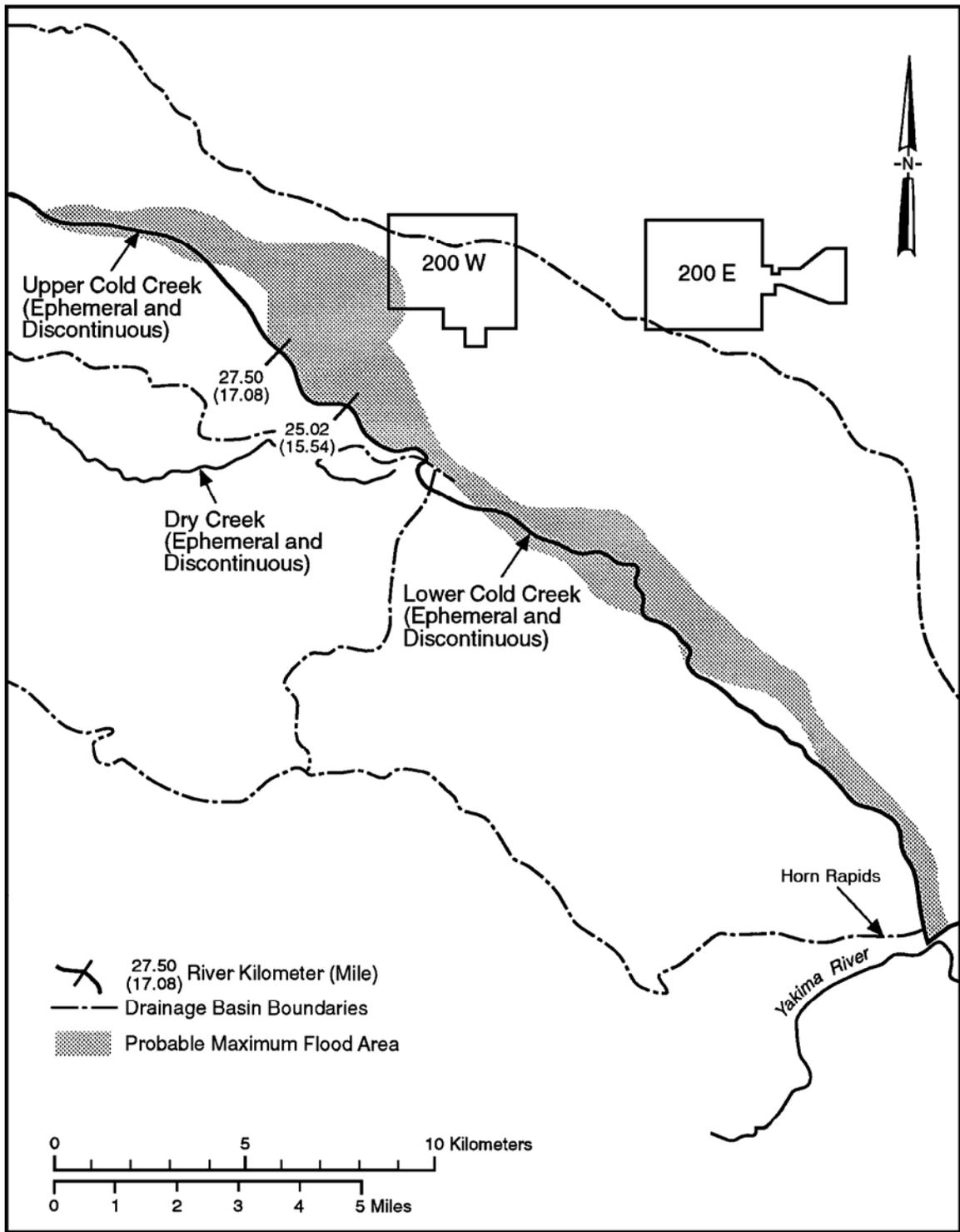
Active ponds on the Hanford Site include West Lake and the 200 Area Treated Effluent Disposal Facility (TEDF) disposal ponds (Figure 4.4-1). West Lake is north of the 200 East Area and is a natural feature recharged from groundwater (Gephart et al. 1976, Poston et al. 1991). West Lake has not received direct effluent discharges from Site facilities; rather, its existence is caused by the intersection of the elevated water table with the land surface in the topographically low area. Water levels of West Lake fluctuate with water table elevation, which is influenced by wastewater discharge in the 200 Areas. The water level and size of the lake has been decreasing over the past several years because of reduced wastewater discharge (Section 4.4.3.2). There is unsubstantiated information that sewage sludge may have been dumped in the vicinity of West Lake during the 1940s, and this has been cited as the reason for elevated dissolved solids and nitrate in the lake water (Emery and McShane 1978, Meinhardt and Frostenson 1979). However, it is possible that the concentration of salts resulted from evaporation of groundwater at the lake, which has no outlet. Total dissolved solids are approximately 15,000 mg/L and pH is greater than 9. Nitrate and ammonia concentrations of about 1.8 and 2.6 mg/L, respectively, have been reported, which are greater than freshwater lakes, but lower than other alkaline lakes in Washington such as Soap Lake and Lake Lenore. West Lake contains relatively high levels of uranium that are thought to be from natural sources concentrated by evaporation in the lake (Poston et al. 1991, 2003).

TEDF is east of the 200 East Area and consists of two disposal ponds. These ponds are each 0.02 km<sup>2</sup> (0.008 mi<sup>2</sup>) in size and receive industrial wastewater permitted in accordance with Ecology's State Waste Discharge Permit Program (WAC 173-216). The wastewater evaporates into the air or percolates into the ground from the disposal ponds.

There are several naturally occurring vernal ponds near Gable Mountain and Gable Butte (Hall 1998). These ponds appear to occur where a depression is present in a relatively shallow buried basalt surface. Water collects within the depression over the winter resulting in a shallow pond that dries during the summer months. The formation of these ponds in any particular year depends on the amount and temporal distribution of precipitation and snowmelt events. The vernal ponds range in size from about 20 ft x 20 ft to 150 ft x 100 ft (6.1 m x 6.1 m to 45.73 m x 30.5 m), and were found in three clusters.



**Figure 4.4-9.** Flood Area from a 100-Year Flood of the Yakima River near the Hanford Site, Washington (DOE 1986)



**Figure 4.4-10.** Extent of Probable Maximum Flood in Cold Creek Area, Hanford Site, Washington, delineated using the U.S. Army Corps of Engineers' HEC-2 Water Surface Profiles model (Skaggs and Walters 1981)

Approximately 10 were documented at the eastern end of Umtanum Ridge, 7 were observed in the central part of Gable Butte, and 3 were found at the eastern end of Gable Mountain (Figure 4.0-1).

Other than rivers and springs, there are no naturally occurring bodies of surface water adjacent to the Hanford Site. There are wetlands caused by irrigation, on the east and west sides of the Wahluke Slope, which lies north of the Columbia River and on the White Bluffs east of the Columbia River. Hatcheries and irrigation canals constitute the only other surface water in the Hanford Site vicinity. The Ringold Hatchery is located just south of the Hanford Site boundary on the east side of the Columbia River (Figure 4.4-1).

#### **4.4.2 Hanford Site Vadose Zone**

The vadose zone is that part of the geologic media which extends from the earth's surface to the water table. At the Hanford Site, the thickness of the vadose zone ranges from 0 m (0 ft) near the Columbia River to greater than 100 m (328 ft) beneath parts of the central plateau (Hartman 2000). Unconsolidated glacio-fluvial sands and gravels of the Hanford formation make up most of the vadose zone. In some areas, such as most of the 200 West Area and in some of the 100 Areas, the fluvial-lacustrine sediments of the Ringold Formation make up the lower part of the vadose zone. The Cold Creek unit also makes up part of the vadose zone. The integrated knowledge obtained from previous and on-going studies provides a good conceptual understanding of the geologic, hydraulic, and geochemical environment and its controls on the distribution and movement of contaminants within the vadose zone (DOE 1999b; Last et al. 2004).

Moisture movement through the vadose zone is important because it is the driving force for migration of most contaminants to the groundwater. Radioactive and hazardous wastes in the soil column from liquid-waste disposals, unplanned leaks, solid waste burial, and underground tank storage are potential sources of continuing and future vadose zone and groundwater contamination. Contaminants may continue to move downward for long periods (tens to hundreds of years depending on recharge rates and the distribution coefficient of the contaminant) after termination of liquid waste disposal.

Except for the State Approved Land Disposal Site (SALDS), the 200 Area TEDF ponds (Figure 4.4-1), and septic drain fields, liquid discharges to the vadose zone ended during the mid-1990s. Currently, the major source of moisture to the vadose zone is precipitation. Infiltration and deep drainage of meteoric water in the vadose zone causes older preexisting water to be displaced downward by newly infiltrated water. The amount of deep drainage (below the root zone) at any particular site is dependent on the total amount of water available at the time of the event, soil type, and the presence of vegetation. Usually, vegetation reduces the amount of deep drainage through the biological process of transpiration.

The vadose-zone stratigraphy influences the movement of liquid through the soil column. Where conditions are favorable, lateral spreading of liquid effluent and/or local perched water zones may develop. Lateral spreading can occur along any strata with contrasting conductivity. Perched water zones form where downward moving moisture accumulates on top of less-permeable soil lenses or highly cemented horizons. Even in relatively uniform sediments the influence of grain orientation is important and can give rise to anisotropic hydraulic properties, causing significant lateral movement of contaminant plumes (Ward et al. 2002a, b; Zhang et al. 2003). Lateral spreading can delay the arrival of contaminants at the water table but may cause mixing of the subsurface plume at one site with that of an adjacent site. Spreading may also require increasing the area of surface barriers to cover wider plumes.

Preferential flow may also occur along discontinuities, such as clastic dikes and fractures. Clastic dikes are a common geologic feature in the suprabasalt sediments at the Hanford Site. Their most

important feature is their potential to either enhance or inhibit vertical and lateral movement of contaminants in the subsurface, depending on textural relationships (Fecht et al. 1999).

#### 4.4.2.1 Vadose Zone Contamination

The Hanford Site has more than 800 past-practice liquid-disposal facilities. Radioactive liquid waste was discharged to the vadose zone through reverse (injection) wells, French drains, cribs, ponds, trenches, and ditches. From 1944 through the late 1980s, 1.5 to 1.7 billion m<sup>3</sup> (396 to 449 billion gal) of effluent were disposed to the soils (Gephart 1999). Most effluent was released in the 200 Areas. The major groundwater contaminant plumes emanating from the 200 Areas are those of tritium and nitrate. The major source for both was discharges from chemical processing of irradiated nuclear fuel rods.

Also present are technetium-99 and iodine-129 which, like tritium and nitrate, are mobile in both the vadose zone and groundwater. The major sources of technetium-99 and iodine-129 were discharges to liquid disposal facilities. Vadose zone sources for these contaminants remain beneath many past-practice disposal facilities. However, other than physical sampling and laboratory analysis, there are few direct ways to monitor tritium, nitrate, technetium-99, and iodine-129 in the vadose zone.

Liquid wastes generated during plutonium recovery processes at Z Plant in the 200 West Area contained carbon tetrachloride. These wastes were discharged to nearby subsurface liquid waste disposal facilities from 1955 to 1973 (Rohay et al. 1994, Swanson *et al.* 1999). Soil vapor extraction is being used to remove carbon tetrachloride from the vadose zone in the 200 West Area (Hartman et al. 2004).

Approximately 280 unplanned releases in the 200 Areas also contributed contaminants to the vadose zone (DOE 1997b). Many of these were from underground tanks and have contributed significant contamination to the vadose zone. In addition, approximately 50 active and inactive septic tanks and drain fields and numerous radioactive and non-radioactive landfills and dumps have impacted the vadose zone (DOE 1997b). The landfills are and were used to dispose of solid wastes, which, in most instances, are easier to locate, retrieve, and remediate than are liquid wastes.

One hundred and forty-nine single-shell tanks and 28 double-shell tanks have been used to store high-level radioactive and mixed wastes in the 200 Areas. The wastes resulted from uranium and plutonium recovery processes and, to a lesser extent, from strontium and cesium recovery processes. Sixty-seven of the single-shell tanks are assumed to have leaked an estimated total of 2839 to 3975 m<sup>3</sup> (750,000 to 1,050,000 gal) of contaminated liquid to the vadose zone (Hanlon 2001). The three largest tank leaks were 435,320 L (115,000 gal), 37,850 to 1,048,560 L (10,000 to 277,000 gal), and 265,980 L (70,365 gal). The average tank leak was between 41,640 and 60,565 L (11,000 and 16,000 gal) (Hanlon 2001).

In addition to removing pumpable liquids from the single-shell tanks, interim measures have been taken to reduce the movement of tank farm contaminants in the vadose zone. Infiltration of water has been identified as the primary means by which contaminants are displaced beneath the farms. Surface water controls have been constructed to reduce surface water run-on from major meteorological events and from breaks in waterlines. Also, waterlines that were determined unnecessary have been isolated, cut, and capped. Waterlines that were found to be necessary for continued operations are being leak tested and any lines found to be leaking will be replaced.

Cooling water from the single-pass reactors along the Columbia River was routinely routed to retention basins in the 100 Areas prior to return to the river. Thermal shock from the hot cooling water cracked the basins so that much of the cooling water leaked into the vadose zone. In addition, trenches were used for disposal of cooling water from 100-KE, 100-KW, and 100-N Reactors. The disposed cooling waters contained fission and neutron activation products and some chemicals and actinides.

Tritium, strontium-90, nitrate, and chromium migrate through the vadose zone to groundwater, and ultimately, to the Columbia River in the 100 Areas. Chromium is actively being remediated at the 100-K and 100-H Areas by pump-and-treat methods and in the 100-D/DR Area by pump-and-treat and in situ redox methods (Hartman et al. 2004).

Contaminated cooling water that had contacted broken fuel rods was routed to trenches rather than being directly returned to the river. These fluids contained large quantities of fission and neutron activation products. In addition, leakage from fuel-storage basins in the 100-K Area also contributed quantities of fission products, transuranics, and carbon-14 to the soil column (Johnson et al. 1995). Thus, both past-practice sites and fuel-storage basin leakage are potential vadose zone sources of contaminants in the 100 Areas. Groundwater monitoring data from wells near the 100-KE and 100-KW basins do not show any indication of current leakage from either basin.

The amount of contamination remaining in the vadose zone is uncertain. Several compilations of vadose zone contamination have been formulated through the past years. DOE (1997b), Kincaid et al. (1998, 2001), and Simpson et al. (2001) contain the most recent inventories of contaminants disposed to past-practice liquid disposal facilities in the 200 Areas. Dorian and Richards (1978) list contaminant inventories disposed to most 100 Area past-practice facilities. Agnew (1997) and Anderson (1990) list inventories of effluents sent to single-shell tanks and Simpson et al. (2001) list the compositions of fluids leaked from single-shell tanks. Most recently, the Hanford Tank Farm Vadose Zone Project has issued a series of reports that estimate the curies of gamma-emitting radionuclides and the volumes of contaminated soil associated with each single-shell tank farm (<http://www.gjo.doe.gov/programs/hanf/>).

Further information on vadose zone characterization and monitoring activities on the Hanford Site is available online at <http://vadose.pnl.gov> and <http://www.hanford.gov/cp/gpp/> as well as in the annually updated Hanford Site groundwater monitoring report (i.e., Hartman et al. 2004).

### **4.4.3 Hanford Site Groundwater**

Groundwater at the Hanford Site originated as either recharge from rain and snowmelt, or from excess irrigation, canal seepage, and wastewater disposal. Most of this groundwater will eventually discharge to the Columbia River. Some will be brought to the surface through wells, or excavations, or through evaporation or transpiration in shallow water table areas.

Groundwater beneath the Hanford Site is found in both an upper unconfined aquifer system and deeper basalt-confined aquifers. The unconfined aquifer system is also referred to as the suprabasalt aquifer system because it is within the sediments that overlie the basalt bedrock. Portions of the suprabasalt aquifer system are locally confined. However, because the entire suprabasalt aquifer system is interconnected on a site-wide scale, it is referred to in this report as the Hanford unconfined aquifer system.

#### **4.4.3.1 Basalt-Confined Aquifer System**

Relatively permeable sedimentary interbeds and the more porous tops and bottoms of basalt flows provide the confined aquifers within the Columbia River Basalts. The horizontal hydraulic conductivities of most of these aquifers fall in the range of  $10^{-10}$  to  $10^{-4}$  m/s ( $3 \times 10^{-10}$  to  $3 \times 10^{-4}$  ft/s). Saturated but relatively impermeable dense interior sections of the basalt flows have horizontal hydraulic conductivities ranging from  $10^{-15}$  to  $10^{-9}$  m/s ( $3 \times 10^{-15}$  to  $3 \times 10^{-9}$  ft/s), about five orders of magnitude lower than some of the confined aquifers that lie between these basalt flows (DOE 1988). Hydraulic-head information indicates that groundwater in the basalt-confined aquifers generally flows toward the Columbia River and,

in some places, toward areas of enhanced vertical interaquifer flow with the unconfined aquifer system (Hartman et al. 2004, DOE 1988, Spane 1987). The basalt-confined aquifer system is important because there is a potential for significant groundwater movement between the two systems. Head relationships presented in previous reports (DOE 1988) demonstrate the potential for such interaquifer flow. In addition, limited water chemistry data indicate that interaquifer flow has occurred in an area near the Gable Mountain anticlinal structure, north of the 200 East Area (Graham et al. 1984, Jensen 1987).

#### **4.4.3.2 Unconfined Aquifer System**

The unconfined aquifer system is composed primarily of the Ringold Formation and overlying Hanford formation (Section 4.3). In some areas, the coarse-grained multilithic facies of the Cold Creek unit (pre-Missoula gravels) lie between these formations and below the water table. The other subunits of the Cold Creek unit are generally above the water table.

Water table elevations (Figure 4.4-11) show that groundwater in the unconfined aquifer at Hanford generally flows from recharge areas in the elevated region near the western boundary of the Hanford Site toward the Columbia River on the eastern and northern boundaries. The Columbia River is the primary discharge area for the unconfined aquifer. The Yakima River borders the Hanford Site on the southwest and is generally regarded as a source of recharge. Along the Columbia River shoreline, daily river level fluctuations may result in water table elevation changes of up to 3 m (10 ft). During the high river stage periods of 1996 and 1997, some wells near the Columbia River showed water level changes of more than 3 m (10 ft). As the river stage rises, a pressure wave is transmitted inland through the groundwater. The longer the duration of the higher river stage, the farther inland the effect is propagated. The pressure wave is observed farther inland than the water actually moves. For the river water to flow inland, the river level must be higher than the groundwater surface and must remain high long enough for the water to flow through the sediments. Typically, this inland flow of river water is restricted to within several hundred feet of the shoreline (McMahon and Peterson 1992).

Gee et al. (1992) and Fayer et al. (1996) estimate that recharge rates from precipitation across the Hanford Site range from near zero to over 100 mm/year (3.94 in./yr). Recharge is variable both spatially and temporally. It is greatest for coarse-textured soils bare of deep-rooted vegetation and in years with rapid snowmelt events and precipitation during cool months. The magnitude of recharge at a particular location is influenced by five main factors: climate, soils, vegetation, topography, and springs and streams. Events such as the fire that burned vegetation from a large portion of the Hanford Site during the summer of 2000 also affect recharge rates. Fayer et al. (1996) used several types of field data and computer modeling to estimate the areal distribution of mean recharge rates for the soil and vegetation conditions at the Hanford Site, including any disturbance by Hanford operations.

Between 1944 and the mid-1990s, the volume of artificial recharge from Hanford wastewater disposal was significantly greater than recharge from precipitation. An estimated  $1.68 \times 10^{12}$  L ( $4.44 \times 10^{11}$  gal) of liquid was discharged to disposal ponds, trenches, and cribs during this period. Wastewater discharge has decreased since 1984 and currently contributes a volume of recharge in the same range as the estimated natural recharge from precipitation. Because of the reduction in discharges, groundwater levels are falling, particularly around the operational areas (Hartman et al. 2004).

After the beginning of Hanford operations during 1943, the water table rose about 27 m (89 ft) under the U Pond disposal area in the 200 West Area and about 9.1 m (30 ft) under disposal ponds near the 200 East Area (Figure 4.4-11). The volume of water that was discharged to the ground at the 200 West Area was actually less than that discharged at the 200 East Area. However, the lower hydraulic conductivity of the aquifer near the 200 West Area inhibited groundwater movement in this area resulting in a higher groundwater mound. The presence of the groundwater mounds locally affected the direction

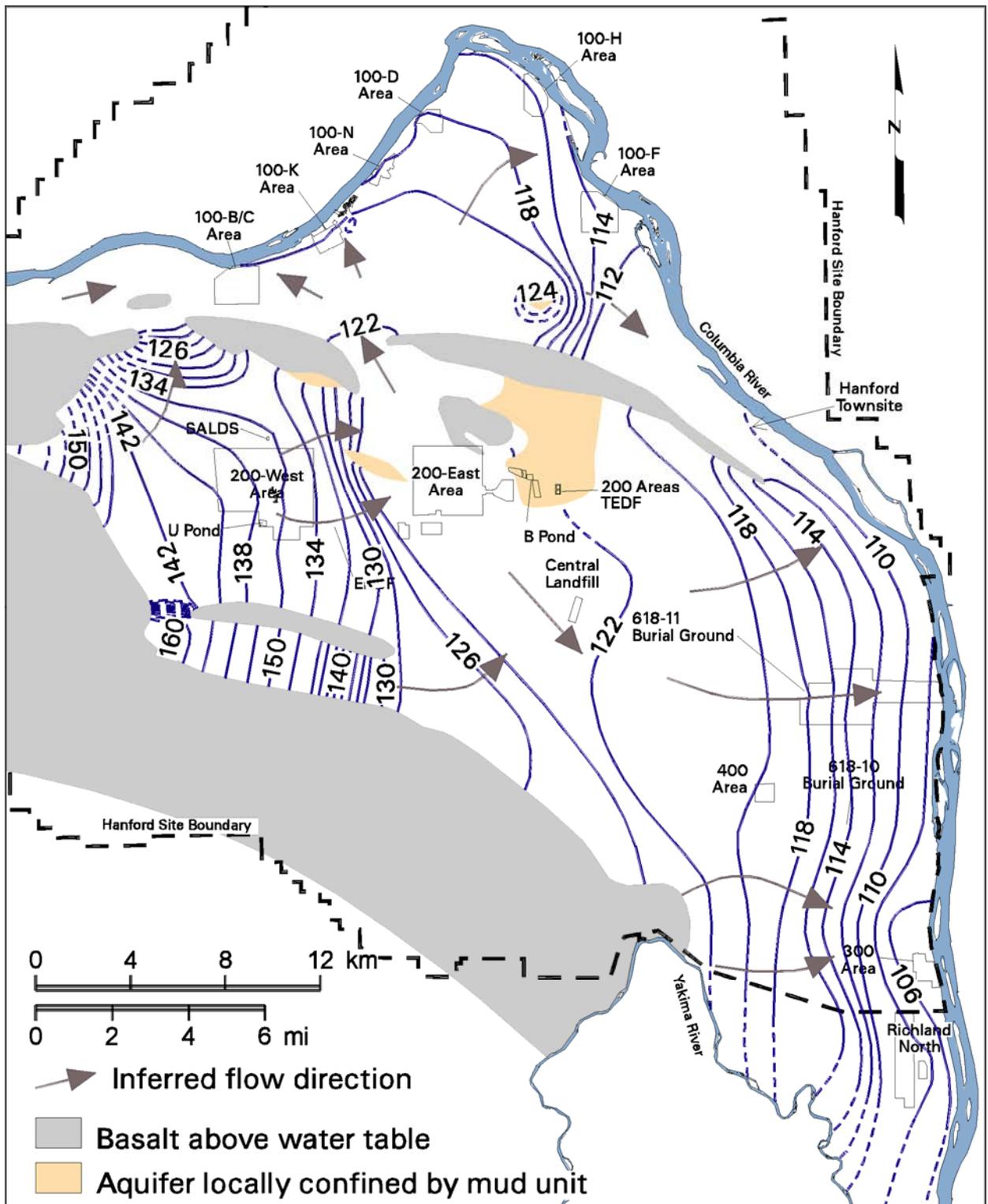


Figure 4.4-11. Water Table Elevations in Meters (1 m = 3.28 ft) and Inferred Groundwater Flow Directions for the Unconfined Aquifer at Hanford, Washington, March 2004 (Hartman *et al.* 2005)

of groundwater movement, causing radial flow from the discharge areas. Zimmerman et al. (1986) documented changes in water table elevations between 1950 and 1980. Until about 1980, the edge of the mounds migrated outward from the sources over time. Groundwater levels have declined over most of the Hanford Site since 1984 because of decreased wastewater discharges (Hartman et al. 2004). Although the reduction of wastewater discharges has caused water levels to drop significantly, a residual groundwater mound beneath the 200 West Area is still shown by the curved water table contours near this area and small groundwater mounds exist near the 200 Area Treated Effluent Disposal Facility (TEDF) and SALDS wastewater disposal sites (Figure 4.4-11).

Horizontal hydraulic conductivities of sand and gravel facies within the Ringold Formation generally range from about 1 to 100 m/d (3 to 330 ft/d), compared to 10 to 3000 m/d (33 to 10,000 ft/d) for the Hanford formation and the coarse-grained multilithic facies of the Cold Creek unit (pre-Missoula gravels) (DOE 1988, Cole et al. 2001, Thorne and Newcomer 2002). Because the Ringold Formation sediments are more consolidated and partially cemented, they are about 10 to 100 times less permeable than the sediments of the overlying Hanford formation. Before wastewater disposal operations at the Hanford Site, the uppermost aquifer was mainly within the Ringold Formation, and the water table extended into the Hanford formation at only a few locations (Newcomb et al. 1972). However, wastewater discharges raised the water table elevation across the Site. The general increase in groundwater elevation caused the unconfined aquifer to extend upward into the Hanford formation over a larger area, particularly near the 200 East Area. This resulted in an increase in groundwater velocity because of both the greater volume of groundwater and the higher permeability of the newly saturated Hanford formation sediments.

#### **4.4.3.3 Limitations of Hydrogeologic Information**

The sedimentary architecture of the unconfined aquifer is very complex because of repeated deposition and erosion. Although hundreds of wells have been drilled on the Hanford Site, many penetrate only a small percentage of the total unconfined aquifer thickness, and there are a limited number of wells that can be used for defining the deeper sediment facies. A number of relatively deep wells were drilled in the early 1980s as part of a study for a proposed nuclear power plant (PSPL 1982), and these data are helpful in defining facies architecture. For most of the thinner and less extensive sedimentary units, correlation between wells is either not possible or uncertain. Major sand and gravel units of the Ringold Formation (e.g., Units A, B, C, D, and E) are separated by mud-dominated units (Figure 4.3-5). In some places the mud units act as aquitards that locally confine groundwater in deeper permeable sediments.

A limited amount of hydraulic property data is available from testing of wells. Hydraulic test results from wells on the Hanford Site have been compiled for the Hanford Groundwater Monitoring Project and for environmental restoration efforts (Kipp and Mudd 1973; Connelly et al. 1992 (a, b); Thorne and Newcomer 1992, 2002; Spane and Thorne 1995, 2000; Spane et al. 2001(a, b); Spane et al. 2002). Most hydraulic tests were conducted within the upper 15 m (49 ft) of the aquifer, and many were open to more than one geologic unit. In some cases, changes in water table elevation may have significantly changed the unconfined aquifer transmissivity at a well since the time of the hydraulic test. Few hydraulic tests within the Hanford Site unconfined aquifer system have yielded accurate estimates of aquifer-specific yield.

#### **4.4.3.4 Groundwater Travel Times**

Tritium and carbon-14 measurements indicate that groundwater residence time (time that ground water has been in the subsurface) is up to thousands of years for the unconfined aquifer and more than 10,000 years for groundwater in the shallow confined aquifer (Johnson et al. 1992). Chlorine-36 and

noble gas isotope data suggest groundwater ages of greater than 100,000 years in the deeper confined systems (Johnson et al. 1992). These relatively long residence times are consistent with semiarid-site recharge conditions. However, groundwater travel time from the 200 East Area to the Columbia River has been shown to be much faster, in the range of 10 to 30 years (USGS 1987, Freshley and Graham 1988). This is because of large volumes of recharge from wastewater that was disposed in the 200 Areas between 1944 and the mid-1990s and the relatively high permeability of Hanford formation sediments, which are below the water table between the 200 East Area and the Columbia River. Travel time from the 200 West Area is greater because of the lower permeability of Ringold Formation sediments. Plume monitoring indicates that groundwater from the 200 West Area has moved about 6 km (3.7 mi) during the past 50 years. Groundwater travel times from the 200 Areas to the Columbia River are expected to decrease because of diminishing wastewater recharge in the 200 Areas and the resulting reduction of the hydraulic gradient.

#### **4.4.3.5 Groundwater East and North of the Columbia River**

The Hanford Site boundary extends east and north of the Columbia River. Hanford Site activities in these areas have not impacted the groundwater. However, the groundwater in this area is impacted by high recharge from irrigation and canal leakage. The South Columbia Basin Irrigation District manages surface water used to irrigate land east and north of the Columbia River. Recharge from irrigation water has increased water table elevations in large areas of the Pasco Basin by as much as 92 m (300 ft) (Drost et al. 1989).

There are two general hydrologic areas that impinge upon the Hanford Site boundaries to the east and north of the river. The eastern area extends from north to south between the lower slope of Saddle Mountain and the Esquatzel Diversion canal and includes the Ringold Coulee, White Bluffs area, and Esquatzel Coulee. The water table occurs in the Pasco gravels of the Hanford formation in both Ringold and Esquatzel Coulees. Brown (1979) reported that runoff from spring discharge at the mouth of Ringold Coulee is greater than 0.631 m<sup>3</sup>/s (22.3 ft<sup>3</sup>/s). Elsewhere in this area, the unconfined aquifer is in the less-transmissive Ringold Formation. Irrigation has also created perched aquifers and resulted in a series of springs issuing from perched water along the White Bluffs. The increased hydraulic pressure in these sediments has caused subsequent slumping and landslides (Brown 1979, Newcomer et al. 1991).

The other principal irrigated area is the northern part of the Pasco Basin on the Wahluke Slope, which lies between the Columbia River and the Saddle Mountain anticline. Irrigation return waste-water paths off of the Wahluke Slope have created ponds and springs in the Saddle Mountain Wildlife Refuge. The direction of unconfined groundwater flow is southward from the basalt ridges toward the Columbia River. Bauer et al. (1985) reported that lateral water table gradients are essentially equal to or slightly less than the structural gradients on the flanks of the anticlinal fold mountains where the basalt dips steeply.

#### **4.4.4 Groundwater Quality**

The quality of groundwater at the Hanford Site, uncontaminated by Hanford activities, varies depending on the aquifer system and depth, which generally is related to residence time in the aquifer (DOE 1992a, 1997c; Hartman et al. 2004). DOE has conducted a study examining historical data and new data from wells in areas not affected by Hanford Site contaminants (DOE 1997c).

Groundwater chemistry in the basalt-confined aquifers displays a range depending on depth and residence time (DOE 1988). The chemical type varies from calcium- and magnesium-carbonate water to sodium- and chloride-carbonate water. Some of the shallower basalt-confined aquifers in the region (e.g., the Wanapum basalt aquifer) have exceptionally good water quality characteristics: less than

300 mg/L dissolved solids; less than 0.1 mg/L iron and magnesium; less than 20 mg/L sodium, sulfate, and chloride; and less than 10 ppb heavy metals (Johnson et al. 1992). However, deeper basalt-confined aquifers typically have high dissolved solids content and some have fluoride concentrations greater than the drinking water standard of 5 mg/L (DOE 1988).

Groundwater beneath large areas of the Hanford Site has been contaminated by radiological and chemical constituents resulting from past Hanford Site operations. These contaminants were primarily introduced through wastewater discharged to cribs, ditches, injection wells, trenches, and ponds (Kincaid et al. 1998). Additional contaminants from spills, leaking waste tanks, and burial grounds (landfills) have also entered groundwater in some areas. Contaminant concentrations in the existing groundwater plumes are expected to decline through radioactive decay, mineral adsorption, chemical degradation, and dispersion. However, contaminants also exist within the vadose zone beneath waste sites (Section 4.4.2) as well as in waste storage and disposal facilities. These contaminants have a potential to continue to move downward into the aquifer.

Some contaminants, including tritium and chloride, move at the same velocity as groundwater. The movement of other contaminants is slower because they react with or are sorbed on the surface of minerals within the aquifer or the vadose zone. The factor by which the velocity of a constituent is reduced compared to average groundwater flow velocity is called the "retardation factor." Therefore, tritium in groundwater will move ten times faster than a contaminant with a retardation factor of ten. For Hanford sediments, it has been estimated that technetium and chromium have small retardation factors and move at nearly the same velocity as groundwater (Thorne 2004). Iodine, nitrate, uranium, and carbon tetrachloride were estimated to have median retardation factors between 3 and 12. Strontium, cesium, and plutonium were estimated to have median retardation factors between 290 and 27,000. Cantrell *et al.* (2002) and Serne and Kaplan (2000) offer additional information on retardation of chemicals transported in groundwater.

Groundwater contamination is being actively remediated through pump-and-treat operations at the 200-West Area, 100-F Area, and 100-K Area. These operations are summarized in Hartman et al. (2004). At the 100-N Area, pump-and-treat remediation has been terminated and a passive treatment barrier is being used to reduce contaminant migration.

Monitoring of radiological and chemical constituents in groundwater at the Hanford Site is performed to characterize physical and chemical trends in the flow system, establish groundwater quality baselines, assess groundwater remediation, and identify new or existing groundwater problems. Groundwater monitoring is also performed to verify compliance with applicable environmental laws and regulations. Samples were collected from 710 wells and 79 shoreline aquifer sampling tubes during FY 2003 to determine the distributions of radiological and chemical constituents in Hanford Site groundwater (Hartman et al. 2004).

To assess the quality of groundwater, concentrations measured in samples were compared with maximum contaminant levels (MCL) or interim Drinking Water Standards (DWS) and DOE's Derived Concentration Guides (DCG). The MCL or DWS standards are legal limits for contaminant concentrations in public drinking water supplies enforceable by the Washington State Department of Health or EPA. Although these standards are only applicable at the point of consumption of the water, they provide a useful indicator of negative impacts to the groundwater resource. The DCG applies only to radionuclides and is based on the concentration that would result in a dose exposure of 1 mSv/year (100-mrem/year) effective dose equivalent, a calculation of dose that assumes ingestion under specified intake scenarios.

Radiological constituents including carbon-14, iodine-129, strontium-90, technetium-99, gross alpha,

gross beta, tritium, and uranium were detected at levels greater than the DWS in one or more onsite wells. Concentrations of strontium-90, tritium, and uranium were detected at levels greater than DOE's DCG. Certain nonradioactive chemicals regulated by EPA and the State of Washington (nitrate, fluoride, chromium, cyanide, carbon tetrachloride, chloroform, trichloroethylene, and tetrachloroethylene) were also present in Hanford Site groundwater during fiscal year 2003 (Table 4.4-2). The extent of radiological and non-radiological contamination in Hanford Site groundwater above the applicable DWS is determined annually (Figures 4.4-12 and 4.4-13). The area of contaminant plumes on the Hanford Site with concentrations exceeding drinking water standards was estimated to be 190 km<sup>2</sup> (89.2 mi<sup>2</sup>) during fiscal year 2004.

#### **4.4.5 100 Area Hydrology**

The hydrology of the 100 Area is affected by its location adjacent to the Columbia River. The water table ranges in depth from near 0 m (0 ft) at the river edge to 30 m (107 ft). The groundwater flow direction is generally toward the river. However, during high river stage, the flow direction may reverse immediately adjacent to the river. The unconfined aquifer in the 100 Area is composed of either the Ringold Unit E gravels or a combination of the Unit E gravels and the Hanford formation (Figure 4.3-5). There are two large areas where the water table is within the Ringold Formation (Lindsey 1992), and the Hanford formation is unsaturated (Figure 4.4-14). In the 100-H and 100-F Areas, the Ringold Unit E gravels are missing and the Hanford formation lies directly over the fine-grained Ringold lower-mud unit. In most of the 100 Area, the lower Ringold mud forms an aquitard, and the Ringold gravels below the mud are locally confined. Additional information on the hydrology of the 100 Area is available in Hartman and Peterson (1992) and Peterson et al. (1996). A number of studies of various sites in the 100 Area present specific hydrologic information. These include: 100-B/C Area - Lindberg (1993a); 100-D Area - Lindsey and Jaeger (1993); 100-F Area - Lindsey (1992), Peterson (1992); 100-H Area - Liikala et al. (1988), Lindsey and Jaeger (1993); 100-K Area - Lindberg (1993b); and 100-N Area - Gilmore et al. (1992), Hartman and Lindsey (1993).

#### **4.4.6 200 Areas Hydrology**

In the 200 West Area, the water table occurs almost entirely in the Ringold Unit E gravels, while in the 200 East Area, it occurs primarily in the Hanford formation and in the Ringold Unit A gravels (Figure 4.3-5). Along the southern edge of the 200 East Area, the water table is in the Ringold Unit E gravels. The upper Ringold facies were eroded in most of the 200 East Area by the ancestral Columbia River and, in some places, by the Missoula floods that subsequently deposited Hanford gravels and sands on what was left of the Ringold Formation (DOE 2002b). Because the Hanford formation and possibly the Cold Creek unit sand and gravel deposits are much more permeable than the Ringold gravels, the water table is relatively flat in the 200 East Area, but groundwater flow velocities are higher. On the north side of the 200 East Area, there is evidence of erosional channels that may allow interaquifer flow between the unconfined and uppermost basalt-confined aquifer (Graham et al. 1984, Jensen 1987).

The hydrology of the 200 Areas has been strongly influenced by the discharge of large quantities of wastewater to the ground during a 50-year period. The discharges caused elevated groundwater levels across much of the Hanford Site resulting in a large groundwater mound beneath the former U Pond (Figure 4.4-11) in the 200 West Area and a smaller mound beneath the former B Pond, east of the 200 East Area. Water table changes beneath the 200 West Area have been greatest because of the lower transmissivity of the aquifer in this area (Cole et al. 2001). Discharges of water to the ground have been greatly reduced, and corresponding decreases in the elevation of the water table have been observed.

**Table 4.4-2.** Maximum Concentrations of Selected Groundwater Contaminants during Fiscal Year 2003 (modified from Hartman et al. 2004)

Contaminant, units (alphabetical order)	DWS(a)	100-BC-5		100-KR-4		100-NR-2	100-HR-3-D		100-HR-3-H		100-FR-3	
		Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Aquifer Tubes
arsenic (filtered), µg/L	10											
cadmium (filtered), µg/L	5	3.3				3.1	3.4				3.9	
carbon tetrachloride, µg/L	5											
carbon-14, pCi/L	2,000			<b>20,900</b>	67.2	15.4						
cesium-137, pCi/L	200					ND						
chloroform, µg/L	100			1		7.2					1.1	
chromium (dissolved), µg/L	100	46	38	<b>542</b>	52	<b>168</b>	<b>5,440</b>	<b>295</b>	<b>154</b>	43	90	
cis-1,2-dichloroethene, µg/L	70											
cobalt-60, pCi/L	100					ND						
cyanide, µg/L	200											
fluoride, mg/L	4	0.51		0.49		1	0.45		0.45		0.72	
gross alpha, pCi/L	15	2.99		7.14		3.07	3.94		<b>72.4</b>		10.1	
gross beta, pCi/L	50	<b>221</b>		<b>3,590</b>		<b>16,000</b>	<b>466</b>		<b>183</b>		<b>51.1</b>	
iodine-129, pCi/L	1											
nickel (filtered), µg/L	100			28.8		17	<b>416</b>		21.6			
nitrate, mg/L	45	27.9		<b>195</b>	3.6	<b>228</b>	<b>107</b>		<b>474</b>		<b>177</b>	
nitrite, mg/L	3.3			0.135		0.299	<b>7.55</b>					
plutonium-239/240, pCi/L	NA(b)											
strontium-90, pCi/L	8	<b>98.9</b>	<b>15</b>	<b>2,440</b>	ND	<b>8,000</b>	7.06		<b>23.2</b>		<b>27.8</b>	
technetium-99, pCi/L	900	46.7		85.4					<b>986</b>	ND		
trichloroethene, µg/L	5			<b>11</b>							9.8	
tritium, pCi/L	20,000	<b>21,900</b>	<b>32,200</b>	<b>1,270,000</b>	ND	<b>31,400</b>	<b>23,700</b>	<b>29,700</b>	6,210		11,500	
uranium, µg/L	30						3.58		<b>119</b>			

Note: Location description refers to Operable Unit groundwater interest area designation.  
 Table lists highest measured concentration for fiscal year 2003 in each groundwater interest area. Concentrations in bold exceed drinking water standards. Blank space indicates the constituent not of concern in the given area.

(a) DWS = Drinking water standard or U.S. Environmental Protection Agency maximum contaminant level (MCL) if there is no DWS

(b) There is no drinking water standard for plutonium-239/240. The Department of Energy Derived Concentration Guide is 30 pCi/L (1.1 Bq/L)

Conversion: 27 pCi/L = 1 Bq/L

NA = Not applicable ND = Not detected.

Table 4.4-2. (cont'd)

Contaminant, units (alphabetical order)	DWS(a)	200-ZP-1	200-UP-1	200-BP-5	200-PO-1	300-FF-5	1100-EM-1
		Wells	Wells	Wells	Wells	Wells	Wells
arsenic (filtered), µg/L	10	4.1	8.7	7.6	9.2		
cadmium (filtered), µg/L	5	3.2	3.1	4.6	3.3		
carbon tetrachloride, µg/L	5	<b>6,200</b>	<b>690</b>		0.29	0.35	
carbon-14, pCi/L	2,000						
cesium-137, pCi/L	200			<b>1,170</b>			
chloroform, µg/L	100	31	20		0.46	3	4.4
chromium (dissolved), µg/L	100	<b>592</b>	<b>209</b>	54.9	<b>6,250</b>	7.3	
cis-1,2-dichloroethene, µg/L	70	0.09				<b>160</b>	48
cobalt-60, pCi/L	100			48.4			
cyanide, µg/L	200	6.4		<b>275</b>			
fluoride, mg/L	4	<b>4.3</b>	0.7	0.98	1.3	0.52	<b>4.3</b>
gross alpha, pCi/L	15	6.73	13.9	<b>324</b>	10.7	<b>43.9</b>	<b>77</b>
gross beta, pCi/L	50	<b>4,390</b>	<b>71,200</b>	<b>12,100</b>	<b>79.7</b>	<b>97.5</b>	34.7
iodine-129, pCi/L	1	<b>36.7</b>	<b>35.3</b>	<b>3.65</b>	<b>11.9</b>		
nickel (filtered), µg/L	100	<b>328</b>	<b>120</b>	<b>133</b>	<b>864</b>	41.6	
nitrate, mg/L	45	<b>2,160</b>	<b>1,930</b>	<b>735</b>	<b>170</b>	<b>134</b>	<b>261</b>
nitrite, mg/L	3.3	0.361	0.46	1.12	0.233	0.069	0.043
plutonium-239/240, pCi/L	NA(b)			<b>74.8</b>			
strontium-90, pCi/L	8	1.29	<b>53.6</b>	<b>5,680</b>	<b>21.4</b>	4.03	
technetium-99, pCi/L	900	<b>11,117</b>	<b>188,000</b>	<b>10,600</b>	287	319	27
trichloroethene, µg/L	5	<b>18</b>	<b>11</b>		0.88	<b>7.2</b>	<b>27</b>
tritium, pCi/L	20,000	<b>2,170,000</b>	<b>634,000</b>	<b>27,600</b>	<b>5,570,000</b>	<b>3,670,000</b>	251
uranium, µg/L	30	<b>367</b>	<b>1,190</b>	<b>554</b>	7.19	<b>235</b>	18

Note: Location description refers to Operable Unit groundwater interest area designation.

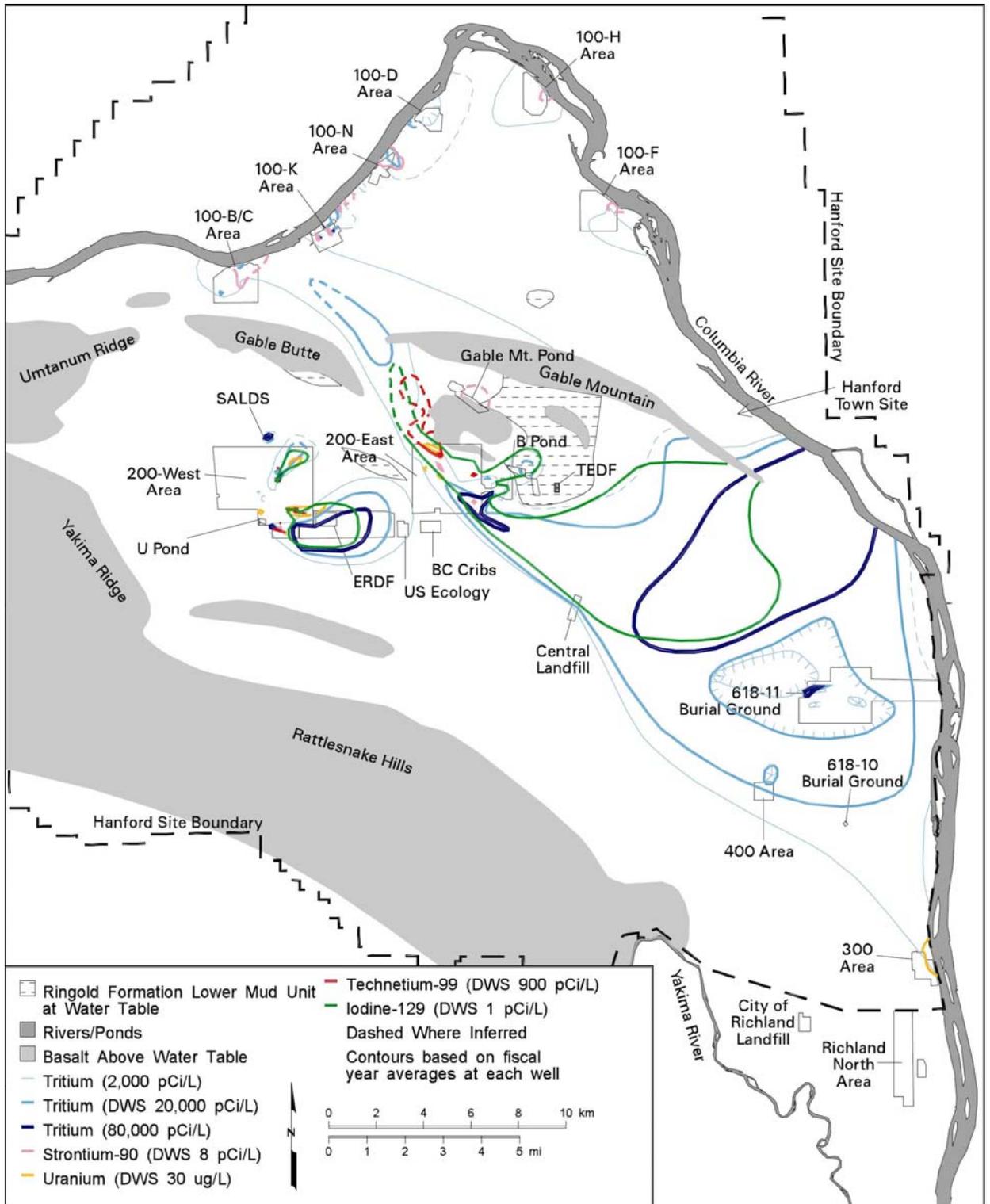
Table lists highest measured concentration for fiscal year 2003 in each groundwater interest area. Concentrations in bold exceed drinking water standards. Blank space indicates the constituent was not of concern in the given area..

(a) DWS = Drinking water standard or U.S. Environmental Protection Agency maximum contaminant level (MCL) if there is no DWS

(b) There is no drinking water standard for plutonium-239/240. The Department of Energy Derived Concentration Guide is 30 pCi/L (1.1 Bq/L)

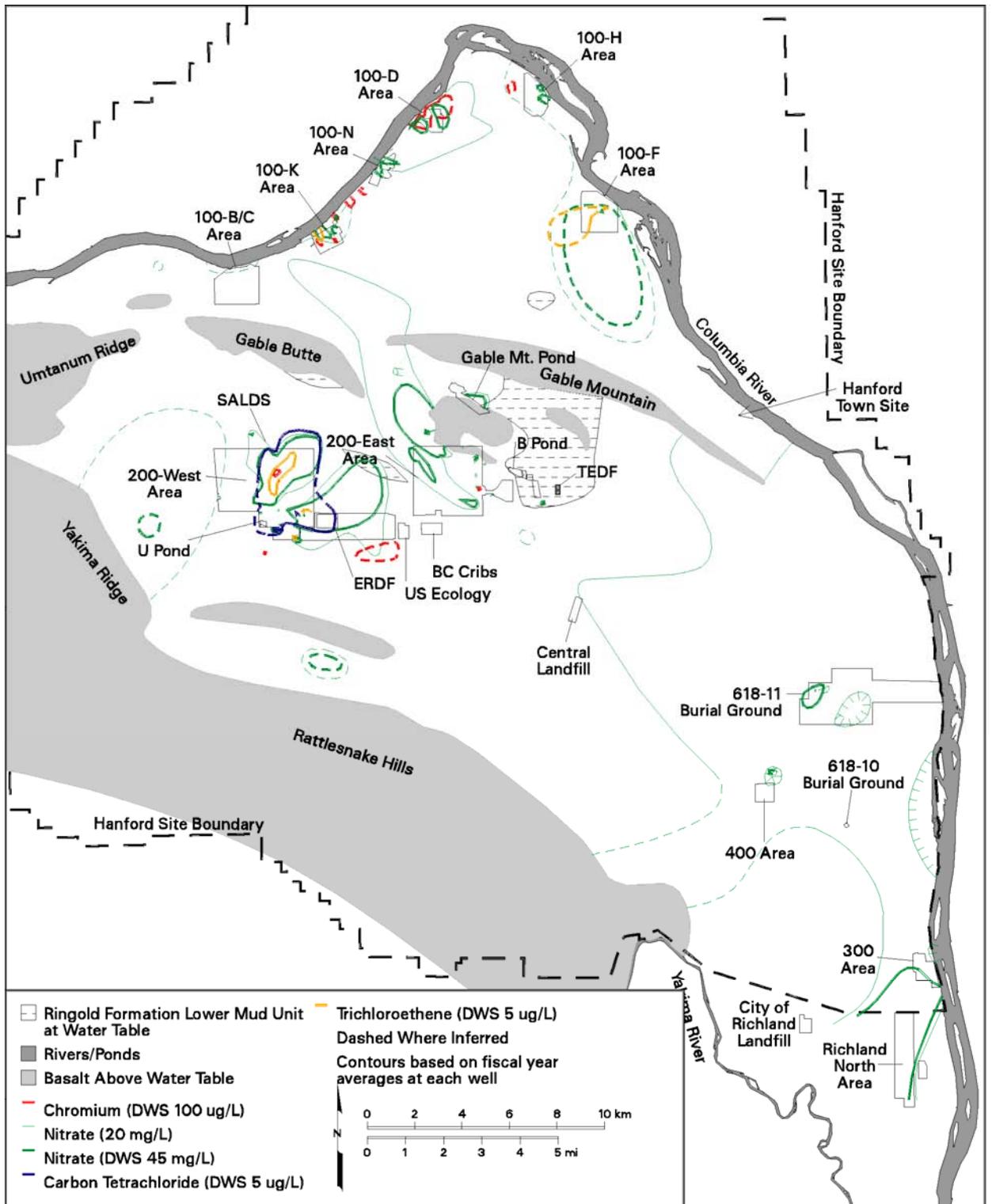
Conversion: 27 pCi/L = 1 Bq/L

NA = Not applicable ND = Not detected.



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**Figure 4.4-12.** Distribution of Radionuclides in Groundwater on the Hanford Site, Washington, at Concentrations above the Maximum Contaminant Level or Interim Drinking Water Standard during Fiscal Year 2003 (Hartman et al. 2004) (27 pCi/L = 1 Bq/L)



**Figure 4.4-13.** Distribution of Hazardous Chemicals in Groundwater on the Hanford Site, Washington, at Concentrations above the Maximum Contaminant Level or Interim Drinking Water Standard during Fiscal Year 2003 (Hartman et al. 2004)

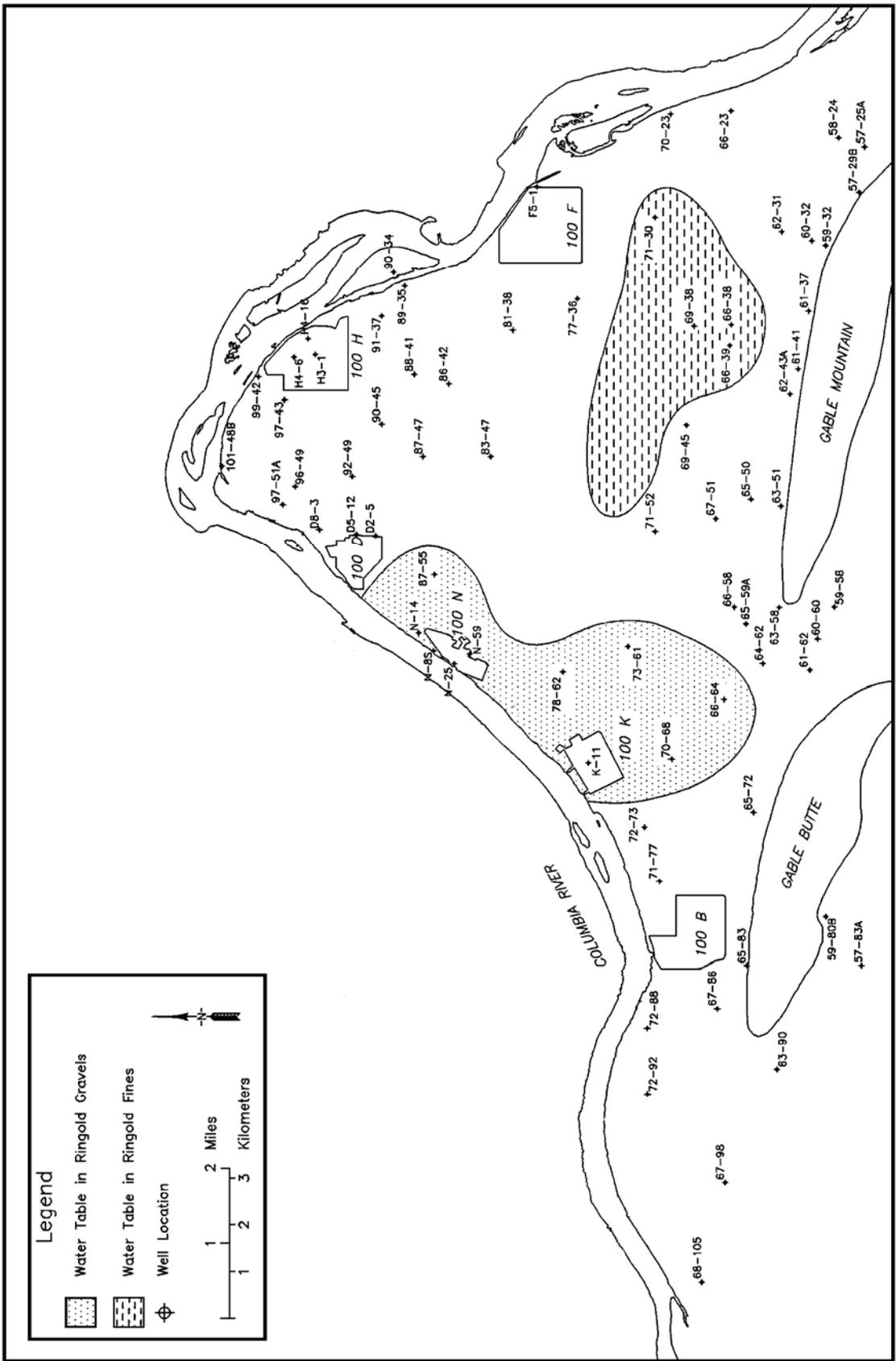


Figure 4.4-14. Geologic Units Intersected by the Water Table in the 100 Areas, Hanford Site, Washington (modified from Lindsey 1992).

The decline in part of the 200 West Area groundwater mound has been more than 8 m (26 ft) (Hartman et al. 2004). Water levels are expected to continue to decrease as the unconfined groundwater system reaches equilibrium with the new level of artificial recharge (Wurstner and Freshley 1994).

A number of reports dealing with the hydrogeology of the 200 Areas are available including Williams *et al.* (2000, 2002), Graham et al. (1981), Last et al. (1989), and Connelly et al. (1992a, b).

#### **4.4.7 300 Area Hydrology**

The unconfined aquifer water table in the 300 Area (Figure 4.4-11) is found in both the Hanford formation and the Ringold Formation. It is 0 to 19 m (0 to 62 ft) below ground surface depending on location. Elevation of the Columbia River stage strongly affects the groundwater levels and flow near the river in the 300 Area. Water table contours in the vicinity of the 300 Area are somewhat concentric, showing that there is a groundwater discharge area for the unconfined aquifer system in the area of convergence. Groundwater flows from the northwest, west, and even the southwest to discharge into the Columbia River near the 300 Area. Schalla et al. (1988), Swanson (1992), and Hartman *et al.* (2004) have provided more detailed information on the hydrogeology of the 300 Area.

#### **4.4.8 Richland North Area Hydrology**

The Richland North Area (Figure 4.4-13) is located in the southern part of the Hanford Site and includes the former 1100 Area,<sup>(a)</sup> which was transferred from the DOE to the Port of Benton on October 1, 1998. The groundwater in this area is influenced by artificial recharge associated with the North Richland recharge basins and nearby irrigated farming (Liikala 1994). Water is pumped from the Columbia River to the recharge basins and subsequently pumped from nearby wells. This system is used by the city of Richland as a backup filtration system for city water. Because an excess of water is pumped into the recharge basins, a mound has been created in the water table, which helps to reduce the potential for groundwater flow from the Hanford Site into this area (Hartman et al. 2004). The river stage elevation of the Yakima River, which flows just west of the area, is high enough such that the river also acts as a recharge source for the groundwater system. However, a study of water levels in wells adjacent to the river showed that flow between the Yakima River and aquifer may be inhibited in some areas by mud deposited along the riverbed (Thorne et al. 1993).

The southern portion of the tritium plume from the 200 East Area extends to the 300 Area. However, tritium concentrations decrease from greater than 10,000 pCi/L (373.4 Bq/L) to less than 100 pCi/L (3.734 Bq/L) across the 300 Area and the distribution across this area has changed little since fiscal year 1999 (Hartman et al. 2004). A few wells south of the 300 Area, in the vicinity of Richland's recharge ponds, have shown slightly elevated tritium levels compared to expected background levels for the groundwater. However, the observed tritium levels are consistent with tritium concentrations in the Columbia River water that is pumped into the ponds (Hartman et al. 2004). Nitrate contamination is also found in the Richland North Area. This is the result of industrial and agricultural sources off the Hanford Site. The nitrate plume is migrating eastward and entering the Columbia River. Concentrations above the 45-mg/L maximum contaminant level are found over most of the Richland North Area (Hartman et al. 2004).

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(a) The 1100 Area was the location of general stores and transportation maintenance facilities at the Hanford Site. The 1100 Area was declared clean by the regulatory agencies during September 1996.

## 4.5. Ecology

*T.M. Poston and M.R. Sackschewsky*

Ecology is an integrating discipline that defines the relationships between organisms and their environment. Ecological evaluations are organized by broad habitat type and include terrestrial and aquatic ecosystems. Terrestrial ecosystems include upland and riparian/wetland habitats. This section addresses the habitat, flora, and fauna found in terrestrial (Section 4.5.1) and aquatic ecosystems (Section 4.5.2). A third section addresses species formally listed as threatened, endangered, or special status by federal and state agencies (Section 4.5.3).

Other descriptions of the ecology of the Hanford Site can be found in Cadwell (1994); Downs et al. (1993); ERDA (1975); Jamison (1982); Landeen (1996); Rogers and Rickard (1977); Sackschewsky and Downs (2001); Watson et al. (1984); Weiss and Mitchell (1992); and Poston et al. (2004).

### 4.5.1 Terrestrial Ecology

Terrestrial ecosystems on the Hanford Site include upland and riparian/wetland habitat. Upland habitat at Hanford is influenced by arid climate and characterized by vegetation and wildlife adapted to hot summers, cold winters, and low precipitation. Riparian habitat occurs along bodies of water and is inhabited by plants requiring more water than that provided by precipitation. Wetlands are areas where some open water is present and soils and associated vegetation reflect the presence of water. The upland habitat within the Hanford Site, located within the Columbia Basin (Plateau) Ecoregion is predominantly shrub-steppe (Stroms *et al.* 1997). Shrub-steppe ecosystems are typified by a shrub overstory and a grass and forb understory (Daubenmire 1970). Lichens and mosses, often times referred to as “microbiotic or cryptogamic crust,” provide a soil stabilizing growth on undisturbed soils in the shrub-steppe ecosystem. The Columbia Basin (Plateau) Ecoregion historically included over 6 million hectares (14.8 million acres) of steppe and shrub-steppe vegetation across most of central and southeastern Washington, as well as portions of north-central Oregon. Much of this land has been developed for agriculture, industrial, and other developments.

In the early 1800s, the dominant vascular plants in the area were big sagebrush underlain by perennial bunchgrasses and forbs. With the advent of Euro-American settlement, livestock grazing and agricultural production contributed to colonization by non-native plant species that currently dominate portions of the landscape. Agriculture and livestock production were the primary subsistence activities at the turn of the 20<sup>th</sup> century. Although these activities ceased when the Hanford Site was created in January 1943, remnants of past agricultural practices are still evident. Many places on the Hanford Site are relatively free of non-native species and are extensive enough to retain characteristic populations of shrub-steppe plants and animals that are absent or scarce in developed or fire-impacted areas of the ecoregion. Because of its location, the Hanford Site provides important connectivity with other undeveloped portions of the ecoregion.

Large areas of the Hanford Site have experienced recent range fires that influence the vegetation composition and distribution of wildlife. During 1984, a major fire burned across 800 km<sup>2</sup> (310 mi<sup>2</sup>) of the Hanford Site (Price et al. 1986). During 2000, a range fire burned across the Hanford Site consuming most of the shrub-steppe habitat on the Fitzner-Eberhardt Arid Lands Ecology Reserve Unit, a small section of the McGee-Riverlands Unit, and other southwestern portions of the Site. The fire burned a total of 655 km<sup>2</sup> (250 mi<sup>2</sup>) of federal, state, and private lands before it was controlled (BAER 2000).

These fires have altered the composition of the shrub-steppe habitat. Much of the year 2000 burn was considered to be low severity. Low severity refers to a burn that leaves the soil structure and seed bank intact. The belowground portions of most perennial plants were unharmed and have returned. Much of the burned area is in various stages of recovery. Sagebrush may take considerably longer to recover than perennial bunchgrass areas depending on the availability of seed in the soil, severity of the burn, and the distance to other seed sources. Reestablishment of mature sagebrush stands is likely to take a minimum of 10 to 20 years. Some of the burned areas continue to be invaded by non-indigenous plant species such as Russian thistle (*Salsola tragus*, formerly *kali*) and tumble mustard (*Sisymbrium altissimum*). In some areas, efforts have been taken to reestablish big sagebrush (*Artemisia tridentata*).

#### 4.5.1.1 Vegetation

The Hanford Site contains some of the highest quality shrub-steppe habitat in the state of Washington and the larger ecoregions in the northwest. In some areas, unique and rare communities exist in spite of past wildfires and the presence of non-native species introduced by man. Because of the diversity of habitats on the Hanford Site, including a relatively large elevation range of 1000 m, the riparian corridor, sand dunes, and other special habitats, there is a high number of plant species on site. A total of 727 species representing 90 families of vascular plants are recorded for the Hanford Site (Sackschewsky and Downs 2001). Of this total, 179 are non-native species. Cheatgrass (*Bromus tectorum*) is the dominant non-native species. It is an aggressive colonizer and has become well established across the Hanford Site (Rickard and Rogers 1983). Hanford Site plants are adapted to low annual precipitation (17 cm [6.8 in.]), low water-holding capacity of the rooting substrate (sand), dry summers, and cold winters.

Microbiotic crusts are an important component of the shrub-steppe communities found at Hanford. The microbiotic (or cryptogamic) crusts generally occur in the top 1 to 4 mm (0.04 to 0.16 in.) of soil and are composed of primarily algae, lichens, and mosses. These crusts are formed by organisms and their by-products, creating a consolidated layer of soil particles bound together by organic materials. Microbiotic crusts are common in the semi-arid Columbia Basin, where the dominant organism tends to be green algae (Johansen et al. 1993). The functions of microbiotic crusts include soil stability and protection from erosion; fixation of atmospheric nitrogen; nutrient contribution to plants influencing soil-plant water relations; and increasing water infiltration, seedling germination, and plant growth. The ecological roles of microbiotic crusts depend on the relative cover of various crustal components. Carbon inputs are higher when mosses and lichens are present than when the crust is dominated by cyanobacteria. Nitrogen inputs are higher with greater water infiltration. Soil surface stability is related to cyanobacterial biomass as well as total moss and lichen cover (Belnap et al. 2001). The lichen and mosses of the Hanford Site were surveyed and evaluated by Link et al. (2000). They found 29 soil lichens in 19 genera and 6 moss species in 4 genera. Twelve (41 percent) lichen species are of the crustose growth form (flat and firmly attached to the substrate), eight (28 percent) are squamulose (having small, flat scales that do not adhere tightly to substrate), seven (24 percent) are foliose (having leaf-like lobes, attached in the center to substrate by clusters of rhizomes), and two (7 percent) are fruticose (plant-like growth attached at one point). More recent surveys have found a total of 120 taxa of lichens and mosses on the Hanford Monument lands surrounding the central portion of the Hanford Site (Evans et al. 2003).

Soll et al. (1999) conducted plant surveys on Fitzner-Eberhardt Arid Lands Ecology Reserve Unit, the Wahluke Slope, central Hanford, and riparian communities along the Columbia River shoreline from 1994 through 1997. These surveys tentatively identified 30 “potential” terrestrial plant communities. Designation as a potential community indicates a type of community that would exist in an area if it were free of disturbance. In addition to characterizing potential plant communities, Soll et al. (1999) found 112 populations/occurrences of 28 rare plant taxa on the Hanford Site. Rare plant taxa are defined by the Washington Natural Heritage Program as plants that are followed because of loss of habitat and dwindling populations. When combined with observations preceding the 1994-1999 inventory, a total of

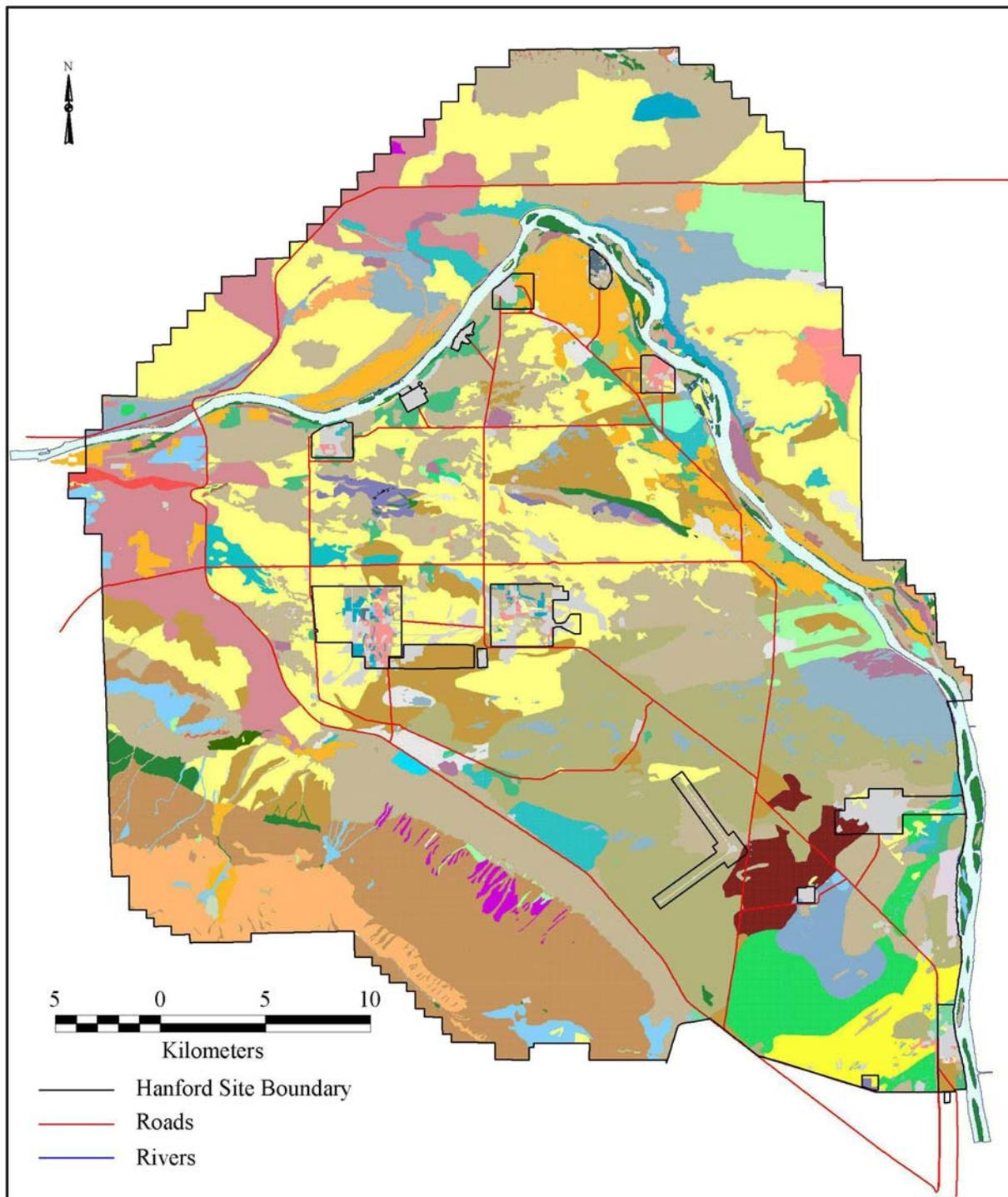
127 populations of 30 rare plant taxa have been documented on the Hanford Site. A more general description of the vegetation cover types found on Hanford, including shrublands, grasslands, microbiotic crust, tree zones, and riparian habitat, follows.

**Shrublands.** Shrublands occupy the largest area in terms of acreage and comprise seven of the nine major plant communities on the Hanford Site (Sackschewsky and Downs 2001). Of the shrubland types, sagebrush-dominated communities are predominant, with other shrub communities varying with changes in soil and elevation. About 287 km<sup>2</sup> (111 mi<sup>2</sup>) of shrub habitat dominated by big sagebrush was destroyed in the year 2000 fire and is in various stages of shrub recovery.

Of the vegetation types found on the Hanford Site (Figure 4.5-1), those with a shrub component (i.e., big sagebrush, threetip sagebrush [*Artemisia tripartita*], bitterbrush [*Purshia tridentata*], gray rabbitbrush [*Ericameria nauseosa* previously *Chrysothamnus nauseosus*], green rabbitbrush [*Chrysothamnus viscidiflorus*], black greasewood [*Sarcobatus vermiculatus*], winterfat [*Krascheninnikovia (Ceratoides) lanata*], snow buckwheat [*Eriogonum niveum*], and spiny hopsage [*Grayia (Atriplex) spinosa*]) are considered shrub-steppe. These stands typically have an understory dominated by bunchgrasses such as bluebunch wheatgrass (*Pseudoroegneria spicata* previously *Agropyron spicatum*), Sandberg's bluegrass (*Poa sandbergii [secunda]*), needle-and-thread grass (*Hesperostipa comata* previously *Stipa comata*), Indian ricegrass (*Achnatherum hymenoides* previously *Oryzopsis hymenoides*), bottlebrush squirreltail (*Elymus elymoides* previously *Sitanion hystrix*), and prairie junegrass (*Koeleria cristata*), as well as a number of broad-leaf forbs. Heavily grazed or disturbed areas often have an understory dominated by cheatgrass. Heterogeneity of species composition varies with soil, slope, and elevation. Vegetation types with a significant cheatgrass component are generally of lower habitat quality than those with bunchgrass understories. A list of common plant species in Hanford areas is presented in Appendix B, Table B-1 and Sackschewsky and Downs (2001).

**Grasslands.** Most grasses occur as understory in shrub-dominated plant communities. Because shrubs have been removed by fire in many areas, there are large areas of grass-dominated communities on the Hanford Site. Cheatgrass has replaced many native perennial grass species and is well established in many low-elevation (less than 244 m [800 ft]) and/or disturbed areas (Rickard and Rogers 1983, Soll et al. 1999). Of the native grasses that occur on the Hanford Site, bluebunch wheatgrass occurs at higher elevations. Sandberg's bluegrass is widely distributed throughout the Columbia Basin and the intermountain west. Needle-and-thread grass, Indian ricegrass, and thickspike wheatgrass (*Elymus macrourus* previously *Agropyron dasystachyum*) occur in sandy soils and dune habitats. Species preferring more moist locations include streambank or riparian wheatgrass (*Elymus lanceolatus* previously *Agropyron dasystachyum* var. *smithii*), bentgrass (*Agrostis* spp.), bluegrass (*Poa* spp.), meadow foxtail (*Alopecurus aequalis*), lovegrasses (*Eragrostis* spp.), and reed canarygrass (*Phalaris arundinacea*) (DOE 2001a). A list of common plant species in grassland areas is presented in Appendix B, Table B-1.

**Trees.** Within the past few hundred years, the Hanford Site upland landscape had few trees and the Columbia River shoreline supported a few scattered cottonwood (*Populus* spp.) or willows (*Salix* spp.). Homesteaders and Manhattan Project construction workers planted trees in association with agricultural areas and housing camps. Shade and ornamental trees were planted in the 1950s around former military installations and industrial areas on the Hanford Site. Currently, approximately 23 species of trees occur on the Site. The most commonly occurring species are black locust (*Robinia pseudo-acacia*), Russian olive (*Eleagnus angustifolia*), cottonwood (*Populus trichocarpa*), mulberry (*Morus alba*), sycamore (*Platanus occidentalis*), and poplar (*Populus* spp.). Many of these non-indigenous species are aggressive colonizers and have become established along the Columbia River (e.g., mulberry, poplar, Russian olive), serving as a functional component of the riparian zone (DOE 2001a). Trees provide nesting habitat and cover for many species of mammals and birds.



**Figure 4.5-1.** Distribution of Vegetation Types and Areas on the Hanford Site, Washington, before the Year 2000 Fire

## LEGEND

	Abandoned Old Agricultural Fields
	Alkali Saltgrass - Cheatgrass
	Big Sagebrush - Bitterbrush / Bunchgrass
	Big Sagebrush - Bitterbrush / Needle-and-Thread Grass
	Big Sagebrush - Bitterbrush / Sandberg's Bluegrass
	Big Sagebrush - Rigid Sagebrush / Bunchgrass
	Big Sagebrush - Rock Buckwheat / Bunchgrass
	Big Sagebrush - Spiny Hopsage / Bunchgrass
	Big Sagebrush - Spiny Hopsage / Sandberg's Bluegrass - Cheatgrass
	Big Sagebrush / Bluebunch Wheatgrass
	Big Sagebrush / Bunchgrass
	Big Sagebrush / Needle-and-Thread Grass
	Big Sagebrush / Sand Dropseed
	Big Sagebrush / Sandberg's Bluegrass - Cheatgrass
	Bitterbrush / Bunchgrass
	Bitterbrush / Indian Ricegrass
	Bitterbrush / Needle-and-Thread Grass
	Black Greasewood / Alkali Saltgrass
	Bluebunch Wheatgrass - Needle-and-Thread Grass
	Bluebunch Wheatgrass - Sandberg's Bluegrass
	Bunchgrass - Cheatgrass
	Crested Wheatgrass
	Disturbed
	Gray Rabbitbrush - Snow Buckwheat / Bunchgrass
	Gray Rabbitbrush / Bunchgrass
	Gray Rabbitbrush / Cheatgrass
	Gray Rabbitbrush / Needle-and-Thread Grass
	Gray Rabbitbrush / Sand Dropseed
	Gray Rabbitbrush / Sandberg's Bluegrass - Cheatgrass
	Needle-and-Thread Grass - Indian Ricegrass
	Needle-and-Thread Grass - Sandberg's Bluegrass
	Non-Riverine Wetlands and Associated Deepwater Habitats
	Rabbitbrush / Bunchgrass
	Rigid Sagebrush / Sandberg's Bluegrass
	Riparian
	Riverine Wetlands and Associated Deepwater Habitats
	Sand Dropseed - Sandberg's Bluegrass - Cheatgrass
	Sandberg's Bluegrass - Cheatgrass
	Snow Buckwheat - Bitterbrush / Bunchgrass
	Snow Buckwheat / Bunchgrass
	Snow Buckwheat / Sandberg's Bluegrass - Cheatgrass
	Spiny Hopsage / Sandberg's Bluegrass - Cheatgrass
	Talus
	Threetip Sagebrush / Bunchgrass
	Thymeleaf Buckwheat / Sandberg's Bluegrass
	Vernal Pool
	White Bluffs
	Winterfat / Bunchgrass

**Figure 4.5-1. (cont'd)**

**Hanford Operational Facilities and Retired Reactor Areas.** Yearly vegetation surveys are conducted around many of the Hanford Site operational facilities and retired reactor areas including facilities in the 100, 200, and 300 Areas (Figure 4.0-1). In addition, there have been several studies that examined the vegetation in the 200 Area Plateau region and vegetation north of the 300 Area (Sackschewsky *et al.* 2001, Brandt *et al.* 1993).

The 100 Area upland region consists of old agricultural fields dominated by cheatgrass and tumble mustard. Scattered big sagebrush and gray rabbitbrush also occur throughout the 100 Areas (Landeem *et al.* 1993). An area of natural big sagebrush habitat near the 100-D Area experienced a significant and apparently natural decline during the mid 1990s (Cardenas *et al.* 1997). A total area encompassing 17.8 km<sup>2</sup> (6.9 mi<sup>2</sup>) was affected, and a central core area of 2.8 km<sup>2</sup> (1.1 mi<sup>2</sup>) experienced more than 80 percent mortality of sagebrush.

Waste management areas, reactors, and crib sites are generally either barren or vegetated by non-native species, including Russian thistle, tumble mustard, and cheatgrass. Most of the waste disposal and storage sites are covered with non-native vegetation such as crested wheatgrass or are kept in a vegetation-free condition with the use of herbicides to prevent plant root intrusion to waste constituents. Russian thistle and gray rabbitbrush that occur in these areas are deep rooted and have the potential to function as a pathway to other parts of the ecosystem (Landeem *et al.* 1993).

The undisturbed portions of the 200 Areas are characterized as sagebrush/cheatgrass or sagebrush/Sandberg's bluegrass communities. The dominant plants on the 200 Area Plateau are big sagebrush, rabbitbrush, cheatgrass, and Sandberg's bluegrass (Sackschewsky and Downs 2001, Sackschewsky *et al.* 2001). Most of the waste disposal and storage sites are planted with crested or Siberian wheatgrass to stabilize surface soil, control soil moisture, or displace more invasive deep-rooted species like Russian thistle.

Vegetation surveys were conducted at the 300-FF-5 Operable Unit located north of the 300 Area during 1992. The shrub-steppe vegetation community in the unit is characterized as antelope bitterbrush/Sandberg's bluegrass with an overstory of bitterbrush and big sagebrush and an understory of cheatgrass and Sandberg's bluegrass (Brandt *et al.* 1993).

**Riparian and Wetland Areas.** Riparian areas are vegetated wetlands, especially associated with rivers and streams, and include shoreline areas along sloughs and backwaters. Wetlands also include the shorelines of lakes, ponds, vernal pools temporarily formed by melting snow in basalt outcrops, industrialized ponds, and irrigation wasteways and ponds on the Wahluke Slope.

Riparian habitat that occurs in association with the Columbia River includes riffles, gravel bars, backwater sloughs, and cobble shorelines. These habitats occur infrequently along the Hanford Reach and have acquired greater significance because of the net loss of wetland habitat elsewhere within the region. Vegetation that occurs along the river shoreline includes water smartweed (*Polygonum amphibium*), sedges (*Carex* spp.), reed canary grass (*Phalaris arundinacea*), bulbous bluegrass (*Poa bulbosa*), common witchgrass (*Panicum capillare*), and large barnyard grass (*Echinochloa crusgalli*). Rushes and sedges occur along the shorelines of the Columbia River and at several sloughs along the Hanford Reach. Trees include willow (*Salix* spp.), mulberry (*Morus alba*), and Siberian elm (*Ulmus pumila*). A list of common Hanford Site riparian plants is provided in Appendix B, Table B-1.

Noxious weeds are also becoming established along the riparian zones of the Hanford Reach. Purple loosestrife (*Lythrum salicaria*), tamarisk (*Tamarix parviflora*), yellow nutsedge (*Cyperus esculentus*), reed canary grass, knapweed (*Centaurea* spp.), and yellow star thistle (*Centaurea solstitialis*) are some of the more common species found near or on wetlands on the Hanford Site. The Department of Energy and

the USFWS have an ongoing program to control populations of noxious weeds with aerial applications of herbicides.

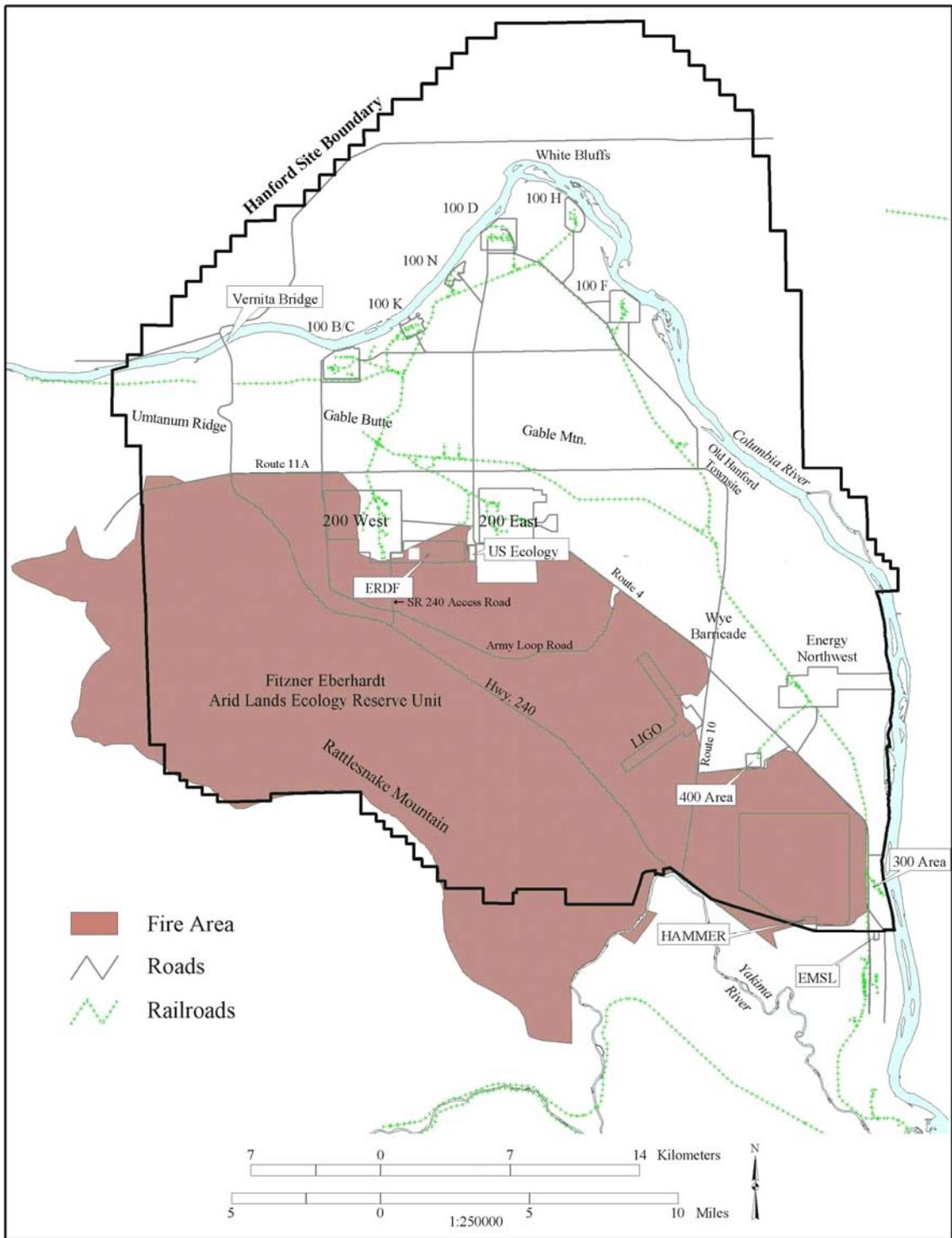
Some wetland habitat exists in the riparian zones of some of the larger spring streams on the Fitzner-Eberhardt Arid Lands Ecology Reserve Unit. These are not extensive and usually amount to less than 0.01 km<sup>2</sup> (0.004 mi<sup>2</sup>) in size, although the riparian zone along Rattlesnake Springs is probably about 2 km (1.2 mi) in length and consists of peach leaf willows, cattails, and other non-indigenous plants. Rattlesnake and Snively Springs support highly diverse biological communities (Cushing and Wolf 1984) that include bulrush (*Scirpus* spp.), spike rush (*Eleocharis* spp.), and cattail (*Typha latifolia*). Watercress (*Rorippa nasturtium-aquaticum*), which persists at these sites, is also abundant for a large portion of the year. In the past 30 years, introduced trees and shrubs have become established in the riparian zone along these springs. The riparian transects associated with Snively and Rattlesnake Springs were greatly impacted by the year 2000 fire (BAER 2000) (Figure 4.5-2).

Other wetland habitats can be found within the Saddle Mountain National Wildlife Refuge Unit and the Wahluke Unit. These two areas encompass all the lands extending from the north bank of the Columbia River northward to the Hanford Site boundary and east of the Columbia River from Ringold Springs north to Highway 24 in Adams County. Wetland habitat in these areas consists of fairly large pond habitat resulting from irrigation runoff. These ponds have extensive stands of cattails and other emergent aquatic vegetation surrounding the open-water regions (Figure 4.5-1). They are extensively used as nesting sites by waterfowl and support populations of warm water fish that have been introduced by the irrigation network.

**Other Habitats.** Basalt outcrops, river bluffs, dunes, and islands occur on the Hanford Site and their unique qualities create habitat for a distinct assemblage of vegetation (DOE 2001a). The top of Rattlesnake Mountain, Umtanum Ridge, Gable Butte, and Gable Mountain include rock outcrops and have thin rocky soils. Plant communities dominated by thyme buckwheat (*Eriogonum thymoides*) and Sandberg's bluegrass most often occupy these basalt outcrops.

The White Bluffs border the Columbia River along the northern shoreline from RM 376 downstream to RM 356 presenting a steep environment with sparse and patchy vegetation. Dense patches of Indian ricegrass occupy the top of the bluff area. Primary shrubs found on the slopes of the bluff are greasewood and spiny hopsage. Bluff areas provide habitat for sensitive species (e.g., Hoover's desert parsley [*Lomatium tuberosum*] and the White Bluffs bladderpod [*Lesquerella tuplashensis*], a Washington State endangered plant).

Bitterbrush and Indian ricegrass dominate a large dune area north of the Energy Northwest complex along the Columbia River shoreline (Figure 4.5-1). The terrain of the dune habitat rises and falls between 3 and 5 m (10 and 16 ft) above ground level, creating areas that range from 2.5 to several hundred acres in size (U.S. Department of the Army 1990). The dunes vegetation consists of a mosaic of shrubs and grasses, primarily bitterbrush and gray and green rabbitbrush with understory forbs and grasses that include scurfpea (*Psoralea lanceolata*), needle-and-thread grass, and thickspike wheatgrass. Smaller dunes containing basalt grains that impart a dark color to the sand are found near the 100-F Area and westward across the Site north of Gable Mountain. As a result of the fire that occurred during 2000, temporary dunes have formed along State Route 240 east to the 200 West Area and Army Loop Road. These burnt areas are in various stages of recovery.



**Figure 4.5-2.** Area of Hanford Site, Washington, Burned as a Result of the June 27 to July 2, 2000, Wildfire

Island habitat accounts for approximately 4.74 km<sup>2</sup> (1.8 mi<sup>2</sup>) (Hanson and Browning 1959) and 64.3 km (39.9 mi) of river shoreline within the main channel of the Hanford Reach (Figure 4.5-3).<sup>(a)</sup> DOE owns and administers the upland portions of Locke Island (RM 371-373.5) and Wooded Island (RM 348-351). The Washington State Department of Natural Resources manages the shorelines of Locke and Wooded islands. Landslides caused by rotational slumping in the White Bluffs area caused accelerated erosion of Locke Island by the Columbia River. Shoreline riparian vegetation on the islands includes willow, poplar, Russian olive, and mulberry. Before regulation of river flows by dams, trees were generally not found along river shoreline habitat, with the exception of small willows and a few juniper trees near the 100-B/C Area and Riverlands. The most common tree to establish itself along the shoreline is mulberry. Species occurring on the island interior include buckwheat, lupine, mugwort, thickspike wheatgrass, giant wildrye, yarrow, and cheatgrass (Warren 1980).

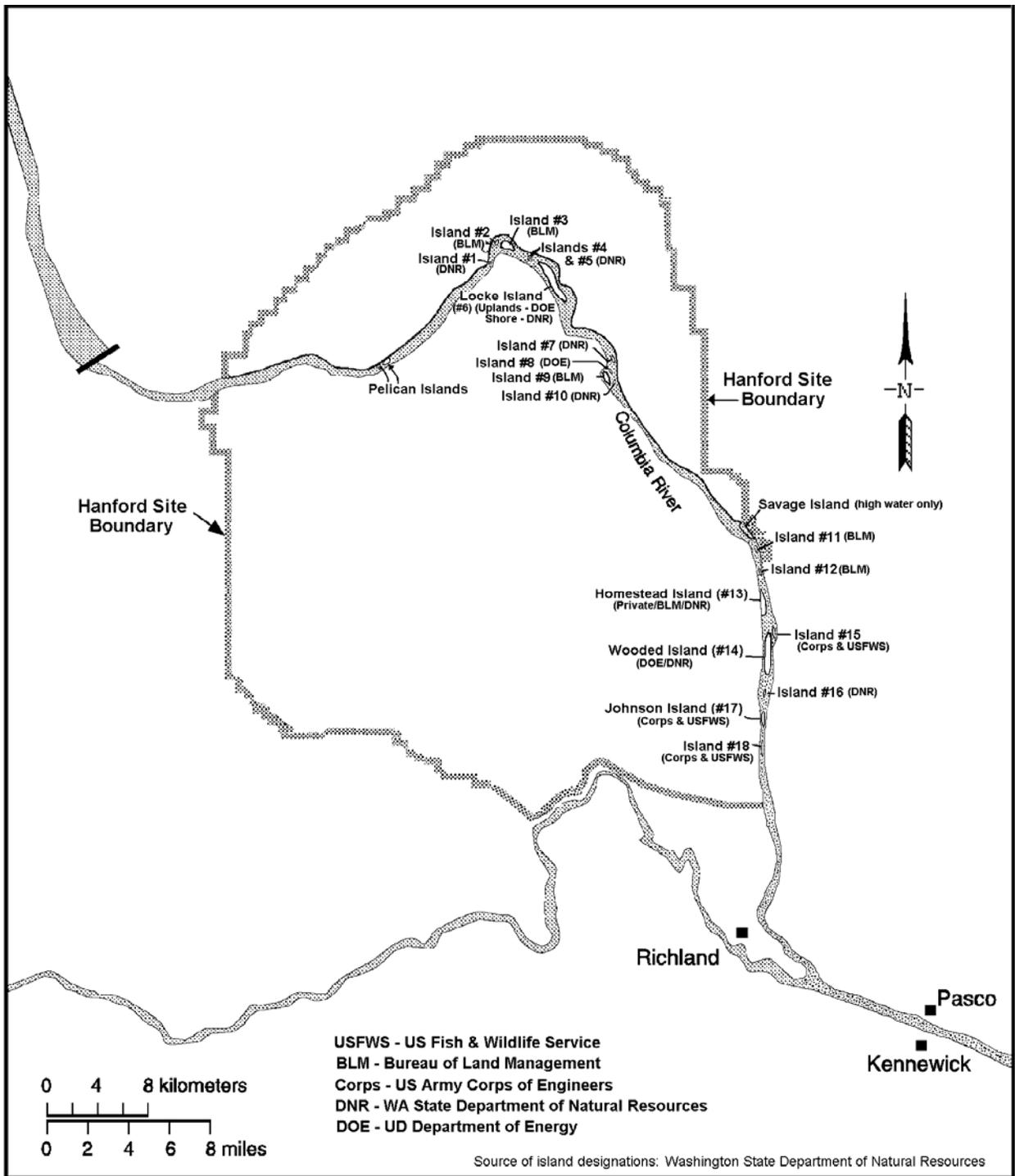
West Lake and its immediate basin represent a habitat that is characterized by highly saline conditions (Poston et al. 1991). These conditions occur most likely from the evaporation of water from the pond and the accumulation of dissolved solids during the early years of operations on the Hanford Site. West Lake is now classified as a waste site under the Comprehensive Environmental Restoration, Compensation, and Liability Act of 1980 (CERCLA) (42 USC 9601, *et seq.*). Water levels of the pond fluctuate with wastewater discharge levels in the 200 Areas. Dominant plants at West Lake include salt grass (*Distichlis stricta*), plantain (*Plantago* species), and salt rattlepod (*Swainsona salsula*). Bulrush (*Scirpus* species) grows along the shoreline; however, the water in the lake is too saline to support aquatic macrophytes. The water level of West Lake has dropped following the decrease in water discharged to the ground in the 200 Areas during the early 1990s, exposing large sections of saline mud flats and salt deposits along the shoreline.

A series of vegetation/land cover maps (Appendix C) were prepared to provide information on available habitat in support of a review of ecological data for clean-up activities along the Columbia River shoreline (Poston et al. 2004). These maps represent the best available information on vegetation cover types and plant associations located in specific areas at the time the data were collected (from 1997 to 2004). Vegetation communities are subject to change depending on climatic conditions, physical disturbance, progress with clean-up, and natural recruitment and succession at the sites. For descriptions of upland vegetation the reader is referred Sackschewsky and Downs (2001); for descriptions of riparian vegetation, see Section 8.0 of the Hanford Site Annual Environmental Report (Poston et al. 2004).

The maps in Appendix C are subsets of maps originally constructed using aerial photography and limited ground surveys and should be appropriate for use in project planning. Maps are updated as information becomes available. However, the extent and boundaries of the vegetation cover types may change over time and the accuracy of the boundaries is further limited by the resolution of the source data used for mapping (usually +/- 20 to 30 m [66 to 98 ft] depending on the source). Reference to these maps cannot be used in place of project-specific site biological surveys for compliance. To access the most recent vegetation maps maintained for the areas of the Hanford Site, visit the PNNL project web site for the Ecological Monitoring and Compliance (EMC) Project (<http://www.pnl.gov/ecomon>) or request updated maps from the EMC Project at PNNL.

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(a) Management of these islands is the responsibility of the island owners, which include DOE, USFWS, and the U.S. Bureau of Land Management. Island ownership descriptions pertain to status prior to national monument designation and are subject to change with agreements among the agencies.



**Figure 4.5-3.** Columbia River Islands in the Vicinity of the Hanford Site, Washington

#### 4.5.1.2 Wildlife

The characterization of Hanford Site wildlife includes descriptions of mammals, birds, reptiles, amphibians, and insects. Approximately 300 species of terrestrial vertebrates have been observed on the Hanford Site. The species list includes approximately 46 species of mammals (Appendix B, Table B-2), 246 species of birds (Appendix B, Table B-3), 6 species of amphibians, and 10 species of reptiles (Appendix B, Table B-4) (Soll and Soper 1996, Brandt et al. 1993). From 1991 to 1993, surveys for birds, mammals, insects, and vegetation were conducted at several of the 100 and 300 Area operable units (Brandt et al. 1993, Landeen et al. 1993). Soll et al. (1999) recently summarized its observations of birds and mammal surveys. These surveys did not account for all of the species that have been documented historically on the Hanford Site. For example, 221 species of birds were observed in the bird surveys of The Nature Conservancy's biodiversity 4-year effort (Soll et al. 1999). This number falls short of the 238 species identified historically (Landeen et al. 1992). By combining the 1994-1999 list of The Nature Conservancy with the site list (Landeen et al. 1992), a total of 258 species of birds have been documented on the Hanford Site (Soll et al. 1999). There are 144 bird species considered common to the Hanford Site (Appendix B, Table B 3). Site wildlife communities are generally associated with specific vegetation communities.

**Shrub-steppe and Grassland Wildlife.** The shrub and grassland habitat of the Hanford Site supports many groups of terrestrial wildlife. Species include large animals like Rocky Mountain elk (*Cervus elaphus*) and mule deer (*Odocoileus hemionus*); predators such as coyote (*Canis latrans*), bobcat (*Lynx rufus*), and badger (*Taxidea taxus*); and herbivores including deer mice (*Peromyscus maniculatus*), harvest mice (*Riethrodontomys megalotis*), ground squirrels (*Spermophilus* spp.), voles (*Lagurus* spp., *Microtus* spp.), and black-tailed jackrabbits (*Lepus californicus*). The most abundant mammal on the Hanford Site is the Great Basin pocket mouse (*Perognathus parvus*). Many of the rodent species and some predators (badgers) construct burrows on the site. Other non-borrowing animals including cottontails (*Sylvilagus nutalli*), jackrabbits, snakes, and burrowing owls (*Athene cunicularia*) may utilize abandoned burrows of other animals.

There was a reported sighting of a cougar (*Felis concolor*) on Fitzner-Eberhardt Arid Lands Ecology Reserve Unit by experienced biologists during the elk relocation effort in March 2000, supplementing anecdotal accounts of other observations of the presence of cougars at the Hanford Site.

Mule deer rely mainly on shoreline vegetation and bitterbrush shrubs for browse (Tiller et al. 1997). Elk, which are more dependent on open grasslands for forage, seek the cover of sagebrush and other shrub species during the summer months. Elk first appeared on the Hanford Site during 1972 (Fitzner and Gray 1991), and have increased from approximately 8 animals observed in 1975 to approximately 900 in 1999. The Rattlesnake Hills herd of elk that inhabits the Hanford Site primarily occupies Fitzner-Eberhardt Arid Lands Ecology Reserve Unit and private lands that adjoin the reserve to the south and west. They are occasionally seen on the 200 Area Plateau and have been sighted at the White Bluffs boat launch on the Hanford Site. The herd tends to congregate on Fitzner-Eberhardt Arid Lands Ecology Reserve Unit in the winter and disperses during the summer months to higher elevations on the reserve, private land to the west, and the Yakima Training Center. Efforts were taken in March 2000 to remove and relocate about 200 elk from the Fitzner-Eberhardt Arid Lands Ecology Reserve Unit and another 31 elk were removed during 2002. Special hunts adjacent to the Hanford Site during 2000 accounted for the removal of 207 additional elk. The fire in June 2000 temporarily destroyed nearly all the elk forage on Fitzner-Eberhardt Arid Lands Ecology Reserve Unit. The herd moved onto unburned private land west of the site, to unburned areas on central Hanford, and along the Columbia River near the 100-B/C and 100-K Areas. Elk have returned to burned areas as the vegetation recovered.

Shrub-steppe and grassland provide nesting and foraging habitat for many passerine (i.e., perching) bird species. Surveys conducted during 1993 (Cadwell 1994) reported the occurrence of western meadowlarks (*Sturnella neglecta*) and horned larks (*Eremophila alpestris*) more frequently in shrub-steppe habitats than in other habitats on the Hanford Site. Soll et al. (1999) reported a total of 41 species that are considered steppe or shrub-steppe habitat dependent. Long-billed curlews (*Numenius americanus*) and vesper sparrows (*Pooecetes gramineus*) were also noted as commonly occurring species in shrub-steppe habitat. Species that are dependent on undisturbed shrub habitat include sage sparrow (*Amphispiza belli*), sage thrasher (*Oreoscoptes montanus*), and loggerhead shrike (*Lanius ludovicianus*). Both the sage sparrow and loggerhead shrike tend to roost and nest in sagebrush or bitterbrush that occurs at lower elevations (DOE 2001a). Ground-nesting species that occur in grass-covered uplands include long-billed curlews, western meadowlark, and burrowing owls.

Common upland gamebird species that occur in shrub and grassland habitat include chukar (*Alectoris chukar*), partridge (*Perdix perdix*), California quail (*Callipepla californica*), and ring-necked pheasant (*Phasianus colchicus*). Chukars are most numerous in the Rattlesnake Hills, Yakima Ridge, Umtanum Ridge, Saddle Mountain, and Gable Mountain areas of the Hanford Site. Less common species include greater sage grouse (*Centrocercus urophasianus*), and scaled quail (*Callipepla squamata*). Greater sage grouse were historically abundant on the Hanford Site; however, populations have declined since the early 1800s because of the conversion of sagebrush-steppe habitat to farmland, hunting, and destruction of habitat by range fires. Surveys conducted by the Washington Department of Fish and Wildlife and PNNL during 1993 and biodiversity inventories conducted in 1997 (Soll et al. 1999) did not observe greater sage grouse in the sagebrush-steppe habitat at Fitzner-Eberhardt Arid Lands Ecology Reserve Unit. Greater sage grouse were observed on Fitzner-Eberhardt Arid Lands Ecology Reserve Unit during 1999 and 2000.<sup>(a)</sup> A greater sage grouse was killed by an automobile near the 100-F area in the spring of 2003; however, this is considered an abnormal occurrence for this part of the Hanford Site. The fire in June 2000 destroyed potential greater sage grouse habitat, and it is unlikely that greater sage grouse will return until the vegetation has recovered to a point where it can support them.

Among the more common raptor species that use shrub and grassland habitat are the ferruginous hawk (*Buteo regalis*), Swainson's hawk (*B. swainsoni*), and red-tailed hawk (*B. jamaicensis*). Northern harriers (*Circus cyaneus*), sharp-shinned hawks (*Accipiter striatus*), rough-legged hawks (*B. lagopus*), and golden eagles (*Aquila chrysaetos*) also occur in this habitat, although infrequently. During 1994, nesting by red-tailed, Swainson's, and ferruginous hawks was known to occur in 41 nests located across the Hanford Site on high voltage transmission towers, trees, cliffs, and basalt outcrops. Since the mid-1990s, the number of breeding ferruginous hawks (a Washington State threatened species) on the Hanford Site has increased, due, in part, to their use of steel powerline towers for nesting in the open grass and shrub-steppe habitats.

The side-blotched lizard (*Uta stansburiana*) is the most abundant reptile species occurring on the Hanford Site. Short-horned (*Phrynosoma douglassii*) and sagebrush (*Sceloporus graciosus*) lizards are also found on the Hanford Site, but occur infrequently. The most common snake species include gopher snake (*Pituophis melanoleucus*), yellow-bellied racer (*Coluber constrictor*), and western rattlesnake (*Crotalus viridis*).

Many species of insects occur throughout all habitats on the Hanford Site. Butterflies, grasshoppers, and darkling beetles are among the most conspicuous of the about 1500 species of insects that have been identified from specimens collected on the Hanford Site (Soll et al. 1999). The actual number of insect species occurring on the Hanford Site may reach as high as 15,500. A total of 1509 species-level identifications were completed during 1999 and 500 more are expected. Recent surveys included the

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(a) Source: Personal communication between T. M. Poston and L.L. Cadwell, PNNL, April 2002.

collection of 40,000 specimens and have resulted in the identification of 43 new taxa and 142 new findings in the state of Washington (Soll et al. 1999). The high diversity of insect species on the Hanford Site reflects the size, complexity, and relatively undisturbed quality of the shrub-steppe habitat.

**Riparian Wildlife.** Riparian areas provide nesting and foraging habitat and escape cover for many species of birds and mammals. Shoreline riparian communities are seasonally important for a variety of species. Willows trap food for waterfowl (e.g., Canada geese [*Branta canadensis*]) and birds that use shoreline habitat (e.g., Forster's tern [*Sterna forsteri*]) as well as providing nesting habitat for passerines (e.g., mourning doves [*Zenaidura macroura*]). Terrestrial and aquatic insects are abundant in emergent grasses and provide food for fish, waterfowl, and shorebirds.

Mammals occurring primarily in riparian areas include rodents, bats, furbearers (e.g., mink [*Mustela vison*] and weasel [*Mustela* spp.]), porcupine (*Erithizon dorsatum*), raccoon (*Procyon lotor*), skunk (*Mephitis mephitis*), and mule deer. Beavers (*Castor canadensis*) rely on shoreline habitat for dens and foraging. River otters (*Lutra canadensis*) have been observed infrequently in the Hanford Reach. During the summer, mule deer rely on riparian vegetation for foraging. Mule deer use Columbia River islands for fawning and nursery areas. Beaver and muskrat (*Ondatra zibethica*) rely on shoreline habitat for dens and foraging. The Columbia River and Rattlesnake Springs provide foraging habitat for bats including Yuma myotis (*Myotis yumanensis*), small-footed myotis (*Myotis subulatus*), silver-haired bats (*Lasiorycteris octivagans*), and pallid bats (*Antrozous pallidus*), all of which feed on emergent aquatic insects (Becker 1993).

Common bird species that occur in riparian habitats include red-winged blackbird (*Agelaius phoeniceus*), American robin (*Turdus migratorius*), black-billed magpie (*Pica pica*), song sparrow (*Melospiza melodia*), and dark-eyed junco (*Junco hyemalis*) (Cadwell 1994). Upland gamebirds that use this habitat include ring-necked pheasants and California quail. Predatory birds include common barn owl (*Tyto alba*) and great horned owl (*Bubo virginianus*). Burrowing owls have been observed on some of the islands in the Columbia River. Species known or expected to nest in riparian habitat are Brewer's blackbird (*Euphagus cyanocephalus*), mourning dove, black-billed magpie, northern oriole (*Icterus galbula*), lazuli bunting (*Passerina amoena*), eastern kingbird (*Tyrannus tyrannus*), western kingbird (*Tyrannus verticalis*), and western wood peewee (*Contopus sordidulus*). Bald eagles (*Haliaeetus leucocephalus*) have wintered on the Hanford Site since 1960. Great blue herons (*Ardea herodias*) and black-crowned night herons (*Nycticorax nycticorax*) are associated with trees in riparian habitat along the Columbia River and use groves or individual trees for perching and nesting. On occasion, great blue herons have constructed nests in the large metal powerline towers that are present on the shores of the Columbia River.

The Hanford Site is located in the Pacific Flyway, and the Hanford Reach serves as a resting area for neotropical migrant birds, migratory waterfowl, and shorebirds (Soll et al. 1999). The area between the Old Hanford Townsite and Vernita Bridge is closed to recreational hunting, and large numbers of migratory waterfowl find refuge in this portion of the river. Other species observed during this period include American white pelicans (*Pelecanus erythrorhynchos*), egrets (*Casmerodius albus*), double-crested cormorants (*Phalacrocorax auritus*), coots (*Fulica americana*), and common loons (*Gavia immer*).

Along with the reptiles and insects identified in the grasslands discussion, six amphibians have been identified on the site. The Great Basin spadefoot toad (*Scaphiopus intermontanus*), western toad (*Bufo boreas*), Woodhouse's toad (*Bufo woodhousei*), Pacific tree frog (*Hyla regilla*), tiger salamander (*Ambystoma tigrinum*), and bullfrog (*Rana catesbeiana*) are the only amphibians found in close proximity to water on the Hanford Site (Soll et al. 1999, Brandt et al. 1993).

**Wildlife Occurring in Other Hanford Site Habitats.** Bluffs provide perching, nesting, and escape habitat for several bird species on the Hanford Site. The White Bluffs and Umtanum Ridge provide nesting habitat for prairie falcons (*Falco mexicanus*), red-tailed hawks, cliff swallows (*Hirundo pyrrhonota*), bank swallows (*Riparia riparia*), and rough-winged swallows (*Stelgidopteryx serripennis*). In the 1970s and '80s, Canada geese used the lower elevations of the White Bluffs for nesting and brooding. Bald eagles use the White Bluffs for roosting. Bluff areas provide habitat for sensitive species (e.g., peregrine falcon [*Falco peregrinus*]) that otherwise may be subject to impact from frequent or repeated disturbance. Trees that do not normally occur in arid steppe habitat supply nesting, perching, and roosting sites for many birds. Consequently, herons and raptors, such as ferruginous and Swainson's hawks, can use trees for breeding in areas that previously did not support breeding populations. Ferruginous hawks also nest on electrical transmission line towers. These occurrences of raptor nesting in non-native trees occur in upland areas as well as riparian zones along the Hanford Reach.

Dune habitat is unusual in its association with the surrounding shrub-steppe vegetation type. The individuality of the dunes is noted in its vegetation component as well as its geologic formation. The Hanford dunes, located on the eastern border of the Site, provide habitat for mule deer, burrowing owls, and coyotes as well as many transient species. In contrast, the dunes in west central Hanford, formed as a result of the fire in June 2000, may be temporary and could disappear once vegetation is reestablished.

Islands provide resting, nesting, and escape habitat for waterfowl and shorebirds. Use of islands for nesting by Canada geese has been monitored since 1950. The suitability of habitat for nesting Canada geese is attributed to restricted human use of islands during the nesting season, suitable substrate, and adequate forage and cover for broods (Eberhardt et al. 1989). The nesting population fluctuates annually. Since the early 1990s, geese have used the downstream islands in the Hanford Reach for nesting as a result of coyote predation in the upper Reach islands. Islands also accommodate colonial nesting species including California gulls (*Larus californicus*), ring-billed gulls (*Larus delawarensis*), and Forster's terns (*Sterna forsteri*). Island areas ranging from 0.1 to 0.2 km<sup>2</sup> (0.05 to 0.08 mi<sup>2</sup>) accommodate colonial nesting species that may range in population size up to 2000 individuals.

## **4.5.2 Aquatic Ecology**

Aquatic resources on the Hanford Site are primarily associated with the Columbia River. The river crosses the Hanford Site entering at the northwest corner of the site, traveling eastward and then turning south, forming the eastern boundary of the site. The Columbia River and associated riparian zones provide habitat for numerous wildlife and plant species. The area known as the Hanford Reach, the Columbia River from Priest Rapids Dam (river mile [RM] 397) to McNary Pool (RM 346) is the last non-impounded, non-tidal segment of the Columbia River in the United States. Several small intermittent spring/streams are also found on the site and, with their unique riparian habitat, provide a break in the vast expanses of shrub-steppe habitat that dominate the Hanford Site.

### **4.5.2.1 Columbia River**

The Columbia River is the dominant aquatic ecosystem on the Hanford Site and supports a large and diverse community of plankton, benthic and lotic invertebrates, fish, and other communities. Large rivers, like the Columbia River with its series of large reservoirs, contain significant populations of primary energy producers (e.g., algae and plants) that contribute to the biota's basic energy requirements.

Phytoplankton (free-floating algae) and periphyton (sessile algae) are abundant in the Columbia River and provide food for herbivores such as immature insects. Plankton populations in the Hanford Reach are influenced by communities that develop in the reservoirs of upstream dams, particularly Priest Rapids

Reservoir, and by the manipulation of water levels by dam operations in upstream and downstream reservoirs. Phytoplankton and zooplankton populations at the Hanford Site are largely transient, flowing from one reservoir to another. With the relatively rapid flow of the Columbia River, there is generally insufficient time for characteristic endemic groups of phytoplankton and zooplankton to develop in the Hanford Reach.

**Phytoplankton.** Phytoplankton species identified from the Hanford Reach include diatoms, golden or yellow-brown algae, green algae, blue-green algae, red algae, and dinoflagellates. Studies show diatoms are the dominant algae in the Columbia River phytoplankton, usually representing more than 90 percent of the populations. The main genera include *Asterionella*, *Cyclotella*, *Fragilaria*, *Melosira*, *Stephanodiscus*, and *Synedra* (Neitzel et al. 1982a). These are typical of those forms found in lakes and ponds and originate in upstream reservoirs. A number of algae found as free-floating species in the Hanford Reach of the Columbia River are actually derived from the periphyton; they were detached and suspended by currents and frequent fluctuations of the water level.

Cushing (1967a) found peak concentrations of phytoplankton occurred in April and May, with a secondary peak in late summer/early autumn. The spring pulse in phytoplankton density was probably related to increasing light and water temperature rather than to availability of nutrients, as phosphate and nitrate nutrient concentrations are never limiting. Minimum numbers were present in December and January. Green algae (*Chlorophyta*) and blue-green algae (*Cyanophyta*) occur in phytoplankton communities during warmer months but in substantially fewer numbers than diatoms. Diversity indices, carbon uptake, and chlorophyll concentrations for the phytoplankton show similar seasonal trends (Neitzel et al. 1982a, Wolf et al. 1976).

**Periphyton.** Communities of periphytic species or “benthic microflora” develop on suitable solid substrate wherever there is sufficient light for photosynthesis and adequate currents to prevent sediment from covering the colonies. Operation of Priest Rapids Dam results in frequent river level fluctuations. These fluctuations result in exposed shoreline areas that do not allow for the establishment of viable and persistent periphyton communities in shoreline areas inundated by water at flows greater than 1310 m<sup>3</sup>/s (46,300 cfs) (Tiller and Downs 2004). Cushing (1967b) observed peaks of production to occur in spring and late summer. Dominant genera are the diatoms *Achnanthes*, *Asterionella*, *Cocconeis*, *Fragilaria*, *Gomphonema*, *Melosira*, *Nitzschia*, *Stephanodiscus*, and *Synedra* (Beak Consultants Inc. 1980, Neitzel et al. 1982a, Page and Neitzel 1978, Page et al. 1979).

**Macrophytes.** Macrophytes are sparse in the Columbia River because of strong currents, rocky bottom, and frequently fluctuating water levels. Rushes (*Juncus* spp.) and sedges (*Carex* spp.) occur along shorelines of the slack-water areas such as White Bluffs Slough below the 100-H Area, the slough area downstream of the 100-F Area, and the Hanford Slough. Reed canary grass (*Phalaris arundinacea*) is a common non-native species found along shoreline areas. Macrophytes are also present along gently sloping shorelines that are subject to flooding during the spring freshet and daily fluctuating river levels (downstream of Coyote Rapids and the 100-D Area). Commonly found plants include duckweed (*Lemna* sp.) and the native rooted pond weeds (*Potamogeton* sp. and *Elodea canadensis*). Where they exist, macrophytes have considerable ecological value. They provide food and shelter for juvenile fish and spawning areas for some species of warm-water game fish. Eurasian milfoil (*Myriophyllum spicatum*), an introduced macrophyte, has increased to nuisance levels since the late 1980s and may encourage increased sedimentation of fine particulate matter.

**Zooplankton.** The zooplankton populations in the Hanford Reach of the Columbia River are generally sparse. Studies by Neitzel et al. (1982b) indicate crustacean zooplankters were dominant in the open-water regions. Dominant genera were *Bosmina*, *Diaptomus*, and *Cyclops*. Densities were lowest in winter and highest in the summer, with summer peaks dominated by *Bosmina*, ranging up to 160,650

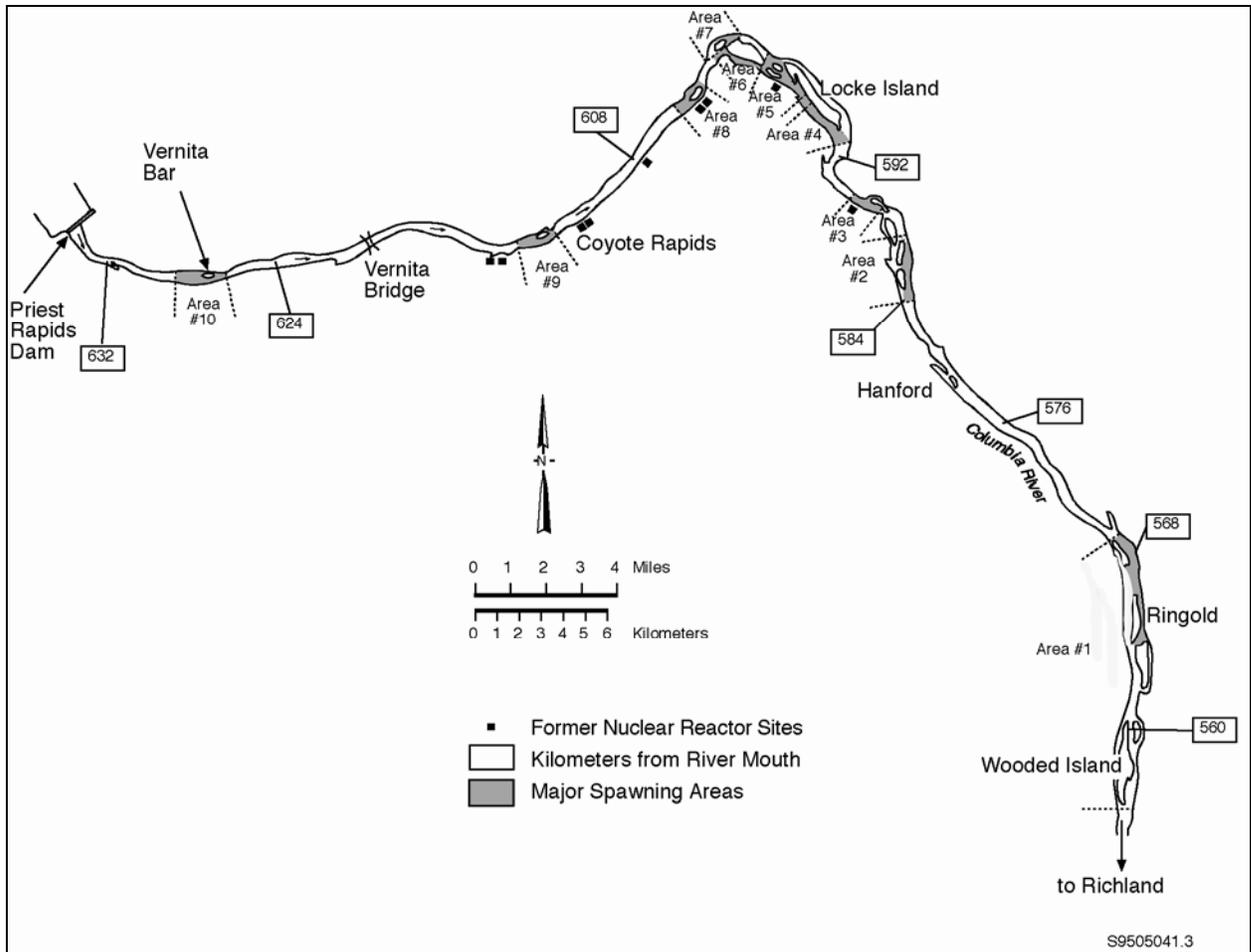
organisms/m<sup>3</sup> (4500 organisms/ft<sup>3</sup>). Winter densities were generally less than 1785 organisms/m<sup>3</sup> (50 organisms/ft<sup>3</sup>). *Diaptomus* and *Cyclops* dominated in winter and spring, respectively (Neitzel et al. 1982b).

**Benthic Organisms.** Benthic organisms are found either attached to or closely associated with the substratum. All major freshwater benthic taxa are represented in the Columbia River. Insect larvae such as caddisflies (*Trichoptera*), midge flies (*Chironomidae*), and black flies (*Simuliidae*) are dominant. Dominant caddisfly species are *Hydropsyche cockerelli*, *Cheumatopsyche campyla*, and *C. enonis*. Other benthic organisms include clams (*Corbicula* spp., *Anodontia* spp.), limpets (*Fisherola* spp.), snails (*Physa* spp.), sponges (*Spongilla* spp.), and crayfish (*Astacus trowbridgii*). Operation of Priest Rapids Dam results in frequent river level fluctuations. These fluctuations result in exposed shoreline areas during low-flow periods that do not allow for the establishment of persistent benthic communities. Clams and crayfish have difficulty in establishing populations in stranded shoreline areas that are frequently left dewatered by river level fluctuations. Species with rapid life cycles are less likely to be impacted by river fluctuations.

Early Hanford studies found crayfish numbers in shallow water areas ranged from 0.02 to 0.10 individuals/m<sup>2</sup> (0.2 to 1.1 individuals/ft<sup>2</sup>) of river bottom, with a diet primarily of vegetation (Coopey 1953), while insect larvae numbers were sometimes as high as 185.8/m<sup>2</sup> (2000/ft<sup>2</sup>) (Davis and Cooper 1951). Peak larval insect densities are found in late fall and winter, and the major emergence is in spring and summer (Wolf 1976). Stomach contents of fish collected in the Hanford Reach from June 1973 through March 1980 revealed that benthic invertebrates were important food items for nearly all juvenile and adult fish. There was a correlation between food organisms in the stomach contents and those in the benthic and invertebrate drift communities. A survey by Soll et al. (1999) identified 21 new taxa of aquatic invertebrates in the Hanford Reach bringing the total number of aquatic invertebrate taxa to 151.

**Fish.** Gray and Dauble (1977) listed 43 species of fish in the Hanford Reach of the Columbia River. The brown bullhead (*Ictalurus nebulosus*), collected since 1977, and the blue catfish (*Ictalurus furcatus*) listed by Washington Department of Fish and Game, brings the total number of fish species identified in the Hanford Reach to 45 (Appendix B, Table B-5). Sixteen of these 45 species are introduced (Wydoski and Whitney 1979). Of these species, Chinook salmon (*Oncorhynchus tshawytscha*), sockeye salmon (*Oncorhynchus nerka*), coho salmon (*Oncorhynchus kisutch*), and steelhead trout (*Oncorhynchus mykiss*) use the river as a migration route to and from upstream spawning areas and are of the greatest economic importance. Additionally, fall Chinook salmon and steelhead trout spawn in the Hanford Reach. The relative contribution of up-river bright stocks to fall Chinook salmon runs in the Columbia River increased from about 24 percent of the total in the early 1980s, to 50 to 60 percent of the total by 1988 (Dauble and Watson 1990). Inundation of other mainstream Columbia spawning grounds by dams has increased the relative importance of the Hanford Reach to fall Chinook salmon production in the Columbia and Snake rivers (Watson 1970, 1973; Dauble and Watson 1997). Operation of Priest Rapids Dam can result in frequent river level fluctuations exposing shoreline and cobble bars during low-flow periods. In recent years, Priest Rapids Dam has operated with an objective to stabilize fall river levels to prevent salmon from spawning in areas that will be exposed at low river flow during the winter, thus protecting salmon redds from desiccation and temperature extremes. Fall Chinook salmon redd surveys have been conducted in Hanford Reach since 1950. There are presently 10 areas identified in the Hanford Reach (Figure 4.5.4) that support salmon spawning (Dauble and Watson 1997, Poston et al. 2004).

The steelhead fishery in the Hanford Reach (Highway 395 Bridge to Priest Rapids Dam) consists almost exclusively of summer-run fish. The Washington State Department of Fish and Wildlife (WDFW)



**Figure 4.5.4.** Fall Chinook Salmon Spawning Areas in Hanford Reach Area of the Columbia River, Washington

estimates steelhead sport catch for the 2002 season at 1100 fish. The majority of these fish were marked hatchery fish. In recent years the return of fall Chinook salmon has been high with 7550 adults and about 1000 jacks (precocious males) harvested during 2002 (<http://wdfw.wa.gov/fish/harvest/harvest.htm>).

American shad (*Alosa sapidissima*), an introduced anadromous species, may also spawn in the Hanford Reach. The upstream range of the shad has been increasing since 1956 when less than 10 adult shad passed McNary Dam. Since then, the number of shad ascending Priest Rapids Dam has risen to many thousands each year, and young-of-the-year have been collected in the Hanford Reach. Shad are not dependent on the same conditions that are required by salmonids for spawning and apparently have found favorable conditions for reproduction.

Other fish of importance to sport fishermen are the native mountain whitefish (*Prosopium williamsoni*) and white sturgeon (*Acipenser transmontanus*). Introduced species like smallmouth bass (*Micropterus dolomieu*), crappie (*Pomoxis nigromaculatus*), catfish (*Ictalurus punctatus*), walleye (*Stizostedion vitreum*), and yellow perch (*Perca flavescens*) are also popular. Large populations of rough fish are also present, including introduced carp (*Cyprinus carpio*) and native species such as reidside shiner (*Richardsonius balteatus*), suckers (*Catostomus macrocheilus*), and northern pikeminnow (*Ptychocheilus oregonensis*). Because northern pikeminnow feed on juvenile salmon, WDFW has

established a bounty program on adult pikeminnow to bolster salmon runs. Northern pikeminnow removed from the Hanford Reach are usually turned in at bounty stations located at Columbia Point in Richland and at the Vernita Bridge rest stop.

#### 4.5.2.2 Spring Streams

Small interrupted streams, such as Rattlesnake, Bobcat, and Snively springs located on the Fitzner-Eberhardt Arid Lands Ecology Reserve Unit, contain diverse biotic communities and are extremely productive (Cushing and Wolf 1984). Dense blooms of watercress arise and are lost when flash floods occur. Aquatic insect production is fairly high as compared with mountain streams (Gaines 1987). The macrobenthic biota varies from site to site and is related to the proximity of colonizing insects and other factors. The fire of 2000 has had little direct impact on the stream ecology, even though the riparian transect along the lower two-thirds of the stream was heavily damaged by the fire (BAER 2000).

Rattlesnake Springs, on the western side of the Hanford Site, forms a small surface stream that flows for about 2.5 km (1.6 mi) before disappearing into the ground as a result of seepage and evapotranspiration. Base flow of this stream is about 0.01 m<sup>3</sup>/s (0.4 ft<sup>3</sup>/s) (Cushing and Wolf 1982). Water temperature ranges from 2° to 22°C (36° to 72°F). Mean annual total alkalinity (as CaCO<sub>3</sub>), nitrate nitrogen, phosphate phosphorus, and total dissolved solids are 127, 0.3, 0.18, and 217 mg/L, respectively (Cushing and Wolf 1982, Cushing et al. 1980). The sodium content of the spring water is about 7 ppm (Brown 1970). Rattlesnake Springs is of ecological importance because it provides a source of water to terrestrial animals in an otherwise arid part of the Hanford Site. Snively Springs, located west of and at a higher elevation than Rattlesnake Springs, is another source of drinking water for terrestrial animals. Both springs provide a valuable source of drinking water for the Rattlesnake Hills elk herd. The major rooted aquatic plant, which in places may cover the entire width of the stream, is watercress. Isolated patches of bulrush, spike rush, and cattail occupy less than 5 percent of the streambed.

Primary productivity at Rattlesnake Springs is greatest during the spring and coincident with the maximum periphyton standing crop. Net primary productivity averaged 0.9 g/cm<sup>2</sup>/d organic matter during 1969 and 1970; the spring maximum was 2.2 g/cm<sup>2</sup>/d. Seasonal productivity and respiration rates are within the ranges reported for arid region streams. Although Rattlesnake Springs is a net exporter of organic matter during much of the growing season, it is subject to flash floods and severe scouring and denuding of the streambed during winter and early spring, making it an importer of organic materials on an annual basis (Cushing and Wolf 1984).

Secondary production is dominated by detritus-feeding collector-gatherer insects (mostly Chironomidae and Simuliidae) that have multiple cohorts and short generation times (Gaines et al. 1992). Overall production is not high and is likely related to the low diversity found in these systems related to the winter spates that scour the spring streams. Total secondary production in Rattlesnake and Snively springs is 16,356 and 14,154 g dry weight/m<sup>2</sup>/yr, respectively. There is an indication that insects in these spring-streams depend on both autochthonous (originating within the stream) and allochthonous (originating outside the stream) primary production as an energy source, despite significant shading by non-native species of trees and shrubs (Mize 1993).

Invertebrate surveys on the Fitzner-Eberhardt Arid Lands Ecology Reserve Unit identified 30 new taxa at Rattlesnake Springs and 12 new taxa at Snively Springs (Soll et al. 1999). These recent findings bring the total number of taxa at each spring to 43 and 24, respectively.

There are other springs occurring on the Rattlesnake Hills (Schwab et al. 1979). Limited physical and chemical data are reported for each site.

### 4.5.2.3 Temporary Water Bodies

West Lake is a small saline pond created by a rise in the water table in the 200 Areas and is not fed by surface flow. Evaporation of groundwater and possible disposal of sewage during the early Hanford years created highly saline and alkaline conditions that greatly restricted the complement of biota in West Lake (Poston et al. 1991).

Several artificial water bodies, both ponds and ditches, were formed as a result of wastewater disposal practices associated with operation of the reactors and separation facilities. Most of these have been taken out of service and have been backfilled with the cessation of activities. When present, however, they formed established aquatic ecosystems complete with representative flora and fauna (Emery and McShane 1980). The temporary wastewater ponds and ditches existed for as long as two decades and covered fairly large areas. Rickard et al. (1981) discusses the ecology of Gable Mountain Pond, one of the former major lentic sites at Hanford. Emery and McShane (1980) present ecological characteristics of all the temporary water bodies. The ponds developed luxuriant riparian communities and became quite attractive to autumn and spring migrating birds. Several species have nested near the ponds. Section 4.4.1.8 describes those water bodies still active. These former sites have been decommissioned and are now covered with overburden and planted with grasses for stabilization.

### 4.5.3 Threatened and Endangered Species

There are a number of species of plants and animals on the Hanford Site that are considered to be rare and of management concern. Species listed as endangered or threatened by either the federal government under the Endangered Species Act (ESA) (50 CFR 17) or by the State of Washington (WNHP 2005, WDFW 2005) are listed in Table 4.5.1. There are no federal- or state-listed endangered or threatened mammals, reptiles, amphibians, or invertebrates on the Hanford Site, but there are three species of fish, five species of birds, and 11 species of plants listed as threatened or endangered by either the state or federal governments.

Of the three listed fish species, only the upper Columbia River steelhead trout (*Oncorhynchus mykiss*) spawns in the Hanford Reach, although the extent of spawning is not known. Upper Columbia River spring Chinook salmon (*O. tshawytscha*) do not spawn in the Hanford Reach, but adults pass through the Hanford Reach while migrating to spawning grounds, and the juveniles use the Hanford Reach as a nursery area while they migrate toward the ocean. The bull trout (*Salvelinus confluentus*) primarily inhabits smaller streams, usually at higher elevations. Bull trout have been observed in the Hanford Reach on very rare occasions, usually associated with the spring freshets. Bull trout are not considered to be residents of the Hanford Site.

The bald eagle (*Haliaeetus leucocephalus*) is a relatively common winter resident along the Hanford Reach that occasionally attempts to nest on the Hanford Site. However, bald eagles have never successfully nested on the Hanford Site. Bald eagle roosting and nesting sites are protected from site employees by access controls that are in place from November to March of each year.

Ferruginous hawks (*Buteo regalis*) have successfully nested on site, especially on several steel transmission line towers. The white pelican (*Pelecanus erythrorhynchos*) is relatively common along the Hanford Reach but does not appear to nest or reproduce on site. The sandhill crane (*Grus canadensis*) migrates over the site, and on rare occasions is observed on the shore or islands of the Hanford Reach. The greater sage grouse (*Centrocercus urophasianus*) was formerly more common on the Hanford Site, especially on the Fitzner-Eberhardt Arid Lands Ecology (ALE) Reserve Unit. It disappeared for a number of years following several large fires in the 1980s. Since the late 1990s, there have been

**Table 4.5.1.** Federal or Washington State Threatened and Endangered Species on the Hanford Site

Common Name	Scientific Name	Federal <sup>(a)</sup>	State <sup>(a)</sup>
<b>Fish<sup>(b)</sup></b>			
Bull trout	<i>Salvelinus confluentus</i>	Threatened	Candidate
Spring-run Chinook	<i>Oncorhynchus tshawytscha</i>	Endangered	Candidate
Steelhead	<i>Oncorhynchus mykiss</i>	Endangered	Candidate
<b>Birds<sup>(b)</sup></b>			
American white pelican	<i>Pelecanus erythrorhynchos</i>		Endangered
Bald eagle <sup>(c)</sup>	<i>Haliaeetus leucocephalus</i>	Threatened	Threatened
Ferruginous hawk	<i>Buteo regalis</i>	Species of Concern	Threatened
Sandhill crane	<i>Grus canadensis</i>		Endangered
Greater sage grouse	<i>Centrocercus urophasianus</i>	Candidate	Threatened
<b>Plants<sup>(d)</sup></b>			
Awned halfchaff sedge	<i>Lipocarpha (= Hemicarpha) aristulata</i>		Threatened
Desert dodder	<i>Cuscuta denticulata</i>		Threatened
Geyer's milkvetch	<i>Astragalus geyeri</i>		Threatened
Grand redstem	<i>Ammannia robusta</i>		Threatened
Loeflingia	<i>Loeflingia squarrosa var. squarrosa</i>		Threatened
Lowland toothcup	<i>Rotala ramosior</i>		Threatened
Persistentsepal yellowcress	<i>Rorippa columbiae</i>	Species of Concern	Endangered
Rosy pussypaws	<i>Calyptridium roseum</i>		Threatened
Umtanum desert buckwheat	<i>Eriogonum codium</i>	Candidate	Endangered
White Bluffs bladderpod	<i>Lesquerella tuplashensis</i>	Candidate	Threatened
White eatonella	<i>Eatonella nivea</i>		Threatened
<p>(a) Endangered = species in danger of extinction within all or a significant portion of its range.            Threatened = species likely to become endangered in the foreseeable future.            Candidate = species believed to qualify for threatened or endangered species status, but for which listing proposals have not been prepared.            Species of concern = species not currently listed or candidates under the ESA, but are of conservation concern within specific USFWS regions.</p> <p>(b) <a href="http://www.dnr.wa.gov/nhp/refdesk/lists/animal_ranks.html">http://www.dnr.wa.gov/nhp/refdesk/lists/animal_ranks.html</a> .</p> <p>(c) Currently under review for removal from the list of threatened or endangered species.</p> <p>(d) <a href="http://www.dnr.wa.gov/nhp/refdesk/lists/plantrnk.html">http://www.dnr.wa.gov/nhp/refdesk/lists/plantrnk.html</a> .</p>			

scattered sightings of greater sage grouse on ALE, and during 2003 a dead sage grouse was found near the 100-F Area.

There are no plant species on the Hanford Site that are currently listed as threatened or endangered under the ESA, but two species of plants are candidates for federal protection: Umtanum desert buckwheat (*Eriogonum codium*) which occurs in several small, highly localized populations on Umtanum Ridge, and the White Bluffs bladderpod (*Lesquerella tuplashensis*) which occurs on the White Bluffs. Several additional plant species are listed as threatened or endangered by Washington State. Several of these, including the awned halfchaff sedge (*Lipocarpa aristulata*), grand redstem (*Ammannia robusta*), lowland toothcup (*Rotala ramosior*), and persistentsepal yellowcress (*Rorippa columbiae*) are restricted to wetlands in the riparian zone of the Columbia River. Other plant species, such as loeflingia (*Loeflingia squarrosa*) and rosy pussypaws (*Calyptridium roseum*), are small annuals that have been found in relatively undisturbed sagebrush areas in the vicinity of Gable Mountain. The remaining three state threatened or endangered plant species (Geyer's milkvetch [*Astragalus geyeri*], white eatonella [*Eatonella nivea*], and desert dodder [*Cuscuta denticulata*]) have been found at various sites on the Wahluke slope.

In addition to the species listed by the state or federal resource agencies as threatened or endangered, there are numerous species listed by the State of Washington as candidate or sensitive animal species (Table 4.5-2) or as sensitive, review, or watch list plants (Table 4.5-3). The common loon (*Gavia immer*) and the peregrine falcon (*Falco peregrinus*) are the only animal species on the Hanford Site listed as sensitive by Washington State; there are 17 species of plants listed as state sensitive species.

The Washington ground squirrel (*Spermophilus washingtoni*), listed as a candidate species by both the state and federal governments, is most likely to occur in the Franklin or Grant county portions of the Hanford Site. The Townsend's ground squirrel (*S. townsendii*), a Washington State candidate species, may be found on the Benton County portions of the Hanford Site.

Several state candidate and sensitive species, including the loggerhead shrike (*Lanius ludovicianus*), burrowing owl (*Athene cunicularia*), sagebrush lizard (*Sceloporus graciosus*), peregrine falcon, goshawk (*Accipiter gentilis*), Columbia River spire snail (*Fluminicola columbiana*), and California floater (*Anodonta californiensis*), as well as the state threatened ferruginous hawk are considered to be animal species of concern by the U.S. Fish and Wildlife Service (USFWS). Three state sensitive plant species, Columbia milkvetch (*Astragalus columbianus*), Hoover's desert parsley (*Lomatium tuberosum*), and gray cryptantha (*Cryptantha leucophaea*), as well as the state endangered persistentsepal yellowcress, are considered by USFWS to be species of concern in the mid-Columbia Basin. Species of concern are not protected under federal law, but are considered to be vulnerable and of special management concern. More information about the plant species listed in Table 4.5-3 can be found in Sackschewsky and Downs (2001).

A species of springsnail was discovered in the lower Hanford Reach during 2004 that, depending on the taxonomic system used, is either the Columbia springsnail (a species of *Pyrgulopsis* that has not been formally described or named) or the Jackson Lake springsnail (*Pyrgulopsis robusta*). Regardless of the name, the USFWS is currently evaluating this species for possible listing as endangered or threatened (70 FR 20512). This species currently has no federal or state status.

The USFWS has indicated that four additional federally listed threatened, endangered, or candidate species may be present in Benton, Franklin, or Grant counties (USFWS 2004). The pygmy rabbit (*Brachylagus idahoensis*) is a federal and state endangered species that is restricted to a few small populations north of the Hanford Site in Grant and Adams counties. Biologists have searched for this species on the Hanford Site, but it has not been conclusively observed. Ute Ladies tresses (*Spiranthes*

*diluvialis*) is a threatened orchid that potentially could be found along the Columbia River but has not been observed near the Site; it is documented in Chelan and Okanogan counties (WNHP 2005). The yellow-billed cuckoo (*Coccyzus americanus*) is a federal candidate species that has been rarely observed in southeast Washington. It normally requires relatively large forested wetland areas for successful breeding. Such habitat is not available on the Hanford Site, and the species has not been observed on the Hanford Site. The northern wormwood (*Artemisia campestris* var *wormskioldii*) is a federal candidate and state endangered species that occurs along the Columbia River near Wanapum Dam. Extensive surveys along the shore of the Hanford Reach have failed to locate this species on the Hanford Site. The USFWS (2004) also lists a number of additional species of concern for Benton, Franklin, and Grant Counties, including a number of bat species that may occur on the Hanford Site; most of these have no Washington State-level status designation.

**Table 4.5-2.** Washington State Candidate and Sensitive Animal Species on the Hanford Site

Common Name	Scientific Name
<b>Molluscs</b>	
California floater <sup>(a)</sup>	<i>Anodonta californiensis</i>
Giant Columbia River limpet	<i>Fisherola (= Lanx) nuttalli</i>
Giant Columbia River spire snail <sup>(a)</sup>	<i>Fluminicola (= Lithoglyphus) columbiana</i>
<b>Fish</b>	
Bull trout <sup>(b,c)</sup>	<i>Salvelinus confluentus</i>
Mountain sucker <sup>(c)</sup>	<i>Catostomus platyrhynchus</i>
Leopard dace <sup>(c)</sup>	<i>Rhinichthys flacatus</i>
River Lamprey <sup>(c)</sup>	<i>Lampetra ayresi</i>
Spring-run Chinook salmon <sup>(d)</sup>	<i>Oncorhynchus tshawytscha</i>
Steelhead <sup>(d)</sup>	<i>Oncorhynchus mykiss</i>
<b>Insects</b>	
Columbia River tiger beetle <sup>(e)</sup>	<i>Cicindela columbica</i>
<b>Birds</b>	
Burrowing owl <sup>(a)</sup>	<i>Athene cunicularia</i>
Common loon <sup>(f)</sup>	<i>Gavia immer</i>
Flamulated owl <sup>(c)</sup>	<i>Otus flammeolus</i>
Golden eagle	<i>Aquila chrysaetos</i>
Lewis's woodpecker <sup>(c)</sup>	<i>Melanerpes lewis</i>
Loggerhead shrike <sup>(a)</sup>	<i>Lanius ludovicianus</i>
Peregrine falcon <sup>(a,f)</sup>	<i>Falco peregrinus</i>
Merlin	<i>Falco columbarius</i>
Northern goshawk <sup>(a,c)</sup>	<i>Accipter gentilis</i>
Sage sparrow	<i>Amphispiza belli</i>
Sage thrasher	<i>Oreoscoptes montanus</i>
Western grebe	<i>Aechmorus occidentalis</i>
<b>Reptiles</b>	
Sagebrush lizard <sup>(a)</sup>	<i>Sceloporus graciosus</i>
Striped whipsnake	<i>Masticophis taeniatus</i>
<b>Mammals</b>	
Black-tailed jackrabbit	<i>Lepus californicus</i>
Merriam's shrew	<i>Sorex merriami</i>
Townsend's ground squirrel	<i>Spermophilus townsendii</i>
Washington ground squirrel <sup>(c,g)</sup>	<i>Spermophilus washingtoni</i>
White-tailed jackrabbit	<i>Lepus townsendii</i>
(a) Federal species of concern. (b) Federal threatened. (c) Reported, but seldom observed, on the Hanford Site. (d) Federal endangered (e) Probable, but not observed, on the Hanford Site.	(f) State Sensitive (i.e., taxa vulnerable or declining) and could become endangered or threatened without active management or removal of threats.. (g) Federal candidate

**Table 4.5-3.** Washington State Plant Species of Concern on the Hanford Site

<b>Common Name</b>	<b>Scientific Name</b>	<b>State Listing<sup>(a)</sup></b>
Annual paintbrush	<i>Castilleja exilis</i>	Watch List
Annual sandwort	<i>Minuartia pusilla var. pusilla</i>	Review Group 1
Basalt milk-vetch	<i>Astragalus conjunctus var. rickardii</i>	Watch List
Beaked spike-rush	<i>Eleocharis rostellata</i>	Sensitive
Bristly combseed	<i>Pectocarya setosa</i>	Watch List
Brittle prickly pear	<i>Opuntia fragilis</i>	Review Group 1
Canadian St. John's wort	<i>Hypericum majus</i>	Sensitive
Chaffweed	<i>Centunculus minimus</i>	Review Group 1
Columbia milkvetch	<i>Astragalus columbianus</i>	Sensitive <sup>(b)</sup>
Columbia River mugwort	<i>Artemisia lindleyana</i>	Watch List
Coyote tobacco	<i>Nicotiana attenuata</i>	Sensitive
Crouching milkvetch	<i>Astragalus succumbens</i>	Watch List
Desert evening-primrose	<i>Oenothera caespitosa</i>	Sensitive
Dwarf evening primrose	<i>Camissonia (= Oenothera) pygmaea</i>	Sensitive
False pimpernel	<i>Lindernia dubia anagallidea</i>	Watch List
Fuzzytongue penstemon	<i>Penstemon eriantherus whitedii</i>	Sensitive
Giant helleborine	<i>Epipactis gigantea</i>	Watch List
Gray cryptantha	<i>Cryptantha leucophaea</i>	Sensitive <sup>(b)</sup>
Great Basin gilia	<i>Gilia leptomeria</i>	Sensitive
Hedge hog cactus	<i>Pediocactus simpsonii var. robustior</i>	Review Group 1
Hoover's desert parsley	<i>Lomatium tuberosum</i>	Sensitive <sup>(b)</sup>
Kittitas larkspur	<i>Delphinium multiplex</i>	Watch List
Medic milkvetch	<i>Astragalus speirocarpus</i>	Watch List
Miner's candle	<i>Cryptantha scoparia</i>	Sensitive
Mousetail	<i>Myosurus clavicaulis</i>	Sensitive
Piper's daisy	<i>Erigeron piperianus</i>	Sensitive
Porcupine sedge	<i>Carex hystericina</i>	Watch List
Robinson's onion	<i>Allium robinsonii</i>	Watch List
Rosy balsamroot	<i>Balsamorhiza rosea</i>	Watch List
Scilla onion	<i>Allium scilloides</i>	Watch List
Shining flatsedge	<i>Cyperus bipartitus (rivularis)</i>	Sensitive
Small-flowered evening-primrose	<i>Camissonia (= Oenothera) minor</i>	Sensitive
Small-flowered nama	<i>Nama densum var. parviflorum</i>	Watch List
Smooth cliffbrake	<i>Pellaea glabella simplex</i>	Watch List
Snake River cryptantha	<i>Cryptantha spiculifera (= C. interrupta)</i>	Sensitive
Southern mudwort	<i>Limosella acaulis</i>	Watch List
Stalked-pod milkvetch	<i>Astragalus sclerocarpus</i>	Watch List

<b>Common Name</b>	<b>Scientific Name</b>	<b>State Listing<sup>(a)</sup></b>
Suksdorf's monkey flower	<i>Mimulus suksdorfii</i>	Sensitive
Thompson's sandwort	<i>Arenaria franklinii thompsonii</i>	Review Group 2
Winged combseed	<i>Pectocarya penicillata</i>	Watch List
<p>(a) Sensitive - Taxa that are vulnerable or declining and could become endangered or threatened without active management or removal of threats.  Review Group 1 - Taxa for which currently there are insufficient data available to support listing as threatened, endangered, or sensitive, and the State is actively searching for additional data or information.  Review Group 2 - Taxa with unresolved taxonomic questions that would affect the listing status.  Watch List - Taxa that are more abundant and/or less threatened than previously assumed, but still of interest to the State.</p> <p>(b) USFWS Columbia Basin federal species of concern.</p>		

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## 4.6. Cultural, Archaeological, and Historical Resources

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The following section represents a summary of cultural, archaeological, and historical resources that are known to be located on the Hanford Site. The inventory is based on a review of archaeological, historical, and ethnographic data collected from archival records, archaeological surveys, and ethnographic interviews. It does not reflect a complete inventory as presently only 24 percent of the Hanford Site has been surveyed for archaeological resources (Figure 4.6-1).

The Hanford Site is one of the richest cultural resource areas remaining in the western Columbia Plateau. The Hanford Site comprises a series of cultural landscapes that have been documented and evaluated containing the cumulative record of multiple occupations by both Native and non-Native Americans. For management and interpretive purposes, these cultural landscapes have been divided into the Native American landscape, the Early Settlers/Farming landscape, and the Manhattan Project and Cold War landscape. These landscapes contain numerous well-preserved archaeological and above-ground resources representing pre-contact, ethnographic, and historic periods. Period resources include sites with cultural materials that are thousands of years old, traditional cultural places, and buildings and structures from the pre-Hanford, Manhattan Project, and Cold War eras (DOE 1997a). Site-wide management of Hanford's cultural resources follows the *Hanford Cultural Resources Management Plan* (DOE 2003).

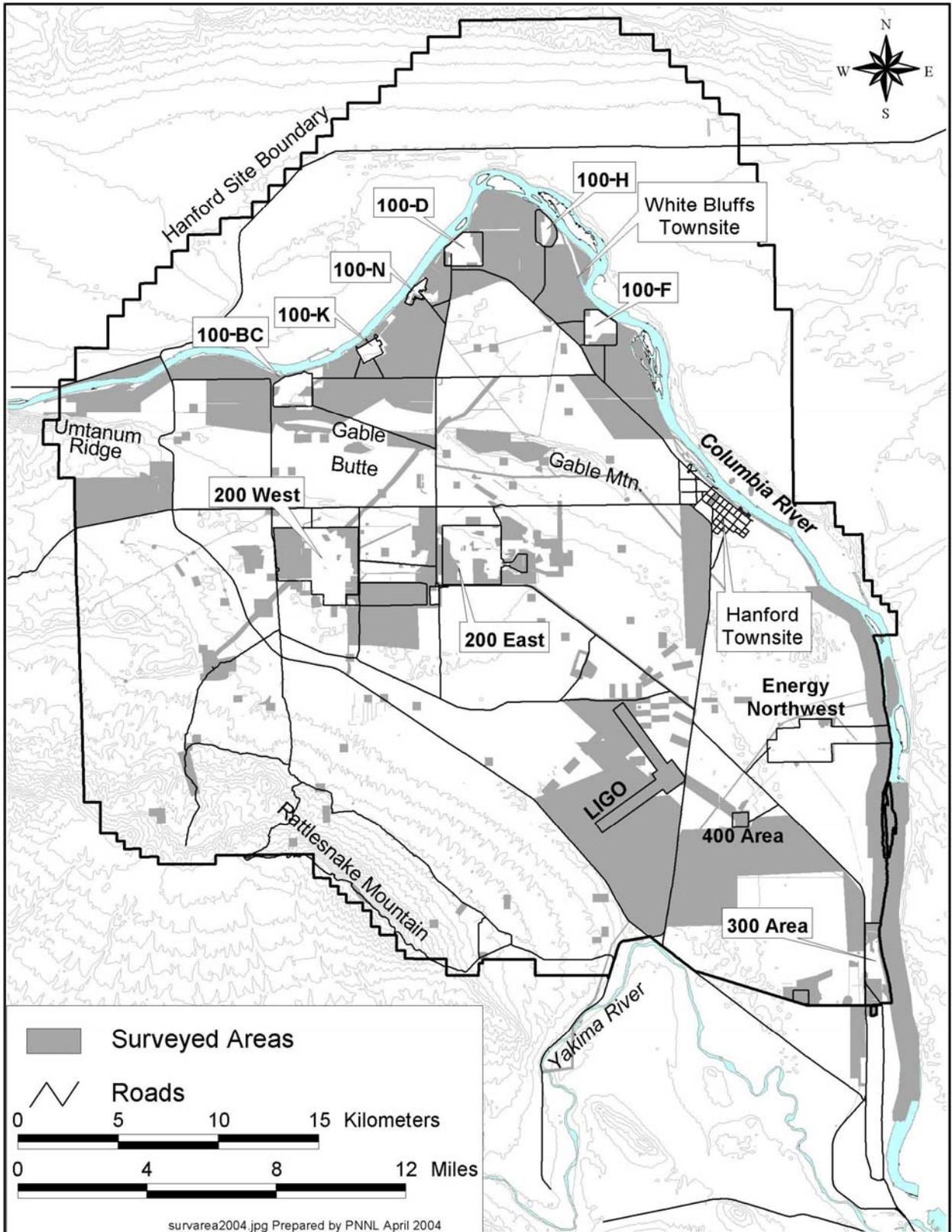
Approximately 1447 cultural resources sites and isolated finds, and 531 buildings and structures have been documented since 1926 on the Hanford Site. Early archaeological reconnaissance projects dating from 1926 to 1968 (Drucker 1948; Krieger 1928; Rice 1968a, b) and more recent National Historic Preservation Act Section 110 and 106 archaeological surveys conducted between 1987 and 2004 have resulted in formal recording of these resources on archaeological site and isolate forms and Washington State Historic Property Inventory forms. The DOE Hanford Cultural Resources Laboratory archives these records.

Of the 127 sites that have been evaluated for listing in the National Register of Historic Places (National Register), 49 have been listed (Table 4.6-1). Except for B-Reactor, which is associated with the Manhattan Project and Cold War period, the other listed sites are associated with the Native American landscape. Most of these are part of six Archaeological Districts and with the exception of the Rattlesnake Springs sites and the Snively Canyon Archaeological District, are situated on the shores and islands of the Columbia River.<sup>(a)</sup>

Eleven individual archaeological sites and three historic districts comprising 59 archaeological sites and 530 buildings or structures have also been determined to be eligible for listing in the National Register (Table 4.6-2). These sites are dispersed throughout the Hanford Site and represent the three cultural landscapes found on the Hanford Site. In addition to the National Register sites and districts, 47 of Hanford's cultural resource sites (46 in three districts and one site) are listed in the Washington Heritage Register (Table 4.6-3). These are associated with the Native American cultural landscape and are located predominantly along the Columbia River.

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(a) In order to protect resources, the National Historic Preservation Act (16 USC 470) Section 304, and Archaeological Resources Protection Act (16 USC 470aa) Section 9 requires agencies to withhold from public disclosure information on the location and character of cultural resources.



**Figure 4.6-1.** Areas Surveyed for Cultural Resources on the Hanford Site, Washington

**Table 4.6-1.** Historic Buildings, Archaeological Sites, and Districts Listed in the National Register of Historic Places on the Hanford Site, Washington

Property Name	General Location	Landscape Association
<b>Districts:</b>		
Hanford North Archaeological District	100-F	Native American
Locke Island Archaeological District	100-H	Native American
Ryegrass Archaeological District	100-K	Native American
Savage Island Archaeological District	Energy Northwest	Native American
Snively Canyon Archaeological District	Rattlesnake Hills	Native American
Wooded Island Archaeological District	300 Area	Native American
<b>Sites:</b>		
Hanford Island Archaeological site	Hanford Townsite	Native American
Paris Archaeological site	Vernita Bridge	Native American
Rattlesnake Springs sites	Rattlesnake Mountain	Native American
<b>Building:</b>		
105-B Reactor	100-B/C Area	Manhattan Project

**Table 4.6-2.** Historic Buildings, Archaeological Sites, and Districts Determined Eligible for Listing in the National Register of Historic Places on the Hanford Site, Washington

Property Name	General Location
<b>Native American:</b>	
<i>Wanawish</i> fishing village	600 Area
Gable Mountain/Gable Butte Cultural District	200 East Area
45BN423 <sup>(a)</sup>	100-K Area
45BN434	100-K Area
45BN446	100-B/C Area
45BN606	100-F Area
45BN888	100-D Area
<b>Early Settlers:</b>	
Midway-Benton transmission line	600 Area
McGee Ranch/Cold Creek Valley District	Cold Creek Valley
Fry and Conforth farm	100-B/C Area
White Bluffs Road	200 West to White Bluffs townsite
First Bank of White Bluffs	White Bluffs townsite
Bruggemann's Warehouse	100-B/C Area
Hanford Electrical Substation-Switching Station	Hanford Townsite
Hanford High School	Hanford Townsite
Coyote Rapids Hydroelectric Pumping Plant	100-B/C Area
<b>Manhattan Project/Cold War:</b>	
Hanford Site Manhattan Project and Cold War Era Historic District	100, 200-E and W, 300, 400, 600, 700, and 1100 Areas
Five Anti-Aircraft Artillery sites	600 Area
Hanford Atmospheric Dispersion Test Facility	600 Area
(a) Smithsonian Trinomial numbers are the standard designation for archaeological sites in the United States. 45 represents the state of Washington. BN, GR and FR represent Benton, Grant and Franklin counties. The number that follows indicates that the site was the n <sup>th</sup> archaeological site to be recorded.	

**Table 4.6-3.** Archaeological Sites and Districts Listed in the Washington Heritage Register on the Hanford Site, Washington

<b>Property Name</b>	<b>General Location</b>
<b>Districts:</b>	
Coyote Rapids Archaeological District	100-K Area
Hanford South Archaeological District	300 Area
Wahluke Archaeological District	100-D Area
<b>Site:</b>	
Gable Mountain Archaeological site	600 Area, North of 200 East

DOE identified a National Register-eligible Hanford Site Manhattan Project and Cold War Era Historic District (Historic District) that serves to organize and delineate the evaluation and mitigation of Hanford’s plutonium production built environment (Table 4.6-2). Standards for evaluating and mitigating the built environment were established in accordance with National Register criteria, as well as historic contexts and themes associated with nuclear technology for national defense and non-military purposes, energy production, and human health and environmental protection. DOE completed a programmatic agreement that addresses management of the built environment (buildings and structures) constructed during the Manhattan Project and Cold War periods. The Federal Advisory Council on Historic Preservation and the Washington State Historic Preservation Officer accepted this programmatic agreement during 1996 (DOE 1996a).

Establishment of the Historic District resulted in the selection of 190 buildings, structures, and complexes as contributing properties within the historic district recommended for individual documentation. Certain property types, such as mobile trailers, modular buildings, storage tanks, towers, wells, and structures with minimal or no visible surface manifestations, were exempt from the identification and evaluation requirements.

Approximately 900 buildings and structures were identified as either contributing properties with no individual documentation requirement (not selected for mitigation) or as non-contributing/exempt properties (DOE 1998b).

Hanford Site projects that entail transfer or lease of property, disturbing ground, and/or altering or demolishing existing structures result in cultural resource reviews. These reviews ensure that archeological sites, traditional cultural places, and buildings and structures listed in or eligible for the National Register are considered before impacts by proposed projects.

#### **4.6.1 Native American Cultural Landscape**

For thousands of years American Indians have utilized the lands both within and around the Hanford Site (Relander 1956, Spier 1936, Walker 1998). When Euro-American explorers arrived in the early 1800s, peoples presently referred to as the Wanapum were observed inhabiting numerous villages and fishing camps scattered throughout this segment of the mid-Columbia River.

Neighboring groups known today as the Yakama, Umatilla, Cayuse, Walla Walla, Palus, Nez Perce, and Middle Columbia Salish frequented the area to trade, gather resources, and conduct other activities. Many descendants of these tribes and bands are affiliated with the Wanapum, Confederated Tribes and Bands of the Yakama Nation, Confederated Tribes of the Umatilla Reservation, Nez Perce Tribe of Idaho, or the Confederated Tribes of the Colville Reservation, and they retain traditional, cultural, and religious ties to Hanford's places and resources. The record of Native American use and history is reflected in the archaeological sites and traditional cultural places that are located across the Hanford Site.

#### **4.6.1.1 Archaeological Resources**

More than 8000 years of pre-contact human activity in the largely arid environment of the mid-Columbia River region have left extensive archaeological deposits along the river shores (DOE 2003, Greengo 1982, Leonhardy and Rice 1970). Well-watered areas inland from the river also show evidence of concentrated human activity (Chatters 1982, DOE 2003, Daugherty 1952, Greene 1975, Leonhardy and Rice 1970, Rice 1980a) and recent research (Woody 2003) has indicated ephemeral use of arid lowlands for hunting and other resource procurement activities. Throughout most of the region, hydroelectric development, agricultural activities, and domestic and industrial construction have destroyed or covered many of these deposits. Amateur artifact collectors have impacted numerous sites. Because the areas included in the Hanford Site were restricted to public access, archaeological deposits found in the Hanford Reach of the Columbia River and on adjacent plateaus and mountains are more protected than many other areas.

Approximately 720 archaeological sites and isolated finds associated with the pre-contact period have been recorded on the Hanford Site; of these, 80 contain historic components as well. Pre-contact period sites common to the Hanford Site include pit house villages, various types of open campsites, spirit quest monuments (rock cairns), hunting camps, game drive complexes, and quarries in nearby mountains and rocky bluffs (Rice 1968a, b; Rice 1980a); hunting/kill sites in lowland stabilized dunes; and small temporary camps near perennial sources of water located away from the river (Rice 1968b).

A historic context for the pre-contact period of the Hanford Site has been prepared as part of a National Register Multiple Property Documentation form to assist with the evaluation of the National Register eligibility of pre-contact archaeological resources (DOE 1997a).

#### **4.6.1.2 Traditional Cultural Places**

During 1990, the National Park Service formalized the concept of traditional cultural property or traditional cultural place (TCP) as a means to identify and protect cultural landscapes, places, and objects that have special cultural significance to American Indians and other ethnic groups (Parker and King 1990). A TCP eligible for the National Register is associated with "cultural practices or beliefs of a living community that are rooted in that community's history and are important in maintaining the continuing cultural identity of the community" (Parker and King 1990).

The Hanford Reach and the greater Hanford Site, a geographic center for regional American Indian religious activities, is central to the practice of Indian religion of the region, and many believe the Creator made the first people here (DOI 1994). Indian religious leaders such as *Smoholla*, a prophet of Priest Rapids who brought the Washani religion to the Wanapum and others during the late 19<sup>th</sup> century, began their teachings here. Native plant and animal foods, some of which can be found on the Hanford Site, are used in the ceremonies performed by tribal members. Based on consultation with affected tribal members and interviews with tribal elders, it is known that prominent landforms such as Rattlesnake

Mountain, Gable Mountain, and Gable Butte, as well as various sites along and including the Columbia River, remain sacred to them.

American Indian traditional cultural places within the Hanford Site include, but are not limited to, a wide variety of places and landscapes: archaeological sites, cemeteries, trails and pathways, campsites and villages, fisheries, hunting grounds, plant gathering areas, holy lands, landmarks, important places in Indian history and culture, places of persistence and resistance, and landscapes of the heart (Bard 1997). Because affected tribal members consider these places sacred, many traditional cultural sites remain unidentified. The DOE and HCRL continue to consult with Hanford Tribes for input on these locations, as their importance is determined through methods that are mutually agreed upon by DOE and the American Indian community.

A historic context for the Ethnographic/Contact Periods of the Hanford Site has been prepared as part of a National Register Multiple Property Documentation form to assist with the evaluation of the National Register eligibility of American Indian ethnographic resources (DOE 1997a).

## **4.6.2 Early Settlers/Farming Landscape**

The Early Settlers/Farming landscape is comprised of those areas on the Hanford Site where people, mainly of European descent, and some of other ethnicity, settled in the Columbia River Plateau prior to the start of the Manhattan Project during 1943. Non-Native American presence in the mid-Columbia began during 1805 with the arrival of the Lewis and Clark Expedition. It was not until the late 19<sup>th</sup> and early 20<sup>th</sup> centuries, however, that non-Native American peoples began intensive settlement on the Hanford Site. A record of their activities and use is present in the archaeological sites, traditional cultural places, and buildings and structures that are located throughout the Hanford Site.

A historic context for the Euro-American resettlement period (pre-Hanford era) has been prepared as part of a National Register Multiple Property Documentation form to assist with the evaluation of the National Register eligibility of historic archaeological resources, traditional cultural places, and historic structures (DOE 1997a).

### **4.6.2.1 Archaeological Resources**

The first Euro-Americans to pass near the Hanford Site were part of the Lewis and Clark expedition, which traveled along the Columbia and Snake rivers during their 1803 to 1806 exploration of the Louisiana Territory. The first European explorer to cross the Hanford Site was David Thompson, who traveled along the Columbia River from Canada during his 1811 exploration of the Columbia River. Other visitors included fur trappers, military units, and miners who traveled through the Hanford Site on their way to lands up and down the Columbia River and across the Columbia Basin. It was not until the 1860s that merchants set up stores, a freight depot, and the White Bluffs Ferry on the Hanford Reach. Chinese miners began to work the gravel bars for gold during the 1860s. Cattle ranches were established in the 1880s and farmers followed during the next two decades. Agricultural development, irrigation districts, and roads were established in the eastern portion of the central Hanford Site. Several small towns, including Hanford, White Bluffs, Richland, and Ringold, grew up along the riverbanks during the early 20<sup>th</sup> century. The communities' accessibility to outside markets expanded with the arrival during 1913 of the Chicago, Milwaukee, St. Paul and Pacific Railroad branch line (Priest Rapids-Hanford Line) from Beverly, Washington. Ferries were established at Richland, Hanford, Wahluke, and Vernita (Figure 4.6-2). The towns and nearly all other structures were razed in the years after the U.S. Government acquired the land for the Hanford Engineer Works during 1943 (DOE 2003, ERTEC 1981, Rice 1980a).

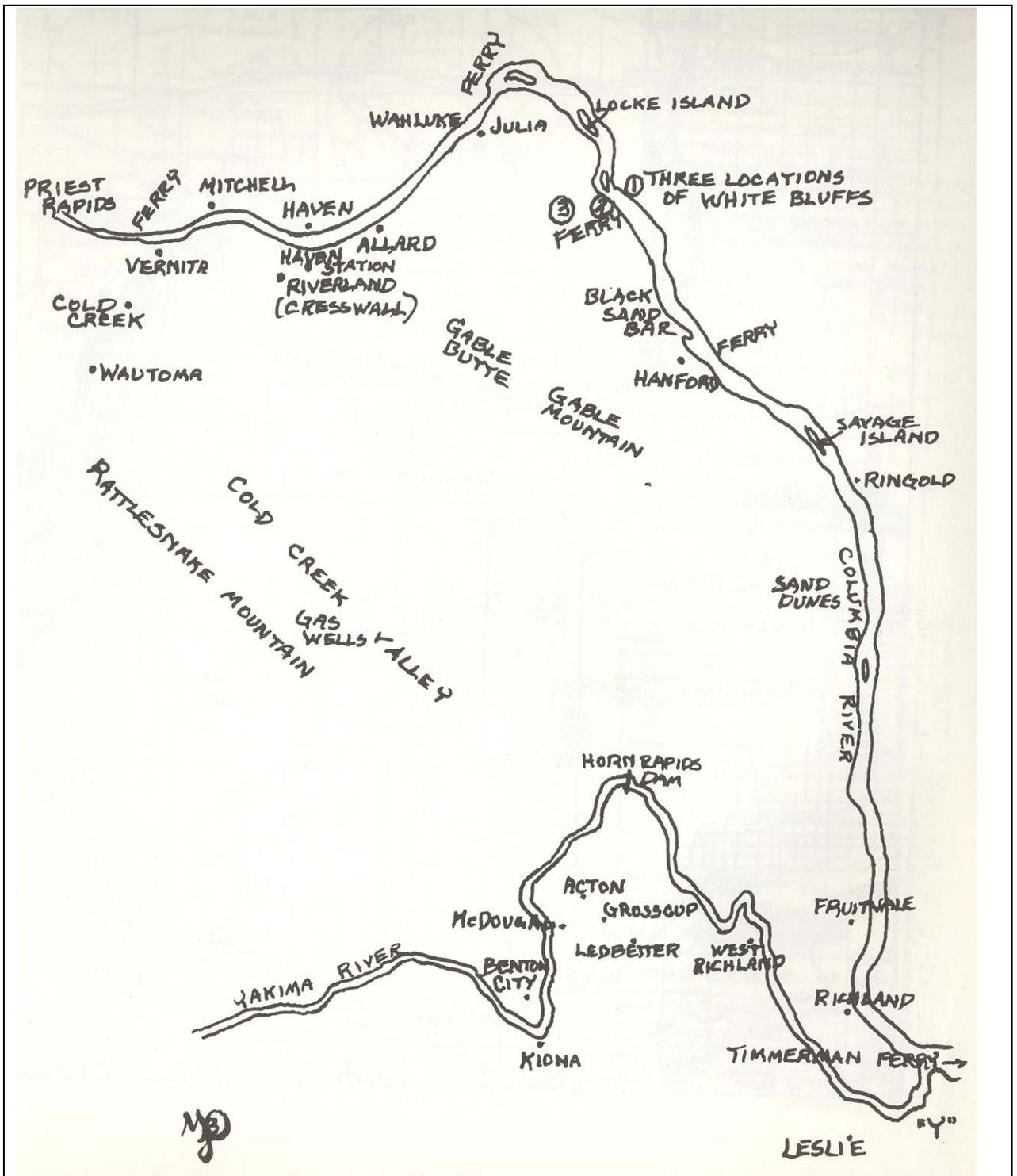


Figure 4.6-2. Map of the Hanford Site, Washington, showing towns, ferries and prominent features associated with the Early Settlers landscape (Parker 1986)

Approximately 650 historic archaeological sites associated with the Early Settlers/Farming landscape including an assortment of towns, farmsteads, corrals and domestic debris are recorded by the HCRL since 1987. Approximately 80 of these sites contain pre-contact components as well. Archaeological resources from the Early Settlers/Farming period are scattered over the entire Hanford Site and include numerous areas of gold mining features along the riverbanks of the Columbia and remains of homesteads, building foundations, agricultural equipment and fields, ranches, and irrigation features. Archaeological properties from this period include the Hanford Irrigation Canal; Hanford Townsite; Wahluke Ferry; White Bluffs townsite; Vernita Ferry; White Bluffs Road; and Chicago, Milwaukee, St. Paul and Pacific Railroad (Priest Rapids-Hanford Line) and associated stops.

#### **4.6.2.2 Traditional Cultural Places**

Traditional cultural places associated with the Early Settlers/Farming landscape that are located on the Hanford Site include structures and places that are important to descendants of pre-1943 settlers in the region. These places are deeply rooted in the memories of local residents and include but are not limited to numerous home sites and townsites, orchards, fields, and places of former community activities, e.g., swimming holes and town square. Previous residents of the region and their descendants visit their homes annually with friends and family.

#### **4.6.2.3 Buildings and Structures**

Although most of the Early Settlers/Farming structures were demolished by the U.S. Government to build infrastructure for the Hanford Engineer Works during 1943 (DOE 2003, ERTEC 1981, Rice 1980a), a small number of buildings associated with the Early Settlers/Farming landscape remain standing today. They include the Hanford Irrigation and Power Company's pumping plant at Coyote Rapids, the high school and the electrical substation at the Hanford Townsite, First Bank of White Bluffs, Bruggemann's fruit warehouse, and the blacksmith cabin at the East White Bluffs ferry landing. These structures are located near the Columbia River.

### **4.6.3 Manhattan Project and Cold War Cultural Landscape**

The Manhattan Project and Cold War era landscape is comprised of cultural resources associated with plutonium production, military operations, research and development, waste management, and environmental monitoring activities that took place beginning with the establishment of the Hanford Site (Hanford Engineer Works) during 1943 to the end of the Cold War during 1990.

The Hanford Site built environment is an industrial landscape that consists of buildings and structures constructed during the Manhattan Project and Cold War period. This industrial landscape makes up the Hanford Site Manhattan Project and Cold War Era Historic District. The DOE Richland Operations Office, the State Historic Preservation Officer, and the Federal Advisory Council on Historic Preservation, through a programmatic agreement to manage the Manhattan Project and Cold War built environment, determined that a historic district afforded the best means to inventory, assess, and mitigate the most significant buildings and structures constructed during the Manhattan Project and Cold War. Industrial, scientific, administrative, environmental monitoring, waste management, infrastructure, and military facilities constructed during the Manhattan Project and Cold War era can be found in all of the Site areas.

While buildings and structures representing this era are located throughout the site, evidence of military operations consists mostly of archaeological remains. Military operations in various forms took

place on the Site from World War II to the early 1960s. Most of the military operations, however, took place beginning with the establishment of Camp Hanford by the U.S. Army during 1950-51 until its closure in 1961. Camp Hanford was a military outpost, with the main cantonment located in North Richland and forward positions situated throughout the Site consisting of anti-aircraft artillery sites and Nike missile installations.

Historic contexts were completed for the Manhattan Project and Cold War eras as part of a National Register Multiple Property Documentation Form prepared for the Hanford Site to assist with the evaluation of National Register eligibility of buildings and structures site wide (DOE 1997a).

Additionally, historical narratives and individual building documentations have been completed for the *History of the Plutonium Production Facilities at the Hanford Site Historic District, 1943-1990* (DOE 2002c). Five hundred twenty-eight Manhattan Project and Cold War era buildings/structures and complexes are eligible for the National Register as contributing properties within the Historic District. Of that number, 190 were documented individually as required by the programmatic agreement signed in 1996 (DOE 1996a). DOE/RL is undertaking an assessment of the contents of the contributing buildings and structures to locate and identify any Manhattan Project and Cold War era artifacts that may have interpretive or educational value for museum exhibit purposes (DOE 1998b).

#### **4.6.3.1 Archaeological Resources**

Archaeological remains of military sites associated with the Manhattan Project and Cold War landscape are scattered throughout the Hanford Site's 600 Area. These archaeological resources are mainly located within the former Camp Hanford forward positions, the 16 anti-aircraft artillery sites that encircled the 100 and 200 Areas, and the three Nike missile installations on Wahluke Slope. (A fourth Nike position, in relatively intact condition, is located at the base of Rattlesnake Mountain on Fitzner-Eberhardt Arid Lands Ecology Reserve Unit.) The Nike position on the reserve is eligible for inclusion in the National Register as a contributing property within the Hanford Site Manhattan Project and Cold War Era Historic District. Five of the 16 anti-aircraft artillery sites are eligible for the National Register.

The anti-aircraft artillery and Nike sites were strategic components in Camp Hanford's military defense of the Site's plutonium production facilities during the 1950s. Potential archeological resources at these sites include former gun emplacements, launch and radar sites, concrete foundations and pads, pathways/sidewalks, associated dumpsites, small arms firing ranges, and ammunition caches.

The archaeological remains of the Atmospheric Dispersion Test Facility Grid are located in the Hanford Site east of the 200 West Area. The facility was used for monitoring airborne waste dispersions during the operation of the plutonium production facilities on the Hanford Site.

#### **4.6.3.2 Buildings and Structures**

Historic built resources documented from the Manhattan Project and Cold War eras include buildings and structures found in the 100, 200, 300, 400, 600, 700, and the former 1100 Areas. The most significant of these are the plutonium production and test reactors, chemical separation and plutonium finishing buildings, and fuel fabrication/manufacturing facilities. The first reactors, 105-B, 105-D, and 105-F, were constructed during the Manhattan Project. Plutonium for the first atomic explosion and the bomb dropped on Nagasaki, Japan, at the end of World War II were produced at the Hanford Site. Additional reactors and processing facilities were constructed after World War II during the Cold War period. All reactor containment buildings still stand, although many ancillary structures have been removed, and C, D, DR, F, and H Reactors have been considerably modified.

DOE/RL will consider the retention of National Register-eligible buildings and structures that may qualify for adaptive reuse as interpretive centers, museums, industrial, or manufacturing facilities (DOE 1996a).

#### **4.6.4 Site Areas**

Archaeological sites, traditional cultural places, buildings, and structures are found in each of several areas on the Hanford Site, including the 100, 200, 300, 400, 600, and 700 Areas. Since it was the Manhattan Project that established these areas as geographical locations on the Hanford Site, many cultural resources located within these areas are associated with that landscape. Many of these areas were developed over the top of existing cultural resources from the Native American and Early Settlers/Farming landscape. Hence, these earlier landscapes were changed; however, many resources remain as they were prior to 1943. A brief synopsis of known resources found in these areas is presented in the following subsections.

##### **4.6.4.1 100 Areas**

Field surveys were completed in the 100 Areas from 1991 to 1995 (Andrefsky et al. 1996, Chatters et al. 1992, Wright 1993). Much of the surface area within the 100 Areas operable units has been disturbed by the industrial activities that have taken place during the past 50 years. However, these areas still contain many cultural resources.

Each of the three landscapes is represented in the 100 Areas by the presence of archaeological sites, traditional cultural properties, and reactor facilities. Most of these resources reflect past use of river resources such as open camps, fishing sites, farmsteads, pump houses, gold mining pits, and water intake and outtake structures.

Plutonium production reactors and their ancillary and support facilities were located in the 100 Areas. The production reactors functioned to irradiate uranium fuel elements, the essential second step in the plutonium production process. A complete inventory of 100 Areas buildings and structures was completed during FY 1995, and a National Register evaluation for each was finalized during 1996. To date, 146 buildings/structures have been inventoried in the 100 Areas. Of that number, 55 have been individually documented and determined eligible for the National Register as contributing properties within the Historic District recommended for individual documentation (DOE 1998b). As remediation continues in the 100 Areas, the potential exists for inadvertent discoveries of archaeological resources. To understand impacts to cultural resources and to reduce the need to perform extensive reviews on highly disturbed areas, disturbance maps and reports have been completed for 100-B/C, 100-D/DR, and 100-F Areas.

##### **100-B/C Area**

**Archaeological Resources.** There is a high density of archaeological resources associated with the Native American cultural landscape in the 100-B/C Area. Three are located partially within the 100-B/C Area (Rice 1968a, Rice 1980a, b), and 35 have been recorded within the immediate vicinity of the B/C Area during archaeological surveys completed during 1995.

Historic archaeological resources include the remains of Haven Station, a small stop on the former Chicago, Milwaukee, St. Paul and Pacific Railroad, located to the west of the 100-B/C Area. One archaeological site and the remains of the small community of Haven lie on the opposite bank of the Columbia River.

Two archaeological sites (45BN447 and 45BN446<sup>(a)</sup>) located near 100-B/C have been investigated. Test excavations conducted during 1991 at archaeological site 45BN447 revealed large quantities of deer and mountain sheep bone, and projectile points dating from 500 to 1500 years ago. The second archaeological site, 45BN446, is considered to be eligible for listing in the National Register, in part, because it may contain new information about the Frenchman Springs and Cayuse Phases of mid-Columbia prehistory.

**Traditional Cultural Places.** Many sites related to hunting and religious activities are located at the west end of Gable Butte. These sites are associated with the Gable Mountain Cultural District.

**Buildings and Structures.** The only structure associated with the Early Settlers/Farming landscape in the 100-B/C Area is the Hanford Irrigation and Power Company pumping plant built at Coyote Rapids during 1908. It is located east of the 100-B/C Area.

The 105-B Reactor was the world's first full-scale plutonium production reactor and is designated as a National Historic Mechanical Engineering Landmark. It is also listed in the National Register, is a National Civil Engineering Landmark, and was given the Nuclear Historic Landmark Award. Historic American Engineering Record (HAER) documentation of B Reactor was completed during 1999 (DOE 2001b). A total of 14 buildings and structures within the reactor area have been recorded on historic property inventory forms. Of that number, 10 were selected as representative examples of buildings and structures eligible for the National Register as contributing properties within the Historic District recommended for individual documentation. These include 105-B Reactor, 181-B River Pump house, 104-B-1 Tritium Vault, 104-B-2 Tritium Laboratory, 105-B-Rod Tip Cave, 116-B Reactor Exhaust Stack, 117-B Exhaust Air Filter Building, 118-B-1 Solid Waste Burial Trench, and 182-B Reservoir and Pump house (DOE 1998b).

An assessment of the contents of the 105-B Reactor was conducted to locate and identify Manhattan Project and Cold War era artifacts that may have interpretive or educational value in potential exhibits. Thirty-nine industrial artifacts were identified and tagged, with many on display as interpretive exhibits in the reactor. Tagged artifacts from 105-D and F Reactors were transferred to B Reactor to be displayed as interpretive exhibits.

### **100-D/DR Area**

**Archaeological Resources.** Twenty-three known archaeological sites lie within 1 km (0.6 mi) of the 100-D/DR Area: three on the northern bank and the remainder on the southern bank of the Columbia River. The Wahluke Archaeological District is located north of the reactor area. Most remaining sites represent early Euro-American settlement activities. The former community of Wahluke, which was at the landing of a ferry of the same name, is situated on the river's north bank. Remains of historic farmsteads are scattered throughout the nearby area. An archaeological excavation was completed during 2001 of 45BN888, a camp site associated with the Native American cultural landscape adjacent to the reactor area.

**Traditional Cultural Places.** Twenty-seven individual rock cairns located south of the reactor area are associated with an area known to have traditional cultural importance to affected tribes.

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(a) Smithsonian Trinomial numbers are the standard designation for archaeological sites in the United States. 45 represents the state of Washington. BN, GR and FR represent Benton, Grant and Franklin counties. The number that follows indicates that the site was the n<sup>th</sup> archaeological site to be recorded in that county.

**Buildings and Structures.** All the buildings and structures in the 100-D/DR Area were built during the Manhattan Project and Cold War eras. Twenty buildings/structures have been inventoried, including the 105-D and 105-DR Reactor buildings. Both reactors are eligible for the National Register as contributing properties within the Historic District. An assessment of the contents of 105-D and 105-DR was conducted to locate and identify Manhattan Project and Cold War era artifacts that may have interpretive or educational value in potential exhibits. Twenty-four industrial artifacts were identified and tagged in 105-D, including control panels, a reactor curtain, lunch tables, benches, tools, and signs. All the tagged artifacts in 105-D were transferred to B Reactor. Ten industrial artifacts were identified and tagged on 105-DR, including a radiological worker procedures poster, an instrument ladder, three metal signs, a lead sampling chamber “pig,” a control panel, vintage ceiling lights, and graphite blocks. The 185/189-D buildings and adjoining facilities, all part of the 190-D complex, are eligible for the National Register and were documented to HAER standards (DOE 1998b). The 190-D Complex has been demolished.

### **100-F Area**

**Archaeological Resources.** The 100-F Area is situated on the shore of the Columbia River and contains many cultural sites associated with the Native American cultural landscape. According to Relander (1956), a nearly continuous string of camps and villages of the Wanapum extended from the Hanford Townsite upstream to the White Bluffs Townsite. Sixty-seven archaeological sites have been recorded within 1 km (0.6 mi) of the 100-F Area. Sites of particular importance include a site that is eligible to the National Register (45BN606) and an historic Wanapum cemetery.

The principal site associated with the Early Settlers/Farming landscape near 100-F is the White Bluffs Townsite and ferry landing. This location was the upriver terminus of shipping during the mid-19<sup>th</sup> century. It was at this point that supplies for trappers, traders, and miners were off-loaded, and commodities from the interior were transferred from pack trains and wagons to riverboats. The first store and ferry of the mid-Columbia region were located at the ferry landing (ERTEC 1981). A log cabin, thought to have been a blacksmith shop built during the late 19<sup>th</sup> century, still stands there. Test excavations conducted at the cabin by the University of Idaho revealed historic and pre-contact cultural materials. The structure was recorded according to standards of the Historic American Buildings Survey (Rice 1976). Stabilization of the structure was carried out by the USFWS during 2001. The only remaining structure associated with the White Bluffs townsite (near the railroad) is the First Bank of White Bluffs.

**Traditional Cultural Places.** Cemeteries associated with the Native American landscape are known to be in the vicinity of the 100-F Area.

**Buildings and Structures.** Three Manhattan Project/Cold War era buildings/structures have been inventoried in this area, including the 105-F Reactor building. An assessment of the contents of 105-F was conducted to identify any artifacts that may have value as potential museum exhibits. Eleven industrial artifacts were identified and tagged, including a fuel scale, elevator control panel, two shop signs, four safety signs, a hardhat, graphite blocks, and vintage ceiling lights. All tagged artifacts were transferred to B Reactor or the Columbia River Exhibition of History, Science and Technology (CREHST) museum in Richland, Washington, for inclusion into the Hanford Collection.

### **100-H Area**

**Archaeological Resources.** As of 2004, there have been 31 archaeological sites recorded within 1 km (0.6 mi) of the 100-H Area. Included in this group are two historic Wanapum cemeteries, six

camp, and three house pit villages. The largest village contains approximately 100 house pits and numerous storage caches. It appears to have been occupied consistently from 2500 years ago to 1943 (Rice 1968a). The cemeteries, camps, and villages are included in the Locke Island Archaeological District.

Archaeological sites associated with the Early Settlers/Farming landscape in the 100-H Area include several 20<sup>th</sup> century farmsteads and associated domestic debris. None of these sites have yet been evaluated for eligibility to the National Register. Remains of military encampments associated with the Manhattan Project and Cold War landscape are also located near the 100-H Area.

**Traditional Cultural Places.** Wanapum cemeteries are known to be located in the vicinity of the 100-H Area.

**Buildings and Structures.** Four Cold War era buildings/structures were inventoried in the 100-H Area. Of that number, only the 105-H Reactor is eligible for the National Register as a contributing property within the Historic District (DOE 1998b). An assessment of the contents of 105-H was conducted to locate and identify Cold War era artifacts that may have interpretive or educational value in potential exhibits. No items were tagged.

### **100-K Area**

**Archaeological Resources.** An archaeological survey of the 100-K Area during 1991 revealed five previously unrecorded archaeological sites. Archaeological surveys conducted in the 100-K Area during 1995 resulted in documentation of 31 additional pre-contact and historic sites. Two of these sites (45BN423 and 45BN434) are believed to date to the Cascade Phase 8000 to 4000 years ago and are eligible for listing in the National Register. The Coyote Rapids Archaeological District and the Ryegrass Archaeological District are located near the 100-K Area.

The Hanford Irrigation Canal and the former Chicago, Milwaukee, St. Paul and Pacific Railroad, two important linear features associated with the Early Settlers/Farming landscape, are also present in the 100-K Area. Archaeological remains of the Early Settlers/Farming community at Coyote Rapids and a number of historic farmstead sites are located west of the 100-K Area.

**Traditional Cultural Places.** Events took place at this locale during the mid-19<sup>th</sup> century that are important to American Indian people of the interior northwest (Relander 1956). The Washani religion (also known as Seven Drums or Dreamer religion) was first practiced here, eventually spreading to many neighboring tribes. A group of pit houses with an associated long house and sweat lodge have been identified that may have been the site of the Wanapum religious leader Smohalla's first *Washat* dance. An area located a short distance upstream is also recognized as a traditional cultural place because of its association with Wanapum history and traditional cultural beliefs (Relander 1956).

**Buildings and Structures.** Thirty-eight buildings and structures have been inventoried in the 100-K Area, including the 105-KE and KW Reactor buildings. Of that number, 13 were selected as representative examples of buildings and structures eligible for the National Register as contributing properties within the Historic District recommended for individual documentation. These include the 105-KW Reactor, 190-KW Main Pump house, 107-KW Retention Basin, 183-KW Filter Plant, and 181-KW River Pump house (DOE 1998b).

An assessment of the contents of 105-KE and KW was conducted to identify any artifacts that may have educational or interpretive value as potential museum exhibits. Twenty-two industrial artifacts were identified and tagged in 105-KE Reactor, including tools, signage, radiation monitoring equipment,

and furniture. Nine artifacts were identified and tagged from 105-KW Reactor, including furniture, a measurement scale, tools, and a floodlight. An assessment of the contents of the other historic buildings in the 100-K Area resulted in 23 additional artifacts being identified and tagged.

## 100-N Area

**Archaeological Resources.** Twenty archaeological sites associated with the Native American cultural landscape have been recorded within 1 km (0.6 mi) of the 100-N Area perimeter. Three sites (two house pit villages, 45BN150 and 45BN180, and one cemetery, 45BN151) comprise the Ryegrass Archaeological District. Site 45BN179, once considered for a National Register nomination as the Hanford Generating Plant Site, has been found to be part of 45BN149, which is already listed in the National Register. Extant knowledge about the archaeology of the 100-N Area is based largely on reconnaissance-level archaeological surveys conducted during the late 1960s to late 1970s (Rice 1968b; Rice 1980a, b), which do not purport to produce complete inventories of the areas covered.

The most common evidence of activities associated with the Early Settlers/Farming landscape found near the 100-N Area consists of the archaeological remains of farmhouses and agricultural fields. The historic Hanford Irrigation Canal is adjacent to and south of the 100-N Area.

**Traditional Cultural Places.** Three places near the 100-N Area are known to have been of importance to the Wanapum. Cataclysmic flooding at the end of the Pleistocene formed the numerous small rolling hills known as *Mooli Mooli*, which means Little Stacked Hills. Gable Mountain (called *Nookshai* or Otter) and Gable Butte, which lie to the south of the river, are highly significant to the affected tribes. According to Relander (1956) these are places where Wanapum youths would go on overnight vigils seeking guardian spirits. Rock cairns located in these areas indicate ethnographic use of these areas. Sites of religious importance may also exist near the 100-N Area.

**Buildings and Structures.** The 100-N Reactor, completed during 1963, was the last of the plutonium production, graphite-moderated reactors. The design of N Reactor differed from the previous eight reactors in several ways to afford greater safety and to enable co-generation of electricity. Sixty-six Cold War era buildings and structures were inventoried in the 100-N Area. Thirty 100-N Area buildings/structures were selected as representative examples of facilities eligible for the National Register as contributing properties within the Historic District recommended for individual documentation (DOE 1998b). These include the 105-N Reactor, 109-N Heat Exchanger Building, 181-N River Water Pump house, 183-N Water Filter Plant, 184-N Plant Service Powerhouse, 185-N Export Powerhouse, and the 1112-N Guard Station (DOE 1997d).

An assessment of the contents of 185-N was conducted to locate and identify Cold War era artifacts that may have interpretive or educational value in potential exhibits. Six artifacts were identified and tagged, including control room panels, phone booths, a “hear-here” phone, metal cart, and a safety sign. All the artifacts were photographed and transferred to CREHST Museum in Richland, Washington, for inclusion in the Hanford Collection. Building 185-N was recently demolished.

### 4.6.4.2 200 Areas

Much of the 200 Areas has been altered by Hanford operations. The Hanford Cultural Resources Laboratory conducted a comprehensive archaeological resources survey of the fenced portions of the 200 Areas during 1987 and 1988 (Chatters and Cadoret 1990). The results indicate that evidence of cultural resources associated with the Native American cultural landscape and the Early Settlers/Farming landscape is minimal. Archaeological surveys conducted since that time have revealed much the same pattern.

**Archaeological Resources.** The most significant archaeological resource located in the 200 Areas is an extensive linear feature known as the White Bluffs Road, a portion of which passes diagonally southwest to northeast through the 200 West Area. This road, in its entirety, is eligible for listing in the National Register, except for non-contributing segments of the White Bluffs Road that are located in the 200 West Area. Non-contributing segments of the White Bluffs Road are those sections that have been so considerably altered that they lack historic integrity, but retain evidence of its contiguous bearing. Originally a trail used by area tribes, it played a role in Euro-American immigration, development, agriculture, and Hanford Site operations. The survey conducted during 2000 on the White Bluffs Road recorded an additional 54 historic isolated finds and 2 pre-contact isolated finds, as well as six can dump features.

**Traditional Cultural Places.** Many sites related to hunting and religious activities are located on Gable Mountain and Gable Butte north of the 200 West and 200 East Areas. These sites are associated with the Gable Mountain/Gable Butte Cultural District.

**Buildings and Structures.** The 200 Areas contain many significant buildings and structures associated with the Manhattan Project and Cold War landscape. They were formerly used as chemical separations (processing) plants and ancillary and support facilities. The plants functioned to dissolve the irradiated fuel elements to separate out the plutonium, the essential third step in plutonium production. Historic property inventory forms have been completed for 72 buildings/structures in the 200 Areas. Of that number, 58 were selected as representative examples of buildings and structures eligible for the National Register as contributing properties within the Historic District recommended for individual documentation. These include the 202-A Purex Plant, 212-N Lag Storage Facility, 221-T Plant, 222-S Redox Plant, 225-B Encapsulation Building, 231-Z Plutonium Metallurgical Laboratory, 234-5Z Plutonium Finishing Plant, 236-Z Plutonium Reclamation Facility, 242-Z Water Treatment Facility, 282-E Pump house and Reservoir Building, 283-E Water Filtration Plant, and the 284-W Powerhouse and Steam Plant. The 232-Z Waste Incinerator Facility and the 233-S Plutonium Concentration Building are also eligible for the National Register and along with 221-T Plant, have been documented to HAER standards (DOE 1998b). The 233-S building was recently demolished.

An assessment of the contents of nine facilities in the Plutonium Finishing Plant (PFP) complex was conducted during 1998 and 2002, and a letter report was completed entitled "Interpretive and Curation Plan for the Deactivation and Decommissioning of Historic Buildings at the PFP Complex". These buildings and structures included the 234-5Z PFP, 291-Z Exhaust Stack, 232-Z Waste Recovery Facility, 236-Z Plutonium Reclamation Facility, 2704-Z Safeguards and Security Building, the 2736-Z, ZA, and ZB Plutonium Storage Facilities, and 2736-ZC (non-historic) Cargo Restraint Transport Facility. Because of security/radiological exposure concerns, Buildings 2701-ZA and 242-Z were not accessible for walkthroughs. In 234-5Z, the entire Remote Mechanical C line (glove boxes) and control room, and the Remote Mechanical A line (glove boxes) and control room were identified and tagged. Ten additional Cold War era artifacts were identified and tagged as a result of a walkthrough of the Analytical Laboratories in 234-5Z. The assessment of the 2704-Z Building resulted in two tagged artifacts: a typology of "cans" poster and demonstration training cans. A third artifact, the classified documents vault, was identified but not tagged. The non-historic 2736-ZA building contains historic metal pedestals and a wooden mockup pedestal that were tagged.

Thirty-two industrial artifacts were identified and tagged in chemical separations buildings located outside the PFP complex in the 200 Areas. The following buildings were inspected for artifacts during the walkthroughs: 202-A, 202-S, 221-T, 221-U, 224-U, 224-B, and 271-U. Types of artifacts selected included electrical equipment, control panels, tools, vintage lights, health and safety items, signage, and communications equipment.

#### 4.6.4.3 300 Area

Much of the 300 Area has been used for industrial activities associated with the Manhattan Project and Cold War cultural landscape. Prior to the Manhattan Project during 1943, the 300 Area was used by Native Americans as a camp location and by early settlers who developed a farming community known as Fruitvale. Due to its proximity to the Columbia River, many archaeological resources associated with both these landscapes are located along the river shore outside of the 300 Area fence. Subsurface archaeological deposits are likely to be located underneath existing 300 Area facilities in pockets of undisturbed ground.

**Archaeological Resources.** Five recorded archaeological sites, including campsites, house pits, and a historic trash scatter, are located at least partially within the 300 Area. Many more may be located in subsurface deposits. Twenty-three archaeological sites and 10 isolated artifacts have been recorded within 1 km (0.6 mi) of the 300 Area fence. Archaeological site 45BN162 has been determined eligible for listing in the National Register. Several archaeological sites in this area are in the Hanford South Archaeological District, which is listed in the Washington Heritage Register. Archaeological sites associated with the Early Settlers/Farming cultural landscape in the 300 Area are comprised mainly of domestic debris scatters and roadbeds associated with farmsteads.

**Traditional Cultural Places.** A documented historic Wanapum cemetery is located near the 300 Area.

**Buildings and Structures.** The 300 Area, the location of the uranium fuel fabrication plants that manufactured fuel rods to be irradiated in the Hanford Site reactors, provided the first essential step in the plutonium production process. The 300 Area was also the location of most of the Hanford Site's research and development laboratories. One hundred fifty-nine buildings/structures in the 300 Area have been documented on historic property inventory forms. Of that number, 47 were selected as representative examples of buildings and structures eligible for the National Register as contributing properties within the Historic District recommended for individual documentation. This total includes the 305 Test Pile, 313 Fuels Fabrication Facility, 314 Metal Press/Extrusion Building, 318 High Temperature Lattice Test Reactor, 321 Separation Building, 325 Radiochemistry Laboratory, 333 Fuel Cladding Facility, 3706 Radiochemistry Laboratory, and the 3760 (former) Hanford Technical Library (DOE 1998b).

Assessments/walkthroughs of the contents of former fuel manufacturing and reactor operations facilities in the 300 Area have been conducted including the 303-A Magazine Product Storage Building, 305 Test Pile, 305-B Engineers Development Lab Annex, 306-W Materials Development Laboratory, 306-E Fabrication Test Lab, 308 Plutonium Fabrication Pilot Plant, 309 Plutonium Recycle Test Reactor, 313 Fuels Fabrication Facility/Metal Fabrication Building, 314 Press Building, and the 333 Fuel Cladding Facility. The 27 Manhattan Project/Cold War era artifacts that were identified and tagged are mainly industrial in nature associated with the fuel manufacturing processes and reactor operations. A second walkthrough of Building 333 resulted in an additional 12 artifacts being identified including a selection of safety signs/posters, a control panel, a safety shower, protective worker clothes, and a sample uranium fuel element.

Other 300 Area buildings assessed include the 303-K Fresh Metal Storage Building, 304 Uranium Scrap Concentration Storage Facility, 324 Chemical Engineering Laboratory, 325 Radiochemistry Laboratory, 327 Post Irradiation Test Laboratory, 329 Biophysics Laboratory, 334 Chemical Handling Facility, 334-A Acid Pump house, 3701-D (former) Hanford Patrol Building, 3707-G Change House, 3716 Fuels Manufacturing Storage/Automotive Repair Shop, 3727 Classified Storage Facility, 3746 Radiological Physics Building, 3762 Technical Safety Building, the 340 Waste Neutralization

Complex, 3745-B Positive Ion Accelerator Building, 3708 Radiochemical Lab, 3706 Radiochemistry Lab, 326 Physics Lab, 3707-D Patrol Headquarters, 384 Power House, 328 Engineering Services Building, 3720 Environmental Sciences Laboratory, 3745-A Electron Accelerator Building, 3722 Area Shop, and the 3713 Storeroom. Approximately 75 to 80 Manhattan Project/Cold War era artifacts were identified and tagged in these buildings.

#### **4.6.4.4 400 Area**

Most of the 400 Area has been so altered by construction activities that archaeologists surveying the site during 1978 were able to find only 0.12 km<sup>2</sup> (0.047 mi<sup>2</sup>) of land that was undisturbed (Rice et al. 1978). They found no cultural resources in this area. No archaeological sites are known to be located within 1 km (0.6 mi) of the 400 Area.

The 400 Area consists of the Fast Flux Test Facility (FFTF) complex. The 405 Reactor Containment Building includes a 400-megawatt, sodium-cooled test reactor designed primarily to test fuels and materials for advanced nuclear power plants. All the buildings and structures in the 400 Area were constructed during the Cold War era. Twenty-one building/structures have been recorded on historic property inventory forms. Of that number, six were selected as representative examples of buildings and structures eligible for the National Register as contributing properties within the Historic District recommended for individual documentation. These include the 405 Reactor Containment Building, 436 Training Facility, 4621-W Auxiliary Equipment Facility, 4703 FFTF Control Building, 4710 Operation Support Building, and the 4790 Patrol Headquarters (DOE 1998b). In response to the production of a Curation Plan for the Deactivation and Decommissioning of Historic Buildings at the FFTF, walkthroughs were conducted of the contributing properties requiring mitigation except for the 4790 patrol headquarters. In addition, walkthroughs were also conducted of 16 contributing properties at FFTF where no individual documentation was required. Operations carried out in these facilities were closely related to the work conducted in the five contributing buildings that required mitigation. Thirty artifacts were identified and tagged in 8 of the 21 historic buildings: 405, 4703, 436, 403, 4621-W, 4621-E, 4710, and 4701-A. Two of the identified artifacts are located in Building 4732-C, a non-historic building. The types of artifacts included industrial equipment and machinery, photographs, publications, control room panels, and models.

An assessment of the contents of Building 427 was also conducted to locate and identify Cold War era artifacts that may have interpretive or educational value in potential exhibits. Four artifacts were identified and tagged, including fuel assembly components.

#### **4.6.4.5 600 Area**

The 600 Area includes all of the Hanford Site not occupied by the 100, 200, 300, and 400 Areas. Project-driven surveys have been conducted throughout the area, but much of the 600 Area has not been surveyed. Based on what is known, the 600 Area contains cultural resources associated with all three cultural landscapes that exist on the Hanford Site. Representing a full range of human activity across the Hanford Site, the activities are best characterized for the Native American cultural landscape by the gathering of inland resources (quarry sites, hunting sites, religious use sites, plant gathering sites) and riverine resources (fishing sites, open camp sites, root gathering). The Early Settlers/Farming landscape is present in the 600 Area, mainly consisting of the archaeological remains of former farmsteads, ranches, and pre-1943 transportation routes. Evidence of cultural resources associated with the Manhattan Project and Cold War Era landscape consists of anti-aircraft artillery sites, meteorological towers, and roads located in the 600 Area.

**Archaeological Resources.** Numerous National Register Districts associated with the Native American landscape are located within the 600 Area including the Hanford Archaeological Site, Hanford North Archaeological District, the Paris Archaeological Site (45GR317), Rattlesnake Springs sites (45BN170 and 45BN171), Savage Island Archaeological District, Snively Basin Archaeological District, and Wooded Island Archaeological District.

Archaeological properties associated with the Early Settlers/Farming landscape in the 600 Area include the Hanford Townsite; the White Bluffs townsite and ferry landing; the Chicago, Milwaukee, St. Paul and Pacific Railroad line and associated whistle stops; early settler's farmsteads; and the Hanford Irrigation Canal and associated irrigation features. The McGee Ranch/Cold Creek Valley District is located in the 600 Area and is eligible for listing in the National Register.

Cold War era archaeological resources that are located in the 600 Area include five National Register-eligible anti-aircraft artillery sites associated with Camp Hanford's defense of the Hanford Site during the 1950s. The Hanford Atmospheric Dispersion Test Facility is a contributing property within the Historic District. Numerous artifacts in the facility were identified as having interpretive or educational value in potential exhibits. A selected representative number of artifacts were removed from the facility and curated into the Hanford Collection.

**Traditional Cultural Places.** Areas of traditional cultural importance include Rattlesnake Mountain and foothills, the Columbia River, Gable Mountain, Gable Butte, and National Register-eligible *Wanawish*. Cemeteries associated with the Native American cultural landscape are also dispersed throughout the 600 Area.

**Buildings and Structures.** There are several structures associated with the Early Settlers/Farming landscape that are located in the 600 Area. The Bruggemann Warehouse, located approximately 1.6 km (3 mi) west of 100-B/C, is eligible for listing in the National Register. During 2002, the Hanford Electrical Substation-Switching Station, the Hanford Townsite high school, the Coyote Rapids Pumping Plant, and the First Bank of White Bluffs became eligible for listing in the National Register.

Fifteen Cold War era buildings/structures, including the former underground missile storage facility, have been inventoried at the former 6652 Nike launch and control center in the Fitzner-Eberhardt Arid Lands Ecology Reserve Unit. The 622 Meteorological Complex, located near 200 West, includes seven inventoried properties. Both complexes are eligible for the National Register as contributing properties within the Historic District. An assessment of the contents of 622-F and the 6652 Nike site were conducted. No artifacts of interpretive or educational value were identified.

Five other 600 Area properties, the 604 Yakima Patrol Checking Station, 604-A Sentry House, 607 Batch Plant, 618-10 Solid Waste Burial Trench, and Hanford Site Railroad System are eligible for the National Register as contributing properties within the Historic District. Twenty-five railcars located at the 212-N rail spur were designated Register-eligible as contributing features of the Hanford Site Railroad. Documentation/ mitigation of the 25 railcars was completed as an addendum to the Expanded Historic Property Inventory form of the Hanford Site Railroad system. Due to their high contamination levels, most of the railcars have been removed from the Hanford Site.

The former Central Shops complex located in the 600 Area north of the 200 Areas is not eligible for the National Register (DOE 1997a).

Buildings 623 (Gable Mountain Relay Station) and 213 (Magazine/Waste Storage Vault) are contributing properties within the Historic District.

#### **4.6.4.6 700 Area**

The 700 Area was the location of the administrative functions of the early Hanford Site period. Most of the 700 Area was altered by industrial and demolition activities. Of the seven Manhattan Project and Cold War era buildings/structures identified in this area, the 703 Administrative Building, 712 Records/Printing/Mail Office Facility, and the 748 Emergency Decontamination Facility are eligible for listing in the National Register as contributing properties within the Historic District (DOE 1998b).

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## 4.7. Socioeconomics

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Activity on the Hanford Site plays a dominant role in the socioeconomics of the Tri-Cities and other parts of Benton and Franklin counties (Figure 4.7-1). The agricultural community also has a significant effect on the local economy. Any major changes in Hanford activity would potentially affect the Tri-Cities and other areas of Benton and Franklin counties. Unless otherwise specifically cited, data in this section are collected from interviews with the referenced organization.

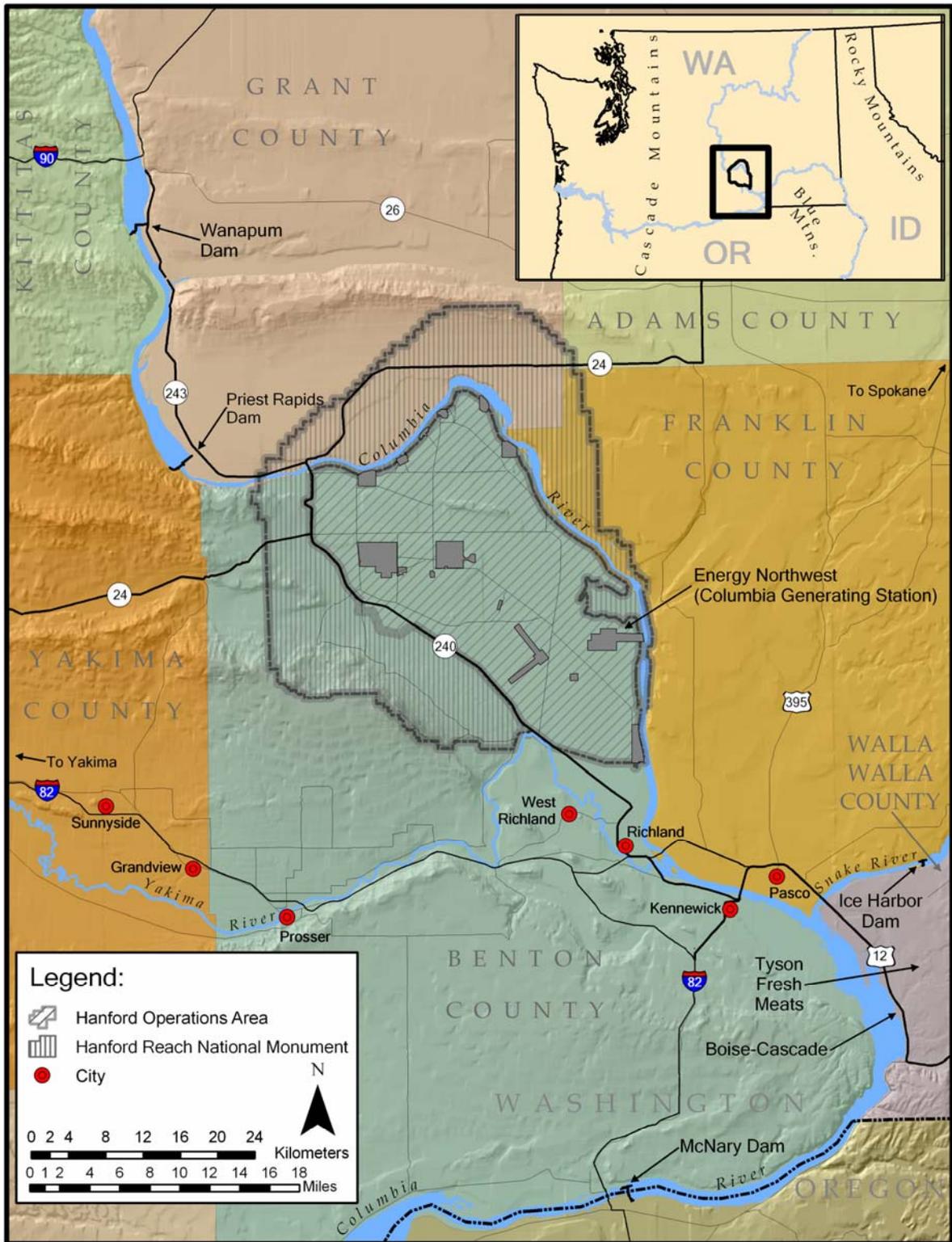
### 4.7.1 Local Economy

Three major sectors have been the principal driving forces of the economy in the Tri-Cities since the early 1970s: 1) DOE and its contractors operating the Hanford Site; 2) Energy Northwest (formerly the Washington Public Power Supply System) in its construction and operation of nuclear power plants; 3) the agricultural community, including a substantial food-processing component. Increasingly, a growing cluster of technology-based businesses, many with roots in the Hanford Site and Pacific Northwest National Laboratory, are playing a role in the expansion and diversification of the local private business sector.

In addition to these three major employment sectors, three other components can be readily identified as contributors to the economic base of the Tri-Cities. The first of these, loosely termed “other major employers,” includes the five major non-Hanford employers in the region (discussed in more detail in subsection 4.7.1.4). The second component is tourism. The Tri-Cities area has increased its convention business substantially in recent years as well as recreational travel. The third component to the economic base relates to the local purchasing power generated from retired former employees. Government transfer payments, specifically retirement and disability insurance benefit payments constitute a significant proportion of the total spendable income in the local economy.

#### 4.7.1.1 DOE Contractors (Hanford)

DOE contractors compose the largest single source of employment in the Tri-Cities. During fiscal year (FY) 2004, an average of 10,247 employees were employed by DOE Office of River Protection (ORP) and its prime contractor CH2M HILL Hanford Group, Inc.; DOE-Richland Operations Office (RL) and its prime contractors Fluor Hanford, Inc.; Bechtel Hanford, Inc.; AdvanceMed Hanford; and Pacific Northwest National Laboratory, which is operated by Battelle for the DOE Office of Science’s Pacific Northwest Site Office. Fiscal year 2004 year-end employment for all DOE contractors was 10,225, down slightly from 10,288 at the end of FY 2003. In addition to these totals, Bechtel National, Inc. (BNI) and its subcontractors, including prime subcontractor Washington Group International, employed 3780 at the end of FY 2004. (Bechtel Hanford is a subsidiary of Bechtel National. During 2004, Bechtel Hanford was the Environmental Restoration Contractor for the Hanford Site, planning, managing, and executing a full range of activities to clean up contaminated soils and inactive nuclear facilities under DOE’s Environmental Restoration Project.) As of August 2005, Washington Closure, a limited liability corporation (LLC) formally replaces Bechtel Hanford, Inc. Washington Closure LLC is a partnership consisting of Washington Group International Inc., Bechtel National Inc., and CH2M HILL Inc. During December 2000, ORP awarded a contract directly to BNI to design, build, and start up waste treatment facilities for the glassification of liquid radioactive waste.



**Figure 4.7-1.** Hanford Site, Washington, and Surrounding Communities

The annual average number of employees at Hanford has declined by nearly 5700 since FY 1994 when employment peaked at 19,200, but Hanford still represents 14 percent of the total jobs in the economy. Total employment in the Richland, Kennewick, and Pasco metropolitan statistical area averaged 99,900 during 2004, up from 96,400 in 2003 (LMEA 2005a).

Based on employee records as of February 2005, 91 percent of the direct employees of Hanford live in Benton and Franklin counties. Approximately 73 percent of Hanford employees reside in Richland, Pasco, or Kennewick. More than 36 percent are Richland residents, 10 percent are Pasco residents, and 26 percent live in Kennewick. Residents of other areas of Benton and Franklin counties, including West Richland, Benton City, and Prosser, account for about 17 percent of total Hanford Site employment.

#### **4.7.1.2 Energy Northwest**

Energy Northwest is a joint operating agency comprising 19 member public utilities from across the state of Washington. Energy Northwest provides electricity, at cost, to public utilities and municipalities in the Northwest and operates four electricity generating stations: Columbia Generating Station, Packwood Lake Hydroelectric Project, Nine Canyon Wind Project, and the White Bluffs Solar Station. Although commercial nuclear power plant construction activity ceased with the completion of the 1157-megawatt (MW) WNP-2 nuclear reactor during 1983 (now named Columbia Generating Station), Energy Northwest continues to be a major employer in the Tri-Cities area. Headquarters personnel based in Richland oversee the operation of the Columbia Generating Station. Decommissioning of mothballed nuclear power plants WNP-1 and WNP-3, which were never completed, began during 1995. Since 2000, Energy Northwest has maintained an average of 20 employees at WNP-1, which is located near the Columbia Generating Station. As part of an effort to reduce electricity production costs, Energy Northwest headquarters decreased the size of its total workforce from over 1900 during 1994 to 1016 at the end of 1999. At the end of calendar year 2004, employment was 1240 personnel.

#### **4.7.1.3 Agriculture**

During 2004, over 11 percent of workers in Benton and Franklin counties were employed in agriculture. The total agricultural employment was 11,200, an increase from the 2003 total of 10,920 (LMEA 2005b). Seasonal farm workers are not included in that total but are estimated by the U.S. Department of Labor (DOL) for the agricultural areas in the state of Washington. During 2004, the number of seasonal farm workers averaged 5665 per month in Benton, Franklin, and Walla Walla counties, ranging from 1671 workers during the winter pruning season to 12,764 workers at the peak of harvest. An estimated average of 4091 seasonal workers were classified as local (ranging from 1284 to 9546). An average of 46 workers were classified as intrastate (ranging from 0 to 143), and an average of 423 were classified as interstate (ranging from 0 to 1112). The weighted seasonal wage for 2004 ranged from \$7.27/hr to \$7.84/hr, with an average wage of \$7.45/hr (DOL 2005).

According to the U.S. Department of Commerce's Regional Economic Information System (REIS), 2288 people were classified as farm proprietors in Benton and Franklin counties during 2003. Total farm proprietors' income, according to this same source, was estimated to be \$21.8 million (DOC 2005).

The area's farms and ranches generate a sizable number of jobs in supporting activities, such as agricultural services (e.g., application of pesticides and fertilizers and irrigation system development) and wholesale trade (e.g., farm supply and equipment sales and fruit packing). Although formally classified as a manufacturing activity, food processing is a natural extension of the farm sector. As of March 2005, 56 processors in Benton and Franklin counties produce such items as potato products, canned fruits and

vegetables, wine, and animal feed. During 2004, food manufacturing jobs accounted for 53 percent of all the manufacturing jobs in the area.

#### **4.7.1.4 Other Major Employers**

The five largest non-Hanford and non-government employers employed approximately 6522 people in Benton and Franklin counties during 2003. These companies include 1) ConAgra/Lamb Weston, which employed 3063; 2) Tyson Fresh Meats (formerly Iowa Beef Processing Inc.), which employed 1450; 3) Boise Cascade Corporation Paper and Corrugated Container Divisions, which employed 862; 4) Framatome ANP, Richland Inc. (formerly Siemens Power Corporation), which employed 747; and 5) Wal-Mart (two stores), which employed 700. Both Boise Cascade and Tyson Fresh Meats are located in western Walla Walla County, but most of their workforce resides in Benton and Franklin counties. Four of the largest agriculture growers and processors in the area, AgriNorthwest, Broetje Orchards, J.R. Simplot Company, and Twin City Foods, Inc., employed approximately 2278 people during 2003; however, a large portion of the workers were seasonal (BFCOG 2004).

Other area employers include three major school districts: Richland, Kennewick, and Pasco, which employed a total of 4043; the three major health care facilities: Kadlec Medical Center, Kennewick General Hospital, and Lourdes Health Network, which employed a total of 2294; local government offices: Benton and Franklin county and Richland, Kennewick, and Pasco city offices, which employed 1833; and the Tri-Cities Airport, which employed 400.

#### **4.7.1.5 Tourism**

A significant rise in the number of visitors to the Tri-Cities over the last several years has resulted in tourism playing an increasing role in helping to diversify and stabilize the area's economy. The Tri-Cities Visitors and Convention Bureau reported that 114,635 attended meetings, conventions, sporting, and group events, spending an estimated \$30.3 million in the mid-Columbia during 2004, up from 106,995 attendees and down from \$35.3 million in spending during 2003. The number of people attending conventions and group events has more than doubled since 1995 and more than tripled since 1991.

The importance of tourism is evidenced by the amount of money spent on local goods and services. Overall tourism expenditures in the Tri-Cities were over \$264 million during 2003, up from \$247 million during 2002. Travel-generated employment in Benton and Franklin counties was about 4070 with an estimated \$70.3 million in payroll, up from an estimated 3660 employed and up from a \$63.8 million payroll during 2002. In addition, tourism generated \$4.5 million in local taxes and \$17.6 million in state taxes during 2003 (OTED 2005).

#### **4.7.1.6 Retirees**

In the Tri-Cities, retirees are a major source of consumer spending. Although Benton and Franklin counties have a relatively young population (approximately 52 percent under the age of 35), 20,964 people over the age of 65 resided in Benton and Franklin counties during 2004. Washington State Office of Financial Management (OFM) reports the portion of the total population 65 years and older in Benton and Franklin counties accounts for 9.9 percent of the total population, which is below the 11.3 percent for the state of Washington (OFM 2005a). This segment of the population supports the local economy through income received from government transfer payments and pensions, private pension benefits, and prior individual savings. Although the retirees are not employed, their income affects the local economy in much the same way as local spending on salaries by the federal government and the area's private sector employers.

Although information on private pensions and savings is not available, data are available regarding the magnitude of government transfer payments. REIS has estimated transfer payments by various programs at the county level. Estimated major government transfer payments received by the residents of Benton and Franklin counties during 2003 totals greater than \$871 million (Table 4.7-1). Nearly 40 percent of the payments are for retirement and disability insurance benefit payments, which provide over \$343 million of spendable income to the local economy.

**Table 4.7-1.** Federal Government Transfer Payments in Benton County and Franklin County, Washington, 2003 <sup>(a)</sup>

<b>Government Payments to Individuals</b>	<b>Benton County (\$Millions)</b>	<b>Franklin County (\$Millions)</b>	<b>Total (\$Millions)</b>
Retirement and disability insurance payments	275.3	68.6	343.9
Medical payments	229.1	120.2	349.3
Income maintenance benefits	52.1	30.1	82.2
Unemployment insurance benefits	51.0	21.5	72.5
Veterans benefits	13.7	3.0	16.7
Federal education and training assistance	0.8	4.3	5.1
Other payments to individuals	1.0	0.4	1.4
<b>Total</b>	<b>623.0</b>	<b>248.1</b>	<b>871.1</b>

(a) DOC 2005.

## 4.7.2 Employment and Income

Nonagricultural employment in the Tri-Cities grew steadily from 1988 to 1994. The total annual average employment fell during 1995 and 1996, but has grown every year since then. During 2004, nonagricultural employment rose 1.7 percent (Table 4.7-2). There was an average of 84,500 non-agricultural jobs in the Tri-Cities during 2004, an increase of approximately 1400 from the previous year. Most of the gains were in the services and government sectors. Modest gains were seen in manufacturing, construction, natural resources, and mining; trade, transportation, and utilities; and the finance, insurance, and real estate sectors, while the information sector was down 10 percent (LMEA 2005c).

Three measures of area income are presented in this section: total personal income, per capita income, and median household income. Total personal income comprises all forms of income received by the populace, including wages, dividends, and other revenues. Per capita income is equivalent to total personal income divided by the number of people residing in the area. Median household income is the point at which half of the households have incomes greater than the median and half have less.

During 2003, the total personal income was \$4.6 billion for Benton County and \$1.2 billion for Franklin County, compared to the State of Washington's total of \$203.9 billion. Per capita income during 2003 was \$29,689 for Benton County, \$20,757 for Franklin County, and \$33,254 for Washington State (DOC 2005). The preliminary estimate of median household income during 2003 for Benton County was \$50,425; Franklin County was estimated at \$37,757. Estimated median incomes for both counties were below the Washington State estimate of \$50,664 (OFM 2005b).

**Table 4.7-2.** Nonagricultural Wage and Salary Workers in Benton County and Franklin County, Washington, 2003 and 2004 <sup>(a)</sup>

<b>Industry</b>	<b>2003 Annual Average Employment (Revised)</b>	<b>2004 Annual Average Employment (Preliminary)</b>	<b>Change 2003-2004 (Percent)</b>
Manufacturing	5,600	5,700	1.8
Construction, natural resources, and mining	4,900	5,000	2.0
Trade, transportation and utilities	13,900	14,000	0.7
Information	1,000	900	-10.0
Finance, insurance, and real estate	3,100	3,300	6.5
Services	38,900	39,700	2.1
Government	15,500	15,800	1.9
<b>Total nonagricultural wage and salary workers</b>	<b>83,100</b>	<b>83,200</b>	<b>1.7</b>
(a) Source: Washington State Employment Security Department (LMEA 2005c).			

### 4.7.3 Demography

An estimated total of 155,100 people lived in Benton County and 57,000 lived in Franklin County during 2004, totaling 212,100, an increase of almost 11 percent from the Census 2000 figure (OFM 2005c). According to the 2000 Census, population totals for Benton and Franklin counties were 142,475 and 49,347, respectively (Census 2001a). Both Benton and Franklin counties grew at a faster pace than Washington as a whole during the 1990s. The population of Benton County grew 26.6 percent, up from 112,560 during 1990. The population of Franklin County grew 31.7 percent, up from 37,473 during 1990 (Census 2001a).

The distribution of the 2004 Tri-Cities population by city is as follows: Richland 42,660; Pasco 40,840; and Kennewick 58,970. The combined populations of Benton City, Prosser, and West Richland totaled 17,640 during 2004. The unincorporated population of Benton County was 35,830. In Franklin County, incorporated areas other than Pasco had a total population of 3855. The unincorporated population of Franklin County was 12,305 (OFM 2005c).

During 2004, Benton and Franklin counties accounted for 3.4 percent of Washington's population. The population demographics of Benton and Franklin counties are quite similar to those found within Washington. In general, the population of Benton and Franklin counties is somewhat younger than that of Washington as a whole. The 0- to 14-year old age group accounts for 24.6 percent of the total bi-county population compared with 20.4 percent for Washington. The population in Benton and Franklin counties under the age of 35 is 51.9 percent; it is 48.2 percent for the state of Washington (OFM 2005a).

Population estimates and percentages by race and Hispanic origin for Benton, Franklin, Grant, Adams, and Yakima counties and within the 80-km (50-mi) radius of the Hanford Site from the 2000 Census indicate Asians and individuals of Hispanic origin from Benton and Franklin counties represent lower and higher proportions of the population, respectively, than in the state of Washington as a whole,

(Table 4.7-3). During 2004, county-level estimates of minority populations in Benton, Franklin, Grant, Adams, and Yakima counties demonstrate similar trends (Table 4.7-4).

Additional Hanford area demographic data are available from *Hanford Area 2000 Population* (Elliott et al. 2004). This document includes 2000 Census estimates for the resident population by distance and compass direction within an 80-km (50-mi) radius of the Hanford Site. Population distributions are reported relative to five reference points centered on meteorological stations within major operating areas of the Hanford Site: the 100-F, 100-K, 200, 300, and 400 Areas. Data are presented in both graphical and tabular format and are provided for total populations residing within 80 km (50 mi) of the reference points, as well as for Native American, Hispanic and Latino, total minority, and low-income populations.

#### **4.7.4 Environmental Justice**

Executive Order 12898, “Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations,” (59 FR 7629), directs federal agencies in the Executive Branch to consider environmental justice so that their programs will not have “disproportionately high and adverse human health or environmental effects” on minority and low-income populations. Executive Order 12898 further directs federal agencies to consider effects to “populations with differential patterns of subsistence consumption of fish and wildlife.” The Executive Branch agencies also were directed to develop plans for carrying out the order. The Council on Environmental Quality (CEQ) later provided additional guidance for integrating environmental justice (EJ) into the National Environmental Policy Act process in a December 1997 document, *Environmental Justice Guidance under the National Environmental Policy Act* (CEQ 1997).

Minority populations are defined as all nonwhite individuals plus all white individuals of Hispanic origin. The most recent detailed counts are reported in the 2000 Census (Census 2001b), while more recent county-level estimates are reported by the Washington State Office of Financial Management (OFM 2005d). Following federal Office of Management and Budget guidance, the OFM estimates have re-evaluated the “other race” category in the 2000 Census and have reassigned individuals to one of the five Census races, where possible, in addition to accounting for population growth. Low-income persons are defined as living in households that report an annual income less than the United States’ official poverty level, as reported by the Census Bureau. The poverty level varies by size and relationship of the members of the household. The year 2000 poverty level was \$17,761 for a family of four (Census 2000, 2001a). Nationally, during 1999, 29.9 percent of all persons were minorities, and 11.8 percent of all persons lived in households that had incomes less than the poverty level (which was \$17,029 for a family of four during that year) (Census 2000, 2001a). The 2000 Census reports that 10.6 percent of Washington’s population lived in poverty during 1999, while 10.3 percent of Benton County persons and 19.2 percent of Franklin County persons were below the poverty level (Census 2003a). No post-2000 Census estimates are available for local low-income populations.

**Table 4.7-3.** Population Estimates and Percentages by Race and Hispanic Origin by County in Washington State and Within the 80-km (50 mi) Radius of Hanford as Determined by the 2000 Census (Census 2003b)

Subject	WA State	Percent	Benton/Franklin/ Grant/Adams/ Yakima	Percent	Benton County	Franklin County	Grant County	Adams County	Yakima County	80-km (50-mi) Radius of Hanford <sup>(a,b)</sup>
Total population	5,894,121	100	505,529	100	142,475	49,347	74,698	16,428	222,581	482,280
Single race	5,680,602	96.4	489,206	96.8	138,646	47,302	72,451	15,977	214,830	466,626
White	4,821,823	81.8	367,283	72.7	122,879	30,553	57,174	10,672	146,005	347,047
Black or African American	190,267	3.2	5,494	1.1	1,319	1,230	742	46	2,157	5,507
American Indian/Alaska Native	93,301	1.6	12,468	2.5	1,165	362	863	112	9,966	10,288
Asian	322,335	5.5	6,809	1.3	3,134	800	652	99	2,124	6,681
Native Hawaiian/Pacific Islander	23,953	0.4	482	0.1	163	57	53	6	203	479
Other race	228,923	3.9	96,670	19.1	9,986	14,300	12,967	5,042	54,375	96,625
Two or more races	213,519	3.6	16,323	3.2	3,829	2,045	2,247	451	7,751	15,654
Hispanic origin (of any race) <sup>(c)</sup>	441,509	7.5	150,951	29.9	17,806	23,032	22,476	7,732	79,905	149,588

(a) Includes a portion of Oregon

(b) The Hanford Site National Environmental Policy Act (NEPA) Characterization Rev.14 (Neitzel 2002) shows the total population “within” 80 km as 511,500, which was estimated by a geographical information system from the populations of individual census block groups, the smallest geographic area for which both minority and poverty status were estimated in the 2000 Census. The higher number resulted because the total population of a census block group was previously assigned to the 80-km area if *any part* of the block group lay within 80 km of the Hanford Meteorological Station in the middle of the Hanford Site. The new estimate splits boundary block groups to include only those portions within 80 km, which should result in a lower and more accurate estimate.

(c) Hispanic origin is not a racial category. It may be viewed as the ancestry, nationality group, lineage, or country of birth of the person or person's parents or ancestors before arrival in the United States. Persons of Hispanic origin may be of any race and are counted in the racial categories shown.

**Table 4.7-4.** Year 2004 Population Estimates and Percentages by Race and Hispanic Origin by County in Washington State (OFM 2005d).

<b>Subject</b>	<b>Washington State</b>	<b>Percent</b>	<b>Benton/ Franklin/ Grant/ Adams/ Yakima</b>	<b>Percent</b>	<b>Benton County</b>	<b>Franklin County</b>	<b>Grant County</b>	<b>Adams County</b>	<b>Yakima County</b>
Total Population	6,167,800	100.0	534,600	100.0	155,100	57,000	78,300	16,700	227,500
White	5,276,114	85.5	497,337	93.0	145,632	53,478	74,489	16,182	207,555
Black	213,183	3.5	6,301	1.2	1,520	1,228	818	66	2,668
American Indian/Alaska Native	103,349	1.7	13,740	2.6	1,371	468	1,079	144	10,679
Asian/Native Hawaiian/Pacific Islander	394,692	6.4	8,922	1.7	3,799	1,076	845	165	3,038
Two or More Races	180,461	2.9	8,300	1.6	2,778	751	1,069	142	3,561
Hispanic Origin (of any race) <sup>(a)</sup>	517,645	8.4	176,332	33.0	22,815	31,798	25,673	8,551	87,495
(a) Hispanic origin is not a racial category. It may be viewed as the ancestry, nationality group, lineage, or country of birth of the person or person's parents or ancestors before arrival in the United States. Persons of Hispanic origin may be of any race and are counted in the racial categories shown.									

Based on the 2000 census (Census 2001b, c), the 80-km (50-mi) radius area surrounding the Hanford Site had a total population of 482,300 and a minority population of 178,500.<sup>(a)</sup> The ethnic composition of the minority population is primarily White Hispanic (24 percent), self-designated “other and multiple” races (63 percent), and Native American (6 percent). Asians and Pacific Islanders (4 percent) and African Americans (3 percent) make up the rest. The Hispanic population resides predominantly in Franklin, Yakima, Grant, and Adams counties. Native Americans within the 80-km (50-mi) area reside primarily on the Yakama Reservation and upstream of the Hanford Site near the town of Beverly, Washington.

The low-income population during 2000 was approximately 80,800, or 17 percent of the total population residing in the 80-km (50-mi) radius of the HMS at the center of the Hanford Site (Census 2002 a, b), approximately the same percentage as the 1990 Census. The majority of these households were located to the southwest and northwest of the Site (Yakima and Grant counties) and in the cities of Pasco and Kennewick.

Figure 4.7-2 shows the location of Census block groups from the 2000 Census that had either a majority of residents who were members of a minority group (racial minority or Hispanic), or a percentage of residents belonging to any minority group that was at least 20 percentage points greater than the corresponding percentage of the state population (Census 2001a, b, c).

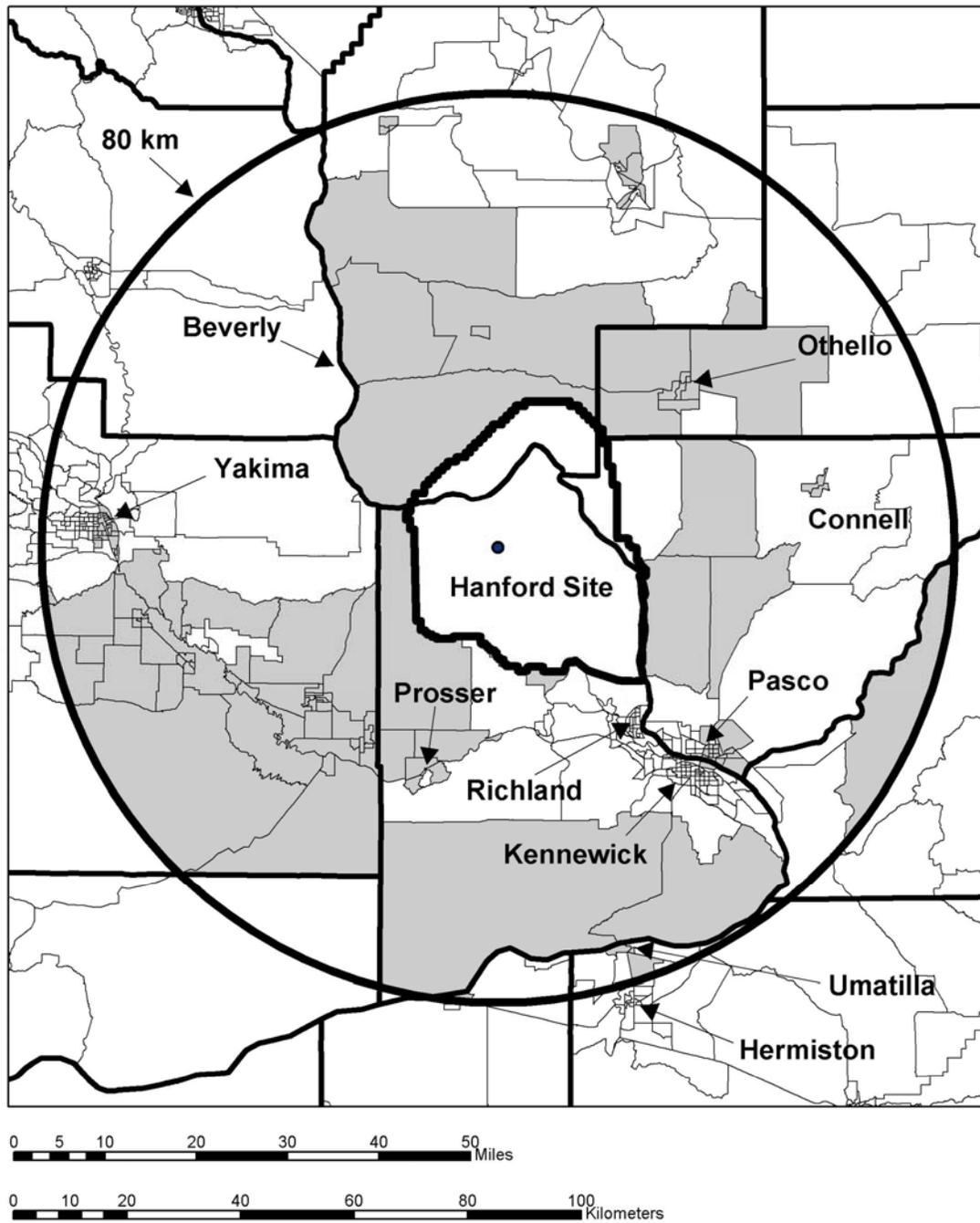
Figure 4.7-3 shows the location of Census block groups from the 2000 Census that had either a majority of residents who were low income (members of a household below the national poverty level), or a percentage of low-income residents at least 20 percentage points greater than the corresponding percentage of the state population (Census 2002 a, b).

The CEQ guidance for identifying potential disproportionate impacts on minority and low-income populations recognizes that some minority and low-income groups may be more reliant than the majority population on subsistence hunting, fishing, and gathering activities (sometimes for species unlike those consumed by the majority population), or may be dependent on water supplies or other resources that are atypical or used at different rates than other groups. These differential patterns of resource use are to be identified “where practical and appropriate.” While no hunting and gathering activities take place on the Hanford Site, some Native Americans of various tribal affiliations who live in the greater Columbia Basin do participate in tribal fishing for salmon and resident fish that use the Hanford Reach for habitat.

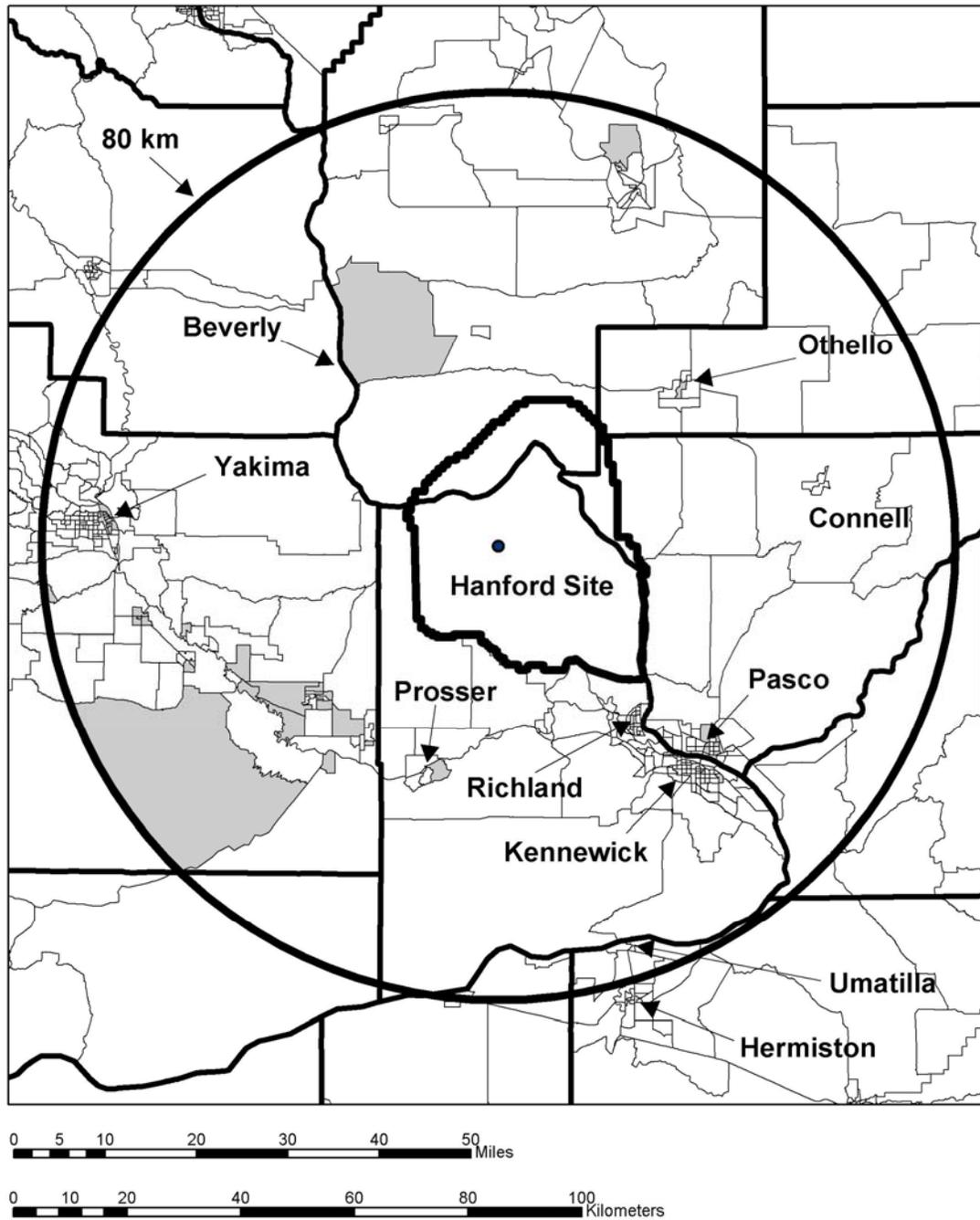
Fishing access rights for Native Americans is guaranteed by federal treaty. For example, the Treaty of 1855 with the Confederated Tribes and Bands of the Yakama Nation (Yakama 1855) secured to the Yakamas, “the right of taking fish at all usual and accustomed places, in common with the citizens of the Territory [now the state of Washington] and of erecting temporary buildings for curing them; together with the privilege of hunting, gathering roots and berries, and pasturing their horses and cattle upon open and unclaimed lands” ceded to the government. Some of this ceded territory is located on the Hanford Site. Similar guarantees were extended to the Umatilla, Nez Perce, and Warm Springs groups.

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(a) The Hanford Site National Environmental Policy Act (NEPA) Characterization Rev.14 (Neitzel 2002) shows the total population “within” 80 km as 511,500, which was estimated by a geographical information system from the populations of individual census block groups, the smallest geographic area for which both minority and poverty status were estimated in the 2000 Census. The higher number resulted because the total population of a census block group was previously assigned to the 80-km area if *any part* of the block group lay within 80 km of the Hanford Meteorological Station in the middle of the Hanford Site. The new estimate splits boundary block groups to include only those portions within 80 km, which should result in a lower and more accurate estimate.



**Figure 4.7-2.** Location of Minority Populations near the Hanford Site, Washington, Based on 2000 Census. Shaded areas indicate regions that have a majority of residents who are members of a minority group or for which the percentage of minority population is 20 percentage points greater than the statewide average. Minority groups include all nonwhite individuals plus Hispanic whites.



**Figure 4.7-3.** Location of Low-Income Populations near the Hanford Site, Washington, Based on 2000 Census. Shaded areas indicate regions that have a majority of low-income residents or for which the percentage of low-income population is 20 percentage points greater than the statewide average. Low-income persons live in households with incomes that fall below the official U.S. poverty level (\$17,761 for a family of four in the year 2000).

The Wanapum, a non-treaty tribe, historically lived along the Columbia River and continue to live upstream of the Hanford Site. They fish on the Columbia River and gather food resources near the Hanford Site. The Confederated Tribes of the Colville Reservation, established by the Executive Order of April 9, 1872, traditionally fished and gathered food resources in the Hanford area. They also are recognized as having cultural and religious ties to the Hanford Site.

The Walker Research Group discussed the historical location of Native American fishing sites, the level and productivity of the fishing effort, estimates from several studies of fish consumption in traditional Native American diets (Hewes 1947, 1973; Hunn and Bruneau 1989; Walker 1967), and possible exposure levels to radionuclides (Walker and Pritchard 1999). According to the studies, annual rates of fish consumption by Native Americans in the region before European contact ranged from 23 kg (50 lb) to as much as 438 kg (900 lb). Estimates of contemporary fish consumption tend to be somewhat lower but still indicate a heavy reliance on fish among Native Americans following a traditional diet (CRITFC 1994, Harris and Harper 1997).

#### **4.7.5 Housing**

During FY 2004, 3199 houses were sold in the Tri-Cities with an average price of \$162,821; 2927 houses sold at an average price of \$160,611 during 2003 (TCAR 2005). During FY 2004, 2139 single-family houses were built, a 22 percent increase from the 1750 that were built during 2003. The FY 2003 total had surpassed the previous annual peak of 1117 that occurred during 1994 (WCRER 2005a).

As of April 1, 2004, there were an estimated 80,032 housing units in Benton and Franklin counties, 36.7 percent more than the 58,541 units during 1990 (OFM 2005e). The number of apartments has increased from 8225 during 1990 to 11,229 during 2004. The vacancy rate of apartments in Benton and Franklin counties during 2004 was 6.1 percent, up from the 5.5 percent vacancy rate in 2003. Average rent during 2004 was \$593 per month, down from the \$606 average rent during 2003 (WCRER 2005b).

#### **4.7.6 Transportation**

The Tri-Cities serves as a regional transportation and distribution center with major air, land, and river connections. The Burlington Northern and Santa Fe Railway (BNSF) and Union Pacific Railroad provide direct rail service. Union Pacific Railroad operates the largest fleet of refrigerated rail cars in the United States and is essential to food processors that ship frozen food from this area. Passenger rail service is provided by Amtrak, which has a station in Pasco. Rail service on the Hanford Site is maintained and operated by the Tri-City and Olympia Railroad Company.

Docking facilities at the Ports of Benton, Kennewick, and Pasco are important aspects of this region's infrastructure. These facilities are located on the 525-km- (325.5-mi-) long commercial waterway, which includes the Snake and Columbia rivers, that extends from the Ports of Lewiston-Clarkston in Idaho to the deep-water ports of Portland, Oregon, and Vancouver, Washington.

Daily air passenger and freight services connect the area with most major cities through the Tri-Cities Airport, located in Pasco. This modern commercial airport links the Tri-Cities to major hubs and provides access to destinations anywhere in the world. There are two runways, a main runway and a minor runway for use during crosswinds. The main runway is equipped for precision instrumentation landings and takeoffs. Each runway is 2347 m (7700 ft) long and 46 m (150 ft) wide and can accommodate landings and takeoffs by medium-range commercial aircraft.

During 2004, Delta Airlines, Skywest, and Horizon Air provided daily connections to domestic and international flights through Salt Lake City, Seattle, Denver, Spokane, and Portland. There were 215,878 enplanements at the Tri-Cities Airport during 2004, which was up from 203,729 during 2003, a new record for the airport. From 1995 to 2002, the number of annual passengers increased 25 percent. Projections indicate that the terminal can serve almost 300,000 passengers annually.

The Tri-Cities region has three general aviation airports that serve private aircraft. The Richland Airport, owned by the Port of Benton, is northwest of the Richland central business district, adjacent to the Richland Bypass highway (SR-240). Vista Field Airport, owned by the Port of Kennewick, is located on West Grandridge Boulevard in central Kennewick, with easy access to SR-240, I-82, and I-182. The Prosser Airport, owned by the Port of Benton, is located 1.61 km (1 mi) northwest of the business district of Prosser and is adjacent to US-12. Airfreight shippers that service the region include DHL from Richland, United Parcel Service from Kennewick, and Federal Express from the Tri-Cities Airport in Pasco.

Mass transit within the Tri-Cities is provided by the Ben Franklin Transit (BFT) system. BFT is a municipal corporation that provides public transportation services in a 588-square mile area of Benton and Franklin counties. The area includes the cities of Kennewick, Pasco, Richland, West Richland, Benton City, and Prosser and certain unincorporated areas of Benton and Franklin counties. As of the end of 2004 the Ben Franklin fleet consisted of 68 buses, 55 Dial-a-Ride para-transit vehicles, and 183 VanPool vans. The total number of boardings in 2004 was 4,113,785, an 8.5% increase from 2003 (BFT 2005). Two local taxi companies provide radio-dispatched taxicab service 24 hours per day: A-1 Tri-Cities Taxi and Tri-City Cab.

The regional transportation network in the Hanford vicinity includes the areas in Benton and Franklin counties from which most of the commuter traffic associated with the Site originates. Interstate highways that serve the area are I-82 and I-182. I-82 is 8 km (5 mi) south-southwest of the Site. I-182, a 24-km (15-mi)-long urban connector route located 8 km (5 mi) south-southeast of the Site, provides an east-west corridor linking I-82 to the Tri-Cities area. I-90, located north of the Site, is the major link to Seattle and Spokane and extends to the east coast. I-82 serves as a primary link between Hanford and I-90, as well as I-84. I-84, located south of the Hanford Site in Oregon, is a major corridor leading to Portland, Oregon. SR 224 (Van Giesen Street), also south of the Site, serves as a 16-km (10-mi) link between I-82 and SR 240. SR 24 enters the Site from the west, continues eastward across the northernmost portion of the Site, and intersects SR 17 approximately 24 km (15 mi) east of the Site boundary. SR 17 is a north-south route that links I-90 to the Tri-Cities and joins U.S. Route 395, continuing south through the Tri-Cities. U.S. Route 395 north also provides direct access to I-90. SR 240 and SR 24 traverse the Site and are maintained by Washington State.

A DOE-maintained road network within the Hanford Site consists of 607 km (377 mi) of asphalt-paved road and provides access to the various work centers. Primary access roads to the industrial areas of the Hanford Site are Routes 1, 2, 3, 5, 6, 10, 11, and Beloit Avenue (Figure 4.0-1). Public access to the 200 Areas and interior locations of the Hanford Site has been restricted by guarded gates at the Wye Barricade (at the intersection of Routes 10 and 4), the Yakima Barricade (at the intersection of SR 240 and Route 11A), and Rattlesnake Barricade south of the 200 West Area. None of those roadways have experienced any substantial congestion except Route 4 (WHC 1994).

Access to the Hanford Site is via four main routes: Hanford Route 4S from Stevens Drive in the City of Richland, Route 10 from SR 240 near its intersection with SR 225, Beloit Avenue from SR 240, or Route 11A from SR 240 near its intersection with SR 24. The Beloit Avenue route, through the Rattlesnake Barricade, is 35 km (22 mi) northwest of Stevens Drive and is for passenger vehicle access only. The estimated total number of daily commuters to this area is 3100. Approximately 87 percent of

the workers commuting to the 200 Areas are from the Tri-Cities, West Richland, Benton City, and Prosser (Perteet et al. 2001). The remaining workers commute from the surrounding counties of Yakima, Adams, Grant, and Walla Walla.

The portion of SR 240 most affected by 200 Areas commuters is between U.S. 395 in Kennewick and Stevens Drive in Richland. Portions of this roadway currently operate below the minimum level of service established by the Regional Transportation Planning Organization. Peak annual average daily traffic (AADT) on the section from Columbia Center Boulevard in Kennewick to I-182 is 54,000 (Perteet et al. 2001).

I-182 has peak traffic counts of 35,000 AADT in the vicinity of SR 240 in Richland. I-182 has deficiencies at the interchanges with Queensgate Drive in Richland and 20<sup>th</sup> Avenue in Pasco. SR 224 (Van Giesen Street) transports most of the commuters from West Richland and Benton City to SR 240. The intersection of SR 224 and SR 240 is the only section of SR 224 with current level of service (LOS) deficiencies. LOS is a qualitative measure of a roadway's ability to accommodate vehicular traffic, ranging from free-flow conditions (LOS A) to extreme congestion (LOS F). LOS D is considered the lower end of acceptable LOS (Perteet et al. 2001).

Stevens Drive (in and north of Richland) has peak traffic counts of 8300 AADT at Horn Rapids Road and 22,000 AADT just north of its intersection with SR 240 (Bypass Highway). This roadway currently experiences LOS deficiencies. George Washington Way is the principal north-south arterial through Richland. AADT at the entrance of the Hanford Site on George Washington Way is 1800. Counts north of McMurray are 18,000 AADT and counts on George Washington Way just north of I-182 are 43,000 AADT. George Washington Way has LOS deficiencies between I-182 and Swift Boulevard (Perteet et al. 2001).

Private vehicles account for 91 percent of the person trips to the Hanford Site. The remaining person trips are by forms of high-occupancy vehicles (mostly Ben-Franklin Vanpools). Of the 91 percent of private vehicles, only 3 percent are by carpool, and the remaining 88 percent are single-occupancy vehicles. The draft Regional Transportation Plan identifies 11,468 employees working at Hanford. Based on 88 percent of the trips carrying a single person to Hanford, 10,092 single occupancy trips are made daily or an AADT of 10,184 (Perteet et al. 2001). Several local highway construction projects are underway to reduce some of the traffic bottlenecks.

The Hanford Site rail system originally consisted of approximately 210 km (130 mi) of track. It connected to the Union Pacific Railroad commercial track at the Richland Junction (at Columbia Center in Kennewick) and to a now abandoned commercial right-of-way (Chicago, Milwaukee, St. Paul and Pacific Railroad) near Vernita Bridge in the northwest section of the Site. Prior to 1990, annual railcar movements numbered about 1400 sitewide, transporting materials including coal, fuel, hazardous process chemicals, and radioactive materials and equipment (DOE 1996b). During October 1998, 26 km (16 mi) of track from Columbia Center to Horn Rapids Road were transferred to the Port of Benton and are currently operated by the Tri-City and Olympia Railroad. The Port of Benton has been granted the right to operate portions of the railroad on the Hanford Site.

#### **4.7.7 Educational Services**

Most of the primary and secondary students in the Tri-Cities area are served by the Richland, Pasco, Kennewick, and Kiona-Benton (Benton City) school districts. The total 2004 fall enrollment for all districts in Benton and Franklin counties was 43,316 students, an increase of 1.3 percent from the 2003 total of 42,759 students. The 2004 totals include 9975 students from the Richland School District, an

increase from 9790 during 2003; 11,020 students from the Pasco School District, an increase from 10,477 during 2003; 14,776 students from the Kennewick School District, a decrease from 14,981 during 2003; and 1631 from the Kiona-Benton School District, an increase from 1459 during 2003 (OSPI 2005).

There are fourteen private elementary and secondary schools in the Tri-Cities, including Bethlehem Lutheran (K-8), Calvary Christian (K-5), and St. Joseph's (K-8) in Kennewick; Christ the King (K-8) and Liberty Christian (K-12) in Richland; and Kingspoint Christian (K-12), Country Haven Academy, St. Patrick's (K-8), Tri-City Junior Academy (K-10), and Tri-Cities Prep Catholic High School in Pasco. Fall 2003 enrollment at these schools totaled 2292 students, slightly lower than the 2002 total of 2300 (OSPI 2005).

Post-secondary education in the Tri-Cities area is provided by Columbia Basin College (CBC), City University, and Washington State University, Tri-Cities branch campus (WSU-TC). The 2004 fall/winter enrollment was 6996 at CBC, 150 at City University, and 1200 at WSU-TC. Many of the programs offered by these three institutions are geared toward the vocational and technical needs of the area. During 2003-04, CBC offered 22 Associate in Applied Science (AAS) degree programs. City University offers three undergraduate and four graduate programs plus access to several more programs through distance learning. WSU-TC offers 16 undergraduate and 14 graduate programs, as well as access to graduate programs via satellite.

#### **4.7.8 Health Care and Human Services**

The Tri-Cities has three major hospitals and five emergency centers. All three hospitals offer general medical services and include a 24-hr emergency room, surgical services, and intensive and neonatal care.

Kadlec Medical Center in Richland has 153 beds and functioned at 67.1 percent capacity with 9002 total admissions during 2004, at an average stay of 3.5 days per admission. Non-Medicare/Medicaid patients accounted for 46.9 percent of Kadlec's admissions.

Kennewick General Hospital maintained a 35.3 percent occupancy rate of its 101 beds with 4157 total admissions during 2004, with an average stay of 3.1 days per admission. Non-Medicare/Medicaid patients represented 41 percent of its total admissions during 2003.

Lourdes Medical Center operates a 132-bed health center located in Pasco that provides acute, subacute, skilled nursing and rehabilitation, and alcohol and chemical dependency services. Lourdes operates the Lourdes Counseling Center, a 32-bed mental health hospital in Richland. They also provide a significant amount of outpatient and home health services. For calendar year 2004, Lourdes had a total of 3730 admissions, 26 percent of which were non-Medicare/Medicaid. Lourdes had an average acute care length of stay of 2.5 days, and the occupancy rate was 26 percent during 2004.

The Tri-Cities offers a broad range of social services. State human service offices in the Tri-Cities include the Job Service Center within the Employment Security Department; food stamp offices; the Developmental Disabilities Division; financial and medical assistance; Child Protective Service; emergency medical service; a senior companion program; and vocational rehabilitation.

The Tri-Cities is also served by a large number of private agencies and voluntary human service organizations. The United Way, an umbrella fund-raising organization, incorporated 19 Community Impact Partners and 6 Community Solutions Partners during 2004. The Community Impact budget of \$34.4 million funded 38 programs during 2004, and the Community Solutions budget of \$2.0 million funded seven programs during 2004. The number of organizations receiving donor designations was 572.

## 4.7.9 Police and Fire Protection

Benton and Franklin counties' sheriff departments, local municipal police departments, and the Washington State Patrol Division, with headquarters in Kennewick, provide police protection in Benton and Franklin counties, with a total of 345 officers (commissioned and reserved) in the Tri-Cities (Table 4.7-5). The Kennewick Municipal Police Department maintains the largest staff of commissioned officers with 92.

**Table 4.7-5.** Police Personnel in the Tri-Cities, Washington, 2004

<b>Area</b>	<b>Commissioned Officers</b>	<b>Reserve Officers</b>	<b>Patrol Cars</b>
Kennewick Municipal	92	9	20
Pasco Municipal	55	14	28
Richland Municipal	56	6	15
West Richland Municipal	12	4	12
Benton County Sheriff	53	10	53
Franklin County Sheriff	<u>22</u>	<u>12</u>	<u>24</u>
<b>Tri-Cities total</b>	<b>290</b>	<b>55</b>	<b>152</b>

Fire protection is provided by the fire departments of the cities of Kennewick, Pasco, and Richland, and by Benton County Rural Fire Departments #1, #2, and #4. A total of 360 fire fighting personnel (187 paid and 173 volunteer) are on staff in the Tri-Cities. In addition, the Hanford Fire Department, a highly trained and professional career industrial fire department with 145 members, provides fire protection on the Hanford Site and nearby areas (Table 4.7-6). There are four fire stations strategically located on the Hanford Site. From these stations four pumper crews, staffed with at least three firefighters each, provide suppression response. The Hanford Fire Department provides coverage to the entire Hanford Site and to SR 240 and SR 24. Coverage on the highways extends from the Vernita Bridge to the Silver Dollar Cafe on SR 24 and along SR 240 from the Yakima Barricade to the intersection with SR 225. Additionally, the Hanford Fire Department responds to mutual aid requests from 10 surrounding fire districts. Four ambulance crews (one in each fire station), staffed with two firefighters (Emergency Medical Technicians [EMT] or paramedic trained), provide emergency medical services 24 hours per day, seven days a week. A total of 40 emergency response vehicles, representing diverse capabilities, are maintained at the four fire stations. Some emergency equipment is specifically intended to control situations exclusive to the Hanford Site.

**Table 4.7-6.** Fire Protection Personnel in the Tri-Cities, Washington, 2004

<b>Fire Department</b>	<b>Fire Fighting Personnel</b>	<b>Volunteers</b>	<b>Total</b>	<b>Service Area</b>
Kennewick	67	0	67	City of Kennewick
Richland	55	0	55	City of Richland
Pasco	47	0	47	City of Pasco
BCRFD <sup>(a)</sup> 1	10	100	110	Kennewick Area
BCRFD 2	5	26	31	Benton City
BCRFD 4	<u>3</u>	<u>47</u>	<u>50</u>	West Richland
<b>Tri-Cities total</b>	<b>187</b>	<b>173</b>	<b>360</b>	
Hanford	145	0	145	Hanford Site
(a) BCRFD = Benton County Rural Fire Department.				

#### 4.7.10 Parks and Recreation

The convergence of the Columbia, Snake, and Yakima rivers offers residents of the Tri-Cities a variety of recreational opportunities. The Lower Snake River Project includes Ice Harbor, Lower Monumental, Little Goose, and Lower Granite locks and dams, and a levee system and parkway at Clarkston and Lewiston (Figure 4.4-6). Although navigation capabilities and the electrical output are the major benefits of this project, recreational benefits have also resulted. The Lower Snake River Project provides boating, camping, and picnicking facilities in nearly a dozen areas along the Snake River. During FY 2004, 1.8 million people visited the area and participated in activities along the river.

Similarly, the Columbia River provides ample water recreational opportunities on the lakes formed by the dams. Lake Wallula, formed by McNary Dam, offers a large variety of parks and activities that attracted more than 3.9 million visitors during FY 2004. The Columbia River Basin is also a popular area for migratory waterfowl and upland game bird hunting.

Other opportunities for recreational activities in the Tri-Cities are accommodated by indoor and outdoor facilities, including numerous tennis courts, ball fields, and golf courses which offer outdoor recreation to residents and tourists (Table 4.7-7). Several privately owned health clubs in the area offer indoor tennis and racquetball courts, pools, and exercise programs. Bowling lanes and skating rinks also serve the Tri-Cities.

#### 4.7.11 Utilities

The principal source of water in the Tri-Cities and the Hanford Site is the Columbia River. The water systems of Richland, Pasco, and Kennewick drew a large portion of the 50.2-billion L (13.3 billion gal) used during 2004 from the Columbia River. Each city operates its own supply and treatment system. The Richland water supply system derives about 82 percent of its water directly from the Columbia River, while the remainder is split between a well field in North Richland (that is recharged from the river) and groundwater wells. The City of Richland's total usage during 2004 was 21.6 billion L (5.9 billion gal). The city of Pasco system also draws from the Columbia River for its water needs. During 2004, Pasco consumed 14.5 billion L (3.8 billion gal). The Kennewick system uses two wells and the Columbia River for its supply. These wells serve as the sole source of water between November and March and can

**Table 4.7-7.** Examples of Physical Recreational Facilities Available in the Tri-Cities, Washington

Activity	Facilities
Team sports	Baseball fields and basketball courts are located throughout the Tri-Cities. Soccer and football fields are also located in various areas. Spectator sports include minor league baseball and junior professional hockey.
Bowling	Lanes are found in each city, including Fiesta Bowling Center, Celebrity Bowl, and Go-Bowl.
Camping	Several hundred campsites can be found within driving distance from the Tri-Cities area, including Fishhook Park and Sun Lakes.
Fishing	Steelhead, sturgeon, trout, walleye, bass, and crappie fishing is excellent in the lakes and rivers near the Tri-Cities.
Golf	Several public courses include Sun Willows, Columbia Park, Canyon Lakes, Columbia Point, Buckskin, and West Richland Municipal, two semi-private courses, two private courses, and a number of driving ranges and pro shops.
Hunting	Duck, geese, pheasant, and quail hunting is available. Deer and elk hunting is available in the Blue Mountains and the Cascade Range.
Skating	There are roller-skating arenas in Richland and Prosser and recreational ice skating in Kennewick; a junior professional ice hockey arena is available to the public in Kennewick.
Water sports	There are public swimming pools in Pasco, Kennewick, and Richland, plus numerous private club pools. Boating, sailing, windsurfing, diving, water-skiing, swimming, etc. are available on the Columbia River, with 31 boat ramps in the Tri-Cities.
Tennis	Several outdoor city courts are available in each city, with additional outdoor courts located at area schools. Two private health clubs have indoor courts available
Walking/bicycling	There are over 30 miles of paved bike/hike paths and 5600 acres of parks in the Tri-Cities

provide approximately 40 percent of the total maximum supply of 30 billion L (8 billion gal). Total 2004 usage in Kennewick was 14.2 billion L (3.7 billion gal). A significant number of Kennewick’s residents (about 15,000 residential customers) draw irrigation water from the Kennewick Irrigation District, which has the Yakima River as its source (TCH 2001).

The major incorporated areas of Benton and Franklin counties are served by municipal wastewater treatment systems, whereas the unincorporated areas are served by onsite septic systems. Richland’s wastewater treatment system processed an average flow of 23.2 million L/d (6.1 million gal/d) during 2004 and is designed to treat 43.1 million L/d (11.4 million gal/d). Kennewick’s waste treatment system processed an average 22.2 million L/d (5.9 million gal/d) during 2004. Their system is capable of treating about 46.1 million L/d (12.2 million gal/d). Pasco’s waste treatment system processed an average 11.4 million L/d (3.0 million gal/d) and is capable of treating 16.1 million L/d (4.25 million gal/d).

The Benton County Public Utility District, Franklin County Public Utility District, and City of Richland Energy Services Department provide electricity to the Tri-Cities and surrounding areas. Nearly all the power these utilities provide in the local area is purchased from the Bonneville Power

Administration (BPA), a federal power-marketing agency. These three utilities served over 85,000 customers and had 3.08 billion kilowatt-hour (kWh) total sales during 2004. The average rate for residential customers was approximately \$0.069/kWh during 2004, up slightly from \$0.0647 during 2003. The Benton Rural Electrical Association serves portions of the rural areas of Benton and adjacent counties.

Electrical power for the Hanford Site is purchased wholesale from BPA, which provided 90 percent of the electricity consumed on the Hanford Site during 2004. Energy requirements for the Hanford Site during FY 2004 were 239.3 million kWh for a total cost of \$8.4 million. Additionally, the Site spends about \$0.024/kWh for electrical transportation and distribution within the Hanford Site.

Natural gas, provided by the Cascade Natural Gas Corporation (CNG), serves a small but growing portion of local residents, with 12,876 residential customers served in 2004. During 2000, CNG had 7300 residential customers. The average annual gas bill for residential customers is approximately \$1100. CNG also serves the Hanford Site 300 Area.

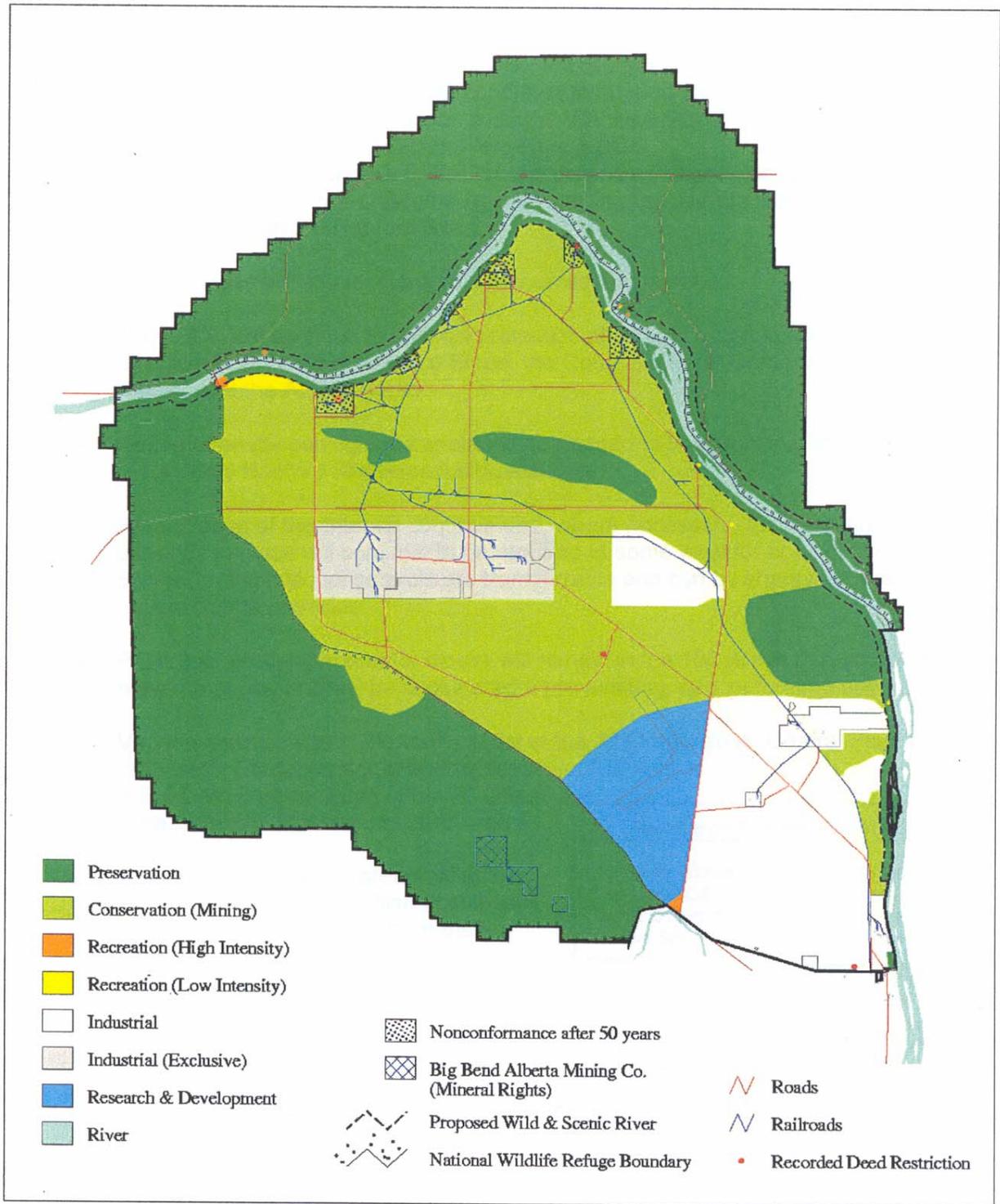
Wind energy is a new but growing component of Pacific Northwest generating resources and is quite visible in the Tri-Cities area. Phase I of FPL Energy's Stateline wind generation project (180 megawatt [MW]) entered service during December 2001 near Walla Walla and has been expanded to 300 MW (FPL 2003). Energy Northwest's Nine Canyon Wind Farm (48 MW) entered service during October 2002 near Kennewick (American Wind Energy Association 2003). A number of other wind power projects (including a 40 MW Phase II for Stateline) have been proposed for the Northwest, although many have been put on hold because of low electricity demand, declining wholesale electricity prices, and reduced economic activity due to recession. At prices of 4.0 to 6.0 cents per kWh, wind energy is close to competitive with other sources, despite relatively high costs per installed kWh and capacity factors of around 35 percent (OTED 2005). A capacity factor is the net electricity generated, for the period of time considered, to the energy that could have been generated at continuous full-power operation during the same period. For comparison, the average capacity factor for nuclear plants in the United States during 2002 was 90 percent (EIA 2004).

#### **4.7.12 Land Use**

The DOE completed a Hanford Comprehensive Land-Use Plan EIS (HCP-EIS) during September 1999 (DOE 1999a), and a Record of Decision (ROD) was issued on November 2, 1999 (64 FR 61615). The purpose of this land-use plan and its implementing policies and procedures is to facilitate decision-making about the Hanford Site's uses and facilities over at least the next 50 years. The DOE Preferred Alternative addresses future and existing use. Proposed future uses include nine land-use designations defining permissible uses of the Hanford Site (Figure 4.7-4 and Table 4.7-8).

For analysis purposes, the HCP-EIS used existing land use activities presented on a map that divided the Hanford Site into five geographical areas: Wahluke Slope, Columbia River Corridor, Central Plateau, All Other Areas of the Site, and the Fitzner-Eberhardt Arid Lands Ecology Reserve Unit (Figure 4.7-5). The key features of the Hanford Site that formed the basis of analysis of the five geographic areas used in the environmental impact analysis and land-use plans were as follows:

**The Wahluke Slope.** The area north of the Columbia River and the Hanford Site proper encompassed approximately 357 km<sup>2</sup> (138 mi<sup>2</sup>) and was designated as part of the Hanford Reach National Monument by President Clinton. This is an area of relatively undisturbed or recovering shrub-steppe habitat managed by the USFWS for the DOE. These lands consisted of two wildlife



**Figure 4.7-4.** DOE's Preferred Alternative for Land Use on the Hanford Site, Washington (DOE 1999a)

**Table 4.7-8.** Definitions and Descriptions of DOE's Preferred Alternative Land Use Designations for the Hanford Site, Washington (DOE 1999a)

<b>Land-Use Designation</b>	<b>Definition</b>
Industrial-Exclusive	An area suitable and desirable for treatment, storage, and disposal of hazardous, dangerous, radioactive, and nonradioactive wastes. Includes related activities consistent with Industrial-Exclusive uses.
Industrial	An area suitable and desirable for activities such as reactor operations, rail, barge transport facilities, mining, manufacturing, food processing, assembly, warehouse, and distribution operations. Includes related activities consistent with Industrial uses.
Agricultural	An area designated for the tilling of soil, raising of crops and livestock, and horticulture for commercial purposes along with all those activities normally and routinely involved in horticulture and the production of crops and livestock. Includes related activities consistent with Agricultural uses.
Research and Development	An area designated for conducting basic or applied research that requires the use of a large-scale or isolated facility or smaller scale time-limited research conducted in the field or within facilities that consume limited resources. Includes scientific, engineering, technology development, technology transfer, and technology deployment activities to meet regional and national needs. Includes related activities consistent with Research and Development.
High-Intensity Recreation	An area allocated for high-intensity, visitor-serving activities and facilities (commercial and governmental), such as golf courses, recreational vehicle parks, boat launching facilities, Tribal fishing facilities, destination resorts, cultural centers, and museums. Includes related activities consistent with High-Intensity Recreation.
Low-Intensity Recreation	An area allocated for low-intensity, visitor-serving activities and facilities, such as improved recreational trails, primitive boat launching facilities, and permitted campgrounds. Includes related activities consistent with Low-Intensity Recreation.
Conservation (Mining and Grazing)	An area reserved for the management and protection of archeological, cultural, ecological, and natural resources. Limited and managed mining (e.g., quarrying for sand, gravel, basalt, and topsoil for governmental purposes only) and grazing could occur as a special use (i.e., a permit would be required) within appropriate areas. Limited public access would be consistent with resource conservation. Includes activities related to Conservation (Mining and Grazing) consistent with the protection of archeological, cultural, ecological, and natural resources.
Conservation (Mining)	An area reserved for the management and protection of archeological, cultural, ecological, and natural resources. Limited and managed mining (e.g., quarrying for sand, gravel, basalt, and topsoil for governmental purposes) could occur as a special use (i.e., a permit would be required) within appropriate areas. Limited public access would be consistent with resource conservation. Includes activities related to Conservation (Mining) consistent with the protection of archeological, cultural, ecological, and natural resources.
Preservation	An area managed for the preservation of archeological, cultural, ecological, and natural resources. No new consumptive uses (i.e., mining or extraction of non-renewable resources) would be allowed within this area. Limited public access would be consistent with resource preservation. Includes activities related to Preservation uses.

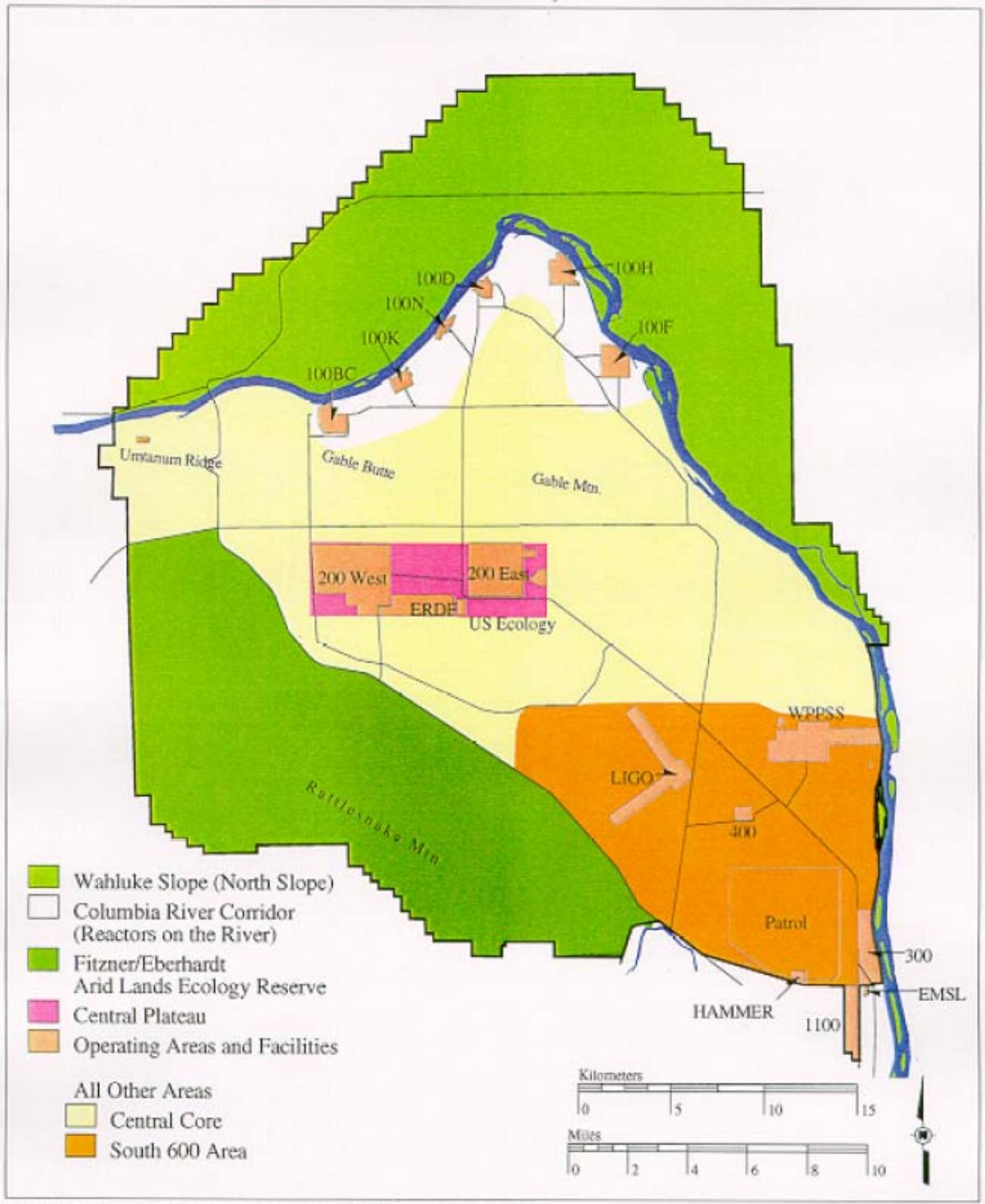


Figure 4.7-5. Geographic Study Areas for the Hanford Site, Washington (DOE 1999a)

management units within the Hanford Reach National Monument/Saddle Mountain National Wildlife Refuge: the 130 km<sup>2</sup> (50 mi<sup>2</sup>) Saddle Mountain Unit and the 225 km<sup>2</sup> (87 mi<sup>2</sup>) Wahluke Unit. Portions of the Saddle Mountain Unit, which are closed to public access, still serve as buffer areas for the Hanford Site. The Wahluke Unit was open to public recreational access. A small strip of land [approximately 1.62 km<sup>2</sup> (0.63 mi<sup>2</sup>)] located between SR 243 and the Columbia River west of SR 24 is still managed by the Washington State Department of Fish and Wildlife under DOE permit and retains public access.

- **Columbia River Corridor.** The 111.6 km<sup>2</sup> (43.1 mi<sup>2</sup>) Columbia River Corridor was placed into the Hanford Reach National Monument by President Clinton. Adjacent to and running through the Hanford Site, it is used for boating, water skiing, fishing, and hunting of upland game birds and migratory waterfowl. Although public access is allowed on certain islands below the high water mark, access to other islands and adjacent areas is restricted because of distinctive habitats and the presence of cultural resources.

Along the southern shoreline of the Columbia River Corridor, the 100 Areas occupy approximately 68 km<sup>2</sup> (26 mi<sup>2</sup>). The facilities in the 100 Areas included nine retired plutonium production reactors, associated facilities, and structures. The Resource Conservation and Recovery Act of 1976 (RCRA) (42 USC 6901 *et seq.*) closure permit restrictions have been placed in the vicinity of the 100-H Area, which is associated with the 183-H Solar Evaporation Basins and the N Reactor cribs. Additional deed restrictions or covenants for activities that potentially extend more than 4.6 m (15 ft) below ground surface are expected for the Comprehensive Environmental Restoration, Compensation, and Liability Act of 1980 (CERCLA) (42 USC 9601, *et seq.*) remediation areas.

The area within the Columbia River Corridor known as the Hanford Reach includes a 402-m (1320-ft) strip of public land on both sides of the Columbia River.

- **Central Plateau.** The 200 East and 200 West Areas occupy approximately 51 km<sup>2</sup> (19.5 mi<sup>2</sup>) in the Central Plateau of the Hanford Site. Facilities in the Central Plateau were built to process irradiated fuel from the plutonium production reactors. The operation of these facilities resulted in the treatment, storage, disposal, and unplanned release of radioactive and nonradioactive waste. The Environmental Restoration Disposal Facility for CERCLA cleanup wastes is located in the Central Plateau. The Integrated Disposal Facility as authorized by the Hanford Solid Waste EIS ROD (69 FR 39449) is being constructed to process low-level and mixed low-level wastes.

A commercial low-level radioactive waste disposal facility, licensed by the State of Washington and run by U.S. Ecology, Inc., currently operates on 0.4 km<sup>2</sup> (0.16 mi<sup>2</sup>) of the Central Plateau (DOH and Ecology 2000).

- **All Other Areas.** All Other Areas comprise 689 km<sup>2</sup> (266 mi<sup>2</sup>) and contain the 300 and 400 Areas, the former 1100 Area, Energy Northwest facilities, and a section of land currently owned by the State of Washington for the disposal of hazardous substances.

The former Hanford 1100 Area and the Hanford railroad southern connection (from Horn Rapids Road to Columbia Center) have been transferred from DOE ownership to Port of Benton ownership to support future economic development. Although the 1100 Area is no longer under DOE control, it was included in the HCP EIS to support the local governments with their State Environmental Policy Act (SEPA) EIS analyses of the Hanford subarea of Benton County under the State of Washington's Growth Management Act (RCW 36.70A).

The 300 Area is just north of the city of Richland and covers 1.5 km<sup>2</sup> (0.6 mi<sup>2</sup>). The 300 Area is the site of former reactor fuel fabrication facilities and was also the principal location of nuclear research and development facilities serving the Hanford Site.

The 400 Area, located southeast of the 200 East Area, is the site of the Fast Flux Test Facility (FFTF), a 400-megawatt (thermal) liquid metal (sodium) fast neutron flux nuclear test reactor. The construction of the FFTF was completed during 1978 and its initial operation began in 1980. From 1982 to 1992, the FFTF operated as a national research facility to test advanced nuclear fuels, materials, components, nuclear power plant operations and maintenance protocols, and reactor safety designs. During this time, the FFTF also produced a wide variety of medical and industrial isotopes, made tritium for the U.S. fusion research program, and conducted cooperative international research work. Deactivation activities are underway at the FFTF. Sodium has been drained from the primary heat transport system loops and auxiliary systems, as well as the upper portion of the reactor vessel to the Sodium Storage Facility tanks, where approximately 150,000 gallons of sodium is now stored, pending future conversion to sodium hydroxide for use by the Waste Treatment Plant.

Energy Northwest operates the Columbia Generating Station on leased land approximately 10 km (6 mi) north of Richland. This land was originally leased for the operation of three nuclear power plants, but construction of two of the plants was halted and other industrial options are being considered.

During 1980, the federal government sold a 2.59 km<sup>2</sup> (1 mi<sup>2</sup>) section of land (known as Section 1) south of the 200 East Area and near SR 240 to the State of Washington for nonradioactive hazardous waste disposal. To date, this parcel has not been used for hazardous waste disposal. It is undeveloped and uncontaminated (although the underlying groundwater might be contaminated). The deed requires that if it were used for any purpose other than hazardous waste disposal, ownership would revert to the federal government.

Additional activities in All Other Areas include:

- *A specialized training center:* The Hazardous Materials Management and Emergency Response (HAMMER) Volpentest Training and Education Center is used to train hazardous materials response personnel and operating personnel for the Waste Treatment Plant. It is located north of the former 1100 Area and covers about 0.3 km<sup>2</sup> (0.12 mi<sup>2</sup>).
- *A regional law-enforcement training facility:* The Hanford Patrol Training Academy provides a range of training environments including classrooms, library resources, practice shoot houses, an exercise gym, and an obstacle course.
- *A national research facility:* The Laser Interferometer Gravitational Wave Observatory (LIGO), built by the National Science Foundation for scientific research, is designed to detect cosmic gravitational waves. The facility consists of two optical tube arms, each 4 km (2.5 mi) long, arrayed in an "L" shape, which are extremely sensitive to vibrations.
- *A national utilities training center:* The National Utility Training Services facility in Richland, Washington, will help continue to develop curriculum for the state-of-the-art training facility located adjacent to the Volpentest HAMMER Training Center for emergency workers at Hanford. National Utility Training Services is a facility designed to provide the best in electric utility hands-on, performance-based training. Originally a project of the Northwest Public Power Association (NWPPA), National Utility Training

Services is now a nonprofit educational 501(c)3 organization providing hands-on performance-based training to the west's electric utility employees.

- *A national counter-drug center:* National Counternarcotics Center pilot. The drug interdiction prototype will support future interest and funding for a permanent multi-jurisdictional counternarcotics program involving federal and local agencies.
- **Fitzner-Eberhardt Arid Lands Ecology Reserve Unit.** The 308.7 km<sup>2</sup> (119.2 mi<sup>2</sup>) Fitzner-Eberhardt Arid Lands Ecology Reserve Unit is part of the Hanford Reach National Monument and is managed by the USFWS for the DOE. The unit is located in the southwestern portion of the Hanford Site and is managed as a wildlife reserve. The public is restricted from the site.

The Hanford Site facilities and activities are consolidated within operating areas that occupy about 6 percent of the total available area of the Site (DOE 1999a). Some of the Hanford Site that is not involved with the current mission has been leased, disposed, or permitted to federal or state agencies or private entities (Table 4.7-9).

**Table 4.7-9.** Key Areas of the Hanford Site, Washington, Outgranted/Released to Date <sup>(a)</sup>

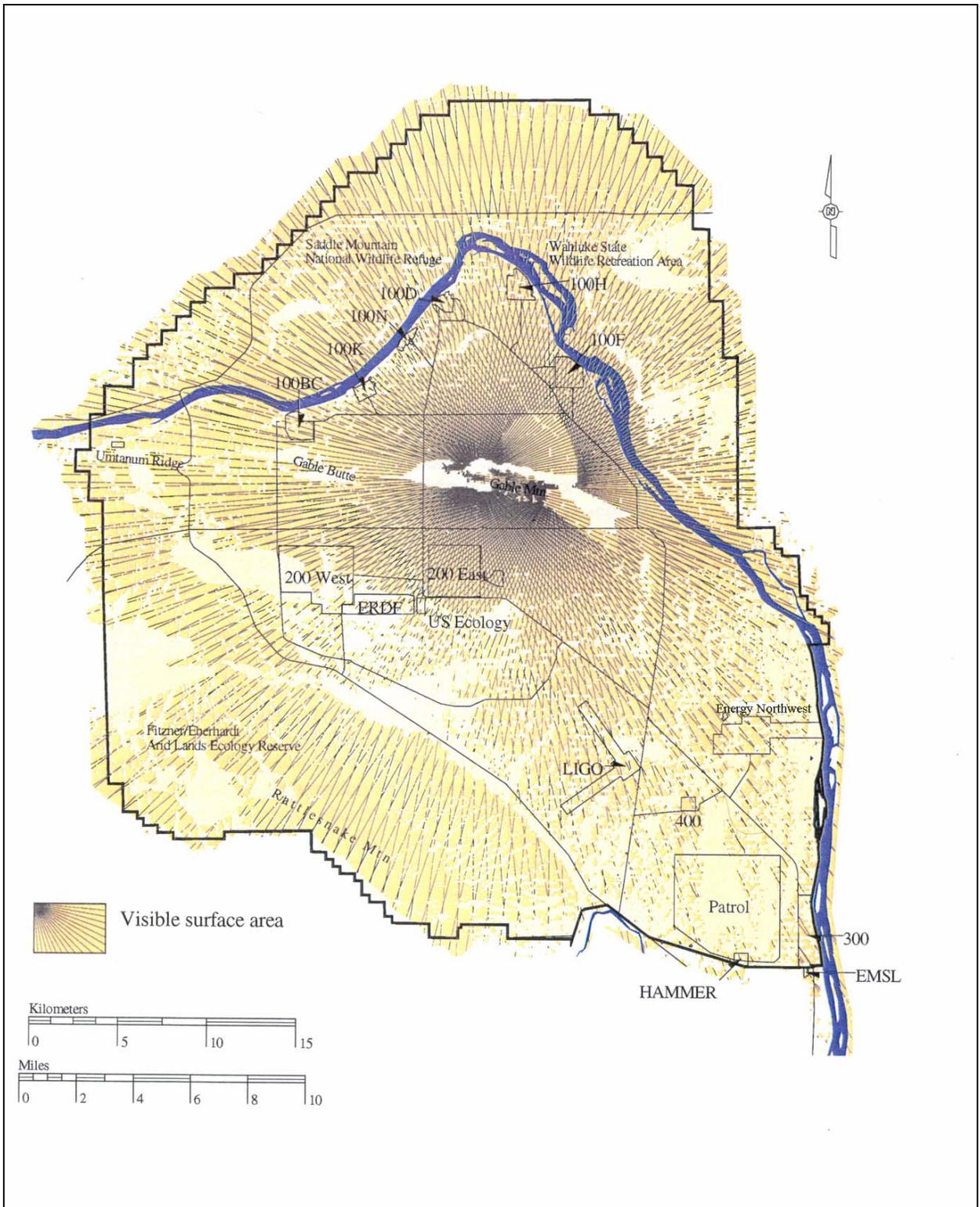
Area	Management	Use	Year	Controls
US Ecology Low-Level Radioactive Waste Disposal Facility	State of Washington	Commercial Radioactive Waste Disposal	1964	Leased
Vernita Rest Area <sup>(b)</sup>	Washington State Department of Transportation	Highway Rest Area	1966	Washington State Highway Patrol
Columbia Generating Station	Energy Northwest	Power Production	1971	Leased
West End of Wahluke Slope (Saddle Mountain National Wildlife Refuge) <sup>(b)</sup> (superseded)	U.S. Fish and Wildlife Service	Wildlife Refuge	1971	Permitted with the following controls: <ul style="list-style-type: none"> <li>• No overnight camping</li> <li>• Access control plans required</li> <li>• No drilling of wells for residential water</li> </ul>
East End of Wahluke Slope <sup>(b)</sup> (superseded)	WA State Department of Fish and Wildlife	Wildlife & Recreational Reserve	1971-1999	Permitted with same controls as mentioned for Wahluke Slope above.
Southwest End of Wahluke Slope <sup>(b)</sup> between Rt 24 and Columbia River (upstream of Vernita)	WA State Department of Fish and Wildlife	Wildlife Refuge	1999	Permitted with same controls as mentioned for Wahluke Slope above
3000 Area	Port of Benton	Economic Development	1980	Disposed (title transfer)
3000 Area	Port of Benton	Economic Development	1996	Disposed (title transfer)
Fitzner-Eberhardt Arid Lands Ecology Reserve Unit <sup>(b)</sup>	U.S. Fish and Wildlife Service	Wildlife Reserve	1998	Permitted with same controls as mentioned for Wahluke Slope above.
Laser Interferometer Gravitational Wave Observatory (LIGO)	The National Science Foundation	Research	1998	Permitted
1100 Area	Port of Benton	Economic Development	1998	Disposed (title transfer)
Wahluke Slope <sup>(b)</sup> (remainder/all)	U.S. Fish and Wildlife Service	Wildlife Refuge	1999	Permitted with same controls as mentioned for Wahluke Slope above.
(a) Does not include release of lands within the City of Richland, lease of the city itself, leased facilities on the Hanford Site, or lands released before 1964.				
(b) Included in Hanford Reach National Monument, established June 9, 2000 (65 FR 37253).				

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## 4.8. Visual Resources

With the exception of Rattlesnake Mountain, the land near the Hanford Site is generally flat with little relief. Rattlesnake Mountain, rising to 1060 m (3477 ft) above mean sea level forms the western boundary of the Hanford Site, and Gable Mountain and Gable Butte are the highest landforms within the Site (Figure 4.8-1). The view toward Rattlesnake Mountain is visually pleasing, especially during the springtime when wildflowers are in bloom. Large rolling hills are located to the west and far north. The Columbia River, flowing across the northern part of the Hanford Site and forming the eastern boundary, is generally considered scenic, with its contrasting blue against a background of brown basaltic rocks and sagebrush (DOE 1999a). The White Bluffs, steep whitish-brown bluffs adjacent to the Columbia River and above the northern boundary of the river in this region, are a major feature of the landscape.

Traditional Native American religion is manifest in the earth, water, sky, and all animate or inanimate beings that inhabit a given location. The National Historic Preservation Act (16 USC 470, *et seq.*), the Native American Graves Protection and Repatriation Act (25 USC 3001, *et seq.*), the Archaeological Resources Protection Act (16 USC 470aa, *et seq.*), and DOE's American Indian Policy (DOE 1992b), among other legislation and guidelines, all require the identification and protection of areas and resources of concern to Native Americans. The acquisition of spiritual guidance and assistance through personal vision quests is a religious practice of the Native Americans that lived near the Hanford Site. High spots were selected as sacred sites in part because they afforded extensive views of the landscape and seclusion for meditation, and the Gable Butte Block Survey during 2001 determined that Gable Butte and Gable Mountain likely were used for vision quests (Hale and Harvey 2002). Many Hanford facilities that clearly are not part of the "natural" landscape are easily seen from these sites.



**Figure 4.8-1.** Viewshed from Gable Mountain on the Hanford Site, Washington (modified from DOE 1999a)

## 4.9. Noise

*B.G. Fritz*

Noise is technically defined as the intensity, duration, and character of sounds from any and all sources (RCW 70.107). Sound waves are characterized by frequency, measured in Hertz (Hz), and sound pressure expressed as decibels (dB). Humans have a perceptible hearing range of 31 to 20,000 Hz. The decibel is a value equal to 10 times the logarithm of the ratio of a sound pressure squared to a standard reference sound-pressure level (20 micropascals) squared (Harris 1991). The threshold of audibility ranges from about 60 dB at a frequency of 31 Hz to less than about 1 dB between 900 and 8000 Hz. (For regulatory purposes, noise levels for perceptible frequencies are weighted to provide an A-weighted sound level [dBA] that correlates highly with individual community response to noise.) Sound levels outside the range of human hearing are not considered noise in a regulatory sense, even though wildlife may hear at these frequencies.

Noise levels are often reported as the equivalent sound level ( $L_{eq}$ ). The  $L_{eq}$  is expressed in dBA over a specified period of time, usually 1 hour or 24 hours. The  $L_{eq}$  is the equivalent steady sound level that, if continuous during a specified time period, would contain the same total energy as the actual time-varying sound over the monitored or modeled time period (Harris 1991).

### 4.9.1 Background Information

Studies of the propagation of noise at Hanford have been concerned primarily with occupational noise at work sites. Environmental noise levels have not been extensively evaluated because of the remoteness of most Hanford activities and isolation from receptors that are covered by federal or state statutes. This discussion focuses on what few environmental noise data are available. The majority of available information consists of model predictions, which in many cases have not been verified because the predictions indicate that the potential to violate federal or state standards is remote or unrealistic.

### 4.9.2 Environmental Noise Regulations

The Noise Control Act of 1972 (42 USC 4901) and its subsequent amendments (Quiet Communities Act of 1978 and 40 CFR 201-211) direct the regulation of environmental noise to states. The State of Washington has adopted Revised Code of Washington (RCW) 70.107, which authorizes Ecology to implement rules consistent with federal noise control legislation. RCW 70.107 and the implementing regulations embodied in WAC 173-60 through 173-70 define the management of environmental noise levels. Maximum noise levels are defined for the zoning of the area in accord with the environmental designation for noise abatement (EDNA). The Hanford Site is classified as a Class C EDNA on the basis of industrial activities. Unoccupied areas are also classified as Class C areas by default because they are neither Class A (residential) nor Class B (commercial). Maximum noise levels are established based on the EDNA classification of the receiving area and the source area (Table 4.9-1).

**Table 4.9-1.** Applicable State Noise Limitations for the Hanford Site, Washington, Based on Source and Receptor EDNA Designation

Source Hanford Site	Receptor		
	Class A Residential (dBA)	Class B Commercial (dBA)	Class C Industrial (dBA)
Class C - Day	60	65	70
Night	50	--	--

### 4.9.3 Hanford Site Sound Levels

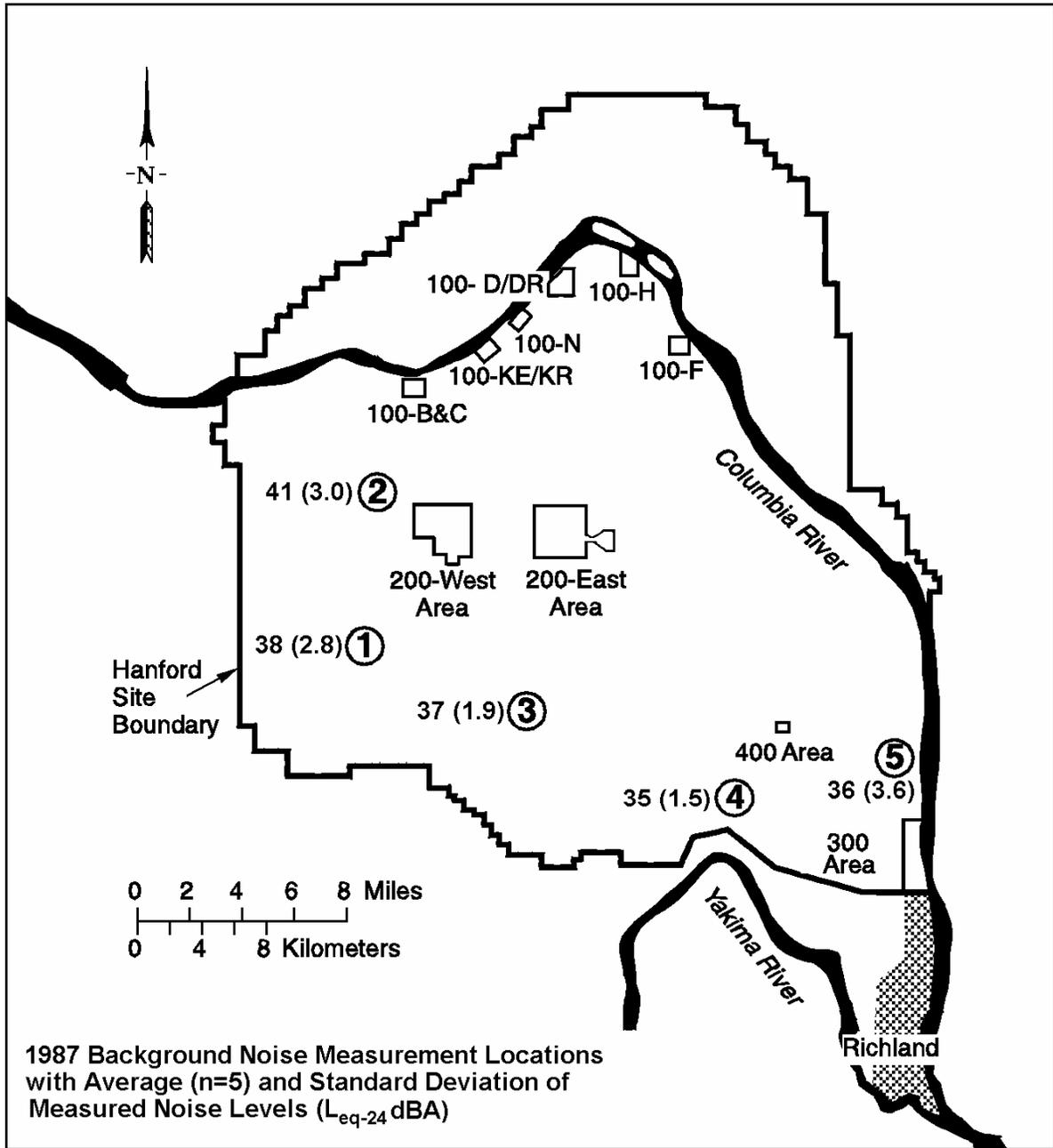
Most industrial facilities on the Hanford Site are located far enough away from the Site boundary that noise levels at the boundary are not measurable or are barely distinguishable from background noise levels. Modeling of environmental noises has been performed for commercial reactors and SR 240 through the Hanford Site. These data are not concerned with background levels of noise and are not reviewed here. There have been two studies measuring environmental noise at Hanford: during a 1981 site characterization for the Skagit/Hanford Nuclear Power Plant Site (NRC 1982) and when the Hanford Site was considered for a geologic waste repository (Basalt Waste Isolation Project) for spent commercial nuclear fuel and other high-level nuclear waste. Hanford Site characterization studies performed during 1987 included measurement of background environmental noise levels at five locations (Figure 4.9-1). Additionally, certain activities such as well drilling and sampling have the potential for producing noise in the field apart from major permanent facilities.

#### 4.9.3.1 Skagit/Hanford Data

Measurements of environmental noise were collected during June 1981 on the Hanford Site during site characterization prior to the construction of the Skagit/Hanford Nuclear Power Plant (NRC 1982). Fifteen sites were monitored and noise levels ranged from 30 to 61 dBA ( $L_{eq}$ ). The values for isolated areas ranged from 30 to 39 dBA. Measurements taken around the sites where Energy Northwest was constructing nuclear power plants (WNP-1, WNP-2 (now the Columbia Generating Station), and WNP-4) ranged from 51 to 64 dBA. Measurements taken along the Columbia River near the intake structures for the Columbia Generating Station were 48 and 52 dBA compared with more remote river noise levels of 46 dBA (measured about 4.8 km [3 mi] upstream of the intake structures). Community noise levels in North Richland (Horn Rapids Road and SR 240) were 61 dBA.

#### 4.9.3.2 Basalt Waste Isolation Project (BWIP) Data

Background noise levels were measured at five locations within the Hanford Site boundary (Figure 4.9-1). Noise levels are expressed as  $L_{eq}$  for 24 hours ( $L_{eq-24}$ ). Wind was identified as the primary contributor to background noise levels, with winds exceeding 19 km/hr (12 mi/hr) having a significant effect on noise levels. Background noise levels ( $L_{eq-24}$ ) in undeveloped areas around the Hanford Site were observed to range between 24 to 36 dBA (Coleman 1988). Periods of high wind, which normally occur in the spring, would elevate background noise levels (Harris 1991).



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**Figure 4.9-1.** Location of Background Noise Measurements Collected for the Basalt Waste Isolation Project, Hanford Site, Washington (modified from Coleman 1988)

### 4.9.3.3 New Production Reactor (NPR) EIS

Baseline noise estimates were determined for two locations: SR 24, leading from the Hanford Site west to Yakima, and SR 240, south of the Hanford Site and west of Richland where it handles maximum traffic volume (DOE 1991). Traffic volumes were predicted based on an operational work force and a construction work force. Both peak (rush hour) and off-peak hours were estimated. Noise levels were expressed in  $L_{eq}$  for 1-hr periods in dBA at a receptor located 15 m (49 ft) from the road edge (Table 4.9-2). Adverse responses would not be expected at increases of 5 dBA over background noise levels.

**Table 4.9-2.** Estimated Noise Resulting from Automobile Traffic at Hanford, Washington, with the New Production Reactor Environmental Impact Statement (DOE 1991)<sup>(a)</sup>

Location <sup>(b)</sup>	Scenario	Traffic flow (Vehicles/hr)		Noise levels ( $L_{eq}$ -1 hr in dBA)		Maximum Increase (dBA)
		Baseline	Maximum <sup>(c)</sup>	Baseline Noise Levels	Estimated Noise Levels <sup>(c)</sup>	
<b>Construction phase</b>						
SR 24	Off-Peak	91	91	62.0	62.0	0.0
	Peak	91	343	62.0		
SR 240	Off-Peak	571	579	70.2	70.6	0.4
	Peak	571	2839	70.2	73.5	3.3
<b>Operation phase</b>						
SR 24	Off-Peak	91	91	62.0	62.0	0.0
	Peak	300	386	65.7	66.2	1.5
SR 240	Off-Peak	571	582	70.2	70.5	0.3
	Peak	2239	3009	74.1	74.7	0.6

(a) Measured 15 m (49 ft) from the road edge.  
(b) SR 24 leads to Yakima; SR 240 leads to the Tri-Cities area.  
(c) Traffic flow and noise estimates varied with NPR technology; the maximum impacts from three NPR techniques are shown here.

#### 4.9.3.4 Noise Levels of Hanford Field Activities

Numerous field activities performed routinely by Hanford Site workers have the potential to generate noise at levels above typical background noise levels. These activities could possibly disturb wildlife when performed in remote areas. Typical field activities include well drilling, operation of pile drivers, driving heavy trucks on rough roads, and operation of heavy construction equipment such as dumptrucks and bulldozers. Typical noise levels achieved from Hanford Site activities range from 85 to 100 dBA at 15 m (49 ft). Attenuation of noise levels to 80 dBA and 60 dBA range from 30 to 150 m (98 to 492) and 250 to 1300 m (820 to 4270 ft), respectively (Harris 1991).

**Table 4.9-3.** Noise Levels Propagated from Construction Activities (Harris 1991)

<b>Activity</b>	<b>Noise Level (dBA) at 15 m (49 ft)</b>	<b>Distance to Attenuate to 80 dBA</b>	<b>Distance to Attenuate to 60 dBA</b>
Truck	85	30 m (98 ft)	250 m (820 ft)
Pile driver	100	150 m (492 ft)	1300 m (4270 ft)
Bulldozer	95	80 m (262 ft)	800 m (2620 ft)

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## **4.10. Occupational Health and Safety**

*J.P. Duncan*

This section describes worker health and safety experience at the Hanford Site for use in comparing and estimating projected effects of proposed activities evaluated in NEPA documents. Information is presented on industrial accident and illness experience as well as worker exposure to radiation.

### **4.10.1 Industrial Illness and Injury Experience at the Hanford Site**

Total occupational work hours at the Hanford Site for the five-year period 2000-2004 was 141,642,120 hours, or about 82,000 worker-years, based on 1735 hours of project-related labor per DOE worker-year. The DOE records occupational injuries and illnesses in four categories pertinent to NEPA analysis. Total recordable cases (TRC) are work-related deaths, illnesses, or injuries resulting in loss of consciousness, restriction of work or motion, transfer to another job, or requiring medical treatment beyond first aid. Lost workday cases (LWC) represent the number cases recorded resulting in days away from work or days of restricted work activity, or both, for affected employees. Fatalities are the number of occupationally related deaths (DOE 2005a).

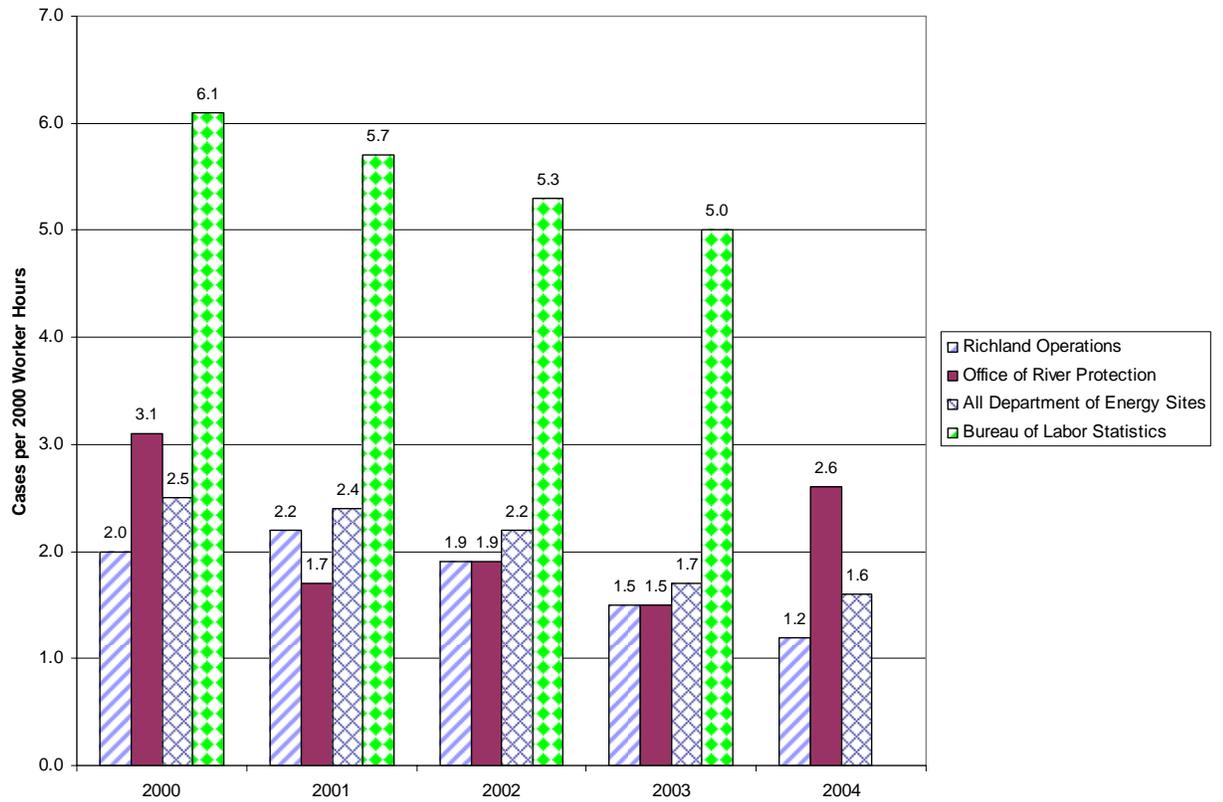
Occupational injury and illness TRC incidence rates for the Hanford Site Office of River Protection were 3.1 and 1.7 cases per 200,000 worker hours during 2000 and 2001, respectively (Figure 4.10-1). Rates increased to 1.9 cases per 200,000 worker hours during 2002. Due to changes in record-keeping requirements, recent data are not directly comparable to pre-2002 rates (DOE 2005a). Data for 2003 and 2004 indicate the occupational injury and illness incidence rates for the Office of River Protection were 1.5 and 2.6 cases per 200,000 worker hours, respectively.

Occupational injury and illness incidence rates for Richland Operations during 2000 and 2001 were 2.0 and 2.2 cases per 200,000 worker hours, respectively. Rates decreased during 2002 to 1.9 cases. Rates for 2003 and 2004 indicate the occupational injury and illness incidence rates for Richland Operations were 1.5 and 1.2 cases per 200,000 worker hours, respectively (DOE 2005a).

Occupational injury and illness incidence rates for all DOE sites demonstrate annual decreases, ranging from 2.5 cases per 200,000 worker hours during 2000 to 1.9 cases in 2002. Data for 2003 and 2004 decreased from 1.7 to 1.6 cases per 200,000 worker hours (DOE 2005a).

Over the 5-yr period from 2000 to 2004, rates on the Hanford Site averaged 2.0 cases per 200,000 worker hours, whereas the incidence rate for all DOE sites averaged slightly higher, at 2.1 cases per 200,000 worker hours (DOE 2005a). However, average rates for Office of River Protection for the period were slightly higher than DOE, at 2.2 cases per 200,000 hours. Both the Hanford Site and DOE-wide average TRC rates were well below the Bureau of Labor Statistics (BLS) rates for U.S. private industry of 5.5 cases per 200,000 worker hours during the same period (BLS 2005).

During the 5-yr period from 2000-2004, Hanford Site TRC and LWC rates were somewhat lower than those for all DOE sites, whereas the private sector was consistently higher (Table 4.10-1). There were no fatalities at the Hanford Site during the 2000 to 2004 period (DOE 2005a).



**Figure 4.10-1.** Occupational Injury and Illness Total Recordable Case Rates at the Hanford Site, Washington, Compared with Department of Energy and Private Industry (Note: Due to changes in the record-keeping requirement, 2002 through 2004 data are not comparable to pre-2002 rates) (DOE 2005a).

**Table 4.10-1.** Occupational Injury and Illness Incidence Rates, and Fatality Counts for Department of Energy Facilities and Private Industry.  
 (Note: Due to recordkeeping requirement changes, 2002-2004 data are not comparable to prior years) (DOE 2005a, BLS 2005).

	Total Recordable Cases <sup>(a)</sup>					Lost Work Cases <sup>(a)</sup>					Fatalities <sup>(b)</sup>				
	2000	2001	2002	2003	2004	2000	2001	2002	2003	2004	2000	2001	2002	2003	2004
Bureau of Labor Statistics	6.1	5.7	5.3	5.0	NA	3.0	2.8	2.8	2.6	NA	4.3	4.3	4.0	4.0	NA
2000-2003 Average	5.5					2.8					4.2				
U.S. Department of Energy	2.5	2.4	2.2	1.7	1.6	1.1	1.0	1.0	0.7	0.7	3.1	0	0.7	0	0
2000-2004 Average	2.1					0.9					1.0				
DOE Office of River Protection, Hanford Site	3.1	1.7	1.9	1.5	2.6	1.1	0.5	0.9	0.9	1.5	0	0	0	0	0
2000-2004 Average	2.2					1.0					0				
DOE Richland Operations Office, Hanford Site	2.0	2.2	1.9	1.5	1.2	0.9	0.8	1.0	0.8	0.5	0	0	0	0	0
2000-2004 Average	1.8					0.8					0				
(a) Per 200,000 worker hours. (b) Per 100,000 workers. NA – Data not available.															

#### 4.10.2 Occupational Radiation Exposure at the Hanford Site

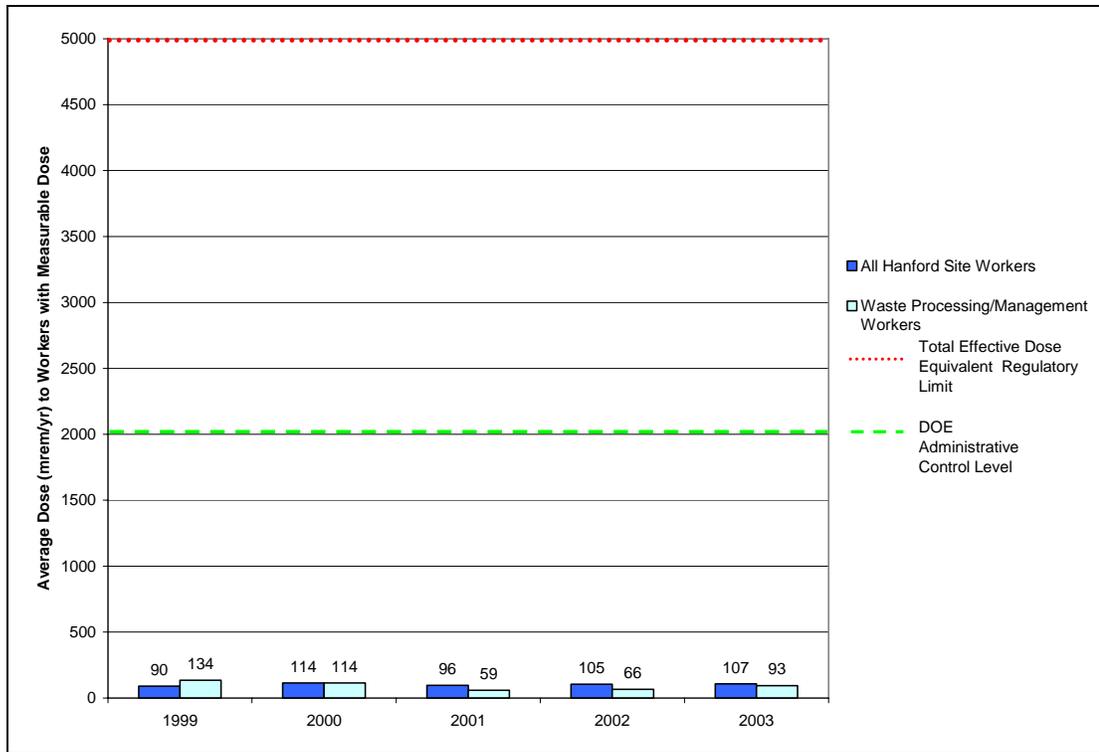
DOE's Office of Safety and Health reports occupational radiation exposure data for all monitored DOE employees, contractors, subcontractors, and members of the public associated with DOE facilities. The number of workers monitored during the 5-yr period, 1999-2003, at the Hanford Site ranged from 10,048 to 11,310, for a total of 53,090 worker-years of monitored exposure. Waste processing and management facility employees on the Hanford Site, monitored for the same period, represented approximately 12 percent of the site's monitored workers, a total of 6180 worker-years of exposure (DOE 2005b).

DOE has established dose limits to control radiation exposures. Doses are expressed as Total Effective Dose Equivalent (TEDE), which is defined as the sum of the dose from radiation sources internal and external to the body, reported in units of rem or mrem. The regulatory limit for an individual worker is 5000 mrem (50 mSv) per year TEDE (10 CFR 835). A DOE Administrative Control Level (ACL) of 2000 mrem (20 mSv) per year TEDE has been established for all DOE workers to maintain doses well below the regulatory limit (DOE 1999c). There were no individual worker doses in excess of the 2000 mrem (20 mSv) per year TEDE ACL or the 5000 mrem (50 mSv) per year TEDE regulatory limit at the Hanford Site during the period 1999-2003 (DOE 2005b).

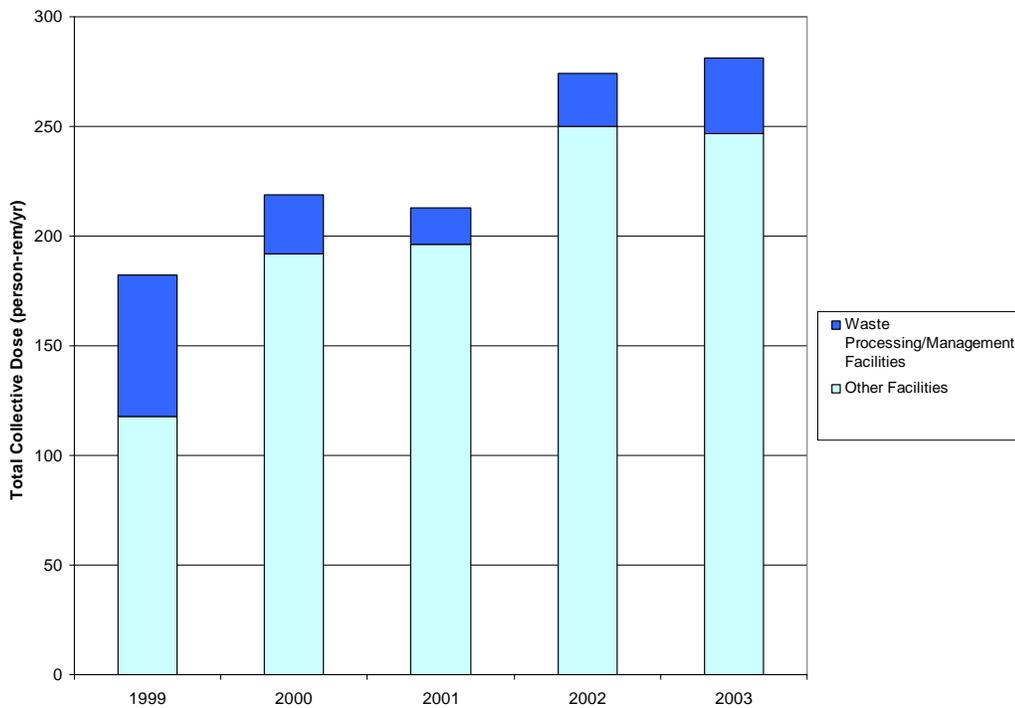
Measurable dose is used to report the dose for individuals whose TEDE is statistically greater than background measurements. Twenty-one percent of the total monitored Hanford Site employees and 28 percent of the waste processing and management facility employees had measurable doses during the 1999-2003 period. The average measurable dose for all monitored waste processing and management facility employees decreased 30 percent from 134 to 93 mrem/yr (1.34 to 0.93 mSv/yr) TEDE for the period 1999 to 2003. The average dose for all monitored Hanford workers increased from 90 mrem/yr (0.90 mSv/yr) TEDE during 1999 to 107 mrem/yr (1.07 mSv/yr) TEDE during 2003, an increase of 19 percent (Figure 4.10-2) (DOE 2005b).

Collective dose, an indicator of the overall workforce radiation exposure, is the sum of the dose received by all individual workers with measurable dose and is expressed in units of person-rem. (For example, a dose of 1 rem to each of 10 workers would result in a collective dose of 10 person-rem.) The collective dose for Hanford Site waste processing and management facility employees ranged from 17 to 64 person-rem during the 5-year period from 1999-2003. The corresponding collective dose to all Hanford workers ranged from 182 to 281 person-rem per year during this same period (Figure 4.10-3).

Radiation exposure data for the period 1999-2003 indicate the total number of individuals monitored on the Hanford Site has generally decreased, while the number of individuals with measurable dose has increased (Table 4.10-2) (DOE 2005b). The 5-yr average occupational dose for workers with measurable dose was 103 mrem/yr (10.3 mSv/yr) for all Hanford workers and 96 mrem/yr (9.6 mSv/yr) for waste management facility workers, well below the established ACL of 2000 mrem/yr (20 mSv/yr).



**Figure 4.10-2.** Average Measureable Dose (mrem/yr) to Hanford Site, Washington, 1999-2003 (DOE 2005b) (1 mrem = 0.01 mSv)



**Figure 4.10-3.** Collective Operational Dose (person-mrem/yr) at the Hanford Site, Washington, 1999-2003 (DOE 2005b) (1 rem = 0.01 Sv)

**Table 4.10-2.** Radiation Exposure Data for the Hanford Site, Washington, 1999-2003 (DOE 2005b)  
(1 mrem = 0.01 mSv)

<b>Year</b>	<b>Total Number Monitored</b>	<b>Number with Measurable Dose</b>	<b>Percent with Dose &gt;0</b>	<b>Total Collective Dose (TEDE) to Workers with Measurable Dose (Person-mrem/yr)</b>	<b>Average Dose to Workers with Measurable Dose (mrem) (Dose &gt;0)</b>
<b>Hanford Site</b>					
2003	10,564	2,626	25	281,000	107
2002	10,669	2,611	24	274,000	105
2001	10,499	2,219	21	214,000	96
2000	10,048	1,923	19	219,000	114
1999	11,310	2,013	18	182,000	90
<b>Cumulative Totals</b> 1999-2003	<b>53,090</b>	<b>11,392</b>	<b>21</b>	<b>1,170,000</b>	<b>103</b>
<b>Waste Processing/Management Facility</b>					
2003	1,203	366	30	34,000	93
2002	1,225	360	29	24,000	66
2001	1,216	294	24	17,000	59
2000	938	234	25	27,000	114
1999	1,598	479	30	64,000	134
<b>Cumulative Totals</b> 1999-2003	<b>6,180</b>	<b>1,733</b>	<b>28</b>	<b>166,000</b>	<b>96</b>

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# **Appendix A**

## **Atmospheric Dispersion Tables**

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# Atmospheric Dispersion Tables

## Definitions:

X = Air Concentration in Curies per Cubic Meter (Ci/m<sup>3</sup>)

Q = Emission Rate in Curies per Second (Ci/s)

E = Short term 95 Percent Centerline Concentration (Ci/m<sup>3</sup>)

## Atmospheric Stability Class:

A – Extremely unstable

B – Moderately unstable

C – Slightly unstable

D – Neutral

E – Slightly stable

F – Moderately stable

G – Very stable

## Conversion Factors:

1 Ci = 37,000 mBq

1 pCi = 0.037 Bq

1 Ci = 10<sup>12</sup> pCi

1 m<sup>3</sup> = 35.3 ft<sup>3</sup>

1.61 km = 1 mi

## Examples for the use of Chronic (X/Q') and Acute (E/Q') Release Tables:

- **Chronic Release (Long Term):**

Assume wind is from 100N Area towards the south. To find the estimated air concentration 1 km downwind from a constant source (i.e. stack) with a release rate of 0.0028Ci/s, multiply the X/Q' value from the table ( $3.1 \times 10^{-6} \text{ s/m}^3$ ) by the release rate (0.0028Ci/s):

$$\mathbf{X} = (3.1 \times 10^{-6} \text{ s/m}^3) (0.0028\text{Ci/s}) = 10^{-8} \text{ Ci/m}^3 = 10,000 \text{ pCi/m}^3$$

- **Acute Release (Short Term):**

Assume wind is from 100N Area towards the south. To find the estimated maximum centerline concentration (95 percent in this direction from a ground level accidental release (10 Ci in 1 hr = 0.0028 Ci/s) at a location 1 km downwind, multiply the E/Q' value from the table ( $9.8 \times 10^{-4} \text{ s/m}^3$ ) by the release rate (0.0028 Ci/s):

$$\mathbf{E} = (9.8 \times 10^{-4} \text{ s/m}^3) (0.0028 \text{ Ci/s}) = 2.7 \times 10^{-6} \text{ Ci/m}^3 = 2.7 \times 10^6 \text{ pCi/m}^3$$

- **Maximum Emission Rate:**

Another use of the X/Q' value is to estimate a maximum allowable release rate. Assume that the maximum allowable air concentration of a radionuclide 4 km north of 100-N Area is 100 pCi/m<sup>3</sup>. The maximum allowable release rate can be estimated by dividing the X/Q' value from the table (2.5 x 10<sup>-7</sup> s/m<sup>3</sup>) by the maximum allowable concentration:

$$Q = 2.5 \times 10^{-7} \text{ s/m}^3 / 100 \text{ pCi/m}^3 = 2.5 \times 10^{-9} \text{ pCi/s}$$

**Table A1.** Joint Frequency Distributions of Atmospheric Stability, Wind Speed, and Transport Direction for the 100 Area at 9.1 m (30 ft) above Ground Level, Hanford Site, Washington. Based on 1983-2002 data from the 100-N Area instrumented tower.

Average Wind Speed	Atmospheric Stability Class 9.1 m	Percentage of Time Wind Blows in the 100N Area toward the Direction Indicated															
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.89 m/s (2 mph)	A	0.09	0.07	0.05	0.05	0.07	0.06	0.05	0.03	0.03	0.04	0.06	0.09	0.12	0.12	0.14	0.11
	B	0.07	0.05	0.04	0.03	0.04	0.03	0.03	0.03	0.02	0.02	0.04	0.05	0.08	0.10	0.09	0.08
	C	0.10	0.08	0.07	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.06	0.06	0.11	0.12	0.14	0.12
	D	0.47	0.40	0.44	0.50	0.76	0.87	0.70	0.47	0.44	0.41	0.48	0.55	0.62	0.64	0.68	0.57
	E	0.77	0.68	0.79	0.95	1.31	1.31	1.07	0.82	0.76	0.71	0.82	1.00	1.22	1.20	1.05	0.87
	F	0.35	0.36	0.46	0.53	0.63	0.52	0.41	0.28	0.24	0.25	0.37	0.48	0.56	0.56	0.53	0.42
	G	0.30	0.26	0.29	0.31	0.37	0.30	0.23	0.16	0.15	0.17	0.27	0.41	0.59	0.63	0.54	0.36
2.65 m/s (6 mph)	A	0.25	0.23	0.15	0.07	0.12	0.12	0.10	0.07	0.06	0.08	0.20	0.30	0.37	0.33	0.30	0.27
	B	0.16	0.17	0.12	0.06	0.07	0.07	0.04	0.03	0.04	0.10	0.15	0.18	0.17	0.18	0.16	
	C	0.14	0.15	0.13	0.05	0.08	0.12	0.10	0.05	0.04	0.04	0.09	0.13	0.15	0.12	0.14	0.13
	D	0.34	0.41	0.35	0.30	0.50	0.62	0.54	0.30	0.19	0.19	0.36	0.65	0.70	0.54	0.41	0.35
	E	0.46	0.52	0.62	0.97	1.22	1.10	0.99	0.56	0.42	0.45	0.91	1.93	2.15	1.33	0.79	0.50
	F	0.08	0.10	0.18	0.42	0.56	0.40	0.27	0.17	0.12	0.14	0.30	0.68	0.70	0.39	0.20	0.10
	G	0.04	0.04	0.08	0.13	0.20	0.22	0.16	0.06	0.04	0.05	0.17	0.44	0.61	0.33	0.13	0.05
4.7 m/s (10.5 mph)	A	0.05	0.15	0.13	0.02	0.03	0.03	0.04	0.02	0.02	0.05	0.17	0.21	0.28	0.26	0.09	0.04
	B	0.02	0.05	0.05	0.01	0.02	0.02	0.03	0.01	0.01	0.02	0.07	0.07	0.09	0.08	0.03	0.01
	C	0.02	0.06	0.04	0.01	0.01	0.02	0.04	0.02	0.02	0.02	0.07	0.06	0.06	0.07	0.03	0.02
	D	0.17	0.23	0.12	0.04	0.05	0.12	0.21	0.10	0.06	0.08	0.20	0.29	0.43	0.38	0.18	0.15
	E	0.17	0.30	0.20	0.11	0.11	0.15	0.40	0.23	0.17	0.25	0.54	1.11	1.95	1.34	0.33	0.14
	F	0.02	0.02	0.02	0.03	0.02	0.02	0.08	0.06	0.03	0.03	0.06	0.27	0.38	0.17	0.03	0.02
	G	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.01	0.01	0.00	0.02	0.07	0.04	0.01	0.00	0.00
7.2 m/s (16 mph)	A	0.02	0.05	0.04	0.01	0.00	0.01	0.01	0.01	0.00	0.02	0.11	0.08	0.11	0.17	0.06	0.01
	B	0.01	0.02	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.05	0.03	0.05	0.08	0.02	0.00
	C	0.01	0.02	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.04	0.02	0.05	0.08	0.03	0.00
	D	0.09	0.13	0.06	0.01	0.00	0.01	0.04	0.04	0.03	0.06	0.18	0.11	0.23	0.49	0.29	0.05
	E	0.06	0.16	0.11	0.03	0.01	0.01	0.07	0.07	0.08	0.15	0.37	0.31	0.78	1.22	0.30	0.06
	F	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.04	0.02	0.01	0.01
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.8 m/s (22 mph)	A	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.02	0.02	0.04	0.02	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.01	0.03	0.01	0.00
	C	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.01	0.04	0.02	0.00
	D	0.02	0.04	0.03	0.01	0.00	0.00	0.00	0.00	0.01	0.04	0.08	0.05	0.07	0.27	0.22	0.00
	E	0.02	0.05	0.03	0.01	0.00	0.00	0.00	0.01	0.02	0.09	0.17	0.08	0.11	0.36	0.17	0.01
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12.7 m/s (29 mph)	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00
	D	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.02	0.02	0.08	0.06	0.00
	E	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.04	0.02	0.02	0.06	0.04	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.6 m/s (35 mph)	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19 m/s (43 mph)	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

**Table A2.** Joint Frequency Distributions of Atmospheric Stability, Wind Speed, and Transport Direction for the 100 Area at 60 m (197 ft) above Ground Level, Hanford Site, Washington. Based on 1986-2002 data from the 100-N Area instrumented tower.

Average Wind Speed	Atmospheric Stability Class	Percentage of Time Wind Blows in the 100N Area toward the Direction Indicated															
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.89 m/s (2 mph)	A	0.05	0.04	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.03	0.05	0.05	0.05	0.07	0.07
	B	0.07	0.04	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.02	0.04	0.05	0.08	0.09	0.09
	C	0.13	0.08	0.06	0.04	0.04	0.03	0.04	0.03	0.03	0.02	0.04	0.06	0.11	0.12	0.13	0.13
	D	0.40	0.37	0.39	0.47	0.71	0.81	0.68	0.48	0.38	0.33	0.35	0.45	0.54	0.54	0.46	0.43
	E	0.71	0.66	0.69	0.86	1.12	1.11	0.90	0.69	0.57	0.52	0.55	0.58	0.68	0.67	0.66	0.59
	F	0.20	0.21	0.31	0.45	0.69	0.58	0.41	0.26	0.22	0.18	0.20	0.19	0.26	0.24	0.23	0.21
	G	0.23	0.23	0.32	0.43	0.59	0.46	0.37	0.24	0.19	0.16	0.14	0.19	0.23	0.31	0.30	0.25
2.65 m/s (6 mph)	A	0.21	0.19	0.11	0.05	0.07	0.09	0.06	0.05	0.04	0.05	0.11	0.22	0.24	0.18	0.16	0.17
	B	0.17	0.20	0.13	0.05	0.07	0.07	0.07	0.05	0.03	0.04	0.10	0.15	0.19	0.14	0.11	0.11
	C	0.14	0.21	0.13	0.06	0.09	0.14	0.11	0.06	0.04	0.04	0.10	0.15	0.14	0.10	0.07	0.07
	D	0.31	0.37	0.34	0.30	0.53	0.67	0.63	0.36	0.20	0.17	0.26	0.39	0.52	0.45	0.30	0.23
	E	0.68	0.71	0.61	0.72	1.27	1.30	1.04	0.61	0.44	0.34	0.51	0.76	1.23	1.25	0.83	0.56
	F	0.10	0.09	0.15	0.38	0.73	0.63	0.41	0.20	0.12	0.10	0.13	0.22	0.40	0.53	0.34	0.14
	G	0.10	0.09	0.12	0.22	0.31	0.27	0.27	0.16	0.07	0.06	0.06	0.11	0.29	0.48	0.36	0.15
4.7 m/s (10.5 mph)	A	0.03	0.13	0.12	0.02	0.03	0.04	0.04	0.02	0.02	0.04	0.16	0.19	0.23	0.15	0.04	0.02
	B	0.02	0.07	0.06	0.01	0.02	0.03	0.04	0.02	0.01	0.02	0.09	0.08	0.10	0.05	0.02	0.02
	C	0.02	0.06	0.06	0.01	0.01	0.03	0.04	0.02	0.02	0.02	0.08	0.07	0.05	0.06	0.03	0.02
	D	0.21	0.25	0.14	0.07	0.06	0.13	0.25	0.10	0.06	0.07	0.13	0.17	0.28	0.23	0.15	0.16
	E	0.33	0.43	0.31	0.25	0.29	0.37	0.59	0.32	0.26	0.27	0.43	0.66	1.50	1.29	0.47	0.29
	F	0.04	0.05	0.05	0.05	0.06	0.10	0.19	0.12	0.06	0.06	0.08	0.15	0.40	0.51	0.13	0.03
	G	0.03	0.03	0.02	0.02	0.02	0.02	0.06	0.03	0.02	0.01	0.02	0.03	0.10	0.27	0.10	0.02
7.2 m/s (16 mph)	A	0.01	0.10	0.05	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.10	0.07	0.16	0.16	0.02	0.01
	B	0.01	0.03	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.05	0.03	0.06	0.06	0.01	0.00
	C	0.01	0.03	0.02	0.00	0.00	0.00	0.02	0.01	0.01	0.01	0.05	0.03	0.05	0.06	0.02	0.00
	D	0.14	0.16	0.06	0.01	0.01	0.01	0.09	0.08	0.05	0.06	0.13	0.12	0.26	0.36	0.18	0.05
	E	0.19	0.28	0.19	0.13	0.13	0.14	0.30	0.24	0.17	0.24	0.46	0.55	1.63	1.79	0.38	0.12
	F	0.02	0.02	0.02	0.01	0.01	0.01	0.05	0.06	0.03	0.03	0.04	0.07	0.37	0.48	0.05	0.01
	G	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.04	0.09	0.01	0.00
9.8 m/s (22 mph)	A	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.06	0.03	0.05	0.08	0.01	0.00
	B	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.02	0.04	0.01	0.00
	C	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.03	0.05	0.01	0.00
	D	0.07	0.08	0.05	0.01	0.00	0.00	0.01	0.02	0.02	0.05	0.13	0.09	0.16	0.39	0.23	0.01
	E	0.13	0.18	0.12	0.06	0.08	0.07	0.10	0.09	0.10	0.14	0.28	0.26	0.69	1.27	0.30	0.07
	F	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.05	0.09	0.01	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00
12.7 m/s (29 mph)	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.01	0.02	0.01	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.03	0.01	0.00
	D	0.02	0.03	0.03	0.01	0.00	0.00	0.00	0.00	0.01	0.05	0.07	0.05	0.07	0.19	0.16	0.00
	E	0.05	0.10	0.08	0.02	0.02	0.02	0.03	0.04	0.04	0.10	0.17	0.11	0.22	0.44	0.15	0.03
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.6 m/s (35 mph)	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.02	0.02	0.05	0.03	0.00
	E	0.01	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.05	0.03	0.04	0.08	0.04	0.01
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19 m/s (43 mph)	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.00	0.01	0.03	0.01	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

**Table A3.** Joint Frequency Distributions of Atmospheric Stability, Wind Speed, and Transport Direction for the 200 Areas at 9.1 m (30 ft) above Ground Level, Hanford Site, Washington. Based on 1983-2002 data from the Hanford Meteorology Station instrumented tower.

Average Wind Speed	Atmospheric Stability Class	Percentage of Time Wind Blows in the 200 Areas toward the Direction Indicated															
		9.1 m	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE
0.89 m/s (2 mph)	A	0.32	0.36	0.39	0.29	0.29	0.27	0.21	0.16	0.14	0.12	0.11	0.10	0.11	0.13	0.19	0.25
	B	0.15	0.14	0.16	0.11	0.10	0.10	0.09	0.05	0.06	0.05	0.05	0.04	0.06	0.07	0.10	0.12
	C	0.13	0.13	0.13	0.09	0.08	0.08	0.08	0.06	0.04	0.04	0.05	0.04	0.05	0.06	0.08	0.12
	D	0.76	0.65	0.62	0.49	0.52	0.55	0.57	0.40	0.34	0.29	0.32	0.35	0.44	0.52	0.69	0.73
	E	0.37	0.28	0.26	0.24	0.28	0.33	0.44	0.38	0.34	0.33	0.45	0.48	0.54	0.59	0.58	0.50
	F	0.24	0.16	0.15	0.14	0.16	0.19	0.25	0.24	0.26	0.29	0.34	0.34	0.40	0.42	0.39	0.30
	G	0.10	0.08	0.10	0.08	0.08	0.07	0.10	0.09	0.10	0.10	0.12	0.10	0.12	0.14	0.15	0.13
2.65 m/s (6 mph)	A	0.75	0.53	0.42	0.37	0.44	0.46	0.42	0.28	0.23	0.25	0.33	0.25	0.21	0.31	0.71	0.83
	B	0.24	0.16	0.11	0.10	0.10	0.12	0.10	0.07	0.07	0.06	0.08	0.07	0.08	0.15	0.31	0.32
	C	0.18	0.11	0.08	0.07	0.07	0.08	0.08	0.05	0.04	0.05	0.05	0.05	0.05	0.09	0.23	0.25
	D	0.58	0.39	0.27	0.24	0.30	0.31	0.38	0.28	0.21	0.21	0.28	0.38	0.55	1.02	1.60	1.02
	E	0.28	0.15	0.12	0.12	0.21	0.27	0.33	0.39	0.32	0.30	0.55	1.01	1.78	2.11	1.69	0.71
	F	0.14	0.07	0.05	0.06	0.08	0.12	0.27	0.35	0.33	0.41	0.71	1.33	1.79	1.89	1.54	0.56
	G	0.04	0.03	0.02	0.03	0.03	0.03	0.11	0.17	0.18	0.20	0.31	0.63	0.64	0.71	0.64	0.17
4.7 m/s (10.5 mph)	A	0.22	0.24	0.14	0.05	0.06	0.04	0.03	0.05	0.06	0.15	0.33	0.42	0.24	0.31	0.75	0.33
	B	0.04	0.04	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.04	0.07	0.11	0.08	0.11	0.23	0.08
	C	0.03	0.02	0.01	0.01	0.01	0.00	0.01	0.01	0.02	0.03	0.05	0.07	0.06	0.08	0.18	0.07
	D	0.13	0.12	0.06	0.03	0.04	0.03	0.05	0.09	0.11	0.19	0.34	0.50	0.60	1.23	1.46	0.31
	E	0.06	0.05	0.04	0.02	0.02	0.02	0.05	0.10	0.12	0.16	0.38	0.72	1.10	2.00	1.70	0.21
	F	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.09	0.04	0.03	0.10	0.35	0.33	0.55	0.68	0.09
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.01	0.02	0.05	0.21	0.09	0.18	0.30	0.02
7.2 m/s (16 mph)	A	0.03	0.06	0.04	0.01	0.00	0.00	0.00	0.01	0.02	0.06	0.26	0.37	0.15	0.20	0.52	0.11
	B	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.06	0.08	0.03	0.05	0.13	0.02
	C	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.04	0.06	0.03	0.04	0.09	0.01
	D	0.02	0.04	0.03	0.01	0.00	0.00	0.01	0.03	0.08	0.19	0.41	0.36	0.24	0.72	0.93	0.08
	E	0.01	0.04	0.02	0.00	0.00	0.00	0.00	0.03	0.08	0.14	0.28	0.24	0.15	0.43	0.81	0.04
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.02	0.01	0.01	0.01	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.8 m/s (22 mph)	A	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.11	0.14	0.04	0.04	0.18	0.01
	B	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.03	0.01	0.01	0.05	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.01	0.03	0.00
	D	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.10	0.19	0.10	0.03	0.12	0.27	0.01
	E	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.05	0.07	0.04	0.01	0.05	0.15	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12.7 m/s (29 mph)	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.01	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.04	0.03	0.01	0.01	0.01	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.01	0.00	0.00	0.01	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.6 m/s (35 mph)	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19 m/s (43 mph)	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

**Table A4.** Joint Frequency Distributions of Atmospheric Stability, Wind Speed, and Transport Direction for the 200 Areas at 60 m (197 ft) above Ground Level, Hanford Site, Washington. Based on 1983-2002 data from the Hanford Meteorology Station instrumented tower.

Average Wind Speed	Atmospheric Stability Class	Percentage of Time Wind Blows in the 200 Areas toward the Direction Indicated															
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.89 m/s (2 mph)	A	0.11	0.15	0.16	0.12	0.13	0.13	0.08	0.07	0.05	0.04	0.05	0.04	0.05	0.04	0.06	0.09
	B	0.08	0.08	0.08	0.07	0.07	0.06	0.06	0.04	0.02	0.03	0.02	0.02	0.03	0.03	0.05	0.07
	C	0.08	0.07	0.09	0.07	0.05	0.06	0.06	0.04	0.02	0.02	0.02	0.02	0.03	0.03	0.04	0.07
	D	0.49	0.46	0.42	0.38	0.40	0.39	0.46	0.33	0.22	0.20	0.20	0.19	0.24	0.30	0.39	0.48
	E	0.25	0.20	0.18	0.17	0.21	0.24	0.31	0.23	0.16	0.15	0.16	0.16	0.21	0.23	0.27	0.28
	F	0.18	0.13	0.11	0.11	0.13	0.13	0.18	0.15	0.12	0.12	0.13	0.12	0.16	0.18	0.21	0.20
	G	0.06	0.04	0.05	0.05	0.06	0.06	0.08	0.07	0.08	0.07	0.07	0.08	0.08	0.10	0.11	0.09
2.65 m/s (6 mph)	A	0.67	0.62	0.54	0.49	0.58	0.45	0.51	0.42	0.26	0.24	0.24	0.19	0.16	0.22	0.74	
	B	0.22	0.19	0.15	0.12	0.14	0.12	0.12	0.10	0.08	0.07	0.07	0.06	0.07	0.11	0.24	0.28
	C	0.19	0.13	0.11	0.08	0.08	0.08	0.10	0.07	0.05	0.05	0.06	0.04	0.04	0.07	0.19	0.25
	D	0.68	0.50	0.36	0.31	0.36	0.31	0.44	0.32	0.20	0.20	0.22	0.24	0.34	0.58	1.19	1.01
	E	0.34	0.23	0.18	0.16	0.23	0.23	0.34	0.33	0.18	0.18	0.25	0.34	0.52	0.78	0.90	0.61
	F	0.28	0.13	0.12	0.08	0.12	0.12	0.24	0.25	0.19	0.18	0.23	0.33	0.55	0.79	0.83	0.59
	G	0.08	0.05	0.04	0.03	0.05	0.03	0.07	0.12	0.09	0.10	0.14	0.19	0.32	0.37	0.30	0.20
4.7 m/s (10.5 mph)	A	0.35	0.33	0.21	0.10	0.12	0.08	0.10	0.09	0.10	0.19	0.32	0.32	0.16	0.25	0.76	0.48
	B	0.08	0.07	0.03	0.02	0.03	0.02	0.02	0.03	0.03	0.04	0.08	0.09	0.06	0.11	0.29	0.13
	C	0.05	0.04	0.03	0.01	0.01	0.01	0.02	0.01	0.02	0.03	0.05	0.06	0.04	0.08	0.21	0.11
	D	0.18	0.14	0.08	0.06	0.09	0.07	0.11	0.13	0.10	0.15	0.24	0.30	0.32	0.83	1.47	0.42
	E	0.19	0.10	0.10	0.07	0.11	0.09	0.13	0.20	0.12	0.14	0.27	0.54	0.98	1.76	1.52	0.42
	F	0.12	0.06	0.03	0.02	0.04	0.03	0.08	0.20	0.08	0.06	0.16	0.38	0.81	1.37	1.39	0.46
	G	0.03	0.01	0.00	0.00	0.01	0.00	0.02	0.04	0.03	0.03	0.06	0.15	0.34	0.46	0.59	0.23
7.2 m/s (16 mph)	A	0.06	0.13	0.08	0.02	0.01	0.01	0.01	0.02	0.03	0.11	0.31	0.40	0.14	0.21	0.56	0.12
	B	0.01	0.02	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.03	0.05	0.09	0.04	0.08	0.14	0.03
	C	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.04	0.06	0.03	0.05	0.11	0.01
	D	0.06	0.08	0.04	0.02	0.01	0.01	0.03	0.08	0.09	0.16	0.34	0.44	0.40	0.98	1.17	0.12
	E	0.06	0.05	0.04	0.02	0.02	0.01	0.04	0.10	0.10	0.14	0.33	0.66	0.90	2.18	1.69	0.14
	F	0.04	0.02	0.02	0.01	0.01	0.00	0.03	0.08	0.03	0.03	0.06	0.24	0.39	0.92	1.26	0.14
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.01	0.00	0.01	0.05	0.08	0.18	0.59	0.09
9.8 m/s (22 mph)	A	0.01	0.02	0.03	0.01	0.00	0.00	0.00	0.00	0.01	0.04	0.18	0.23	0.06	0.12	0.37	0.03
	B	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.05	0.01	0.03	0.08	0.01
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.04	0.01	0.03	0.06	0.00
	D	0.02	0.03	0.02	0.01	0.00	0.00	0.00	0.03	0.05	0.13	0.31	0.27	0.15	0.64	0.73	0.03
	E	0.01	0.04	0.03	0.00	0.00	0.00	0.01	0.03	0.06	0.12	0.27	0.29	0.19	0.75	0.95	0.03
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.02	0.03	0.04	0.08	0.18	0.01
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.08	0.00
12.7 m/s (29 mph)	A	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.11	0.11	0.02	0.03	0.19	0.01
	B	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.03	0.01	0.01	0.05	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.00	0.01	0.04	0.00
	D	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.03	0.13	0.26	0.13	0.04	0.29	0.52	0.01
	E	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.03	0.08	0.13	0.08	0.03	0.17	0.31	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.6 m/s (35 mph)	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.02	0.00	0.00	0.02	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.06	0.09	0.03	0.01	0.03	0.06	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.04	0.01	0.01	0.02	0.05	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19 m/s (43 mph)	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.02	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

**Table A5.** Joint Frequency Distributions of Atmospheric Stability, Wind Speed, and Transport Direction for the 300 Area at 9.1 m (30 ft) above Ground Level, Hanford Site, Washington. Based on 1983-2002 data from the 300 Area instrumented tower.

Average Wind Speed	Atmospheric Stability Class	Percentage of Time Wind Blows in the 300 Area toward the Direction Indicated															
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.89 m/s (2 mph)	A	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.01	0.01
	B	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.01
	C	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.01
	D	0.29	0.21	0.21	0.22	0.26	0.37	0.38	0.33	0.28	0.24	0.25	0.20	0.22	0.20	0.28	0.34
	E	0.56	0.33	0.25	0.24	0.34	0.54	0.76	0.82	0.83	0.68	0.63	0.57	0.58	0.65	0.79	0.82
	F	0.19	0.10	0.08	0.07	0.12	0.20	0.36	0.37	0.34	0.26	0.26	0.21	0.25	0.27	0.35	0.28
	G	0.22	0.10	0.06	0.06	0.08	0.13	0.24	0.30	0.27	0.20	0.20	0.18	0.19	0.25	0.36	0.32
2.65 m/s (6 mph)	A	0.03	0.04	0.04	0.04	0.07	0.07	0.07	0.04	0.04	0.04	0.05	0.02	0.01	0.01	0.01	0.02
	B	0.01	0.01	0.03	0.02	0.03	0.04	0.05	0.05	0.04	0.05	0.04	0.01	0.00	0.00	0.00	0.01
	C	0.02	0.05	0.12	0.13	0.10	0.10	0.09	0.06	0.05	0.08	0.07	0.03	0.01	0.01	0.01	0.02
	D	0.87	0.63	0.50	0.60	0.85	1.11	1.36	0.68	0.65	0.72	0.58	0.29	0.17	0.16	0.45	0.90
	E	1.64	0.71	0.33	0.35	0.65	1.78	2.96	1.88	1.67	1.22	0.91	0.63	0.49	0.52	0.94	1.77
	F	0.52	0.12	0.03	0.03	0.13	0.97	1.60	0.65	0.44	0.30	0.22	0.16	0.15	0.17	0.32	0.62
	G	0.41	0.07	0.01	0.00	0.03	0.33	0.72	0.33	0.16	0.09	0.05	0.04	0.05	0.10	0.34	0.61
4.7 m/s (10.5 mph)	A	0.04	0.07	0.04	0.01	0.02	0.04	0.03	0.02	0.03	0.12	0.10	0.05	0.02	0.01	0.01	0.02
	B	0.02	0.09	0.07	0.00	0.01	0.02	0.04	0.02	0.04	0.11	0.11	0.04	0.01	0.01	0.01	0.01
	C	0.08	0.19	0.17	0.03	0.02	0.05	0.06	0.03	0.05	0.18	0.23	0.07	0.02	0.01	0.02	0.04
	D	0.70	0.59	0.30	0.13	0.17	0.35	0.48	0.25	0.42	0.98	0.97	0.47	0.15	0.11	0.31	0.71
	E	1.62	0.75	0.24	0.09	0.13	0.40	0.68	0.47	0.97	1.53	1.55	0.86	0.33	0.25	0.63	1.24
	F	0.64	0.18	0.01	0.01	0.02	0.24	0.26	0.06	0.11	0.21	0.26	0.12	0.05	0.04	0.10	0.31
	G	0.38	0.07	0.00	0.00	0.01	0.14	0.14	0.01	0.01	0.03	0.03	0.02	0.01	0.01	0.03	0.23
7.2 m/s (16 mph)	A	0.02	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.07	0.13	0.08	0.01	0.01	0.01	0.02
	B	0.02	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.08	0.13	0.09	0.02	0.01	0.02	0.00
	C	0.04	0.06	0.01	0.00	0.00	0.00	0.01	0.00	0.02	0.11	0.17	0.11	0.02	0.01	0.02	0.02
	D	0.18	0.14	0.04	0.01	0.00	0.01	0.03	0.03	0.10	0.49	0.72	0.42	0.15	0.08	0.26	0.34
	E	0.24	0.15	0.06	0.03	0.01	0.01	0.07	0.07	0.22	0.68	1.18	0.57	0.20	0.10	0.51	0.49
	F	0.04	0.02	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.05	0.07	0.03	0.00	0.01	0.03	0.03
	G	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01
9.8 m/s (22 mph)	A	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.04	0.01	0.00	0.01	0.01
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.04	0.01	0.00	0.01	0.00
	C	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.05	0.02	0.01	0.01	0.00
	D	0.02	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.11	0.25	0.16	0.09	0.02	0.14	0.08
	E	0.02	0.04	0.02	0.00	0.00	0.00	0.01	0.02	0.05	0.22	0.50	0.17	0.07	0.02	0.16	0.07
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12.7 m/s (29 mph)	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00
	D	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.11	0.03	0.02	0.01	0.03	0.01
	E	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.08	0.25	0.05	0.02	0.00	0.02	0.01
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.6 m/s (35 mph)	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.07	0.01	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19 m/s (43 mph)	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

**Table A6.** Joint Frequency Distributions of Atmospheric Stability, Wind Speed, and Transport Direction for the 300 Area at 60 m (197 ft) above Ground Level, Hanford Site, Washington. Based on 1986-2002 data from the 300 Area instrumented tower.

Average Wind Speed	Atmospheric Stability Class	Percentage of Time Wind Blows in the 300 Area toward the Direction Indicated															
		60 m															
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.89 m/s (2 mph)	A	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
	D	0.26	0.22	0.21	0.22	0.28	0.37	0.37	0.30	0.25	0.19	0.16	0.16	0.16	0.18	0.24	0.30
	E	0.43	0.33	0.25	0.23	0.29	0.40	0.47	0.51	0.51	0.40	0.36	0.30	0.32	0.35	0.39	0.44
	F	0.19	0.12	0.12	0.10	0.12	0.17	0.24	0.21	0.22	0.18	0.14	0.12	0.12	0.12	0.14	0.16
	G	0.15	0.12	0.13	0.10	0.12	0.17	0.20	0.19	0.18	0.13	0.14	0.11	0.12	0.15	0.18	0.18
2.65 m/s (6 mph)	A	0.01	0.01	0.01	0.02	0.03	0.03	0.04	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.01	
	B	0.01	0.00	0.02	0.01	0.02	0.03	0.03	0.03	0.03	0.04	0.02	0.01	0.00	0.00	0.00	
	C	0.01	0.04	0.12	0.11	0.11	0.10	0.08	0.05	0.05	0.06	0.06	0.03	0.01	0.01	0.01	
	D	0.80	0.64	0.57	0.66	0.90	1.09	1.33	0.70	0.60	0.66	0.51	0.28	0.16	0.13	0.34	
	E	1.19	0.65	0.35	0.30	0.54	0.96	1.61	1.29	1.26	1.16	0.98	0.62	0.46	0.44	0.61	
	F	0.40	0.20	0.06	0.05	0.11	0.37	0.67	0.69	0.66	0.44	0.30	0.23	0.18	0.14	0.18	
	G	0.44	0.23	0.05	0.03	0.06	0.28	0.51	0.38	0.26	0.13	0.08	0.08	0.08	0.08	0.19	
4.7 m/s (10.5 mph)	A	0.02	0.03	0.02	0.02	0.02	0.04	0.03	0.01	0.03	0.08	0.05	0.02	0.01	0.00		
	B	0.02	0.09	0.05	0.01	0.01	0.02	0.05	0.02	0.04	0.10	0.10	0.03	0.01	0.00		
	C	0.05	0.22	0.17	0.04	0.02	0.06	0.08	0.03	0.05	0.18	0.20	0.06	0.02	0.01		
	D	0.71	0.68	0.43	0.18	0.15	0.35	0.59	0.30	0.41	1.04	0.97	0.42	0.13	0.12		
	E	1.44	0.64	0.22	0.12	0.16	0.49	1.06	0.62	1.01	1.75	1.56	0.84	0.41	0.33		
	F	0.54	0.16	0.02	0.02	0.04	0.23	0.64	0.31	0.32	0.30	0.36	0.25	0.14	0.09		
	G	0.56	0.24	0.01	0.00	0.01	0.08	0.26	0.15	0.09	0.05	0.06	0.06	0.04	0.02		
7.2 m/s (16 mph)	A	0.01	0.05	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.07	0.11	0.06	0.01			
	B	0.02	0.07	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.07	0.13	0.08	0.02			
	C	0.06	0.11	0.02	0.00	0.00	0.00	0.01	0.00	0.02	0.13	0.21	0.12	0.02			
	D	0.28	0.23	0.05	0.01	0.01	0.01	0.05	0.05	0.13	0.57	0.79	0.48	0.15			
	E	0.78	0.29	0.07	0.03	0.02	0.09	0.22	0.17	0.33	1.06	1.69	0.93	0.33			
	F	0.36	0.08	0.01	0.02	0.01	0.05	0.11	0.04	0.03	0.11	0.30	0.21	0.06			
	G	0.30	0.09	0.00	0.00	0.00	0.02	0.05	0.01	0.01	0.01	0.03	0.02	0.01			
9.8 m/s (22 mph)	A	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.06				
	B	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.06	0.05				
	C	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.06	0.06				
	D	0.07	0.04	0.03	0.01	0.00	0.00	0.01	0.01	0.03	0.18	0.31	0.23				
	E	0.09	0.08	0.04	0.03	0.01	0.01	0.03	0.04	0.08	0.37	0.95	0.44				
	F	0.02	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.03	0.07	0.05				
	G	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00				
12.7 m/s (29 mph)	A	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02					
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02					
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03					
	D	0.01	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.06	0.17					
	E	0.01	0.03	0.02	0.02	0.00	0.00	0.01	0.01	0.03	0.16	0.54					
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02					
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00					
15.6 m/s (35 mph)	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00					
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00					
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00					
	D	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.07					
	E	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.21					
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00					
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00					
19 m/s (43 mph)	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00					
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00					
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00					
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03					
	E	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.13					
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00					
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00					

**Table A7.** Joint Frequency Distributions of Atmospheric Stability, Wind Speed, and Transport Direction for the 400 Area at 9.1 m (30 ft) above Ground Level, Hanford Site, Washington. Based on 1983-2002 data from the Fast Flux Test Facility (FFTF) instrumented tower.

Average Wind Speed	Atmospheric Stability Class	Percentage of Time Wind Blows at FFTF toward the Direction Indicated															
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.89 m/s (2 mph)	A	0.03	0.03	0.02	0.03	0.03	0.04	0.03	0.02	0.03	0.02	0.01	0.01	0.01	0.02	0.02	0.02
	B	0.01	0.03	0.03	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.01
	C	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.04	0.03	0.02	0.02	0.02	0.04
	D	0.28	0.29	0.28	0.23	0.24	0.30	0.31	0.28	0.26	0.24	0.21	0.15	0.17	0.20	0.27	0.30
	E	0.51	0.44	0.39	0.34	0.37	0.42	0.46	0.48	0.57	0.52	0.55	0.45	0.47	0.53	0.60	0.56
	F	0.19	0.17	0.14	0.11	0.13	0.13	0.17	0.18	0.24	0.26	0.24	0.19	0.19	0.20	0.23	0.21
	G	0.14	0.10	0.07	0.06	0.06	0.06	0.07	0.08	0.14	0.16	0.13	0.14	0.16	0.14	0.16	0.13
2.65 m/s (6 mph)	A	0.10	0.15	0.14	0.11	0.12	0.16	0.16	0.14	0.20	0.15	0.07	0.05	0.04	0.05	0.05	0.06
	B	0.11	0.12	0.10	0.09	0.10	0.10	0.12	0.13	0.17	0.13	0.05	0.04	0.03	0.03	0.04	0.07
	C	0.14	0.15	0.11	0.09	0.09	0.11	0.13	0.16	0.16	0.12	0.08	0.03	0.05	0.04	0.08	0.09
	D	0.69	0.57	0.42	0.24	0.29	0.34	0.64	0.72	0.67	0.49	0.29	0.18	0.21	0.36	0.70	0.81
	E	1.00	0.91	0.74	0.46	0.40	0.52	1.14	1.63	1.62	1.31	0.82	0.58	0.65	0.90	1.49	1.29
	F	0.50	0.43	0.25	0.10	0.10	0.15	0.37	0.70	0.81	0.72	0.43	0.23	0.23	0.31	0.57	0.58
	G	0.30	0.36	0.17	0.05	0.04	0.05	0.15	0.36	0.56	0.65	0.29	0.13	0.14	0.26	0.55	0.38
4.7 m/s (10.5 mph)	A	0.12	0.19	0.11	0.02	0.03	0.04	0.06	0.07	0.32	0.37	0.15	0.07	0.07	0.06	0.07	0.06
	B	0.10	0.12	0.06	0.02	0.02	0.03	0.03	0.05	0.20	0.20	0.08	0.05	0.04	0.03	0.04	0.05
	C	0.13	0.11	0.06	0.02	0.02	0.02	0.05	0.05	0.15	0.22	0.09	0.05	0.06	0.05	0.08	0.09
	D	0.42	0.27	0.13	0.05	0.04	0.06	0.21	0.37	0.69	0.88	0.32	0.17	0.16	0.33	0.70	0.66
	E	0.43	0.48	0.25	0.09	0.06	0.09	0.52	1.34	1.54	1.70	0.77	0.40	0.42	0.93	2.04	1.05
	F	0.12	0.08	0.04	0.01	0.00	0.01	0.23	0.86	0.65	0.59	0.22	0.06	0.07	0.22	0.62	0.48
	G	0.09	0.10	0.05	0.00	0.00	0.00	0.11	0.48	0.33	0.31	0.08	0.01	0.01	0.05	0.45	0.36
7.2 m/s (16 mph)	A	0.04	0.07	0.04	0.00	0.00	0.00	0.00	0.01	0.09	0.40	0.21	0.10	0.07	0.06	0.08	0.03
	B	0.02	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.04	0.17	0.10	0.06	0.04	0.04	0.06	0.01
	C	0.03	0.02	0.01	0.00	0.00	0.00	0.01	0.01	0.05	0.17	0.11	0.05	0.04	0.03	0.07	0.03
	D	0.10	0.06	0.03	0.01	0.00	0.01	0.03	0.04	0.17	0.62	0.37	0.18	0.13	0.18	0.52	0.21
	E	0.07	0.12	0.06	0.01	0.00	0.01	0.05	0.14	0.43	1.25	0.87	0.34	0.19	0.48	0.92	0.21
	F	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.05	0.11	0.25	0.09	0.02	0.01	0.03	0.07	0.02
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.07	0.03	0.06	0.01	0.00	0.00	0.00	0.01	0.00
9.8 m/s (22 mph)	A	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.07	0.07	0.07	0.04	0.02	0.04	0.01
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.05	0.03	0.02	0.01	0.03	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.04	0.03	0.02	0.01	0.04	0.01
	D	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.12	0.19	0.10	0.04	0.05	0.21	0.02
	E	0.01	0.06	0.03	0.00	0.00	0.00	0.00	0.01	0.04	0.29	0.43	0.15	0.06	0.10	0.16	0.01
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
12.7 m/s (29 mph)	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.01	0.00	0.02	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.00
	D	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.09	0.02	0.01	0.01	0.03	0.00
	E	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.09	0.19	0.04	0.01	0.02	0.02	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.6 m/s (35 mph)	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.01	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.06	0.01	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19 m/s (43 mph)	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

**Table A8.** Joint Frequency Distributions of Atmospheric Stability, Wind Speed, and Transport Direction for the 400 Area at 60 m (197 ft) above Ground Level, Hanford Site, Washington. Based on 1986-2002 data from the Fast Flux Test Facility (FFTF) instrumented tower.

Average Wind Speed	Atmospheric Stability Class	Percentage of Time Wind Blows at FFTF toward the Direction Indicated															
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.89 m/s (2 mph)	A	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	B	0.02	0.01	0.02	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01
	C	0.03	0.04	0.03	0.02	0.03	0.03	0.03	0.03	0.02	0.03	0.02	0.02	0.01	0.02	0.03	0.02
	D	0.21	0.21	0.22	0.18	0.23	0.26	0.27	0.23	0.20	0.15	0.16	0.12	0.12	0.14	0.19	0.20
	E	0.34	0.32	0.29	0.26	0.31	0.32	0.41	0.41	0.40	0.34	0.34	0.28	0.32	0.31	0.35	0.34
	F	0.14	0.11	0.09	0.10	0.10	0.12	0.15	0.17	0.18	0.15	0.13	0.13	0.12	0.10	0.11	0.13
	G	0.09	0.07	0.05	0.06	0.07	0.08	0.09	0.11	0.12	0.11	0.12	0.11	0.11	0.08	0.08	0.09
2.65 m/s (6 mph)	A	0.03	0.06	0.07	0.06	0.07	0.07	0.07	0.06	0.08	0.05	0.02	0.01	0.01	0.02	0.02	
	B	0.08	0.09	0.11	0.09	0.09	0.09	0.10	0.11	0.15	0.10	0.04	0.03	0.03	0.03	0.02	
	C	0.12	0.15	0.11	0.10	0.10	0.12	0.12	0.15	0.16	0.12	0.07	0.04	0.04	0.04	0.06	
	D	0.58	0.49	0.38	0.24	0.28	0.35	0.53	0.62	0.53	0.40	0.23	0.17	0.16	0.25	0.53	
	E	0.76	0.74	0.62	0.42	0.40	0.51	0.78	1.10	1.13	0.87	0.61	0.47	0.57	0.73	0.93	
	F	0.34	0.28	0.15	0.08	0.09	0.11	0.24	0.45	0.57	0.40	0.28	0.26	0.24	0.21	0.29	
	G	0.24	0.20	0.14	0.07	0.03	0.04	0.15	0.30	0.35	0.35	0.35	0.20	0.16	0.14	0.24	
4.7 m/s (10.5 mph)	A	0.07	0.16	0.10	0.02	0.03	0.03	0.06	0.06	0.23	0.20	0.07	0.03	0.03	0.03	0.02	
	B	0.12	0.13	0.07	0.03	0.03	0.03	0.05	0.07	0.21	0.18	0.07	0.03	0.03	0.04	0.04	
	C	0.15	0.13	0.08	0.03	0.02	0.03	0.05	0.07	0.17	0.20	0.08	0.05	0.05	0.04	0.06	
	D	0.46	0.31	0.19	0.08	0.06	0.07	0.27	0.35	0.61	0.74	0.27	0.13	0.12	0.21	0.63	
	E	0.67	0.63	0.44	0.15	0.11	0.15	0.60	1.03	1.35	1.38	0.85	0.43	0.45	0.75	1.43	
	F	0.25	0.20	0.09	0.04	0.03	0.03	0.21	0.46	0.61	0.60	0.38	0.13	0.15	0.27	0.42	
	G	0.20	0.13	0.08	0.02	0.00	0.00	0.10	0.28	0.32	0.36	0.34	0.09	0.07	0.10	0.35	
7.2 m/s (16 mph)	A	0.05	0.08	0.04	0.00	0.00	0.00	0.01	0.00	0.11	0.36	0.15	0.06	0.04	0.04	0.01	
	B	0.04	0.05	0.02	0.00	0.00	0.00	0.00	0.01	0.05	0.16	0.10	0.06	0.03	0.03	0.04	
	C	0.05	0.04	0.01	0.00	0.00	0.00	0.01	0.01	0.05	0.19	0.11	0.04	0.04	0.04	0.06	
	D	0.17	0.09	0.03	0.01	0.00	0.01	0.06	0.08	0.24	0.64	0.32	0.14	0.11	0.15	0.51	
	E	0.28	0.25	0.11	0.03	0.02	0.02	0.25	0.39	0.74	1.65	1.18	0.43	0.30	0.83	1.93	
	F	0.07	0.05	0.05	0.01	0.00	0.01	0.12	0.21	0.26	0.53	0.36	0.05	0.05	0.29	0.62	
	G	0.06	0.01	0.02	0.01	0.00	0.00	0.03	0.10	0.14	0.18	0.16	0.01	0.01	0.12	0.49	
9.8 m/s (22 mph)	A	0.00	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.09	0.09	0.07	0.04	0.03	0.04	
	B	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.06	0.03	0.03	0.02	0.04	
	C	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.06	0.03	0.03	0.02	0.05	
	D	0.03	0.03	0.01	0.00	0.00	0.00	0.00	0.01	0.03	0.20	0.23	0.12	0.07	0.09	0.38	
	E	0.07	0.11	0.07	0.02	0.02	0.02	0.06	0.08	0.21	0.80	0.85	0.29	0.15	0.52	1.24	
	F	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.04	0.16	0.13	0.02	0.01	0.16	0.28	
	G	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.02	0.00	0.00	0.07	0.17	
12.7 m/s (29 mph)	A	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.04	0.02	0.01	0.03	
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.01	0.01	0.02	
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.01	0.00	0.03	
	D	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.13	0.07	0.03	0.04	0.20	
	E	0.02	0.06	0.03	0.01	0.00	0.01	0.03	0.03	0.05	0.28	0.50	0.17	0.07	0.13	0.33	
	F	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.00	0.00	0.01	0.01	
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
15.6 m/s (35 mph)	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.01	
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.02	0.01	0.01	0.03	
	E	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.12	0.22	0.06	0.01	0.01	0.04	
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
19 m/s (43 mph)	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.01	0.01	0.00	0.00	
	E	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.11	0.01	0.01	0.00	0.00	
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

**Table A9.** X/Q' Values (s m<sup>-3</sup>) for Chronic Ground-Level Releases from 100-N Area Based on 1983 through 2002 Meteorological Information, Hanford Site, Washington

Distance km (mi)	Sector (Wind from 100-N toward Direction Indicated)															
	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.1 (0.06)	2.0E-04	1.9E-04	2.1E-04	2.5E-04	3.2E-04	3.0E-04	2.5E-04	1.7E-04	1.5E-04	1.5E-04	2.3E-04	3.5E-04	4.4E-04	4.0E-04	3.1E-04	2.3E-04
0.2 (0.12)	5.4E-05	5.2E-05	5.9E-05	6.9E-05	8.9E-05	8.3E-05	6.9E-05	4.6E-05	4.1E-05	4.2E-05	6.4E-05	9.7E-05	1.2E-04	1.1E-04	8.6E-05	6.3E-05
0.3 (0.19)	2.6E-05	2.5E-05	2.8E-05	3.3E-05	4.3E-05	4.0E-05	3.3E-05	2.2E-05	2.0E-05	2.0E-05	3.1E-05	4.6E-05	5.9E-05	5.3E-05	4.1E-05	3.0E-05
0.4 (0.25)	1.5E-05	1.5E-05	1.7E-05	2.0E-05	2.6E-05	2.4E-05	2.0E-05	1.3E-05	1.2E-05	1.2E-05	1.8E-05	2.8E-05	3.5E-05	3.2E-05	2.5E-05	1.8E-05
0.5 (0.31)	1.0E-05	9.9E-06	1.1E-05	1.3E-05	1.7E-05	1.6E-05	1.3E-05	9.0E-06	7.9E-06	8.1E-06	1.2E-05	1.9E-05	2.4E-05	2.1E-05	1.7E-05	1.2E-05
0.6 (0.37)	7.5E-06	7.2E-06	8.2E-06	9.7E-06	1.3E-05	1.2E-05	9.6E-06	6.5E-06	5.7E-06	5.9E-06	8.9E-06	1.4E-05	1.7E-05	1.5E-05	1.2E-05	8.7E-06
0.7 (0.43)	5.7E-06	5.5E-06	6.2E-06	7.4E-06	9.5E-06	8.9E-06	7.3E-06	5.0E-06	4.3E-06	4.5E-06	6.8E-06	1.0E-05	1.3E-05	1.2E-05	9.1E-06	6.6E-06
0.8 (0.50)	4.5E-06	4.3E-06	4.9E-06	5.8E-06	7.6E-06	7.0E-06	5.8E-06	3.9E-06	3.4E-06	3.5E-06	5.3E-06	8.1E-06	1.0E-05	9.3E-06	7.2E-06	5.2E-06
0.9 (0.56)	3.7E-06	3.5E-06	4.0E-06	4.7E-06	6.1E-06	5.7E-06	4.7E-06	3.2E-06	2.8E-06	2.9E-06	4.3E-06	6.6E-06	8.4E-06	7.5E-06	5.9E-06	4.3E-06
1 (0.62)	3.1E-06	2.9E-06	3.3E-06	3.9E-06	5.1E-06	4.8E-06	3.9E-06	2.7E-06	2.3E-06	2.4E-06	3.6E-06	5.5E-06	7.0E-06	6.3E-06	4.9E-06	3.5E-06
2.4 (1.5)	7.1E-07	6.8E-07	7.8E-07	9.2E-07	1.2E-06	1.1E-06	9.2E-07	6.2E-07	5.4E-07	5.6E-07	8.5E-07	1.3E-06	1.6E-06	1.5E-06	1.1E-06	8.3E-07
4 (2.5)	3.2E-07	3.1E-07	3.6E-07	4.2E-07	5.5E-07	5.1E-07	4.2E-07	2.8E-07	2.5E-07	2.6E-07	3.9E-07	5.9E-07	7.5E-07	6.7E-07	5.2E-07	3.8E-07
5.6 (3.5)	2.0E-07	1.9E-07	2.2E-07	2.6E-07	3.3E-07	3.1E-07	2.5E-07	1.7E-07	1.5E-07	1.6E-07	2.3E-07	3.6E-07	4.6E-07	4.1E-07	3.2E-07	2.3E-07
7.2 (4.5)	1.4E-07	1.3E-07	1.5E-07	1.8E-07	2.3E-07	2.1E-07	1.8E-07	1.2E-07	1.0E-07	1.1E-07	1.6E-07	2.5E-07	3.2E-07	2.8E-07	2.2E-07	1.6E-07
12 (7.5)	6.5E-08	6.2E-08	7.2E-08	8.6E-08	1.1E-07	1.0E-07	8.4E-08	5.7E-08	5.0E-08	5.1E-08	7.8E-08	1.2E-07	1.5E-07	1.4E-07	1.1E-07	7.6E-08
24 (15)	2.5E-08	2.4E-08	2.8E-08	3.3E-08	4.3E-08	3.9E-08	3.2E-08	2.2E-08	1.9E-08	2.0E-08	3.0E-08	4.6E-08	5.9E-08	5.2E-08	4.1E-08	2.9E-08
40 (25)	1.3E-08	1.2E-08	1.4E-08	1.7E-08	2.1E-08	1.9E-08	1.6E-08	1.1E-08	9.4E-09	9.7E-09	1.5E-08	2.3E-08	2.9E-08	2.6E-08	2.0E-08	1.5E-08
56 (35)	8.0E-09	7.6E-09	8.9E-09	1.1E-08	1.4E-08	1.2E-08	1.0E-08	6.8E-09	6.0E-09	6.2E-09	9.5E-09	1.5E-08	1.9E-08	1.7E-08	1.3E-08	9.3E-09
72 (45)	5.7E-09	5.5E-09	6.4E-09	7.6E-09	9.7E-09	8.8E-09	7.2E-09	4.9E-09	4.3E-09	4.4E-09	6.8E-09	1.1E-08	1.4E-08	1.2E-08	9.3E-09	6.7E-09

**Table A10.** X/Q' Values (s m<sup>-3</sup>) for Chronic 60-m Stack Releases from 100-N Area Based on 1986 through 2002 Meteorological Information, Hanford Site, Washington

Distance km (mi)	Sector (Wind from 100-N toward Direction Indicated)															
	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.1 (0.06)	2.3E-10	2.5E-10	1.7E-10	9.3E-11	1.1E-10	1.2E-10	8.7E-11	7.2E-11	6.9E-11	8.3E-11	2.1E-10	3.1E-10	3.6E-10	3.0E-10	2.4E-10	2.4E-10
0.2 (0.12)	6.0E-08	6.6E-08	4.5E-08	2.4E-08	2.7E-08	3.1E-08	2.3E-08	1.8E-08	1.7E-08	2.1E-08	5.3E-08	7.7E-08	9.0E-08	7.7E-08	6.3E-08	6.2E-08
0.3 (0.19)	1.4E-07	1.5E-07	1.1E-07	5.4E-08	6.2E-08	6.9E-08	5.3E-08	4.2E-08	3.7E-08	4.9E-08	1.2E-07	1.7E-07	2.0E-07	1.8E-07	1.5E-07	1.5E-07
0.4 (0.25)	1.6E-07	1.6E-07	1.1E-07	5.6E-08	6.5E-08	7.2E-08	6.0E-08	4.5E-08	3.8E-08	4.9E-08	1.1E-07	1.6E-07	2.0E-07	1.8E-07	1.6E-07	1.5E-07
0.5 (0.31)	1.5E-07	1.5E-07	1.0E-07	5.6E-08	6.7E-08	7.5E-08	6.5E-08	4.7E-08	3.9E-08	4.6E-08	1.0E-07	1.4E-07	1.8E-07	1.7E-07	1.5E-07	1.4E-07
0.6 (0.37)	1.4E-07	1.4E-07	1.0E-07	6.1E-08	7.7E-08	8.7E-08	7.9E-08	5.4E-08	4.4E-08	4.8E-08	9.7E-08	1.3E-07	1.7E-07	1.7E-07	1.4E-07	1.4E-07
0.7 (0.43)	1.4E-07	1.4E-07	1.1E-07	7.1E-08	9.5E-08	1.1E-07	9.9E-08	6.7E-08	5.3E-08	5.4E-08	9.7E-08	1.3E-07	1.7E-07	1.7E-07	1.4E-07	1.3E-07
0.8 (0.50)	1.5E-07	1.4E-07	1.1E-07	8.4E-08	1.2E-07	1.3E-07	1.2E-07	8.1E-08	6.3E-08	6.2E-08	1.0E-07	1.4E-07	1.8E-07	1.8E-07	1.5E-07	1.4E-07
0.9 (0.56)	1.5E-07	1.5E-07	1.2E-07	9.8E-08	1.4E-07	1.6E-07	1.4E-07	9.6E-08	7.4E-08	7.0E-08	1.1E-07	1.4E-07	1.9E-07	1.9E-07	1.5E-07	1.4E-07
1 (0.62)	1.5E-07	1.5E-07	1.3E-07	1.1E-07	1.6E-07	1.8E-07	1.6E-07	1.1E-07	8.4E-08	7.9E-08	1.1E-07	1.5E-07	2.0E-07	2.0E-07	1.6E-07	1.4E-07
2.4 (1.5)	1.5E-07	1.5E-07	1.4E-07	1.5E-07	2.2E-07	2.4E-07	2.1E-07	1.4E-07	1.1E-07	9.9E-08	1.2E-07	1.5E-07	2.2E-07	2.3E-07	1.6E-07	1.3E-07
4 (2.5)	1.0E-07	1.0E-07	9.9E-08	1.2E-07	1.7E-07	1.7E-07	1.5E-07	1.0E-07	7.9E-08	7.1E-08	8.8E-08	1.1E-07	1.6E-07	1.6E-07	1.1E-07	9.0E-08
5.6 (3.5)	7.4E-08	7.4E-08	7.4E-08	8.8E-08	1.3E-07	1.3E-07	1.1E-07	7.5E-08	5.8E-08	5.3E-08	6.4E-08	7.8E-08	1.2E-07	1.2E-07	8.4E-08	6.6E-08
7.2 (4.5)	5.7E-08	5.7E-08	5.8E-08	7.0E-08	1.0E-07	1.0E-07	8.6E-08	5.8E-08	4.5E-08	4.1E-08	5.0E-08	6.0E-08	9.0E-08	9.4E-08	6.5E-08	5.1E-08
12 (7.5)	3.2E-08	3.2E-08	3.4E-08	4.2E-08	6.1E-08	6.0E-08	5.0E-08	3.4E-08	2.6E-08	2.3E-08	2.8E-08	3.4E-08	5.1E-08	5.5E-08	3.8E-08	2.9E-08
24 (15)	1.4E-08	1.5E-08	1.6E-08	2.0E-08	2.9E-08	2.8E-08	2.3E-08	1.5E-08	1.2E-08	1.1E-08	1.3E-08	1.5E-08	2.3E-08	2.5E-08	1.8E-08	1.3E-08
40 (25)	7.9E-09	7.9E-09	8.8E-09	1.1E-08	1.7E-08	1.5E-08	1.3E-08	8.5E-09	6.5E-09	5.8E-09	6.8E-09	8.3E-09	1.3E-08	1.4E-08	9.9E-09	7.4E-09
56 (35)	5.3E-09	5.3E-09	6.0E-09	7.7E-09	1.1E-08	1.0E-08	8.6E-09	5.7E-09	4.4E-09	3.9E-09	4.5E-09	5.5E-09	8.5E-09	9.5E-09	6.7E-09	5.0E-09
72 (45)	3.9E-09	3.9E-09	4.4E-09	5.8E-09	8.4E-09	7.8E-09	6.4E-09	4.2E-09	3.2E-09	2.9E-09	3.3E-09	4.1E-09	6.3E-09	7.1E-09	5.0E-09	3.7E-09

**Table A11.** X/Q' Values ( $\text{s m}^{-3}$ ) for Chronic Ground-Level Releases from 200 Areas Based on 1983 through 2002 Meteorological Information, Hanford Site, Washington

Distance km (mi)	Sector (Wind from 200 Areas toward Direction Indicated)															
	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.1 (0.06)	1.5E-04	1.2E-04	1.1E-04	9.2E-05	1.0E-04	1.1E-04	1.4E-04	1.3E-04	1.3E-04	1.3E-04	1.9E-04	2.5E-04	3.0E-04	3.7E-04	3.8E-04	2.1E-04
0.2 (0.12)	4.1E-05	3.1E-05	3.0E-05	2.5E-05	2.8E-05	3.0E-05	3.9E-05	3.7E-05	3.5E-05	3.7E-05	5.1E-05	7.0E-05	8.4E-05	1.0E-04	1.1E-04	5.8E-05
0.3 (0.19)	1.9E-05	1.5E-05	1.4E-05	1.2E-05	1.3E-05	1.4E-05	1.9E-05	1.7E-05	1.7E-05	1.8E-05	2.5E-05	3.3E-05	4.0E-05	4.9E-05	5.0E-05	2.8E-05
0.4 (0.25)	1.1E-05	8.6E-06	8.2E-06	6.9E-06	7.7E-06	8.4E-06	1.1E-05	1.0E-05	9.9E-06	1.0E-05	1.5E-05	2.0E-05	2.4E-05	2.9E-05	3.0E-05	1.6E-05
0.5 (0.31)	7.5E-06	5.7E-06	5.4E-06	4.6E-06	5.1E-06	5.6E-06	7.4E-06	6.9E-06	6.6E-06	7.0E-06	9.8E-06	1.3E-05	1.6E-05	2.0E-05	2.0E-05	1.1E-05
0.6 (0.37)	5.4E-06	4.1E-06	3.9E-06	3.3E-06	3.7E-06	4.0E-06	5.3E-06	5.0E-06	4.8E-06	5.1E-06	7.1E-06	9.7E-06	1.2E-05	1.4E-05	1.5E-05	7.9E-06
0.7 (0.43)	4.1E-06	3.1E-06	2.9E-06	2.5E-06	2.8E-06	3.1E-06	4.0E-06	3.8E-06	3.7E-06	3.9E-06	5.4E-06	7.4E-06	8.9E-06	1.1E-05	1.1E-05	6.0E-06
0.8 (0.50)	3.2E-06	2.4E-06	2.3E-06	2.0E-06	2.2E-06	2.4E-06	3.2E-06	3.0E-06	2.9E-06	3.0E-06	4.3E-06	5.8E-06	7.1E-06	8.6E-06	8.7E-06	4.7E-06
0.9 (0.56)	2.6E-06	2.0E-06	1.9E-06	1.6E-06	1.8E-06	2.0E-06	2.6E-06	2.4E-06	2.3E-06	2.5E-06	3.5E-06	4.7E-06	5.7E-06	7.0E-06	7.1E-06	3.8E-06
1 (0.62)	2.2E-06	1.6E-06	1.6E-06	1.3E-06	1.5E-06	1.6E-06	2.1E-06	2.0E-06	1.9E-06	2.1E-06	2.9E-06	3.9E-06	4.8E-06	5.8E-06	5.9E-06	3.2E-06
2.4 (1.5)	4.9E-07	3.8E-07	3.6E-07	3.0E-07	3.4E-07	3.7E-07	5.0E-07	4.7E-07	4.5E-07	4.8E-07	6.7E-07	9.2E-07	1.1E-06	1.4E-06	1.4E-06	7.3E-07
4 (2.5)	2.2E-07	1.7E-07	1.6E-07	1.4E-07	1.5E-07	1.7E-07	2.3E-07	2.2E-07	2.1E-07	2.2E-07	3.1E-07	4.2E-07	5.1E-07	6.2E-07	6.3E-07	3.3E-07
5.6 (3.5)	1.3E-07	1.0E-07	9.7E-08	8.3E-08	9.3E-08	1.0E-07	1.4E-07	1.3E-07	1.3E-07	1.9E-07	2.6E-07	3.1E-07	3.8E-07	3.8E-07	2.0E-07	2.0E-07
7.2 (4.5)	9.3E-08	7.0E-08	6.7E-08	5.7E-08	6.4E-08	7.0E-08	9.5E-08	9.1E-08	8.8E-08	9.3E-08	1.3E-07	1.8E-07	2.2E-07	2.6E-07	2.6E-07	1.4E-07
12 (7.5)	4.4E-08	3.3E-08	3.1E-08	2.7E-08	3.0E-08	3.3E-08	4.5E-08	4.3E-08	4.2E-08	4.5E-08	6.3E-08	8.6E-08	1.0E-07	1.3E-07	1.3E-07	6.6E-08
24 (15)	1.7E-08	1.2E-08	1.2E-08	1.0E-08	1.2E-08	1.3E-08	1.7E-08	1.7E-08	1.6E-08	1.7E-08	2.4E-08	3.3E-08	4.0E-08	4.9E-08	4.8E-08	2.5E-08
40 (25)	8.2E-09	6.2E-09	5.9E-09	5.1E-09	5.7E-09	6.3E-09	8.6E-09	8.4E-09	8.1E-09	8.6E-09	1.2E-08	1.7E-08	2.0E-08	2.4E-08	2.4E-08	1.2E-08
56 (35)	5.2E-09	3.9E-09	3.8E-09	3.3E-09	3.7E-09	4.0E-09	5.5E-09	5.3E-09	5.2E-09	5.5E-09	7.8E-09	1.1E-08	1.3E-08	1.5E-08	1.5E-08	8.0E-09
72 (45)	3.7E-09	2.8E-09	2.7E-09	2.3E-09	2.6E-09	2.9E-09	3.9E-09	3.8E-09	3.7E-09	4.0E-09	5.6E-09	7.7E-09	9.3E-09	1.1E-08	1.1E-08	5.7E-09

**Table A12.** X/Q' Values ( $\text{s m}^{-3}$ ) for Chronic 60-m Stack Releases from 200 Areas Based on 1983 through 2002 Meteorological Information, Hanford Site, Washington

Distance km (mi)	Sector (Wind from 200 Areas toward Direction Indicated)															
	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.1 (0.06)	7.3E-10	7.8E-10	7.0E-10	5.5E-10	6.2E-10	5.3E-10	4.8E-10	4.1E-10	2.9E-10	3.1E-10	4.6E-10	4.4E-10	2.8E-10	3.6E-10	8.9E-10	8.0E-10
0.2 (0.12)	1.8E-07	1.9E-07	1.7E-07	1.3E-07	1.5E-07	1.3E-07	1.2E-07	9.9E-08	6.9E-08	7.6E-08	1.1E-07	1.0E-07	6.9E-08	8.8E-08	2.2E-07	1.9E-07
0.3 (0.19)	3.6E-07	3.8E-07	3.4E-07	2.7E-07	3.0E-07	2.6E-07	2.4E-07	2.0E-07	1.4E-07	1.5E-07	2.1E-07	2.1E-07	1.4E-07	1.8E-07	4.4E-07	4.0E-07
0.4 (0.25)	3.2E-07	3.2E-07	2.9E-07	2.3E-07	2.5E-07	2.2E-07	2.1E-07	1.7E-07	1.2E-07	1.3E-07	1.8E-07	1.7E-07	1.2E-07	1.6E-07	3.8E-07	3.5E-07
0.5 (0.31)	2.5E-07	2.5E-07	2.3E-07	1.8E-07	1.9E-07	1.7E-07	1.6E-07	1.3E-07	9.0E-08	1.0E-07	1.3E-07	1.3E-07	1.0E-07	1.4E-07	3.1E-07	2.8E-07
0.6 (0.37)	2.2E-07	2.1E-07	1.9E-07	1.5E-07	1.6E-07	1.4E-07	1.4E-07	1.1E-07	7.5E-08	8.5E-08	1.1E-07	1.1E-07	9.0E-08	1.3E-07	2.7E-07	2.4E-07
0.7 (0.43)	2.0E-07	1.8E-07	1.7E-07	1.3E-07	1.4E-07	1.3E-07	1.3E-07	1.0E-07	6.9E-08	7.7E-08	9.8E-08	9.7E-08	8.7E-08	1.3E-07	2.6E-07	2.2E-07
0.8 (0.50)	1.9E-07	1.7E-07	1.5E-07	1.3E-07	1.3E-07	1.2E-07	1.3E-07	1.0E-07	6.7E-08	7.4E-08	9.3E-08	9.3E-08	9.0E-08	1.4E-07	2.6E-07	2.1E-07
0.9 (0.56)	1.8E-07	1.6E-07	1.5E-07	1.2E-07	1.3E-07	1.2E-07	1.3E-07	1.0E-07	6.7E-08	7.4E-08	9.2E-08	9.3E-08	9.5E-08	1.5E-07	2.6E-07	2.1E-07
1 (0.62)	1.8E-07	1.6E-07	1.4E-07	1.2E-07	1.2E-07	1.2E-07	1.3E-07	1.0E-07	6.8E-08	7.4E-08	9.3E-08	9.5E-08	1.0E-07	1.6E-07	2.7E-07	2.1E-07
2.4 (1.5)	1.2E-07	1.0E-07	9.1E-08	7.9E-08	8.8E-08	8.6E-08	1.1E-07	8.6E-08	5.9E-08	6.1E-08	7.8E-08	8.8E-08	1.1E-07	1.9E-07	2.5E-07	1.6E-07
4 (2.5)	8.0E-08	6.6E-08	5.7E-08	5.0E-08	5.7E-08	5.6E-08	7.2E-08	5.9E-08	4.0E-08	4.2E-08	5.4E-08	6.3E-08	8.3E-08	1.4E-07	1.7E-07	1.1E-07
5.6 (3.5)	5.7E-08	4.6E-08	3.9E-08	3.5E-08	4.0E-08	4.0E-08	5.2E-08	4.3E-08	3.0E-08	3.1E-08	3.9E-08	4.7E-08	6.3E-08	1.0E-07	1.3E-07	7.6E-08
7.2 (4.5)	4.3E-08	3.4E-08	2.9E-08	2.6E-08	3.0E-08	3.0E-08	4.0E-08	3.3E-08	2.3E-08	2.4E-08	3.0E-08	3.7E-08	5.0E-08	8.2E-08	9.9E-08	5.8E-08
12 (7.5)	2.4E-08	1.8E-08	1.6E-08	1.4E-08	1.7E-08	1.6E-08	2.2E-08	1.9E-08	1.3E-08	1.4E-08	1.7E-08	2.2E-08	3.0E-08	4.8E-08	5.7E-08	3.3E-08
24 (15)	1.0E-08	7.9E-09	6.9E-09	6.1E-09	7.3E-09	7.2E-09	9.8E-09	8.7E-09	6.2E-09	6.3E-09	8.0E-09	1.0E-08	1.4E-08	2.3E-08	2.6E-08	1.5E-08
40 (25)	5.5E-09	4.2E-09	3.6E-09	3.2E-09	3.9E-09	3.8E-09	5.3E-09	4.8E-09	3.4E-09	3.5E-09	4.4E-09	5.6E-09	8.0E-09	1.2E-08	1.5E-08	8.2E-09
56 (35)	3.7E-09	2.7E-09	2.4E-09	2.1E-09	2.6E-09	2.5E-09	3.5E-09	3.2E-09	2.3E-09	2.3E-09	3.0E-09	3.8E-09	5.4E-09	8.4E-09	9.8E-09	5.5E-09
72 (45)	2.7E-09	2.0E-09	1.8E-09	1.6E-09	1.9E-09	1.9E-09	2.6E-09	2.4E-09	1.7E-09	1.7E-09	2.2E-09	2.8E-09	4.1E-09	6.2E-09	7.2E-09	4.1E-09

**Table A13.** X/Q' Values ( $s\ m^{-3}$ ) for Chronic Ground-Level Releases from 300 Area Based on 1983 through 2002 Meteorological Information, Hanford Site, Washington

Distance km (mi)	Sector (Wind from 300 Area toward Direction Indicated)															
	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.1 (0.06)	2.6E-04	1.2E-04	7.3E-05	6.8E-05	1.0E-04	2.3E-04	3.6E-04	2.6E-04	2.4E-04	2.2E-04	2.1E-04	1.6E-04	1.4E-04	1.5E-04	2.4E-04	3.1E-04
0.2 (0.12)	7.1E-05	3.3E-05	2.0E-05	1.9E-05	2.8E-05	6.2E-05	9.8E-05	7.3E-05	6.7E-05	6.1E-05	5.9E-05	4.3E-05	3.9E-05	4.3E-05	6.7E-05	8.5E-05
0.3 (0.19)	3.4E-05	1.6E-05	9.5E-06	8.9E-06	1.3E-05	3.0E-05	4.7E-05	3.5E-05	3.2E-05	2.9E-05	2.8E-05	2.1E-05	1.9E-05	2.1E-05	3.2E-05	4.1E-05
0.4 (0.25)	2.0E-05	9.4E-06	5.7E-06	5.3E-06	8.0E-06	1.8E-05	2.8E-05	2.1E-05	1.9E-05	1.7E-05	1.7E-05	1.2E-05	1.1E-05	1.2E-05	1.9E-05	2.4E-05
0.5 (0.31)	1.4E-05	6.4E-06	3.8E-06	3.6E-06	5.4E-06	1.2E-05	1.9E-05	1.4E-05	1.3E-05	1.2E-05	1.1E-05	8.3E-06	7.5E-06	8.4E-06	1.3E-05	1.6E-05
0.6 (0.37)	1.0E-05	4.6E-06	2.8E-06	2.6E-06	3.9E-06	8.7E-06	1.4E-05	1.0E-05	9.5E-06	8.5E-06	8.3E-06	6.0E-06	5.4E-06	6.1E-06	9.5E-06	1.2E-05
0.7 (0.43)	7.6E-06	3.5E-06	2.1E-06	2.0E-06	3.0E-06	6.7E-06	1.1E-05	7.9E-06	7.2E-06	6.5E-06	6.3E-06	4.6E-06	4.1E-06	4.6E-06	7.2E-06	9.1E-06
0.8 (0.50)	6.0E-06	2.8E-06	1.7E-06	1.6E-06	2.3E-06	5.3E-06	8.3E-06	6.2E-06	5.7E-06	5.1E-06	5.0E-06	3.6E-06	3.3E-06	3.7E-06	5.7E-06	7.2E-06
0.9 (0.56)	4.9E-06	2.3E-06	1.4E-06	1.3E-06	1.9E-06	4.3E-06	6.8E-06	5.1E-06	4.7E-06	4.2E-06	4.1E-06	3.0E-06	2.7E-06	3.0E-06	4.6E-06	5.9E-06
1 (0.62)	4.1E-06	1.9E-06	1.1E-06	1.0E-06	1.6E-06	3.6E-06	5.6E-06	4.2E-06	3.9E-06	3.5E-06	3.4E-06	2.5E-06	2.2E-06	2.5E-06	3.9E-06	4.9E-06
2.4 (1.5)	9.6E-07	4.4E-07	2.6E-07	2.4E-07	3.7E-07	8.4E-07	1.3E-06	9.9E-07	9.1E-07	8.1E-07	7.9E-07	5.8E-07	5.2E-07	5.8E-07	9.1E-07	1.1E-06
4 (2.5)	4.4E-07	2.0E-07	1.2E-07	1.1E-07	1.7E-07	3.8E-07	6.1E-07	4.5E-07	4.2E-07	3.7E-07	3.6E-07	2.6E-07	2.4E-07	2.7E-07	4.2E-07	5.3E-07
5.6 (3.5)	2.7E-07	1.2E-07	7.1E-08	6.6E-08	1.0E-07	2.3E-07	3.7E-07	2.8E-07	2.5E-07	2.2E-07	2.2E-07	1.6E-07	1.5E-07	1.6E-07	2.5E-07	3.2E-07
7.2 (4.5)	1.8E-07	8.3E-08	4.9E-08	4.6E-08	7.0E-08	1.6E-07	2.6E-07	1.9E-07	1.8E-07	1.6E-07	1.5E-07	1.1E-07	1.0E-07	1.1E-07	1.8E-07	2.2E-07
12 (7.5)	8.8E-08	3.9E-08	2.3E-08	2.1E-08	3.3E-08	7.7E-08	1.2E-07	9.2E-08	8.4E-08	7.4E-08	7.2E-08	5.3E-08	4.8E-08	5.5E-08	8.5E-08	1.1E-07
24 (15)	3.4E-08	1.5E-08	8.6E-09	8.0E-09	1.2E-08	2.9E-08	4.7E-08	3.5E-08	3.2E-08	2.8E-08	2.7E-08	2.0E-08	1.9E-08	2.1E-08	3.3E-08	4.1E-08
40 (25)	1.7E-08	7.4E-09	4.2E-09	3.9E-09	6.1E-09	1.5E-08	2.4E-08	1.8E-08	1.6E-08	1.4E-08	1.4E-08	1.0E-08	9.3E-09	1.1E-08	1.6E-08	2.0E-08
56 (35)	1.1E-08	4.7E-09	2.7E-09	2.5E-09	3.9E-09	9.3E-09	1.5E-08	1.1E-08	1.0E-08	8.9E-09	8.6E-09	6.4E-09	5.9E-09	6.7E-09	1.0E-08	1.3E-08
72 (45)	7.7E-09	3.3E-09	1.9E-09	1.8E-09	2.7E-09	6.6E-09	1.1E-08	8.1E-09	7.3E-09	6.3E-09	6.1E-09	4.6E-09	4.2E-09	4.8E-09	7.5E-09	9.3E-09

**Table A14.** X/Q' Values ( $s\ m^{-3}$ ) for Chronic 60-m Stack Releases from 300 Area Based on 1986 through 2002 Meteorological Information, Hanford Site, Washington

Distance km (mi)	Sector (Wind from 300 Area toward Direction Indicated)															
	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.1 (0.06)	1.7E-11	3.0E-11	1.7E-11	1.9E-11	2.5E-11	4.9E-11	5.2E-11	3.3E-11	2.4E-11	6.1E-11	5.6E-11	3.8E-11	8.5E-12	2.2E-12	1.0E-11	1.4E-11
0.2 (0.12)	4.4E-09	8.5E-09	5.0E-09	4.6E-09	6.2E-09	1.2E-08	1.3E-08	8.4E-09	6.7E-09	1.7E-08	1.6E-08	1.0E-08	2.3E-09	5.9E-10	2.6E-09	3.6E-09
0.3 (0.19)	1.1E-08	2.4E-08	1.6E-08	1.2E-08	1.5E-08	2.7E-08	3.0E-08	2.0E-08	1.7E-08	4.3E-08	4.3E-08	2.6E-08	6.3E-09	1.7E-09	6.0E-09	7.9E-09
0.4 (0.25)	1.4E-08	3.4E-08	2.7E-08	1.7E-08	2.0E-08	3.0E-08	3.4E-08	2.2E-08	2.1E-08	5.2E-08	5.5E-08	3.0E-08	8.0E-09	2.9E-09	7.2E-09	9.0E-09
0.5 (0.31)	2.0E-08	4.3E-08	3.6E-08	2.4E-08	2.7E-08	3.7E-08	4.1E-08	2.6E-08	2.6E-08	5.8E-08	6.3E-08	3.3E-08	1.1E-08	5.8E-09	1.1E-08	1.5E-08
0.6 (0.37)	3.3E-08	5.4E-08	4.7E-08	3.3E-08	3.8E-08	5.0E-08	5.6E-08	3.6E-08	3.5E-08	6.8E-08	7.3E-08	3.9E-08	1.5E-08	1.1E-08	2.0E-08	2.8E-08
0.7 (0.43)	5.1E-08	6.7E-08	5.8E-08	4.5E-08	5.3E-08	6.8E-08	7.8E-08	5.0E-08	4.8E-08	8.3E-08	8.7E-08	4.8E-08	2.2E-08	1.9E-08	3.2E-08	4.7E-08
0.8 (0.50)	7.1E-08	8.0E-08	6.9E-08	5.6E-08	6.7E-08	8.8E-08	1.0E-07	6.7E-08	6.3E-08	9.9E-08	1.0E-07	5.8E-08	3.0E-08	2.7E-08	4.6E-08	6.8E-08
0.9 (0.56)	9.0E-08	9.3E-08	7.8E-08	6.6E-08	8.1E-08	1.1E-07	1.2E-07	8.3E-08	7.9E-08	1.2E-07	1.2E-07	6.8E-08	3.8E-08	3.5E-08	5.9E-08	8.8E-08
1 (0.62)	1.1E-07	1.0E-07	8.6E-08	7.4E-08	9.2E-08	1.2E-07	1.4E-07	9.8E-08	9.4E-08	1.3E-07	1.3E-07	7.8E-08	4.6E-08	4.3E-08	7.2E-08	1.1E-07
2.4 (1.5)	1.6E-07	1.2E-07	8.5E-08	7.6E-08	9.9E-08	1.4E-07	1.9E-07	1.4E-07	1.5E-07	1.7E-07	1.7E-07	1.1E-07	7.3E-08	7.1E-08	1.1E-07	1.6E-07
4 (2.5)	1.2E-07	8.1E-08	5.6E-08	5.1E-08	6.7E-08	1.0E-07	1.4E-07	1.1E-07	1.1E-07	1.2E-07	1.2E-07	7.8E-08	5.5E-08	5.3E-08	7.9E-08	1.2E-07
5.6 (3.5)	8.9E-08	5.9E-08	4.0E-08	3.6E-08	4.8E-08	7.3E-08	1.0E-07	8.1E-08	8.3E-08	9.1E-08	9.0E-08	5.8E-08	4.1E-08	4.0E-08	5.9E-08	8.6E-08
7.2 (4.5)	7.0E-08	4.5E-08	3.1E-08	2.7E-08	3.6E-08	5.7E-08	8.0E-08	6.4E-08	6.5E-08	7.0E-08	6.9E-08	4.5E-08	3.2E-08	3.1E-08	4.6E-08	6.7E-08
12 (7.5)	4.1E-08	2.6E-08	1.7E-08	1.5E-08	2.0E-08	3.2E-08	4.7E-08	3.8E-08	3.8E-08	4.0E-08	3.9E-08	2.6E-08	1.9E-08	1.8E-08	2.7E-08	3.8E-08
24 (15)	1.9E-08	1.2E-08	7.6E-09	6.6E-09	8.8E-09	1.5E-08	2.2E-08	1.8E-08	1.8E-08	1.8E-08	1.7E-08	1.2E-08	8.7E-09	8.5E-09	1.2E-08	1.8E-08
40 (25)	1.1E-08	6.4E-09	4.1E-09	3.5E-09	4.7E-09	8.0E-09	1.2E-08	9.7E-09	9.7E-09	9.4E-09	9.2E-09	6.3E-09	4.8E-09	4.7E-09	6.7E-09	9.7E-09
56 (35)	7.2E-09	4.3E-09	2.8E-09	2.3E-09	3.1E-09	5.3E-09	8.0E-09	6.6E-09	6.5E-09	6.2E-09	6.1E-09	4.2E-09	3.2E-09	3.2E-09	4.5E-09	6.5E-09
72 (45)	5.4E-09	3.2E-09	2.0E-09	1.7E-09	2.3E-09	3.9E-09	5.9E-09	4.9E-09	4.8E-09	4.6E-09	4.5E-09	3.1E-09	2.4E-09	2.3E-09	3.3E-09	4.8E-09

**Table A15.** X/Q' Values ( $\text{s m}^{-3}$ ) for Chronic Ground-Level Releases from 400 Area Based on 1983 through 2002 Meteorological Information, Hanford Site, Washington

Distance km (mi)	Sector (Wind from 400 Area toward Direction Indicated)															
	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.1 (0.06)	1.8E-04	1.6E-04	1.2E-04	8.2E-05	8.5E-05	9.8E-05	1.5E-04	2.3E-04	2.7E-04	2.8E-04	1.9E-04	1.3E-04	1.3E-04	1.7E-04	2.7E-04	2.3E-04
0.2 (0.12)	5.0E-05	4.5E-05	3.3E-05	2.2E-05	2.3E-05	2.7E-05	4.2E-05	6.4E-05	7.4E-05	7.7E-05	5.2E-05	3.5E-05	3.7E-05	4.7E-05	7.6E-05	6.2E-05
0.3 (0.19)	2.4E-05	2.2E-05	1.6E-05	1.1E-05	1.1E-05	1.3E-05	2.0E-05	3.1E-05	3.6E-05	3.7E-05	2.5E-05	1.7E-05	1.8E-05	2.2E-05	3.6E-05	3.0E-05
0.4 (0.25)	1.4E-05	1.3E-05	9.4E-06	6.4E-06	6.6E-06	7.7E-06	1.2E-05	1.8E-05	2.1E-05	2.2E-05	1.5E-05	1.0E-05	1.1E-05	1.3E-05	2.2E-05	1.8E-05
0.5 (0.31)	9.6E-06	8.7E-06	6.3E-06	4.3E-06	4.5E-06	5.1E-06	8.2E-06	1.2E-05	1.4E-05	1.5E-05	1.0E-05	6.8E-06	7.2E-06	9.1E-06	1.5E-05	1.2E-05
0.6 (0.37)	6.9E-06	6.3E-06	4.6E-06	3.1E-06	3.2E-06	3.7E-06	5.9E-06	8.9E-06	1.0E-05	1.1E-05	7.3E-06	5.0E-06	5.2E-06	6.6E-06	1.1E-05	8.7E-06
0.7 (0.43)	5.3E-06	4.8E-06	3.5E-06	2.4E-06	2.5E-06	2.8E-06	4.5E-06	6.8E-06	7.9E-06	8.2E-06	5.5E-06	3.8E-06	4.0E-06	5.0E-06	8.1E-06	6.7E-06
0.8 (0.50)	4.2E-06	3.8E-06	2.8E-06	1.9E-06	1.9E-06	2.2E-06	3.6E-06	5.4E-06	6.2E-06	6.5E-06	4.4E-06	3.0E-06	3.1E-06	4.0E-06	6.4E-06	5.3E-06
0.9 (0.56)	3.4E-06	3.1E-06	2.2E-06	1.5E-06	1.6E-06	1.8E-06	2.9E-06	4.4E-06	5.1E-06	5.3E-06	3.6E-06	2.4E-06	2.5E-06	3.2E-06	5.2E-06	4.3E-06
1 (0.62)	2.8E-06	2.6E-06	1.9E-06	1.3E-06	1.3E-06	1.5E-06	2.4E-06	3.6E-06	4.2E-06	4.4E-06	3.0E-06	2.0E-06	2.1E-06	2.7E-06	4.3E-06	3.6E-06
2.4 (1.5)	6.6E-07	6.0E-07	4.4E-07	2.9E-07	3.0E-07	3.5E-07	5.6E-07	8.5E-07	9.9E-07	1.0E-06	6.9E-07	4.7E-07	5.0E-07	6.3E-07	1.0E-06	8.3E-07
4 (2.5)	3.0E-07	2.7E-07	2.0E-07	1.3E-07	1.4E-07	1.6E-07	2.6E-07	3.9E-07	4.5E-07	4.7E-07	3.2E-07	2.2E-07	2.3E-07	2.9E-07	4.7E-07	3.8E-07
5.6 (3.5)	1.8E-07	1.7E-07	1.2E-07	8.1E-08	8.4E-08	9.7E-08	1.6E-07	2.4E-07	2.8E-07	2.9E-07	1.9E-07	1.3E-07	1.4E-07	1.8E-07	2.8E-07	2.3E-07
7.2 (4.5)	1.3E-07	1.1E-07	8.3E-08	5.6E-08	5.8E-08	6.7E-08	1.1E-07	1.6E-07	1.9E-07	2.0E-07	1.3E-07	9.2E-08	9.6E-08	1.2E-07	2.0E-07	1.6E-07
12 (7.5)	6.0E-08	5.5E-08	3.9E-08	2.6E-08	2.7E-08	3.2E-08	5.1E-08	7.9E-08	9.2E-08	9.5E-08	6.4E-08	4.4E-08	4.6E-08	5.8E-08	9.4E-08	7.7E-08
24 (15)	2.3E-08	2.1E-08	1.5E-08	1.0E-08	1.0E-08	1.2E-08	1.9E-08	3.0E-08	3.5E-08	3.7E-08	2.5E-08	1.7E-08	1.8E-08	2.2E-08	3.6E-08	2.9E-08
40 (25)	1.2E-08	1.0E-08	7.5E-09	5.0E-09	5.2E-09	5.9E-09	9.7E-09	1.5E-08	1.8E-08	1.8E-08	1.2E-08	8.4E-09	8.8E-09	1.1E-08	1.8E-08	1.5E-08
56 (35)	7.3E-09	6.7E-09	4.8E-09	3.2E-09	3.3E-09	3.8E-09	6.1E-09	9.7E-09	1.1E-08	1.2E-08	7.8E-09	5.4E-09	5.7E-09	7.1E-09	1.2E-08	9.4E-09
72 (45)	5.3E-09	4.8E-09	3.4E-09	2.3E-09	2.3E-09	2.7E-09	4.4E-09	6.9E-09	8.1E-09	8.5E-09	5.6E-09	3.9E-09	4.0E-09	5.1E-09	8.2E-09	6.7E-09

**Table A16.** X/Q' Values ( $\text{s m}^{-3}$ ) for Chronic 60-m Stack Releases from 400 Area Based on 1986 through 2002 Meteorological Information, Hanford Site, Washington

Distance km (mi)	Sector (Wind from 400 Area toward Direction Indicated)															
	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.1 (0.06)	7.1E-11	1.3E-10	1.1E-10	6.1E-11	7.0E-11	7.0E-11	8.2E-11	7.4E-11	1.7E-10	2.1E-10	1.1E-10	6.6E-11	5.2E-11	5.5E-11	6.0E-11	4.1E-11
0.2 (0.12)	2.1E-08	3.4E-08	2.8E-08	1.7E-08	1.9E-08	1.9E-08	2.3E-08	2.1E-08	4.6E-08	5.4E-08	2.8E-08	1.7E-08	1.3E-08	1.5E-08	1.6E-08	1.2E-08
0.3 (0.19)	5.8E-08	8.2E-08	7.1E-08	4.2E-08	5.0E-08	4.7E-08	5.8E-08	5.4E-08	1.1E-07	1.3E-07	6.5E-08	4.1E-08	3.1E-08	3.6E-08	3.9E-08	3.2E-08
0.4 (0.25)	7.1E-08	9.0E-08	7.8E-08	4.8E-08	5.7E-08	5.4E-08	6.6E-08	6.5E-08	1.2E-07	1.3E-07	7.0E-08	4.5E-08	3.2E-08	3.9E-08	4.6E-08	4.2E-08
0.5 (0.31)	7.6E-08	8.9E-08	7.6E-08	4.8E-08	5.7E-08	5.5E-08	6.8E-08	6.9E-08	1.1E-07	1.2E-07	6.7E-08	4.3E-08	3.2E-08	4.0E-08	5.1E-08	4.8E-08
0.6 (0.37)	8.1E-08	9.0E-08	7.5E-08	4.9E-08	5.8E-08	5.8E-08	7.1E-08	7.4E-08	1.1E-07	1.2E-07	6.7E-08	4.4E-08	3.3E-08	4.2E-08	6.0E-08	5.7E-08
0.7 (0.43)	8.8E-08	9.3E-08	7.7E-08	5.2E-08	6.1E-08	6.3E-08	7.8E-08	8.2E-08	1.1E-07	1.2E-07	7.0E-08	4.6E-08	3.6E-08	4.6E-08	7.2E-08	6.9E-08
0.8 (0.50)	9.6E-08	9.7E-08	8.1E-08	5.5E-08	6.5E-08	6.9E-08	8.7E-08	9.1E-08	1.1E-07	1.2E-07	7.5E-08	4.9E-08	4.1E-08	5.2E-08	8.7E-08	8.2E-08
0.9 (0.56)	1.0E-07	1.0E-07	8.5E-08	5.9E-08	6.9E-08	7.6E-08	9.6E-08	1.0E-07	1.2E-07	1.3E-07	8.2E-08	5.4E-08	4.6E-08	6.0E-08	1.0E-07	9.4E-08
1 (0.62)	1.1E-07	1.1E-07	9.0E-08	6.2E-08	7.4E-08	8.1E-08	1.0E-07	1.1E-07	1.3E-07	1.4E-07	9.0E-08	5.8E-08	5.2E-08	6.8E-08	1.2E-07	1.1E-07
2.4 (1.5)	1.2E-07	1.1E-07	9.0E-08	6.5E-08	7.3E-08	8.3E-08	1.2E-07	1.4E-07	1.5E-07	1.6E-07	1.2E-07	7.5E-08	7.4E-08	9.7E-08	1.6E-07	1.3E-07
4 (2.5)	8.2E-08	7.6E-08	6.2E-08	4.5E-08	5.0E-08	5.7E-08	8.4E-08	1.0E-07	1.1E-07	1.1E-07	8.7E-08	5.6E-08	5.6E-08	7.2E-08	1.2E-07	9.6E-08
5.6 (3.5)	6.1E-08	5.5E-08	4.5E-08	3.3E-08	3.6E-08	4.1E-08	6.1E-08	7.5E-08	8.3E-08	8.5E-08	6.5E-08	4.2E-08	4.2E-08	5.4E-08	8.8E-08	7.1E-08
7.2 (4.5)	4.7E-08	4.3E-08	3.4E-08	2.5E-08	2.8E-08	3.2E-08	4.7E-08	5.9E-08	6.6E-08	6.6E-08	5.2E-08	3.3E-08	3.3E-08	4.3E-08	6.8E-08	5.6E-08
12 (7.5)	2.7E-08	2.4E-08	1.9E-08	1.4E-08	1.5E-08	1.8E-08	2.7E-08	3.4E-08	3.8E-08	3.9E-08	3.0E-08	2.0E-08	2.0E-08	2.5E-08	3.9E-08	3.2E-08
24 (15)	1.2E-08	1.1E-08	8.6E-09	6.3E-09	6.8E-09	7.8E-09	1.2E-08	1.6E-08	1.8E-08	1.8E-08	1.4E-08	9.3E-09	9.2E-09	1.1E-08	1.8E-08	1.5E-08
40 (25)	6.7E-09	5.9E-09	4.6E-09	3.4E-09	3.6E-09	4.2E-09	6.5E-09	8.7E-09	9.9E-09	9.9E-09	8.0E-09	5.2E-09	5.1E-09	6.2E-09	9.8E-09	8.2E-09
56 (35)	4.5E-09	4.0E-09	3.1E-09	2.3E-09	2.4E-09	2.8E-09	4.4E-09	5.9E-09	6.7E-09	6.7E-09	5.4E-09	3.5E-09	3.4E-09	4.1E-09	6.6E-09	5.5E-09
72 (45)	3.3E-09	2.9E-09	2.2E-09	1.7E-09	1.8E-09	2.0E-09	3.2E-09	4.3E-09	5.0E-09	5.0E-09	4.1E-09	2.6E-09	2.6E-09	3.0E-09	4.8E-09	4.1E-09

**Table A17.** 95th Percentile E/Q Values ( $s\ m^{-3}$ ) for Acute Ground Level Releases from 100-N Area Based on 1983 through 2002  
 Meteorological Information, Hanford Site, Washington

Distance km (mi)	Sector (Wind from 100-N toward Direction Indicated)															
	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.1 (0.06)	4.9E-02	3.8E-02	4.4E-02	4.7E-02	4.2E-02	3.4E-02	3.4E-02	3.4E-02	3.4E-02	3.4E-02	3.4E-02	3.3E-02	3.4E-02	3.7E-02	5.1E-02	5.3E-02
0.2 (0.12)	1.5E-02	1.1E-02	1.3E-02	1.4E-02	1.3E-02	1.0E-02	1.1E-02	1.5E-02	1.6E-02							
0.3 (0.19)	7.4E-03	5.8E-03	6.7E-03	7.1E-03	6.4E-03	5.2E-03	5.1E-03	5.1E-03	5.2E-03	5.2E-03	5.1E-03	5.1E-03	5.1E-03	5.7E-03	7.7E-03	8.0E-03
0.4 (0.25)	4.5E-03	3.5E-03	4.1E-03	4.3E-03	4.0E-03	3.2E-03	3.1E-03	3.2E-03	3.2E-03	3.2E-03	3.1E-03	3.1E-03	3.2E-03	3.5E-03	4.8E-03	4.9E-03
0.5 (0.31)	3.1E-03	2.4E-03	2.8E-03	3.0E-03	2.7E-03	2.2E-03	2.2E-03	2.2E-03	2.2E-03	2.2E-03	2.2E-03	2.1E-03	2.2E-03	2.4E-03	3.3E-03	3.4E-03
0.6 (0.37)	2.3E-03	1.8E-03	2.1E-03	2.2E-03	2.0E-03	1.6E-03	1.8E-03	2.4E-03	2.5E-03							
0.7 (0.43)	1.8E-03	1.4E-03	1.6E-03	1.7E-03	1.6E-03	1.3E-03	1.2E-03	1.2E-03	1.3E-03	1.3E-03	1.2E-03	1.2E-03	1.2E-03	1.4E-03	1.9E-03	1.9E-03
0.8 (0.50)	1.4E-03	1.1E-03	1.3E-03	1.4E-03	1.2E-03	1.0E-03	9.8E-04	9.9E-04	1.0E-03	1.0E-03	9.8E-04	9.8E-04	9.9E-04	1.1E-03	1.5E-03	1.5E-03
0.9 (0.56)	1.2E-03	9.2E-04	1.1E-03	1.1E-03	1.0E-03	8.3E-04	8.1E-04	8.2E-04	8.3E-04	8.2E-04	8.1E-04	8.1E-04	8.1E-04	9.0E-04	1.2E-03	1.3E-03
1 (0.62)	9.8E-04	7.7E-04	9.0E-04	9.4E-04	8.6E-04	6.9E-04	6.8E-04	6.8E-04	6.9E-04	6.9E-04	6.8E-04	6.8E-04	6.8E-04	7.6E-04	1.0E-03	1.1E-03
2.4 (1.5)	2.5E-04	2.0E-04	2.3E-04	2.4E-04	2.2E-04	1.8E-04	1.7E-04	1.8E-04	1.8E-04	1.8E-04	1.7E-04	1.7E-04	1.8E-04	1.9E-04	2.7E-04	2.7E-04
4 (2.5)	1.2E-04	9.7E-05	1.1E-04	1.2E-04	1.1E-04	8.7E-05	8.5E-05	8.6E-05	8.7E-05	8.7E-05	8.5E-05	8.5E-05	8.6E-05	9.5E-05	1.3E-04	1.3E-04
5.6 (3.5)	7.9E-05	6.2E-05	7.2E-05	7.6E-05	6.9E-05	5.5E-05	5.4E-05	5.5E-05	5.5E-05	5.5E-05	5.4E-05	5.4E-05	5.5E-05	6.1E-05	8.3E-05	8.6E-05
7.2 (4.5)	5.7E-05	4.4E-05	5.2E-05	5.4E-05	5.0E-05	4.0E-05	3.9E-05	3.9E-05	4.0E-05	4.0E-05	3.9E-05	3.9E-05	3.9E-05	4.4E-05	6.0E-05	6.2E-05
12 (7.5)	2.9E-05	2.3E-05	2.7E-05	2.8E-05	2.5E-05	2.1E-05	2.0E-05	2.0E-05	2.1E-05	2.1E-05	2.0E-05	2.0E-05	2.0E-05	2.2E-05	3.1E-05	3.2E-05
24 (15)	1.2E-05	9.7E-06	1.1E-05	1.2E-05	1.1E-05	8.7E-06	8.6E-06	8.6E-06	8.7E-06	8.7E-06	8.5E-06	8.5E-06	8.6E-06	9.5E-06	1.3E-05	1.4E-05
40 (25)	6.7E-06	5.2E-06	6.1E-06	6.4E-06	5.8E-06	4.7E-06	4.6E-06	4.6E-06	4.7E-06	4.7E-06	4.6E-06	4.6E-06	4.6E-06	5.1E-06	7.0E-06	7.2E-06
56 (35)	4.5E-06	3.5E-06	4.1E-06	4.3E-06	3.9E-06	3.1E-06	3.4E-06	4.7E-06	4.8E-06							
72 (45)	3.3E-06	2.6E-06	3.0E-06	3.2E-06	2.9E-06	2.3E-06	2.5E-06	3.5E-06	3.6E-06							

**Table A18.** 95th Percentile E/Q Values ( $s\ m^{-3}$ ) for Acute 60-m Stack Releases from 100-N Area Based on 1986 through 2002  
 Meteorological Information, Hanford Site, Washington

Distance km (mi)	Sector (Wind from 100-N toward Direction Indicated)															
	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.1 (0.06)	2.4E-08	2.0E-08	1.6E-08	5.0E-18	3.1E-18	4.0E-18	3.9E-18	4.0E-18	6.6E-18	7.6E-11	1.6E-08	2.0E-08	1.3E-08	2.3E-10	2.3E-10	2.6E-08
0.2 (0.12)	5.9E-06	5.5E-06	5.5E-06	3.1E-08	1.9E-08	2.5E-08	2.4E-08	2.5E-08	4.1E-08	1.4E-06	5.5E-06	5.5E-06	3.6E-06	2.2E-06	4.1E-06	6.5E-06
0.3 (0.19)	1.4E-05	1.1E-05	1.1E-05	2.7E-06	1.2E-06	1.6E-06	1.5E-06	1.6E-06	3.6E-06	6.8E-06	1.0E-05	1.1E-05	9.6E-06	6.5E-06	1.1E-05	1.6E-05
0.4 (0.25)	1.6E-05	1.4E-05	1.4E-05	6.5E-06	4.5E-06	5.8E-06	6.2E-06	5.8E-06	6.7E-06	7.6E-06	1.0E-05	1.3E-05	1.0E-05	7.3E-06	1.5E-05	1.9E-05
0.5 (0.31)	1.7E-05	1.3E-05	1.1E-05	7.2E-06	4.8E-06	7.6E-06	6.5E-06	7.2E-06	7.2E-06	8.1E-06	9.2E-06	1.1E-05	8.6E-06	6.8E-06	1.4E-05	2.7E-05
0.6 (0.37)	1.4E-05	1.3E-05	1.3E-05	5.7E-06	5.7E-06	5.7E-06	5.7E-06	5.7E-06	5.7E-06	6.6E-06	8.9E-06	1.2E-05	7.5E-06	5.7E-06	1.3E-05	1.9E-05
0.7 (0.43)	1.3E-05	1.2E-05	1.1E-05	1.0E-05	1.1E-05	1.1E-05	1.0E-05	9.6E-06	1.1E-05	1.7E-05						
0.8 (0.50)	1.5E-05	1.5E-05	1.5E-05	1.5E-05	1.5E-05	1.5E-05	1.5E-05	1.5E-05	1.5E-05	1.5E-05	1.4E-05	1.4E-05	1.4E-05	1.3E-05	1.5E-05	1.8E-05
0.9 (0.56)	1.9E-05	1.7E-05	1.5E-05	1.6E-05	1.4E-05	1.3E-05	1.8E-05	2.1E-05								
1 (0.62)	2.2E-05	2.1E-05	2.2E-05	2.1E-05	2.1E-05	2.0E-05	1.8E-05	2.2E-05	2.3E-05							
2.4 (1.5)	2.2E-05	2.2E-05	2.2E-05	2.2E-05	2.2E-05	2.2E-05	2.2E-05	2.2E-05	2.2E-05	2.2E-05	2.2E-05	2.2E-05	2.1E-05	2.1E-05	2.2E-05	2.2E-05
4 (2.5)	1.7E-05	1.6E-05	1.7E-05	1.6E-05	1.6E-05	1.4E-05	1.4E-05	1.6E-05	1.7E-05							
5.6 (3.5)	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05
7.2 (4.5)	1.1E-05	1.1E-05	1.1E-05	1.2E-05	1.2E-05	1.2E-05	1.1E-05	1.1E-05	1.2E-05	1.1E-05	1.0E-05	1.0E-05	8.8E-06	7.9E-06	1.0E-05	1.1E-05
12 (7.5)	6.4E-06	6.4E-06	7.1E-06	7.9E-06	8.0E-06	7.6E-06	6.9E-06	6.9E-06	7.2E-06	6.6E-06	6.4E-06	6.4E-06	6.3E-06	6.3E-06	6.4E-06	6.5E-06
24 (15)	5.3E-06	4.8E-06	5.5E-06	5.6E-06	5.6E-06	5.5E-06	5.5E-06	5.5E-06	5.5E-06	5.3E-06	3.8E-06	3.7E-06	2.8E-06	2.7E-06	5.0E-06	5.5E-06
40 (25)	3.2E-06	2.9E-06	3.6E-06	3.8E-06	3.8E-06	3.6E-06	3.4E-06	3.4E-06	3.5E-06	3.2E-06	2.2E-06	2.1E-06	1.6E-06	1.6E-06	3.0E-06	3.5E-06
56 (35)	2.3E-06	2.1E-06	2.6E-06	2.9E-06	2.8E-06	2.6E-06	2.5E-06	2.5E-06	2.5E-06	2.3E-06	1.6E-06	1.5E-06	1.1E-06	1.2E-06	2.2E-06	2.6E-06
72 (45)	1.8E-06	1.6E-06	2.1E-06	2.3E-06	2.3E-06	2.1E-06	1.9E-06	1.9E-06	2.0E-06	1.8E-06	1.3E-06	1.2E-06	9.2E-07	9.3E-07	1.7E-06	2.0E-06

**Table A19.** 95th Percentile E/Q Values ( $s\ m^{-3}$ ) for Acute Ground-Level Releases from 200 Areas Based on 1983 through 2002 Meteorological Information, Hanford Site, Washington

Distance km (mi)	Sector (Wind from 200 Areas toward Direction Indicated)															
	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.1 (0.06)	3.1E-02	3.0E-02	3.2E-02	3.2E-02	3.2E-02	3.2E-02	3.3E-02	3.2E-02	3.3E-02	3.2E-02	3.1E-02	2.8E-02	2.9E-02	2.6E-02	2.2E-02	3.0E-02
0.2 (0.12)	9.4E-03	9.1E-03	9.6E-03	9.8E-03	9.7E-03	9.6E-03	9.8E-03	9.8E-03	1.0E-02	9.8E-03	9.3E-03	8.6E-03	8.7E-03	7.8E-03	6.7E-03	9.0E-03
0.3 (0.19)	4.7E-03	4.6E-03	4.8E-03	4.9E-03	4.9E-03	4.8E-03	4.9E-03	4.9E-03	5.0E-03	4.9E-03	4.7E-03	4.3E-03	4.4E-03	3.9E-03	3.4E-03	4.5E-03
0.4 (0.25)	2.9E-03	2.8E-03	3.0E-03	3.0E-03	3.0E-03	3.0E-03	3.0E-03	3.0E-03	3.1E-03	3.0E-03	2.9E-03	2.7E-03	2.7E-03	2.4E-03	2.1E-03	2.8E-03
0.5 (0.31)	2.0E-03	1.9E-03	2.0E-03	2.1E-03	2.1E-03	2.0E-03	2.1E-03	2.1E-03	2.1E-03	2.1E-03	2.0E-03	1.8E-03	1.9E-03	1.7E-03	1.4E-03	1.9E-03
0.6 (0.37)	1.5E-03	1.4E-03	1.5E-03	1.5E-03	1.5E-03	1.5E-03	1.5E-03	1.5E-03	1.6E-03	1.5E-03	1.5E-03	1.3E-03	1.4E-03	1.2E-03	1.1E-03	1.4E-03
0.7 (0.43)	1.1E-03	1.1E-03	1.2E-03	1.1E-03	1.0E-03	1.1E-03	9.5E-04	8.1E-04	1.1E-03							
0.8 (0.50)	9.1E-04	8.9E-04	9.3E-04	9.5E-04	9.4E-04	9.3E-04	9.5E-04	9.5E-04	9.7E-04	9.5E-04	9.0E-04	8.3E-04	8.5E-04	7.6E-04	6.5E-04	8.7E-04
0.9 (0.56)	7.5E-04	7.3E-04	7.7E-04	7.8E-04	7.7E-04	7.7E-04	7.8E-04	7.8E-04	7.9E-04	7.8E-04	7.4E-04	6.8E-04	7.0E-04	6.2E-04	5.3E-04	7.2E-04
1 (0.62)	6.3E-04	6.1E-04	6.4E-04	6.5E-04	6.5E-04	6.4E-04	6.6E-04	6.6E-04	6.7E-04	6.6E-04	6.2E-04	5.7E-04	5.8E-04	5.2E-04	4.5E-04	6.0E-04
2.4 (1.5)	1.6E-04	1.6E-04	1.7E-04	1.6E-04	1.5E-04	1.5E-04	1.4E-04	1.2E-04	1.6E-04							
4 (2.5)	7.9E-05	7.7E-05	8.1E-05	8.2E-05	8.2E-05	8.1E-05	8.3E-05	8.2E-05	8.4E-05	8.2E-05	7.9E-05	7.3E-05	7.4E-05	6.6E-05	5.7E-05	7.6E-05
5.6 (3.5)	5.0E-05	4.9E-05	5.2E-05	5.2E-05	5.2E-05	5.2E-05	5.3E-05	5.3E-05	5.3E-05	5.3E-05	5.0E-05	4.6E-05	4.7E-05	4.2E-05	3.6E-05	4.9E-05
7.2 (4.5)	3.6E-05	3.5E-05	3.7E-05	3.8E-05	3.7E-05	3.7E-05	3.8E-05	3.8E-05	3.8E-05	3.8E-05	3.6E-05	3.3E-05	3.4E-05	3.0E-05	2.6E-05	3.5E-05
12 (7.5)	1.9E-05	1.8E-05	1.9E-05	1.9E-05	1.9E-05	1.9E-05	2.0E-05	1.9E-05	2.0E-05	1.9E-05	1.9E-05	1.7E-05	1.7E-05	1.6E-05	1.3E-05	1.8E-05
24 (15)	7.9E-06	7.8E-06	8.2E-06	8.3E-06	8.2E-06	8.1E-06	8.3E-06	8.3E-06	8.4E-06	8.3E-06	7.9E-06	7.3E-06	7.4E-06	6.7E-06	5.7E-06	7.6E-06
40 (25)	4.3E-06	4.2E-06	4.4E-06	4.4E-06	4.4E-06	4.4E-06	4.5E-06	4.4E-06	4.5E-06	4.4E-06	4.2E-06	3.9E-06	4.0E-06	3.6E-06	3.1E-06	4.1E-06
56 (35)	2.8E-06	2.8E-06	2.9E-06	3.0E-06	2.9E-06	2.9E-06	3.0E-06	3.0E-06	3.0E-06	3.0E-06	2.8E-06	2.6E-06	2.7E-06	2.4E-06	2.1E-06	2.7E-06
72 (45)	2.1E-06	2.1E-06	2.2E-06	2.1E-06	1.9E-06	2.0E-06	1.8E-06	1.5E-06	2.0E-06							

**Table A20.** 95th Percentile E/Q Values ( $s\ m^{-3}$ ) for Acute 60-m Stack Releases from 200 Areas Based on 1983 through 2002 Meteorological Information, Hanford Site, Washington

Distance km (mi)	Sector (Wind from 200 Areas toward Direction Indicated)															
	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.1 (0.06)	3.6E-08	3.8E-08	4.0E-08	4.0E-08	3.9E-08	4.0E-08	3.7E-08	3.5E-08	3.4E-08	3.0E-08	2.3E-08	1.9E-08	1.4E-08	9.7E-09	1.8E-08	3.3E-08
0.2 (0.12)	8.9E-06	9.4E-06	9.8E-06	9.7E-06	9.7E-06	9.8E-06	9.0E-06	8.7E-06	8.5E-06	7.5E-06	5.5E-06	5.5E-06	3.6E-06	2.5E-06	5.5E-06	8.0E-06
0.3 (0.19)	1.8E-05	2.2E-05	3.1E-05	3.0E-05	2.7E-05	3.1E-05	1.8E-05	1.7E-05	1.6E-05	1.5E-05	1.1E-05	9.8E-06	8.3E-06	6.4E-06	9.6E-06	1.6E-05
0.4 (0.25)	1.7E-05	2.3E-05	2.9E-05	3.0E-05	2.7E-05	2.8E-05	1.7E-05	1.5E-05	1.4E-05	1.3E-05	1.1E-05	8.4E-06	7.6E-06	6.9E-06	8.2E-06	1.4E-05
0.5 (0.31)	1.7E-05	2.2E-05	2.6E-05	2.6E-05	2.3E-05	2.4E-05	1.8E-05	1.4E-05	1.3E-05	1.0E-05	8.6E-06	7.5E-06	6.8E-06	4.8E-06	7.8E-06	1.3E-05
0.6 (0.37)	1.4E-05	1.5E-05	1.7E-05	1.9E-05	1.6E-05	1.6E-05	1.4E-05	1.3E-05	1.3E-05	1.2E-05	7.4E-06	5.7E-06	5.7E-06	5.5E-06	6.1E-06	1.3E-05
0.7 (0.43)	1.2E-05	1.3E-05	1.4E-05	1.6E-05	1.3E-05	1.3E-05	1.2E-05	1.1E-05	1.1E-05	1.1E-05	9.6E-06	7.8E-06	8.3E-06	4.9E-06	7.2E-06	1.1E-05
0.8 (0.50)	1.5E-05	1.5E-05	1.6E-05	1.7E-05	1.5E-05	1.6E-05	1.5E-05	1.5E-05	1.5E-05	1.4E-05	9.9E-06	7.5E-06	7.9E-06	5.2E-06	6.7E-06	1.4E-05
0.9 (0.56)	1.8E-05	1.9E-05	2.0E-05	2.0E-05	1.9E-05	2.0E-05	1.9E-05	1.7E-05	1.7E-05	1.5E-05	8.5E-06	6.8E-06	7.0E-06	6.4E-06	6.7E-06	1.6E-05
1 (0.62)	2.2E-05	2.2E-05	2.3E-05	2.3E-05	2.2E-05	2.2E-05	2.2E-05	2.2E-05	2.1E-05	2.1E-05	8.3E-06	7.3E-06	7.6E-06	7.1E-06	7.4E-06	2.1E-05
2.4 (1.5)	2.1E-05	2.1E-05	2.1E-05	2.2E-05	2.2E-05	2.2E-05	2.2E-05	2.2E-05	2.1E-05	2.1E-05	2.0E-05	1.4E-05	9.2E-06	1.2E-05	7.4E-06	1.9E-05
4 (2.5)	1.4E-05	1.4E-05	1.4E-05	1.5E-05	1.5E-05	1.6E-05	1.6E-05	1.5E-05	1.4E-05	1.4E-05	1.3E-05	1.0E-05	1.2E-05	6.0E-06	5.8E-06	1.3E-05
5.6 (3.5)	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.3E-05	8.5E-06	6.9E-06	8.0E-06	4.7E-06	4.7E-06	1.1E-05
7.2 (4.5)	9.7E-06	9.2E-06	9.5E-06	1.0E-05	1.1E-05	1.1E-05	1.1E-05	1.1E-05	1.1E-05	9.3E-06	6.2E-06	5.4E-06	6.0E-06	4.4E-06	4.3E-06	7.6E-06
12 (7.5)	6.4E-06	6.3E-06	6.3E-06	6.4E-06	6.4E-06	6.4E-06	6.4E-06	6.4E-06	6.4E-06	6.3E-06	6.1E-06	3.2E-06	5.0E-06	3.2E-06	3.2E-06	6.3E-06
24 (15)	2.9E-06	2.7E-06	2.9E-06	3.6E-06	3.6E-06	3.9E-06	4.0E-06	3.5E-06	4.3E-06	3.2E-06	2.4E-06	1.9E-06	2.2E-06	1.9E-06	1.7E-06	2.5E-06
40 (25)	1.6E-06	1.6E-06	1.6E-06	2.0E-06	2.1E-06	2.3E-06	2.3E-06	2.0E-06	2.5E-06	1.8E-06	1.5E-06	1.5E-06	1.5E-06	1.2E-06	1.1E-06	1.5E-06
56 (35)	1.2E-06	1.1E-06	1.2E-06	1.5E-06	1.5E-06	1.7E-06	1.7E-06	1.5E-06	1.8E-06	1.4E-06	1.1E-06	1.1E-06	1.1E-06	9.1E-07	7.7E-07	1.1E-06
72 (45)	9.6E-07	8.2E-07	9.4E-07	1.2E-06	1.2E-06	1.3E-06	1.3E-06	1.2E-06	1.4E-06	1.1E-06	8.4E-07	8.0E-07	8.8E-07	6.8E-07	6.0E-07	8.7E-07

**Table A21.** 95th Percentile E/Q Values ( $s\ m^{-3}$ ) for Acute Ground-Level Releases from 300 Area Based on 1983 through 2002  
 Meteorological Information, Hanford Site, Washington

Distance km (mi)	Sector (Wind from 300 Area toward Direction Indicated)															
	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.1 (0.06)	2.8E-02	2.1E-02	2.9E-02	2.2E-02	3.1E-02	2.8E-02	3.0E-02	3.4E-02	3.3E-02	2.9E-02	1.6E-02	3.1E-02	4.0E-02	5.4E-02	4.2E-02	3.1E-02
0.2 (0.12)	8.3E-03	6.2E-03	8.8E-03	6.6E-03	9.3E-03	8.5E-03	9.0E-03	1.0E-02	1.0E-02	8.7E-03	4.8E-03	9.4E-03	1.2E-02	1.6E-02	1.3E-02	9.5E-03
0.3 (0.19)	4.2E-03	3.1E-03	4.4E-03	3.3E-03	4.7E-03	4.2E-03	4.5E-03	5.2E-03	5.0E-03	4.4E-03	2.4E-03	4.7E-03	6.0E-03	8.2E-03	6.3E-03	4.7E-03
0.4 (0.25)	2.6E-03	1.9E-03	2.7E-03	2.0E-03	2.9E-03	2.6E-03	2.8E-03	3.2E-03	3.1E-03	2.7E-03	1.5E-03	2.9E-03	3.7E-03	5.1E-03	3.9E-03	2.9E-03
0.5 (0.31)	1.8E-03	1.3E-03	1.9E-03	1.4E-03	2.0E-03	1.8E-03	1.9E-03	2.2E-03	2.1E-03	1.8E-03	1.0E-03	2.0E-03	2.6E-03	3.5E-03	2.7E-03	2.0E-03
0.6 (0.37)	1.3E-03	9.7E-04	1.4E-03	1.0E-03	1.5E-03	1.3E-03	1.4E-03	1.6E-03	1.6E-03	1.4E-03	7.6E-04	1.5E-03	1.9E-03	2.6E-03	2.0E-03	1.5E-03
0.7 (0.43)	1.0E-03	7.5E-04	1.1E-03	8.1E-04	1.1E-03	1.0E-03	1.1E-03	1.2E-03	1.2E-03	1.1E-03	5.8E-04	1.1E-03	1.5E-03	2.0E-03	1.5E-03	1.1E-03
0.8 (0.50)	8.1E-04	6.0E-04	8.5E-04	6.5E-04	9.0E-04	8.2E-04	8.8E-04	1.0E-03	9.7E-04	8.4E-04	4.7E-04	9.2E-04	1.2E-03	1.6E-03	1.2E-03	9.2E-04
0.9 (0.56)	6.6E-04	4.9E-04	7.0E-04	5.3E-04	7.4E-04	6.8E-04	7.2E-04	8.2E-04	8.0E-04	6.9E-04	3.9E-04	7.5E-04	9.6E-04	1.3E-03	1.0E-03	7.5E-04
1 (0.62)	5.6E-04	4.2E-04	5.9E-04	4.5E-04	6.2E-04	5.7E-04	6.0E-04	6.9E-04	6.7E-04	5.8E-04	3.2E-04	6.3E-04	8.1E-04	1.1E-03	8.4E-04	6.3E-04
2.4 (1.5)	1.4E-04	1.1E-04	1.5E-04	1.1E-04	1.6E-04	1.5E-04	1.6E-04	1.8E-04	1.7E-04	1.5E-04	8.4E-05	1.6E-04	2.1E-04	2.8E-04	2.2E-04	1.6E-04
4 (2.5)	7.1E-05	5.3E-05	7.4E-05	5.5E-05	7.9E-05	7.2E-05	7.6E-05	8.6E-05	8.4E-05	7.4E-05	4.1E-05	8.0E-05	1.0E-04	1.4E-04	1.1E-04	8.0E-05
5.6 (3.5)	4.5E-05	3.4E-05	4.7E-05	3.5E-05	5.0E-05	4.6E-05	4.9E-05	5.5E-05	5.4E-05	4.7E-05	2.6E-05	5.1E-05	6.5E-05	8.8E-05	6.7E-05	5.1E-05
7.2 (4.5)	3.2E-05	2.4E-05	3.4E-05	2.5E-05	3.6E-05	3.3E-05	3.5E-05	4.0E-05	3.9E-05	3.4E-05	1.9E-05	3.7E-05	4.6E-05	6.3E-05	4.8E-05	3.7E-05
12 (7.5)	1.7E-05	1.2E-05	1.8E-05	1.3E-05	1.9E-05	1.7E-05	1.8E-05	2.0E-05	2.0E-05	1.7E-05	9.5E-06	1.9E-05	2.4E-05	3.3E-05	2.5E-05	1.9E-05
24 (15)	7.1E-06	5.3E-06	7.5E-06	5.3E-06	7.9E-06	7.2E-06	7.7E-06	8.7E-06	8.5E-06	7.4E-06	4.0E-06	8.0E-06	1.0E-05	1.4E-05	1.1E-05	8.0E-06
40 (25)	3.8E-06	2.8E-06	4.0E-06	2.8E-06	4.2E-06	3.9E-06	4.1E-06	4.6E-06	4.5E-06	4.0E-06	2.1E-06	4.3E-06	5.5E-06	7.4E-06	5.7E-06	4.3E-06
56 (35)	2.5E-06	1.9E-06	2.7E-06	1.9E-06	2.8E-06	2.6E-06	2.8E-06	3.1E-06	3.0E-06	2.7E-06	1.4E-06	2.9E-06	3.7E-06	5.0E-06	3.8E-06	2.9E-06
72 (45)	1.9E-06	1.4E-06	2.0E-06	1.4E-06	2.1E-06	1.9E-06	2.0E-06	2.3E-06	2.3E-06	2.0E-06	1.1E-06	2.1E-06	2.7E-06	3.7E-06	2.8E-06	2.1E-06

**Table A22.** 95th Percentile E/Q Values ( $s\ m^{-3}$ ) for Acute 60-m Stack Releases from 300 Area Based on 1986 through 2002  
 Meteorological Information, Hanford Site, Washington

Distance km (mi)	Sector (Wind from 300 Area toward Direction Indicated)															
	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.1 (0.06)	6.1E-42	4.7E-18	4.4E-18	3.8E-18	3.6E-18	1.7E-18	1.2E-41	1.1E-41	1.3E-41	3.8E-18	3.6E-18	1.9E-11	1.1E-18	1.1E-41	9.7E-42	5.3E-42
0.2 (0.12)	1.4E-14	3.0E-08	2.8E-08	2.4E-08	2.2E-08	1.0E-08	2.9E-14	2.6E-14	3.0E-14	2.3E-08	2.2E-08	3.6E-07	6.6E-09	2.6E-14	2.3E-14	1.2E-14
0.3 (0.19)	1.7E-09	1.9E-06	1.8E-06	1.5E-06	1.4E-06	6.6E-07	3.4E-09	2.9E-09	3.4E-09	1.5E-06	1.4E-06	2.2E-06	4.2E-07	3.0E-09	2.6E-09	1.4E-09
0.4 (0.25)	1.1E-07	4.4E-06	6.4E-06	5.6E-06	5.2E-06	3.2E-06	2.3E-07	2.0E-07	2.3E-07	3.9E-06	3.8E-06	3.7E-06	1.5E-06	2.0E-07	1.8E-07	9.6E-08
0.5 (0.31)	1.5E-06	5.9E-06	8.6E-06	8.9E-06	8.4E-06	4.3E-06	1.8E-06	1.8E-06	1.8E-06	4.7E-06	4.1E-06	3.7E-06	2.2E-06	1.8E-06	1.9E-06	1.3E-06
0.6 (0.37)	2.5E-06	6.3E-06	7.6E-06	8.2E-06	7.2E-06	5.7E-06	5.6E-06	5.6E-06	5.6E-06	5.6E-06	4.9E-06	4.9E-06	5.1E-06	5.2E-06	5.0E-06	1.9E-06
0.7 (0.43)	3.6E-06	7.5E-06	1.1E-05	1.1E-05	1.1E-05	9.7E-06	8.1E-06	8.6E-06	7.5E-06	6.1E-06	4.8E-06	4.7E-06	7.4E-06	8.5E-06	5.1E-06	3.5E-06
0.8 (0.50)	5.2E-06	7.2E-06	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.0E-05	1.3E-05	7.2E-06	5.3E-06	5.2E-06	5.2E-06	7.0E-06	1.4E-05	5.3E-06	5.2E-06
0.9 (0.56)	6.3E-06	6.8E-06	1.4E-05	1.6E-05	1.6E-05	1.4E-05	9.0E-06	1.2E-05	6.8E-06	6.6E-06	6.0E-06	6.0E-06	6.8E-06	1.4E-05	6.6E-06	6.4E-06
1 (0.62)	7.5E-06	7.7E-06	1.5E-05	1.7E-05	1.7E-05	1.5E-05	8.7E-06	1.1E-05	7.7E-06	7.4E-06	6.9E-06	7.2E-06	7.7E-06	1.4E-05	7.6E-06	7.6E-06
2.4 (1.5)	2.0E-05	2.1E-05	2.2E-05	2.2E-05	2.2E-05	2.2E-05	2.1E-05	2.2E-05	2.2E-05	1.6E-05	7.9E-06	1.8E-05	2.2E-05	2.2E-05	2.2E-05	2.1E-05
4 (2.5)	1.4E-05	1.4E-05	1.5E-05	1.6E-05	1.6E-05	1.5E-05	1.4E-05	1.6E-05	1.5E-05	1.3E-05	8.5E-06	1.3E-05	1.6E-05	1.6E-05	1.5E-05	1.4E-05
5.6 (3.5)	1.3E-05	1.4E-05	1.1E-05	6.1E-06	1.2E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05							
7.2 (4.5)	8.0E-06	8.6E-06	1.0E-05	1.1E-05	1.1E-05	9.8E-06	9.0E-06	1.0E-05	1.0E-05	7.2E-06	5.0E-06	7.5E-06	1.0E-05	1.1E-05	9.3E-06	8.2E-06
12 (7.5)	6.3E-06	6.3E-06	6.4E-06	6.4E-06	6.4E-06	6.4E-06	6.3E-06	6.4E-06	6.4E-06	6.2E-06	4.0E-06	6.2E-06	6.4E-06	6.4E-06	6.3E-06	6.3E-06
24 (15)	2.6E-06	2.8E-06	4.9E-06	5.0E-06	4.7E-06	3.9E-06	2.9E-06	4.0E-06	3.7E-06	2.5E-06	2.0E-06	2.5E-06	4.3E-06	5.5E-06	3.6E-06	2.7E-06
40 (25)	1.5E-06	1.6E-06	2.9E-06	3.0E-06	2.8E-06	2.3E-06	1.6E-06	2.3E-06	2.1E-06	1.5E-06	1.5E-06	1.5E-06	2.5E-06	3.4E-06	2.1E-06	1.6E-06
56 (35)	1.2E-06	1.2E-06	2.1E-06	2.2E-06	2.0E-06	1.7E-06	1.2E-06	1.7E-06	1.5E-06	1.0E-06	8.8E-07	1.0E-06	1.8E-06	2.4E-06	1.5E-06	1.2E-06
72 (45)	9.2E-07	9.4E-07	1.6E-06	1.7E-06	1.6E-06	1.3E-06	9.9E-07	1.4E-06	1.2E-06	7.5E-07	6.6E-07	7.5E-07	1.5E-06	1.9E-06	1.2E-06	9.3E-07

**Table A23.** 95th Percentile E/Q Values ( $s\ m^{-3}$ ) for Acute Ground-Level Releases from 400 Area Based on 1983 through 2002  
 Meteorological Information, Hanford Site, Washington

Distance km (mi)	Sector (Wind from 400 Area toward Direction Indicated)															
	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.1 (0.06)	3.0E-02	2.8E-02	2.9E-02	3.2E-02	3.2E-02	3.1E-02	2.7E-02	2.3E-02	2.6E-02	2.5E-02	2.8E-02	3.2E-02	3.3E-02	3.0E-02	2.5E-02	2.7E-02
0.2 (0.12)	9.0E-03	8.6E-03	8.9E-03	9.6E-03	9.7E-03	9.4E-03	8.2E-03	6.9E-03	7.7E-03	7.4E-03	8.3E-03	9.7E-03	1.0E-02	9.1E-03	7.5E-03	8.1E-03
0.3 (0.19)	4.5E-03	4.3E-03	4.5E-03	4.8E-03	4.9E-03	4.7E-03	4.1E-03	3.5E-03	3.9E-03	3.7E-03	4.2E-03	4.9E-03	5.1E-03	4.6E-03	3.8E-03	4.1E-03
0.4 (0.25)	2.8E-03	2.6E-03	2.7E-03	3.0E-03	3.0E-03	2.9E-03	2.5E-03	2.1E-03	2.4E-03	2.3E-03	2.6E-03	3.0E-03	3.1E-03	2.8E-03	2.3E-03	2.5E-03
0.5 (0.31)	1.9E-03	1.8E-03	1.9E-03	2.0E-03	2.1E-03	2.0E-03	1.8E-03	1.5E-03	1.6E-03	1.6E-03	1.8E-03	2.1E-03	2.1E-03	1.9E-03	1.6E-03	1.7E-03
0.6 (0.37)	1.4E-03	1.3E-03	1.4E-03	1.5E-03	1.5E-03	1.5E-03	1.3E-03	1.1E-03	1.2E-03	1.2E-03	1.3E-03	1.5E-03	1.6E-03	1.4E-03	1.2E-03	1.3E-03
0.7 (0.43)	1.1E-03	1.0E-03	1.1E-03	1.2E-03	1.2E-03	1.1E-03	1.0E-03	8.4E-04	9.4E-04	9.0E-04	1.0E-03	1.2E-03	1.2E-03	1.1E-03	9.1E-04	9.8E-04
0.8 (0.50)	8.8E-04	8.3E-04	8.6E-04	9.3E-04	9.4E-04	9.1E-04	8.0E-04	6.7E-04	7.5E-04	7.2E-04	8.1E-04	9.4E-04	9.8E-04	8.8E-04	7.3E-04	7.9E-04
0.9 (0.56)	7.2E-04	6.8E-04	7.1E-04	7.7E-04	7.7E-04	7.5E-04	6.6E-04	5.5E-04	6.2E-04	5.9E-04	6.6E-04	7.7E-04	8.0E-04	7.3E-04	6.0E-04	6.5E-04
1 (0.62)	6.1E-04	5.7E-04	5.9E-04	6.4E-04	6.5E-04	6.3E-04	5.5E-04	4.6E-04	5.2E-04	4.9E-04	5.6E-04	6.5E-04	6.7E-04	6.1E-04	5.0E-04	5.4E-04
2.4 (1.5)	1.6E-04	1.5E-04	1.5E-04	1.7E-04	1.7E-04	1.6E-04	1.4E-04	1.2E-04	1.3E-04	1.3E-04	1.4E-04	1.7E-04	1.7E-04	1.6E-04	1.3E-04	1.4E-04
4 (2.5)	7.7E-05	7.3E-05	7.5E-05	8.1E-05	8.2E-05	7.9E-05	7.0E-05	5.9E-05	6.6E-05	6.3E-05	7.1E-05	8.2E-05	8.5E-05	7.7E-05	6.4E-05	6.9E-05
5.6 (3.5)	4.9E-05	4.6E-05	4.8E-05	5.2E-05	5.2E-05	5.0E-05	4.5E-05	3.7E-05	4.2E-05	4.0E-05	4.5E-05	5.2E-05	5.4E-05	4.9E-05	4.1E-05	4.4E-05
7.2 (4.5)	3.5E-05	3.3E-05	3.5E-05	3.7E-05	3.8E-05	3.6E-05	3.2E-05	2.7E-05	3.0E-05	2.9E-05	3.2E-05	3.8E-05	3.9E-05	3.5E-05	2.9E-05	3.2E-05
12 (7.5)	1.8E-05	1.7E-05	1.8E-05	1.9E-05	1.9E-05	1.9E-05	1.6E-05	1.4E-05	1.5E-05	1.5E-05	1.7E-05	1.9E-05	2.0E-05	1.8E-05	1.5E-05	1.6E-05
24 (15)	7.7E-06	7.3E-06	7.6E-06	8.1E-06	8.2E-06	8.0E-06	7.0E-06	5.9E-06	6.6E-06	6.3E-06	7.1E-06	8.2E-06	8.5E-06	7.7E-06	6.4E-06	6.9E-06
40 (25)	4.1E-06	3.9E-06	4.1E-06	4.4E-06	4.4E-06	4.3E-06	3.8E-06	3.2E-06	3.5E-06	3.4E-06	3.8E-06	4.4E-06	4.6E-06	4.1E-06	3.4E-06	3.7E-06
56 (35)	2.8E-06	2.6E-06	2.7E-06	2.9E-06	3.0E-06	2.9E-06	2.5E-06	2.1E-06	2.4E-06	2.3E-06	2.5E-06	3.0E-06	3.1E-06	2.8E-06	2.3E-06	2.5E-06
72 (45)	2.0E-06	1.9E-06	2.0E-06	2.2E-06	2.2E-06	2.1E-06	1.9E-06	1.6E-06	1.8E-06	1.7E-06	1.9E-06	2.2E-06	2.3E-06	2.1E-06	1.7E-06	1.8E-06

**Table A24.** 95th Percentile E/Q Values ( $s\ m^{-3}$ ) for Acute 60-m Stack Releases from 400 Area Based on 1986 through 2002  
 Meteorological Information, Hanford Site, Washington

Distance km (mi)	Sector (Wind from 400 Area toward Direction Indicated)															
	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.1 (0.06)	5.0E-11	1.3E-08	1.4E-08	9.3E-11	8.1E-09	9.4E-11	6.5E-11	7.5E-18	9.4E-11	1.1E-08	4.3E-11	4.5E-09	4.6E-11	4.3E-18	9.7E-19	1.8E-18
0.2 (0.12)	9.5E-07	3.3E-06	4.5E-06	1.8E-06	5.5E-06	1.8E-06	1.2E-06	4.7E-08	1.8E-06	2.7E-06	8.2E-07	1.8E-06	8.6E-07	2.7E-08	6.1E-09	1.1E-08
0.3 (0.19)	6.0E-06	8.2E-06	1.0E-05	1.1E-05	1.1E-05	1.1E-05	7.7E-06	3.9E-06	7.0E-06	6.3E-06	4.1E-06	4.6E-06	4.1E-06	1.7E-06	3.9E-07	7.1E-07
0.4 (0.25)	7.6E-06	8.3E-06	1.2E-05	1.4E-05	1.4E-05	1.4E-05	8.4E-06	6.9E-06	7.6E-06	6.5E-06	4.7E-06	5.2E-06	4.9E-06	3.8E-06	1.4E-06	3.0E-06
0.5 (0.31)	8.6E-06	9.2E-06	1.1E-05	1.2E-05	1.3E-05	1.2E-05	9.4E-06	8.6E-06	8.6E-06	5.9E-06	4.3E-06	5.3E-06	5.3E-06	3.7E-06	2.0E-06	3.8E-06
0.6 (0.37)	7.5E-06	8.8E-06	1.2E-05	1.3E-05	1.3E-05	1.3E-05	9.2E-06	7.5E-06	7.5E-06	6.0E-06	5.2E-06	5.7E-06	5.7E-06	5.6E-06	3.2E-06	5.7E-06
0.7 (0.43)	1.0E-05	1.1E-05	1.1E-05	1.2E-05	1.2E-05	1.2E-05	1.1E-05	1.0E-05	8.8E-06	6.4E-06	4.9E-06	7.7E-06	8.0E-06	5.8E-06	3.6E-06	7.4E-06
0.8 (0.50)	1.2E-05	1.3E-05	1.4E-05	1.5E-05	1.5E-05	1.5E-05	1.5E-05	1.4E-05	1.1E-05	8.6E-06	5.3E-06	5.2E-06	7.5E-06	8.1E-06	5.3E-06	7.0E-06
0.9 (0.56)	1.1E-05	1.2E-05	1.5E-05	1.7E-05	1.8E-05	1.7E-05	1.4E-05	9.9E-06	7.3E-06	6.6E-06	6.3E-06	6.8E-06	7.0E-06	6.6E-06	6.2E-06	6.8E-06
1 (0.62)	1.0E-05	1.1E-05	2.1E-05	2.1E-05	2.2E-05	2.2E-05	2.0E-05	9.3E-06	7.6E-06	6.9E-06	6.7E-06	7.5E-06	7.6E-06	7.3E-06	7.1E-06	7.6E-06
2.4 (1.5)	2.1E-05	2.1E-05	2.2E-05	2.2E-05	2.2E-05	2.2E-05	2.2E-05	2.1E-05	1.7E-05	7.7E-06	1.2E-05	2.1E-05	2.2E-05	2.1E-05	7.9E-06	1.8E-05
4 (2.5)	1.4E-05	1.4E-05	1.5E-05	1.6E-05	1.7E-05	1.6E-05	1.6E-05	1.4E-05	1.3E-05	6.9E-06	1.3E-05	1.5E-05	1.5E-05	1.4E-05	7.1E-06	1.3E-05
5.6 (3.5)	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.2E-05	5.2E-06	8.5E-06	1.4E-05	1.4E-05	1.4E-05	5.3E-06	1.2E-05
7.2 (4.5)	9.0E-06	8.7E-06	9.4E-06	1.1E-05	1.1E-05	1.1E-05	1.1E-05	1.0E-05	8.9E-06	7.6E-06	4.6E-06	6.2E-06	9.4E-06	9.9E-06	7.8E-06	7.3E-06
12 (7.5)	6.3E-06	6.3E-06	6.3E-06	6.4E-06	6.4E-06	6.4E-06	6.4E-06	6.3E-06	6.3E-06	3.2E-06	6.1E-06	6.3E-06	6.4E-06	6.3E-06	3.2E-06	6.2E-06
24 (15)	2.7E-06	2.6E-06	2.7E-06	4.2E-06	4.5E-06	4.5E-06	2.9E-06	2.7E-06	2.5E-06	1.9E-06	2.3E-06	3.2E-06	3.7E-06	2.5E-06	1.9E-06	2.4E-06
40 (25)	1.6E-06	1.6E-06	1.6E-06	2.5E-06	2.7E-06	2.6E-06	1.6E-06	1.6E-06	1.5E-06	1.5E-06	1.5E-06	1.7E-06	2.1E-06	1.5E-06	1.4E-06	1.5E-06
56 (35)	1.2E-06	1.1E-06	1.1E-06	1.8E-06	1.9E-06	1.9E-06	1.2E-06	1.2E-06	1.1E-06	1.0E-06	1.1E-06	1.3E-06	1.5E-06	1.1E-06	9.1E-07	1.1E-06
72 (45)	9.3E-07	8.9E-07	9.1E-07	1.4E-06	1.5E-06	1.5E-06	9.8E-07	9.3E-07	8.8E-07	7.6E-07	8.5E-07	1.1E-06	1.2E-06	7.9E-07	6.8E-07	8.3E-07

## **Appendix B**

### **Hanford Site Species Lists**

**This appendix contains five tables that list species of vascular plants, mammals, birds, reptiles and amphibians, and fish that have been sighted on the Hanford Site. The lists are for those species likely to be encountered on the site and are not intended to represent a complete listing of all species. When appropriate, more comprehensive listings have been identified.**

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**Table B-1.** Common Vascular Plants on the Hanford Site, Washington (Taxonomy follows Hitchcock and Cronquist 1973). See Sackschewsky and Downs (2001) for a complete listing of Hanford Site vascular plants

<b>A. Shrub-Steppe Species</b>	<b>Scientific Name</b>
<b>Shrub</b>	
big sagebrush	<i>Artemisia tridentata</i>
bitterbrush	<i>Purshia tridentata</i>
gray rabbitbrush	<i>Ericameria nauseosa</i>
green rabbitbrush	<i>Chrysothamnus viscidiflorus</i>
snow buckwheat	<i>Eriogonum niveum</i>
spiny hopsage	<i>Grayia (Atriplex) spinosa</i>
threetip sagebrush	<i>Artemisia tripartita</i>
<b>Perennial Grasses</b>	
bluebunch wheatgrass	<i>Pseudoroegneria spicata</i>
bottlebrush squirreltail	<i>Elymus elymoides</i>
crested wheatgrass	<i>Agropyron desertorum (cristatum)<sup>(a)</sup></i>
Indian ricegrass	<i>Achnatherum hymenoides</i>
needle-and-thread grass	<i>Stipa comata</i>
prairie junegrass	<i>Koeleria cristata</i>
sand dropseed	<i>Sporobolus cryptandrus</i>
Sandberg's bluegrass	<i>Poa sandbergii (secunda)</i>
thickspike wheatgrass	<i>Elymus macrourus</i>
<b>Biennial/Perennial Forbs</b>	
bastard toad flax	<i>Comandra umbellata</i>
buckwheat milkvetch	<i>Astragalus caricinus</i>
carey's balsamroot	<i>Balsamorhiza careyana</i>
Cusick's sunflower	<i>Helianthus cusickii</i>
cutleaf ladysfoot mustard	<i>Thelypodium laciniatum</i>
Douglas' clusterlily	<i>Brodiaea douglasii</i>
dune scurfpea	<i>Psoralea lanceolata</i>
Franklin's sandwort	<i>Arenaria franklinii</i>
Gray's desertparsley	<i>Lomatium grayi</i>
hoary aster	<i>Machaeranthera canescens</i>
hoary falseyarrow	<i>Chaenactis douglasii</i>
longleaf phlox	<i>Phlox longifolia</i>
Munro's globemallow	<i>Sphaeralcea munroana</i>
pale eveningprimrose	<i>Oenothera pallida</i>
rough wallflower	<i>Erysimum asperum</i>
sand beardtongue	<i>Penstemon acuminatus</i>

**Table B-1 (cont'd)**

<b>A. Shrub-Steppe Species (cont'd.)</b>	<b>Scientific Name</b>
slender hawksbeard	<i>Crepis atrabarba</i>
stalked-pod milkvetch	<i>Astragalus sclerocarpus</i>
threadleaf fleabane	<i>Erigeron filifolius</i>
turpentine spring parsley	<i>Cymopterus terebinthinus</i>
winged dock	<i>Rumex venosus</i>
yarrow	<i>Achillea millefolium</i>
yellow bell	<i>Fritillaria pudica</i>
yellow salsify	<i>Tragopogon dubius</i> <sup>(a)</sup>
<b>Annual Forbs</b>	
annual Jacob's ladder	<i>Polemonium micranthum</i>
blue mustard	<i>Chorispora tenella</i> <sup>(a)</sup>
bur ragweed	<i>Ambrosia acanthicarpa</i>
clasping pepperweed	<i>Lepidium perfoliatum</i>
Indian wheat	<i>Plantago patagonica</i>
jagged chickweed	<i>Holosteum umbellatum</i> <sup>(a)</sup>
Jim Hill's tumbled mustard	<i>Sisymbrium altissimum</i> <sup>(a)</sup>
matted cryptantha	<i>Cryptantha circumscissa</i>
pink microsteris	<i>Microsteris gracilis</i>
prickly lettuce	<i>Lactuca serriola</i> <sup>(a)</sup>
Russian thistle (tumbleweed)	<i>Salsola kali</i> <sup>(a)</sup>
spring whitlowgrass	<i>Draba verna</i> <sup>(a)</sup>
storksbill	<i>Erodium cicutarium</i> <sup>(a)</sup>
tall willowherb	<i>Epilobium paniculatum</i>
tarweed fiddleneck	<i>Amsinckia lycopsoides</i>
threadleaf scorpion weed	<i>Phacelia linearis</i>
western tansymustard	<i>Descurainia pinnata</i>
white cupseed	<i>Plectritis macrocera</i>
whitestem stickleaf	<i>Mentzelia albicaulis</i>
winged cryptantha	<i>Cryptantha pterocarya</i>
<b>Annual Grasses</b>	
cheatgrass	<i>Bromus tectorum</i> <sup>(a)</sup>
slender sixweeks	<i>Festuca octoflora</i>
small sixweeks	<i>Festuca microstachys</i>
<b>B. Riparian Species</b>	<b>Scientific Name</b>
<b>Trees and Shrubs</b>	
black cottonwood	<i>Populus trichocarpa</i>
black locust	<i>Robinia pseudo-acacia</i>
coyote willow	<i>Salix exigua</i>
peach, apricot, cherry	<i>Prunus</i> spp.
peachleaf willow	<i>Salix amygdaloides</i> <sup>(a)</sup>

**Table B-1 (cont'd)**

<b>Trees and Shrubs (cont'd)</b>	
willow	<i>Salix</i> spp.
white mulberry	<i>Morus alba</i> <sup>(a)</sup>
<b>Perennial Grasses and Forbs</b>	
bentgrass	<i>Agrostis</i> spp. <sup>(b)</sup>
blanket flower	<i>Gaillardia aristata</i>
bulrushes	<i>Scirpus</i> spp. <sup>(b)</sup>
cattail	<i>Typha latifolia</i> <sup>(b)</sup>
Columbia River gumweed	<i>Grindelia columbiana</i>
dogbane	<i>Apocynum cannabinum</i>
hairy golden aster	<i>Heterotheca villosa</i>
heartweed	<i>Polygonum persicaria</i>
horsetails	<i>Equisetum</i> spp.
horseweed tickseed	<i>Coreopsis atkinsoniana</i>
lovegrass	<i>Eragrostis</i> spp. <sup>(b)</sup>
lupine	<i>Lupinus</i> spp.
meadow foxtail	<i>Alopecurus aequalis</i> <sup>(b)</sup>
Pacific sage	<i>Artemisia campestris</i>
prairie sagebrush	<i>Artemisia ludoviciana</i>
reed canary grass	<i>Phalaris arundinacea</i> <sup>(a,b)</sup>
rushes	<i>Juncus</i> spp.
Russian knapweed	<i>Centaurea repens</i> <sup>(a)</sup>
sedge	<i>Carex</i> spp. <sup>(b)</sup>
water speedwell	<i>Veronica anagallis-aquatica</i>
western goldenrod	<i>Solidago occidentalis</i>
wild onion	<i>Allium</i> spp.
wiregrass spikerush	<i>Eleocharis</i> spp. <sup>(b)</sup>
<b>C. Aquatic Vascular Species</b>	<b>Scientific Name</b>
Canadian waterweed	<i>Elodea canadensis</i>
duckweed	<i>Lemna minor</i>
pondweed	<i>Potamogeton</i> spp.
spiked water milfoil	<i>Myriophyllum spicatum</i>
watercress	<i>Rorippa nasturtium-aquaticum</i>
(a) Introduced	
(b) Perennial grasses and graminoids.	

**Table B-2.** Mammals that Have Been Observed on the Hanford Site, Washington (Becker 1993, Fitzner and Gray 1991, Soll *et al.* 1999)

<b>Common Name</b>	<b>Scientific Name</b>
<b><u>Shrews (family Soricidae)</u></b>	
Merriam's shrew	<i>Sorex merriami</i>
vagrant shrew	<i>Sorex vagrans</i>
<b><u>Evening bats (family Vespertilionidae)</u></b>	
pallid bat	<i>Antrozous pallidus</i>
big brown bat	<i>Eptesicus fuscus</i>
silver-haired bat	<i>Lasionycteris noctivagans</i>
hoary bat	<i>Lasiurus cinereus</i>
California myotis	<i>Myotis californicus</i>
small-footed myotis	<i>Myotis leibii</i>
little brown myotis	<i>Myotis lucifugus</i>
long-legged myotis	<i>Myotis volans</i>
Yuma myotis	<i>Myotis yumanensis</i>
western pipistrelle	<i>Pipistrellus hesperus</i>
<b><u>Hares, rabbits (family Leporidae)</u></b>	
black-tailed jackrabbit	<i>Lepus californicus</i>
white-tailed jackrabbit	<i>Lepus townsendii</i>
Nuttall's (or mountain) cottontail	<i>Sylvilagus nuttallii</i>
<b><u>Chipmunks, marmots, Squirrels (family Sciuridae)</u></b>	
yellow-bellied marmot	<i>Marmota flaviventris</i>
Townsend's ground squirrel	<i>Spermophilus townsendii</i>
Washington ground squirrel	<i>Spermophilus washingtoni</i>
least chipmunk	<i>Tamias minimus</i>
<b><u>Pocket gophers (family Geomyidae)</u></b>	
northern pocket gopher	<i>Thomomys talpoides</i>
<b><u>Heteromyid rodents, pocket mice (family Heteromyidae)</u></b>	
Great Basin pocket mouse	<i>Perognathus parvus</i>
<b><u>Beavers (family Castoridae)</u></b>	
beaver	<i>Castor canadensis</i>
<b><u>Campagnols, mice, rats, souris, voles (family Muridae)</u></b>	
sagebrush vole	<i>Lemmyscus curtatus</i>
montane vole	<i>Microtus montanus</i>

Table B-2 (cont'd)

Common Name	Scientific Name
<b><u>Campagnols, mice, rats, souris, voles (family Muridae) cont'd</u></b>	
house mouse	<i>Mus musculus</i>
bushy-tailed woodrat	<i>Neotoma cinerea</i>
muskrat	<i>Ondatra zibethicus</i>
northern grasshopper mouse	<i>Onychomys leucogaster</i>
deer mouse	<i>Peromyscus maniculatus</i>
Norway rat	<i>Rattus norvegicus</i>
western harvest mouse	<i>Reithrodontomys megalotis</i>
<b><u>New World porcupines (family Erethizontidae)</u></b>	
porcupine	<i>Erethizon dorsatum</i>
<b><u>Coyotes, dogs, foxes, jackals, wolves (family Canidae)</u></b>	
coyote	<i>Canis latrans</i>
<b><u>Raccoons (family Procyonidae)</u></b>	
raccoon	<i>Procyon lotor</i>
<b><u>Martins, weasels, wolverines, otters, badgers (family Mustelidae)</u></b>	
river otter	<i>Lontra canadensis</i>
short-tail weasel	<i>Mustela erminea</i>
long-tailed weasel	<i>Mustela frenata</i>
mink	<i>Mustela vison</i>
badger	<i>Taxidea taxus</i>
<b><u>Skunks (family Mephitidae)</u></b>	
striped skunk	<i>Mephitis mephitis</i>
<b><u>Cats (family Felidae)</u></b>	
bobcat	<i>Lynx rufus</i>
mountain lion	<i>Puma concolor concolor</i>
<b><u>Caribou, cervids, deer, moose, Wapiti (family Cervidae)</u></b>	
Rocky Mountain elk	<i>Cervus elaphus</i>
mule deer	<i>Odocoileus hemionus</i>
white-tailed deer	<i>Odocoileus virginianus</i>

**Table B-3.** Common Bird Species Known to Occur on the Hanford Site, Washington (Fitzner and Gray 1991, Landeen et al. 1992, Duberstein 1997). Season Code: Yr = all year, W = winter, B = Breeding, M = Migration

Common Name	Scientific Name	Season of highest abundance
<b><u>Gaviiformes - Loons or divers</u></b>		
common loon	<i>Gavia immer</i>	Yr
<b><u>Podicipediformes - Grebes</u></b>		
eared grebe	<i>Podiceps nigricollis</i>	W
horned grebe	<i>Podiceps auritus</i>	W
pied-billed grebe	<i>Podilymbus podiceps</i>	Yr
western grebe	<i>Aechmophorus occidentalis</i>	W
<b><u>Pelecaniformes - Pelicans and allies</u></b>		
American white pelican	<i>Pelecanus erythrorhynchos</i>	Yr
double-crested cormorant	<i>Phalacrocorax auritus</i>	Yr
<b><u>Anseriformes - Waterfowl</u></b>		
American green-winged teal	<i>Anas crecca</i>	Yr
American wigeon	<i>Anas americana</i>	W
Barrow's goldeneye	<i>Bucephala islandica</i>	W
blue-winged teal	<i>Anas discors</i>	B
bufflehead	<i>Bucephala albeola</i>	W
cinnamon teal	<i>Anas cyanoptera</i>	B
Canada goose	<i>Branta canadensis</i>	Yr
common goldeneye	<i>Bucephala clangula</i>	W
common merganser	<i>Mergus merganser</i>	Yr
gadwall	<i>Anas strepera</i>	Yr
hooded merganser	<i>Lophodytes cucullatus</i>	W
mallard	<i>Anas platyrhynchos</i>	Yr
northern pintail	<i>Anas acuta</i>	Yr
northern shoveler	<i>Anas clypeata</i>	Yr
redhead	<i>Aythya americana</i>	W
ruddy duck	<i>Oxyura jamaicensis</i>	Yr
<b><u>Gruiformes - Cranes, rails, and allies</u></b>		
American coot	<i>Fulica americana</i>	Yr
sora	<i>Porzana carolina</i>	B
Virginia rail	<i>Rallus limicola</i>	B
<b><u>Charadriiformes - Shorebirds and allies</u></b>		
California gull	<i>Larus californicus</i>	Yr
Forster's tern	<i>Sterna forsteri</i>	B

**Table B-3** (cont'd)

<b>Common Name</b>	<b>Scientific Name</b>	<b>Season of highest abundance</b>
<b><u>Charadriiformes - Shorebirds and allies (cont'd)</u></b>		
American avocet	<i>Recurvirostra americana</i>	B
black-crowned night-heron	<i>Nycticorax nycticorax</i>	B
Caspian tern	<i>Sterna caspia</i>	B
common snipe	<i>Gallinago gallinago</i>	B
dunlin	<i>Calidris alpinis</i>	M
glaucous-winged gull	<i>Leucosticte tephrocotis</i>	Yr
great blue heron	<i>Ardea herodias</i>	Yr
great egret	<i>Casmerodius albus</i>	B
greater yellowlegs	<i>Tringa melanoleuca</i>	M
herring gull	<i>Larus argentatus</i>	W
killdeer	<i>Charadrius vociferus</i>	B
lesser yellowlegs	<i>Tringa flavipes</i>	M
long-billed curlew	<i>Numenius americanus</i>	B
long-billed dowitcher	<i>Limnodromus scolopaceus</i>	M
red-necked phalarope	<i>Larus glaucescens</i>	M
ring-billed gull	<i>Larus delawarensis</i>	Yr
sandhill crane	<i>Grus canadensis</i>	M
spotted sandpiper	<i>Actitis macularia</i>	B
solitary sandpiper	<i>Tringa solitaria</i>	M
western sandpiper	<i>Calidris mauri</i>	M
<b><u>Galliformes - Chicken-like birds</u></b>		
California quail	<i>Callipepla californica</i>	Yr
chukar	<i>Alectoris chukar</i>	Yr
grey partridge	<i>Perdix perdix</i>	Yr
ring-necked pheasant	<i>Phasianus colchicus</i>	Yr
<b><u>Falconiformes - Diurnal birds of prey</u></b>		
American kestrel	<i>Falco sparverius</i>	Yr
bald eagle	<i>Haliaeetus leucocephalus</i>	W
Cooper's hawk	<i>Accipiter cooperii</i>	W
ferruginous hawk	<i>Buteo regalis</i>	B
golden eagle	<i>Aquila chrysaetos</i>	Yr
merlin	<i>Falco columbarius</i>	M
northern harrier	<i>Circus cyaneus</i>	Yr
northern rough-legged hawk	<i>Buteo lagopus</i>	W
osprey	<i>Pandion haliaetus</i>	B
prairie falcon	<i>Falco mexicanus</i>	Yr
red-tailed hawk	<i>Buteo jamaicensis</i>	Yr
sharp-shinned hawk	<i>Accipiter striatus</i>	W
Swainson's hawk	<i>Buteo swainsoni</i>	B

**Table B-3** (cont'd)

<b>Common Name</b>	<b>Scientific Name</b>	<b>Season of highest abundance</b>
<b><u>Strigiformes - Owls</u></b>		
burrowing owl	<i>Athene cunicularia</i>	B
common barn-owl	<i>Tyto alba</i>	Yr
great horned owl	<i>Bubo virginianus</i>	Yr
long-eared owl	<i>Asio otus</i>	Yr
short-eared owl	<i>Asio flammeus</i>	Yr
<b><u>Coraciiformes - Rollers and allies</u></b>		
belted kingfisher	<i>Ceryle alcyon</i>	Yr
<b><u>Columbiformes - Pigeons</u></b>		
mourning dove	<i>Zenaida macroura</i>	Yr
rock dove	<i>Columba livia</i>	Yr
<b><u>Caprimulgiformes - Nightjars and allies</u></b>		
common nighthawk	<i>Chordeiles minor</i>	B
common poorwill	<i>Phalaenoptilus nuttallii</i>	B
<b><u>Apodiformes - Hummingbirds, swifts</u></b>		
rufous hummingbird	<i>Selasphorus rufus</i>	M
<b><u>Piciformes - Woodpeckers and allies</u></b>		
Northern flicker	<i>Colaptes auratus</i>	Yr
<b><u>Passeriformes - Perching birds</u></b>		
American crow	<i>Corvus brachyrhynchos</i>	Yr
American goldfinch	<i>Carduelis tristis</i>	Yr
American robin	<i>Turdus migratorius</i>	Yr
bank swallow	<i>Riparia riparia</i>	B
barn swallow	<i>Hirundo rustica</i>	B
Bewick's wren	<i>Thryomanes bewickii</i>	B
black-billed magpie	<i>Pica pica</i>	Yr
black-headed grosbeak	<i>Pheucticus melanocephalus</i>	B
Blue-headed vireo	<i>Vireo solitarius</i>	M
Brewer's blackbird	<i>Euphagus cyanocephalus</i>	B
Brewer's sparrow	<i>Spizella breweri</i>	B
brown-headed cowbird	<i>Molothrus ater</i>	B
Bullock's oriole	<i>Icterus galbula</i>	B
canyon wren	<i>Catherpes mexicanus</i>	B
cedar waxwing	<i>Bombycilla cedrorum</i>	M
chipping sparrow	<i>Spizella passerina</i>	M
cliff swallow	<i>Hirundo pyrrhonota</i>	B

**Table B-3** (cont'd)

<b>Common Name</b>	<b>Scientific Name</b>	<b>Season of highest abundance</b>
<b><u>Passeriformes - Perching birds</u></b>		
<b><u>(cont'd)</u></b>		
common raven	<i>Corvus corax</i>	Yr
dark-eyed junco	<i>Junco hyemalis</i>	Yr
eastern kingbird	<i>Tyrannus tyrannus</i>	B
European starling	<i>Sturnus vulgaris</i>	Yr
golden-crowned kinglet	<i>Regulus satrapa</i>	M
golden-crowned sparrow	<i>Zonotrichia atricapilla</i>	M
grasshopper sparrow	<i>Ammodramus savannarum</i>	B
gray-crowned rosy finch	<i>Phalaropus lobatus</i>	M
Hammond's flycatcher	<i>Empidonax hammondii</i>	M
horned lark	<i>Eremophila alpestris</i>	Yr
house finch	<i>Carpodacus mexicanus</i>	Yr
house sparrow	<i>Passer domesticus</i>	Yr
house wren	<i>Troglodytes aedon</i>	B
lark sparrow	<i>Chondestes grammacus</i>	B
lazuli bunting	<i>Passerina amoena</i>	B
Lincoln's sparrow	<i>Melospiza lincolnii</i>	M
loggerhead shrike	<i>Lanius ludovicianus</i>	Yr
MacGillivray's warbler	<i>Oporornis tolmiei</i>	B
marsh wren	<i>Cistothorus palustris</i>	B
Nashville warbler	<i>Vermivora ruficapilla</i>	M
northern rough-winged swallow	<i>Stelgidopteryx serripennis</i>	B
orange-crowned warbler	<i>Vermivora celata</i>	M
Pacific-slope flycatcher	<i>Empidonax difficilis</i>	M
red-breasted nuthatch	<i>Sitta canadensis</i>	W
red-winged blackbird	<i>Agelaius phoeniceus</i>	B
rock wren	<i>Salpinctes obsoletus</i>	B
ruby-crowned kinglet	<i>Regulus calendula</i>	M
rufous-sided towhee	<i>Pipilo erythrophthalmus</i>	B
sage sparrow	<i>Amphispiza belli</i>	B
sage thrasher	<i>Oreoscoptes montanus</i>	B
savannah sparrow	<i>Passerculus sandwichensis</i>	B
Say's phoebe	<i>Sayornis saya</i>	B
song sparrow	<i>Melospiza melodia</i>	Yr
Townsend's solitaire	<i>Myadestes townsendi</i>	M
Townsend's warbler	<i>Dendroica townsendi</i>	M
tree swallow	<i>Tachycineta bicolor</i>	M
varied thrush	<i>Ixoreus naevius</i>	W
vesper sparrow	<i>Pooecetes gramineus</i>	B
violet-green swallow	<i>Tachycineta thalassina</i>	M
warbling vireo	<i>Vireo gilvus</i>	M
western kingbird	<i>Tyrannus verticalis</i>	B
western meadowlark	<i>Sturnella neglecta</i>	Yr

**Table B-3** (cont'd)

<b>Common Name</b>	<b>Scientific Name</b>	<b>Season of highest abundance</b>
<b><u>Passeriformes - Perching birds</u></b>		
<b><u>(cont'd)</u></b>		
white-crowned sparrow	<i>Zonotrichia leucophrys</i>	W
western tanager	<i>Piranga ludoviciana</i>	M
western wood-pewee	<i>Contopus sordidulus</i>	M
Wilson's warbler	<i>Wilsonia pusilla</i>	M
winter wren	<i>Troglodytes troglodytes</i>	W
yellow-breasted chat	<i>Icteria virens</i>	B
yellow-rumped warbler	<i>Dendroica coronata</i>	M
yellow warbler	<i>Dendroica petechia</i>	M
yellow-headed blackbird	<i>Xanthocephalus xanthocephalus</i>	B

**Table B-4.** Reptiles and Amphibians Found on the Hanford Site, Washington

<b>Common Name</b>	<b>Scientific Name</b>
<b><u>Reptiles</u></b>	
common garter snake	<i>Thamnophis sirtalis</i>
Great Basin gopher snake	<i>Pituiphis melanoleucus</i>
night snake	<i>Hypsiglena torquata</i>
northern sagebrush lizard	<i>Scleropus graciosus</i>
painted turtle	<i>Chrysemys picta</i>
short-horned lizard	<i>Phrynosoma douglassii</i>
side-blotched lizard	<i>Uta stansburiana</i>
striped whipsnake	<i>Masticophis taeniatus</i>
western rattlesnake	<i>Crotalus viridis</i>
western yellow-bellied racer	<i>Coluber constrictor</i>
<b><u>Amphibians</u></b>	
bullfrog	<i>Rana catesbeiana</i>
Great Basin spadefoot	<i>Scaphiopus intermontanus</i>
Pacific tree frog	<i>Hyla regilla</i>
tiger Salamander	<i>Ambystoma tigrinum</i>
western toad	<i>Bufo boreas</i>
Woodhouse's toad	<i>Bufo woodhousii</i>

**Table B-5.** Fish Species in the Hanford Reach, Washington, Region of the Columbia River

<b>Common Name</b>	<b>Scientific Name</b>
<b><u>Paddlefishes, spoonfishes, sturgeons (family Acipenseridae)</u></b>	
white sturgeon	<i>Acipenser transmontanus</i>
<b><u>Anchovies, herrings (family Clupeidae)</u></b>	
American shad	<i>Alosa sapidissima</i>
<b><u>Cyprins, minnows, suckers (family Catostomidae)</u></b>	
chiselmouth	<i>Acrocheilus alutaceus</i>
bridgelip sucker	<i>Catostomus columbianus</i>
largescale sucker	<i>Catostomus macrocheilus</i>
mountain sucker	<i>Catostomus platyrhynchus</i>
common carp	<i>Cyprinus carpio</i>
peamouth	<i>Mylocheilus caurinus</i>
northern pikeminnow	<i>Ptychocheilus oregonensis</i>
longnose dace	<i>Rhinichthys cataractae</i>
leopard dace	<i>Rhinichthys falcatus</i>
speckled dace	<i>Rhinichthys osculus</i>
reduceside shiner	<i>Richardsonius balteatus</i>
<b><u>Livebearers (family Poeciliidae)</u></b>	
Western mosquitofish	<i>Gambusia affinis</i>
<b><u>Cods (family Gadidae)</u></b>	
burbot	<i>Lota lota</i>
<b><u>Pipefishes, sticklebacks (family Gasterosteidae)</u></b>	
threespine stickleback	<i>Gasterosteus aculeatus</i>
ninespine stickleback	<i>Pungitius pungitius</i>
<b><u>Perch-like fishes (family Centrarchidae)</u></b>	
pumpkinseed	<i>Lepomis gibbosus</i>
bluegill	<i>Lepomis macrochirus</i>
smallmouth bass	<i>Micropterus dolomieu</i>
largemouth bass	<i>Micropterus salmoides</i>
yellow perch	<i>Perca flavescens</i>
white crappie	<i>Pomoxis annularis</i>
black crappie	<i>Pomoxis nigromaculatus</i>
walleye	<i>Sander vitreus</i>
<b><u>Trout perches (family Percopsidae)</u></b>	
sand roller	<i>Percopsis transmontana</i>

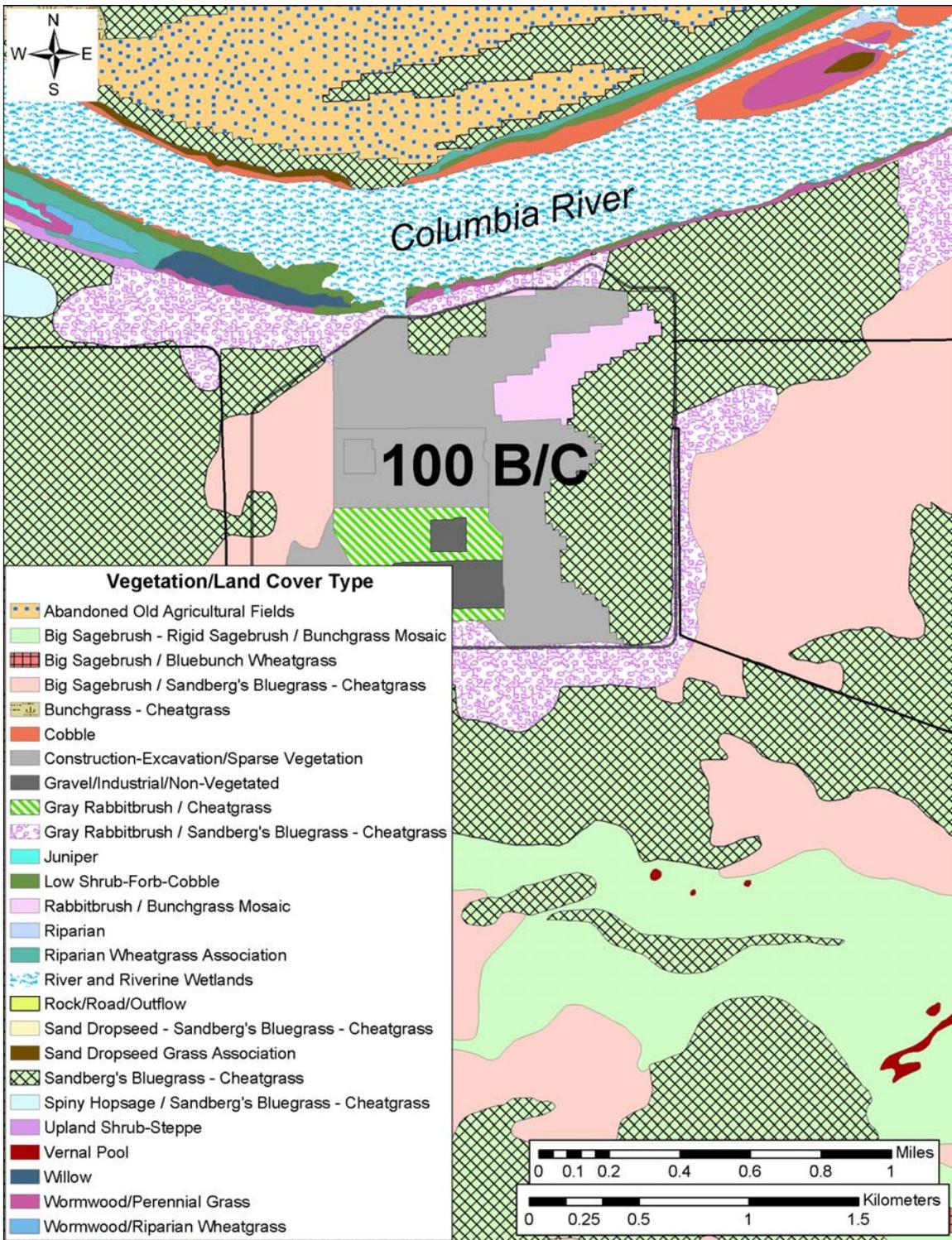
<b>Common Name</b>	<b>Scientific Name</b>
<b><u>Lampreys (family Petromyzontidae)</u></b>	
river lamprey	<i>Lampetra ayresii</i>
Pacific lamprey	<i>Lampetra tridentata</i>
<b><u>Salmonids, salmon, trouts (family Salmonidae)</u></b>	
lake whitefish	<i>Coregonus clupeaformis</i>
bull trout	<i>Salvelinus confluentus</i>
cutthroat trout	<i>Oncorhynchus clarkii</i>
coho salmon	<i>Oncorhynchus kisutch</i>
rainbow trout (steelhead)	<i>Oncorhynchus mykiss</i>
sockeye salmon	<i>Oncorhynchus nerka</i>
Chinook salmon	<i>Oncorhynchus tshawytscha</i>
mountain whitefish	<i>Prosopium williamsoni</i>
Dolly Varden	<i>Salvelinus malma</i>
<b><u>Chabots, sculpins (family Cottidae)</u></b>	
prickley sculpin	<i>Cottus asper</i>
mottled sculpin	<i>Cottus bairdii</i>
Piute sculpin	<i>Cottus beldingii</i>
reticulate sculpin	<i>Cottus perplexus</i>
torrent sculpin	<i>Cottus rhotheus</i>
<b><u>Bullhead catfishes, North American freshwater catfishes (family Ictaluridae)</u></b>	
yellow bullhead	<i>Ameiurus natalis</i>
brown bullhead	<i>Ameiurus nebulosus</i>
black bullhead	<i>Ameiurus melas</i>
channel catfish	<i>Ictalurus punctatus</i>

## Appendix B References

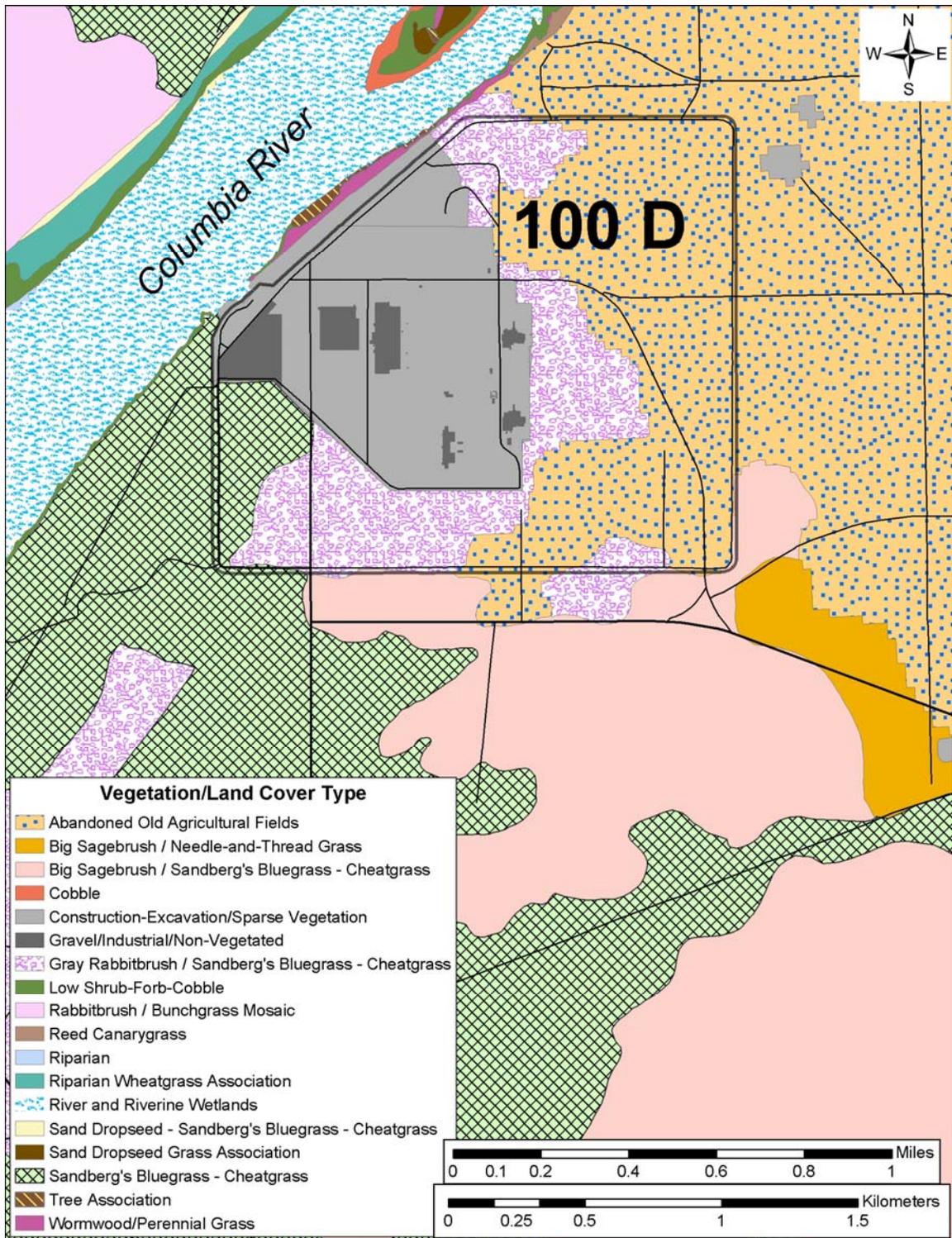
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## **Appendix C - Vegetation Maps**

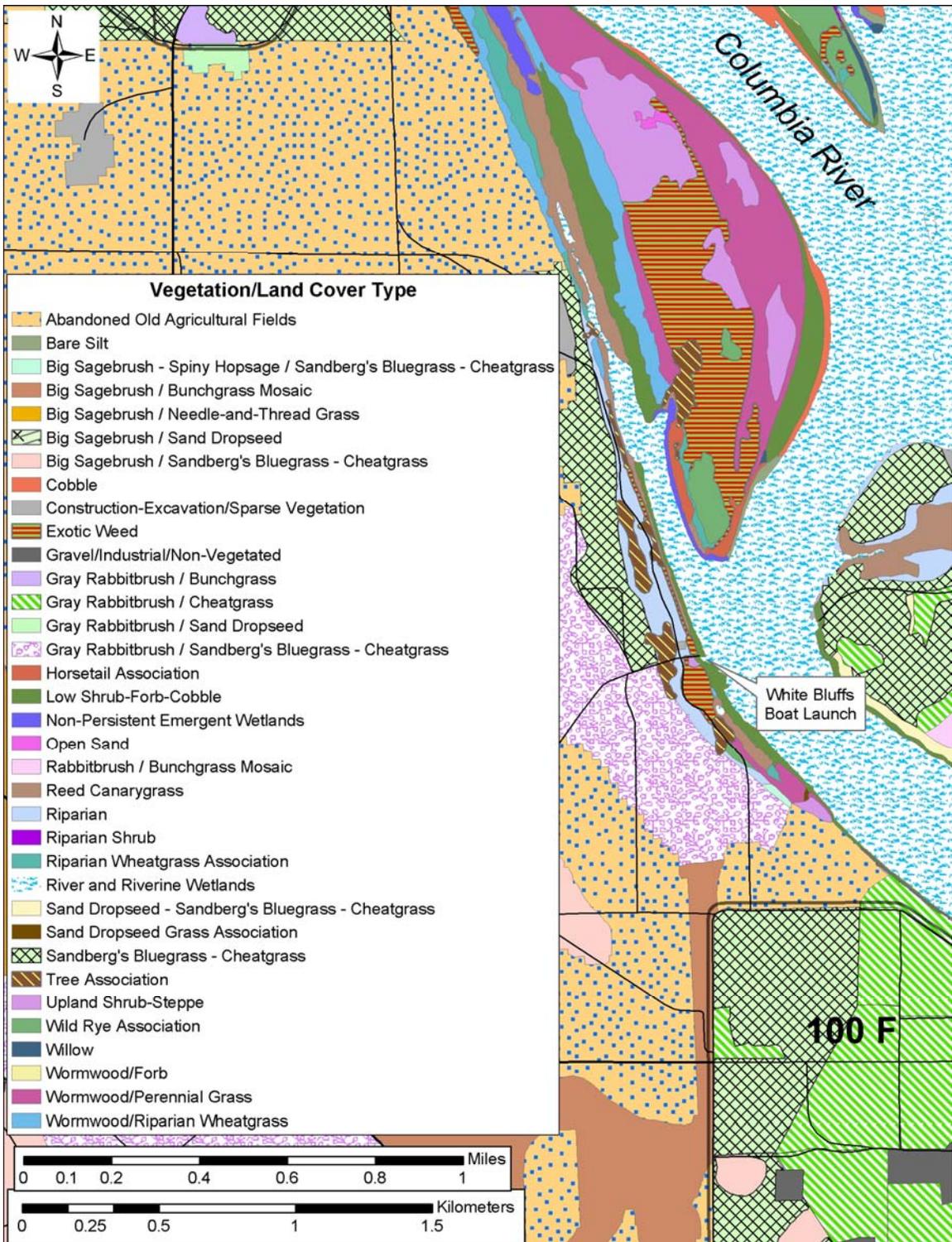
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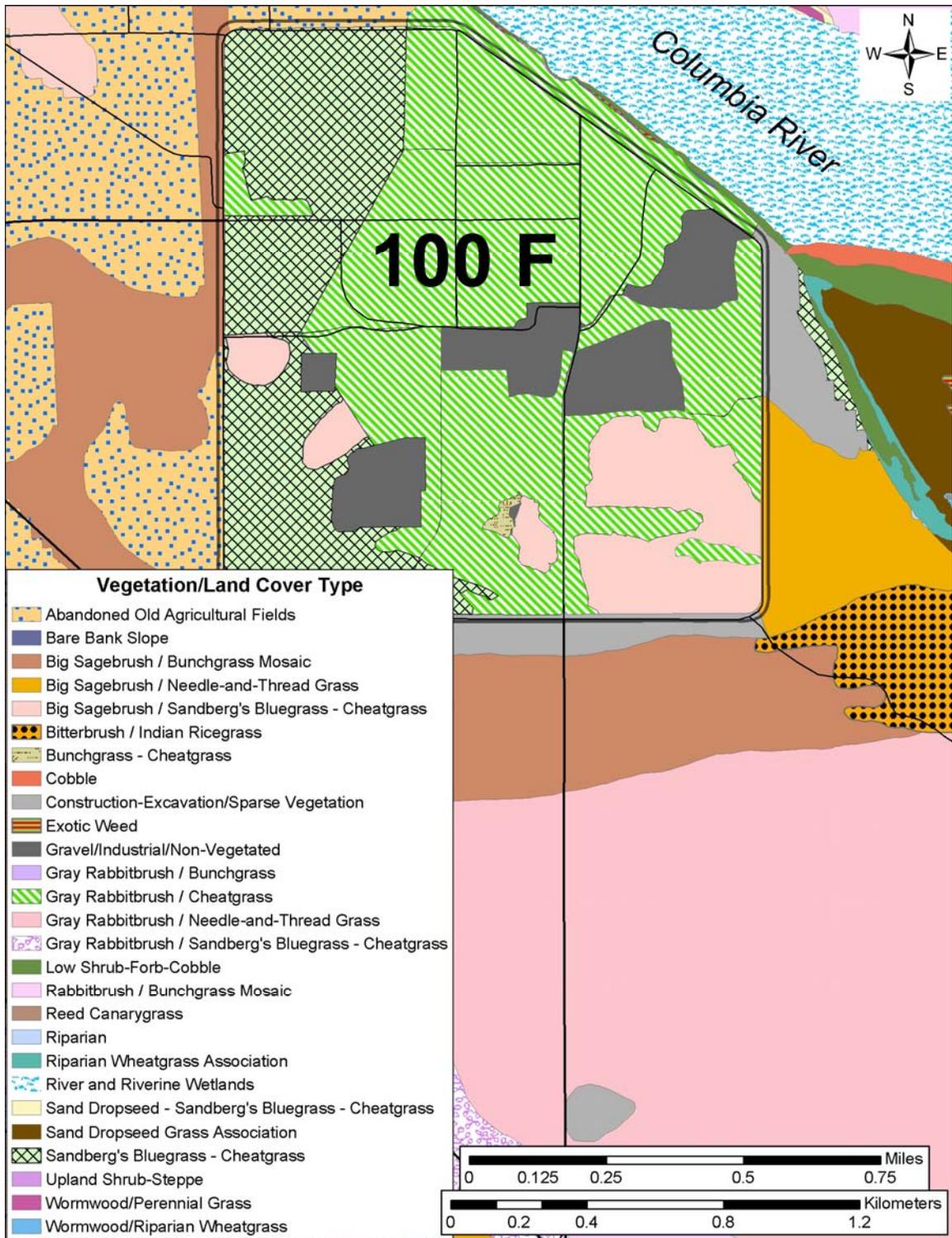
**Figure C-1.** Vegetation/Land Coverage Map for the 100-B/C Area, Hanford Site, Washington, during 2004



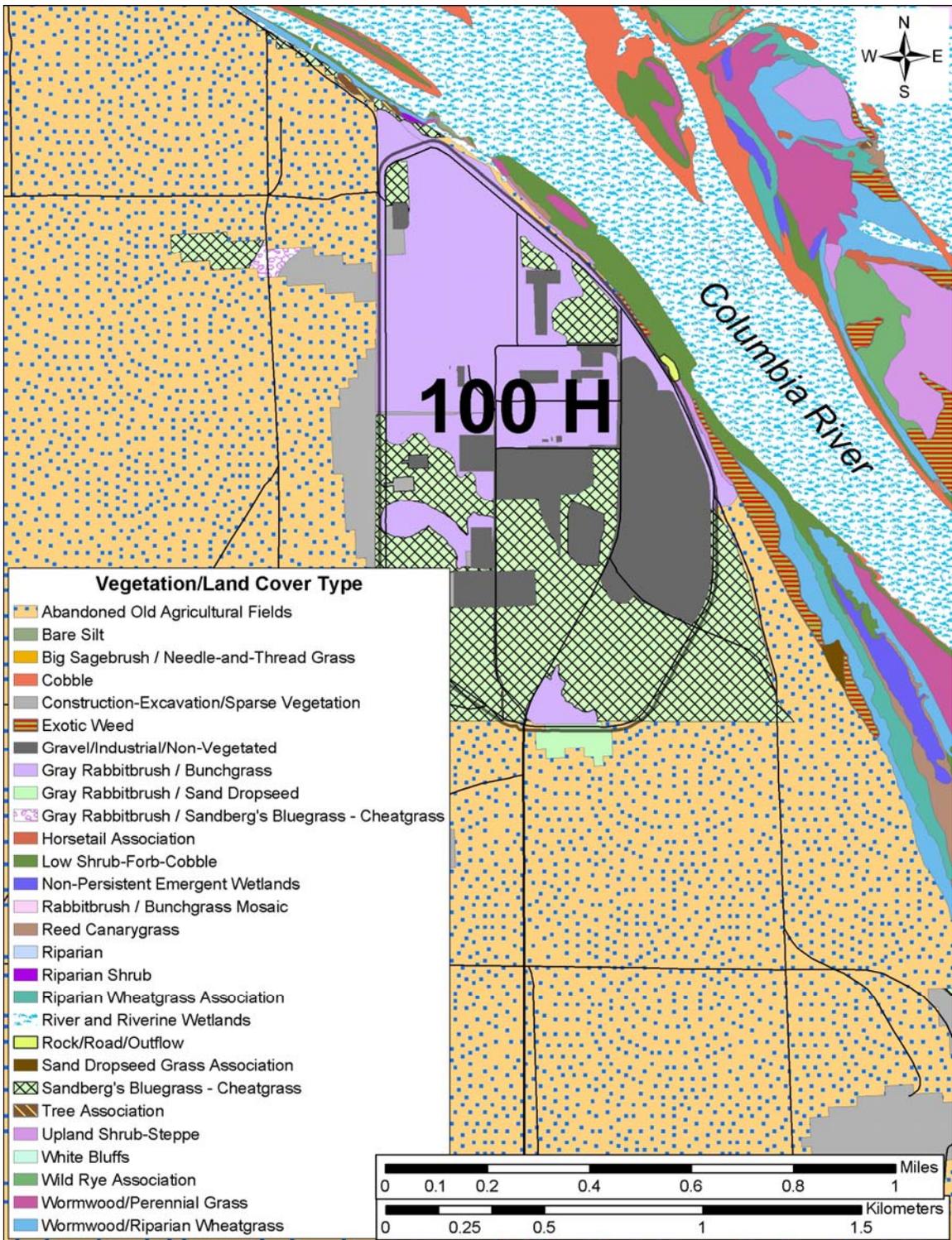
**Figure C-2.** Vegetation/Land Coverage Map for the 100-D Area, Hanford Site, Washington, during 2004



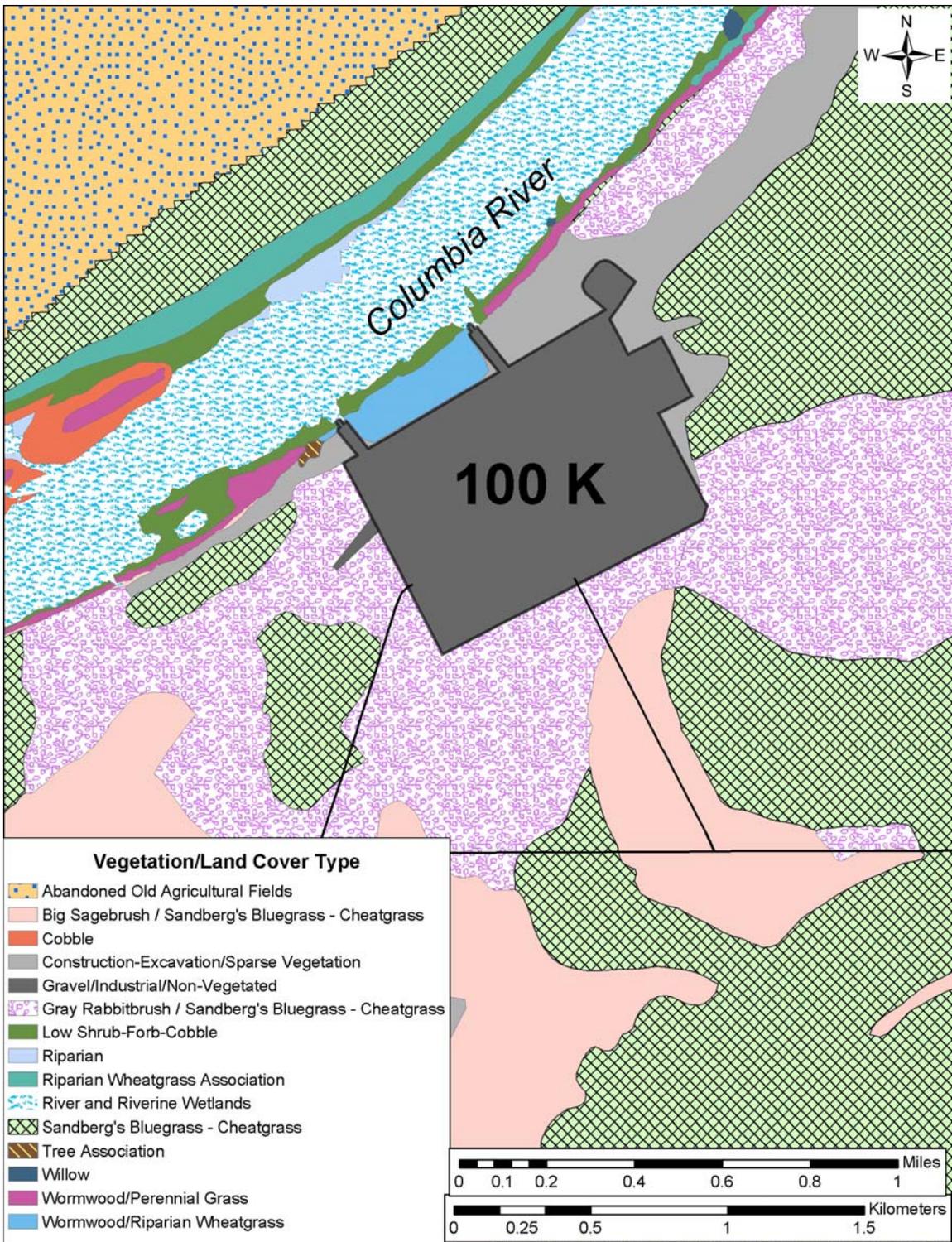
**Figure C-3.** Vegetation/Land Coverage Map for the White Bluffs Boat Launch Vicinity, Hanford Site, Washington, during 2004



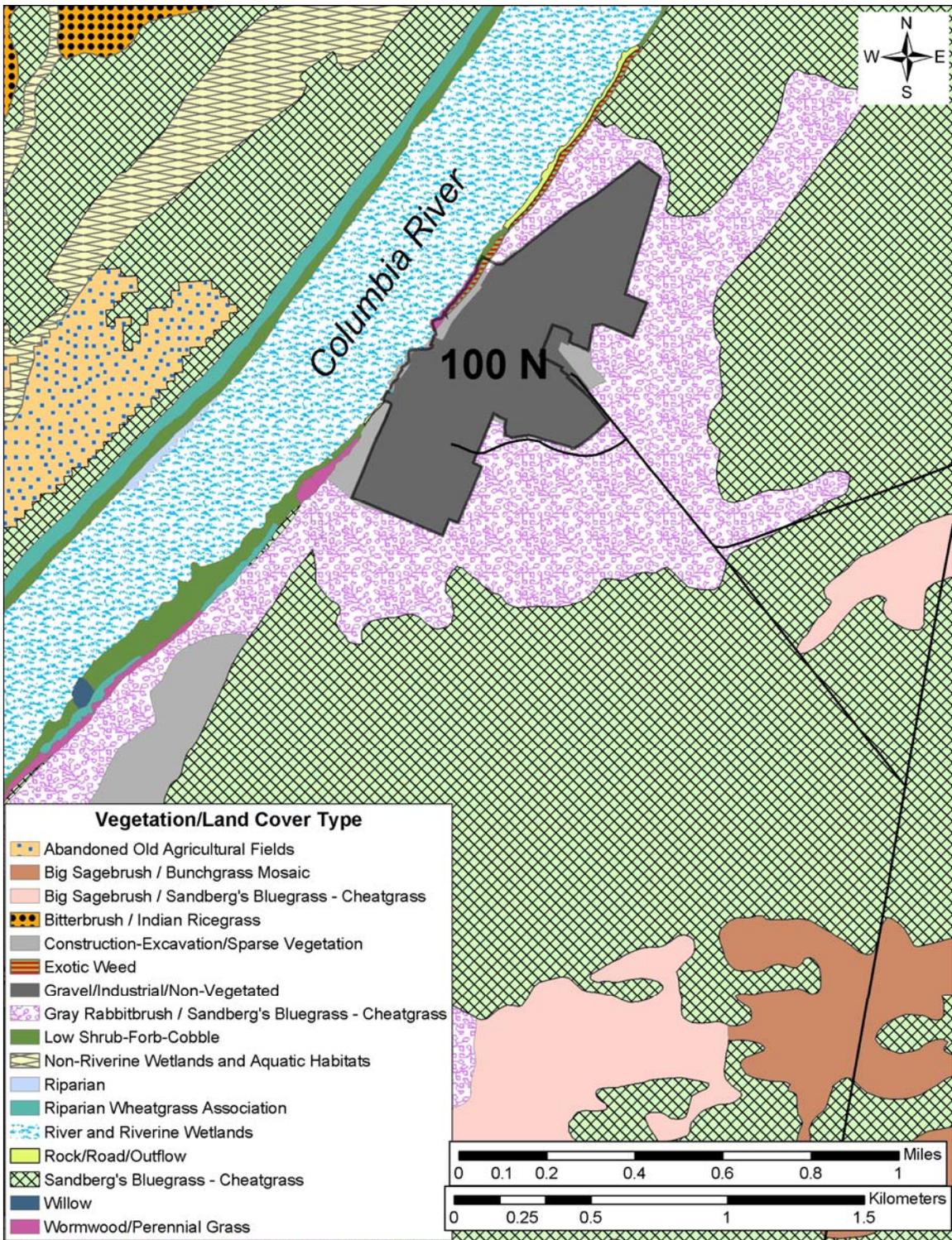
**Figure C-4.** Vegetation/Land Coverage Map for the 100-F Area, Hanford Site, Washington, during 2004



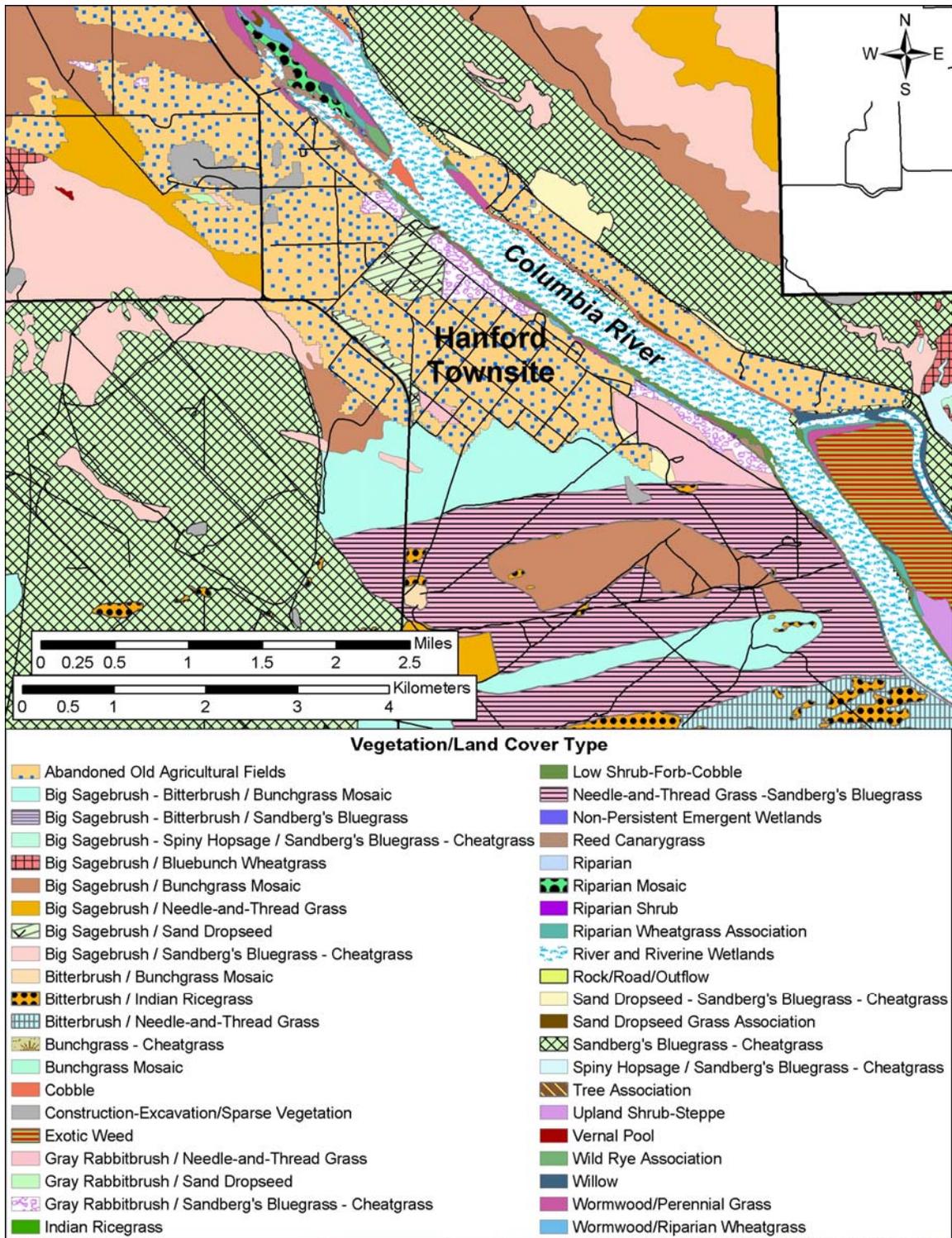
**Figure C-5.** Vegetation/Land Coverage Map for the 100-H Area, Hanford Site, Washington, during 2004



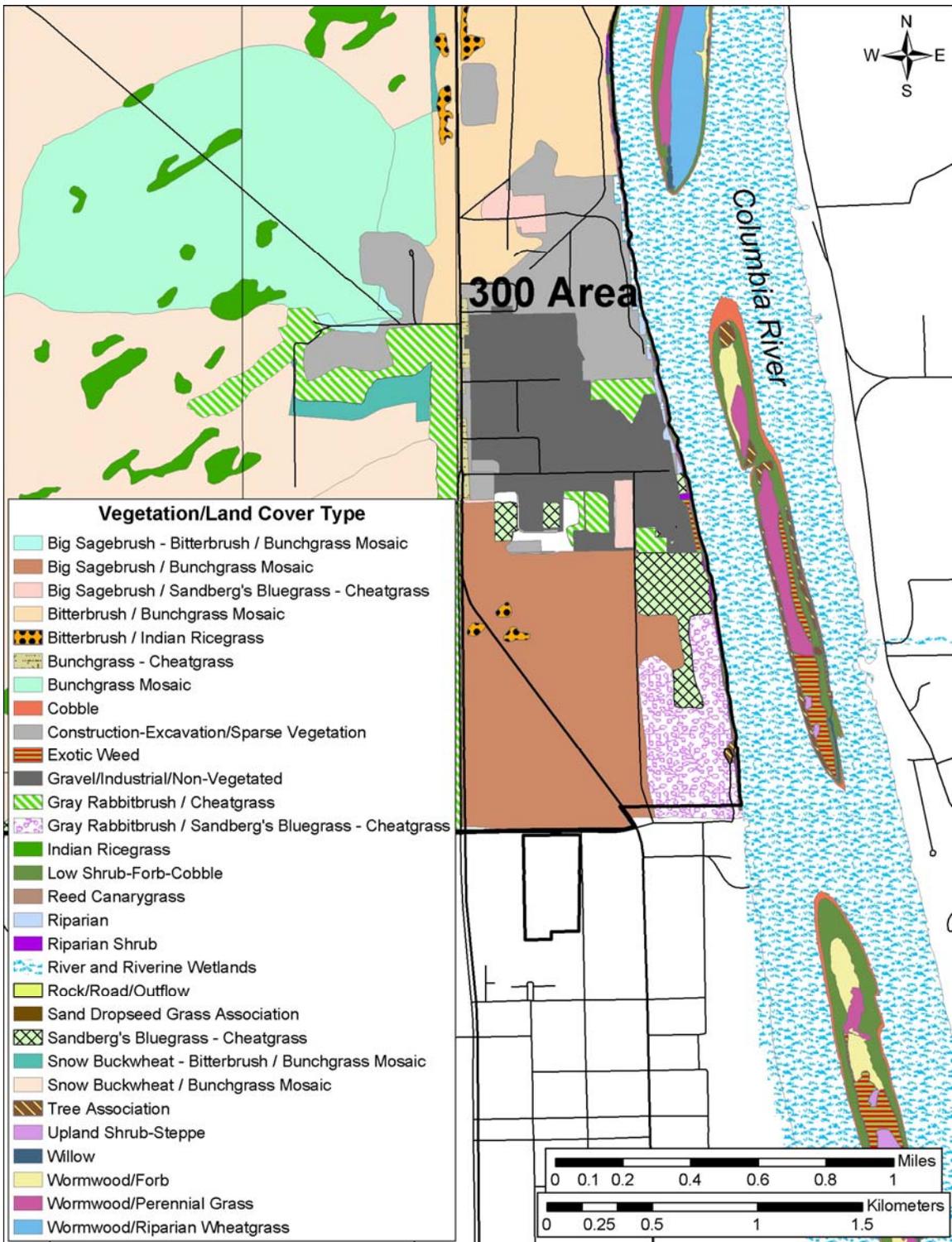
**Figure C-6.** Vegetation/Land Coverage Map for the 100-K Area, Hanford Site, Washington, during 2004



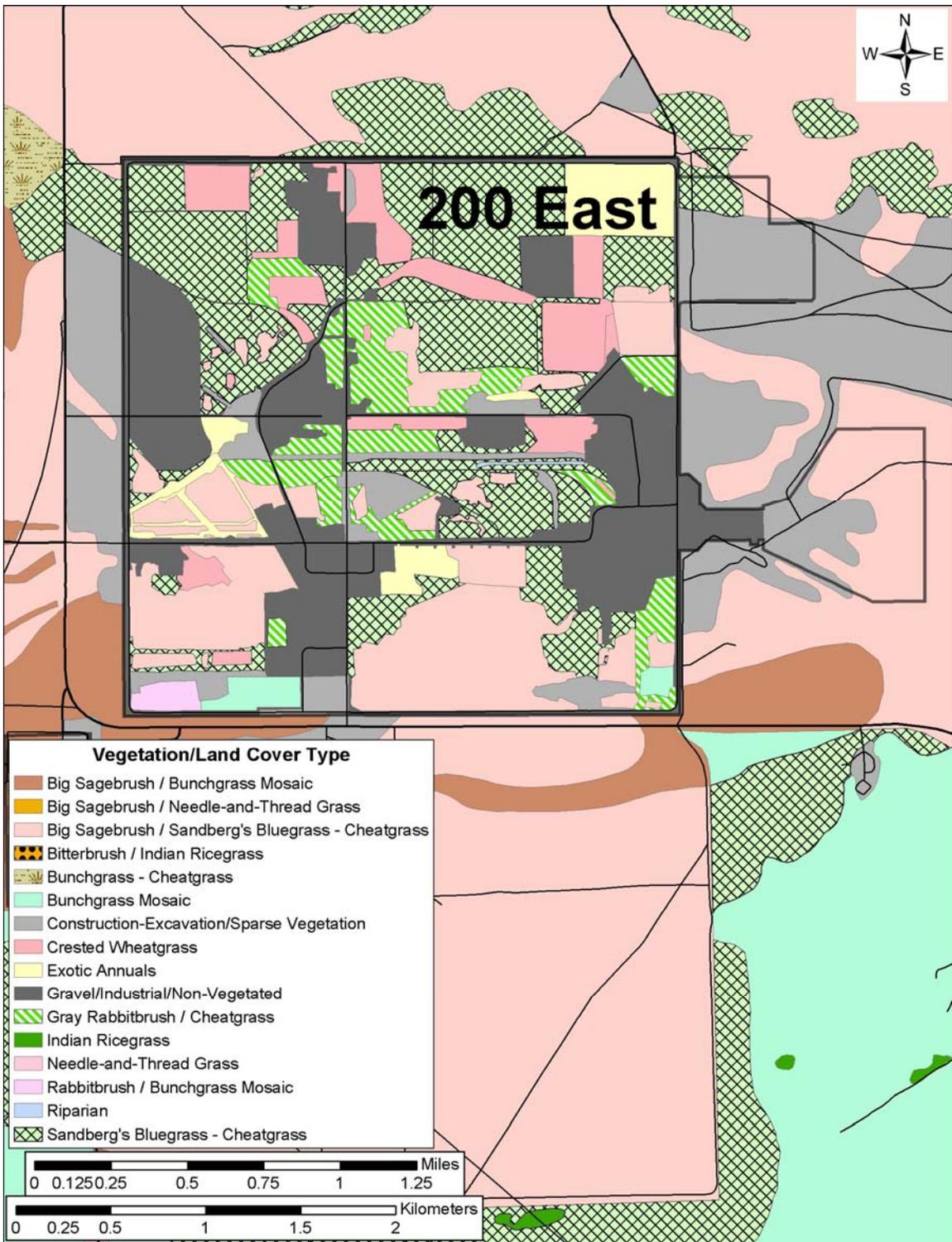
**Figure C-7.** Vegetation/Land Coverage Map for the 100-N Area, Hanford Site, Washington, during 2004



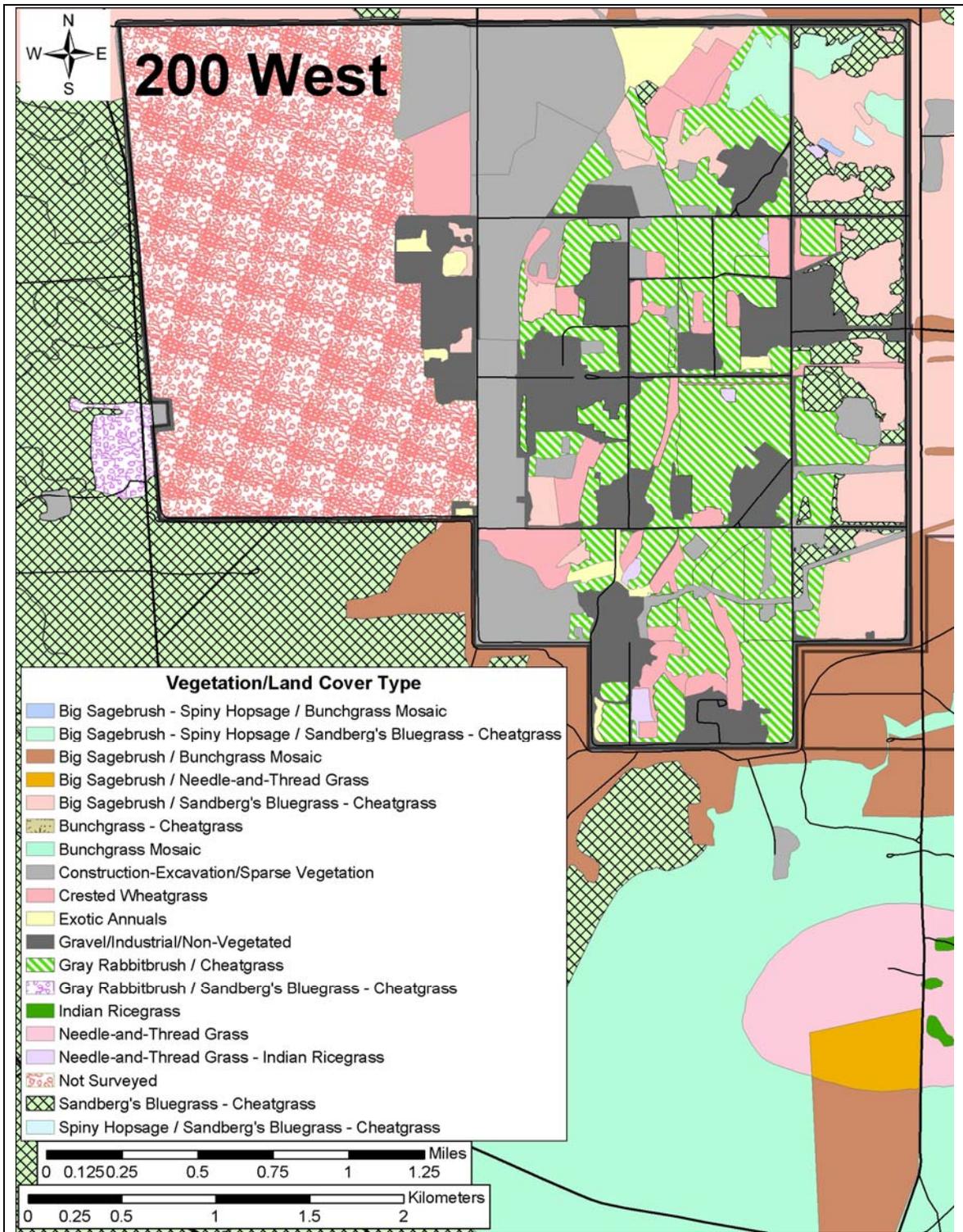
**Figure C-8.** Vegetation/Land Coverage Map for the Hanford Townsite Vicinity, Hanford Site, Washington, during 2004



**Figure C-9.** Vegetation/Land Coverage Map for the 300 Area, Hanford Site, Washington, during 2004



**Figure C-10.** Vegetation/Land Coverage Map for the 200-East Area, Hanford Site, Washington, during 2004



**Figure C-11.** Vegetation/Land Coverage Map for the 200-West Area, Hanford Site, Washington, during 2004

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## 6.0 Statutory and Regulatory Requirements

P.L. Hendrickson

The Hanford Site is owned by the U.S. Government and is managed by the U.S. Department of Energy (DOE). It is the policy of the DOE to carry out its operations in compliance with all applicable federal, state, and local laws and regulations, presidential executive orders, DOE directives, and treaty rights. Environmental regulatory authority over the Hanford Site is vested both in federal agencies, primarily the U.S. Environmental Protection Agency (EPA), and in Washington State agencies, primarily the Washington State Department of Ecology (Ecology) and the Washington State Department of Health (DOH). In addition, the Benton Clean Air Authority (BCAA) has certain regulatory authority over Hanford activities, including open burning, asbestos removal, and fugitive dust control. Significant environmental laws, regulations, and other requirements are discussed in this chapter in the following order:

- Major federal environmental laws
- Significant applicable federal and state regulations
- Presidential executive orders
- DOE directives
- Treaties, statutes, and policies relating to Indian Tribes of the Hanford region
- Existing environmental permits covering activities at the Hanford Site.

There are a number of sources of information available concerning statutory and regulatory requirements as they relate to the National Environmental Policy Act (NEPA) process. Sources available over the Internet include the following:

- Links to Hanford NEPA documents at: <http://www.hanford.gov/rl/?page=113&parent=0>
- DOE's NEPA web site at: <http://www.eh.doe.gov/nepa/>
- Council on Environmental Quality's (CEQ's) web site at: <http://www.whitehouse.gov/ceq/>
- EPA's NEPA web site at: <http://epa.gov/compliance/nepa/index.html>.

The DOE Office of Environment, Safety, and Health has issued a variety of guidance documents to aid the preparation of DOE NEPA documents. The guidance documents are posted at <http://www.eh.doe.gov/nepa/guidance.html>.

(The following introduction [boxed text] is intended to be explanatory for persons writing the chapter of a Hanford Site environmental impact statement [EIS] or environmental assessment [EA] covering regulatory requirements, but is not intended to be included in the EIS or EA.) The material following the boxed text can be adapted, as appropriate, for use in an EIS or EA at the discretion of the authors. Additional specificity should be added to the material to reflect the particular circumstances and facts that are the subject of the EIS or EA. An EIS will normally contain more detail than an EA.

## Introduction

The CEQ regulations in the Code of Federal Regulations (CFR) at 40 CFR 1500-1508 implement NEPA and set forth requirements for the preparation of environmental documentation by federal agencies that satisfy NEPA. DOE has adopted the CEQ regulations as part of its NEPA implementing procedures (10 CFR 1021.103). The CEQ regulations identify the types of actions proposed by a federal agency that require preparation of an EIS, prescribe the content of an EIS, and identify actions and other environmental reviews that must or should be undertaken by the federal agency in preparing and circulating an EIS. In general, an EIS must be prepared by a federal agency for any major federal action significantly affecting the quality of the human environment (40 CFR 1502.3). The regulations also state reasons why an agency may want to prepare an EA instead of an EIS (40 CFR 1508.9).

A specific requirement in the CEQ regulations (40 CFR 1502.25) is that the draft EIS must list “all federal permits, licenses, and other entitlements which must be obtained in implementing the proposal.” If it is uncertain whether a federal permit or license is needed, the draft EIS is to so indicate. There is, however, no requirement in the CEQ regulations or in the DOE NEPA implementing procedures at 10 CFR Part 1021 that the EIS must list or discuss applicable environmental laws and regulations. Nevertheless, applicable environmental laws and regulations (federal, state, and local) have been discussed in recent Hanford Site EISs and EAs in a chapter usually captioned “Statutory and Regulatory Requirements.” The discussion below assumes this chapter is chapter 6 of the EIS or EA, but another chapter number is possible.

Chapter 6 of Hanford Site EISs and EAs should include the list called for by 40 CFR 1502.25(b). The list should also include significant permits that will be needed from federal, state, and local government agencies. Chapter 6 should not normally include information on environmental impacts associated with any of the requirements. For example, Executive Order (E.O.) 12962 requires federal agencies to evaluate the effects of their actions on aquatic systems and recreational fisheries. Although E.O. 12962 should be mentioned in Chapter 6 in appropriate cases, the actual impacts of the alternatives on aquatic systems and recreational fisheries should be discussed in the Environmental Consequences chapter (normally Chapter 5) of the EIS or EA and any recreational fisheries aspects of the affected environment should be discussed in the Affected Environment chapter (normally Chapter 4) of the EIS or EA. Chapter 6 can refer the reader to the portion of the EIS or EA where the environmental impacts associated with a particular environmental requirement are discussed.

A summary of prior EAs and EISs prepared for activities at the Hanford Site is in National Environmental Policy Act Source Guide for the Hanford Site (Fluor Hanford 2002).

The purpose, then, of Chapter 6 in this document is to present a “reference” that can be used as the basis for the preparation of future Hanford Site EISs and EAs. The intent is to present a reasonably complete discussion of federal, state, and local environmental laws, regulations, and permit requirements that are applicable to activities at the Hanford Site. The information in this chapter can then be adapted to any future Hanford Site EIS/EA by deleting irrelevant parts and by adding some specificity with respect to the proposed action and the alternatives being considered.

It should be noted that environmental standards and permit requirements usually appear in regulations and not in the laws themselves. Thus, more emphasis is placed on regulations and less on laws in this chapter.

## Federal and State Environmental Laws

Federal law governs environmental regulation of federal facilities. Most major federal environmental laws now include provisions for regulation of federal activities that impact the environment. The activity to be regulated is usually an activity being carried out by an agency of the executive branch. The federal environmental law will also typically designate a specific agency, such as EPA or the U.S. Nuclear Regulatory Commission (NRC), as the regulator. In addition, federal laws may provide for the delegation of the environmental regulation of federal facilities to the states or may directly authorize the environmental regulation of federal facilities by the states through waivers of sovereign immunity. At Hanford, all these situations apply in varying degrees. EPA has regulatory authority over Hanford facilities and has delegated regulatory authority to, shares regulatory authority with, or is in the process of delegating regulatory authority to the State of Washington. The State of Washington also asserts its own independent regulatory authority over Hanford facilities under federal waivers of sovereign immunity and state legislation. The Washington State Department of Ecology has also delegated various air compliance responsibilities to the BCAA.

As a legal matter at Hanford, applicable federal and state environmental standards must be met. As a practical matter, differences in language between federal and state laws and regulations may result in some differences in applicability and interpretation. Guidance on specific applicability should be obtained from the Office of Chief Counsel of the DOE Richland Operations Office (DOE/RL) or the Office of River Protection (DOE-ORP).

## Citation of Laws and Regulations

Laws and regulations may be cited both by their common name and by their location in the appropriate document. Federal laws are most often cited by their common name (e.g., Clean Water Act [CWA]), by their public law (Pub. L. or PL) number, or by their location in the United States Code (USC). Section numbers differ between laws as enacted and as codified in the USC, so it must be understood which is being cited. Federal regulations appear in the CFR. Washington State laws are most often cited by their location in the Revised Code of Washington (RCW). Washington State regulations are cited by their location in the Washington Administrative Code (WAC). Links to the RCW and WAC are available at <http://www1.leg.wa.gov/CodeReviser/>. Announcements of proposed and final federal regulations appear in the Federal Register (FR). Announcements of proposed and final Washington State regulations appear in the Washington State Register.

## Specific Federal Laws Cited in the CEQ Regulations

Four federal laws are specifically cited in the CEQ regulations [40 CFR 1502.25(a) and 1504.1(b)]:

- Section 309 of the Clean Air Act (CAA) (42 USC 7609)
- Fish and Wildlife Coordination Act (16 USC 661 *et seq.*)
- National Historic Preservation Act (NHPA) (16 USC 470 *et seq.*)
- Endangered Species Act (ESA) (16 USC 1531 *et seq.*)

Section 309 of the CAA directs EPA to review and comment in writing on the environmental impacts of any matter relating to EPA's authority contained in proposed legislation, federal construction projects, other federal actions requiring EISs, and new regulations. In addition to commenting on EISs, EPA rates every draft EIS prepared by a federal agency under its Section 309 authority. Ratings are made for the environmental impact of the proposed action and the adequacy of the impact statement. Rating categories for environmental impact are: LO - lack of objections, EC - environmental concerns, EO - environmental objections, and EU - environmentally unsatisfactory. Rating categories for adequacy are: Category 1 - adequate, Category 2 - insufficient information, and Category 3 - inadequate. A summary of EPA rating definitions is available at: <http://www.epa.gov/compliance/nepa/comments/ratings.html>. Responses to EPA's comments on a draft EIS are included in the final EIS.

The CEQ regulations (40 CFR 1502.25[a]) direct federal agencies to prepare draft EISs concurrently with and integrated with environmental impact analyses and related surveys required by the Fish and Wildlife Coordination Act, the NHPA, the ESA, and other environmental review laws and executive orders. The three preceding statutes should be cited in Chapter 6 of a draft EIS. Environmental impacts associated with the laws should be discussed in Chapter 5.

## 6.1 Federal Environmental Laws

Significant federal environmental laws potentially applicable to the Hanford Site include the following:

- Antiquities Act (16 USC 431 *et seq.*)
- American Indian Religious Freedom Act (42 USC 1996)
- Archaeological and Historic Preservation Act (16 USC 469 *et seq.*)
- Archaeological Resources Protection Act (ARPA) (16 USC 470aa *et seq.*)
- Bald and Golden Eagle Protection Act (16 USC 668 *et seq.*)
- Clean Air Act (CAA) (42 USC 7401 *et seq.*)
- Clean Water Act (CWA) (33 USC 1251 *et seq.*) (The CWA is also known as the Federal Water Pollution Control Act)
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act (SARA) (42 USC 9601 *et seq.*)
- Emergency Planning and Community Right-to-Know Act (EPCRA) (42 USC 11001 *et seq.*)
- Endangered Species Act (16 USC 1531 *et seq.*)
- Farmland Protection Policy Act of 1981 (7 USC 4201 *et seq.*)
- Fish and Wildlife Coordination Act (16 USC 661 *et seq.*)
- Hanford Reach Study Act (PL 100-605), as amended by PL 104-333
- Hazardous Materials Transportation Act (49 USC 5101 *et seq.*)
- Migratory Bird Treaty Act (16 USC 703 *et seq.*)
- National Historic Preservation Act (NHPA) (16 USC 470 *et seq.*)
- Native American Graves Protection and Repatriation Act (25 USC 3001 *et seq.*)
- National Environmental Policy Act (NEPA) (42 USC 4321 *et seq.*)
- Noise Control Act (42 USC 4901 *et seq.*)
- Pollution Prevention Act (42 USC 13101 *et seq.*)

- Resource Conservation and Recovery Act (RCRA) of 1976 as amended by the Hazardous and Solid Waste Amendments (42 USC 6901 *et seq.*) of 1984
- Safe Drinking Water Act (SDWA) (42 USC 300f *et seq.*)
- Toxic Substances Control Act (TSCA) (15 USC 2601 *et seq.*).

In addition, the Atomic Energy Act (AEA) (42 USC 2011 *et seq.*), the Low-Level Radioactive Waste Policy Act (LLWPA) (42 USC 2021b *et seq.*), and the Nuclear Waste Policy Act (NWPA) (42 USC 10101 *et seq.*), while not environmental laws per se, contain provisions under which environmental regulations applicable to the Hanford Site may be or have been promulgated. Brief descriptions of most of the preceding statutes are in Section 6.1 of the *Hanford Solid (Radioactive and Hazardous) Waste Program Environmental Impact Statement* (DOE 2004a).

## 6.2 Federal and State Environmental Regulations

Under the Supremacy Clause of the U.S. Constitution (Article VI, Clause 2), activities of the federal government are ordinarily not subject to regulation by the states unless Congress creates specific exceptions. Congress has created exceptions with respect to environmental regulation and provisions in several federal laws giving specific authority to the states to regulate federal activities affecting the environment. These waivers (or partial waivers) of sovereign immunity appear in Section 118 of the CAA, Section 313 of the CWA, Section 1447 of the SDWA, Section 6001 of RCRA, and Section 120 of CERCLA/SARA. The Federal Facilities Compliance Act is an amendment to RCRA that makes the RCRA waiver of sovereign immunity more explicit. Many Washington State programs, with respect to the environmental regulation of Hanford Site facilities under the preceding statutes, are coordinated with the U.S. Environmental Protection Agency (EPA) Region 10 office.

Federal and state environmental regulations that may apply to operations at the Hanford Site have been promulgated under the CAA, CWA, SDWA, RCRA, CERCLA, SARA, AEA, LLWPA, NWPA, under other federal statutes, and under relevant state statutes.

Several of the more important existing federal and state environmental regulations are discussed briefly below. These regulations are grouped according to environmental media.

### 6.2.1 Air Quality

The federal Clean Air Act and the Washington Clean Air Act (Revised Code of Washington [RCW] 70.94) provide the statutory basis for air quality regulation of Hanford Site activities. The federal CAA establishes a floor or minimum level of requirements. State requirements can exceed, i.e., be more stringent than, federal requirements.

- 40 Code of Federal Regulations (CFR) 50, “National Primary and Secondary Ambient Air Quality Standards.” EPA regulations in 40 CFR 50 set national ambient air quality standards for sulfur oxides, particulate matter, carbon monoxide, ozone, nitrogen dioxide, and lead. The standards are not directly enforceable, but other enforceable regulations are based on the standards. Washington’s ambient air standards are at Washington Administrative Code (WAC) 173-470 through 173-481 and include standards for radionuclides and fluorides. The Hanford Site is within an area that is in attainment with or is unclassifiable for all national ambient air quality standards (40 CFR 81.348).
- 40 CFR 51-52, State Implementation Plans (SIPs). EPA regulations in 40 CFR 51-52 establish the requirements for SIPs and record the approved plans. The SIPs are directed at the control of emissions for which federal ambient air standards exist. Information on the Washington SIP is available at: <http://yosemite.epa.gov/r10/airpage.nsf/webpage/SIP+-+WA+Table+of+Contents?OpenDocument>.
- 40 CFR 60, “Standards of Performance for New Stationary Sources.” EPA regulations in 40 CFR 60 provide standards for the control of the emission of pollutants to the atmosphere. Construction or modification of an emissions source in an attainment area such as Hanford can require a prevention of significant deterioration (PSD) of air quality permit under 40 CFR 52.21 and WAC 173-400-141.

- 40 CFR 61, “National Emission Standards for Hazardous Air Pollutants” (NESHAP); 40 CFR 63, “National Emission Standards for Hazardous Air Pollutants for Source Categories.” EPA hazardous emission standards in 40 CFR 61 provide for the control of the emission of hazardous pollutants to the atmosphere. Standards in 40 CFR 61 Subpart H apply specifically to the emission of radionuclides from DOE facilities. Emissions of radionuclides (other than radon-220 and radon-222) to the ambient air from DOE facilities are not to exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent of 10 mrem/yr (0.1 mSv/yr) (40 CFR 61.92). Standards in 40 CFR 61 Subpart Q apply to the emission of radon from DOE facilities. No source at a DOE facility is to emit more than 20 picocuries per square meter per second (pCi/(m<sup>2</sup>-s)) (1.9 pCi/(ft<sup>2</sup>-s)) of radon-222 as an average for the entire source into the air (40 CFR 61.192). Approval to construct a new facility or to modify an existing one may be required under 40 CFR 61.07. Emission standards for sources of hazardous air pollutants designated in the 1990 CAA amendments appear at 40 CFR 63.
- 40 CFR 70, “State Operating Permit Programs.” These regulations provide for the establishment of comprehensive state air quality permitting programs. All major sources of air pollutants including hazardous air pollutants are covered. Washington’s operating permit regulations appear at WAC 173-401.
- 40 CFR 93 Subpart B, “Determining Conformity of General Federal Actions to State or Federal Implementation Plans.” The general conformity requirements require that actions of federal agencies are to comply with state implementation plans designed to achieve national ambient air quality standards.
- WAC 173-400 through 173-495, Washington State Air Pollution Control Regulations. Ecology air pollution control regulations, promulgated under the Washington CAA appear in WAC 173-400 through 173-495 and are available at <http://www.ecy.wa.gov/laws-rules/ecywac.html#air>. These regulations include emission standards, ambient air quality standards, and the standards in WAC 173-460, “Controls for New Sources of Toxic Air Pollutants.” The State of Washington has delegated much of its authority under the Washington CAA to the BCAA. However, except for certain air pollution sources (e.g., asbestos removal, fugitive dust, and open burning) administered by the BCAA, Ecology continues to administer air pollution control requirements for the Hanford Site.
- WAC 246-247, “Radiation Protection--Air Emissions.” Washington DOH regulations in WAC 246-247 contain standards and permit requirements for the emission of radionuclides to the atmosphere.
- Regulation 1 of the Benton Clean Air Authority can be accessed at: <http://www.bcaa.net/RegPol.htm>.

## 6.2.2 Water Quality

The CWA and the Washington Water Pollution Control Act provide the statutory basis for the regulation of water quality in Washington State. The CWA established the National Pollutant Discharge Elimination System (NPDES) to limit the amount of pollutants that could be discharged.

- 40 CFR 121, “State Certification of Activities Requiring a Federal License or Permit.” These regulations provide for state certification that any activity requiring a federal water permit, i.e., a

NPDES permit or a discharge of dredged or fill material permit, will not violate state water quality standards.

- 40 CFR 122, “EPA Administered Permit Programs: The National Pollutant Discharge Elimination System.” EPA regulations in 40 CFR 122 (and also in 40 CFR 125 and 129) apply to the discharge of pollutants from any point source into waters of the United States. These regulations also apply to the discharge of storm waters (40 CFR 122.26) and the discharge of runoff waters from construction areas over 0.02 km<sup>2</sup> (0.008 mi<sup>2</sup>) in size into waters of the United States. NPDES permits may be required by 40 CFR 122. EPA has not delegated to the State of Washington the authority to issue NPDES permits at the Hanford Site.
- 40 CFR 141, “National Primary Drinking Water Regulations.” EPA drinking water standards in 40 CFR 141 apply to Columbia River water at community water supply intakes downstream of the Hanford Site. Standards in 40 CFR 141.16 apply indirectly to releases of radionuclides from DOE facilities (and also non-DOE facilities) to the extent that the releases impact community water systems. The average annual concentration of beta particle and photon radioactivity from man-made radionuclides in drinking water are not to produce an annual dose equivalent to the body or any internal organ greater than 4 mrem (0.04 mSv) in a year. Maximum contaminant levels in community water systems of 5 pCi/L (0.18 Bq/L) of combined radium-226 and radium-228; 15 pCi/L (0.56 Bq/L) of gross alpha particle activity, including radium-226 but excluding radon and uranium; and 30 µg/L for uranium are specified in 40 CFR 141.66. The average annual concentration of beta particle and photon radioactivity from man-made radionuclides in drinking water must not produce an annual dose equivalent to the total body or any internal organ greater than 4 mrem/yr (0.04 mSv/yr) [40 CFR 141.66(d)].
- 40 CFR 144-147, Underground Injection Control Program. EPA regulations in 40 CFR 144-147 apply to the underground injection of liquids and wastes and may require a permit for any underground injection. In Washington State, EPA has approved Ecology regulations in WAC 173-218, “Underground Injection Control Program,” to operate in lieu of the EPA program. The Ecology regulations provide standards and permit requirements for the disposal of fluids by well injection.
- 10 CFR 1022, “Compliance with Floodplain/Wetlands Environmental Review Requirements.” DOE regulations in 10 CFR 1022 implement Executive Orders 11988 and 11990 and apply to DOE activities that are proposed to take place either in wetlands or in floodplains.
- 33 CFR 322-323, 40 CFR 230-233. Construction or placement of structures in the Columbia River and work in the Columbia River, as well as the discharge of dredged or fill material into the Columbia River, require permits under these U.S. Army Corps of Engineers and EPA regulations.
- WAC 173-160. Under WAC 173-160, DOE provides notification to Ecology for water-well drilling on the Hanford Site.
- WAC 173-216, “State Waste Discharge Permit Program.” Ecology regulations in WAC 173-216 establish a state permit program for the discharge of waste materials from industrial, commercial, and municipal operations into ground and surface waters of the state. Discharges covered by NPDES or WAC 173-218 permits are excluded from the WAC 173-216 program. DOE has agreed to meet the requirements of this program at the Hanford Site for discharges of liquids to the ground.

- WAC 332-30, “Aquatic Land Management.” Where applicable, DOE will obtain an aquatic land use lease or permit from the Washington Department of Natural Resources for the placement of structures in the Columbia River on lands owned by the State of Washington. The U.S. Government owns most of the riverbed along the Hanford Site to the line of navigation.
- WAC 246-272-08001 and 246-272-09001. These regulations, administered by the Washington DOH, contain permit requirements for onsite sewage systems.
- WAC 246-290. These regulations, administered by the Washington DOH, contain requirements applicable to water systems providing piped water for human consumption.

### 6.2.3 Hazardous Waste Management

Regulation of hazardous wastes at Hanford is conducted under RCRA, CERCLA, the Tri-Party Agreement (Ecology et al. 1989), and the Washington State Hazardous Waste Management Act.

- 40 CFR 300, “National Oil and Hazardous Substances Pollution Contingency Plan.” EPA CERCLA regulations in 40 CFR 300 apply to the cleanup of inactive hazardous waste disposal sites, the cleanup of hazardous substances released into the environment, the reporting of hazardous substances released into the environment, and natural resource damage assessments. Four areas of the Hanford Site (100, 200, 300, and 1100) were listed on the EPA’s National Priorities List (NPL) in November 1989. The 1100 Area was subsequently delisted. Placement on the list requires DOE, in consultation with EPA and Washington State, to conduct remedial investigations and feasibility studies leading to a Record of Decision (ROD) on the cleanup of inactive waste disposal sites at Hanford. Standards for cleanup under CERCLA are “applicable or relevant and appropriate requirements” (ARARs), which may include both federal and state laws and regulations. In anticipation of Hanford’s being placed on the NPL, DOE, EPA, and Ecology signed the Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) on May 15, 1989. This agreement describes the cleanup responsibilities and authorities of the three parties under CERCLA (and RCRA), and also provides for permitting of the treatment, storage, and disposal of hazardous wastes under RCRA. The Tri-Party Agreement has been amended a number of times (<http://www.hanford.gov/tpa/tpahome.htm>).
- 40 CFR 260-268 and 270-272, Hazardous Waste Management. EPA RCRA regulations in 40 CFR 260-268 and 270-272 apply to the generation, transport, treatment, storage, and disposal of hazardous wastes (but not to source, by-product, or special nuclear material [i.e., not in general to radioactive wastes]), and apply to the hazardous component of hazardous radioactive mixed wastes (but not to the radioactive component) owned by DOE. RCRA regulations (40 CFR 268) require treatment of many hazardous wastes before they can be disposed of in landfills (land disposal restrictions). RCRA permits are required for the treatment, storage, or disposal of hazardous wastes. The regulations also require cleanup (corrective action) of any RCRA facility from which there is an unauthorized release before a RCRA permit is granted. Ecology has been authorized by EPA to administer the RCRA program within Washington. Ecology has oversight authority for RCRA corrective actions at Hanford under the Tri-Party Agreement.
- 40 CFR 280-281, Underground Storage Tanks. EPA has regulations in 40 CFR 280-281 issued under RCRA Subtitle IX that apply to new and existing underground storage tanks containing petroleum or substances regulated under CERCLA (except for hazardous wastes regulated under RCRA). New tanks must meet strict design and operating standards. Owners of new tanks must notify the applicable regulatory agency and certify compliance with the regulations. The

regulations require the reporting, investigation, and cleanup of releases from underground tanks. EPA has authorized Washington State to administer the underground storage tank program. Washington's requirements are in RCW 90.76 and WAC 173-360.

- WAC 173-303, "Dangerous Waste Regulations." EPA has authorized the State of Washington through Ecology to conduct its own dangerous waste regulation program in lieu of major portions of the RCRA interim and final permit program for the treatment, storage, and disposal of hazardous wastes. Ecology is also authorized to conduct its own program for the hazardous portion of radioactive - mixed wastes. The state regulations include both standards and permit requirements, as well as a larger universe of covered materials than the federal hazardous waste program.

#### **6.2.4 Species Protection**

- 50 CFR 10-24, 222, 402, and 450-453, Species Protection Regulations. Regulations under the Endangered Species Act, the Bald and Golden Eagle Protection Act, and the Migratory Bird Treaty Act in 50 CFR 10-24 apply to the protection of plant and animal species on the Hanford Site. Regulations in 50 CFR 17, 81, 222, 223, 402, and 450-453 apply to endangered or threatened species. Section 7 of the Endangered Species Act (16 USC 1536) requires that federal agencies 1) utilize their authority in furtherance of the purposes of the Act by carrying out programs for the conservation of listed endangered and threatened species, and 2) consult with appropriate federal agencies to ensure that any action carried out is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of critical habitat for such species. The Fish and Wildlife Coordination Act [16 USC 662(a, h)] requires that a federal agency consult with the U.S. Fish and Wildlife Service and the state agency exercising administration over wildlife if any body of water over 0.04 km<sup>2</sup> (0.016 mi<sup>2</sup>) in size is to be modified by a federal agency, or a licensee or permittee of the agency, for any purpose. The purpose of this consultation is to prevent loss and damage to wildlife resources.

#### **6.2.5 Historic and Cultural Resource Preservation**

The DOE policy on management of cultural resources (DOE 2001a) provides that:

DOE will uphold [the NHPA, the Archaeological Resources Protection Act, and the Native American Graves Protection and Repatriation Act] by preserving, protecting, and perpetuating cultural resources for future generations in a spirit of stewardship to the extent feasible given the agency's mission and mandates. To do this, DOE will implement management accountability for compliance with federal statutes, executive orders, treaties, DOE orders, and implementation guidance. The Department also ensures that DOE contractors are obligated to implement DOE programs and projects in a manner that is consistent with this Policy and that reflects this commitment in site management contracts.

The background statement in "Management of Cultural Resources at Department of Energy Facilities" (DOE 2001b) further states that:

DOE recognizes the cultural and scientific value of the resources that may exist on the properties under its management or over which it has direct or indirect control. Therefore, DOE has implemented a program to protect these resources and ensure that all DOE facilities and programs comply with all existing cultural resource executive orders, laws, and regulations.

The DOE management document (DOE 2001b) defines cultural resources to include “historic properties” as defined in the NHPA, “archaeological resources” as defined in the Archaeological Resources Protection Act of 1979 (16 USC 470aa), and “cultural items” as defined in the Native American Graves Protection and Repatriation Act.

The NHPA authorizes the Secretary of the Interior to maintain a National Register of Historic Places (16 USC 470a[a][1]). Federal agencies are to consider the effect of their actions on properties included in or eligible for inclusion in the Register and afford the Advisory Council on Historic Preservation a reasonable opportunity to comment on such actions (16 USC 470f).

The Archaeological Resources Protection Act of 1979 prohibits the excavation of material remains of past human life that have archaeological interest and are at least 100 years old without a permit from the appropriate federal land manager or an exemption (16 USC 470bb, 470ee).

The Native American Graves Protection and Repatriation Act prohibits the intentional excavation or removal of human remains or cultural items without a written permit, and prescribes protective measures and repatriative actions to be taken in the event that human remains or cultural items are discovered inadvertently (25 USC 3001 *et seq.*).

Additional information is available by contacting the Department of Energy, Richland Operations Office, Hanford Cultural and Historic Resources Program or by accessing the Hanford website at <http://www.hanford.gov/doe/history/>.

## **6.2.6 Land Use**

The Hanford Reach National Monument was created on June 9, 2000, by a proclamation (65 FR 37253) signed by President Clinton under the authority of the Antiquities Act. The Monument includes 792.6 km<sup>2</sup> (306 mi<sup>2</sup>) of federally owned land making up a portion of the Hanford Site. The principal components of the Monument are:

- the Fitzner-Eberhardt Arid Lands Ecology Reserve Unit,
- the McGee Ranch and Riverlands Unit,
- the Saddle Mountain National Wildlife Refuge Unit,
- the quarter-mile study strip along the south and west sides of the Columbia River corridor as designated by the Hanford Reach Study Act (Hanford Reach Study Act [1988] as amended by Public Law 104-333),
- the federally owned islands within the portion of the Columbia River included in the Monument,
- and the Hanford Sand Dune Field Unit.

The U.S. Fish and Wildlife Service (USFWS) manages approximately 67,000 ha (166,000 ac) of Monument lands that are within the Fitzner-Eberhardt Arid Lands Ecology Reserve Unit and the Wahluke Slope (Wahluke Unit and Saddle Mountain Unit) under permit from DOE. DOE manages the remainder of the Monument. The June 9, 2000, proclamation does not affect the responsibilities and authority of DOE on Hanford Site lands nor does it affect DOE activities on lands not included within the Monument boundaries. In a separate memorandum to the Secretary of Energy, DOE was directed by President Clinton to protect the natural values of the Hanford Site land not included within the Monument (Clinton

2000). DOE and USFWS signed a Memorandum of Understanding on June 14, 2001, covering management responsibilities for the Monument. USFWS issued a Notice of Intent to prepare a comprehensive conservation plan and associated EIS for the Monument in June 2002 (67 FR 40333).

In September 1999, DOE issued the Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement (DOE 1999). The ROD issued in November 1999 (64 FR 61615) states that the purpose of the land-use plan and its implementing policies is to facilitate decision making about the Hanford Site's uses and facilities over at least the next 50 years. The ROD adopts the Preferred Alternative land-use maps, designations, policies, and implementing procedures as described in the 1999 EIS and designates the Central Plateau (200 Areas) for Industrial-Exclusive use. In November 1999, USFWS signed a Record of Decision documenting USFWS's adoption of the DOE's Final Comprehensive Land Use Plan.

## **6.2.7 Other**

- 40 CFR 191, “Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes.” EPA regulations in 40 CFR 191 provide environmental standards for the management, storage, and disposal of spent nuclear fuel, high-level radioactive wastes, and transuranic radioactive wastes at high-level or transuranic waste disposal sites.
- 40 CFR 355, 370, and 372. These regulations implement the federal Emergency Planning and Community Right-to-Know Act (EPCRA). EPCRA was signed into law in October 1986 as part of the Superfund Amendments and Reauthorization Act.
- 40 CFR 700-799, TSCA Regulations. EPA’s regulations in 40 CFR 700-799 implement TSCA and, in particular, regulate polychlorinated biphenyls (PCBs) and dioxins and partially regulate asbestos.
- 40 CFR 1500-1508, Council on Environmental Quality. The CEQ regulations in 40 CFR 1500 to 1508 implement NEPA.
- 10 CFR 830, “Nuclear Safety Management.” Part 830 contains nuclear safety management requirements applicable to DOE contractors.
- 10 CFR 835, “Occupational Radiation Protection.” These DOE rules establish radiation protection standards, limits, and program requirements for protecting individuals from ionizing radiation resulting from DOE activities.
- 10 CFR 1021, “National Environmental Policy Act Implementing Procedures.” DOE regulations in 10 CFR 1021 set out procedures that DOE uses to comply with section 102(2) of NEPA and the CEQ regulations for implementing the procedural provisions of NEPA (40 CFR parts 1500-1508). The DOE regulations supplement, and are to be used in conjunction with, the CEQ regulations.
- 49 CFR 171-179, Hazardous Materials Regulations. These Department of Transportation regulations apply to the handling, packaging, labeling, and shipment of hazardous materials offsite, including radioactive materials and wastes.
- WAC 173-60, “Maximum Environmental Noise Levels.” These regulations contain maximum

permissible environmental noise levels in Washington. Additionally, the Occupational Safety and Health Administration has regulations covering noise exposure of occupational workers at 29 CFR 1910.95.

### 6.3 Executive Orders

DOE is subject to a number of presidential executive orders (E.O.s) concerning environmental matters. Some of these orders may be appropriately considered in a Hanford EIS or EA. Potentially relevant E.O.s include:

- E.O. 11514 Protection and Enhancement of Environmental Quality
- E.O. 11593 Protection and Enhancement of the Cultural Environment
- E.O. 11738 Providing for Administration of the Clean Air Act and the Federal Water Pollution Control Act with Respect to Federal Contracts, Grants, or Loans
- E.O. 11988 Floodplain Management
- E.O. 11990 Protection of Wetlands
- E.O. 12088 Federal Compliance with Pollution Control Standards
- E.O. 12114 Environmental Effects Abroad of Major Federal Actions
- E.O. 12196 Occupational Safety and Health Programs for Federal Employees
- E.O. 12580 Superfund Implementation
- E.O. 12898 Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations
- E.O. 12962 Recreational Fisheries
- E.O. 13007 Indian Sacred Sites
- E.O. 13045 Protection of Children from Environmental Health Risks and Safety Risks (as amended by E.O. 13296)
- E.O. 13101 Greening the Government through Waste Prevention, Recycling, and Federal Acquisition
- E.O. 13112 Invasive Species
- E.O. 13123 Greening the Government through Energy Efficient Management
- E.O. 13134 Developing and Promoting Biobased Products and Bioenergy
- E.O. 13148 Greening the Government through Leadership in Environmental Management
- E.O. 13149 Greening the Government through Federal Fleet and Transportation Efficiency
- E.O. 13150 Federal Workforce Transportation

- E.O. 13175 Consultation and Coordination with Indian Tribal Governments
- E.O. 13186 Responsibilities of Federal Agencies to Protect Migratory Birds
- E.O. 13195 Trails for America in the 21<sup>st</sup> Century
- E.O. 13287 Preserve America

## 6.4 DOE Directives

Categories of DOE directives include orders, policy statements, standards, notices, manuals, and contractor requirements documents.

DOE directives can be accessed at: <http://www.directives.doe.gov/>.

Directives with particular application to DOE's environmental activities are found in the 400 series of the new series directives and the 5000 series (particularly the 5400 and 5800 series) under the old series directives.

Topics covered in DOE directives include environmental protection, safety, and health protection standards; hazardous and radioactive-mixed waste management; cleanup of retired facilities; safety requirements for the packaging and transportation of hazardous materials; safety of nuclear facilities; radiation protection; and other standards for the safety and protection of workers and the public. Regulations and standards of other federal agencies and standard setting entities are incorporated by reference into some DOE directives.

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## 6.5 Treaties, Statutes, and Policies Relating to Indian Tribes of the Hanford Region

DOE's relationship with American Indians is based on treaties, statutes, executive orders, and DOE policy statements. Representatives of the United States negotiated treaties with leaders of various Columbia Plateau American Tribes and Bands in June 1855 at Camp Stevens in the Walla Walla Valley. The negotiations resulted in three treaties, one with the 14 tribes and bands of the group that would become the Confederated Tribes and Bands of the Yakama Nation, one with the three tribes that would become the Confederated Tribes of the Umatilla Reservation, and one with the Nez Perce Tribe of Idaho. The U.S. Senate ratified the treaties in 1859. The three treaties are included in Appendix A of the *Final Hanford Comprehensive Land-Use Plan EIS* (DOE 1999). The negotiated treaties are as follows:

1. Treaty with the Walla Walla, Cayuse, etc. (June 9, 1855; 12 Stats. 945)
2. Treaty with the Yakama (June 9, 1855; 12 Stats. 951)
3. Treaty with the Nez Perce (June 11, 1855; 12 Stats. 957).

The Confederated Tribes and Bands of the Yakama Nation, Washington; the Confederated Tribes of the Umatilla Reservation, Oregon; and the Nez Perce Tribe of Idaho are federally recognized tribes that are eligible for funding and services from the U.S. Bureau of Indian Affairs by virtue of their status as Indian tribes (68 FR 68180, December 5, 2003).

The terms of the three preceding treaties are similar. Each of the three tribal organizations agreed to cede large blocks of land to the United States. The Hanford Site is within the ceded lands of the Confederated Tribes and Bands of the Yakama Nation and the Confederated Tribes of the Umatilla Reservation. The treaties reserved to the Tribes certain lands for their exclusive use (the three reservations). The treaties also secured to the Tribes certain rights and privileges to continue traditional activities outside the reservations. These included 1) the right to fish at usual and accustomed places in common with citizens of the United States, and 2) the privileges of hunting, gathering roots and berries, and pasturing horses and cattle on open and unclaimed lands.

The *U.S. Department of Energy American Indian and Alaska Native Tribal Government Policy* (DOE 2000) states, in part, that DOE

- Recognizes the federal trust relationship with American Indians and Alaska Native Nations and will fulfill its trust responsibilities to them
- Recognizes and commits to a government-to-government relationship and will institute appropriate protocols and procedures for program and policy implementation
- Complies with applicable federal cultural resource protection and other laws and executive orders will assist in preservation and protection of historic and cultural sites and traditional religious practices.

DOE also has an Information Brief covering consultation with Native Americans (DOE 2004b).

The American Indian Religious Freedom Act (42 USC 1996) establishes that U.S. policy is to protect and preserve for American Indians their inherent rights of freedom to believe, express, and exercise their traditional religions, including access to sites, use and possession of sacred objects, and the freedom to worship through ceremonies and traditional rites.

The Native American Graves Protection and Repatriation Act establishes the right of lineal descendants, Indian Tribes, and Native Hawaiian organizations to certain Native American human remains, funerary objects, sacred objects, or objects of cultural patrimony discovered on federal lands after November 16, 1990 (25 USC 3002). When discovered during an activity on federal lands, the activity is to cease and appropriate tribal governments are to be notified. Work on the activity may resume, if the activity is otherwise lawful, 30 days after the receipt of certification that tribal governments have received the notice.

Executive Order 13007 “Indian Sacred Sites,” (61 FR 26771, May 29, 1996) directs federal agencies, to the extent practicable, permitted by law, and not clearly inconsistent with essential agency functions, to 1) accommodate access to and ceremonial use of American Indian sacred sites by their religious practitioners, and 2) avoid adversely affecting the physical integrity of such sacred sites. Where appropriate, agencies are to maintain the confidentiality of sacred sites.

DOE/RL interacts and consults regularly and directly with the three federally recognized tribes affected by Hanford operations; that is, the Nez Perce Tribe of Idaho; the Confederated Tribes of the Umatilla Reservation, Oregon; and the Confederated Tribes and Bands of the Yakama Nation, Washington. In addition, the Wanapum, who still live adjacent to the Hanford Site, are a non-federally recognized tribe that has strong cultural ties to the Site. The Hanford area was also used by groups whose descendants are now enrolled members of the Confederated Tribes of the Colville Reservation. The Wanapum and the Confederated Tribes of the Colville Reservation are also consulted on cultural resource issues in accordance with DOE policy and relevant legislation.

## 6.6 Permits

Information on the status of environmental permits at Hanford is included in the *Annual Hanford Site Environmental Permitting Status Report* (DOE 2004). The report includes information on environmental permitting under RCRA; TSCA; CAA; CWA; the State Waste Discharge, Hydraulic Permit, and Underground Injection Control Programs; the Onsite Sewage System Program; and the Petroleum Underground Storage Tank Program.

The Hanford Site RCRA permit is in two portions, one portion issued by EPA Region 10 and the other portion issued by Ecology. The EPA portion of the RCRA permit covers the Hazardous and Solid Waste Amendments portion of the RCRA permit (EPA 1994). The Ecology portion of the Hanford Site RCRA permit covers compliance with Ecology's dangerous waste regulations (Ecology 2001a). The Ecology portion of the permit includes standard conditions, general facility conditions, and specific conditions for individual operating Treatment, Storage, and/or Disposal (TSD) units, TSD units undergoing corrective action, and TSD units undergoing closure.

Clean Air Act compliance requires both facility and sitewide compliance. The *Annual Hanford Site Environmental Permitting Status Report* (DOE 2004) identifies existing facility-specific and sitewide CAA compliance activities. The air operating permit for the Hanford Site issued by Ecology became effective in July 2001 (Ecology 2001b).

The Hanford Site National Pollutant Discharge Elimination System Permit (WA-002591-7) governs liquid process effluent discharges to the Columbia River (DOE 2004).

DOE has asserted a federally reserved water withdrawal right with respect to its Hanford operations. Current Hanford activities use water withdrawn under the DOE's federally reserved water rights.

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