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Pacific Northwest National Laboratory

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Hanford Site National Environmental Policy Act (NEPA) Characterization

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August 1997

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

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Preface

Many National Environmental Policy Act (NEPA) compliance documents have been prepared and are being prepared by Site contractors for the U.S. Department of Energy (DOE). Examination of these documents reveals inconsistencies in the data presented and the method of presentation. Thus, it seemed necessary to prepare a consistent description of the Hanford Site environment and to describe applicable federal and state laws and regulations to assist in the preparation of environmental impact statements (EISs) and other Site-related NEPA documentation.

The two chapters in this document (Chapters 4 and 6) are numbered this way to correspond to the chapters where such information is presented in EISs and other Site-related NEPA documentation. Chapter 4.0 describes the Hanford Site environment. Chapter 6.0 is essentially a definitive NEPA Chapter 6.0, which describes applicable federal and state laws and regulations. People preparing environmental assessments and EISs should also be cognizant of the document entitled *Recommendations for the Preparation of Environmental Assessments and Environmental Impact Statements* published by the DOE Office of NEPA Oversight in May 1993 (DOE 1993).

In this document, a complete description of the environment is presented in Chapter 4.0 without extensive tabular data. For these data, sources are provided. 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 will allow a person requiring information to go immediately to those sections of particular interest. However, specific information on each of these separate areas is not always complete or available. In this case, the general Hanford Site description should be used.

To enhance the usability of the document, a copy is available via FTP upon request to Duane A. Neitzel at (509) 376-0602. The document is also available electronically at http://www.pnl.gov/ which is the homepage of the Pacific Northwest National Laboratory (PNNL).

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Acronyms

AEA	Atomic Energy Act
ALE	Arid Lands Ecology
ARARS	applicable or relevant and appropriate requirements
ARPA	Archaeological Resources Protection Act
BCCAA	Benton County Clean Air Authority
BCRFD	Benton County Rural Fire Department
BHI	Bechtel Hanford, Inc.
BP	before present
BPA	Bonneville Power Association
BWIP	Basalt Waste Isolation Project
CAA	Clean Air Act
CBC	Columbia Basin College
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
CWA	Clean Water Act
dB	decibels
dBA	A-weighted sound level
DOE-RL	U.S. Department of Energy, Richland Operations Office
DOH	Washington Department of Health
EDNA	environmental designation for noise abatement
E.O.	Executive Order
DOE	U.S. Department of Energy
DWS	drinking water standards
Ecology	Washington State Department of Ecology
FFCA	Federal Facilities Compliance Act
EIS	Environmental Impact Statement
FR	Federal Register
EPA	U.S. Environmental Protection Agency
FY	fiscal year
FEMA	Federal Emergency Management Agency
FFTF	Fast Flux Test Facility
Hz	Hertz
HCRL	Hanford Cultural Resources Laboratory
HEHF	Hanford Environmental Health Foundation
HMS	Hanford Meteorological Station
L_{eq}	equivalent sound level
LLWPA	Low-Level Radioactive Waste Policy Act
MACAC	maximum allowable concentrations of air contaminants
MCAS	Mid-Columbia Archaeological Society
MMI	Modified Mercalli Intensity
MOA	Memorandum of Agreement
NAAQS	national ambient air quality standards

National Register	The National Register of Historic Places
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutant
NHPA	National Historic Preservation Act
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NPPC	Northwest Power Planning Council
NPR	New Production Reactor
NRC	U.S. Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act
OFM	Office of Financial Management
OSB	Operations and Service Building
OSHA	Occupational Safety and Health Administration
PCBs	polychlorinated biphenyls
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
RD&D	research, development, and demonstration
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SHPO	State Historic Preservation Office
SIP	state implementation plans
SR	State Route
SSC	System Structure and Component
State Register	State Register of Historic Places
Supply System	Washington Public Power Supply System
Tri-Party Agreement	Hanford Federal Facility Agreement and Consent Order
Tri-Cities	Kennewick, Pasco, and Richland
TSCA	Toxic Substances Control Act
TSP	total suspended particulates
UO_3	Uranium Trioxide
VOC	volatile organic compounds
WAC	Washington Administrative Code
WHC	Westinghouse Hanford Company
WSR	Washington State Register
WSU-TC	Washington State University, Tri Cities
$\overline{X}/Q'$	atmospheric diffusion factors

Summary

This ninth revision of the Hanford Site National Environmental Policy Act (NEPA) Characterization presents current environmental data regarding the Hanford Site and its immediate environs. This information is intended for use in preparing Chapters 4 and 6 in Hanford Site-related NEPA documents.

Chapter 4.0 (Affected Environment) includes information on climate and meteorology, geology, hydrology, ecology, cultural, archaeological and historical resources, socioeconomics, and noise. Chapter 6.0 (Statutory and Regulatory Requirements) provides the preparer with the federal and state regulations, DOE directives and permits, and environmental standards directly applicable to the NEPA documents on the Hanford Site.

Not all of the sections have been updated for this revision. The following lists the updated sections:

- Climate and Meteorology
- Ecology (Threatened and Endangered Species section only)
- Cultural, Archaeological, and Historical Resources
- Socioeconomics
- all of Chapter 6

Remaining sections were last revised in 1995.

The individual sections were prepared by Pacific Northwest National Laboratory (PNNL) staff. More detailed data are available from reference sources cited or from the authors. No conclusions or recommendations are given in this report. Rather, it is a compilation of information on the Hanford Site environment that can be used directly by Site contractors. This information can also be used by any interested individual seeking baseline data on the Hanford Site and its past activities by which to evaluate projected activities and their impacts.

Previous editions of the Hanford Site NEPA Characterization report included sections on "Environmental Monitoring" and "Models Used to Estimate Environmental Impacts." These sections have been deleted from Revisions 8 and 9.

Contents

Figures

Tables

4.0 Affected Environment

The U.S. Department of Energy's (DOE's) Hanford Site lies within the semiarid Pasco Basin of the Columbia Plateau in southeastern Washington State (Figure 4.0-1). The Hanford Site occupies an area of about 1450 km^2 (~560 mi^2) 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 storage, and waste disposal; only about 6% of the land area has been disturbed and is actively used. 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. The Saddle Mountains form 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 (Tri-Cities) constitute the nearest population centers and are located southeast of the Hanford Site.

The Hanford Site encompasses more than 1500 waste management units and 4 groundwater contamination plumes that have been grouped into 79 operable units. Each unit has complementary characteristics of such parameters as geography, waste content, type of facility, and relationship of contaminant plumes. This grouping into operable units allows for economies of scale to reduce the cost and number of characterization investigations and remedial actions that will be required for the Hanford Site to complete environmental clean-up efforts (WHC 1989). The 79 operable units have been aggregated into four areas: 22 in the 100 Area, 43 in the 200 Areas, 5 in the 300 Area, and 4 in the 1100 Area. There are an additional 5 units in the 600 Area Isolated Waste Site Area (WHC 1989). Those persons contemplating National Environmental Policy Act (NEPA)-related activities on the Hanford Site should be aware of the existence and location of the various operable units. Current maps showing the locations of the operable units can be obtained from the environmental restoration contractor.

4.1 Climate and Meteorology

(Subsections 4.1.1 through 4.1.6 updated for PNL-6415 Rev. 9)

The Hanford Site is located in a semiarid region of southeastern Washington State. The Cascade Mountains, beyond Yakima to the west (see Figure 4.2-1 for a location of the Cascade Mountains), greatly influence the climate of the Hanford area by means of their "rain shadow" effect; this mountain range also serves as a source of cold air drainage, which has a considerable effect on the wind regime on the Hanford Site.

Climatological data are available for the Hanford Meteorological Station (HMS), which is located between the 200 East and 200 West Areas. Data have been collected at this location since 1945, and a summary of these data through 1996 has been published by Hoitink and Burk (1997). Data from the

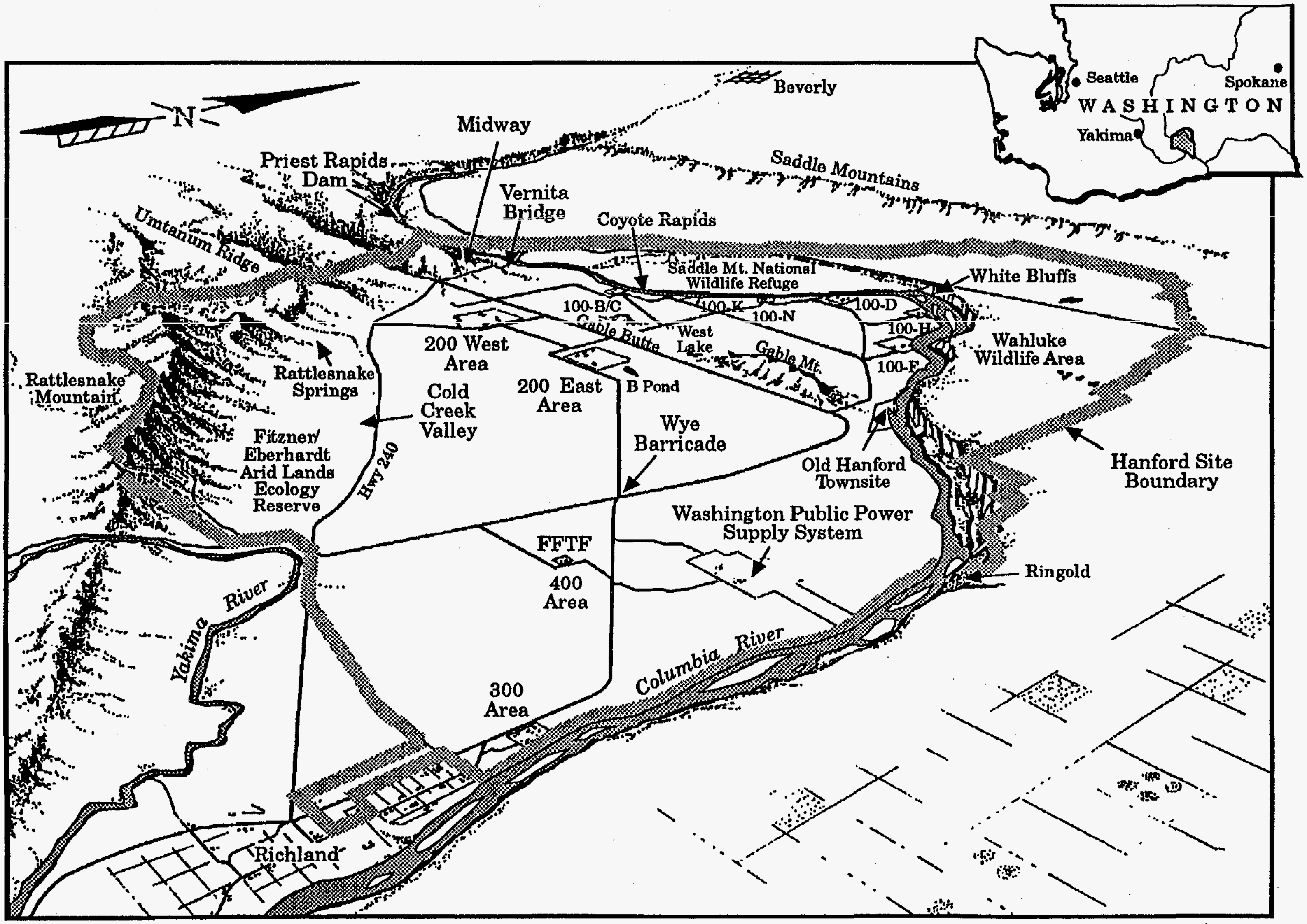

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Figure 4.0-1. DOE's Hanford Site and Surrounding Area

HMS are representative of the general climatic conditions for the region and describe the specific climate of the 200 Area Plateau. Local variations in the topography of the Hanford Site may cause some aspects of climate at portions of the Hanford Site to differ significantly from those of the HMS. For example, winds near the Columbia River are different from those at the HMS. Similarly, precipitation along the slopes of the Rattlesnake Hills differs from that at the HMS.

4.1.1 Wind

Wind data are collected at the HMS at the surface (2.1 m [~7 ft] above ground) and at the 15.2-, 30.5-, 61.0-, 91.4-, and 121.9-m (50-, 100-, 200-, 300-, 400-ft) levels of the 125-m (410-ft) HMS tower. Three 60-m (200-ft) towers, with wind-measuring instrumentation at the 10-, 25-, and 60-m (33-, 82-, and 200-ft) levels, are located at the 300, 400, and 100-N Areas. In addition, wind instruments on twenty-five 9.1-m (30-ft) towers distributed on and around the Hanford Site (Figure 4.1-1) provide supplementary data for defining wind patterns. Instrumentation on each of the towers is described in Table 4.1-1. Stations 8W and 19S are no longer active.

Prevailing wind directions on the 200 Area Plateau are from the northwest in all months of the year (Figure 4.1-2). Secondary maxima occur for southwesterly winds. Summaries of wind direction indicate that winds from the northwest quadrant occur most often during the winter and summer. During the spring and fall, the frequency of southwesterly winds increases with a corresponding decrease in northwest flow. Winds blowing from other directions (e.g., northeast) display minimal variation from month to month.

Monthly and annual joint-frequency distributions of wind direction versus wind speed for the HMS are given by Hoitink and Burk (1997). Monthly average wind speeds are lowest during the winter months, averaging 10 to 11 km/h (6 to 7 mi./h), and highest during the summer, averaging 13 to 15 km/h (8 to 9 mi./h). Wind speeds that are well above average are usually associated with southwesterly winds. However, the summertime drainage winds are generally northwesterly and frequently reach 50 km/h (30 mi./h). These winds are most prevalent over the northern portion of the Hanford Site.

4.1.2 Temperature and Humidity

Temperature measurements are made at the 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) levels of the 125-m (410-ft) tower at the HMS. Temperatures are also measured at the 2-m (~6.5-ft) level on the twenty-five 9.1-m (30-ft) towers located on and around the Hanford Site. The three 60-m (200-ft) towers have temperature-measuring instrumentation at the 2-, 10-, and 60-m (~6.5-, 33-, and 200-ft) levels.

Monthly averages and extremes of temperature, dew point, and humidity are contained in Hoitink and Burk (1997). Ranges of daily maximum temperatures vary from normal maxima of 2°C (35°F) in late December and early January to 35°C (95°F) in late July. There are, on the average, 52 days during the summer months with maximum temperatures ≥32°C (90°F) and 12 days with maxima greater than or equal to 38°C (100°F). From mid-November through early March, minimum temperatures average ≤0°C (32°F), with the minima in late December and early January averaging

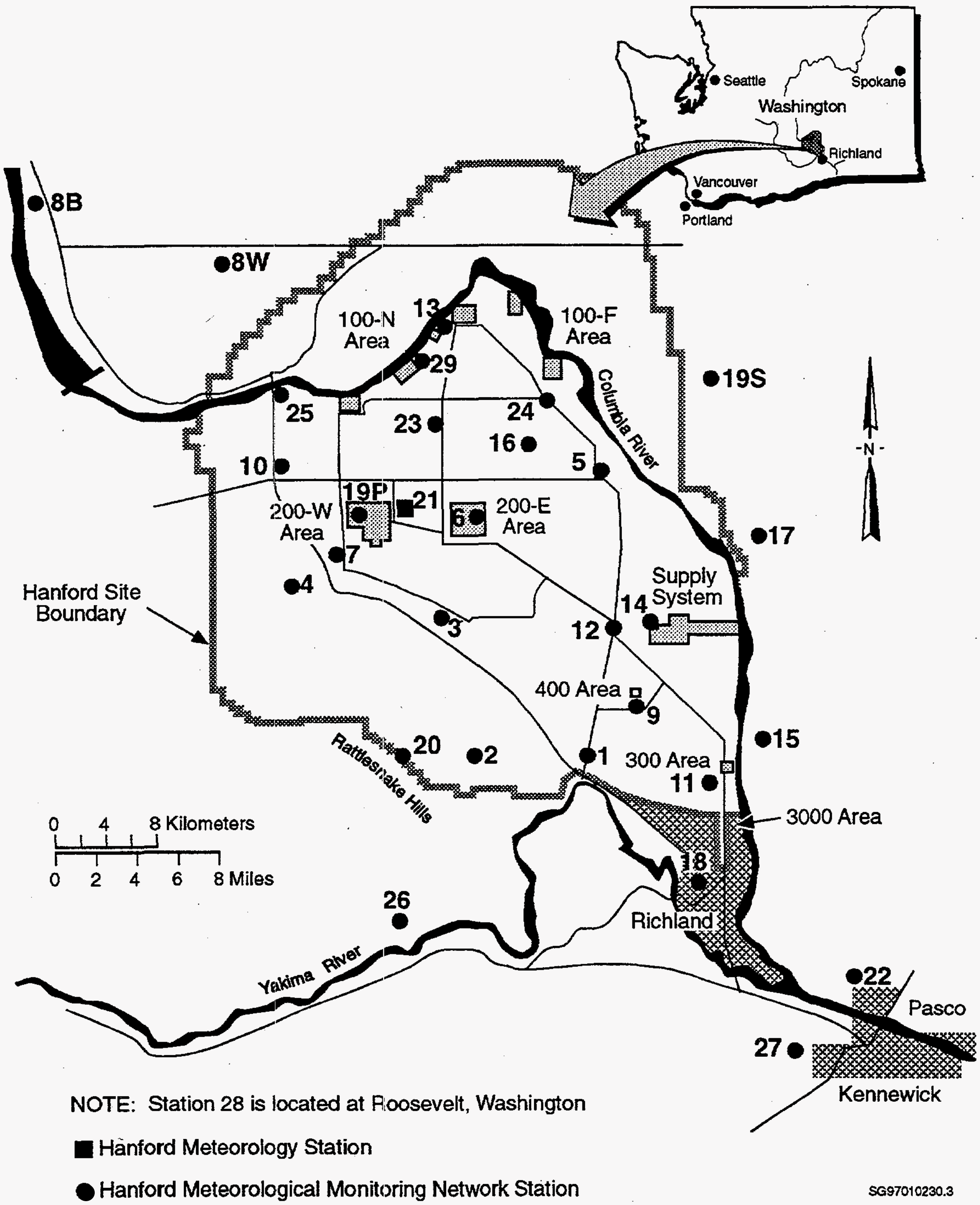

Figure 4.1-1. Hanford Meteorological Monitoring Network

Table 4.1-1. Station Numbers, Names, and Instrumentation for each Hanford Meteorological Monitoring Network Site

Site Number	Site Name	Instrumentation
1	Prosser Barricade	WS, WD, T, P
2	EOC	WS, WD, T, P
3	Army Loop Road	WS, WD, T, P
4	Rattlesnake Springs	WS, WD, T, P
5	Edna	WS, WD, T
6	200 East	WS, WD, T, P, AP
7	200 West	WS, WD, T, P
8B	Beverly	WS, WD, T, P
8W[(a)]	Wahluke Slope	WS, WD, T, P
9	FFTF (60 m)	WD, T, TD, DP, P, AP
10	Yakima Barricade	WS, WD, T, P, AP
11	300 Area (60 m)	WS, WD, T, TD, DP, P, AP
12	Wye Barricade	WS, WD, T, P
13	100-N (60 m)	WS, WD, T, TD, DP, P, AP
14	Supply System	WS, WD, T, P
15	Franklin County	WS, WD, T
16	Gable Mountain	WS, WD, T
17	Ringold	WS, WD, T, P
18	Richland Airport	WS, WD, T, AP
19P	Plutonium Finishing Plant	WS, WD, T, AP
19S[(a)]	Sagehill	WS, WD, T
20	Rattlesnake Mountain	WS, WD, T, P
21	Hanford Meteorology Station (125 m)	WS, WD, T, P, AP
22	Tri-Cities Airport	WS, WD, T, P
23	Gable West	WS, WD, T
24	100-F	WS, WD, T, P
25	Vernita Bridge	WS, WD, T
26	Benton City	WS, WD, T, P
27	Vista	WS, WD, T, P
28[(b)]	Roosevelt	WS, WD, T, P, AP
29	100-K	WS, WD, T, P, AP

Legend:
- WS - Wind Speed
- WD - Wind Direction
- T - Temperature
- TD - Temperature Difference
- DP - Dewpoint Temperature
- P - Precipitation
- AP - Atmospheric Pressure

(a) Station no longer active.
(b) Roosevelt is located offsite.

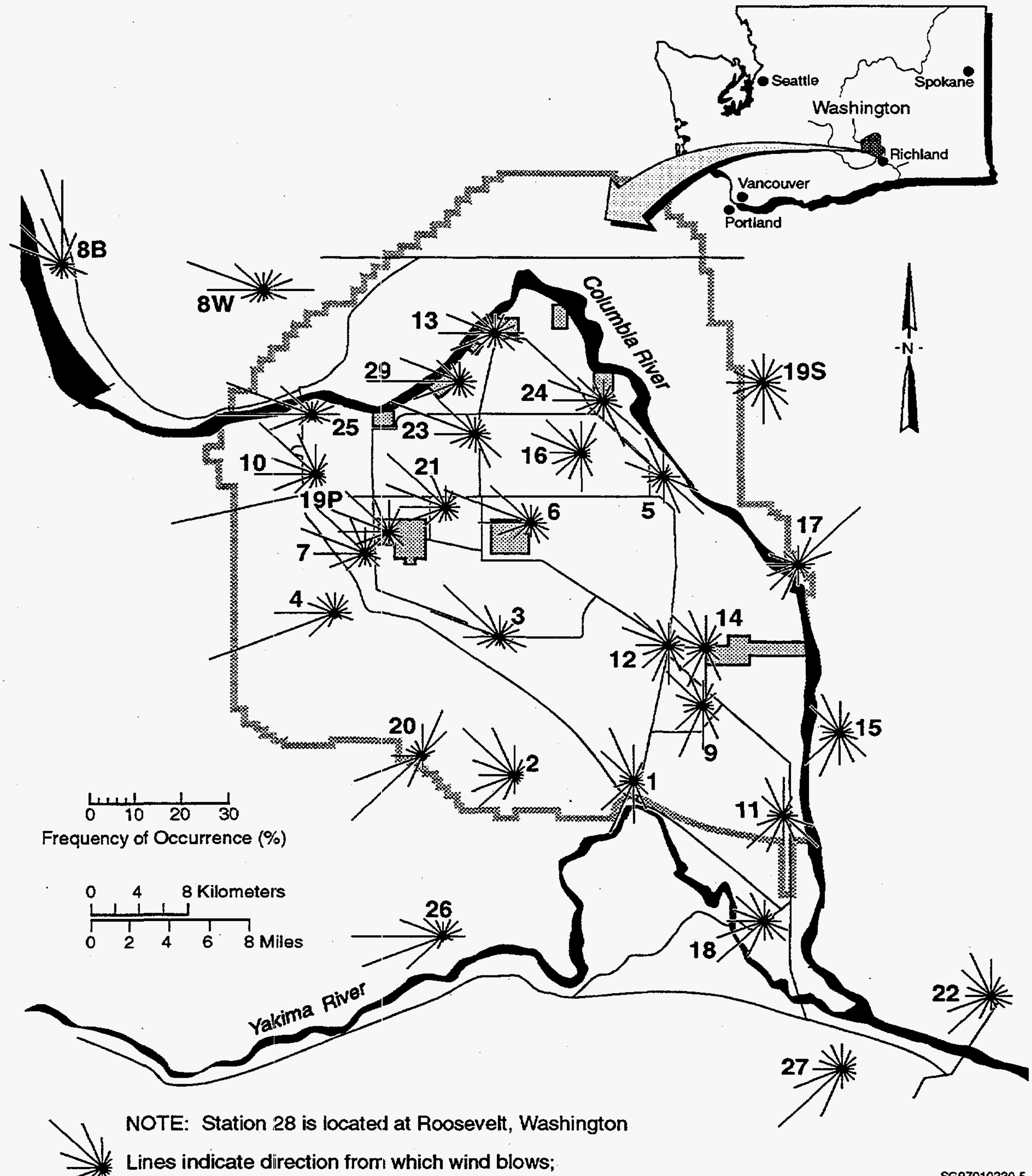

Figure 4.1-2. Wind Roses at the 10 m Level of the Hanford Meteorological Monitoring Network, 1982 to 1996. The point of each rose represents the direction from which the winds come.

-6°C (21°F). During the winter, there are, on average, 3 days with minimum temperatures ≤−18°C (~0°F); however, only about one winter in two experiences such temperatures. The record maximum temperature is 45°C (113°F), and the record minimum temperature is -31°C (-23°F). For the period 1946 through 1996, the average monthly temperatures range from a low of -0.9°C (30°F) in January to a high of 24.6°C (76°F) in July. The highest winter monthly average temperature at the HMS was 6.9°C (44°F) in February 1958, while the record lowest temperature was -11.1°C (12°F) during January 1950. The record maximum summer monthly average temperature was 27.9°C (82°F) in July 1985, while the record lowest temperature was 17.2°C (63°F) in June 1953.

Relative humidity/dew point temperature measurements are made at the HMS and at the three 60-m (200-ft) tower locations. The annual average relative humidity at the HMS is 54%. It is highest during the winter months, averaging about 75%, and lowest during the summer, averaging about 35%. Wet bulb temperatures >24°C (75°F) had not been observed at the HMS before 1975; however, on July 8, 9, and 10 of that year, there were seven hourly observations with wet bulb temperatures ≥24°C (75°F).

4.1.3 Precipitation

Precipitation measurements have been made at the HMS since 1945. Average annual precipitation at the HMS is 16 cm (6.3 in.). In the wettest year on record, 1995, 31.3 cm (12.3 in.) of precipitation was measured; in the driest year, 1976, only 7.6 cm (3 in.) was measured. Most precipitation occurs during the winter, with more than half of the annual amount occurring from November through February. Days with >1.3 cm (0.50 in.) precipitation occur on average less than one time each year. Rainfall intensities of 1.3 cm/h (0.50 in./h) persisting for 1 hour are expected once every 10 years. Rainfall intensities of 2.5 cm/h (1 in./h) for 1 hour are expected only once every 500 years. Winter monthly average snowfall ranges from 0.8 cm (0.32 in.) in March to 13.7 cm (5 in.) in December. The record monthly snowfall of 60 cm (23.4 in.) occurred in January 1950. The seasonal record snowfall of 142 cm (56 in.) occurred during the winter of 1992-1993. Snowfall accounts for about 38% of all precipitation from December through February.

Climatological precipitation measurements have also been made on the Fitzner/Eberhardt Arid Lands Ecology (ALE) Reserve on the northeast slope of the Rattlesnake Hills (Stone et al. 1983).

4.1.4 Fog and Visibility

Fog has been recorded during every month of the year at the HMS; however, 89% of the occurrences are from November through February, with less than 3% from April through September (Table 4.1-2). The average number of days per year with fog (visibility ≤9.6 km [6 mi.]) is 47, while those with dense fog (visibility ≤0.4 km [0.25 mi.]), is 25. The greatest number of days with fog was 84 days in 1985-1986, and the least was 22 in 1948-1949; the greatest number of days with dense fog was 42 days in 1950-1951, and the least was 9 days in 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 ≤9.6 km [6 mi.]) include dust, blowing dust, and smoke from field burning. There are few such days; an average of 5 d/yr. have dust or blowing dust and <1 d/yr. has reduced visibility from smoke.

Table 4.1-2. Number of Days with Fog by Season

Category	Winter	Spring	Summer	Autumn	Total
Fog	32	3	≤½	12	47
Dense fog	17	1	≤½	7	25

4.1.5 Severe Weather

High winds are associated with thunderstorms. The average occurrence of thunderstorms is 10 per year. They are most frequent during the summer; however, they have occurred in every month. The average winds during thunderstorms come from no specific direction. Estimates of the extreme winds, based on peak gusts observed from 1945 through 1980, are given in Stone et al. (1983) and are shown in Table 4.1-3. Using the National Weather Service criteria for classifying a thunderstorm as "severe" (i.e., hail with a diameter ≥20 mm [1 in.] or wind gusts of ≥93 km/h [58 mi./h]), it is observed that only 1.9% of all thunderstorm events surveyed at the HMS have been "severe" storms, and all met the criteria based on wind gusts.

Tornadoes are infrequent and generally small in the northwest portion of the United States. Grazulis (1984) lists no violent tornadoes for the region surrounding Hanford (DOE 1987). The HMS climatological summary (Stone et al. 1983) and the National Severe Storms Forecast Center database list 22 separate tornado occurrences within 161 km (100 mi.) of the Hanford Site from 1916 through August 1982. Two additional tornadoes have been reported since August 1982.

Using the information in the preceding paragraph and the statistics published in Ramsdell and Andrews (1986) for the 5° block centered at 117.5° west longitude and 47.5° north latitude (the area in which the Hanford Site is located), the expected path length of a tornado on the Hanford Site is 7.6 km (5 mi.), the expected width is 95 m (312 ft), and the expected area is about 1.5 km^2 (1 mi^2). The estimated probability of a tornado striking a point at Hanford, also from Ramsdell and Andrews (1986), is 9.6×10^{-6}/yr. The probabilities of extreme winds associated with tornadoes striking a point can be estimated using the distribution of tornado intensities for the region. These probability estimates are given in Table 4.1-4.

Table 4.1-3. Estimates of Extreme Winds at the Hanford Site

	Peak gusts (km/h)	
Return period (yr.)	15.2 m above ground	61 m above ground
2	97	109
10	114	129
100	137	151
1000	159	175

Table 4.1-4. Estimate of the Probability of Extreme Winds Associated with Tornadoes Striking a Point at Hanford[(a)]

Wind speed (km/h)	Probability per year
100	2.6×10^{-6}
200	6.5×10^{-7}
300	1.6×10^{-7}
400	3.9×10^{-8}

(a) Ramsdell and Andrews (1986).

4.1.6 Atmospheric Dispersion

Atmospheric dispersion, the transport and diffusion of gases and particles within the atmosphere, is a function of wind speed, duration and direction of wind, the intensity of atmospheric turbulence (wind motions at very small time scales that act to disperse gas and particles rather than transporting them downwind), and mixing depth. Often the atmospheric turbulence cannot be measured directly and is estimated by the atmospheric stability. Atmospheric stability describes the thermal stratification or vertical temperature structure of the atmosphere. The more unstable the atmosphere, the more atmospheric turbulence is generated. When the atmosphere is considered to be unstable or neutral, i.e., the winds are moderate to strong, and the mixing depth is deep, conditions are favorable for dispersion. These conditions are most common in the summer when neutral and unstable stratification exist about 56% of the time (Stone et al. 1983). Less favorable dispersion conditions may occur when the wind speed is light and the mixing layer is shallow. These conditions are most common during the winter when moderately to extremely stable stratification exists about 66% 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 that occur primarily 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% in May and June to a high of about 64% in September and October. These probabilities decrease rapidly for durations of >12 hours. Table 4.1-5 summarizes the probabilities associated with extended surface-based inversions.

Many dispersion models use joint frequency distribution of atmospheric stability, wind speed, and wind direction to compute diffusion factors for both chronic and acute releases. Tables 4.1-6 through 4.1-13 present joint frequency distribution of atmospheric stability, wind speed, and wind direction for measurements taken at the 100-N, 200 East (200 Areas), 300 Area, and 400 Area at two different heights (10 m and 61 m [33 ft and 200 ft]). The values presented in the joint frequency distributions

Table 4.1-5. Percent Probabilities for Extended Periods of Surface-Based Inversions (Based on Data from 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

are percentage of the time that the wind is blowing towards the direction listed (e.g., S, SSW, SW). For each station, the joint frequency distributions were determined using local wind data measured at the 10 m (33 ft) towers and the HMS atmospheric stability data. For the 61 m (200 ft) joint frequency distributions, wind speed was estimated assuming the wind speed profile was represented by a power law. A more detailed description of the procedures used to develop the joint frequency distributions are found in Appendix H.1 of the *Recommended Environmental Dose Calculation Methods and Hanford-Specific Parameters* (Schreckhise et al. 1993).

Tables 4.1-14 through 4.1-20 present the annual sector-average atmospheric diffusion factors ($\overline{X}/Q'$) and Tables 4.1-21 through 4.1-29 present the 95% centerline atmospheric diffusion factor (E/Q) for the four major Hanford Areas (100-N, 200 Areas, 300 Area, and the 400 Area). For each area except the 400 Area, atmospheric diffusion factors are for a ground-level release and a release at 60 m (197 ft). For the 400 area, the diffusion factors are for a ground-level release and a release at 30 m (98 ft). These diffusion factors are presented as a function of direction and distance from the release point, and were calculated using the GENII code (Napier et al. 1988) based on meteorological measurements averaged over the years 1983 through 1991.

4.1.7 Special Meteorological Considerations on the Hanford Site

Winds exhibit significant variation across the Hanford Site because of its large size and varying terrain. Stations near the Columbia River tend to exhibit wind patterns that are strongly influenced by the topography of the river and the surrounding terrain. For example, in the 100 Area, the river runs southwest to northeast at 100-N and northwest to southeast at 100-F. The wind direction frequency for 100-N shows a high frequency of winds from the west-southwest and southwest; while 100-F shows a high frequency of winds from the southeast and south-southeast (Figure 4.1-2). The 60-m (197-ft) tower at the 100-N Area provides additional data to define the wind up to 60 m (197 ft) above ground level. Winds aloft are less influenced by surface features than winds near the surface, as shown by the much smaller frequency of winds from the west-southwest and southwest at 60 m (197 ft) at 100-N (Figure 4.1-3).

Prevailing winds in the 200 Areas (i.e., HMS) tend to come from the west through the northwest, the direction of summer drainage winds; sites further south (i.e., FFTF) show prevailing winds that come

Table 4.1-6. Joint Frequency Distributions for the 100-N Area 10-m Tower, 1983-1991 Data (Schreckhise et al.1993)

Midpoint Wind Speed Class ($m\ sec^{-1}$)	Pasquill Category	Percentage of Time Wind Blows from the 100-N Area Towards the Direction Indicated															
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.89	A	0.34	0.14	0.14	0.13	0.27	0.17	0.13	0.11	0.17	0.11	0.13	0.19	0.35	0.32	0.34	0.30
	B	0.12	0.06	0.07	0.05	0.14	0.10	0.09	0.08	0.07	0.06	0.08	0.08	0.13	0.11	0.12	0.11
	C	0.15	0.07	0.08	0.10	0.13	0.11	0.10	0.07	0.11	0.07	0.07	0.10	0.11	0.11	0.11	0.10
	D	0.71	0.42	0.38	0.45	1.03	0.89	0.70	0.53	0.75	0.51	0.59	0.57	0.90	0.64	0.62	0.57
	E	0.60	0.37	0.42	0.48	0.98	0.68	0.54	0.44	0.56	0.42	0.51	0.61	0.86	0.67	0.54	0.52
	F	0.57	0.32	0.41	0.46	0.88	0.51	0.42	0.25	0.35	0.29	0.40	0.63	0.92	0.67	0.58	0.52
	G	0.25	0.17	0.18	0.22	0.36	0.18	0.15	0.11	0.15	0.13	0.22	0.35	0.63	0.41	0.32	0.28
2.7	A	0.60	0.42	0.32	0.14	0.32	0.28	0.25	0.17	0.16	0.14	0.33	0.45	0.73	0.48	0.40	0.43
	B	0.13	0.12	0.08	0.05	0.13	0.11	0.10	0.07	0.06	0.03	0.08	0.14	0.20	0.09	0.11	0.09
	C	0.11	0.09	0.09	0.06	0.12	0.10	0.10	0.07	0.05	0.03	0.08	0.11	0.18	0.09	0.08	0.09
	D	0.60	0.47	0.37	0.37	0.72	0.71	0.65	0.39	0.39	0.32	0.52	1.05	1.33	0.68	0.50	0.41
	E	0.33	0.23	0.28	0.42	0.86	0.63	0.48	0.32	0.33	0.24	0.50	1.18	1.97	0.76	0.38	0.22
	F	0.18	0.14	0.16	0.41	0.84	0.38	0.23	0.16	0.14	0.16	0.28	0.68	1.08	0.49	0.28	0.16
	G	0.05	0.05	0.08	0.19	0.32	0.13	0.09	0.05	0.05	0.06	0.13	0.29	0.59	0.18	0.09	0.04
4.7	A	0.15	0.24	0.13	0.04	0.08	0.08	0.13	0.06	0.07	0.10	0.23	0.29	0.48	0.35	0.19	0.09
	B	0.03	0.06	0.05	0.02	0.03	0.03	0.03	0.02	0.03	0.02	0.06	0.07	0.13	0.09	0.04	0.02
	C	0.03	0.06	0.03	0.01	0.03	0.02	0.04	0.03	0.02	0.03	0.06	0.05	0.11	0.07	0.04	0.02
	D	0.19	0.21	0.17	0.07	0.09	0.16	0.26	0.16	0.12	0.20	0.33	0.56	1.17	0.59	0.19	0.12
	E	0.14	0.13	0.09	0.05	0.09	0.08	0.22	0.13	0.12	0.13	0.26	0.68	1.79	0.72	0.17	0.09
	F	0.08	0.07	0.03	0.05	0.06	0.04	0.07	0.04	0.02	0.02	0.06	0.25	0.33	0.13	0.04	0.05
	G	0.02	0.01	0.00	0.01	0.04	0.02	0.01	0.01	0.01	0.01	0.01	0.06	0.06	0.02	0.01	0.01
7.2	A	0.05	0.09	0.07	0.02	0.01	0.01	0.03	0.02	0.02	0.05	0.14	0.12	0.28	0.34	0.17	0.03
	B	0.03	0.05	0.02	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.06	0.03	0.09	0.09	0.04	0.01
	C	0.01	0.02	0.02	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.05	0.03	0.06	0.07	0.03	0.01
	D	0.09	0.13	0.05	0.02	0.01	0.02	0.05	0.05	0.05	0.10	0.28	0.19	0.56	0.61	0.20	0.05
	E	0.10	0.10	0.04	0.02	0.00	0.01	0.03	0.03	0.03	0.07	0.11	0.15	0.65	0.56	0.13	0.04
	F	0.02	0.05	0.01	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.03	0.06	0.02	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	0.01	0.01	0.00	0.00	0.00
9.8	A	0.01	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.07	0.05	0.08	0.16	0.10	0.00
	B	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.02	0.03	0.05	0.03	0.00
	C	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.05	0.02	0.00
	D	0.05	0.06	0.02	0.01	0.00	0.00	0.00	0.01	0.01	0.08	0.12	0.09	0.13	0.25	0.14	0.01
	E	0.05	0.05	0.03	0.01	0.00	0.00	0.00	0.00	0.01	0.03	0.05	0.04	0.07	0.14	0.06	0.01
	F	0.02	0.02	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
	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
13.	A	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	0.05	0.04	0.00
	B	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	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	0.00	0.00	0.00	0.00	0.00
	D	0.01	0.04	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.04	0.04	0.02	0.04	0.06	0.02	0.01
	E	0.02	0.03	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.02	0.02	0.01
	F	0.00	0.01	0.00.	0.00	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
16.	A	0.01	0.01	0.00	0.00	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	0.01	0.01	0.00	0.00	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	0.03	0.02	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
	E	0.03	0.03	0.00	0.00	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	0.01	0.01	0.00	0.00	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.	A	0.02	0.03	0.00	0.00	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	0.02	0.02	0.00	0.00	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	0.02	0.03	0.00	0.00	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	0.07	0.09	0.00	0.00	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	0.07	0.14	0.00	0.00	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	0.03	0.06	0.00	0.00	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 4.1-7. Joint Frequency Distributions for the 100-N Area 61-m Tower, 1983-1991 Data (Schreckhise et al. 1993)

Midpoint Wind Speed Class (m sec^{-1})	Pasquill Category	Percentage of Time Wind Blows from the 100-N Area Towards the Direction Indicated															
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.89	A	0.32	0.14	0.13	0.12	0.26	0.17	0.12	0.09	0.16	0.10	0.12	0.17	0.34	0.30	0.32	0.28
	B	0.10	0.05	0.07	0.05	0.13	0.10	0.09	0.08	0.07	0.05	0.08	0.08	0.12	0.11	0.11	0.09
	C	0.14	0.07	0.07	0.08	0.12	0.10	0.09	0.06	0.10	0.06	0.07	0.09	0.10	0.12	0.10	0.09
	D	0.55	0.34	0.29	0.36	0.80	0.67	0.54	0.41	0.56	0.36	0.46	0.43	0.68	0.49	0.46	0.41
	E	0.39	0.24	0.27	0.32	0.67	0.42	0.33	0.29	0.40	0.28	0.33	0.36	0.48	0.37	0.32	0.33
	F	0.37	0.23	0.26	0.38	0.64	0.34	0.29	0.17	0.25	0.23	0.30	0.42	0.60	0.43	0.39	0.36
	G	0.18	0.14	0.14	0.20	0.34	0.16	0.13	0.09	0.13	0.10	0.16	0.25	0.46	0.30	0.26	0.22
2.7	A	0.59	0.34	0.28	0.14	0.33	0.28	0.24	0.16	0.15	0.12	0.29	0.41	0.65	0.46	0.40	0.43
	B	0.12	0.11	0.06	0.05	0.13	0.10	0.09	0.05	0.05	0.03	0.05	0.11	0.19	0.08	0.12	0.10
	C	0.11	0.08	0.09	0.06	0.11	0.10	0.09	0.06	0.05	0.04	0.08	0.09	0.15	0.08	0.08	0.09
	D	0.59	0.38	0.35	0.35	0.71	0.69	0.57	0.35	0.36	0.28	0.42	0.70	0.93	0.54	0.48	0.43
	E	0.33	0.24	0.30	0.39	0.69	0.53	0.36	0.27	0.29	0.22	0.34	0.58	0.89	0.56	0.37	0.28
	F	0.27	0.16	0.20	0.29	0.61	0.32	0.20	0.15	0.17	0.16	0.21	0.44	0.69	0.43	0.32	0.22
	G	0.08	0.06	0.09	0.14	0.23	0.10	0.06	0.05	0.06	0.07	0.11	0.22	0.49	0.20	0.12	0.08
4.7	A	0.18	0.28	0.15	0.03	0.09	0.09	0.13	0.06	0.07	0.09	0.20	0.29	0.48	0.28	0.14	0.10
	B	0.04	0.06	0.06	0.02	0.04	0.03	0.04	0.03	0.03	0.02	0.06	0.08	0.11	0.06	0.03	0.03
	C	0.04	0.06	0.04	0.03	0.05	0.03	0.05	0.03	0.02	0.02	0.06	0.05	0.10	0.04	0.03	0.02
	D	0.22	0.27	0.20	0.12	0.22	0.24	0.30	0.16	0.15	0.18	0.34	0.65	0.97	0.43	0.19	0.16
	E	0.17	0.14	0.15	0.16	0.34	0.28	0.30	0.16	0.19	0.16	0.35	0.81	1.47	0.50	0.23	0.12
	F	0.11	0.06	0.08	0.16	0.30	0.19	0.14	0.09	0.07	0.07	0.17	0.40	0.61	0.27	0.14	0.10
	G	0.03	0.03	0.02	0.06	0.11	0.05	0.04	0.02	0.03	0.04	0.07	0.16	0.24	0.09	0.05	0.03
7.2	A	0.07	0.12	0.11	0.03	0.02	0.02	0.04	0.03	0.03	0.06	0.17	0.15	0.31	0.32	0.16	0.04
	B	0.02	0.04	0.03	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.05	0.05	0.11	0.07	0.03	0.02
	C	0.02	0.03	0.02	0.00	0.01	0.00	0.02	0.02	0.01	0.03	0.04	0.03	0.08	0.07	0.03	0.01
	D	0.13	0.13	0.11	0.04	0.04	0.06	0.13	0.10	0.09	0.15	0.25	0.43	0.85	0.48	0.16	0.08
	E	0.14	0.10	0.07	0.06	0.10	0.10	0.15	0.09	0.10	0.08	0.21	0.64	1.52	0.57	0.14	0.07
	F	0.07	0.06	0.04	0.06	0.13	0.04	0.06	0.03	0.03	0.02	0.07	0.26	0.37	0.13	0.04	0.05
	G	0.01	0.01	0.01	0.02	0.03	0.01	0.01	0.01	0.01	0.00	0.02	0.05	0.10	0.03	0.01	0.01
9.8	A	0.03	0.05	0.03	0.01	0.00	0.01	0.01	0.01	0.01	0.02	0.08	0.08	0.14	0.21	0.13	0.02
	B	0.03	0.03	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.04	0.02	0.04	0.08	0.03	0.00
	C	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.02	0.02	0.04	0.06	0.03	0.00
	D	0.07	0.08	0.03	0.01	0.01	0.01	0.04	0.05	0.03	0.08	0.20	0.16	0.49	0.45	0.16	0.03
	E	0.06	0.06	0.04	0.02	0.03	0.02	0.06	0.05	0.04	0.07	0.12	0.22	0.77	0.51	0.08	0.03
	F	0.03	0.04	0.01	0.02	0.03	0.02	0.02	0.01	0.01	0.01	0.02	0.08	0.13	0.05	0.02	0.01
	G	0.01	0.00	0.00	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.01	0.03	0.03	0.01	0.00	0.00
13.	A	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.06	0.04	0.07	0.13	0.07	0.00
	B	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.02	0.03	0.04	0.03	0.00
	C	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.01	0.05	0.02	0.00
	D	0.06	0.07	0.02	0.00	0.00	0.00	0.01	0.01	0.02	0.08	0.11	0.10	0.21	0.32	0.13	0.02
	E	0.07	0.07	0.06	0.03	0.00	0.00	0.01	0.02	0.01	0.03	0.06	0.08	0.27	0.32	0.11	0.02
	F	0.01	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.03	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	0.01	0.02	0.00	0.00	0.00
16.	A	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.02	0.05	0.03	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	0.00	0.00	0.01	0.00	0.00
	C	0.01	0.01	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
	D	0.02	0.04	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.05	0.07	0.03	0.06	0.11	0.06	0.01
	E	0.04	0.04	0.03	0.01	0.00	0.00	0.00	0.01	0.01	0.03	0.03	0.02	0.07	0.09	0.04	0.01
	F	0.01	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	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
19.	A	0.02	0.03	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
	B	0.01	0.02	0.00	0.00	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	0.01	0.02	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	0.05	0.07	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.03	0.02	0.01	0.03	0.03	0.01	0.01
	E	0.06	0.09	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.01	0.02	0.03	0.03	0.01
	F	0.03	0.03	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
	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 4.1-8. Joint Frequency Distributions for the 200 Areas 10-m Tower, 1983-1991 Data (Schreckhise et al. 1993)

Midpoint Wind Speed Class ($m\ sec^{-1}$)	Pasquill Category	Percentage of Time Wind Blows from the 200 Areas Towards the Direction Indicated															
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.89	A	0.36	0.20	0.23	0.26	0.40	0.24	0.17	0.10	0.10	0.06	0.06	0.06	0.10	0.10	0.14	0.22
	B	0.15	0.13	0.10	0.11	0.16	0.09	0.07	0.03	0.05	0.02	0.01	0.03	0.04	0.05	0.07	0.10
	C	0.14	0.10	0.09	0.12	0.14	0.10	0.06	0.04	0.04	0.02	0.02	0.02	0.04	0.04	0.10	0.10
	D	0.87	0.58	0.59	0.59	0.77	0.50	0.43	0.32	0.27	0.19	0.21	0.17	0.40	0.44	0.54	0.55
	E	0.39	0.26	0.28	0.25	0.46	0.34	0.31	0.30	0.34	0.21	0.25	0.29	0.49	0.44	0.45	0.39
	F	0.23	0.13	0.12	0.14	0.31	0.23	0.28	0.26	0.35	0.23	0.22	0.27	0.48	0.36	0.32	0.23
	G	0.10	0.04	0.08	0.08	0.13	0.13	0.13	0.14	0.17	0.09	0.10	0.09	0.22	0.14	0.14	0.09
2.7	A	0.69	0.44	0.29	0.32	0.60	0.51	0.45	0.29	0.24	0.12	0.17	0.19	0.25	0.30	0.42	0.48
	B	0.21	0.15	0.06	0.08	0.16	0.13	0.13	0.09	0.08	0.04	0.03	0.05	0.07	0.09	0.16	0.16
	C	0.19	0.12	0.06	0.09	0.13	0.13	0.19	0.10	0.06	0.02	0.03	0.05	0.08	0.10	0.19	0.15
	D	0.84	0.48	0.40	0.33	0.66	0.57	0.75	0.53	0.35	0.18	0.24	0.28	0.69	1.09	1.05	0.77
	E	0.32	0.17	0.11	0.13	0.31	0.34	0.47	0.52	0.46	0.21	0.29	0.48	1.58	1.68	1.11	0.39
	F	0.13	0.05	0.05	0.05	0.16	0.21	0.39	0.44	0.45	0.21	0.27	0.46	1.60	1.69	0.82	0.25
	G	0.04	0.02	0.02	0.03	0.09	0.10	0.20	0.23	0.20	0.08	0.10	0.20	0.82	0.69	0.30	0.08
4.7	A	0.26	0.24	0.10	0.03	0.08	0.10	0.10	0.13	0.12	0.07	0.14	0.34	0.35	0.35	0.40	0.17
	B	0.09	0.06	0.03	0.01	0.03	0.03	0.04	0.05	0.03	0.02	0.05	0.07	0.10	0.14	0.12	0.06
	C	0.08	0.05	0.03	0.01	0.02	0.02	0.04	0.04	0.05	0.02	0.03	0.06	0.09	0.13	0.12	0.03
	D	0.32	0.20	0.09	0.04	0.12	0.11	0.25	0.27	0.24	0.13	0.23	0.39	0.83	1.46	0.84	0.21
	E	0.19	0.09	0.04	0.01	0.06	0.06	0.15	0.25	0.22	0.12	0.18	0.39	1.98	2.50	0.75	0.13
	F	0.04	0.06	0.01	0.01	0.01	0.02	0.05	0.17	0.14	0.03	0.07	0.20	1.19	1.60	0.32	0.06
	G	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.09	0.07	0.01	0.02	0.09	0.56	0.84	0.13	0.01
7.2	A	0.07	0.07	0.05	0.01	0.00	0.00	0.01	0.03	0.04	0.04	0.11	0.25	0.25	0.25	0.33	0.05
	B	0.02	0.03	0.01	0.01	0.00	0.00	0.00	0.01	0.02	0.01	0.04	0.08	0.06	0.07	0.09	0.01
	C	0.02	0.03	0.01	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.02	0.07	0.06	0.07	0.06	0.01
	D	0.10	0.10	0.03	0.01	0.00	0.01	0.03	0.07	0.10	0.11	0.25	0.38	0.58	1.14	0.50	0.05
	E	0.07	0.12	0.01	0.00	0.00	0.00	0.01	0.05	0.07	0.08	0.17	0.30	0.65	1.75	0.41	0.02
	F	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.01	0.02	0.07	0.08	0.03	0.00
	G	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	0.01	0.00	0.00
9.8	A	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.05	0.16	0.10	0.11	0.24	0.00
	B	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.02	0.03	0.06	0.00
	C	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.05	0.02	0.03	0.05	0.00
	D	0.02	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.07	0.16	0.24	0.13	0.50	0.29	0.01
	E	0.01	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.11	0.15	0.06	0.38	0.11	0.00
	F	0.01	0.01	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	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
13.	A	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.06	0.02	0.02	0.03	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	0.02	0.01	0.00	0.01	0.00
	C	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.01	0.01	0.00
	D	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.09	0.09	0.03	0.07	0.08	0.00
	E	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.02	0.01	0.05	0.03	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
16.	A	0.01	0.01	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
	B	0.00	0.01	0.00	0.00	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	0.01	0.01	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
	D	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.02	0.00	0.00	0.00
	E	0.01	0.02	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	0.01	0.01	0.00	0.00	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.	A	0.02	0.02	0.00	0.00	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	0.01	0.01	0.00	0.00	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	0.01	0.02	0.00	0.00	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	0.04	0.07	0.00	0.00	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	0.07	0.12	0.00	0.00	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	0.03	0.05	0.00	0.00	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	0.01	0.00	0.00	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 4.1-9. Joint Frequency Distributions for the 200 Areas 61-m Tower, 1983-1991 Data (Schreckhise et al. 1993)

Midpoint Wind Speed Class (m sec^{-1})	Pasquill Category	Percentage of Time Wind Blows from the 200 Areas Towards the Direction Indicated															
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.89	A	0.35	0.18	0.20	0.24	0.38	0.23	0.17	0.09	0.10	0.06	0.05	0.06	0.10	0.10	0.12	0.18
	B	0.12	0.10	0.09	0.10	0.13	0.08	0.06	0.03	0.05	0.02	0.01	0.02	0.04	0.05	0.06	0.08
	C	0.11	0.08	0.07	0.10	0.13	0.09	0.07	0.04	0.03	0.02	0.02	0.03	0.04	0.03	0.08	0.08
	D	0.62	0.42	0.39	0.45	0.60	0.41	0.36	0.27	0.21	0.16	0.17	0.12	0.26	0.32	0.42	0.39
	E	0.23	0.16	0.17	0.15	0.31	0.26	0.23	0.27	0.27	0.16	0.16	0.19	0.31	0.28	0.24	0.22
	F	0.13	0.08	0.08	0.09	0.19	0.20	0.28	0.31	0.33	0.16	0.16	0.21	0.40	0.29	0.23	0.15
	G	0.07	0.03	0.05	0.05	0.12	0.11	0.16	0.21	0.20	0.09	0.09	0.10	0.25	0.14	0.12	0.07
2.7	A	0.60	0.40	0.29	0.33	0.59	0.52	0.42	0.24	0.20	0.11	0.14	0.14	0.20	0.24	0.35	0.43
	B	0.18	0.13	0.06	0.09	0.16	0.12	0.11	0.07	0.07	0.03	0.02	0.04	0.06	0.07	0.14	0.13
	C	0.18	0.11	0.06	0.10	0.13	0.13	0.15	0.07	0.05	0.02	0.02	0.04	0.05	0.08	0.16	0.15
	D	0.81	0.42	0.39	0.32	0.63	0.50	0.62	0.37	0.29	0.13	0.16	0.22	0.42	0.59	0.71	0.68
	E	0.26	0.13	0.14	0.13	0.27	0.26	0.25	0.30	0.32	0.14	0.21	0.29	0.58	0.60	0.57	0.28
	F	0.15	0.06	0.05	0.04	0.16	0.12	0.20	0.20	0.28	0.16	0.19	0.26	0.64	0.57	0.37	0.17
	G	0.04	0.02	0.03	0.03	0.07	0.07	0.10	0.11	0.11	0.06	0.07	0.12	0.46	0.27	0.14	0.06
4.7	A	0.35	0.27	0.11	0.05	0.12	0.10	0.14	0.15	0.14	0.07	0.15	0.29	0.30	0.31	0.34	0.22
	B	0.11	0.08	0.03	0.01	0.04	0.05	0.06	0.06	0.03	0.02	0.05	0.06	0.08	0.10	0.11	0.09
	C	0.09	0.06	0.04	0.02	0.03	0.02	0.06	0.05	0.05	0.02	0.02	0.03	0.07	0.08	0.12	0.05
	D	0.38	0.26	0.14	0.07	0.17	0.16	0.27	0.24	0.20	0.11	0.19	0.25	0.61	0.90	0.79	0.34
	E	0.20	0.11	0.05	0.04	0.12	0.13	0.23	0.23	0.23	0.11	0.15	0.31	1.05	0.95	0.65	0.25
	F	0.08	0.03	0.02	0.03	0.05	0.09	0.11	0.17	0.19	0.10	0.13	0.27	0.89	0.92	0.44	0.13
	G	0.01	0.01	0.01	0.01	0.01	0.02	0.05	0.07	0.06	0.02	0.05	0.10	0.49	0.38	0.15	0.04
7.2	A	0.11	0.11	0.05	0.02	0.01	0.02	0.02	0.06	0.06	0.05	0.10	0.25	0.25	0.26	0.32	0.07
	B	0.05	0.04	0.02	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.03	0.05	0.07	0.10	0.08	0.03
	C	0.03	0.03	0.02	0.00	0.01	0.00	0.01	0.02	0.02	0.01	0.02	0.07	0.08	0.11	0.06	0.01
	D	0.19	0.13	0.06	0.01	0.03	0.02	0.10	0.20	0.15	0.09	0.20	0.32	0.59	1.11	0.54	0.11
	E	0.13	0.08	0.03	0.02	0.04	0.04	0.11	0.17	0.13	0.09	0.15	0.31	1.52	1.67	0.62	0.12
	F	0.04	0.03	0.01	0.01	0.03	0.02	0.07	0.10	0.09	0.03	0.06	0.15	0.92	1.03	0.32	0.07
	G	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.04	0.04	0.01	0.01	0.05	0.28	0.51	0.13	0.01
9.8	A	0.03	0.05	0.04	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.07	0.14	0.15	0.15	0.23	0.02
	B	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.06	0.05	0.04	0.06	0.00
	C	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.01	0.04	0.04	0.04	0.05	0.00
	D	0.06	0.06	0.01	0.01	0.00	0.01	0.03	0.06	0.07	0.08	0.16	0.29	0.47	0.81	0.35	0.04
	E	0.09	0.09	0.01	0.00	0.01	0.00	0.06	0.08	0.08	0.07	0.13	0.24	0.99	1.92	0.41	0.03
	F	0.03	0.03	0.00	0.00	0.01	0.00	0.02	0.05	0.04	0.01	0.02	0.06	0.45	0.72	0.13	0.01
	G	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.00	0.00	0.02	0.13	0.29	0.04	0.00
13.	A	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.04	0.14	0.08	0.09	0.19	0.00
	B	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.04	0.02	0.03	0.05	0.00
	C	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.04	0.01	0.02	0.04	0.00
	D	0.02	0.04	0.01	0.01	0.00	0.00	0.00	0.02	0.04	0.07	0.15	0.23	0.25	0.77	0.37	0.02
	E	0.05	0.08	0.02	0.00	0.00	0.00	0.02	0.03	0.03	0.04	0.11	0.19	0.36	1.26	0.30	0.01
	F	0.02	0.03	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.00	0.01	0.02	0.12	0.29	0.03	0.01
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.05	0.13	0.01	0.00
16.	A	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.07	0.02	0.02	0.05	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	0.02	0.01	0.01	0.02	0.00
	C	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.01	0.01	0.02	0.00
	D	0.01	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.13	0.13	0.04	0.29	0.14	0.00
	E	0.01	0.03	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.04	0.07	0.10	0.06	0.30	0.10	0.00
	F	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.03	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	0.01	0.03	0.00	0.00
19.	A	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.01	0.01	0.00
	B	0.01	0.01	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	0.01	0.02	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
	D	0.03	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.08	0.07	0.04	0.03	0.02	0.00
	E	0.02	0.06	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.04	0.02	0.01	0.03	0.01	0.00
	F	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
	G	0.00	0.01	0.00	0.00	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 4.1-10. Joint Frequency Distributions for the 300 Area 10-m Tower, 1983-1991 Data (Schreckhise et al. 1993)

Midpoint Wind Speed Class ($m\ sec^{-1}$)	Pasquill Category	Percentage of Time Wind Blows from the 300 Area Towards the Direction Indicated															
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.89	A	0.10	0.05	0.07	0.09	0.14	0.08	0.08	0.11	0.09	0.05	0.04	0.04	0.03	0.03	0.05	0.07
	B	0.08	0.04	0.03	0.03	0.07	0.04	0.04	0.05	0.05	0.04	0.03	0.03	0.04	0.03	0.02	0.06
	C	0.07	0.03	0.03	0.05	0.08	0.06	0.06	0.06	0.07	0.03	0.02	0.03	0.04	0.03	0.04	0.05
	D	0.41	0.19	0.14	0.15	0.28	0.33	0.32	0.38	0.49	0.33	0.38	0.29	0.38	0.25	0.33	0.43
	E	0.36	0.13	0.11	0.11	0.24	0.32	0.40	0.47	0.65	0.40	0.42	0.37	0.52	0.40	0.43	0.42
	F	0.30	0.14	0.09	0.07	0.20	0.24	0.37	0.41	0.59	0.32	0.33	0.27	0.38	0.34	0.35	0.37
	G	0.19	0.07	0.04	0.03	0.10	0.10	0.16	0.19	0.27	0.13	0.16	0.13	0.20	0.17	0.20	0.19
2.7	A	0.28	0.29	0.34	0.33	0.75	0.45	0.42	0.28	0.23	0.21	0.25	0.19	0.11	0.04	0.06	0.16
	B	0.16	0.13	0.11	0.11	0.18	0.15	0.19	0.12	0.11	0.09	0.07	0.06	0.04	0.03	0.03	0.08
	C	0.15	0.14	0.08	0.09	0.17	0.18	0.21	0.12	0.12	0.09	0.09	0.05	0.03	0.03	0.06	0.10
	D	1.26	0.49	0.32	0.32	0.85	1.04	1.23	0.76	0.89	0.65	0.52	0.38	0.34	0.26	0.50	0.98
	E	1.25	0.24	0.07	0.08	0.36	1.04	1.46	0.95	1.31	0.60	0.53	0.41	0.46	0.40	0.56	1.00
	F	0.79	0.12	0.02	0.01	0.16	0.89	1.50	0.87	0.85	0.39	0.23	0.12	0.18	0.18	0.33	0.66
	G	0.39	0.05	0.01	0.00	0.05	0.35	0.70	0.39	0.32	0.12	0.06	0.03	0.06	0.07	0.16	0.31
4.7	A	0.33	0.46	0.28	0.09	0.15	0.18	0.23	0.13	0.27	0.46	0.54	0.33	0.13	0.06	0.08	0.10
	B	0.12	0.14	0.06	0.03	0.04	0.06	0.07	0.03	0.11	0.17	0.17	0.11	0.06	0.02	0.02	0.07
	C	0.17	0.12	0.07	0.02	0.03	0.06	0.07	0.04	0.10	0.12	0.16	0.10	0.04	0.00	0.05	0.08
	D	0.99	0.45	0.29	0.09	0.17	0.22	0.40	0.25	0.57	0.92	0.89	0.53	0.27	0.14	0.42	0.79
	E	1.23	0.24	0.06	0.04	0.08	0.28	0.29	0.19	0.61	0.78	0.81	0.58	0.30	0.16	0.39	0.63
	F	0.99	0.13	0.02	0.02	0.06	0.26	0.18	0.08	0.31	0.34	0.31	0.13	0.04	0.02	0.06	0.31
	G	0.55	0.05	0.00	0.00	0.02	0.14	0.12	0.03	0.11	0.11	0.09	0.04	0.01	0.00	0.01	0.14
7.2	A	0.17	0.12	0.03	0.00	0.00	0.00	0.02	0.01	0.08	0.24	0.44	0.37	0.12	0.05	0.08	0.05
	B	0.04	0.04	0.01	0.00	0.00	0.00	0.01	0.00	0.04	0.09	0.11	0.11	0.05	0.01	0.03	0.03
	C	0.04	0.02	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.10	0.15	0.10	0.04	0.01	0.03	0.03
	D	0.24	0.13	0.03	0.02	0.01	0.02	0.04	0.02	0.21	0.55	0.72	0.45	0.20	0.06	0.34	0.34
	E	0.20	0.07	0.04	0.01	0.01	0.00	0.02	0.01	0.12	0.37	0.53	0.27	0.14	0.05	0.24	0.24
	F	0.07	0.04	0.01	0.02	0.00	0.00	0.00	0.00	0.03	0.07	0.13	0.06	0.01	0.00	0.01	0.05
	G	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.05	0.01	0.00	0.00	0.00	0.01
9.8	A	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.09	0.14	0.11	0.08	0.01	0.03	0.02
	B	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.04	0.05	0.03	0.00	0.01	0.02
	C	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.05	0.05	0.01	0.00	0.01	0.00
	D	0.04	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.18	0.29	0.16	0.08	0.01	0.14	0.08
	E	0.04	0.08	0.02	0.01	0.00	0.00	0.00	0.00	0.02	0.11	0.26	0.05	0.03	0.00	0.08	0.06
	F	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	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	0.02	0.00	0.00	0.00	0.00	0.00
13.	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.05	0.03	0.04	0.00	0.00	0.00
	B	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.01	0.00	0.00	0.00
	C	0.00	0.02	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
	D	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.07	0.18	0.06	0.03	0.00	0.04	0.02
	E	0.03	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.14	0.01	0.01	0.00	0.01	0.00
	F	0.00	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	0.00
	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
16.	A	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
	B	0.00	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	0.00
	C	0.00	0.01	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
	D	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.07	0.01	0.01	0.00	0.00	0.00
	E	0.03	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.00	0.00	0.00	0.00	0.00
	F	0.03	0.01	0.00	0.00	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.	A	0.03	0.05	0.00	0.00	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	0.02	0.05	0.00	0.00	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	0.02	0.07	0.00	0.00	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	0.05	0.18	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
	E	0.12	0.15	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
	F	0.06	0.04	0.00	0.00	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 4.1-11. Joint Frequency Distributions for the 300 Area 61-m Tower, 1983-1991 Data (Schreckhise et al. 1993)

Midpoint Wind Speed Class (m sec^{-1})	Pasquill Category	Percentage of Time Wind Blows from the 300 Area Towards the Direction Indicated															
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.89	A	0.09	0.05	0.07	0.07	0.15	0.08	0.10	0.12	0.09	0.05	0.04	0.05	0.03	0.02	0.05	0.06
	B	0.07	0.03	0.03	0.03	0.07	0.03	0.06	0.05	0.05	0.03	0.03	0.03	0.04	0.03	0.03	0.06
	C	0.07	0.02	0.02	0.04	0.06	0.06	0.07	0.05	0.06	0.03	0.02	0.02	0.04	0.03	0.04	0.05
	D	0.34	0.16	0.11	0.13	0.26	0.31	0.34	0.34	0.41	0.27	0.29	0.22	0.27	0.17	0.25	0.34
	E	0.25	0.08	0.08	0.06	0.18	0.25	0.36	0.28	0.42	0.25	0.26	0.24	0.32	0.23	0.24	0.28
	F	0.23	0.10	0.05	0.05	0.14	0.30	0.41	0.35	0.43	0.24	0.22	0.17	0.25	0.21	0.25	0.26
	G	0.15	0.06	0.03	0.02	0.08	0.17	0.27	0.22	0.29	0.13	0.14	0.10	0.18	0.11	0.14	0.16
2.7	A	0.20	0.20	0.26	0.28	0.66	0.38	0.35	0.21	0.19	0.17	0.20	0.15	0.08	0.04	0.05	0.13
	B	0.12	0.10	0.08	0.10	0.16	0.13	0.14	0.10	0.09	0.09	0.07	0.06	0.04	0.01	0.03	0.06
	C	0.12	0.10	0.06	0.08	0.15	0.13	0.17	0.09	0.09	0.07	0.08	0.04	0.03	0.02	0.04	0.08
	D	0.83	0.35	0.24	0.23	0.67	0.70	0.85	0.56	0.66	0.49	0.37	0.26	0.24	0.19	0.32	0.61
	E	0.52	0.12	0.07	0.09	0.28	0.56	0.68	0.64	0.80	0.41	0.37	0.25	0.37	0.31	0.40	0.49
	F	0.37	0.08	0.04	0.02	0.12	0.40	0.68	0.55	0.55	0.28	0.21	0.14	0.20	0.18	0.22	0.35
	G	0.20	0.03	0.01	0.01	0.05	0.18	0.29	0.23	0.22	0.10	0.06	0.05	0.07	0.08	0.15	0.19
4.7	A	0.29	0.41	0.31	0.15	0.25	0.26	0.26	0.16	0.27	0.35	0.44	0.23	0.12	0.04	0.04	0.09
	B	0.13	0.13	0.07	0.04	0.07	0.07	0.09	0.05	0.09	0.14	0.11	0.08	0.05	0.02	0.01	0.05
	C	0.15	0.11	0.07	0.04	0.06	0.09	0.08	0.04	0.10	0.10	0.13	0.07	0.03	0.01	0.03	0.08
	D	0.87	0.43	0.26	0.18	0.31	0.40	0.55	0.34	0.55	0.66	0.63	0.38	0.26	0.15	0.36	0.66
	E	0.85	0.21	0.06	0.05	0.17	0.54	0.75	0.46	0.82	0.45	0.47	0.35	0.31	0.24	0.31	0.60
	F	0.54	0.07	0.02	0.02	0.09	0.40	0.61	0.32	0.48	0.23	0.15	0.11	0.11	0.10	0.16	0.38
	G	0.28	0.03	0.00	0.00	0.02	0.16	0.29	0.11	0.16	0.08	0.06	0.03	0.03	0.03	0.08	0.16
7.2	A	0.25	0.25	0.10	0.01	0.02	0.01	0.06	0.03	0.10	0.29	0.46	0.38	0.12	0.06	0.08	0.07
	B	0.07	0.07	0.03	0.01	0.01	0.01	0.02	0.01	0.05	0.09	0.12	0.10	0.05	0.02	0.02	0.04
	C	0.10	0.07	0.02	0.01	0.01	0.01	0.02	0.02	0.03	0.10	0.13	0.09	0.03	0.01	0.04	0.04
	D	0.64	0.26	0.15	0.02	0.03	0.09	0.15	0.12	0.34	0.61	0.70	0.45	0.22	0.11	0.29	0.53
	E	0.88	0.16	0.04	0.01	0.05	0.19	0.25	0.19	0.44	0.51	0.53	0.42	0.23	0.15	0.31	0.53
	F	0.57	0.07	0.01	0.02	0.03	0.17	0.25	0.13	0.20	0.20	0.20	0.08	0.04	0.04	0.08	0.25
	G	0.29	0.04	0.00	0.00	0.01	0.06	0.09	0.04	0.05	0.04	0.04	0.01	0.01	0.01	0.02	0.11
9.8	A	0.06	0.04	0.02	0.01	0.00	0.00	0.01	0.01	0.04	0.14	0.22	0.20	0.08	0.02	0.06	0.03
	B	0.03	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.06	0.05	0.06	0.03	0.01	0.03	0.03
	C	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.05	0.07	0.07	0.03	0.01	0.02	0.02
	D	0.19	0.07	0.02	0.01	0.01	0.01	0.03	0.02	0.14	0.34	0.44	0.30	0.15	0.05	0.27	0.31
	E	0.44	0.10	0.03	0.02	0.02	0.05	0.07	0.04	0.14	0.32	0.42	0.26	0.15	0.06	0.22	0.29
	F	0.34	0.07	0.01	0.01	0.01	0.07	0.07	0.02	0.08	0.09	0.13	0.06	0.02	0.01	0.02	0.12
	G	0.18	0.02	0.00	0.00	0.00	0.02	0.03	0.01	0.01	0.03	0.04	0.01	0.01	0.00	0.00	0.04
13.	A	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.07	0.10	0.08	0.08	0.02	0.04	0.01
	B	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.04	0.04	0.04	0.00	0.01	0.02
	C	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.04	0.04	0.01	0.00	0.02	0.01
	D	0.06	0.03	0.00	0.00	0.00	0.00	0.01	0.01	0.06	0.19	0.27	0.17	0.07	0.02	0.19	0.14
	E	0.18	0.08	0.01	0.01	0.01	0.02	0.02	0.01	0.06	0.20	0.28	0.14	0.08	0.02	0.19	0.13
	F	0.14	0.03	0.01	0.01	0.01	0.03	0.02	0.01	0.03	0.05	0.07	0.03	0.01	0.00	0.02	0.03
	G	0.08	0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.01	0.03	0.00	0.00	0.00	0.00	0.01
16.	A	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.04	0.03	0.03	0.00	0.00	0.00
	B	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01
	C	0.01	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	0.00	0.00
	D	0.03	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.03	0.09	0.17	0.07	0.04	0.00	0.07	0.04
	E	0.04	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.02	0.09	0.21	0.05	0.02	0.00	0.04	0.04
	F	0.06	0.03	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.04	0.03	0.00	0.00	0.00	0.00	0.01
	G	0.02	0.01	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	0.00
19.	A	0.02	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.01	0.01	0.00	0.00	0.00
	B	0.01	0.04	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
	C	0.02	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.00	0.00	0.00	0.00	0.00
	D	0.06	0.07	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.09	0.23	0.04	0.03	0.00	0.02	0.02
	E	0.08	0.12	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.10	0.21	0.02	0.01	0.00	0.01	0.00
	F	0.05	0.04	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.04	0.01	0.00	0.00	0.00	0.00
	G	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00

Table 4.1-12. Joint Frequency Distributions for the 400 Area 10-m Tower, 1983-1991 Data (Schreckhise et al. 1993)

Midpoint Wind Speed Class ($m\ sec^{-1}$)	Pasquill Category	Percentage of Time Wind Blows from the 400 Area Towards the Direction Indicated															
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.89	A	0.12	0.11	0.08	0.11	0.14	0.15	0.10	0.07	0.13	0.08	0.06	0.06	0.08	0.06	0.05	0.07
	B	0.06	0.05	0.05	0.05	0.07	0.05	0.04	0.03	0.06	0.03	0.03	0.02	0.03	0.03	0.03	0.03
	C	0.06	0.06	0.04	0.05	0.07	0.05	0.07	0.05	0.04	0.04	0.04	0.02	0.05	0.03	0.04	0.04
	D	0.44	0.28	0.27	0.23	0.33	0.31	0.29	0.31	0.41	0.31	0.26	0.20	0.29	0.26	0.34	0.34
	E	0.34	0.21	0.19	0.15	0.25	0.23	0.20	0.23	0.46	0.32	0.29	0.28	0.38	0.30	0.29	0.34
	F	0.31	0.20	0.15	0.13	0.19	0.13	0.16	0.16	0.34	0.23	0.25	0.19	0.26	0.20	0.20	0.20
	G	0.18	0.09	0.06	0.05	0.08	0.07	0.07	0.08	0.14	0.12	0.09	0.07	0.14	0.08	0.11	0.10
2.7	A	0.40	0.35	0.36	0.30	0.40	0.40	0.41	0.41	0.70	0.38	0.17	0.12	0.21	0.16	0.17	0.19
	B	0.15	0.11	0.11	0.08	0.13	0.08	0.11	0.13	0.19	0.14	0.05	0.05	0.06	0.04	0.08	0.08
	C	0.15	0.11	0.10	0.06	0.09	0.08	0.12	0.14	0.22	0.10	0.05	0.03	0.06	0.06	0.08	0.09
	D	0.84	0.56	0.47	0.34	0.45	0.37	0.64	0.92	1.21	0.71	0.34	0.23	0.49	0.61	0.82	0.69
	E	0.71	0.38	0.28	0.17	0.21	0.25	0.50	0.84	1.37	0.88	0.53	0.40	0.72	0.73	0.91	0.64
	F	0.70	0.48	0.26	0.12	0.15	0.13	0.35	0.64	1.09	0.61	0.39	0.20	0.30	0.33	0.57	0.50
	G	0.39	0.27	0.13	0.05	0.05	0.05	0.11	0.25	0.47	0.22	0.14	0.07	0.10	0.17	0.28	0.28
4.7	A	0.44	0.33	0.17	0.08	0.11	0.08	0.11	0.15	0.77	0.68	0.24	0.16	0.23	0.16	0.23	0.20
	B	0.15	0.09	0.04	0.02	0.03	0.03	0.04	0.06	0.24	0.24	0.07	0.06	0.04	0.03	0.09	0.07
	C	0.10	0.11	0.05	0.02	0.02	0.03	0.04	0.06	0.17	0.21	0.06	0.03	0.06	0.04	0.08	0.10
	D	0.46	0.36	0.21	0.09	0.07	0.09	0.22	0.55	1.25	1.08	0.40	0.20	0.38	0.71	1.04	0.59
	E	0.27	0.22	0.09	0.04	0.02	0.04	0.21	0.83	1.29	1.02	0.44	0.23	0.44	0.93	1.37	0.56
	F	0.22	0.19	0.06	0.02	0.00	0.01	0.14	0.80	0.99	0.58	0.18	0.07	0.09	0.24	0.69	0.40
	G	0.10	0.07	0.02	0.00	0.00	0.00	0.06	0.43	0.40	0.18	0.05	0.01	0.01	0.08	0.32	0.21
7.2	A	0.10	0.09	0.05	0.01	0.00	0.00	0.01	0.02	0.20	0.62	0.34	0.21	0.22	0.13	0.19	0.11
	B	0.03	0.04	0.01	0.01	0.00	0.00	0.01	0.01	0.05	0.21	0.07	0.07	0.07	0.04	0.05	0.03
	C	0.03	0.03	0.01	0.00	0.00	0.00	0.01	0.01	0.05	0.19	0.09	0.06	0.04	0.05	0.04	0.02
	D	0.14	0.12	0.04	0.01	0.01	0.01	0.05	0.05	0.38	1.02	0.48	0.22	0.22	0.37	0.56	0.16
	E	0.05	0.09	0.04	0.01	0.00	0.01	0.01	0.07	0.29	0.72	0.41	0.17	0.15	0.34	0.49	0.14
	F	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.06	0.16	0.30	0.09	0.02	0.02	0.02	0.05	0.04
	G	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.05	0.09	0.12	0.03	0.01	0.00	0.00	0.03	0.02
9.8	A	0.01	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.02	0.13	0.15	0.11	0.09	0.03	0.06	0.01
	B	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.05	0.04	0.02	0.01	0.02	0.01
	C	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.05	0.02	0.01	0.01	0.02	0.01
	D	0.02	0.05	0.01	0.01	0.00	0.00	0.00	0.00	0.03	0.21	0.28	0.13	0.09	0.12	0.25	0.03
	E	0.01	0.09	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.17	0.21	0.06	0.03	0.07	0.11	0.01
	F	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	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	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.00
13.	A	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.06	0.03	0.02	0.01	0.01	0.00
	B	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.00	0.00	0.00	0.00
	C	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.01	0.00	0.01	0.00
	D	0.01	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.21	0.05	0.02	0.01	0.04	0.01
	E	0.00	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.08	0.01	0.00	0.01	0.02	0.00
	F	0.00	0.02	0.00	0.00	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
16.	A	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.01	0.00
	B	0.00	0.02	0.00	0.00	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	0.01	0.00	0.00	0.00	0.00	0.00
	D	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.05	0.01	0.02	0.00	0.00	0.00
	E	0.01	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.00	0.00	0.01	0.00	0.00
	F	0.00	0.01	0.00	0.00	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.	A	0.02	0.03	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
	B	0.01	0.02	0.00	0.00	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	0.02	0.03	0.00	0.00	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	0.07	0.05	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
	E	0.09	0.08	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	0.04	0.04	0.00	0.00	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	0.01	0.00	0.00	0.00	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 4.1-13. Joint Frequency Distributions for the 400 Area 61-m Tower, 1983-1991 Data (Schreckhise et al. 1993)

Midpoint Wind Speed Class ($m\ sec^{-1}$)	Pasquill Category	Percentage of Time Wind Blows from the 400 Area Towards the Direction Indicated															
		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.89	A	0.12	0.10	0.08	0.11	0.14	0.15	0.10	0.08	0.14	0.08	0.05	0.06	0.07	0.05	0.05	0.07
	B	0.05	0.05	0.05	0.05	0.06	0.05	0.04	0.03	0.07	0.03	0.02	0.02	0.03	0.02	0.03	0.03
	C	0.06	0.04	0.04	0.04	0.06	0.04	0.07	0.05	0.04	0.04	0.03	0.01	0.05	0.03	0.04	0.04
	D	0.32	0.23	0.20	0.18	0.25	0.26	0.24	0.28	0.36	0.26	0.19	0.15	0.22	0.19	0.22	0.21
	E	0.19	0.14	0.10	0.10	0.13	0.13	0.14	0.19	0.37	0.22	0.18	0.17	0.23	0.19	0.19	0.19
	F	0.22	0.14	0.10	0.09	0.13	0.11	0.15	0.20	0.34	0.20	0.20	0.12	0.20	0.14	0.16	0.16
	G	0.13	0.08	0.06	0.03	0.06	0.07	0.07	0.18	0.22	0.13	0.09	0.07	0.12	0.09	0.12	0.09
2.7	A	0.32	0.28	0.28	0.28	0.39	0.37	0.37	0.34	0.55	0.32	0.16	0.09	0.17	0.13	0.13	0.15
	B	0.12	0.09	0.08	0.06	0.12	0.07	0.10	0.11	0.15	0.12	0.05	0.05	0.05	0.04	0.06	0.07
	C	0.13	0.08	0.08	0.05	0.09	0.08	0.10	0.11	0.16	0.08	0.04	0.03	0.05	0.03	0.06	0.08
	D	0.58	0.41	0.37	0.26	0.38	0.33	0.46	0.59	0.85	0.49	0.25	0.15	0.33	0.36	0.47	0.41
	E	0.32	0.20	0.19	0.12	0.21	0.21	0.25	0.45	0.68	0.46	0.31	0.24	0.37	0.29	0.38	0.33
	F	0.35	0.23	0.15	0.07	0.12	0.09	0.18	0.36	0.64	0.31	0.23	0.16	0.18	0.18	0.23	0.22
	G	0.18	0.12	0.06	0.03	0.04	0.04	0.08	0.20	0.30	0.16	0.10	0.04	0.08	0.10	0.15	0.16
4.7	A	0.39	0.31	0.21	0.10	0.13	0.13	0.15	0.19	0.77	0.51	0.17	0.13	0.19	0.15	0.16	0.17
	B	0.14	0.09	0.06	0.04	0.04	0.04	0.04	0.07	0.20	0.16	0.06	0.04	0.03	0.02	0.06	0.06
	C	0.10	0.10	0.06	0.03	0.03	0.03	0.04	0.06	0.16	0.16	0.04	0.02	0.05	0.04	0.06	0.07
	D	0.59	0.38	0.26	0.14	0.16	0.14	0.32	0.55	0.97	0.75	0.27	0.15	0.34	0.46	0.63	0.55
	E	0.41	0.21	0.15	0.09	0.10	0.11	0.28	0.60	1.02	0.71	0.37	0.27	0.50	0.53	0.60	0.43
	F	0.37	0.22	0.11	0.06	0.07	0.06	0.17	0.48	0.73	0.44	0.21	0.11	0.16	0.20	0.37	0.29
	G	0.19	0.11	0.05	0.02	0.02	0.01	0.04	0.19	0.26	0.14	0.06	0.02	0.04	0.07	0.19	0.13
7.2	A	0.22	0.17	0.08	0.02	0.02	0.01	0.03	0.05	0.32	0.63	0.28	0.17	0.23	0.11	0.19	0.15
	B	0.07	0.05	0.01	0.01	0.00	0.00	0.02	0.01	0.10	0.22	0.06	0.05	0.05	0.03	0.07	0.03
	C	0.04	0.05	0.02	0.01	0.00	0.01	0.02	0.02	0.07	0.18	0.06	0.04	0.03	0.03	0.05	0.04
	D	0.27	0.19	0.09	0.04	0.02	0.04	0.10	0.25	0.65	0.86	0.37	0.20	0.29	0.50	0.75	0.40
	E	0.27	0.18	0.07	0.02	0.02	0.04	0.15	0.43	0.73	0.74	0.34	0.20	0.39	0.73	0.94	0.44
	F	0.21	0.14	0.06	0.02	0.02	0.01	0.09	0.33	0.52	0.39	0.14	0.07	0.09	0.16	0.45	0.26
	G	0.13	0.08	0.04	0.01	0.01	0.01	0.03	0.11	0.19	0.13	0.04	0.02	0.01	0.04	0.14	0.13
9.8	A	0.05	0.05	0.03	0.01	0.00	0.00	0.00	0.01	0.08	0.29	0.21	0.12	0.12	0.08	0.12	0.04
	B	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.08	0.04	0.04	0.04	0.02	0.03	0.02
	C	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.01	0.02	0.08	0.06	0.03	0.03	0.03	0.03	0.01
	D	0.09	0.08	0.02	0.01	0.00	0.01	0.03	0.04	0.24	0.58	0.32	0.16	0.19	0.33	0.57	0.14
	E	0.10	0.12	0.04	0.01	0.00	0.01	0.06	0.17	0.37	0.51	0.26	0.13	0.17	0.43	0.73	0.22
	F	0.10	0.11	0.03	0.01	0.01	0.00	0.03	0.14	0.21	0.20	0.07	0.02	0.03	0.08	0.23	0.16
	G	0.05	0.04	0.02	0.00	0.00	0.00	0.01	0.07	0.09	0.05	0.03	0.00	0.00	0.02	0.10	0.07
13.	A	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.09	0.10	0.10	0.08	0.03	0.07	0.01
	B	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.04	0.04	0.02	0.01	0.03	0.01
	C	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.04	0.02	0.02	0.01	0.02	0.01
	D	0.03	0.03	0.01	0.00	0.00	0.00	0.01	0.02	0.07	0.27	0.24	0.12	0.09	0.19	0.32	0.05
	E	0.04	0.08	0.03	0.01	0.00	0.00	0.02	0.05	0.13	0.32	0.25	0.10	0.07	0.20	0.33	0.07
	F	0.04	0.05	0.02	0.01	0.00	0.00	0.02	0.06	0.08	0.13	0.05	0.01	0.01	0.02	0.10	0.06
	G	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.03	0.01	0.00	0.00	0.01	0.05	0.04
16.	A	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.06	0.03	0.02	0.01	0.01	0.00
	B	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	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	0.01	0.02	0.01	0.01	0.00	0.01	0.00
	D	0.02	0.03	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.11	0.19	0.06	0.03	0.06	0.10	0.01
	E	0.01	0.04	0.03	0.00	0.00	0.00	0.01	0.02	0.05	0.16	0.16	0.04	0.02	0.04	0.09	0.01
	F	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.03	0.04	0.05	0.02	0.00	0.01	0.00	0.01	0.02
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.02	0.00
19.	A	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.01	0.01	0.00	0.01	0.00
	B	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
	C	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
	D	0.03	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.22	0.04	0.03	0.01	0.02	0.00
	E	0.03	0.10	0.02	0.00	0.00	0.00	0.00	0.02	0.02	0.10	0.14	0.02	0.01	0.01	0.01	0.00
	F	0.02	0.04	0.01	0.00	0.00	0.00	0.00	0.03	0.03	0.04	0.02	0.00	0.00	0.00	0.01	0.00
	G	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.01	0.00

Table 4.1-14. $\overline{X}$/Q′Values (sec m^{-3}) for Chronic Ground-Level Releases from 100-N Area Based on 1983 Through 1991 Meteorological Information (Schreckhise et al. 1993)

Distance (km)	Sector (Wind from 100-N Towards Direction Indicated) S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	Distance (km)
0.1	2.3E-04	1.5E-04	1.6E-04	1.9E-04	3.6E-04	2.3E-04	1.9E-04	1.3E-04	1.7E-04	1.4E-04	2.0E-04	3.1E-04	5.1E-04	3.2E-04	2.4E-04	2.0E-04	0.1
0.2	6.3E-05	4.1E-05	4.3E-05	5.2E-05	1.0E-04	6.4E-05	5.2E-05	3.7E-05	4.7E-05	3.8E-05	5.5E-05	8.6E-05	1.4E-04	8.7E-05	6.5E-05	5.5E-05	0.2
0.3	3.0E-05	1.9E-05	2.1E-05	2.5E-05	4.8E-05	3.1E-05	2.5E-05	1.8E-05	2.2E-05	1.8E-05	2.6E-05	4.1E-05	6.8E-05	4.1E-05	3.1E-05	2.6E-05	0.3
0.4	1.8E-05	1.2E-05	1.2E-05	1.5E-05	2.9E-05	1.8E-05	1.5E-05	1.0E-05	1.3E-05	1.1E-05	1.6E-05	2.5E-05	4.0E-05	2.5E-05	1.8E-05	1.6E-05	0.4
0.5	1.2E-05	7.7E-06	8.2E-06	1.0E-05	1.9E-05	1.2E-05	1.0E-05	7.0E-06	8.9E-06	7.2E-06	1.1E-05	1.7E-05	2.7E-05	1.7E-05	1.2E-05	1.1E-05	0.5
0.6	8.6E-06	5.6E-06	5.9E-06	7.3E-06	1.4E-05	8.8E-06	7.2E-06	5.1E-06	6.4E-06	5.2E-06	7.6E-06	1.2E-05	2.0E-05	1.2E-05	8.9E-06	7.6E-06	0.6
0.7	6.5E-06	4.2E-06	4.5E-06	5.5E-06	1.1E-05	6.7E-06	5.5E-06	3.8E-06	4.9E-06	4.0E-06	5.8E-06	9.1E-06	1.5E-05	9.1E-06	6.8E-06	5.8E-06	0.7
0.8	5.1E-06	3.3E-06	3.5E-06	4.4E-06	8.4E-06	5.3E-06	4.3E-06	3.0E-06	3.9E-06	3.1E-06	4.5E-06	7.2E-06	1.2E-05	7.2E-06	5.3E-06	4.5E-06	0.8
0.9	4.2E-06	2.7E-06	2.9E-06	3.5E-06	6.8E-06	4.3E-06	3.5E-06	2.5E-06	3.1E-06	2.5E-06	3.7E-06	5.8E-06	9.5E-06	5.8E-06	4.3E-06	3.7E-06	0.9
1.0	3.5E-06	2.2E-06	2.4E-06	2.9E-06	5.6E-06	3.6E-06	2.9E-06	2.1E-06	2.6E-06	2.1E-06	3.1E-06	4.8E-06	7.9E-06	4.8E-06	3.6E-06	3.1E-06	1.0
2.4	8.0E-07	5.2E-07	5.5E-07	6.8E-07	1.3E-06	8.3E-07	6.7E-07	4.7E-07	6.0E-07	4.9E-07	7.1E-07	1.1E-06	1.8E-06	1.1E-06	8.3E-07	7.1E-07	2.4
4.0	3.6E-07	2.4E-07	2.5E-07	3.1E-07	6.0E-07	3.8E-07	3.1E-07	2.1E-07	2.7E-07	2.2E-07	3.2E-07	5.2E-07	8.4E-07	5.1E-07	3.8E-07	3.2E-07	4.0
5.6	2.2E-07	1.4E-07	1.5E-07	1.9E-07	3.6E-07	2.3E-07	1.9E-07	1.3E-07	1.7E-07	1.3E-07	2.0E-07	3.1E-07	5.1E-07	3.1E-07	2.3E-07	2.0E-07	5.6
7.2	1.5E-07	9.9E-08	1.1E-07	1.3E-07	2.5E-07	1.6E-07	1.3E-07	9.0E-08	1.1E-07	9.3E-08	1.4E-07	2.2E-07	3.6E-07	2.2E-07	1.6E-07	1.4E-07	7.2
12.1	7.4E-08	4.8E-08	5.2E-08	6.4E-08	1.2E-07	7.6E-08	6.2E-08	4.3E-08	5.5E-08	4.5E-08	6.6E-08	1.1E-07	1.7E-07	1.1E-07	7.8E-08	6.7E-08	12.1
24.1	2.9E-08	1.8E-08	2.0E-08	2.5E-08	4.7E-08	2.9E-08	2.4E-08	1.6E-08	2.1E-08	1.7E-08	2.5E-08	4.1E-08	6.7E-08	4.1E-08	3.0E-08	2.6E-08	24.1
40.3	1.4E-08	9.3E-09	1.0E-08	1.3E-08	2.4E-08	1.4E-08	1.2E-08	8.1E-09	1.0E-08	8.5E-09	1.3E-08	2.0E-08	3.4E-08	2.0E-08	1.5E-08	1.3E-08	40.3
56.3	9.2E-09	5.9E-09	6.4E-09	8.0E-09	1.5E-08	9.2E-09	7.5E-09	5.2E-09	6.6E-09	5.4E-09	8.0E-09	1.3E-08	2.2E-08	1.3E-08	9.7E-09	8.3E-09	56.3
72.4	6.6E-09	4.3E-09	4.6E-09	5.8E-09	1.1E-08	6.6E-09	5.3E-09	3.7E-09	4.7E-09	3.9E-09	5.8E-09	9.4E-09	1.5E-08	9.4E-09	7.0E-09	6.0E-09	72.4

Table 4.1-15. $\overline{X}$/Q′Values (sec m^{-3}) for Chronic 60-m Stack Releases from 100-N Area Based on 1983 Through 1991 Meteorological Information (Schreckhise et al. 1993)

Distance (km)	Sector (Wind from 100-N Towards Direction Indicated) S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	Distance (km)
0.1	1.4E-09	7.9E-10	6.5E-10	4.3E-10	9.4E-10	6.8E-10	5.6E-10	3.8E-10	5.5E-10	4.0E-10	7.0E-10	9.4E-10	1.7E-09	1.4E-09	1.3E-09	1.1E-09	0.1
0.2	2.6E-07	1.5E-07	1.3E-07	8.3E-08	1.8E-07	1.4E-07	1.1E-07	7.8E-08	1.1E-07	7.8E-08	1.4E-07	1.8E-07	3.3E-07	2.7E-07	2.4E-07	2.1E-07	0.2
0.3	4.9E-07	2.9E-07	2.5E-07	1.6E-07	3.6E-07	2.7E-07	2.3E-07	1.6E-07	2.1E-07	1.5E-07	2.7E-07	3.5E-07	6.2E-07	5.0E-07	4.5E-07	3.9E-07	0.3
0.4	4.1E-07	2.5E-07	2.1E-07	1.5E-07	3.2E-07	2.4E-07	2.1E-07	1.5E-07	1.9E-07	1.3E-07	2.3E-07	3.0E-07	5.1E-07	4.2E-07	3.8E-07	3.2E-07	0.4
0.5	3.1E-07	1.9E-07	1.7E-07	1.2E-07	2.7E-07	2.0E-07	1.8E-07	1.3E-07	1.6E-07	1.1E-07	1.9E-07	2.4E-07	4.0E-07	3.2E-07	2.9E-07	2.5E-07	0.5
0.6	2.6E-07	1.6E-07	1.5E-07	1.1E-07	2.4E-07	1.9E-07	1.6E-07	1.2E-07	1.4E-07	1.0E-07	1.7E-07	2.1E-07	3.3E-07	2.7E-07	2.4E-07	2.0E-07	0.6
0.7	2.3E-07	1.5E-07	1.3E-07	1.1E-07	2.3E-07	1.8E-07	1.6E-07	1.2E-07	1.4E-07	1.0E-07	1.6E-07	1.9E-07	3.1E-07	2.4E-07	2.1E-07	1.8E-07	0.7
0.8	2.2E-07	1.4E-07	1.3E-07	1.1E-07	2.3E-07	1.9E-07	1.6E-07	1.2E-07	1.5E-07	1.0E-07	1.6E-07	1.9E-07	3.0E-07	2.3E-07	1.9E-07	1.7E-07	0.8
0.9	2.1E-07	1.4E-07	1.2E-07	1.1E-07	2.3E-07	1.9E-07	1.7E-07	1.2E-07	1.5E-07	1.1E-07	1.6E-07	1.9E-07	3.0E-07	2.2E-07	1.9E-07	1.6E-07	0.9
1.0	2.1E-07	1.4E-07	1.2E-07	1.2E-07	2.4E-07	2.0E-07	1.7E-07	1.3E-07	1.5E-07	1.1E-07	1.6E-07	2.0E-07	3.1E-07	2.2E-07	1.8E-07	1.6E-07	1.0
2.4	1.5E-07	1.0E-07	9.5E-08	1.1E-07	2.2E-07	1.7E-07	1.4E-07	1.0E-07	1.3E-07	9.5E-08	1.3E-07	1.7E-07	2.7E-07	1.8E-07	1.4E-07	1.2E-07	2.4
4.0	1.0E-07	6.7E-08	6.5E-08	7.6E-08	1.5E-07	1.1E-07	9.2E-08	6.7E-08	8.6E-08	6.4E-08	8.9E-08	1.2E-07	1.9E-07	1.2E-07	9.3E-08	8.0E-08	4.0
5.6	7.4E-08	4.8E-08	4.8E-08	5.7E-08	1.1E-07	8.0E-08	6.6E-08	4.8E-08	6.1E-08	4.7E-08	6.5E-08	9.0E-08	1.4E-07	9.0E-08	6.8E-08	5.9E-08	5.6
7.2	5.7E-08	3.7E-08	3.7E-08	4.5E-08	8.8E-08	6.2E-08	5.1E-08	3.7E-08	4.7E-08	3.6E-08	5.0E-08	7.1E-08	1.1E-07	7.1E-08	5.4E-08	4.6E-08	7.2
12.1	3.3E-08	2.2E-08	2.2E-08	2.7E-08	5.2E-08	3.5E-08	2.9E-08	2.1E-08	2.7E-08	2.1E-08	2.9E-08	4.2E-08	6.6E-08	4.2E-08	3.2E-08	2.7E-08	12.1
24.1	1.5E-08	9.9E-09	1.0E-08	1.3E-08	2.5E-08	1.6E-08	1.3E-08	9.1E-09	1.2E-08	9.3E-09	1.3E-08	2.0E-08	3.1E-08	2.0E-08	1.5E-08	1.3E-08	24.1
40.3	8.2E-09	5.5E-09	5.6E-09	7.3E-09	1.4E-08	8.5E-09	6.9E-09	4.9E-09	6.4E-09	5.1E-09	7.2E-09	1.1E-08	1.8E-08	1.1E-08	8.5E-09	7.2E-09	40.3
56.3	5.5E-09	3.7E-09	3.8E-09	5.0E-09	9.3E-09	5.7E-09	4.6E-09	3.3E-09	4.3E-09	3.4E-09	4.9E-09	7.4E-09	1.2E-08	7.4E-09	5.7E-09	4.9E-09	56.3
72.4	4.1E-09	2.7E-09	2.8E-09	3.7E-09	6.9E-09	4.2E-09	3.4E-09	2.4E-09	3.1E-09	2.5E-09	3.6E-09	5.5E-09	8.9E-09	5.5E-09	4.3E-09	3.7E-09	72.4

Table 4.1-16 $\overline{X}$/Q′ Values (sec m⁻³) for Chronic Ground-Level Releases from 200 Areas Based on 1983 Through 1991 Meteorological Information (Schreckhise et al. 1993)

Distance (km) (km)		S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	Distance SSE
						Sector (Wind from 100-N Towards Direction Indicated)											
0.1	1.7E-04	1.0E-04	9.9E-05	1.0E-04	1.7E-04	1.4E-04	1.6E-04	1.5E-04	1.6E-04	9.0E-05	1.1E-04	1.4E-04	3.8E-04	4.0E-04	2.5E-04	1.5E-04	0.1
0.2	4.6E-05	2.8E-05	2.7E-05	2.7E-05	4.7E-05	3.8E-05	4.3E-05	4.3E-05	4.5E-05	2.5E-05	3.0E-05	3.9E-05	1.1E-04	1.1E-04	6.9E-05	4.0E-05	0.2
0.3	2.2E-05	1.3E-05	1.3E-05	1.3E-05	2.2E-05	1.8E-05	2.1E-05	2.0E-05	2.1E-05	1.2E-05	1.4E-05	1.9E-05	5.0E-05	5.3E-05	3.3E-05	1.9E-05	0.3
0.4	1.3E-05	7.8E-06	7.5E-06	7.5E-06	1.3E-05	1.1E-05	1.2E-05	1.2E-05	1.3E-05	7.1E-06	8.4E-06	1.1E-05	3.0E-05	3.2E-05	2.0E-05	1.1E-05	0.4
0.5	8.4E-06	5.2E-06	5.0E-06	5.0E-06	8.7E-06	7.1E-06	8.2E-06	8.1E-06	8.6E-06	4.8E-06	5.7E-06	7.5E-06	2.0E-05	2.2E-05	1.3E-05	7.5E-06	0.5
0.6	6.1E-06	3.7E-06	3.6E-06	3.6E-06	6.3E-06	5.1E-06	5.9E-06	5.9E-06	6.2E-06	3.5E-06	4.1E-06	5.4E-06	1.5E-05	1.6E-05	9.5E-06	5.4E-06	0.6
0.7	4.6E-06	2.8E-06	2.7E-06	2.7E-06	4.8E-06	3.9E-06	4.5E-06	4.5E-06	4.7E-06	2.6E-06	3.1E-06	4.1E-06	1.1E-05	1.2E-05	7.2E-06	4.1E-06	0.7
0.8	3.6E-06	2.2E-06	2.1E-06	2.1E-06	3.8E-06	3.1E-06	3.5E-06	3.5E-06	3.7E-06	2.1E-06	2.5E-06	3.3E-06	8.8E-06	9.4E-06	5.7E-06	3.2E-06	0.8
0.9	2.9E-06	1.8E-06	1.7E-06	1.7E-06	3.1E-06	2.5E-06	2.9E-06	2.9E-06	3.0E-06	1.7E-06	2.0E-06	2.7E-06	7.2E-06	7.6E-06	4.6E-06	2.6E-06	0.9
1.0	2.4E-06	1.5E-06	1.4E-06	1.4E-06	2.5E-06	2.1E-06	2.4E-06	2.4E-06	2.5E-06	1.4E-06	1.7E-06	2.2E-06	6.0E-06	6.3E-06	3.9E-06	2.2E-06	1.0
2.4	5.5E-07	3.4E-07	3.3E-07	3.3E-07	5.8E-07	4.8E-07	5.5E-07	5.5E-07	5.8E-07	3.3E-07	3.9E-07	5.1E-07	1.4E-06	1.5E-06	8.9E-07	5.0E-07	2.4
4.0	2.5E-07	1.5E-07	1.5E-07	1.5E-07	2.6E-07	2.2E-07	2.5E-07	2.5E-07	2.7E-07	1.5E-07	1.8E-07	2.3E-07	6.4E-07	6.7E-07	4.1E-07	2.3E-07	4.0
5.6	1.5E-07	9.1E-08	8.9E-08	8.9E-08	1.6E-07	1.3E-07	1.5E-07	1.5E-07	1.6E-07	9.1E-08	1.1E-07	1.4E-07	3.9E-07	4.1E-07	2.5E-07	1.4E-07	5.6
7.2	1.0E-07	6.2E-08	6.1E-08	6.1E-08	1.1E-07	9.1E-08	1.1E-07	1.1E-07	1.1E-07	6.3E-08	7.5E-08	9.9E-08	2.7E-07	2.9E-07	1.7E-07	9.4E-08	7.2
12.1	4.9E-08	3.0E-08	2.9E-08	2.9E-08	5.3E-08	4.4E-08	5.1E-08	5.2E-08	5.5E-08	3.1E-08	3.6E-08	4.8E-08	1.3E-07	1.4E-07	8.2E-08	4.5E-08	12.1
24.1	1.9E-08	1.1E-08	1.1E-08	1.1E-08	2.0E-08	1.7E-08	2.0E-08	2.0E-08	2.1E-08	1.2E-08	1.4E-08	1.9E-08	5.1E-08	5.3E-08	3.1E-08	1.7E-08	24.1
40.3	9.2E-09	5.5E-09	5.5E-09	5.5E-09	1.0E-08	8.4E-09	9.8E-09	1.0E-08	1.1E-08	6.0E-09	7.0E-09	9.3E-09	2.6E-08	2.7E-08	1.6E-08	8.6E-09	40.3
56.3	5.9E-09	3.5E-09	3.5E-09	3.5E-09	6.4E-09	5.3E-09	6.3E-09	6.4E-09	6.9E-09	3.8E-09	4.5E-09	6.0E-09	1.7E-08	1.7E-08	1.0E-08	5.5E-09	56.3
72.4	4.2E-09	2.5E-09	2.5E-09	2.5E-09	4.6E-09	3.8E-09	4.5E-09	4.6E-09	5.0E-09	2.7E-09	3.2E-09	4.3E-09	1.2E-08	1.2E-08	7.1E-09	3.9E-09	72.4

Table 4.1-17. $\overline{X}$/Q′ Values (sec m⁻³) for Chronic 60-m Stack Releases from 200 Areas Based on 1983 Through 1991 Meteorological Information (Schreckhise et al. 1993)

Distance (km)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	Distance (km)
						Sector (Wind from 100-N Towards Direction Indicated)											
0.1	1.5E-09	9.3E-10	7.9E-10	8.7E-10	1.4E-09	1.0E-09	8.2E-10	5.0E-10	4.9E-10	2.9E-10	3.6E-10	5.3E-10	6.6E-10	7.0E-10	9.1E-10	9.0E-10	0.1
0.2	3.0E-07	1.8E-07	1.5E-07	1.7E-07	2.8E-07	2.0E-07	1.6E-07	9.6E-08	9.5E-08	5.5E-08	6.8E-08	1.0E-07	1.3E-07	1.4E-07	1.8E-07	1.8E-07	0.2
0.3	5.6E-07	3.5E-07	2.9E-07	3.3E-07	5.3E-07	3.7E-07	3.0E-07	1.8E-07	1.9E-07	1.0E-07	1.3E-07	1.9E-07	2.4E-07	2.6E-07	3.5E-07	3.4E-07	0.3
0.4	4.7E-07	3.1E-07	2.5E-07	2.8E-07	4.4E-07	3.1E-07	2.6E-07	1.6E-07	1.6E-07	8.6E-08	1.0E-07	1.6E-07	2.0E-07	2.2E-07	3.0E-07	2.9E-07	0.4
0.5	3.6E-07	2.4E-07	1.9E-07	2.2E-07	3.4E-07	2.4E-07	2.0E-07	1.2E-07	1.3E-07	6.6E-08	7.8E-08	1.2E-07	1.6E-07	1.8E-07	2.5E-07	2.3E-07	0.5
0.6	3.0E-07	2.1E-07	1.6E-07	1.9E-07	2.8E-07	2.0E-07	1.7E-07	1.1E-07	1.1E-07	5.6E-08	6.6E-08	1.0E-07	1.4E-07	1.6E-07	2.2E-07	2.0E-07	0.6
0.7	2.7E-07	1.8E-07	1.5E-07	1.7E-07	2.5E-07	1.8E-07	1.6E-07	1.0E-07	9.6E-08	5.3E-08	6.2E-08	9.0E-08	1.3E-07	1.6E-07	2.1E-07	1.8E-07	0.7
0.8	2.6E-07	1.7E-07	1.4E-07	1.6E-07	2.3E-07	1.7E-07	1.5E-07	1.0E-07	9.3E-08	5.2E-08	6.3E-08	8.6E-08	1.4E-07	1.7E-07	2.1E-07	1.7E-07	0.8
0.9	2.5E-07	1.7E-07	1.3E-07	1.5E-07	2.2E-07	1.6E-07	1.5E-07	1.0E-07	9.2E-08	5.3E-08	6.5E-08	8.5E-08	1.4E-07	1.8E-07	2.1E-07	1.7E-07	0.9
1.0	2.4E-07	1.6E-07	1.3E-07	1.5E-07	2.2E-07	1.6E-07	1.5E-07	1.1E-07	9.3E-08	5.5E-08	6.7E-08	8.6E-08	1.5E-07	2.0E-07	2.1E-07	1.7E-07	1.0
2.4	1.5E-07	1.0E-07	8.6E-08	8.9E-08	1.4E-07	1.1E-07	1.1E-07	9.6E-08	8.7E-08	5.2E-08	6.3E-08	7.9E-08	1.7E-07	2.1E-07	1.7E-07	1.2E-07	2.4
4.0	9.3E-08	6.0E-08	5.2E-08	5.3E-08	8.9E-08	7.0E-08	7.4E-08	6.8E-08	6.4E-08	3.7E-08	4.5E-08	5.7E-08	1.3E-07	1.5E-07	1.1E-07	7.4E-08	4.0
5.6	6.4E-08	4.1E-08	3.6E-08	3.6E-08	6.2E-08	5.0E-08	5.4E-08	5.1E-08	4.9E-08	2.8E-08	3.3E-08	4.3E-08	9.8E-08	1.1E-07	8.2E-08	5.2E-08	5.6
7.2	4.8E-08	3.0E-08	2.7E-08	2.7E-08	4.7E-08	3.8E-08	4.2E-08	4.0E-08	3.9E-08	2.2E-08	2.6E-08	3.4E-08	7.8E-08	8.8E-08	6.3E-08	3.9E-08	7.2
12.1	2.6E-08	1.6E-08	1.4E-08	1.5E-08	2.6E-08	2.1E-08	2.4E-08	2.4E-08	2.4E-08	1.3E-08	1.5E-08	2.1E-08	4.8E-08	5.2E-08	3.6E-08	2.2E-08	12.1
24.1	1.1E-08	6.7E-09	6.1E-09	6.1E-09	1.1E-08	9.6E-09	1.1E-08	1.2E-08	1.2E-08	6.2E-09	7.2E-09	9.7E-09	2.4E-08	2.4E-08	1.6E-08	9.5E-09	24.1
40.3	5.7E-09	3.5E-09	3.2E-09	3.3E-09	6.1E-09	5.2E-09	6.2E-09	6.6E-09	6.6E-09	3.5E-09	4.0E-09	5.4E-09	1.3E-08	1.3E-08	8.8E-09	5.1E-09	40.3
56.3	3.7E-09	2.3E-09	2.1E-09	2.1E-09	4.1E-09	3.5E-09	4.2E-09	4.5E-09	4.5E-09	2.4E-09	2.7E-09	3.7E-09	9.2E-09	9.1E-09	5.9E-09	3.4E-09	56.3
72.4	2.7E-09	1.7E-09	1.6E-09	1.6E-09	3.0E-09	2.6E-09	3.1E-09	3.4E-09	3.4E-09	1.8E-09	2.0E-09	2.7E-09	6.9E-09	6.7E-09	4.3E-09	2.5E-09	72.4

Table 4.1-18. $\overline{X}/Q'$ Values (sec m^{-3}) for Chronic Ground-Level Releases from 300 Area Based on 1983 Through 1991 Meteorological Information (Schreckhise et al. 1993)

Distance						Sector (Wind from 100-N Towards Direction Indicated)											Distance
(km)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	(km)
0.1	2.9E-04	9.0E-05	5.1E-05	4.4E-05	1.2E-04	2.0E-04	2.8E-04	2.3E-04	3.0E-04	1.9E-04	1.9E-04	1.4E-04	1.7E-04	1.3E-04	1.8E-04	2.4E-04	0.1
0.2	7.8E-05	2.5E-05	1.4E-05	1.2E-05	3.2E-05	5.4E-05	7.6E-05	6.2E-05	8.3E-05	5.2E-05	5.3E-05	3.9E-05	4.6E-05	3.7E-05	4.8E-05	6.5E-05	0.2
0.3	3.8E-05	1.2E-05	6.5E-06	5.6E-06	1.5E-05	2.6E-05	3.7E-05	3.0E-05	4.0E-05	2.5E-05	2.5E-05	1.8E-05	2.2E-05	1.8E-05	2.3E-05	3.1E-05	0.3
0.4	2.2E-05	6.9E-06	3.8E-06	3.3E-06	8.8E-06	1.5E-05	2.2E-05	1.8E-05	2.4E-05	1.5E-05	1.5E-05	1.1E-05	1.3E-05	1.1E-05	1.4E-05	1.9E-05	0.4
0.5	1.5E-05	4.6E-06	2.5E-06	2.2E-06	5.9E-06	1.0E-05	1.5E-05	1.2E-05	1.6E-05	1.0E-05	1.0E-05	7.3E-06	8.8E-06	7.1E-06	9.3E-06	1.3E-05	0.5
0.6	1.1E-05	3.3E-06	1.8E-06	1.6E-06	4.2E-06	7.4E-06	1.1E-05	8.6E-06	1.2E-05	7.2E-06	7.3E-06	5.3E-06	6.4E-06	5.1E-06	6.7E-06	9.1E-06	0.6
0.7	8.3E-06	2.5E-06	1.4E-06	1.2E-06	3.2E-06	5.6E-06	8.1E-06	6.6E-06	8.8E-06	5.5E-06	5.5E-06	4.0E-06	4.9E-06	3.9E-06	5.1E-06	6.9E-06	0.7
0.8	6.5E-06	2.0E-06	1.1E-06	9.3E-07	2.5E-06	4.5E-06	6.4E-06	5.2E-06	6.9E-06	4.3E-06	4.4E-06	3.2E-06	3.9E-06	3.1E-06	4.1E-06	5.5E-06	0.8
0.9	5.3E-06	1.6E-06	8.7E-07	7.6E-07	2.1E-06	3.6E-06	5.2E-06	4.2E-06	5.6E-06	3.5E-06	3.6E-06	2.6E-06	3.1E-06	2.5E-06	3.3E-06	4.4E-06	0.9
1.0	4.4E-06	1.3E-06	7.2E-07	6.3E-07	1.7E-06	3.0E-06	4.3E-06	3.5E-06	4.7E-06	2.9E-06	3.0E-06	2.2E-06	2.6E-06	2.1E-06	2.7E-06	3.7E-06	1.0
2.4	1.0E-06	3.1E-07	1.7E-07	1.4E-07	3.9E-07	6.9E-07	1.0E-06	8.1E-07	1.1E-06	6.7E-07	6.8E-07	5.0E-07	6.0E-07	4.9E-07	6.4E-07	8.5E-07	2.4
4.0	4.7E-07	1.4E-07	7.5E-08	6.4E-08	1.8E-07	3.2E-07	4.6E-07	3.7E-07	5.0E-07	3.1E-07	3.1E-07	2.3E-07	2.8E-07	2.2E-07	2.9E-07	3.9E-07	4.0
5.6	2.8E-07	8.4E-08	4.5E-08	3.9E-08	1.1E-07	1.9E-07	2.8E-07	2.3E-07	3.0E-07	1.9E-07	1.9E-07	1.4E-07	1.7E-07	1.4E-07	1.8E-07	2.4E-07	5.6
7.2	2.0E-07	5.8E-08	3.1E-08	2.7E-08	7.4E-08	1.3E-07	2.0E-07	1.6E-07	2.1E-07	1.3E-07	1.3E-07	9.5E-08	1.2E-07	9.4E-08	1.2E-07	1.6E-07	7.2
12.1	9.6E-08	2.8E-08	1.5E-08	1.3E-08	3.6E-08	6.5E-08	9.5E-08	7.7E-08	1.0E-07	6.3E-08	6.3E-08	4.6E-08	5.6E-08	4.6E-08	6.0E-08	7.9E-08	12.1
24.1	3.7E-08	1.1E-08	5.7E-09	4.9E-09	1.4E-08	2.5E-08	3.7E-08	3.0E-08	3.9E-08	2.4E-08	2.4E-08	1.8E-08	2.2E-08	1.8E-08	2.3E-08	3.0E-08	24.1
40.3	1.8E-08	5.4E-09	2.9E-09	2.4E-09	6.9E-09	1.3E-08	1.8E-08	1.5E-08	2.0E-08	1.2E-08	1.2E-08	8.8E-09	1.1E-08	8.9E-09	1.1E-08	1.5E-08	40.3
56.3	1.2E-08	3.4E-09	1.8E-09	1.6E-09	4.4E-09	8.0E-09	1.2E-08	9.5E-09	1.3E-08	7.6E-09	7.7E-09	5.6E-09	6.9E-09	5.7E-09	7.3E-09	9.7E-09	56.3
72.4	8.4E-09	2.5E-09	1.3E-09	1.1E-09	3.2E-09	5.7E-09	8.5E-09	6.8E-09	9.0E-09	5.4E-09	5.5E-09	4.0E-09	4.9E-09	4.1E-09	5.2E-09	6.9E-09	72.4

Table 4.1-19. $\overline{X}/Q'$ Values (sec m^{-3}) for Chronic 60-m Stack Releases from 300 Area Based on 1983 Through 1991 Meteorological Information (Schreckhise et al. 1993)

Distance						Sector (Wind from 100-N Towards Direction Indicated)											Distance
(km)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	(km)
0.1	6.0E-10	5.6E-10	5.5E-10	4.7E-10	1.0E-09	6.2E-10	6.6E-10	5.4E-10	5.3E-10	5.5E-10	6.7E-10	5.2E-10	2.6E-10	1.2E-10	2.2E-10	3.2E-10	0.1
0.2	1.2E-07	1.1E-07	1.1E-07	9.1E-08	2.0E-07	1.2E-07	1.3E-07	1.1E-07	1.1E-07	1.1E-07	1.3E-07	1.0E-07	5.3E-08	2.6E-08	4.4E-08	6.5E-08	0.2
0.3	2.5E-07	2.1E-07	2.0E-07	1.8E-07	3.7E-07	2.3E-07	2.6E-07	2.1E-07	2.1E-07	2.1E-07	2.5E-07	2.0E-07	1.1E-07	5.5E-08	9.0E-08	1.4E-07	0.3
0.4	2.3E-07	1.9E-07	1.7E-07	1.5E-07	3.1E-07	2.0E-07	2.3E-07	1.8E-07	1.9E-07	1.9E-07	2.1E-07	1.7E-07	1.1E-07	5.4E-08	8.4E-08	1.4E-07	0.4
0.5	2.0E-07	1.5E-07	1.3E-07	1.2E-07	2.4E-07	1.6E-07	1.9E-07	1.5E-07	1.6E-07	1.6E-07	1.7E-07	1.3E-07	9.1E-08	4.9E-08	7.6E-08	1.2E-07	0.5
0.6	1.8E-07	1.3E-07	1.0E-07	9.9E-08	2.0E-07	1.4E-07	1.7E-07	1.3E-07	1.5E-07	1.4E-07	1.5E-07	1.1E-07	8.5E-08	4.8E-08	7.5E-08	1.2E-07	0.6
0.7	1.8E-07	1.1E-07	8.7E-08	8.7E-08	1.7E-07	1.4E-07	1.7E-07	1.3E-07	1.5E-07	1.4E-07	1.4E-07	1.1E-07	8.6E-08	5.0E-08	7.9E-08	1.3E-07	0.7
0.8	1.9E-07	1.1E-07	7.9E-08	8.0E-08	1.6E-07	1.4E-07	1.7E-07	1.3E-07	1.6E-07	1.4E-07	1.4E-07	1.1E-07	8.9E-08	5.3E-08	8.6E-08	1.4E-07	0.8
0.9	1.9E-07	1.1E-07	7.5E-08	7.5E-08	1.5E-07	1.4E-07	1.7E-07	1.3E-07	1.6E-07	1.4E-07	1.5E-07	1.1E-07	9.4E-08	5.7E-08	9.3E-08	1.5E-07	0.9
1.0	2.0E-07	1.0E-07	7.1E-08	7.2E-08	1.5E-07	1.4E-07	1.8E-07	1.4E-07	1.7E-07	1.5E-07	1.5E-07	1.1E-07	9.9E-08	6.1E-08	1.0E-07	1.5E-07	1.0
2.4	1.5E-07	6.0E-08	3.8E-08	3.6E-08	7.8E-08	1.0E-07	1.2E-07	1.0E-07	1.4E-07	1.1E-07	1.1E-07	8.3E-08	8.5E-08	5.9E-08	8.7E-08	1.2E-07	2.4
4.0	9.5E-08	3.7E-08	2.3E-08	2.1E-08	4.8E-08	6.7E-08	8.3E-08	7.0E-08	9.6E-08	7.2E-08	7.5E-08	5.4E-08	5.7E-08	4.1E-08	5.9E-08	8.2E-08	4.0
5.6	6.8E-08	2.5E-08	1.5E-08	1.4E-08	3.3E-08	4.8E-08	6.0E-08	5.0E-08	7.0E-08	5.1E-08	5.3E-08	3.9E-08	4.1E-08	3.0E-08	4.2E-08	5.9E-08	5.6
7.2	5.2E-08	1.9E-08	1.1E-08	1.1E-08	2.4E-08	3.6E-08	4.6E-08	3.9E-08	5.4E-08	3.9E-08	4.0E-08	2.9E-08	3.2E-08	2.3E-08	3.2E-08	4.5E-08	7.2
12.1	2.9E-08	1.0E-08	6.1E-09	5.5E-09	1.3E-08	2.0E-08	2.7E-08	2.2E-08	3.1E-08	2.1E-08	2.2E-08	1.6E-08	1.8E-08	1.3E-08	1.8E-08	2.5E-08	12.1
24.1	1.3E-08	4.4E-09	2.6E-09	2.3E-09	5.7E-09	9.0E-09	1.2E-08	1.0E-08	1.4E-08	9.2E-09	9.4E-09	6.9E-09	7.7E-09	5.9E-09	8.0E-09	1.1E-08	24.1
40.3	6.9E-09	2.3E-09	1.4E-09	1.2E-09	3.0E-09	4.8E-09	6.6E-09	5.4E-09	7.3E-09	4.9E-09	5.0E-09	3.7E-09	4.1E-09	3.2E-09	4.3E-09	5.8E-09	40.3
56.3	4.5E-09	1.5E-09	8.9E-10	7.9E-10	2.0E-09	3.2E-09	4.4E-09	3.6E-09	4.9E-09	3.2E-09	3.3E-09	2.4E-09	2.7E-09	2.1E-09	2.8E-09	3.8E-09	56.3
72.4	3.3E-09	1.1E-09	6.5E-10	5.8E-10	1.5E-09	2.3E-09	3.2E-09	2.7E-09	3.6E-09	2.3E-09	2.4E-09	1.8E-09	2.0E-09	1.6E-09	2.1E-09	2.8E-09	72.4

Table 4.1-20. $\overline{X}/Q'$ Values (sec m^{-3}) for Chronic Ground-Level Releases from 400 Area Based on 1983 Through 1991 Meteorological Information (Schreckhise et al. 1993)

Distance (km)	Sector (Wind from 100-N Towards Direction Indicated)																Distance (km)
	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	
0.1	2.1E-04	1.4E-04	9.6E-05	6.9E-05	9.7E-05	8.5E-05	1.2E-04	1.9E-04	3.1E-04	2.2E-04	1.5E-04	9.9E-05	1.5E-04	1.5E-04	2.1E-04	1.7E-04	0.1
0.2	5.8E-05	3.9E-05	2.6E-05	1.9E-05	2.7E-05	2.3E-05	3.1E-05	5.1E-05	8.5E-05	6.0E-05	4.0E-05	2.7E-05	4.2E-05	4.2E-05	5.8E-05	4.8E-05	0.2
0.3	2.8E-05	1.8E-05	1.2E-05	8.9E-06	1.3E-05	1.1E-05	1.5E-05	2.5E-05	4.1E-05	2.9E-05	1.9E-05	1.3E-05	2.0E-05	2.0E-05	2.8E-05	2.3E-05	0.3
0.4	1.7E-05	1.1E-05	7.4E-06	5.3E-06	7.4E-06	6.5E-06	8.9E-06	1.5E-05	2.4E-05	1.7E-05	1.1E-05	7.7E-06	1.2E-05	1.2E-05	1.7E-05	1.4E-05	0.4
0.5	1.1E-05	7.3E-06	4.9E-06	3.5E-06	5.0E-06	4.3E-06	5.9E-06	9.8E-06	1.6E-05	1.2E-05	7.6E-06	5.2E-06	8.0E-06	8.0E-06	1.1E-05	9.1E-06	0.5
0.6	8.0E-06	5.3E-06	3.6E-06	2.5E-06	3.6E-06	3.1E-06	4.3E-06	7.1E-06	1.2E-05	8.3E-06	5.5E-06	3.8E-06	5.8E-06	5.8E-06	8.1E-06	6.6E-06	0.6
0.7	6.1E-06	4.0E-06	2.7E-06	1.9E-06	2.7E-06	2.4E-06	3.3E-06	5.4E-06	8.9E-06	6.3E-06	4.2E-06	2.9E-06	4.4E-06	4.4E-06	6.2E-06	5.0E-06	0.7
0.8	4.8E-06	3.2E-06	2.1E-06	1.5E-06	2.1E-06	1.9E-06	2.6E-06	4.3E-06	7.0E-06	5.0E-06	3.3E-06	2.3E-06	3.5E-06	3.5E-06	4.9E-06	4.0E-06	0.8
0.9	3.9E-06	2.6E-06	1.7E-06	1.2E-06	1.7E-06	1.5E-06	2.1E-06	3.5E-06	5.7E-06	4.0E-06	2.7E-06	1.8E-06	2.8E-06	2.8E-06	4.0E-06	3.2E-06	0.9
1.0	3.3E-06	2.1E-06	1.4E-06	1.0E-06	1.4E-06	1.3E-06	1.7E-06	2.9E-06	4.7E-06	3.4E-06	2.2E-06	1.5E-06	2.3E-06	2.3E-06	3.3E-06	2.7E-06	1.0
2.4	7.5E-07	4.9E-07	3.3E-07	2.3E-07	3.3E-07	2.9E-07	4.0E-07	6.7E-07	1.1E-06	7.8E-07	5.2E-07	3.5E-07	5.4E-07	5.4E-07	7.6E-07	6.2E-07	2.4
4.0	3.4E-07	2.2E-07	1.5E-07	1.1E-07	1.5E-07	1.3E-07	1.8E-07	3.1E-07	5.0E-07	3.5E-07	2.4E-07	1.6E-07	2.5E-07	2.5E-07	3.5E-07	2.8E-07	4.0
5.6	2.1E-07	1.4E-07	9.1E-08	6.4E-08	9.1E-08	8.0E-08	1.1E-07	1.9E-07	3.1E-07	2.2E-07	1.4E-07	9.8E-08	1.5E-07	1.5E-07	2.1E-07	1.7E-07	5.6
7.2	1.5E-07	9.5E-08	6.3E-08	4.4E-08	6.3E-08	5.5E-08	7.6E-08	1.3E-07	2.1E-07	1.5E-07	1.0E-07	6.8E-08	1.0E-07	1.0E-07	1.5E-07	1.2E-07	7.2
12.1	7.0E-08	4.6E-08	3.1E-08	2.1E-08	3.0E-08	2.7E-08	3.7E-08	6.2E-08	1.0E-07	7.2E-08	4.8E-08	3.3E-08	5.0E-08	5.0E-08	7.1E-08	5.8E-08	12.1
24.1	2.7E-08	1.8E-08	1.2E-08	8.2E-09	1.2E-08	1.0E-08	1.4E-08	2.4E-08	4.0E-08	2.8E-08	1.9E-08	1.3E-08	1.9E-08	1.9E-08	2.7E-08	2.2E-08	24.1
40.3	1.4E-08	8.9E-09	5.8E-09	4.1E-09	5.8E-09	5.1E-09	7.0E-09	1.2E-08	2.0E-08	1.4E-08	9.3E-09	6.3E-09	9.6E-09	9.5E-09	1.4E-08	1.1E-08	40.3
56.3	8.7E-09	5.7E-09	3.7E-09	2.6E-09	3.7E-09	3.2E-09	4.5E-09	7.6E-09	1.3E-08	8.8E-09	5.9E-09	4.0E-09	6.1E-09	6.0E-09	8.6E-09	7.0E-09	56.3
72.4	6.3E-09	4.1E-09	2.7E-09	1.9E-09	2.7E-09	2.3E-09	3.2E-09	5.5E-09	9.1E-09	6.3E-09	4.2E-09	2.9E-09	4.4E-09	4.3E-09	6.1E-09	5.0E-09	72.4

Table 4.1-21. $\overline{X}/Q'$ Values (sec m^{-3}) for Chronic 30-m Stack Releases from 400 Area Based on 1983 Through 1991 Meteorological Information (Schreckhise et al. 1993)

Distance (km)	Sector (Wind from 100-N Towards Direction Indicated)																Distance (km)
	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	
0.1	6.3E-07	5.4E-07	4.3E-07	4.0E-07	5.3E-07	5.2E-07	4.6E-07	4.2E-07	9.4E-07	7.5E-07	3.9E-07	3.0E-07	4.0E-07	2.9E-07	3.3E-07	3.3E-07	0.1
0.2	1.1E-06	9.4E-07	7.4E-07	6.8E-07	9.1E-07	8.4E-07	7.9E-07	7.5E-07	1.6E-06	1.3E-06	6.8E-07	5.0E-07	6.8E-07	5.0E-07	6.1E-07	6.1E-07	0.2
0.3	9.7E-07	8.0E-07	6.3E-07	5.5E-07	7.5E-07	6.7E-07	7.0E-07	7.1E-07	1.3E-06	1.1E-06	6.1E-07	4.3E-07	6.1E-07	5.2E-07	6.7E-07	6.1E-07	0.3
0.4	9.3E-07	7.2E-07	5.7E-07	4.8E-07	6.5E-07	5.8E-07	6.5E-07	7.4E-07	1.3E-06	1.0E-06	6.1E-07	4.2E-07	6.2E-07	5.9E-07	7.8E-07	6.7E-07	0.4
0.5	9.0E-07	6.6E-07	5.3E-07	4.3E-07	6.0E-07	5.3E-07	6.2E-07	7.5E-07	1.3E-06	1.0E-06	6.1E-07	4.2E-07	6.4E-07	6.5E-07	8.6E-07	7.0E-07	0.5
0.6	8.6E-07	6.2E-07	4.9E-07	3.9E-07	5.4E-07	4.9E-07	5.8E-07	7.4E-07	1.2E-06	9.9E-07	6.1E-07	4.2E-07	6.4E-07	6.6E-07	8.8E-07	7.0E-07	0.6
0.7	8.1E-07	5.7E-07	4.6E-07	3.6E-07	5.0E-07	4.5E-07	5.4E-07	7.1E-07	1.2E-06	9.4E-07	5.9E-07	4.0E-07	6.2E-07	6.5E-07	8.6E-07	6.8E-07	0.7
0.8	7.6E-07	5.3E-07	4.2E-07	3.2E-07	4.5E-07	4.1E-07	5.0E-07	6.8E-07	1.1E-06	8.9E-07	5.6E-07	3.9E-07	5.9E-07	6.3E-07	8.2E-07	6.5E-07	0.8
0.9	7.1E-07	4.9E-07	3.9E-07	3.0E-07	4.1E-07	3.7E-07	4.7E-07	6.4E-07	1.0E-06	8.3E-07	5.3E-07	3.7E-07	5.6E-07	5.9E-07	7.8E-07	6.1E-07	0.9
1.0	6.6E-07	4.5E-07	3.6E-07	2.7E-07	3.8E-07	3.4E-07	4.3E-07	6.0E-07	9.8E-07	7.7E-07	5.0E-07	3.4E-07	5.2E-07	5.6E-07	7.3E-07	5.7E-07	1.0
2.4	2.9E-07	1.9E-07	1.4E-07	1.1E-07	1.5E-07	1.3E-07	1.8E-07	2.7E-07	4.4E-07	3.3E-07	2.2E-07	1.5E-07	2.3E-07	2.4E-07	3.2E-07	2.5E-07	2.4
4.0	1.6E-07	1.1E-07	7.6E-08	5.6E-08	7.9E-08	7.0E-08	9.3E-08	1.5E-07	2.4E-07	1.8E-07	1.2E-07	8.2E-08	1.2E-07	1.3E-07	1.7E-07	1.4E-07	4.0
5.6	1.0E-07	6.9E-08	4.9E-08	3.6E-08	5.1E-08	4.5E-08	6.0E-08	9.5E-08	1.6E-07	1.2E-07	7.7E-08	5.3E-08	8.0E-08	8.3E-08	1.1E-07	8.9E-08	5.6
7.2	7.6E-08	5.0E-08	3.6E-08	2.6E-08	3.6E-08	3.2E-08	4.3E-08	6.9E-08	1.2E-07	8.3E-08	5.6E-08	3.8E-08	5.8E-08	5.9E-08	8.1E-08	6.4E-08	7.2
12.1	3.9E-08	2.6E-08	1.8E-08	1.3E-08	1.8E-08	1.6E-08	2.2E-08	3.6E-08	5.9E-08	4.3E-08	2.9E-08	2.0E-08	3.0E-08	3.0E-08	4.1E-08	3.3E-08	12.1
24.1	1.6E-08	1.1E-08	7.3E-09	5.2E-09	7.4E-09	6.5E-09	8.8E-09	1.4E-08	2.4E-08	1.7E-08	1.2E-08	7.9E-09	1.2E-08	1.2E-08	1.7E-08	1.3E-08	24.1
40.3	8.3E-09	5.5E-09	3.7E-09	2.7E-09	3.8E-09	3.3E-09	4.5E-09	7.4E-09	1.2E-08	8.8E-09	5.9E-09	4.0E-09	6.1E-09	6.1E-09	8.4E-09	6.8E-09	40.3
56.3	5.4E-09	3.5E-09	2.4E-09	1.7E-09	2.4E-09	2.1E-09	2.9E-09	4.8E-09	8.0E-09	5.7E-09	3.8E-09	2.6E-09	3.9E-09	3.9E-09	5.4E-09	4.4E-09	56.3
72.4	3.9E-09	2.6E-09	1.7E-09	1.3E-09	1.8E-09	1.5E-09	2.1E-09	3.5E-09	5.8E-09	4.1E-09	2.7E-09	1.9E-09	2.8E-09	2.8E-09	3.9E-09	3.2E-09	72.4

Table 4.1-22. 95th Percentile E/Q Values (sec m^{-3}) for Acute Ground-Level Releases from 100-N Area Based on 1983 Through 1991 Meteorological Information (Schreckhise et al. 1993)

Distance	Sector (Wind from 100-N Towards Direction Indicated)																Distance
(km)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	(km)
0.1	6.3E-02	5.1E-02	6.7E-02	7.3E-02	6.9E-02	5.8E-02	5.5E-02	5.3E-02	6.1E-02	5.8E-02	5.5E-02	5.6E-02	5.3E-02	5.7E-02	6.9E-02	7.5E-02	0.1
0.2	1.9E-02	1.5E-02	2.0E-02	2.2E-02	2.1E-02	1.8E-02	1.7E-02	1.6E-02	1.8E-02	1.8E-02	1.6E-02	1.7E-02	1.6E-02	1.7E-02	2.1E-02	2.3E-02	0.2
0.3	9.5E-03	7.7E-03	1.0E-02	1.1E-02	1.0E-02	8.8E-03	8.3E-03	8.0E-03	9.2E-03	8.8E-03	8.3E-03	8.5E-03	8.0E-03	8.6E-03	1.0E-02	1.1E-02	0.3
0.4	5.8E-03	4.8E-03	6.3E-03	6.8E-03	6.5E-03	5.4E-03	5.1E-03	4.9E-03	5.7E-03	5.4E-03	5.1E-03	5.2E-03	4.9E-03	5.3E-03	6.4E-03	7.0E-03	0.4
0.5	4.0E-03	3.3E-03	4.3E-03	4.7E-03	4.4E-03	3.7E-03	3.5E-03	3.4E-03	3.9E-03	3.7E-03	3.5E-03	3.6E-03	3.4E-03	3.6E-03	4.4E-03	4.8E-03	0.5
0.6	3.0E-03	2.4E-03	3.2E-03	3.4E-03	3.3E-03	2.8E-03	2.6E-03	2.5E-03	2.9E-03	2.8E-03	2.6E-03	2.6E-03	2.5E-03	2.7E-03	3.2E-03	3.5E-03	0.6
0.7	2.3E-03	1.9E-03	2.5E-03	2.7E-03	2.5E-03	2.1E-03	2.0E-03	1.9E-03	2.2E-03	2.1E-03	2.0E-03	2.0E-03	1.9E-03	2.1E-03	2.5E-03	2.7E-03	0.7
0.8	1.8E-03	1.5E-03	2.0E-03	2.1E-03	2.0E-03	1.7E-03	1.6E-03	1.5E-03	1.8E-03	1.7E-03	1.6E-03	1.6E-03	1.6E-03	1.7E-03	2.0E-03	2.2E-03	0.8
0.9	1.5E-03	1.2E-03	1.6E-03	1.8E-03	1.7E-03	1.4E-03	1.3E-03	1.3E-03	1.5E-03	1.4E-03	1.3E-03	1.3E-03	1.3E-03	1.4E-03	1.6E-03	1.8E-03	0.9
1.0	1.3E-03	1.0E-03	1.4E-03	1.5E-03	1.4E-03	1.2E-03	1.1E-03	1.1E-03	1.2E-03	1.2E-03	1.1E-03	1.1E-03	1.1E-03	1.1E-03	1.4E-03	1.5E-03	1.0
2.4	3.2E-04	2.6E-04	3.5E-04	3.8E-04	3.6E-04	3.0E-04	2.8E-04	2.7E-04	3.2E-04	3.0E-04	2.8E-04	2.9E-04	2.7E-04	2.9E-04	3.5E-04	3.9E-04	2.4
4.0	1.6E-04	1.3E-04	1.7E-04	1.8E-04	1.8E-04	1.5E-04	1.4E-04	1.3E-04	1.5E-04	1.5E-04	1.4E-04	1.4E-04	1.3E-04	1.4E-04	1.7E-04	1.9E-04	4.0
5.6	1.0E-04	8.2E-05	1.1E-04	1.2E-04	1.1E-04	9.4E-05	8.8E-05	8.5E-05	9.9E-05	9.4E-05	8.8E-05	9.0E-05	8.5E-05	9.2E-05	1.1E-04	1.2E-04	5.6
7.2	7.3E-05	5.9E-05	7.8E-05	8.5E-05	8.0E-05	6.8E-05	6.4E-05	6.1E-05	7.1E-05	6.8E-05	6.3E-05	6.5E-05	6.2E-05	6.6E-05	8.0E-05	8.7E-05	7.2
12.1	3.8E-05	3.1E-05	4.1E-05	4.4E-05	4.2E-05	3.5E-05	3.3E-05	3.2E-05	3.7E-05	3.5E-05	3.3E-05	3.4E-05	3.2E-05	3.4E-05	4.1E-05	4.5E-05	12.1
24.1	1.6E-05	1.3E-05	1.7E-05	1.9E-05	1.8E-05	1.5E-05	1.4E-05	1.3E-05	1.6E-05	1.5E-05	1.4E-05	1.4E-05	1.4E-05	1.5E-05	1.8E-05	1.9E-05	24.1
40.3	8.6E-06	7.0E-06	9.2E-06	1.0E-05	9.5E-06	8.0E-06	7.5E-06	7.2E-06	8.4E-06	8.0E-06	7.5E-06	7.7E-06	7.3E-06	7.8E-06	9.4E-06	1.0E-05	40.3
56.3	5.8E-06	4.7E-06	6.2E-06	6.7E-06	6.4E-06	5.4E-06	5.0E-06	4.8E-06	5.6E-06	5.4E-06	5.0E-06	5.1E-06	4.9E-06	5.2E-06	6.3E-06	6.9E-06	56.3
72.4	4.3E-06	3.5E-06	4.6E-06	5.0E-06	4.7E-06	4.0E-06	3.7E-06	3.6E-06	4.2E-06	4.0E-06	3.7E-06	3.8E-06	3.6E-06	3.9E-06	4.7E-06	5.1E-06	72.4

Table 4.1-23. 95th Percentile E/Q Values (sec m^{-3}) for Acute 60-m Stack Releases from 100-N Area Based on 1983 Through 1991 Meteorological Information (Schreckhise et al. 1993)

Distance	Sector (Wind from 100-N Towards Direction Indicated)																Distance
(km)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	(km)
0.1	1.3E-07	8.4E-08	9.0E-08	5.3E-08	7.4E-08	7.5E-08	5.4E-08	5.8E-08	8.4E-08	5.1E-08	5.0E-08	4.7E-08	4.7E-08	5.7E-08	1.2E-07	1.4E-07	0.1
0.2	2.5E-05	1.6E-05	1.8E-05	1.0E-05	1.5E-05	1.5E-05	1.1E-05	1.1E-05	1.7E-05	9.9E-06	9.7E-06	8.9E-06	8.8E-06	1.1E-05	2.3E-05	2.7E-05	0.2
0.3	4.1E-05	2.8E-05	3.1E-05	2.6E-05	3.1E-05	3.1E-05	2.7E-05	3.0E-05	3.5E-05	2.5E-05	2.2E-05	1.8E-05	1.8E-05	2.5E-05	4.1E-05	4.6E-05	0.3
0.4	3.7E-05	2.1E-05	2.9E-05	2.5E-05	3.0E-05	3.0E-05	2.5E-05	3.1E-05	3.5E-05	2.4E-05	1.6E-05	1.5E-05	1.5E-05	1.9E-05	3.7E-05	4.1E-05	0.4
0.5	3.0E-05	2.1E-05	2.6E-05	2.5E-05	2.6E-05	2.7E-05	2.6E-05	2.8E-05	3.0E-05	2.4E-05	1.5E-05	1.3E-05	1.2E-05	1.8E-05	2.8E-05	3.1E-05	0.5
0.6	2.8E-05	1.5E-05	1.8E-05	1.6E-05	1.8E-05	2.0E-05	1.7E-05	2.2E-05	2.9E-05	1.6E-05	1.4E-05	1.4E-05	1.3E-05	1.4E-05	2.3E-05	2.9E-05	0.6
0.7	1.4E-05	1.3E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.5E-05	1.5E-05	1.3E-05	1.3E-05	1.2E-05	1.2E-05	1.2E-05	1.3E-05	1.5E-05	0.7
0.8	2.4E-05	2.0E-05	2.2E-05	2.3E-05	2.4E-05	2.5E-05	2.5E-05	2.5E-05	2.6E-05	2.3E-05	2.0E-05	1.6E-05	1.5E-05	1.6E-05	2.2E-05	2.4E-05	0.8
0.9	2.3E-05	2.2E-05	2.2E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.2E-05	1.8E-05	1.6E-05	2.0E-05	2.2E-05	2.3E-05	0.9
1.0	2.8E-05	2.5E-05	2.5E-05	2.7E-05	2.8E-05	2.9E-05	2.8E-05	2.8E-05	3.0E-05	2.7E-05	2.5E-05	2.2E-05	2.0E-05	2.2E-05	2.5E-05	2.7E-05	1.0
2.4	2.3E-05	2.2E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.2E-05	2.1E-05	2.2E-05	2.3E-05	2.3E-05	2.4
4.0	1.7E-05	1.7E-05	1.8E-05	1.8E-05	1.8E-05	1.8E-05	1.8E-05	1.8E-05	1.9E-05	1.8E-05	1.7E-05	1.6E-05	1.4E-05	1.5E-05	1.7E-05	1.8E-05	4.0
5.6	1.4E-05	1.4E-05	1.5E-05	1.5E-05	1.5E-05	1.5E-05	1.4E-05	1.4E-05	1.5E-05	1.5E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.5E-05	5.6
7.2	1.3E-05	1.2E-05	1.3E-05	1.3E-05	1.3E-05	1.3E-05	1.3E-05	1.3E-05	1.3E-05	1.3E-05	1.2E-05	1.2E-05	1.1E-05	1.2E-05	1.3E-05	1.3E-05	7.2
12.1	8.5E-06	7.6E-06	8.7E-06	9.8E-06	9.6E-06	8.6E-06	8.4E-06	7.9E-06	8.8E-06	8.7E-06	7.7E-06	7.4E-06	6.6E-06	7.2E-06	8.7E-06	9.4E-06	12.1
24.1	5.6E-06	5.5E-06	5.7E-06	5.9E-06	5.8E-06	5.6E-06	5.6E-06	5.5E-06	5.7E-06	5.6E-06	5.5E-06	5.4E-06	5.2E-06	5.5E-06	5.7E-06	5.8E-06	24.1
40.3	3.6E-06	3.4E-06	3.8E-06	4.2E-06	4.1E-06	3.7E-06	3.6E-06	3.4E-06	3.8E-06	3.7E-06	3.4E-06	3.3E-06	3.1E-06	3.3E-06	3.9E-06	4.1E-06	40.3
56.3	2.7E-06	2.5E-06	2.8E-06	3.2E-06	3.1E-06	2.7E-06	2.6E-06	2.5E-06	2.8E-06	2.7E-06	2.4E-06	2.3E-06	2.2E-06	2.4E-06	2.9E-06	3.2E-06	56.3
72.4	2.1E-06	1.9E-06	2.2E-06	2.6E-06	2.5E-06	2.1E-06	2.0E-06	1.9E-06	2.2E-06	2.1E-06	1.9E-06	1.8E-06	1.7E-06	1.8E-06	2.3E-06	2.6E-06	72.4

Table 4.1-24. 95th Percentile E/Q Values (sec m^{-3}) for Acute Ground-Level Releases from 200 Areas Based on 1983 Through 1991 Meteorological Information (Schreckhise et al. 1993)

Distance (km)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	Distance (km)
	Sector (Wind from 100-N Towards Direction Indicated)																
0.1	3.0E-02	2.4E-02	3.4E-02	4.1E-02	4.5E-02	4.7E-02	4.3E-02	4.5E-02	5.9E-02	6.0E-02	3.9E-02	3.2E-02	3.2E-02	2.7E-02	3.0E-02	3.3E-02	0.1
0.2	9.1E-03	7.3E-03	1.0E-02	1.2E-02	1.4E-02	1.4E-02	1.3E-02	1.4E-02	1.8E-02	1.8E-02	1.2E-02	9.8E-03	9.7E-03	8.2E-03	9.0E-03	1.0E-02	0.2
0.3	4.6E-03	3.6E-03	5.1E-03	6.2E-03	6.8E-03	7.2E-03	6.5E-03	6.8E-03	9.0E-03	9.1E-03	5.9E-03	4.9E-03	4.9E-03	4.1E-03	4.5E-03	5.0E-03	0.3
0.4	2.8E-03	2.2E-03	3.2E-03	3.8E-03	4.2E-03	4.4E-03	4.0E-03	4.2E-03	5.5E-03	5.6E-03	3.7E-03	3.0E-03	3.0E-03	2.5E-03	2.8E-03	3.1E-03	0.4
0.5	1.9E-03	1.5E-03	2.2E-03	2.6E-03	2.9E-03	3.0E-03	2.8E-03	2.9E-03	3.8E-03	3.9E-03	2.5E-03	2.1E-03	2.1E-03	1.7E-03	1.9E-03	2.1E-03	0.5
0.6	1.4E-03	1.1E-03	1.6E-03	1.9E-03	2.1E-03	2.2E-03	2.0E-03	2.1E-03	2.8E-03	2.8E-03	1.9E-03	1.5E-03	1.5E-03	1.3E-03	1.4E-03	1.6E-03	0.6
0.7	1.1E-03	8.8E-04	1.2E-03	1.5E-03	1.6E-03	1.7E-03	1.6E-03	1.6E-03	2.2E-03	2.2E-03	1.4E-03	1.2E-03	1.2E-03	9.9E-04	1.1E-03	1.2E-03	0.7
0.8	8.8E-04	7.1E-04	9.9E-04	1.2E-03	1.3E-03	1.4E-03	1.3E-03	1.3E-03	1.7E-03	1.8E-03	1.1E-03	9.5E-04	9.4E-04	7.9E-04	8.8E-04	9.7E-04	0.8
0.9	7.3E-04	5.8E-04	8.2E-04	9.8E-04	1.1E-03	1.1E-03	1.0E-03	1.1E-03	1.4E-03	1.4E-03	9.4E-04	7.8E-04	7.8E-04	6.5E-04	7.2E-04	8.0E-04	0.9
1.0	6.1E-04	4.9E-04	6.8E-04	8.3E-04	9.1E-04	9.6E-04	8.7E-04	9.1E-04	1.2E-03	1.2E-03	7.9E-04	6.5E-04	6.5E-04	5.5E-04	6.0E-04	6.7E-04	1.0
2.4	1.6E-04	1.3E-04	1.7E-04	2.1E-04	2.3E-04	2.4E-04	2.2E-04	2.3E-04	3.1E-04	3.1E-04	2.0E-04	1.7E-04	1.7E-04	1.4E-04	1.5E-04	1.7E-04	2.4
4.0	7.6E-05	6.1E-05	8.5E-05	1.0E-04	1.1E-04	1.2E-04	1.1E-04	1.1E-04	1.5E-04	1.5E-04	9.9E-05	8.2E-05	8.1E-05	6.9E-05	7.6E-05	8.4E-05	4.0
5.6	4.9E-05	3.9E-05	5.4E-05	6.6E-05	7.2E-05	7.6E-05	6.9E-05	7.2E-05	9.6E-05	9.7E-05	6.3E-05	5.2E-05	5.2E-05	4.4E-05	4.8E-05	5.3E-05	5.6
7.2	3.5E-05	2.8E-05	3.9E-05	4.7E-05	5.2E-05	5.5E-05	5.0E-05	5.2E-05	6.9E-05	7.0E-05	4.5E-05	3.7E-05	3.7E-05	3.2E-05	3.5E-05	3.8E-05	7.2
12.1	1.8E-05	1.4E-05	2.0E-05	2.5E-05	2.7E-05	2.9E-05	2.6E-05	2.7E-05	3.6E-05	3.6E-05	2.4E-05	1.9E-05	1.9E-05	1.6E-05	1.8E-05	2.0E-05	12.1
24.1	7.7E-06	6.0E-06	8.6E-06	1.0E-05	1.1E-05	1.2E-05	1.1E-05	1.1E-05	1.5E-05	1.5E-05	1.0E-05	8.3E-06	8.2E-06	7.0E-06	7.7E-06	8.4E-06	24.1
40.3	4.1E-06	3.2E-06	4.6E-06	5.6E-06	6.1E-06	6.5E-06	5.9E-06	6.2E-06	8.2E-06	8.3E-06	5.4E-06	4.4E-06	4.4E-06	3.7E-06	4.1E-06	4.5E-06	40.3
56.3	2.8E-06	2.1E-06	3.1E-06	3.7E-06	4.1E-06	4.4E-06	3.9E-06	4.1E-06	5.5E-06	5.5E-06	3.6E-06	3.0E-06	3.0E-06	2.5E-06	2.8E-06	3.0E-06	56.3
72.4	2.1E-06	1.6E-06	2.3E-06	2.8E-06	3.1E-06	3.2E-06	2.9E-06	3.1E-06	4.0E-06	4.1E-06	2.7E-06	2.2E-06	2.2E-06	1.9E-06	2.0E-06	2.3E-06	72.4

Table 4.1-25. 95th Percentile E/Q Values (sec m^{-3}) for Acute 60-m Stack Releases from 200 Areas Based on 1983 Through 1991 Meteorological Information (Schreckhise et al. 1993)

Distance (km)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	Distance (km)
	Sector (Wind from 100-N Towards Direction Indicated)																
0.1	1.3E-07	1.1E-07	1.4E-07	1.6E-07	1.5E-07	1.4E-07	1.1E-07	5.2E-08	5.2E-08	5.2E-08	4.1E-08	3.3E-08	2.0E-08	1.5E-08	3.6E-08	1.1E-07	0.1
0.2	2.6E-05	2.2E-05	2.8E-05	3.1E-05	3.0E-05	2.7E-05	2.1E-05	1.0E-05	1.0E-05	1.0E-05	6.3E-06	6.1E-06	4.3E-06	3.2E-06	6.2E-06	2.1E-05	0.2
0.3	4.4E-05	3.6E-05	5.0E-05	5.5E-05	5.3E-05	4.5E-05	3.2E-05	2.0E-05	2.3E-05	2.1E-05	1.3E-05	1.1E-05	8.3E-06	6.8E-06	1.3E-05	3.3E-05	0.3
0.4	4.0E-05	3.7E-05	4.3E-05	4.5E-05	4.3E-05	4.1E-05	2.8E-05	1.6E-05	1.6E-05	1.6E-05	1.2E-05	9.2E-06	7.6E-06	7.0E-06	1.4E-05	3.1E-05	0.4
0.5	3.0E-05	3.0E-05	3.4E-05	3.8E-05	3.4E-05	3.1E-05	2.5E-05	1.4E-05	1.6E-05	1.4E-05	8.7E-06	8.6E-06	5.6E-06	5.0E-06	1.0E-05	2.7E-05	0.5
0.6	2.7E-05	2.6E-05	3.7E-05	4.1E-05	3.8E-05	3.1E-05	1.6E-05	1.4E-05	1.4E-05	1.4E-05	7.4E-06	6.8E-06	5.9E-06	5.5E-06	1.1E-05	1.9E-05	0.6
0.7	1.6E-05	1.7E-05	2.7E-05	3.6E-05	2.9E-05	2.3E-05	1.4E-05	1.2E-05	1.2E-05	1.2E-05	1.2E-05	8.5E-06	5.5E-06	4.4E-06	1.2E-05	1.4E-05	0.7
0.8	2.4E-05	2.5E-05	2.7E-05	3.1E-05	2.7E-05	2.6E-05	2.1E-05	1.7E-05	1.6E-05	1.7E-05	1.4E-05	7.6E-06	6.5E-06	6.0E-06	1.4E-05	2.3E-05	0.8
0.9	2.3E-05	2.3E-05	2.3E-05	2.7E-05	2.3E-05	2.3E-05	2.2E-05	2.0E-05	1.9E-05	2.1E-05	1.4E-05	7.4E-06	7.1E-06	7.1E-06	1.5E-05	2.2E-05	0.9
1.0	2.7E-05	2.7E-05	3.0E-05	3.1E-05	3.0E-05	2.8E-05	2.6E-05	2.3E-05	2.2E-05	2.3E-05	1.8E-05	8.3E-06	7.5E-06	7.3E-06	1.8E-05	2.6E-05	1.0
2.4	2.2E-05	2.2E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.2E-05	1.1E-05	9.6E-06	8.6E-06	1.7E-05	2.3E-05	2.4
4.0	1.5E-05	1.4E-05	1.7E-05	1.7E-05	1.7E-05	1.8E-05	1.7E-05	1.7E-05	1.8E-05	1.7E-05	1.6E-05	1.4E-05	1.3E-05	9.4E-06	1.4E-05	1.6E-05	4.0
5.6	1.3E-05	1.3E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.5E-05	1.5E-05	1.5E-05	1.4E-05	1.4E-05	1.1E-05	6.6E-06	1.1E-05	1.4E-05	5.6
7.2	1.0E-05	1.0E-05	1.2E-05	1.2E-05	1.2E-05	1.3E-05	1.3E-05	1.3E-05	1.3E-05	1.3E-05	1.2E-05	1.1E-05	8.3E-06	4.9E-06	8.1E-06	1.1E-05	7.2
12.1	6.5E-06	5.7E-06	6.6E-06	6.6E-06	7.1E-06	8.0E-06	8.6E-06	9.0E-06	9.3E-06	8.7E-06	6.8E-06	6.6E-06	6.5E-06	3.5E-06	5.7E-06	6.6E-06	12.1
24.1	3.0E-06	2.7E-06	4.5E-06	4.8E-06	5.4E-06	5.6E-06	5.7E-06	5.8E-06	5.8E-06	5.7E-06	5.1E-06	4.1E-06	3.5E-06	2.0E-06	2.5E-06	4.2E-06	24.1
40.3	1.7E-06	1.6E-06	2.7E-06	2.9E-06	3.3E-06	3.5E-06	3.8E-06	4.0E-06	4.1E-06	3.8E-06	3.1E-06	2.4E-06	2.0E-06	1.4E-06	1.6E-06	2.5E-06	40.3
56.3	1.1E-06	1.0E-06	1.3E-06	1.8E-06	2.3E-06	2.5E-06	2.8E-06	3.1E-06	3.1E-06	2.9E-06	2.1E-06	1.6E-06	1.7E-06	9.7E-07	1.1E-06	1.4E-06	56.3
72.4	8.6E-07	7.6E-07	1.1E-06	1.4E-06	1.8E-06	2.0E-06	2.2E-06	2.5E-06	2.5E-06	2.3E-06	1.6E-06	1.3E-06	1.3E-06	7.2E-07	8.5E-07	1.1E-06	72.4

Table 4.1-26. 95th Percentile E/Q Values (sec m^{-3}) for Acute Ground-Level Releases from 300 Area Based on 1983 Through 1991 Meteorological Information (Schreckhise et al. 1993)

Distance	Sector (Wind from 100-N Towards Direction Indicated)																Distance
(km)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	(km)
0.1	3.0E-02	2.4E-02	3.0E-02	2.9E-02	3.4E-02	3.2E-02	3.3E-02	5.1E-02	4.9E-02	3.1E-02	3.0E-02	3.3E-02	6.3E-02	7.4E-02	5.6E-02	3.4E-02	0.1
0.2	9.2E-03	7.3E-03	9.2E-03	8.7E-03	1.0E-02	9.8E-03	1.0E-02	1.5E-02	1.5E-02	9.3E-03	9.0E-03	9.9E-03	1.9E-02	2.2E-02	1.7E-02	1.0E-02	0.2
0.3	4.6E-03	3.6E-03	4.6E-03	4.4E-03	5.1E-03	4.9E-03	5.1E-03	7.7E-03	7.5E-03	4.7E-03	4.5E-03	5.0E-03	9.5E-03	1.1E-02	8.4E-03	5.2E-03	0.3
0.4	2.8E-03	2.2E-03	2.8E-03	2.7E-03	3.2E-03	3.0E-03	3.1E-03	4.7E-03	4.6E-03	2.9E-03	2.8E-03	3.1E-03	5.9E-03	6.9E-03	5.2E-03	3.2E-03	0.4
0.5	2.0E-03	1.5E-03	2.0E-03	1.8E-03	2.2E-03	2.1E-03	2.1E-03	3.3E-03	3.2E-03	2.0E-03	1.9E-03	2.1E-03	4.0E-03	4.7E-03	3.6E-03	2.2E-03	0.5
0.6	1.4E-03	1.1E-03	1.4E-03	1.4E-03	1.6E-03	1.5E-03	1.6E-03	2.4E-03	2.3E-03	1.5E-03	1.4E-03	1.6E-03	3.0E-03	3.5E-03	2.6E-03	1.6E-03	0.6
0.7	1.1E-03	8.8E-04	1.1E-03	1.1E-03	1.2E-03	1.2E-03	1.2E-03	1.9E-03	1.8E-03	1.1E-03	1.1E-03	1.2E-03	2.3E-03	2.7E-03	2.0E-03	1.2E-03	0.7
0.8	8.9E-04	7.0E-04	8.9E-04	8.5E-04	9.9E-04	9.5E-04	9.8E-04	1.5E-03	1.4E-03	9.0E-04	8.7E-04	9.6E-04	1.8E-03	2.2E-03	1.6E-03	1.0E-03	0.8
0.9	7.3E-04	5.8E-04	7.3E-04	7.0E-04	8.2E-04	7.8E-04	8.1E-04	1.2E-03	1.2E-03	7.4E-04	7.2E-04	7.9E-04	1.5E-03	1.8E-03	1.3E-03	8.2E-04	0.9
1.0	6.2E-04	4.9E-04	6.2E-04	5.8E-04	6.9E-04	6.5E-04	6.8E-04	1.0E-03	1.0E-03	6.2E-04	6.0E-04	6.6E-04	1.3E-03	1.5E-03	1.1E-03	6.9E-04	1.0
2.4	1.6E-04	1.2E-04	1.6E-04	1.5E-04	1.7E-04	1.7E-04	1.7E-04	2.6E-04	2.5E-04	1.6E-04	1.5E-04	1.7E-04	3.3E-04	3.8E-04	2.9E-04	1.7E-04	2.4
4.0	7.7E-05	6.1E-05	7.7E-05	7.2E-05	8.5E-05	8.2E-05	8.4E-05	1.3E-04	1.3E-04	7.8E-05	7.6E-05	8.3E-05	1.6E-04	1.9E-04	1.4E-04	8.6E-05	4.0
5.6	4.9E-05	3.9E-05	4.9E-05	4.6E-05	5.4E-05	5.2E-05	5.4E-05	8.2E-05	8.0E-05	5.0E-05	4.8E-05	5.3E-05	1.0E-04	1.2E-04	9.0E-05	5.5E-05	5.6
7.2	3.5E-05	2.8E-05	3.5E-05	3.3E-05	3.9E-05	3.7E-05	3.9E-05	5.9E-05	5.7E-05	3.6E-05	3.5E-05	3.8E-05	7.3E-05	8.6E-05	6.5E-05	3.9E-05	7.2
12.1	1.8E-05	1.5E-05	1.8E-05	1.7E-05	2.0E-05	2.0E-05	2.0E-05	3.1E-05	3.0E-05	1.9E-05	1.8E-05	2.0E-05	3.8E-05	4.5E-05	3.4E-05	2.0E-05	12.1
24.1	7.8E-06	6.2E-06	7.8E-06	7.2E-06	8.6E-06	8.3E-06	8.5E-06	1.3E-05	1.3E-05	7.9E-06	7.6E-06	8.4E-06	1.6E-05	1.9E-05	1.4E-05	8.7E-06	24.1
40.3	4.2E-06	3.3E-06	4.2E-06	3.8E-06	4.6E-06	4.4E-06	4.6E-06	7.0E-06	6.8E-06	4.2E-06	4.1E-06	4.5E-06	8.7E-06	1.0E-05	7.7E-06	4.7E-06	40.3
56.3	2.8E-06	2.2E-06	2.8E-06	2.6E-06	3.1E-06	3.0E-06	3.1E-06	4.7E-06	4.5E-06	2.8E-06	2.7E-06	3.0E-06	5.8E-06	6.8E-06	5.1E-06	3.1E-06	56.3
72.4	2.1E-06	1.6E-06	2.1E-06	1.9E-06	2.3E-06	2.2E-06	2.3E-06	3.5E-06	3.4E-06	2.1E-06	2.0E-06	2.2E-06	4.3E-06	5.0E-06	3.8E-06	2.3E-06	72.4

Table 4.1-27. 95th Percentile E/Q Values (sec m^{-3}) for Acute 60-m Stack Releases from 300 Area Based on 1983 Through 1991 Meteorological Information (Schreckhise et al. 1993)

Distance	Sector (Wind from 100-N Towards Direction Indicated)																Distance
(km)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	(km)
0.1	2.5E-08	4.7E-08	1.0E-07	1.2E-07	1.2E-07	5.0E-08	4.2E-08	4.5E-08	2.9E-08	2.9E-08	3.0E-08	3.1E-08	2.5E-08	1.8E-08	1.4E-08	6.3E-09	0.1
0.2	5.4E-06	7.3E-06	2.1E-05	2.4E-05	2.5E-05	9.6E-06	7.4E-06	8.2E-06	6.0E-06	6.0E-06	6.0E-06	6.1E-06	5.6E-06	4.7E-06	3.1E-06	3.4E-06	0.2
0.3	1.1E-05	1.6E-05	3.0E-05	3.3E-05	3.3E-05	1.8E-05	1.6E-05	1.8E-05	1.1E-05	1.1E-05	1.1E-05	1.1E-05	1.1E-05	9.0E-06	6.7E-06	8.5E-06	0.3
0.4	1.0E-05	1.5E-05	2.1E-05	3.1E-05	2.9E-05	1.5E-05	1.5E-05	1.6E-05	1.2E-05	9.4E-06	8.7E-06	1.0E-05	1.1E-05	9.0E-06	7.5E-06	8.8E-06	0.4
0.5	8.8E-06	1.2E-05	2.1E-05	2.8E-05	2.5E-05	1.3E-05	1.2E-05	1.5E-05	8.8E-06	8.7E-06	8.2E-06	8.7E-06	8.8E-06	8.7E-06	6.7E-06	8.7E-06	0.5
0.6	7.7E-06	1.4E-05	1.5E-05	2.2E-05	1.6E-05	1.4E-05	1.4E-05	1.4E-05	7.7E-06	7.7E-06	7.3E-06	7.7E-06	7.7E-06	7.5E-06	7.4E-06	7.7E-06	0.6
0.7	1.2E-05	1.2E-05	1.3E-05	2.0E-05	1.4E-05	1.2E-05	1.2E-05	1.2E-05	1.2E-05	1.1E-05	1.1E-05	1.2E-05	1.2E-05	1.2E-05	1.2E-05	1.2E-05	0.7
0.8	1.2E-05	1.4E-05	1.6E-05	2.3E-05	2.0E-05	1.6E-05	1.5E-05	1.7E-05	1.5E-05	1.0E-05	8.4E-06	1.2E-05	1.7E-05	1.7E-05	1.5E-05	1.5E-05	0.8
0.9	1.1E-05	1.4E-05	2.0E-05	2.3E-05	2.2E-05	1.8E-05	1.7E-05	2.0E-05	1.7E-05	8.8E-06	7.8E-06	1.0E-05	2.0E-05	2.1E-05	1.7E-05	1.6E-05	0.9
1.0	1.1E-05	1.4E-05	2.1E-05	2.6E-05	2.4E-05	2.2E-05	2.0E-05	2.3E-05	2.1E-05	1.1E-05	9.9E-06	1.1E-05	2.3E-05	2.3E-05	2.1E-05	2.0E-05	1.0
2.4	1.2E-05	1.4E-05	1.6E-05	2.3E-05	2.0E-05	1.6E-05	1.5E-05	1.7E-05	1.5E-05	1.0E-05	8.3E-06	1.1E-05	1.7E-05	1.8E-05	1.5E-05	1.5E-05	2.4
4.0	1.2E-05	1.2E-05	2.2E-05	2.2E-05	2.2E-05	2.2E-05	2.2E-05	2.2E-05	2.2E-05	1.8E-05	1.5E-05	2.2E-05	2.3E-05	2.3E-05	2.2E-05	2.2E-05	4.0
5.6	1.3E-05	1.3E-05	1.4E-05	1.4E-05	1.6E-05	1.6E-05	1.6E-05	1.7E-05	1.6E-05	1.4E-05	1.4E-05	1.5E-05	1.8E-05	1.8E-05	1.6E-05	1.5E-05	5.6
7.2	9.8E-06	9.6E-06	1.2E-05	1.3E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.3E-05	1.1E-05	1.4E-05	1.4E-05	1.5E-05	1.4E-05	1.4E-05	7.2
12.1	7.3E-06	7.1E-06	9.5E-06	1.0E-05	1.1E-05	1.2E-05	1.2E-05	1.3E-05	1.2E-05	9.9E-06	8.7E-06	1.1E-05	1.3E-05	1.3E-05	1.2E-05	1.1E-05	12.1
24.1	5.7E-06	5.0E-06	6.4E-06	6.5E-06	6.6E-06	7.6E-06	7.7E-06	8.5E-06	7.8E-06	6.5E-06	6.5E-06	6.5E-06	8.2E-06	9.1E-06	7.6E-06	6.6E-06	24.1
40.3	2.6E-06	2.3E-06	2.9E-06	3.2E-06	4.5E-06	5.5E-06	5.6E-06	5.7E-06	5.6E-06	3.6E-06	2.9E-06	3.9E-06	5.7E-06	5.8E-06	5.5E-06	4.4E-06	40.3
56.3	1.6E-06	1.6E-06	1.6E-06	1.8E-06	2.7E-06	3.4E-06	3.5E-06	3.8E-06	3.6E-06	2.1E-06	1.6E-06	2.2E-06	3.8E-06	3.9E-06	3.4E-06	2.6E-06	56.3
72.4	1.1E-06	1.0E-06	1.1E-06	1.1E-06	1.6E-06	2.4E-06	2.6E-06	2.8E-06	2.6E-06	1.2E-06	1.1E-06	1.2E-06	2.8E-06	3.0E-06	2.4E-06	1.8E-06	72.4

Table 4.1-28. 95th Percentile E/Q Values (sec m^{-3}) for Acute Ground-Level Releases from 400 Area Based on 1983 Through 1991 Meteorological Information (Schreckhise et al. 1993)

Distance	Sector (Wind from 100-N Towards Direction Indicated)																Distance
(km)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	(km)
0.1	3.4E-02	3.2E-02	3.3E-02	3.7E-02	4.6E-02	3.6E-02	3.2E-02	2.9E-02	2.9E-02	1.9E-02	3.1E-02	3.3E-02	3.4E-02	3.0E-02	2.7E-02	3.2E-02	0.1
0.2	1.0E-02	9.7E-03	9.9E-03	1.1E-02	1.4E-02	1.1E-02	9.7E-03	8.6E-03	8.9E-03	5.9E-03	9.2E-03	1.0E-02	1.0E-02	9.0E-03	8.2E-03	9.5E-03	0.2
0.3	5.1E-03	4.9E-03	5.0E-03	5.6E-03	7.0E-03	5.4E-03	4.9E-03	4.3E-03	4.5E-03	2.9E-03	4.6E-03	5.0E-03	5.2E-03	4.5E-03	4.1E-03	4.8E-03	0.3
0.4	3.2E-03	3.0E-03	3.1E-03	3.4E-03	4.3E-03	3.3E-03	3.0E-03	2.7E-03	2.7E-03	1.8E-03	2.8E-03	3.1E-03	3.2E-03	2.8E-03	2.5E-03	3.0E-03	0.4
0.5	2.2E-03	2.1E-03	2.1E-03	2.4E-03	3.0E-03	2.3E-03	2.1E-03	1.8E-03	1.9E-03	1.2E-03	2.0E-03	2.1E-03	2.2E-03	1.9E-03	1.7E-03	2.0E-03	0.5
0.6	1.6E-03	1.5E-03	1.6E-03	1.7E-03	2.2E-03	1.7E-03	1.5E-03	1.3E-03	1.4E-03	9.2E-04	1.4E-03	1.6E-03	1.6E-03	1.4E-03	1.3E-03	1.5E-03	0.6
0.7	1.2E-03	1.2E-03	1.2E-03	1.3E-03	1.7E-03	1.3E-03	1.2E-03	1.0E-03	1.1E-03	7.1E-04	1.1E-03	1.2E-03	1.3E-03	1.1E-03	9.9E-04	1.2E-03	0.7
0.8	9.9E-04	9.4E-04	9.6E-04	1.1E-03	1.4E-03	1.0E-03	9.4E-04	8.3E-04	8.6E-04	5.7E-04	8.9E-04	9.7E-04	1.0E-03	8.8E-04	7.9E-04	9.3E-04	0.8
0.9	8.2E-04	7.7E-04	7.9E-04	8.8E-04	1.1E-03	8.6E-04	7.7E-04	6.9E-04	7.1E-04	4.7E-04	7.3E-04	7.9E-04	8.3E-04	7.2E-04	6.5E-04	7.6E-04	0.9
1.0	6.9E-04	6.5E-04	6.7E-04	7.4E-04	9.4E-04	7.2E-04	6.5E-04	5.8E-04	5.9E-04	3.9E-04	6.2E-04	6.7E-04	6.9E-04	6.0E-04	5.5E-04	6.4E-04	1.0
2.4	1.7E-04	1.6E-04	1.7E-04	1.9E-04	2.4E-04	1.8E-04	1.7E-04	1.5E-04	1.5E-04	1.0E-04	1.6E-04	1.7E-04	1.8E-04	1.5E-04	1.4E-04	1.6E-04	2.4
4.0	8.5E-05	8.1E-05	8.3E-05	9.2E-05	1.2E-04	9.0E-05	8.1E-05	7.2E-05	7.5E-05	4.9E-05	7.7E-05	8.3E-05	8.6E-05	7.6E-05	6.9E-05	8.0E-05	4.0
5.6	5.4E-05	5.2E-05	5.3E-05	5.9E-05	7.5E-05	5.7E-05	5.2E-05	4.6E-05	4.8E-05	3.1E-05	4.9E-05	5.3E-05	5.5E-05	4.8E-05	4.4E-05	5.1E-05	5.6
7.2	3.9E-05	3.7E-05	3.8E-05	4.2E-05	5.4E-05	4.1E-05	3.7E-05	3.3E-05	3.4E-05	2.3E-05	3.5E-05	3.8E-05	4.0E-05	3.5E-05	3.2E-05	3.7E-05	7.2
12.1	2.0E-05	1.9E-05	2.0E-05	2.2E-05	2.8E-05	2.1E-05	1.9E-05	1.7E-05	1.8E-05	1.2E-05	1.8E-05	2.0E-05	2.1E-05	1.8E-05	1.6E-05	1.9E-05	12.1
24.1	8.6E-06	8.2E-06	8.4E-06	9.3E-06	1.2E-05	9.1E-06	8.2E-06	7.3E-06	7.5E-06	5.0E-06	7.8E-06	8.4E-06	8.7E-06	7.7E-06	7.0E-06	8.1E-06	24.1
40.3	4.6E-06	4.4E-06	4.5E-06	5.0E-06	6.4E-06	4.9E-06	4.4E-06	3.9E-06	4.1E-06	2.7E-06	4.2E-06	4.5E-06	4.7E-06	4.1E-06	3.7E-06	4.3E-06	40.3
56.3	3.1E-06	2.9E-06	3.0E-06	3.4E-06	4.3E-06	3.3E-06	2.9E-06	2.6E-06	2.7E-06	1.8E-06	2.8E-06	3.0E-06	3.1E-06	2.8E-06	2.5E-06	2.9E-06	56.3
72.4	2.3E-06	2.2E-06	2.2E-06	2.5E-06	3.2E-06	2.4E-06	2.2E-06	1.9E-06	2.0E-06	1.3E-06	2.1E-06	2.2E-06	2.3E-06	2.0E-06	1.9E-06	2.2E-06	72.4

Table 4.1-29. 95th Percentile E/Q Values (sec m^{-3}) for Acute 30-m Stack Releases from 400 Area Based on 1983 Through 1991 Meteorological Information (Schreckhise et al. 1993)

Distance	Sector (Wind from 100-N Towards Direction Indicated)																Distance
(km)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	(km)
0.1	3.6E-05	3.7E-05	3.7E-05	5.9E-05	5.9E-05	6.8E-05	3.7E-05	3.2E-05	3.3E-05	2.7E-05	2.3E-05	3.0E-05	3.2E-05	2.1E-05	1.6E-05	2.6E-05	0.1
0.2	5.3E-05	5.4E-05	8.3E-05	1.5E-04	1.5E-04	1.5E-04	8.1E-05	5.2E-05	5.1E-05	4.0E-05	3.6E-05	5.1E-05	5.2E-05	3.6E-05	3.1E-05	5.0E-05	0.2
0.3	4.9E-05	4.9E-05	6.9E-05	1.1E-04	1.2E-04	1.1E-04	7.0E-05	4.8E-05	4.7E-05	4.6E-05	4.7E-05	4.8E-05	4.8E-05	4.7E-05	4.6E-05	4.8E-05	0.3
0.4	8.5E-05	8.1E-05	9.2E-05	9.6E-05	9.7E-05	9.5E-05	9.2E-05	6.3E-05	4.5E-05	3.5E-05	4.8E-05	6.7E-05	7.7E-05	5.3E-05	4.5E-05	7.4E-05	0.4
0.5	9.5E-05	8.8E-05	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04	7.1E-05	5.5E-05	4.5E-05	6.6E-05	8.1E-05	8.9E-05	6.8E-05	5.8E-05	8.6E-05	0.5
0.6	9.9E-05	9.4E-05	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.0E-04	8.5E-05	7.0E-05	5.9E-05	8.2E-05	9.3E-05	9.6E-05	8.4E-05	7.4E-05	9.5E-05	0.6
0.7	9.6E-05	9.0E-05	1.0E-04	1.0E-04	1.0E-04	1.0E-04	9.9E-05	8.6E-05	8.0E-05	7.6E-05	8.6E-05	9.5E-05	9.6E-05	8.8E-05	8.1E-05	9.5E-05	0.7
0.8	9.3E-05	9.1E-05	9.6E-05	9.7E-05	9.7E-05	9.7E-05	9.5E-05	8.9E-05	8.4E-05	6.7E-05	8.9E-05	9.3E-05	9.3E-05	9.0E-05	8.6E-05	9.3E-05	0.8
0.9	8.8E-05	8.8E-05	8.9E-05	8.9E-05	8.9E-05	8.9E-05	8.9E-05	8.8E-05	8.5E-05	6.0E-05	8.8E-05	8.8E-05	8.8E-05	8.8E-05	8.8E-05	8.8E-05	0.9
1.0	8.4E-05	8.2E-05	8.5E-05	8.6E-05	8.7E-05	8.7E-05	8.4E-05	8.1E-05	8.1E-05	6.3E-05	8.2E-05	8.6E-05	8.5E-05	8.3E-05	7.7E-05	8.4E-05	1.0
2.4	4.7E-05	4.4E-05	4.8E-05	5.1E-05	5.2E-05	5.0E-05	4.6E-05	3.6E-05	3.9E-05	3.1E-05	4.5E-05	4.9E-05	4.9E-05	4.4E-05	3.4E-05	4.5E-05	2.4
4.0	3.4E-05	3.1E-05	3.4E-05	3.5E-05	3.5E-05	3.5E-05	3.4E-05	2.3E-05	2.5E-05	2.0E-05	3.1E-05	3.5E-05	3.5E-05	2.9E-05	2.2E-05	3.1E-05	4.0
5.6	2.5E-05	2.1E-05	2.3E-05	2.6E-05	2.6E-05	2.6E-05	2.2E-05	1.5E-05	1.7E-05	1.3E-05	2.0E-05	2.4E-05	2.5E-05	2.0E-05	1.5E-05	2.1E-05	5.6
7.2	1.9E-05	1.6E-05	1.8E-05	2.0E-05	2.1E-05	2.0E-05	1.7E-05	1.1E-05	1.2E-05	1.0E-05	1.5E-05	1.8E-05	1.9E-05	1.5E-05	1.1E-05	1.6E-05	7.2
12.1	1.1E-05	8.6E-06	1.0E-05	1.1E-05	1.2E-05	1.1E-05	9.5E-06	5.8E-06	6.4E-06	5.8E-06	8.5E-06	1.0E-05	1.1E-05	8.0E-06	5.8E-06	8.8E-06	12.1
24.1	4.8E-06	4.1E-06	4.5E-06	5.2E-06	5.9E-06	5.1E-06	4.2E-06	2.9E-06	3.2E-06	2.6E-06	3.6E-06	4.5E-06	5.0E-06	3.4E-06	2.8E-06	4.0E-06	24.1
40.3	2.7E-06	2.3E-06	2.5E-06	2.9E-06	3.3E-06	2.8E-06	2.4E-06	1.7E-06	1.8E-06	1.5E-06	2.1E-06	2.5E-06	2.8E-06	1.9E-06	1.6E-06	2.3E-06	40.3
56.3	1.8E-06	1.6E-06	1.7E-06	2.0E-06	2.3E-06	1.9E-06	1.6E-06	1.2E-06	1.3E-06	9.9E-07	1.4E-06	1.7E-06	1.9E-06	1.3E-06	1.1E-06	1.6E-06	56.3
72.4	1.4E-06	1.2E-06	1.3E-06	1.5E-06	1.7E-06	1.4E-06	1.2E-06	9.0E-07	9.7E-07	7.4E-07	1.1E-06	1.3E-06	1.4E-06	1.0E-06	8.7E-07	1.2E-06	72.4

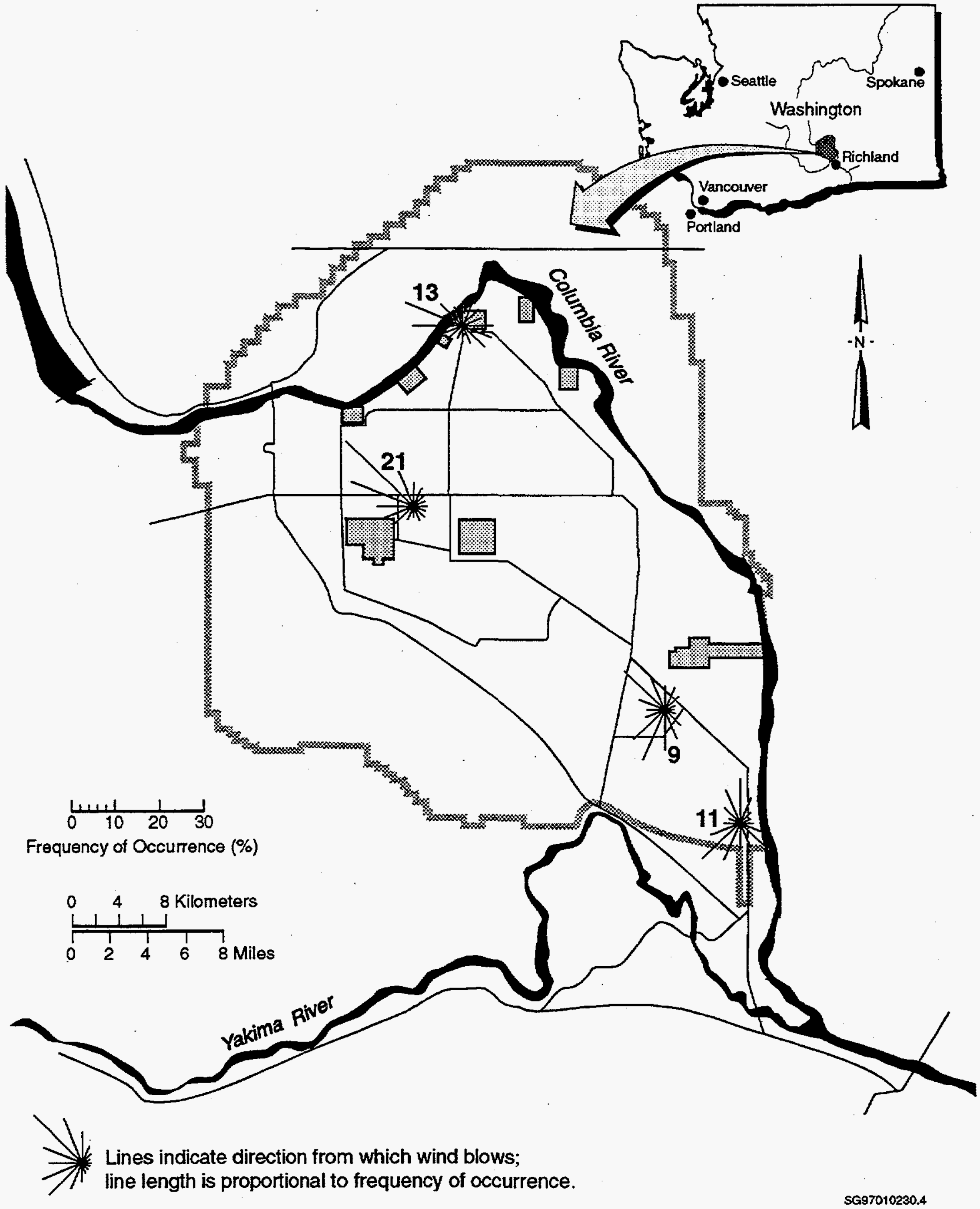

Figure 4.1-3. Wind Roses at the 60-m (200-ft) Level of the Hanford Meteorological Monitoring Network, 1986 to 1996. The point of each rose represents the direction from which the wind blows.

from the south through the southwest (Figure 4.1-2). Even stations close together can exhibit significant differences. For example, the stations at Rattlesnake Springs and 200 West are separated by about 5 km (3 mi.), yet the wind patterns at the two stations are very different (see Figure 4.1-2). Thus, 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 assessing local dispersion conditions. For elevated releases, the most representative data may come from the closest representative 60-m (197-ft) tower rather than the nearest 9.1-m (30-ft) tower.

4.1.8 Nonradiological Air Quality

Ambient Air Quality Standards have been set by the U.S. Environmental Protection Agency (EPA) and by the state of Washington (see Section 6.2.1). Ambient air is that portion of the atmosphere, external to buildings, to which the general public has access (40 CFR 50). The 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). Standards exist for sulfur oxides (measured as sulfur dioxide), nitrogen dioxide, carbon monoxide, total suspended particulates (TSP), fine particulates (PM_{10}), lead, and ozone. 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.

For areas meeting ambient air standards, the EPA has established the Prevention of Significant Deterioration (PSD) program to protect existing ambient air quality while at the same time allowing a margin for future growth. The Hanford Site operates under a PSD permit issued by the EPA in 1980 (see Section 6.5). The permit provides specific limits for emissions of oxides of nitrogen from the Plutonium-Uranium Extraction (PUREX) and Uranium Trioxide (UO_3) Plants.

State and local governments have the authority to impose standards for ambient air quality that are stricter than the national standards. Washington State has established more stringent standards for sulfur dioxide and TSP. In addition, Washington State has established standards for other pollutants, such as fluoride, that are not covered by national standards. The state standards for carbon monoxide, nitrogen dioxide, ozone, PM_{10}, and lead are identical to the national standards. Table 4.1-30 summarizes the relevant air quality standards (federal and supplemental state standards).

4.1.8.1 Prevention of Significant Deterioration

Nitrogen oxide emissions from the PUREX and UO_3 Plants are permitted under the PSD program. These facilities were not operated in 1995 and no PSD permit violations occurred.

4.1.8.2 Emissions of Nonradiological Pollutants

Nonradiological pollutants are mainly emitted from power-generating and chemical-processing facilities located on the Hanford Site. Table 4.1-31 summarizes the 1995 emission rates of nonradiological constituents from these facilities. The 100, 400, and 600 Areas have no nonradioactive emission sources of concern (Dirkes and Hanf 1996).

Table 4.1-30. National and Washington State Ambient Air Quality Standards[a]

Pollutant	National Primary	National Secondary	Washington State
Total Suspended Particulates			
Annual geometric mean	NS[b]	NS	60 μg/m³
24-h average	NS	NS	150 μg/m³
PM-10 (fine particulates)			
Annual arithmetic mean	50 μg/m³	50 μg/m³	50 μg/m³
24-h average	150 μg/m³	150 μg/m³	150 μg/m³
Sulfur Dioxide			
Annual average	0.03 ppm (≈80 μg/m³)	NS	0.02 ppm (≈50 μg/m³)
24-h average	0.14 ppm (≈370μg/m³)	NS	0.10 ppm (≈260 μg/m³)
3-h average	NS	0.50 ppm (≈1.3 mg/m³)	NS
1-h average	NS	NS	0.40 ppm (≈1.0 mg/m³)[c]
Carbon Monoxide			
8-h average	9 ppm (≈10 mg/m³)	9 ppm (≈10 mg/m³)	9 ppm (≈10 mg/m³)
1-h average	35 ppm (≈40 mg/m³)	35 ppm (≈40 mg/m³)	35 ppm (≈40 mg/m³)
Ozone			
1-h average	0.12 ppm (≈230 μg/m³)	0.12 ppm (≈230 μg/m³)	0.12 ppm (≈230 μg/m³)
Nitrogen Dioxide			
Annual average	0.05 ppm (≈100 μg/m³)	0.05 ppm (≈100 μg/m³)	0.05 ppm (≈100 μg/m³)
Lead			
Quarterly average	1.5 μg/m³	1.5 μg/m³	1.5 μg/m³

(a) Source: Ecology (1994). 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 microgram per cubic meter. Gaseous pollutants are in parts per million and equivalent microgram (or milligram) per cubic meter.
Abbreviations: ppm = parts per million; μg/m³ = micrograms per cubic meter; mg/m³ = milligrams per cubic meter.
(b) NS = no standard.
(c) 0.25 ppm not to be exceeded more than twice in any 7 consecutive days.

4.1.8.3 Onsite Monitoring

Routine monitoring is not conducted for most nonradiological pollutants because of the lack of significant anthropogenic pollutant sources onsite. Nonradiological pollutants are monitored when activities at a facility are known to potentially generate pollutants of concern. Monitoring for nitrogen oxides was required by Prevention of Significant Deterioration permits when the PUREX and UO_3 plants were in operation. Operations at these two plants, and associated air quality monitoring, were discontinued after 1990, except in 1994 when the UO_3 plant was operated in May and June (Dirkes and Hanf 1995). Monitoring of total suspended particulates (TSPs) was conducted in the 1980s in support of the Basalt Waste Isolation Project (BWIP) and was discontinued when the project was concluded.

Table 4.1-31. Nonradioactive Constituents Discharged to the Atmosphere, 1995[a] (Dirkes and Hanf 1996)

Constituent	Release, kg 200-East Area	Release, kg 200-West Area	Release, kg 300 Area
Particulate matter	3.40×10^2	8.02×10^1	1.43×10^4
Nitrogen oxides	1.77×10^5	2.82×10^4	4.69×10^4
Sulfur oxides	2.25×10^5	3.53×10^4	2.34×10^5
Carbon monoxide	6.43×10^4	1.01×10^4	4.25×10^3
Lead	1.62×10^2	2.53×10^1	2.52×10^1
Volatile organic compounds[b]	6.43×10^2	1.00×10^2	2.38×10^2
Ammonia[c]	6.18×10^3	1.53×10^3	NM
Arsenic	1.73×10^2	2.70×10^1	1.48×10^1
Beryllium	2.33×10^1	3.64×10^0	5.46×10^1
Cadmium	1.37×10^1	2.18×10^0	2.74×10^1
Carbon tetrachloride[d]	NM	NE	NM
Chromium	5.01×10^2	7.83×10^1	1.67×10^1
Cobalt	NE	NE	1.57×10^1
Copper	3.15×10^2	5.02×10^2	3.62×10^1
Formaldehyde	7.05×10^1	1.25×10^1	5.27×10^1
Manganese	6.93×10^2	1.08×10^2	9.63×10^0
Mercury	5.11×10^0	8.08×10^1	4.16×10^0
Nickel	4.12×10^2	6.43×10^1	3.03×10^2
Polycyclic organic matter	NE	6.00×10^2	7.14×10^3
Selenium	6.26×10^1	9.84×10^0	4.94×10^0
Vanadium	4.31×10^1	7.79×10^0	3.93×10^2

(a) The estimate of volatile organic compound emissions do not include emissions from certain laboratory operations; NM = not measured; NE = no emissions

(b) Produced from burning fossil fuels for steam generation.

(c) Ammonia releases are from the 200-East Area Tank Farms, 200-West Area Tank Farms, and the operation of the 242-A Evaporator.

(d) Does not include CCl_4 Vapor Extraction Project releases from passively ventilated wells.

In 1994, air samples of volatile organic compounds were collected in the 200 and 300 Areas and at a background location near Rattlesnake Springs. The samples were analyzed for halogenated alkenes and alkenes, benzene, and alkylbenzenes. Air concentrations of VOCs at all locations were well below the occupational maximum allowable concentration values as established in 20 CFR 1910 (Dirkes and Hanf 1995). No air samples of volatile organic compounds were collected in 1995.

In 1995, air samples of semivolatile organic compounds were collected in the 200 and 300 Areas, and at a background location near Rattlesnake Springs. In assessing semivolatile organic compound concentrations, samples were analyzed for individual polychlorinated biphenyl (PCB) congener, polycyclic aromatic hydrocarbons, phthalate ester plasticizers, and chlorinated pesticides. The 300 Area had higher average concentrations of polycyclic aromatic hydrocarbons and chlorinated pesticides than the other monitoring locations. Air concentrations at the 300 Area are influenced by sources on the Hanford Site and in the neighboring community and agricultural areas (Dirkes and Hanf 1996). There was little difference between monitoring sites in the average measured concentrations of total PCBs, while the concentrations of phthalate ester plasticizers were below the detection limit (Dirkes and Hanf 1996).

4.1.8.4 Offsite Monitoring

The only offsite monitoring near the Hanford Site for PM_{10}, was conducted by the Washington State Department of Ecology in 1993 (Ecology 1994). PM_{10} was monitored at one location in Benton County, at Columbia Center, located approximately 17 km (10.5 mi.) south-southwest of the 300 Area, in Kennewick. During 1993, the 24-hour PM_{10} standard established by the state of Washington, 150 $\mu g/m^3$, was exceeded twice at the Columbia Center monitoring location; the maximum 24-hour concentration at Columbia Center was ~1200 $\mu g/m^3$ (the suspected cause was windblown dust); the other occurrence >150 $\mu g/m^3$ was 155 $\mu g/m^3$. The site did not exceed the annual primary standard, 50 $\mu g/m^3$, during 1993. The arithmetic mean for 1993 was 32$\mu g/m^3$ at Columbia Center.

4.1.8.5 Background Monitoring

During the past 10 years, carbon monoxide, sulfur dioxide, and nitrogen dioxide have been monitored periodically in communities and commercial areas 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 State because of exceptional natural events (i.e., dust storms, volcanic eruptions, and large brushfires) that occur in the region. Washington State ambient air quality standards have not considered "rural fugitive dust" from exceptional natural events when estimating the maximum background concentrations of particulates in the area east of the Cascade Mountain crest. In the past, EPA has exempted the rural fugitive dust component of background concentrations when considering permit applications and enforcement of air quality standards. However, EPA is now investigating the prospect of designating parts of Benton, Franklin, and Walla Walla Counties as a nonattainment area for PM_{10}. Windblown dust has been identified as large problem in this area. The Washington State Department of Ecology has been working with the EPA and the BCAA under a Memorandum of Agreement (MOA) to characterize and document the sources of PM_{10} emissions and develop appropriate control techniques in the absence of formally designating the area nonattainment. At this time, the parties are characterizing the sources of

PM_{10} emissions and working through other items in the MOA. A final decision on this issue has not yet been determined by EPA, pending the final results of the PM_{10} characterization analysis.

4.2 Geology

(Section 4.2 last updated in PNL-6415 Rev. 7, September 1995)

Geologic considerations for the Hanford Site include physiography, stratigraphy, structural geology, soil characteristics, and seismicity.

4.2.1 Physiography

The Hanford Site lies within the Columbia Basin and Central Highlands subprovinces of the Columbia Intermontane Province (Figure 4.2-1). The Columbia Intermontane Province is the product of Miocene flood basalt volcanism and regional deformation that occurred over the past 17 million years. The Columbia Plateau is that portion of the Columbia Intermontane Province that is underlain by the Columbia River Basalt Group (Thornbury 1965).

The physiography of the Hanford Site is dominated by the low-relief plains of the Central Plains and anticlinal ridges of the Yakima Folds physiographic regions. The surface topography has been modified within the past several million years by several geomorphic processes: 1) Pleistocene cataclysmic flooding, 2) Holocene eolian activity, and 3) landsliding. Cataclysmic flooding occurred when ice dams in western Montana and northern Idaho were breached, allowing large volumes of water to spill across eastern and central Washington forming the channeled scablands and depositing sediments in the Pasco Basin. The last major flood occurred about 13,000 years ago, during the late Pleistocene Epoch. Anastomosing flood channels, giant current ripples, bergmounds, and giant flood bars are among the landforms created by the floods. The 200 Areas' waste management facilities are located on one prominent flood bar, the Cold Creek bar (Figure 4.2-2) (DOE 1988).

Since the end of the Pleistocene, winds have locally reworked the flood sediments, depositing dune sands in the lower elevations and loess (windblown silt) around the margins of the Pasco Basin. Many sand dunes have been stabilized by anchoring vegetation except where they have been reactivated by disturbing the vegetation.

Landslides occur along the north limbs of some Yakima Folds and along steep river embankments such as White Bluffs. Landslides on the Yakima Folds occur along contacts between basalt flows or sedimentary units intercalated with the basalt, whereas active landslides at White Bluffs occur in suprabasalt sediments. The active landslides at White Bluffs are principally the result of irrigation activity east of the Columbia River.

4.2.2 Stratigraphy

The stratigraphy of the Hanford Site consists of Miocene-age and younger rocks. Older Cenozoic sedimentary and volcaniclastic rock underlie the Miocene and younger rocks but are not exposed at the surface. The Hanford Site stratigraphy is summarized in Figure 4.2-3 and described in the following subsections. A more detailed discussion of the Hanford Site stratigraphy is given by DOE (1988).

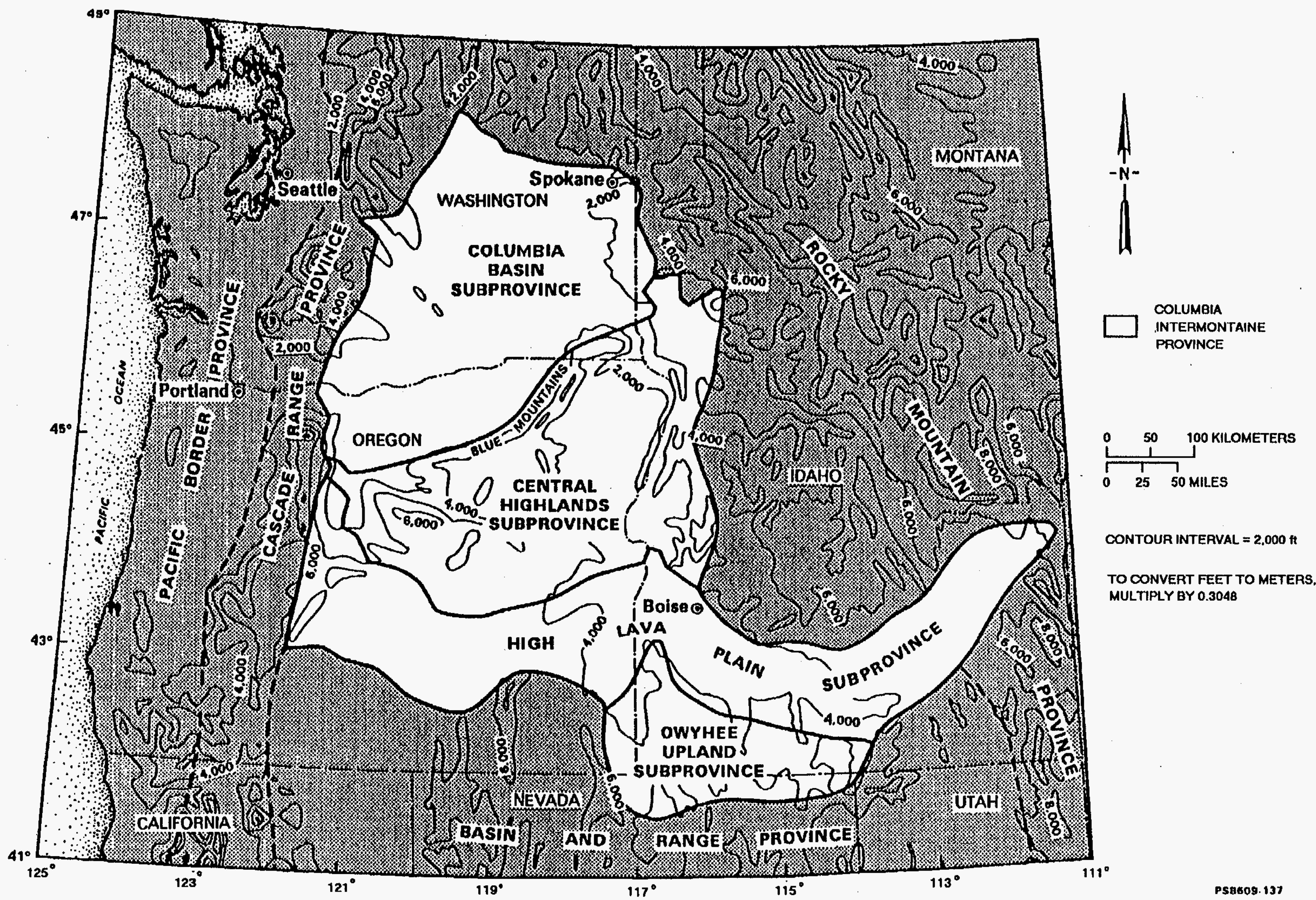

Figure 4.2-1. Physiographic Provinces of the Pacific Northwest, with Columbia Intermontane Province Shown in White (from DOE 1988)

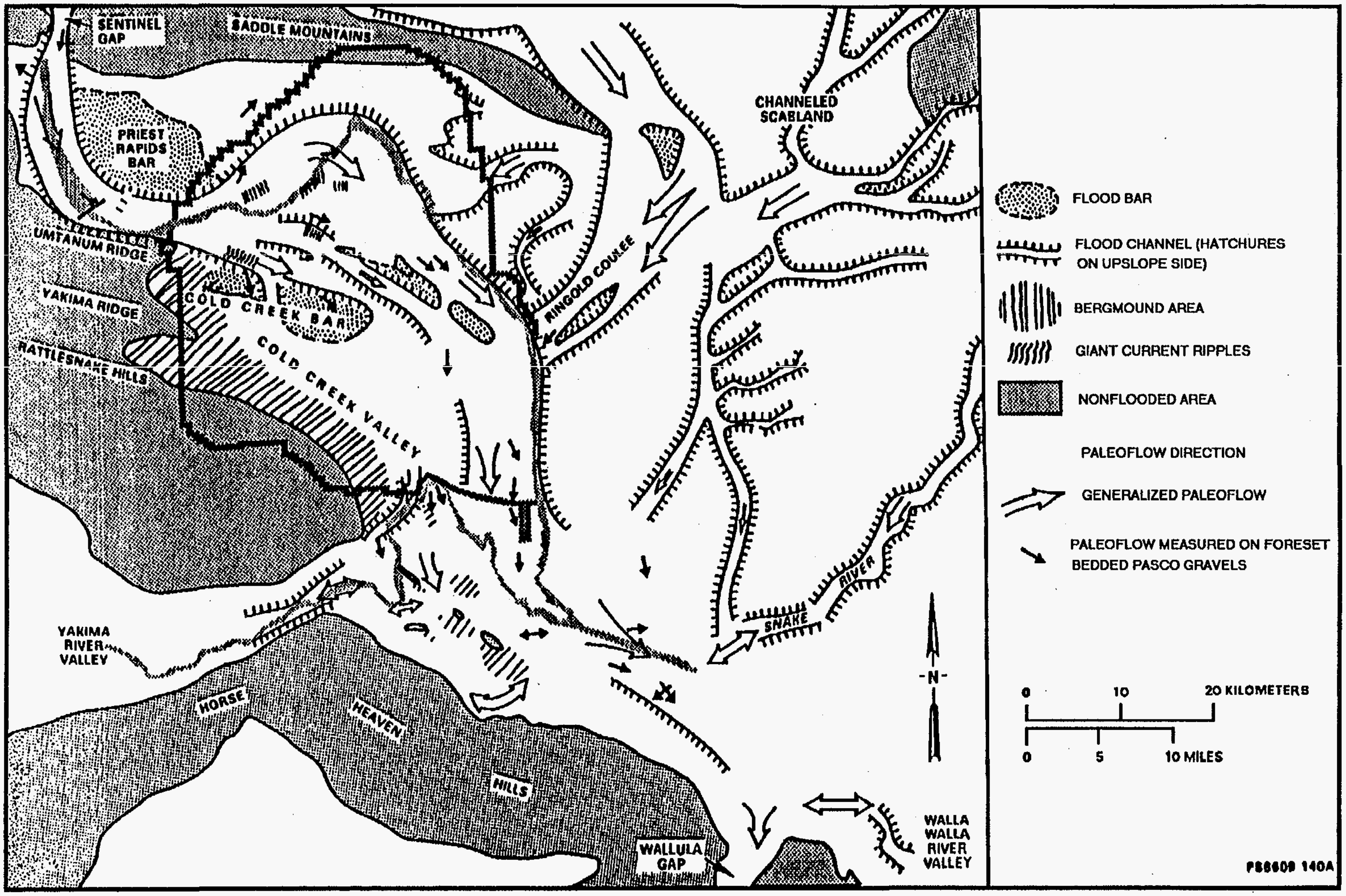

Figure 4.2-2. Paleoflow Directions and Landforms Associated with Cataclysmic Flooding in the Central Columbia Plateau (after DOE 1988)

4.2.2.1 Columbia River Basalt Group

The Columbia River Basalt Group (Figure 4.2-3) consists of an assemblage of tholeiitic, continental flood basalts of Miocene age. These flows cover an area of more than 163,170 km^2 (63,000 mi^2) in Washington, Oregon, and Idaho and have an estimated volume of about 174,000 km^3 (67,200 mi^3) (Tolan et al. 1987). Isotopic age determinations suggest flows of the Columbia River Basalt Group were erupted during a period from approximately 17 to 6 million years ago, with more than 98% by volume being erupted in a 2.5 million-year period (17 to 14.5 million years ago).

Columbia River basalt flows were erupted from north-northwest-trending fissures or linear vent systems in north-central and northeastern Oregon, eastern Washington, and western Idaho (Swanson et al. 1979a,b; Waters 1961). The Columbia River Basalt Group is formally divided into five formations, from oldest to youngest: Imnaha Basalt, Picture Gorge Basalt, Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt. Of these, only the Grande Ronde, Wanapum, and Saddle Mountains Basalts are known to be present in the Pasco Basin. The Saddle Mountains Basalt forms the uppermost basalt unit in the Pasco Basin except along some of the bounding ridges where Wanapum and Grande Ronde Basalt flows are exposed.

4.2.2.2 Ellensburg Formation

The Ellensburg Formation (Figure 4.2-3) includes epiclastic and volcaniclastic sedimentary rocks interbedded with the Columbia River Basalt Group in the central and western part of the Columbia Plateau (Schmincke 1964; Smith 1988; Swanson et al. 1979a,b). The age of the Ellensburg Formation is principally Miocene, although locally it may be equivalent to early Pliocene. The thickest accumulations of the Ellensburg Formation lie along the western margin of the Columbia Plateau where Cascade Range volcanic and volcaniclastic materials interfinger with the Columbia River Basalt Group. Within the Pasco Basin, individual interbeds, primarily in the Wanapum and Saddle Mountains Basalts, have been named (i.e., Mabton, Selah, and Cold Creek). The lateral extent and thickness of interbedded sediments generally increase upward in the section (Reidel and Fecht 1981). Two major facies, volcaniclastic and fluvial, are present either as distinct or mixed deposits.

4.2.2.3 Suprabasalt Sediments

The suprabasalt sediments within and adjacent to the Hanford Site (Figure 4.2-3) are dominated by the fluvial-lacustrine Ringold Formation and glaciofluvial Hanford formation, with minor eolian and colluvium deposits (Baker et al. 1991; DOE 1988; Tallman et al. 1981).

Ringold Formation Late Miocene to Pliocene deposits, younger than the Columbia River Basalt Group, are represented by the Ringold Formation within the Pasco Basin (Grolier and Bingham 1978; Gustafson 1973; Newcomb et al. 1972; Rigby and Othberg 1979). The fluvial-lacustrine Ringold Formation was deposited in generally east-west trending valleys by the ancestral Columbia River and its tributaries in response to development of the Yakima Fold Belt. While exposures of the Ringold Formation are limited to White Bluffs within the central Pasco Basin and to Smyrna and Taunton Benches north of the Pasco Basin, extensive data on the Ringold Formation are available from boreholes.

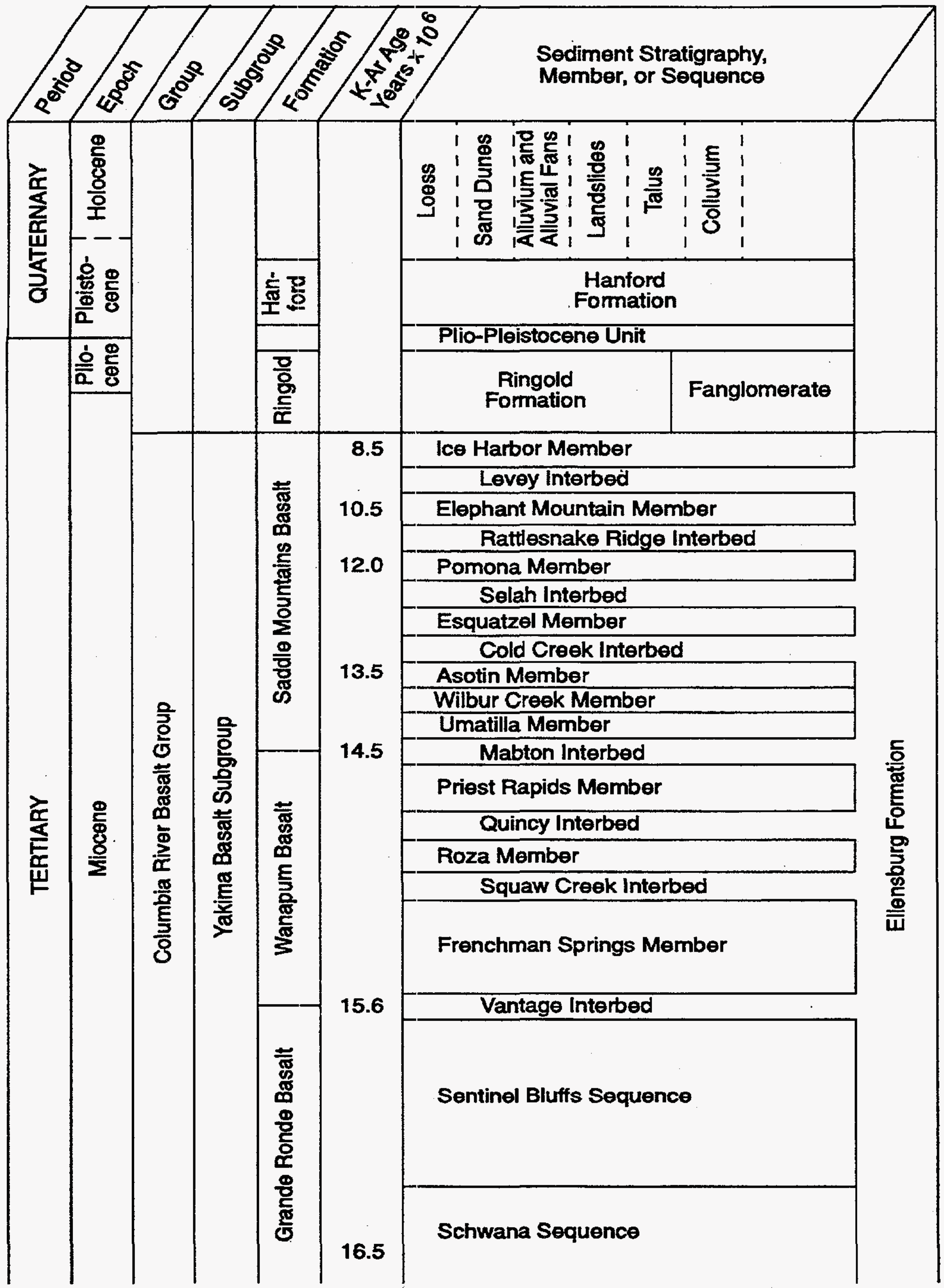

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Figure 4.2-3. Stratigraphic Column for the Pasco Basin

Fluvial deposits of the Ringold Formation can be broken into three facies associations based on proximity to the ancestral Columbia and/or Snake River channels and the related paleography during the time the Ringold Formation was being deposited. Gravel and associated sand and silt represent a migrating channel deposit of the major, thorough going river systems and are generally confined to the central portion of the Pasco Basin. Overbank sand, silt, and clay reflect occasional deposition and flooding beyond the influence of the main river channels, and are generally found along the margins of the Pasco Basin. Fanglomerates, composed of mostly angular basaltic debris derived from side-stream alluvium shed off bedrock ridges, occur locally around the extreme margins of the basin. Over time, the main river channels moved back and forth across the basin, causing a shift in location of the various facies. Periodically, the river channels were blocked, causing lakes to develop in which laminated mud with minor sand was deposited.

In Tallman et al. (1979), the Ringold Formation was divided into four lithofacies units. In ascending order, they are the coarse-grained basal Ringold, the fine-grained lower Ringold, the coarse-grained middle Ringold, and the fine-grained upper Ringold units (Figure 4.2-4). Bjornstad (1984) further subdivided the basal Ringold unit. A new approach is being developed to reevaluate the Ringold stratigraphy using facies associations (Lindsey 1991b; Lindsey and Gaylord 1989). Figure 4.2-4 shows the relationships between these different stratigraphic nomenclatures. The stratigraphic divisions of the Ringold Formation as presented in Lindsey et al. (1992) will be used in this report. Lowermost in the Ringold is Unit A, a fluvial sand and gravel unit that occurs in the central portion of the Pasco Basin, pinching out towards the margins of the basin and onto the anticlines. Unit A correlates to the coarse-grained portion of the Basal Ringold Member. Overlying this coarse-grained unit is the relatively extensive Lower Mud Sequence, consisting of overbank and lacustrine deposits of mud and occasionally sand. The Lower Mud Sequence is found throughout much of the Pasco Basin, pinching out on the southern flank of the Umtanum Ridge-Gable Mountain anticline and near the margins of the basin. It correlates to the fine-grained portion of the Basal Ringold Member and the Lower Ringold Member. Overlying the Lower Mud Sequence is a complex series of sedimentary units deposited by the ancestral Columbia River as it shifted back and forth across the Pasco Basin. Main-channel facies gravel and sand units overlie the Lower Mud Unit over much of the Pasco Basin. Where these coarse-grained units are overlain by an unnamed mud unit, the gravelly sediments are designated Unit B in the eastern part of the basin, or Unit D in the western part. In the 200 West Area and vicinity, there is only one thick sequence of fluvial gravel and sand, part of which may include sediments that correlate to Unit D. In some areas north of Gable Mountain and in the eastern part of the Pasco Basin, the unnamed mud is overlain by another series of coarse-grained fluvial sediments, designated Unit C, and another unnamed mud unit. These unnamed mud units are thickest in the northern and northeastern parts of the Hanford Site, where they form extensive series of overbank/paleosol sequences.

Ringold Unit E correlates to the Middle Ringold Member and may lie directly upon any of the above units. If the underlying unit is a fluvial gravel facies, it is virtually indistinguishable from sediments in Unit E and the entire sequence is generally called Unit E. It is present throughout most of the Hanford Site, with the exception of the northern and northeastern portions, where the Ringold contains virtually no main-channel deposits. Overlying Unit E is the Upper Ringold Unit, which directly corresponds to previous nomenclature and stratigraphy. This unit consists of overbank/paleosol deposits found over much of the Hanford Site but has been eroded from the 200 East and 300 Areas. Most of White Bluffs on the east side of the Columbia River consists of Upper Ringold sediments.

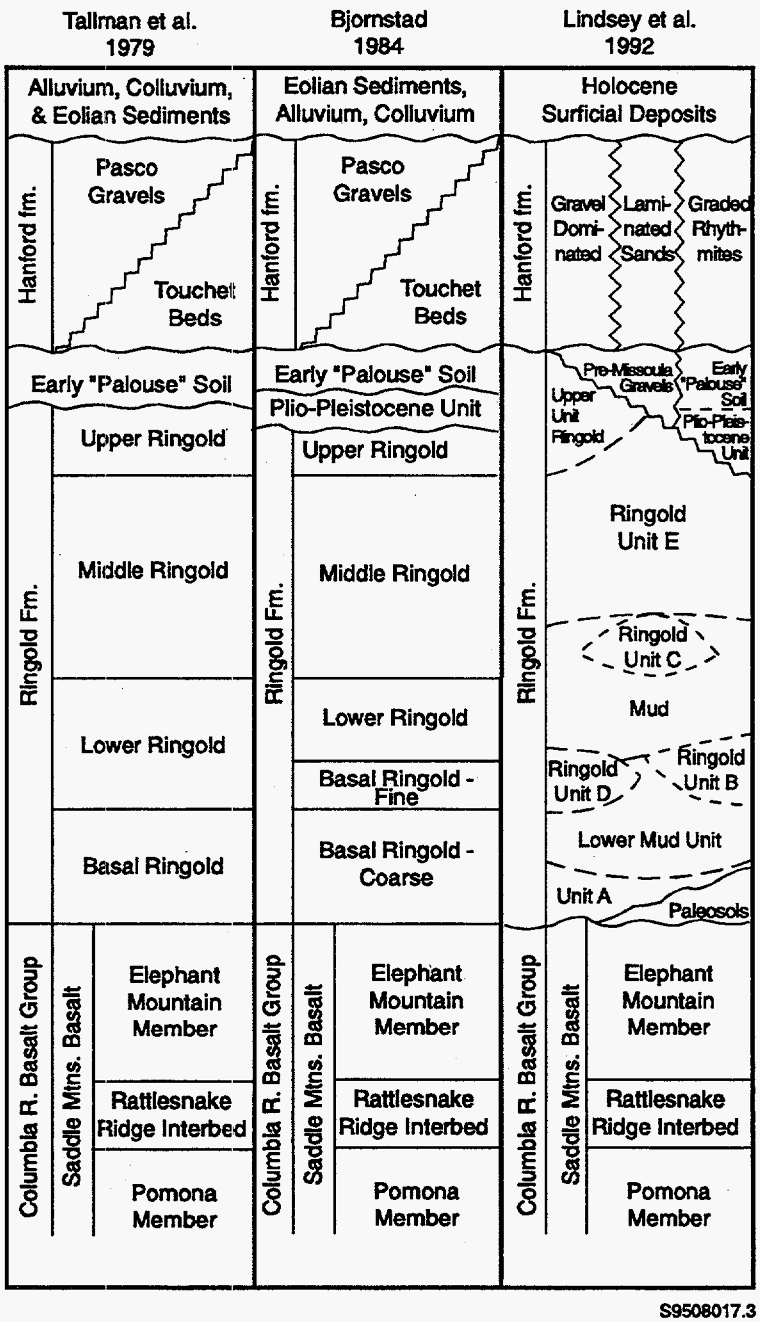

Figure 4.2-4. Stratigraphic Column for the Hanford Site Showing Correlations Among Various Authors

Deposition of the Ringold Formation was followed by a period of regional incision in the late Pliocene to early Pleistocene. Within the Pasco Basin, this is reflected by the abrupt termination and eroded nature of the top of the Ringold Formation (Bjornstad 1985; Brown 1960; Newcomb et al. 1972). Following incision, a well-developed soil formed on top of the eroded surface. The exact timing and duration of incision are unknown; however, the incision probably occurred between 1 and 3.4 million years ago.

Plio-Pleistocene Unit. A locally derived unit consisting of a sidestream alluvium and/or pedogenic calcrete occurs at the unconformity between the Ringold Formation and the Hanford formation (Bjornstad 1984, 1985). The sidestream alluvial facies is derived from Cold Creek and its tributaries and is characterized by relatively thick zones of unweathered basalt clasts along with pedogenically altered loess or colluvium. The calcrete is relatively thick and impermeable in areas of the western Pasco Basin, often forming an aquitard to downward migration of water in the vadose zone where artificial recharge is occurring.

Early "Palouse" Soil. Overlying the Plio-Pleistocene unit in the Cold Creek syncline area is a fine-grained sand to silt. It is believed to be mainly of eolian origin, derived from either an older reworked Plio-Pleistocene unit or upper Ringold. The early Palouse soil differs from the overlying slackwater flood deposits by a greater calcium-carbonate content, massive structure in core samples, and a high natural gamma response in geophysical logs.

Quaternary Deposits. Aggradation of sediments resumed during the Quaternary following the period of late-Pliocene to early-Pleistocene incision. In the central Columbia Plateau, the Quaternary record is dominated by proglacial cataclysmic flood deposits with lesser amounts of fluvial and eolian deposits lying below, between, and above flood deposits.

Sand and gravel river sediments, referred to informally as the pre-Missoula gravels (PSPL 1982), were deposited after incision of the Ringold and before deposition of the cataclysmic flood deposits. The pre-Missoula gravels are very similar to the Ringold Formation main-channel gravel facies, consisting of dominantly nonbasaltic clasts. These sediments appear to occur in a swath that runs from the Old Hanford Townsite on the eastern side of the Hanford Site across the Site toward Horn Rapids on the Yakima River.

Cataclysmic floods inundated the Pasco Basin a number of times during the Pleistocene, beginning as early as 1 million years ago (Bjornstad and Fecht 1989); the last major flood sequence is dated at about 13,000 years ago by the presence of Mount St. Helens "S" tephra (Mullineaux et al. 1978) interbedded with the flood deposits. The number and timing of cataclysmic floods continues to be debated. Baker et al. (1991) document as many as 10 flood events during the last ice age. The largest and most frequent floods came from glacial Lake Missoula in northwestern Montana; however, smaller floods may have escaped down-valley from glacial Lakes Clark and Columbia along the northern margin of the Columbia Plateau (Waitt 1980), or down the Snake River from glacial Lake Bonneville (Malde 1968). The flood deposits, informally called the Hanford formation, blanket low-lying areas over most of the central Pasco Basin.

Cataclysmic floodwaters entering the Pasco Basin quickly became impounded behind Wallula Gap, which was too restrictive for the volume of water involved. Floodwaters formed temporary lakes with a shoreline up to 381.25 m (1250 ft) in elevation, which lasted only a few weeks or less (Baker 1978).

Two end-member types of flood deposits are normally observed: a sand-and-gravel, main-channel facies and a mud-and-sand, slackwater facies. Within the Pasco Basin, these are referred to as the Pasco Gravels and slackwater deposits of the Hanford formation (Myers et al. 1979). Sediments with intermediate grain sizes (e.g., sand-dominated facies) are also present in areas throughout the Pasco Basin, particularly on the south, relatively protected, half of Cold Creek bar.

Clastic dikes are commonly associated with, but not restricted to, cataclysmic flood deposits on the Columbia Plateau. While there is general agreement that clastic dikes formed during cataclysmic flooding, a primary mechanism to satisfactorily explain the formation of all dikes has not been identified (Supply System 1981). Among the more probable explanations are fracturing initiated by hydrostatic loading and hydraulic injection associated with receding floodwaters. These dikes may provide vertical pathways for downward migration of water through the vadose zone.

Alluvium is present, not only as a surficial deposit along major river and stream courses (Figure 4.2-5), but also in the subsurface, where it is found underlying, and interbedded with, proglacial flood deposits. Two types of alluvium are recognized in the Pasco Basin: quartzitic mainstream and basalt-rich sidestream alluvium. Colluvium (talus and slopewash) is a common Holocene deposit in moderate-to-high relief areas. Colluvium, like the dune sand that is found locally in the Pasco Basin, is not commonly preserved in the stratigraphic record. Varying thicknesses of loess or sand mantle much of the Columbia Plateau. Active and stabilized sand dunes are widespread over the Pasco Basin (Figure 4.2-5).

Landslide deposits in the Pasco Basin are of variable age and genesis. Most occur within the basalt outcrops along the ridges, such as on the north side of Rattlesnake Mountain, or steep river embankments such as White Bluffs, where the Upper Ringold Unit crops out in the Pasco Basin (Figure 4.2-5).

4.2.2.4 100 Areas Stratigraphy

The 100 Areas are spread out along the Columbia River in the northern portion of the Pasco Basin (Figure 4.0-1). All of the 100 Areas, except the 100-B/C Area, lie on the north limb of the Wahluke syncline. The 100-B/C Area lies over the axis of the syncline. The top of 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 pre-Missoula gravels may be present near the 100-B/C and 100-K Areas but are not readily distinguished from Ringold and Hanford sediments. The Plio-Pleistocene unit and early "Palouse" soil have not been recognized 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 the front of Umtanum Ridge and through the 100-B/C and 100-K Areas, before turning south to flow along the front of Gable Mountain and/or through the Gable Mountain-Gable Butte gap. This main channel deposited coarse-grained sand and gravel facies of the Ringold Formation (Units A, B, C, and E). Farther to the north and east, however, the Ringold sediments gradually become dominated by the lacustrine and overbank deposits and associated paleosols (Ringold Lower Mud Sequence and unnamed units), with the 100-H Area showing almost none of the gravel facies. In the 100 Areas, the Hanford formation consists primarily

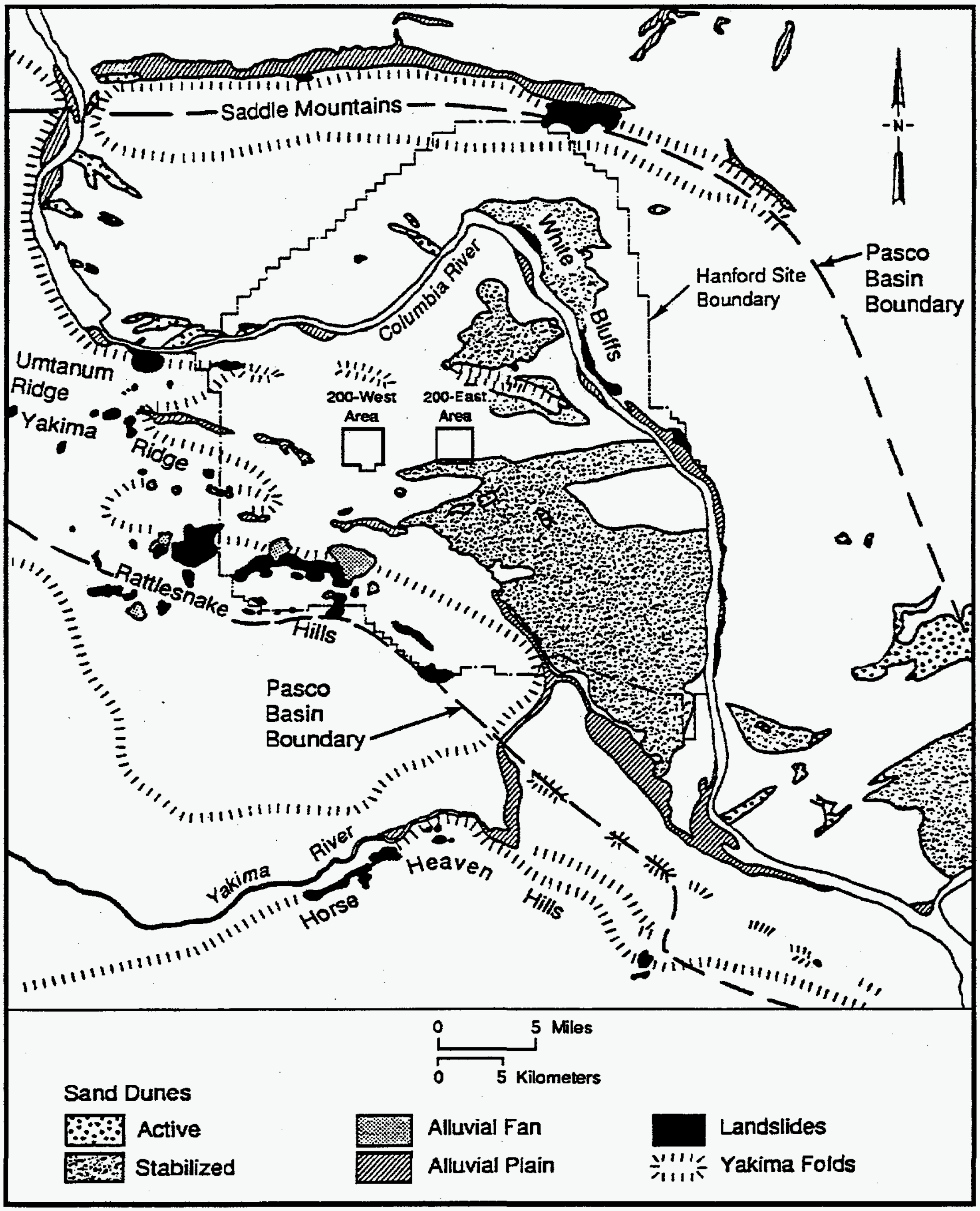

Figure 4.2-5. Location of Surficial Features (after DOE 1988)

of Pasco Gravels facies, with local occurrences of the sand-dominated or slackwater facies. Hydrogeologic reports providing specific information have been written for each of the 100 Areas. These are as follows: 100-B/C Area - Lindberg (1993a); 100-D Area - Lindsey and Jaeger (1993); 100-F Area - Lindsey (1992); 100-H Area - Lindsey and Jaeger (1993); 100-K Area - Lindberg (1993b); and 100-N Area - Hartman and Lindsey (1993).

4.2.2.5 200 Areas Stratigraphy

The geology in the 200 West and 200 East Areas is surprisingly different, although they are separated by a distance of only 6 km (4 mi.) (Figure 4.0-1). One of the most complete suprabasalt stratigraphic sections on the Hanford Site, with most of Lindsey's (1991b) Ringold units, as well as the Plio-Pleistocene unit, early "Palouse" soil, and the Hanford formation, is found in the 200 West Area. There are numerous reports on the geology of the 200 West Area, including Connelly et al. (1992b), Lindsey (1991a), and Tallman et al. (1979).

In the 200 East Area, most of the Ringold Formation units are present in the southern part but have been eroded in a complex pattern to the north. On the north side of the 200 East Area, the Hanford formation rests directly on the basalt, and there are no Ringold sediments present. Erosion by the ancestral Columbia River and catastrophic flooding are believed to have removed the Ringold Formation from this area. Neither the Plio-Pleistocene unit nor the early "Palouse" soil have been identified in the 200 East Area. Reports on the geology of the 200 East Area include Connelly et al. (1992a), Lindsey et al. (1992), and Tallman et al. (1979).

4.2.2.6 300 Area Stratigraphy

The 300 Area is located in the southeastern portion of the Hanford Site (Figure 4.0-1). The 300 Area lies above a gentle syncline formed by the intersection of the Palouse Slope and the western side of the Pasco Basin. Over most of the Hanford Site, the uppermost basalt flows belong to the Elephant Mountain Member, but near the 300 Area, even younger flows belonging to the Ice Harbor Member are found, causing a relative high in the top of basalt surface (Schalla et al. 1988) (the Elephant Mountain and Ice Harbor Members are the top two members of the Saddle Mountains Basalt). Both Ringold Formation and Hanford formation sediments are found in the 300 Area; Swanson (1992) describes the geology in more detail.

4.2.3 Structural Geology of the Region

The Hanford Site is located near the junction of the Yakima Fold Belt and the Palouse structural subprovinces (DOE 1988). These structural subprovinces are defined on the basis of their structural fabric, unlike the physiographic provinces that are defined on the basis of landforms. The Palouse subprovince is primarily a regional paleoslope that dips gently toward the central Columbia Plateau and exhibits only relatively mild structural deformation. The Palouse Slope is underlain by a wedge of Columbia River basalt that thins gradually toward the east and north and laps onto the adjacent highlands.

The principal characteristics of the Yakima Fold Belt are a series of segmented, narrow, asymmetric anticlines that have wavelengths between 5 and 31 km (3 and 19 mi.) and amplitudes commonly <1 km (0.6 mi.) (Reidel et al. 1989). These anticlinal ridges are separated by broad synclines or basins that, in many cases, contain thick accumulations of Neogene- to Quaternary-age sediments. The deformation of the Yakima Folds occurred under north-south compression. The fold belt was growing during the eruption of the Columbia River Basalt Group and continued to grow into the Pleistocene and probably into the present (Reidel 1984).

Thrust or high-angle reverse faults with fault planes that strike parallel or subparallel to the axial trends are principally found along the limbs of the anticlines (Bentley et al. 1980; Hagood 1985; Reidel 1984; Swanson et al. 1979a,b, 1981). The amount of vertical stratigraphic offset associated with these faults varies but commonly exceeds hundreds of meters.

The Saddle Mountains uplift is a segmented anticlinal ridge extending from near Ellensburg to the western edge of the Palouse Slope. This ridge forms the northern boundary of the Pasco Basin and the Wahluke syncline (Figure 4.2-6). It is generally steepest on the north, with a gently dipping southern limb. A major thrust or high-angle reverse fault occurs on the north side (Reidel 1984).

The Umtanum Ridge-Gable Mountain uplift is a segmented, asymmetrical anticlinal ridge extending 137 km (85 mi.) in an east-west direction and passing north of the 200 Areas (Figure 4.2-6), forming the northern boundary of the Cold Creek syncline and the southern boundary of the Wahluke syncline. Three of this structure's segments are located on or adjacent to the Hanford Site. From the west, Umtanum Ridge plunges eastward toward the basin and merges with the Gable Mountain-Gable Butte segment. The latter segment then merges with the Southeast Anticline, which trends southeast before dying out near the Columbia River eastern boundary of the Gable Mountain-Gable Butte segment.

There is a major thrust to high-angle reverse fault on the north side (PSPL 1982) that dies out as it plunges eastward past the Gable Mountain-Gable Butte segment. Gable Mountain and Gable Butte are two topographically isolated, anticlinal ridges composed of a series of northwest-trending, doubly plunging, echelon anticlines, synclines, and associated faults. The potential for present-day faulting has been identified on Gable Mountain (PSPL 1982).

The Yakima Ridge uplift extends from west of Yakima to the center of the Pasco Basin, where it forms the southern boundary of the Cold Creek syncline (DOE 1988) (Figure 4.2-6). The Yakima Ridge anticline plunges eastward into the Pasco Basin, where it continues on a southeastern trend mostly buried beneath sediments. A thrust to high-angle reverse fault is thought to be present on the north side of the anticline, dying out as the fold extends to the east.

Rattlesnake Mountain is an asymmetrical anticline with a steeply dipping and faulted northern unit that forms the southern boundary of the Pasco Basin (Figure 4.2-6). It extends from the structurally complex Snively Basin area southeast to the Yakima River, where the uplift continues as a series of doubly plunging anticlines (Fecht et al. 1984). At Snively Basin, the Rattlesnake Mountain structure intersects the Rattlesnake Hills anticline, which extends beyond Yakima and has an east-west trend.

The Cold Creek syncline (Figure 4.2-6) lies between the Umtanum Ridge-Gable Mountain uplift and the Yakima Ridge uplift. The Cold Creek syncline is an asymmetric and relatively flat-bottomed structure (DOE 1988). The Wahluke syncline lies between Saddle Mountains and the Umtanum Ridge-Gable Mountain uplifts. It, too, is asymmetric and relatively flat-bottomed, and is broader than the Cold Creek syncline (Myers et al. 1979).

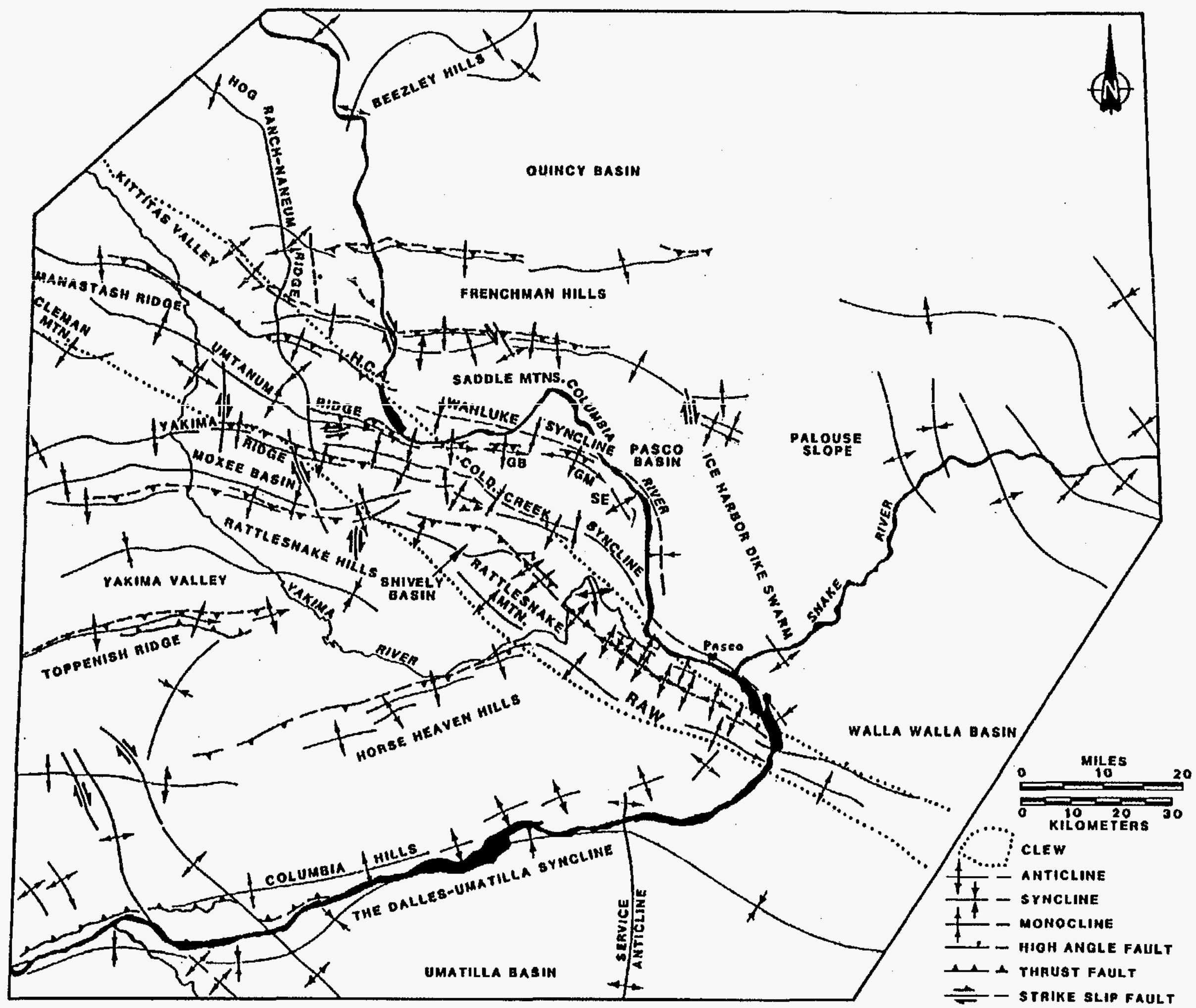

Figure 4.2-6. Location of Structural Features (Reidel et al. 1989)

The Cold Creek Fault (previously called the Yakima Barricade geophysical anomaly) (Figure 4.2-6) occurs on the west end of the Cold Creek syncline and coincides with a west-to-east change in hydraulic gradient. The data suggest that this feature is a high-angle fault that has faulted the basalts and, at least, the older Ringold units (Johnson et al. 1993). This fault apparently has not affected younger Ringold units or the Hanford formation.

Another fault, informally called the May Junction fault, is located nearly 4.5 km (3 mi.) east of the 200 East Area. Like the Cold Creek fault, this fault is thought to be a high-angle fault that has offset the basalts and the older Ringold units. It does not appear to have affected the younger Ringold units or the Hanford formation.

4.2.4 Soils

Hajek (1966) describes 15 different soil types on the Hanford Site, varying from sand to silty and sandy loam. These are shown in Figure 4.2-7 and briefly described in Table 4.2-1. Various classifications, including land use, are also given in Hajek (1966). The soil classifications given in Hajek (1966) have not been updated to reflect current reinterpretations of soil classifications. Until soils on the Hanford Site are resurveyed, the descriptions presented in Hajek (1966) will continue to be used.

4.2.5 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 structural damage and human perception of the shaking, as classified by the Modified Mercalli Intensity (MMI) scale, and is probably incomplete because the region was sparsely populated. 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 >2.5 was installed in eastern Washington in 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 (Richter magnitude >7) in the Pacific Northwest have occurred near Puget Sound, Washington, and near the Rocky Mountains in eastern Idaho and western Montana. One of these events occurred near Vancouver Island in 1946, and produced a maximum MMI of VIII and a Richter magnitude of 7.3. Another large event occurred near Olympia, Washington, in 1949 at a maximum intensity of MMI VIII and a Richter magnitude of 7.1. The two largest events near the Rocky Mountains 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.

A 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. The distribution of intensities suggests a location within a broad region between Lake Chelan, Washington, and the British Columbia border.

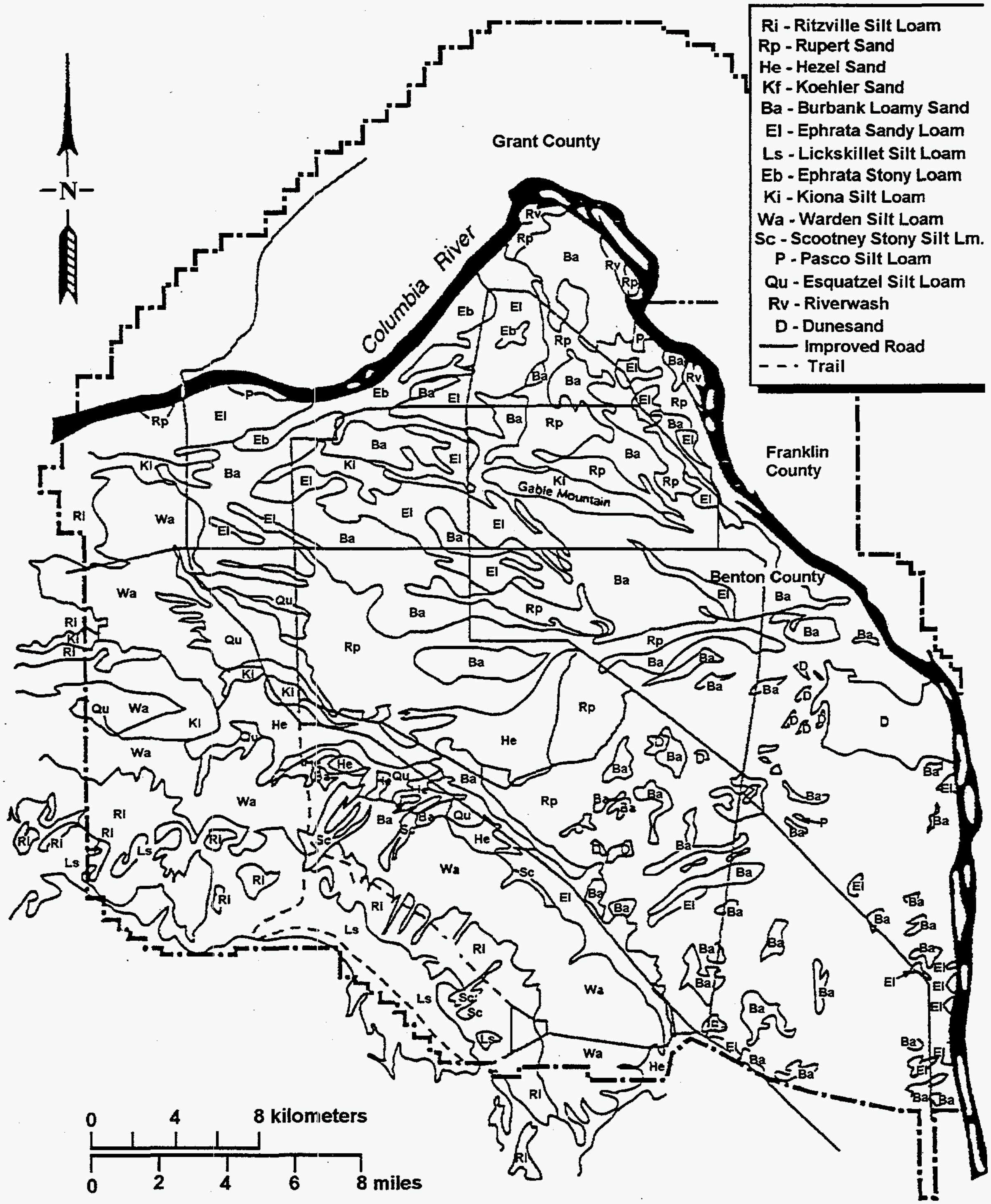

Figure 4.2-7. Soil Map of the Hanford Site (from Hajak 1966)

Table 4.2-1. Soil Types on the Hanford Site (after Hajek 1966)

Name (symbol)	Description
Ritzville Silt Loam (Ri)	Dark-colored silt loam soils midway up the slopes of the Rattlesnake Hills. Developed under bunch grass from silty wind-laid deposits mixed with small amounts of volcanic ash. Characteristically >150 cm (60 in.) deep, but bedrock may occur at <150 cm (60 in.) but >75 cm (30 in.).
Rupert Sand (Rp)	One of the most extensive soils on the Hanford Site. Brown-to-grayish-brown coarse sand grading to dark grayish-brown at 90 cm (35 in.). Developed under grass, sagebrush, and hopsage in coarse sandy alluvial deposits that were mantled by wind-blown sand. Hummocky terraces and dune-like ridges.
Hezel Sand (He)	Similar to Rupert sands; however, a laminated grayish-brown strongly calcareous silt loam subsoil is usually encountered within 100 cm (39 in.) of the surface. Surface soil is very dark brown and was formed in wind-blown sands that mantled lake-laid sediments.
Koehler Sand (Kf)	Similar to other sandy soils on the Hanford Site. Developed in a wind-blown sand mantle. Differs from other sands in that the sand mantles a lime-silica cemented "Hardpan" layer. Very dark grayish-brown surface layer is somewhat darker than Rupert. Calcareous subsoil is usually dark grayish-brown at about 45 cm (18 in.).
Burbank Loamy Sand (Ba)	Dark-colored, coarse-textured soil underlain by gravel. Surface soil is usually about 40-cm (16-in.) thick but can be 75 cm (30 in.) thick. Gravel content of subsoil ranges from 20% to 80%.
Ephrata Sandy Loam (El)	Surface is dark colored and subsoil is dark grayish-brown medium-textured soil underlain by gravelly material, which may continue for many feet. Level topography.
Lickskillet Silt Loam (Ls)	Occupies ridge slopes of Rattlesnake Hills and slopes >765 m (2509 ft) elevation. Similar to Kiona series except surface soils are darker. Shallow over basalt bedrock, with numerous basalt fragments throughout the profile.
Ephrata Stony Loam (Eb)	Similar to Ephrata sandy loam. Differs in that many large hummocky ridges are made up of debris released from melting glaciers. Areas between hummocks contain many boulders several feet in diameter.

Name (symbol)	Description
Kiona Silt Loam (Ki)	Occupies steep slopes and ridges. Surface soil is very dark grayish-brown and about 10-cm (4-in.) thick. Dark-brown subsoil contains basalt fragments 30 cm (12 in.) and larger in diameter. Many basalt fragments found in surface layer. Basalt rock outcrops present. A shallow stony soil normally occurring in association with Ritzville and Warden soils.
Warden Silt Loam (Wa)	Dark grayish-brown soil with a surface layer usually 23-cm (9-in.) thick. Silt loam subsoil becomes strongly calcareous at about 50 cm (20 in.) and becomes lighter colored. Granitic boulders are found in many areas. Usually >150 cm (60 in.) deep.
Scootney Stony Silt Loam (Sc)	Developed along the north slope of Rattlesnake Hills; usually confined to floors of narrow draws or small fan-shaped areas where draws open onto plains. Severely eroded with numerous basaltic boulders and fragments exposed. Surface soil is usually dark grayish-brown grading to grayish-brown in the subsoil.
Pasco Silt Loam (P)	Poorly drained very dark grayish-brown soil formed in recent alluvial material. Subsoil is variable, consisting of stratified layers. Only small areas found on the Hanford Site, located in low areas adjacent to the Columbia River.
Esquatzel Silt Loam (Qu)	Deep dark-brown soil formed in recent alluvium derived from loess and lake sediments. Subsoil grades to dark grayish-brown in many areas, but color and texture of the subsoil are variable because of the stratified nature of the alluvial deposits.
Riverwash (Rv)	Wet, periodically flooded areas of sand, gravel, and boulder deposits that make up overflowed islands in the Columbia River and adjacent land.
Dune Sand (D)	Miscellaneous land type that consists of hills or ridges of sand-sized particles drifted and piled up by wind and are either actively shifted or so recently fixed or stabilized that no soil horizons have developed.

Seismicity of the Columbia Plateau, as determined by the rate of earthquakes per area and the historical magnitude of these events, is relatively low when compared with other regions of the Pacific Northwest, the Puget Sound area, and western Montana/eastern Idaho. Figure 4.2-8 shows the locations of all earthquakes that occurred in the Columbia Plateau before 1969 with an MMI of ≥IV and at Richter magnitude ≥4, and Figure 4.2-9 shows the locations of all earthquakes that occurred from 1969 to 1986 at Richter magnitudes ≥3. The largest known earthquake in the Columbia Plateau occurred in 1936 around Milton-Freewater, Oregon. This earthquake had a Richter magnitude of 5.75 and a maximum MMI of VII, and was followed by a number of after shocks that indicate a northeast-trending fault plane. Other earthquakes with Richter magnitudes ≥5 and/or MMIs of VI occurred along the boundaries of the Columbia Plateau in a cluster near Lake Chelan extending into the northern Cascade Range, in 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 event in the Milton-Freewater, Oregon, region in 1921; one near Yakima, Washington, in 1892; and one near Umatilla, Oregon, in 1893.

In the central portion of the Columbia Plateau, the largest earthquakes near the Hanford Site are two earthquakes that occurred in 1918 and 1973. These two events were magnitude 4.4 and intensity V, and were located north of the Hanford Site. 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.

Frequency of earthquakes in a swarm tend to gradually increase and decay with no one outstanding large event within the sequence. Roughly 90% of the earthquakes in swarms have Richter magnitudes of 2 or less. These earthquake swarms generally occur at shallow depths, with 75% of the events located at depths <4 km (2.5 mi.). Each earthquake swarm typically lasts several weeks to months, consists of several to a 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 elongated 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, thoroughgoing fault plane.

Earthquakes in the central Columbia Plateau also occur to depths of about 30 km (18 mi.). These deeper earthquakes are less clustered and occur more often as single, isolated events. Based on seismic refraction surveys in the region, the shallow earthquake swarms are occurring in the Columbia River Basalts, and the deeper earthquakes are occurring 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 Mountains anticline. However, this association is complex, and the earthquakes do not delineate a thoroughgoing 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 fold of the Yakima Fold Belt (Rohay 1987). However, earthquake focal mechanisms indicate faulting on a variety of fault plane orientations.

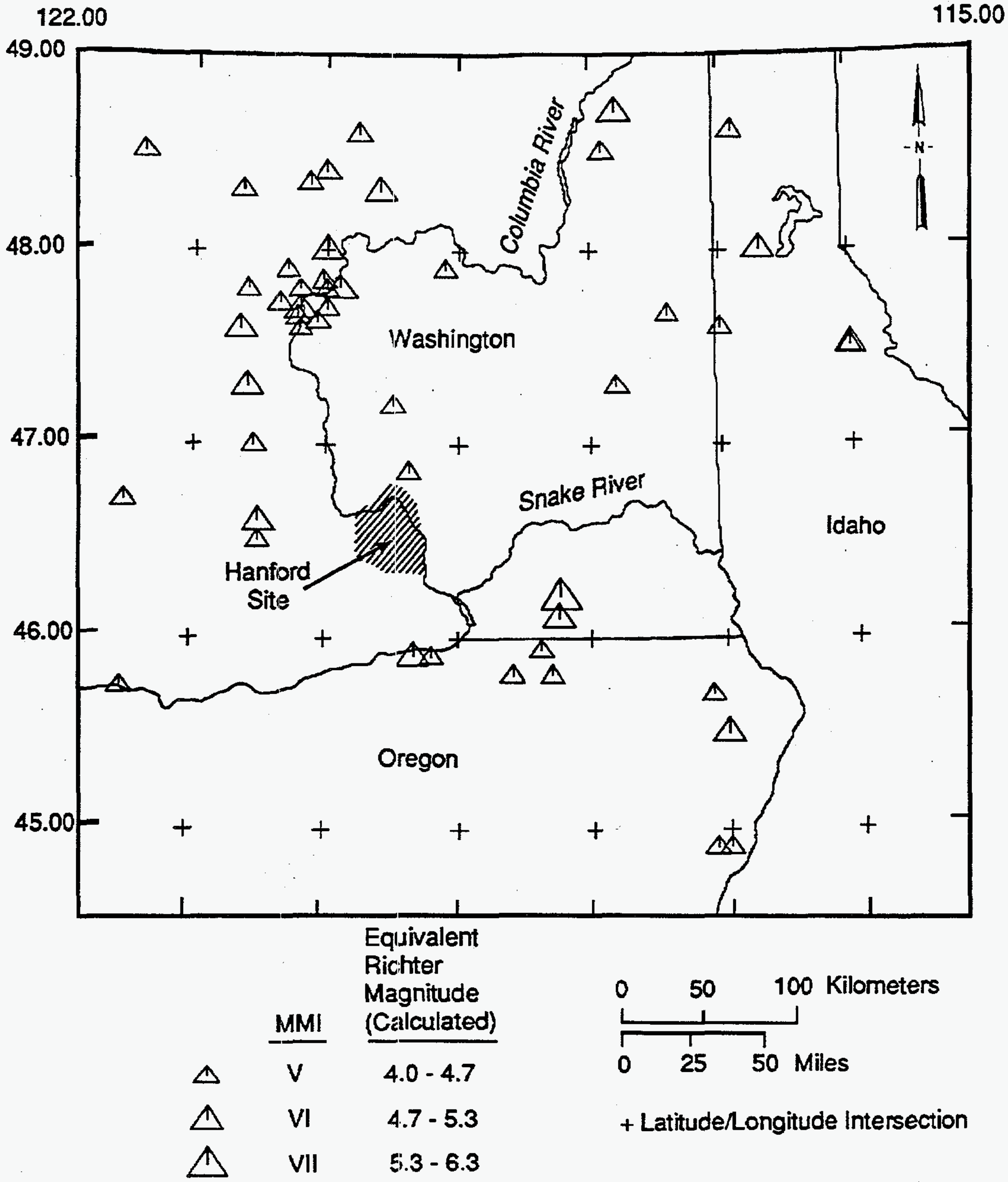

Figure 4.2-8. Historical Seismicity of the Columbia Plateau and Surrounding Areas. All earthquakes between 1850 and March 23, 1969, with a Modified Mercalli Intensity of IV or larger or a Richter magnitude 4 or larger are shown (Rohay 1989).

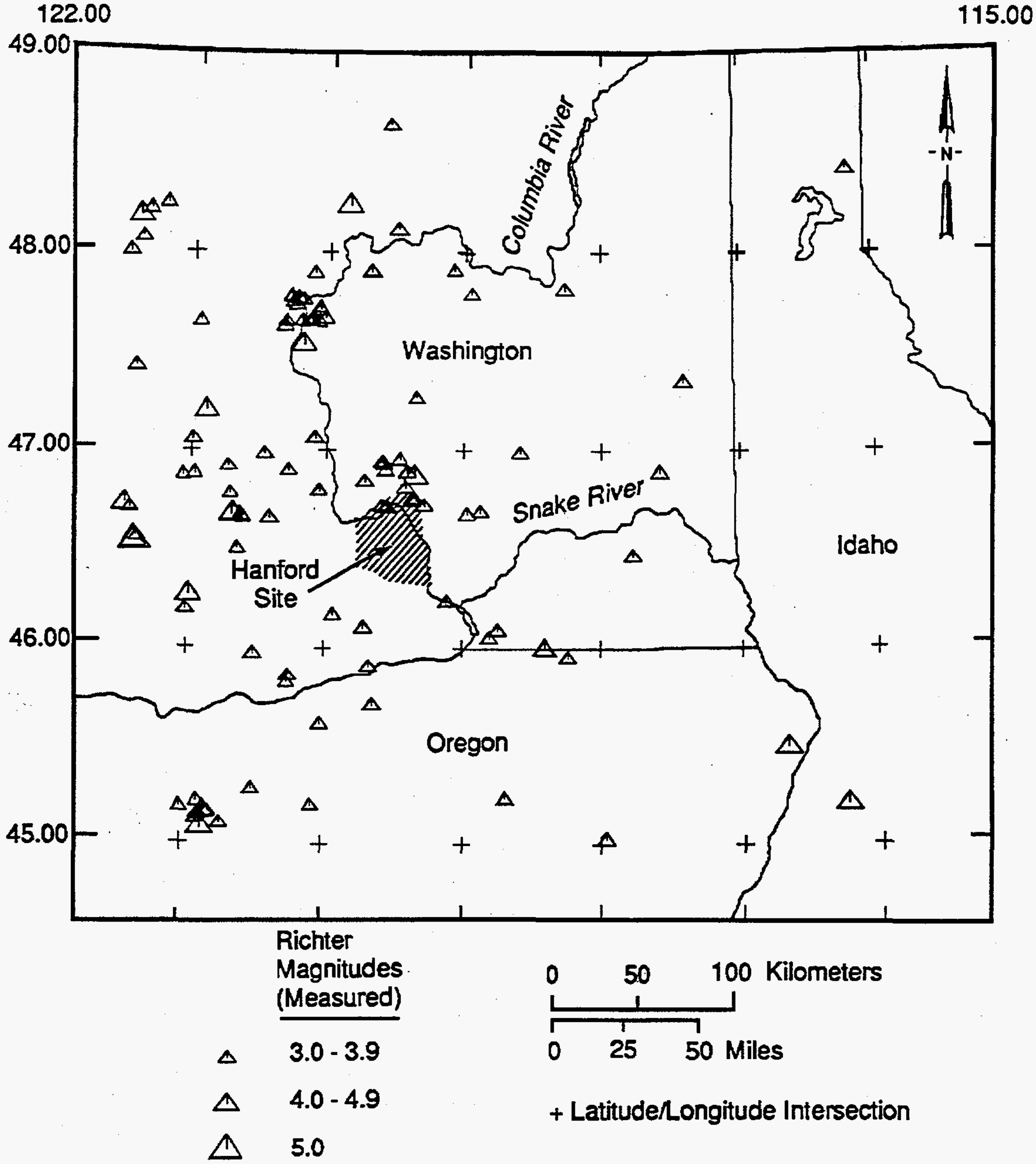

Figure 4.2-9. Seismicity of the Columbia Plateau and Surrounding Areas as Measured by Seismographs. All earthquakes between 1969 and 1989 with Richter magnitude 3 or larger are shown (Rohay 1989).

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-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 the 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 (Supply System) Project WNP-2, the U.S. Nuclear Regulatory Commission (NRC) (NRC 1982) 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.

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, and for Gable Mountain, an east-west structure that passes through the northern portion of the Hanford Site, a maximum Richter magnitude of 5.0. These estimates were based upon 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 purpose of WNP-2 seismic design was a Richter magnitude 4.0 event, based on the maximum swarm earthquake in 1973. (The NRC concluded that the actual magnitude of this event was smaller than estimated previously.)

The Site design basis earthquake for a safety class 1 System Structure and Component (SSC) is 0.20 gravity (Hanford Plant Standard, Standard Design Criterion 4.1). The most recent probabilistic seismic hazard analysis calculated an annual probability of recurrence of 5×10^{-4} for exceeding the design basis earthquake (Geomatrix 1994).

4.3 Hydrology

(Section 4.3 last updated in PNL-6415 Rev. 7, September 1995)

Hydrology considerations at the Hanford Site include surface water and groundwater.

4.3.1 Surface Water

Surface water at Hanford includes the Columbia River (northern and eastern sections), riverbank springs along the river, springs on Rattlesnake Mountain, onsite ponds, and offsite water systems directly east of and across the Columbia River from the Hanford Site. In addition, the Yakima River flows along a short section of the southern boundary of the Site (Figure 4.3-1).

4.3.1.1 Columbia River

The Columbia River is the second largest river in the contiguous limited states in terms of total flow and the dominant surface-water body on the 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 river for irrigation and power, and the Hanford Reach is now currently under consideration for designation as a National Wild and Scenic River as a result of congressional action in 1988 (see Section 6.2.6).

Originating in the mountains of eastern British Columbia, Canada, the Columbia River drains a total area of approximately 680,000 km^2 (262,480 mi^2) en route to the Pacific Ocean. Flow of the Columbia River is regulated by 11 dams within the United States, 7 upstream and 4 downstream of the Site. Priest Rapids is the nearest dam upstream, and McNary is the nearest dam downstream. Lake Wallula, the impoundment created by McNary Dam, extends up near Richland, Washington. 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 to the head of Lake Wallula.

Flows through the Reach fluctuate significantly and are controlled primarily by operations at Priest Rapids Dam. Annual flows near Priest Rapids over the last 68 years have averaged nearly 3360 m^3/s (120,000 ft^3/s) (McGavock et al. 1987). Daily average flows range from 1000 to 7000 m^3/s (36,000 to 250,000 ft^3/s). Monthly mean flows typically peak from April through June during spring runoff from winter snows, and are lowest from September through October, accentuated by extensive river-water removal for irrigated agriculture in the Mid-Columbia Basin. As a result of fluctuations in discharges (called hydropeaking), the depth of the river varies significantly over time. Vertical fluctuations of approximately 1.5 m (>5 vertical ft) are not uncommon along the Reach (Dirkes 1993). The width of the river varies from approximately 300 m (1000 ft) to 1000 m (3300 ft) within the Hanford Site.

The primary uses of the Columbia River include the production of hydroelectric power and extensive irrigation in the Mid-Columbia Basin. Several communities located on the Columbia River rely on the river as their source of drinking water. Water from the Columbia River along the Hanford Reach is also used as a source of drinking water by several onsite facilities and for industrial uses (Dirkes 1993). In addition, the Columbia River is used extensively for recreation, which includes fishing, hunting, boating, sailboarding, water-skiing, diving, and swimming.

4.3.1.2 Yakima River

The Yakima River, bordering a small length of the southern portion of the Hanford Site, has a low annual flow compared to the Columbia River. The average annual flow, based on nearly 60 years of records, is about 104 m^3/s (3712 ft^3/s), with an average monthly maximum of 490 m^3/s (17,500 ft^3/s) and minimum of 4.6 m^3/s (165 ft^3/s). Approximately one-third of the Hanford Site is drained by the Yakima River System.

4.3.1.3 Springs and Streams

Rattlesnake and Snively springs, located on the western part of the Site, form small surface streams. Rattlesnake Springs flows for about 3 km (1.6 mi.) before disappearing into the ground (Figure 4.3-1). Cold Creek and its tributary, Dry Creek, are ephemeral streams within the Yakima River drainage system along the southern portion of the Hanford Site. These streams drain areas to the west of the Hanford Site and cross the southwestern part of the Site towards the Yakima River. Surface flow, when it occurs, infiltrates rapidly and disappears into the surface sediments in the western part of the Site. The ecological characteristics of these systems are described in Section 4.4.2.2.

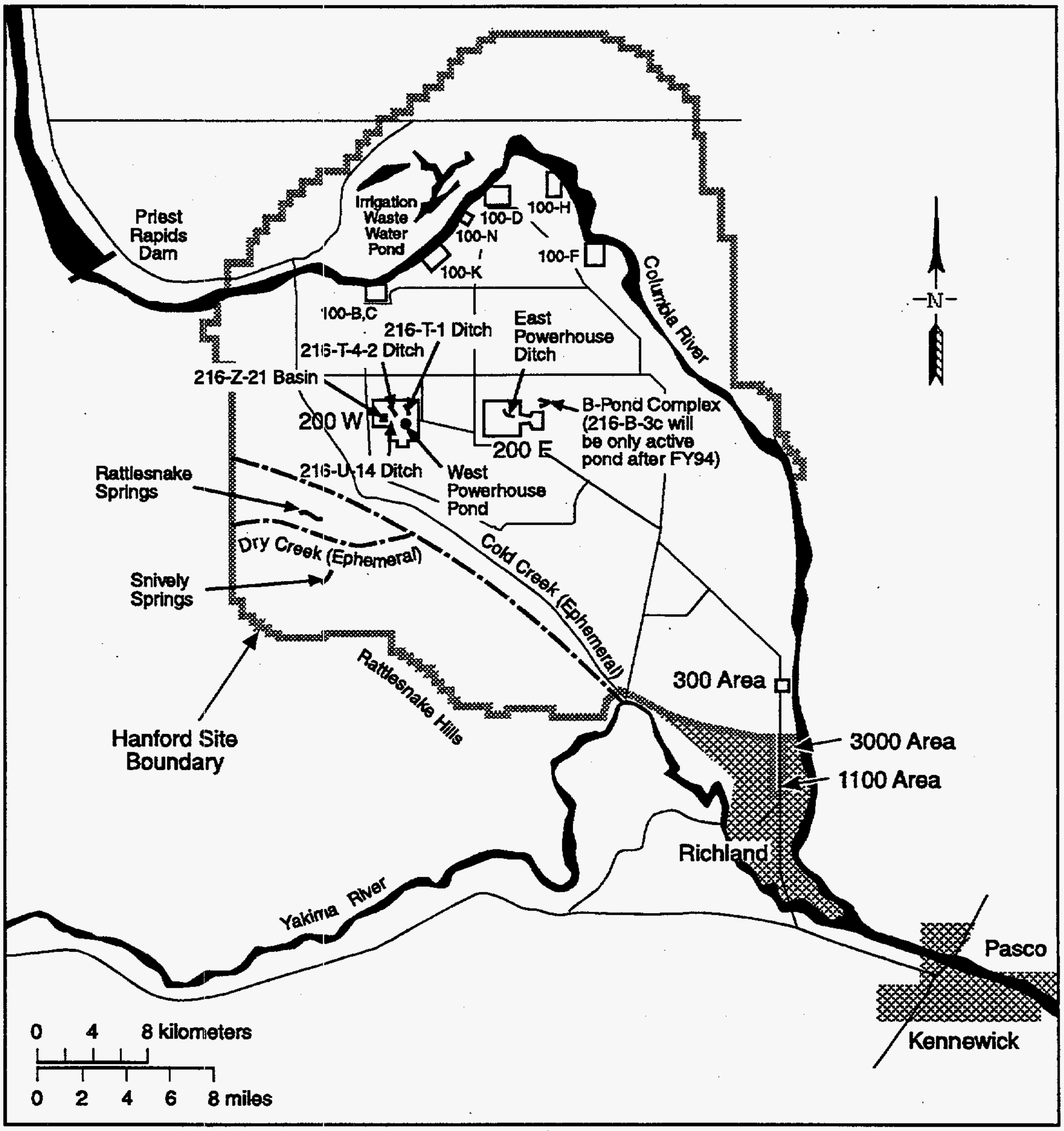

Figure 4.3-1. Temporary Ponds and Ditches, Including Ephemeral Streams, on the Hanford Site

4.3.1.4 Runoff

Total estimated precipitation over the Pasco Basin is about 9×10^8 m^3 (3.2×10^{10} ft^3) annually, averaging <20 cm/yr. (approximately 8 in./yr.). Mean annual runoff from the Pasco Basin is estimated at <3.1×10^7 m^3/yr (1.1x10 ft^3/yr), or approximately 3% of the total precipitation. The basin-wide runoff coefficient is zero for all practical purposes. The remaining precipitation is assumed to be lost through evapotranspiration, with <1% recharging the groundwater system (DOE 1988). However, studies described by Gee et al. (1992) suggest that precipitation may contribute recharge to the groundwater in areas where soils are coarse-textured and bare of vegetation. Studies by Fayer and Walters (1995), Gee and Kirkham (1984), and Gee and Heller (1985) provide information concerning natural recharge rates and evapotranspiration at selected locations on the Hanford Site.

4.3.1.5 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 Site. 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 m^3/s (742,000 ft^3/s). The flood plain associated with the 1894 flood is shown in Figure 4.3-2. The largest recent flood took place in 1948 with an observed peak discharge of 20,000 m^3/s (700,000 ft^3/s) at the Hanford Site. The probability of flooding at the magnitude of the 1894 and 1948 floods has been greatly reduced because of upstream regulation by dams (Figure 4.3-3).

There are no Federal Emergency Management Agency (FEMA) flood plain maps for the Hanford Reach of the Columbia River. FEMA only maps developing areas, and the Hanford Reach is specifically excluded.

There have been fewer than 20 major floods on the Yakima River since 1862 (DOE 1986). The most severe occurred in November 1906, December 1933, and May 1948; discharge magnitudes at Kiona, Washington, were 1870, 1900, and 1050 m^3/s (66,000, 67,000, and 37,000 ft^3/s), respectively. 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 4.3-4).

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^3/s (1.4 million ft^3/s) and is greater than the 500-year flood. The flood plain associated with the probable maximum flood is shown in Figure 4.3-5. This flood would inundate parts of the 100 Areas located adjacent to the Columbia River, but the central portion of the Hanford Site would remain unaffected (DOE 1986).

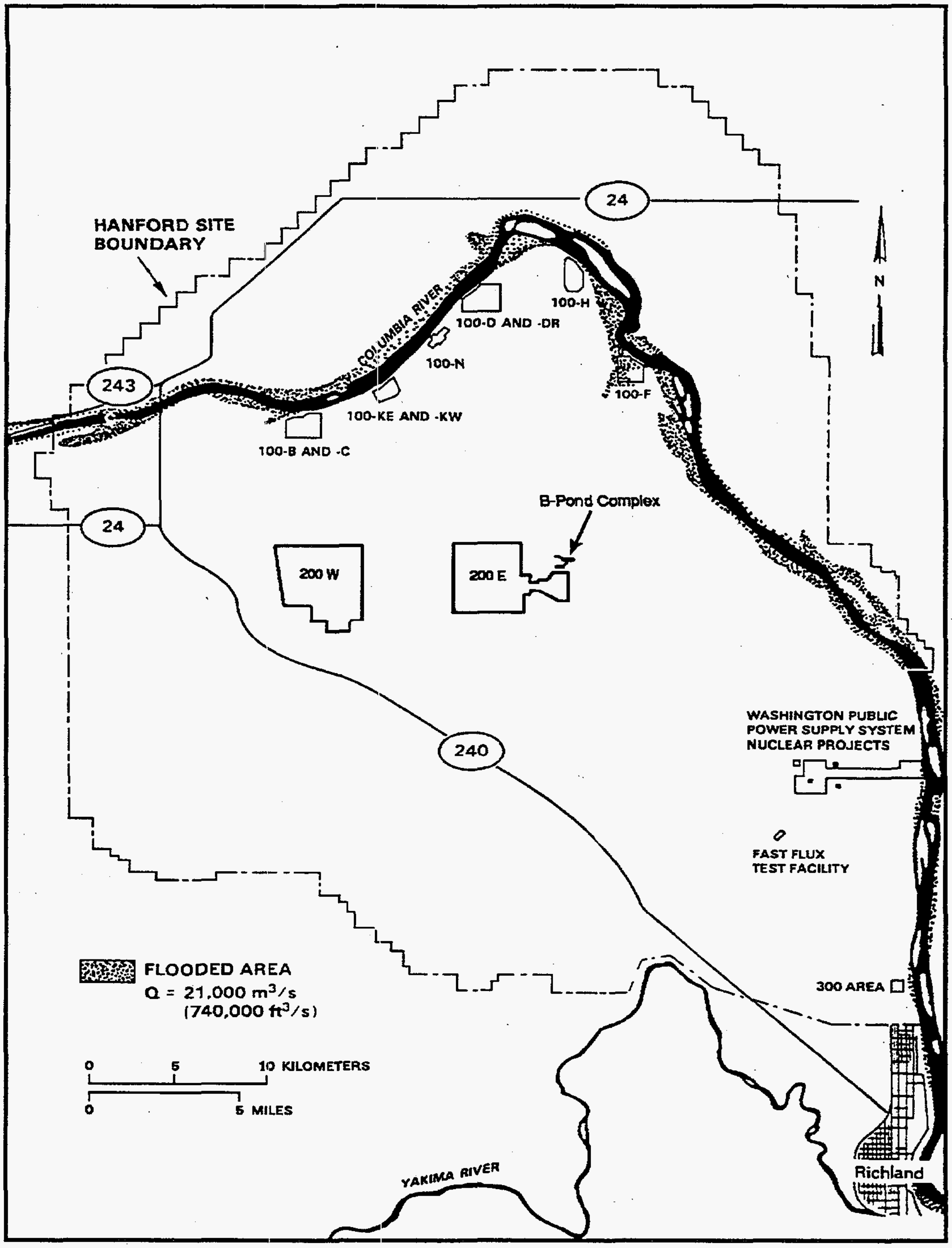

Figure 4.3-2. Flood Area During the 1894 Flood (DOE 1986)

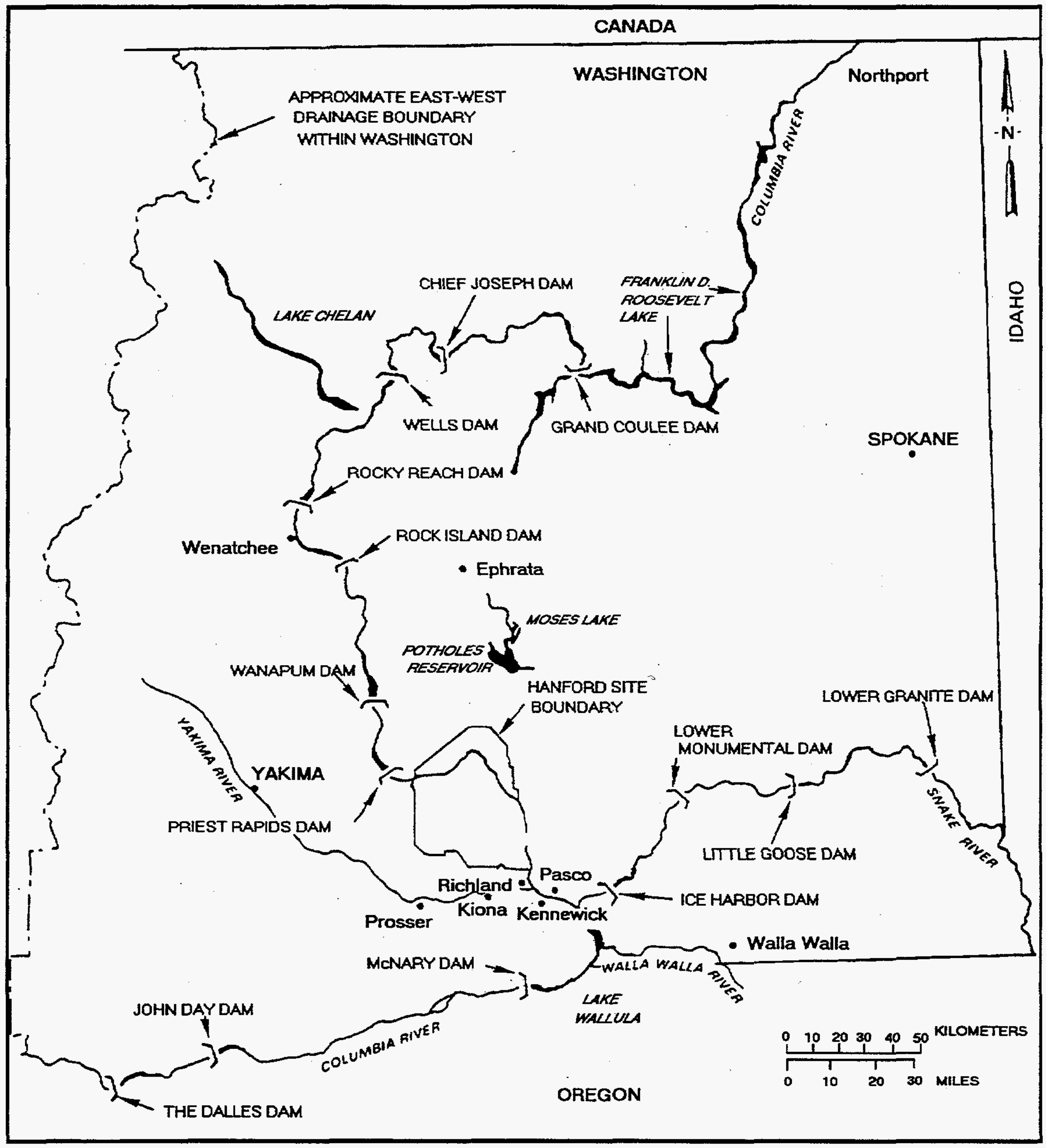

Figure 4.3-3. Locations of Principal Dams Within the Columbia Plateau (after DOE 1988)

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 natural (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^3/s (54,000 ft^3/s) and the 100-year regulated flood as 12,400 m^3/s (440,000 ft^3/s). No maps for the flooded areas are available.

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^3/s (400,000 ft^3/s). For emergency planning, they hypothesized that 25% and 50% breaches, the "instantaneous" disappearance of 25% or 50% of the center section of the dam, would result from the detonation of nuclear explosives in sabotage or war. The discharge or floodwave resulting from such an instantaneous 50% breach at the outfall of the Grand Coulee Dam was determined to be 600,000 m^3/s (21 million ft^3/s). In addition to the areas inundated by the probable maximum flood (Figure 4.3-5), the remainder of the 100 Areas, the 300 Area, and nearly all of Richland, Washington, would be flooded (DOE 1986; see also ERDA 1976). No determinations were made for failures of dams upstream, for associated failures downstream of Grand Coulee, or for breaches >50% of Grand Coulee, for two principal reasons:

1. The 50% scenario was believed to represent the largest realistically conceivable flow resulting from either a natural or human-induced breach (DOE 1986), i.e., it was hard to imagine that a structure as large as Grand Coulee Dam would be 100% destroyed instantaneously.

2. It was also assumed that a scenario such as the 50% 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% 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 also 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 $8x10^5$ m^3 ($1x10^6$ yd^3) landslide volume with a concurrent flood flow of 17,000 m^3/s (600,000 ft^3/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 shown in Figure 4.3-5 (DOE 1986).

A flood risk analysis of Cold Creek was conducted in 1980 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 flood plain studies, a probable maximum flood evaluation was made for a reference repository location directly west of the 200 East Area and encompassing the 200 West Area (Skaggs and Walters 1981). Schematic mapping indicates that access to the reference repository would be unimpaired but that State Route (SR) 240 along the southwestern and western areas would not be usable (Figure 4.3-6).

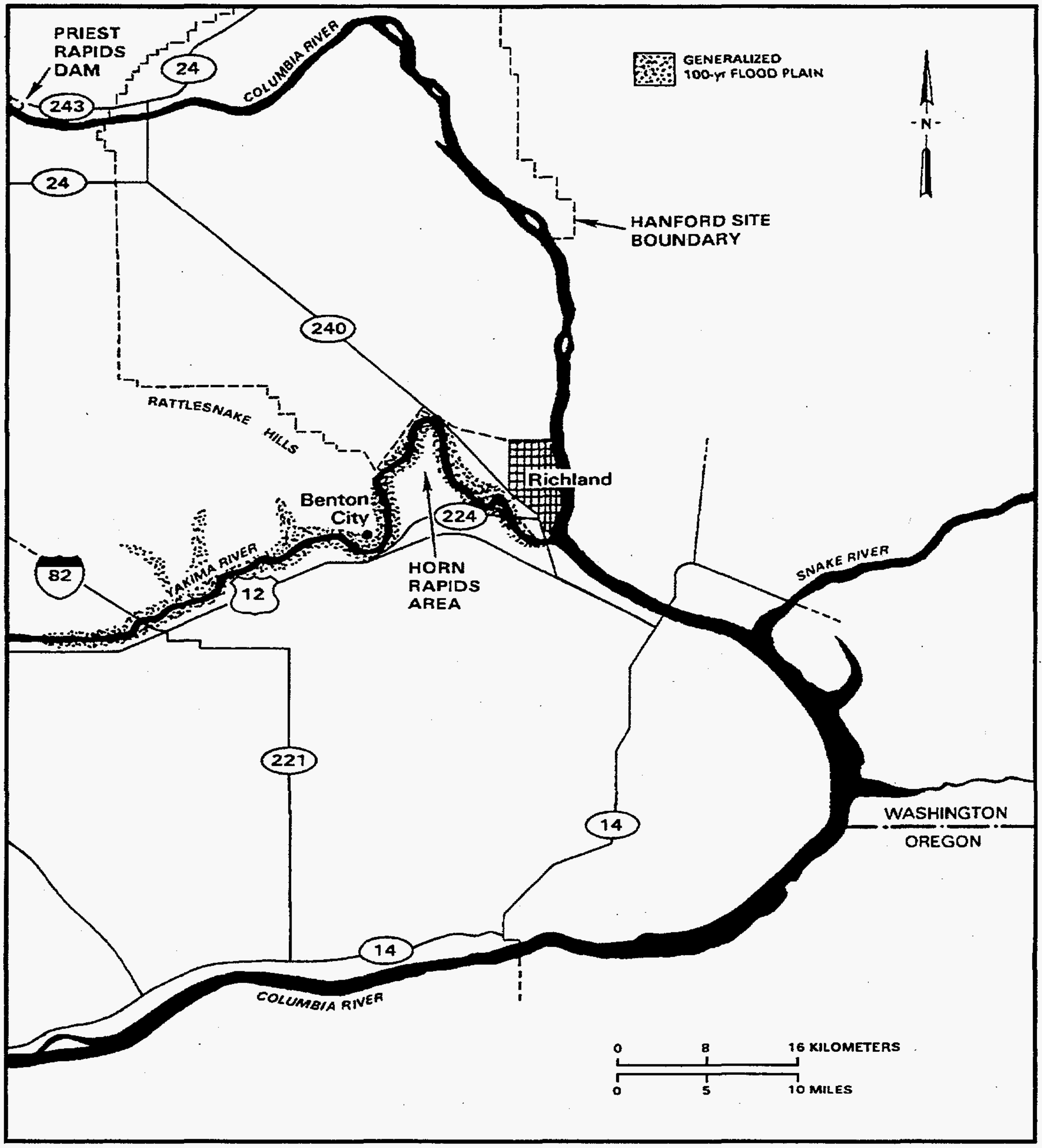

Figure 4.3-4. Flood Area from a 100-Year Flood of the Yakima River near the Hanford Site (DOE 1986)

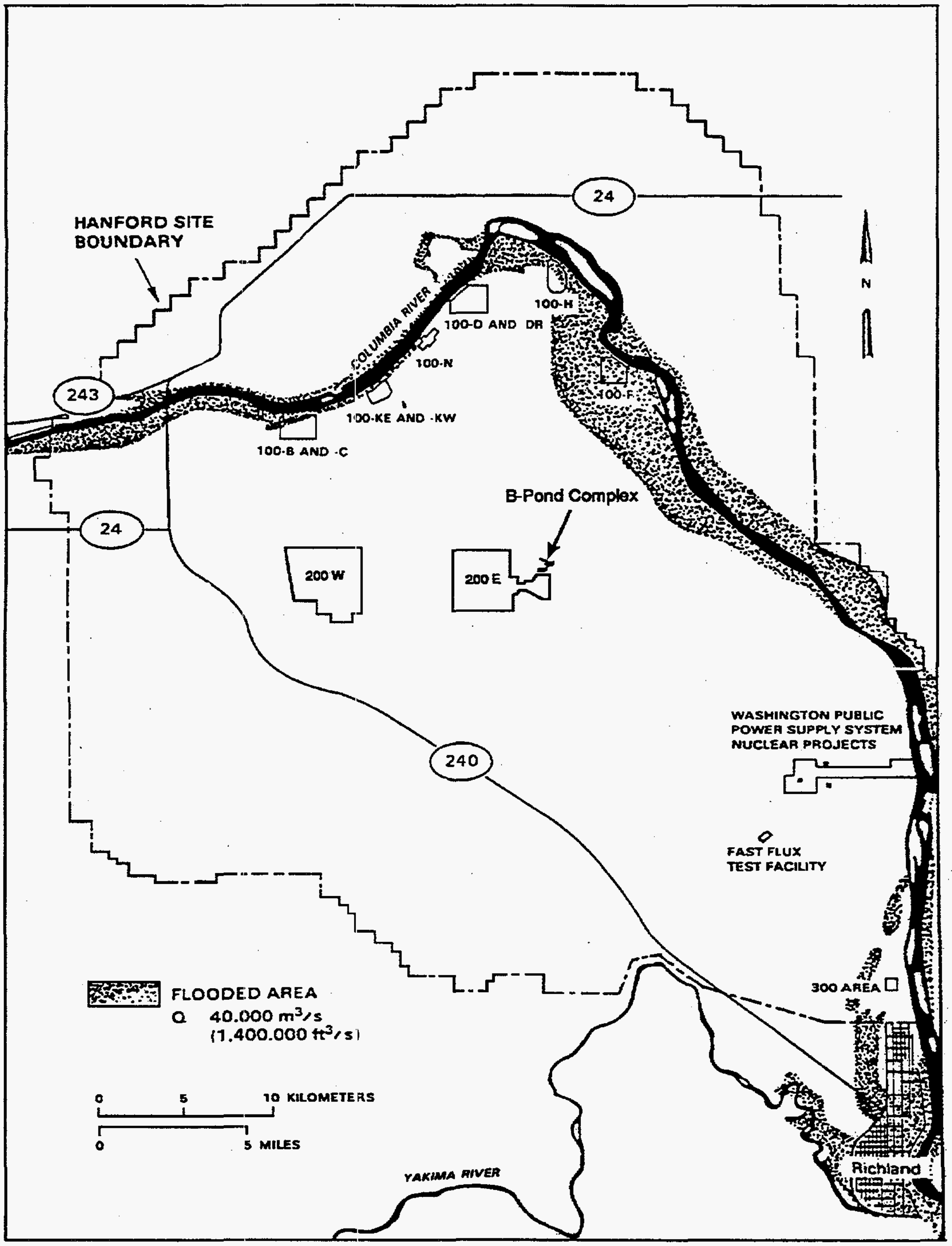

Figure 4.3-5. Flood Area for the Probable Maximum Flood (DOE 1986)

4.3.1.6 Columbia Riverbank Springs

The seepage of groundwater, or springs, into the Columbia River has been known to occur for many years. Riverbank spring discharges were documented along the Hanford Reach long before Hanford operations began during the Second World War (Jenkins 1922). Riverbank springs are monitored for radionuclides at the 100-N Area, the Old Hanford Townsite, and the 300 Area. These relatively small springs flow intermittently, apparently influenced primarily by changes in river level. Hanford-origin contaminants have been documented in these groundwater discharges along the Hanford Reach (Dirkes 1990; DOE 1992a,b; McCormack and Carlile 1984; Peterson and Johnson 1992).

4.3.1.7 Onsite Ponds and Ditches

The ponds and ditches currently active are shown in Figure 4.3-1. In the 200 West Area, the West Powerhouse Pond, the 216-T-1 Ditch, the 216-T-4-2 Ditch, and the 216-Z-21 Basin are active. In the 200 East Area, only the East Powerhouse Ditch and the 216-B-3C Pond are active. The 216-B-3C Pond was originally excavated in the mid-1950s for disposal of process cooling water and other liquid wastes occasionally containing low levels of radionuclides. West Lake is located north of the 200 East Area and is recharged from groundwater (Gephardt et al. 1976). 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 south of Gable Mountain (and north of the 200 East Area). The artificially elevated water table occurs under much of the Hanford Site and reflects the artificial recharge from Hanford Site operations (see Section 4.3.2). The Fast Flux Test Facility (FFTF) Pond is located near the 400 Area and was excavated in 1978 for the disposal of cooling and sanitary water from various facilities in the 400 Area (Woodruff et al. 1993).

The ponds are not accessible to the public and did not constitute a direct offsite environmental impact during 1993 (Dirkes et al. 1994). However, the ponds are accessible to migratory waterfowl, creating a potential pathway for the dispersion of contaminants. Periodic sampling provides an independent check on effluent control and monitoring systems (Woodruff et al. 1993).

Studies were initiated in the spring of 1993 to evaluate the potential for use of water storage facilities at the former 100-K Area fuel production site for fish production (see Section 4.4.2.1).

4.3.1.8 Offsite Water

Other than rivers and springs, there are no naturally occurring bodies of surface water adjacent to the Hanford Site. However, there are artificial wetlands, caused by irrigation, on the east and west sides of the Wahluke Slope portion of the Hanford Site, which lies north of the Columbia River. Hatcheries and canals associated with the Columbia Basin Irrigation Project constitute the only other artificial surface water expressions in the area. The Ringold Hatchery is the only local hatchery, just south of the Hanford Site boundary on the east side of the Columbia River (just north of the 300 Area). The Riverview Irrigation Canal and four other sites were sampled in 1994 for possible "downwind" airborne contamination. Radionuclide concentrations were found at the same levels detected in the Columbia River both upstream and downstream of the Hanford Site (Dirkes and Hanf 1995).

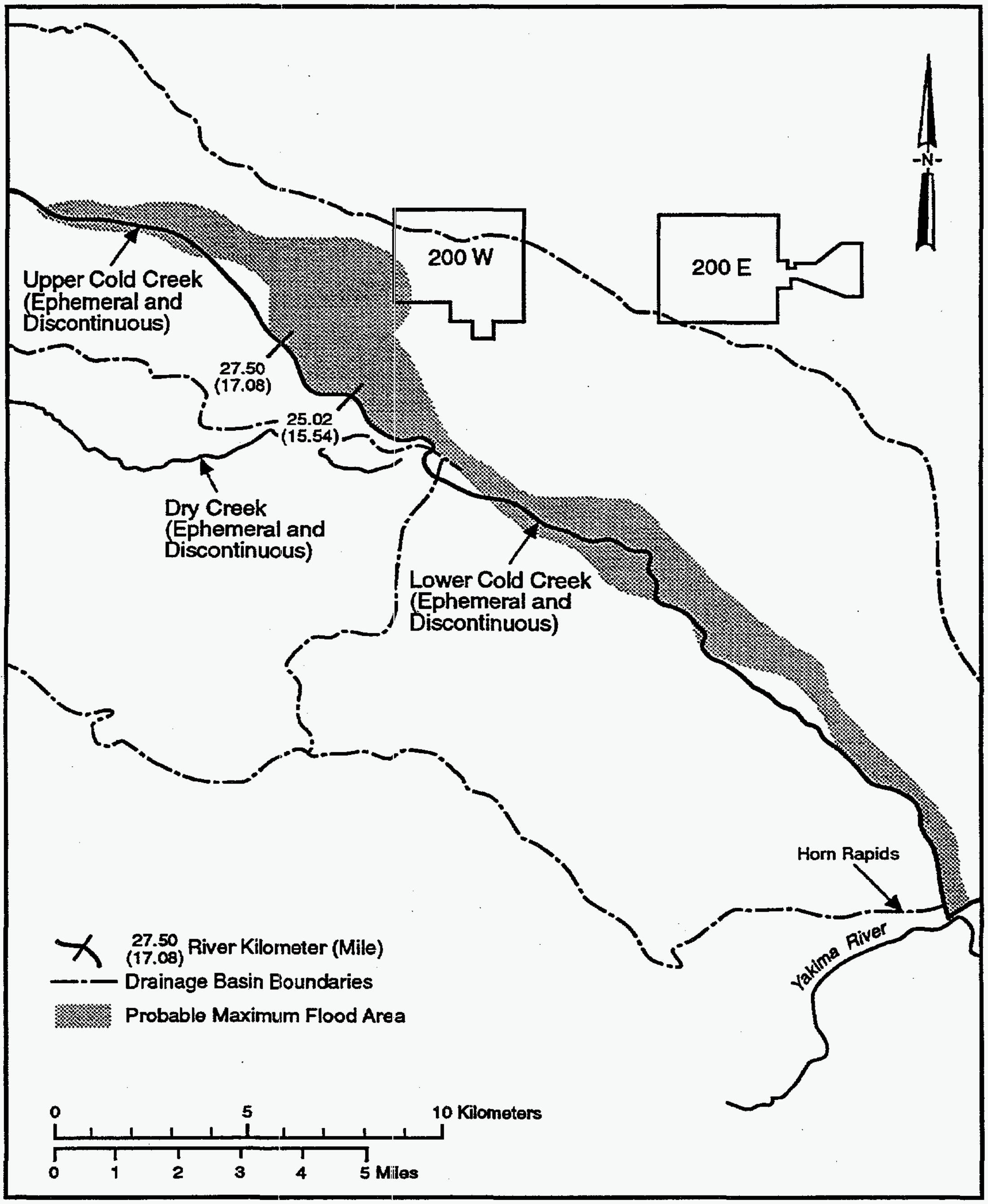

Figure 4.3-6. Extent of Probable Maximum Flood in Cold Creek Area (from Skaggs and Waters 1981).

4.3.2 Groundwater

Groundwater is but one of the many interconnected stages of the hydrologic cycle. Essentially all groundwater, including Hanford's, originates as surface water either from natural recharge such as rain, streams, and lakes, or from artificial recharge such as reservoirs, excess irrigation, canal seepage, deliberate augmentation, industrial processing, and wastewater disposal.

4.3.2.1 Hanford Site Aquifer System

The unconfined aquifer is also referred to as the upper or suprabasalt aquifer system because portions of the upper aquifer system are locally confined or semiconfined, and because in the 200 East Area the unconfined system is in communication with the confined system. However, because the entire suprabasalt aquifer system is interconnected on a Sitewide scale, it is called the Hanford unconfined aquifer for this report. Aquifers located within the Columbia River Basalts are referred to as the confined aquifer system. The following presentation of the Hanford Site aquifer systems is taken from Thorne and Chamness (1992).

Confined Aquifer System. Confined aquifers within the Columbia River Basalts are within relatively permeable sedimentary interbeds and the more porous tops and bottoms of basalt flows. The horizontal hydraulic conductivities of most of these aquifers fall in the range of 10^{-10} to 10^{-4} m/s (3×10^{-10} to 3×10^{-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 (3×10^{-15} to 3×10^{-9} ft/s), about five orders of magnitude lower than those of the confined aquifers (DOE 1988). Hydraulic-head information indicates that groundwater in the confined aquifers flows generally towards the Columbia River and, in some places, towards areas of enhanced vertical low communication with the unconfined system (Bauer et al. 1985; DOE 1988; Spane 1987). The confined aquifer system is important for two reasons. First, the system is known to be in hydraulic communication with the unconfined aquifer in the area northeast of the 200 East Area (Graham et al. 1984); second, there is a potential for significant groundwater leakage between the two systems. No data quantifying the leakage between the upper confined and unconfined aquifers are available. Head relationships presented in previous reports (DOE 1988) demonstrate the potential for such leakage. Water chemistry data indicating that interaquifer leakage has taken place in areas of increased vertical communication also have been presented in published reports (Graham et al. 1984; Jensen 1987; Johnson et al. 1993).

Unconfined Aquifer. Groundwater in the unconfined aquifer at Hanford generally flows from recharge areas in the elevated region near the western boundary of the Hanford Site towards the Columbia River on the eastern and northern boundaries (Figure 4.3-7). 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 river shorelines, daily river level fluctuations may result in an elevation change of 1.8 to 2.4 m (6 to 8 ft), and seasonal fluctuations may range from 2.4 to 3 m (8 to 10 ft). As the river stage rises, a pressure wave is transmitted inland through the groundwater. The longer the duration of the higher river stages, the farther inland the effect is propagated. The pressure wave is observed farther inland than the water actually goes. 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).

Natural areal recharge from precipitation across the entire Hanford Site is thought to range from about 0 to 10 cm/yr. (0 to 4 in./yr.) but is probably <2.5 cm/yr. (1 in./yr.) over most of the Site (Gee and Heller 1985; Bauer and Vaccaro 1990). Since 1944, the artificial recharge from Hanford wastewater disposal has been significantly greater than the natural recharge. An estimated 1.68×10^{12} L (4.44×10^{11} gal) of liquid was discharged to disposal ponds, trenches, and cribs from 1944 to the present.

Horizontal hydraulic conductivities of sand and gravel facies within the Ringold Formation generally range from about 10^{-5} to 10^{-4} m/s (0.9 to 9 ft/d), compared to 10^{-2} to 10^{-3} m/s (1,000 to 10,000 ft/d) for the Hanford formation (DOE 1988). Because the Ringold 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 have raised the water table elevation across the Site and created groundwater mounds under the two main wastewater disposal areas in the 200 Areas. Because of the general increase in groundwater elevation, the unconfined aquifer now extends upward into the Hanford formation. This change has resulted in an increase in groundwater transmissivity not only because of the greater volume of groundwater but also because the newly saturated Hanford sediments are highly permeable.

Since the beginning of Hanford operations in 1943, the water table has risen about 27 m (89 ft) under at least one disposal area in the 200 West Area and about 9 m (30 ft) under disposal ponds near the 200 East Area. The volume of water that has been discharged to the ground at the 200 West Area is actually less than that discharged at the 200 East Area. However, the lower conductivity of the aquifer near the 200 West Area has inhibited groundwater movement in this area and resulted in a higher groundwater mound.

The presence of the groundwater mounds has locally affected the direction of groundwater movement, causing radial flow from the discharge areas. Zimmerman et al. (1986) documented changes in water table elevation between 1950 and 1980. They showed that the edge of the mounds migrated outward from the sources over time until about 1980. Water levels have declined in some areas since 1984 because of decreased wastewater discharges (Kasza et al. 1994).

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 is a limited number of useful wells for defining the deeper 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. Coarse-grained units of the Ringold Formation (e.g., Units A, B, C, D, and E) are more permeable than are the fine-grained units, which generally act as aquitards throughout their extent to form semiconfined aquifers. Because these fine-grained units do not extend across the entire Hanford Site, however, the water can move from unconfined to semiconfined conditions and back to unconfined.

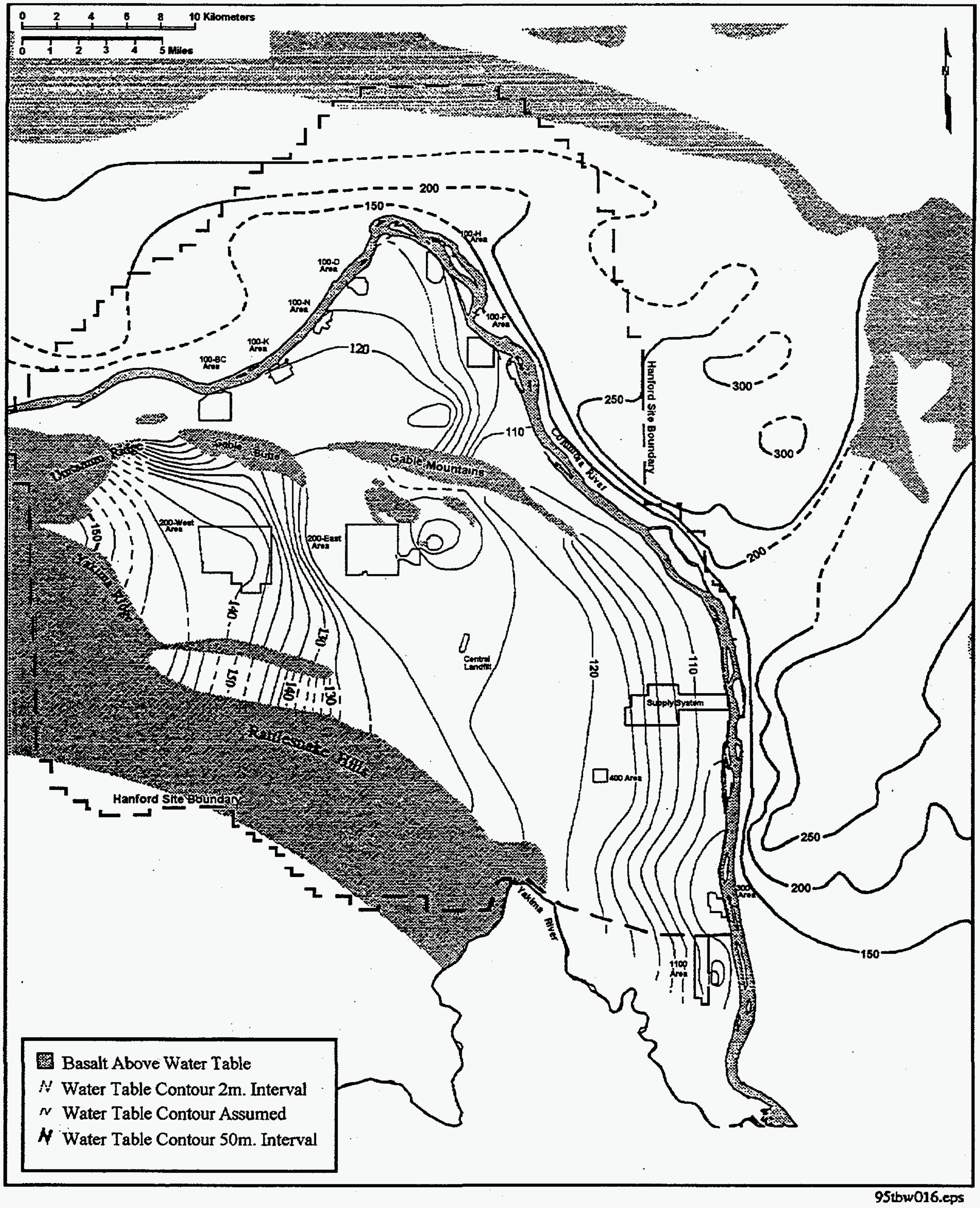

Figure 4.3-7. Water-Table Elevations for the Unconfined Aquifer at Hanford, June 1994 (from Dirkes and Hanf 1995)

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 Ground-Water Surveillance Project and for environmental restoration efforts (Connelly et al. 1992a,b; Kipp and Mudd 1973; Thorne and Newcomer 1992; Thorne et al. 1993). Depths of the tested intervals have been correlated with the top of the unconfined aquifer as defined by the water-table elevations presented in Newcomer et al. (1991). Most hydraulic tests were done 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. Only three hydraulic tests within the Hanford Site have resulted in estimates of aquifer-specific yield.

Natural Groundwater Quality. Groundwater chemistry in the confined aquifer units displays a range, depending upon depth and residence time, from a calcium and magnesium carbonate water to a sodium and chloride carbonate water. Some of the shallower confined aquifers in the region (e.g., the Wanapum basalt aquifer at <300 m [984 ft]) have exceptionally good water-quality characteristics: <300 mg/L dissolved solids; <0.1 mg/L iron and magnesium; <20 mg/L sodium, sulfate, and chloride; and <10 ppb heavy metals (Johnson et al. 1992). DOE (1992b) discusses the water quality of the background (i.e., unaffected by Hanford discharges) unconfined aquifer on the Hanford Site.

Groundwater Residence Times. Tritium and carbon-14 measurements indicate that residence or recharge time (length of time required to replace the groundwater) takes tens to hundreds of years for spring waters, from hundreds 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 ages greater than 100,000 years for groundwater in the deeper confined systems (Johnson et al. 1992). These relatively long residence times are consistent with semiarid-site recharge conditions and point to the need for conservation. For example, in the western Pasco Basin, extensive agricultural groundwater use of the Priest Rapids Member confined aquifer (recharge time >10,000 years) has lowered the potentiometric surface >10 m (33 ft) over several square miles to the west of the Hanford Site. Continued excessive withdrawals along the western edge of the Pasco Basin could eventually impact the confined aquifer flow directions beneath the 200 West Area of the Hanford Site (Johnson et al. 1992).

Hydrology East and North of the Columbia River. The Hanford Site boundary extends to the east and north of the Columbia River to provide a buffer zone for non-Hanford activities such as recreation and agriculture. Hanford Site activities in these areas have not impacted the groundwater. However, the groundwater is impacted by high artificial recharge from irrigation practices and leaky canals. The outlying areas east and north of the Columbia River are irrigated by the South Columbia Basin Irrigation District, which is part of the Columbia Basin Irrigation District, and artificial recharge has elevated the water table throughout the Pasco Basin, in some places 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 the Saddle Mountains and the Esquatzel Diversion canal and includes the Ringold Coulee, White Bluffs area, and Esquatzel Coulee. The water table occurs in the Pasco Gravels in both the Ringold and Esquatzel Coulee, and Brown (1979) reported that runoff from spring discharge at the mouth of Ringold Coulee is >37,850 L/min (10,000 gal/min). Elsewhere, the unconfined aquifer is in the less-transmissive Ringold Formation. Irrigation has also resulted in a series of springs issuing from perched water along the White Bluffs and subsequent slumping and landslides. Irrigation on the Wahluke Slope and the area east of the Columbia River has created perched water tables in addition to very steep hydraulic gradients (Brown 1979; Newcomer et al. 1992).

The other principal area of irrigation is the northern part of the Pasco Basin on the Wahluke Slope between the Columbia River and the Saddle Mountain anticline. Irrigation on Wahluke Slope north of the Columbia River has created ponds and seeps in the Saddle Mountain Wildlife Refuge. The major unconfined groundwater flow is downward movement from the anticlinal axes of the basalt ridges towards the Columbia River where it flows within a syncline. 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.

4.3.3 Water Quality of the Columbia River

The state of Washington has classified the stretch of the Columbia River from Grand Coulee to the Washington-Oregon border, which includes the Hanford Reach, as Class A, Excellent (Ecology 1992). Class A waters are to be suitable for essentially all uses, including raw drinking water, recreation, and wildlife habitat. State and federal drinking water standards (DWS) apply to the Columbia River and are currently being met (see Section 6.2.2).

Water samples were collected quarterly from the Columbia River along cross sections established at the Vernita Bridge (upstream of the Hanford Site) and the Richland Pumphouse (downstream of the Hanford Site), and annually from 100-N, 100-F, Old Hanford Townsite, and the 300 Area during 1994 (Figure 4.3-8) (Dirkes and Hanf 1995). The current major source of heat to the Columbia River in the Hanford Reach is solar radiation (Dauble et al. 1987). The average pH values ranged from 8.0 to 8.4 for all samples from the Vernita Bridge and Richland Pumphouse single-point sampling locations. Mean specific conductance values for the same sampling locations range from 128 to 165 μS/cm. There is no apparent difference between the two locations.

Radionuclides consistently detected in the river during 1994 were ^{3}H, ^{90}Sr, ^{129}I, $^{239/240}Pu$, ^{234}U, and ^{238}U. Total alpha and beta measurements (useful indicators of the general radiological quality of the river that provide an early indication of changes in radioactive contamination levels because results are obtained quickly) were similar to the previous year, and were approximately 5% or less of the applicable DWS of 15 and 50 pCi/L, respectively. Tritium measurements continue to be well below state and federal DWS (Dirkes and Hanf 1995). The presence of a ^{3}H concentration gradient at the Richland Pumphouse supports previous conclusions made by Backman (1962) and Dirkes (1993) that contaminants in the 200 Area groundwater plume entering the river at and upstream of the 300 Area are not completely mixed by the time the river reaches the Richland Pumphouse.

All nonradiological water quality standards were met for Class A-designated water (Dirkes and Hanf 1995).

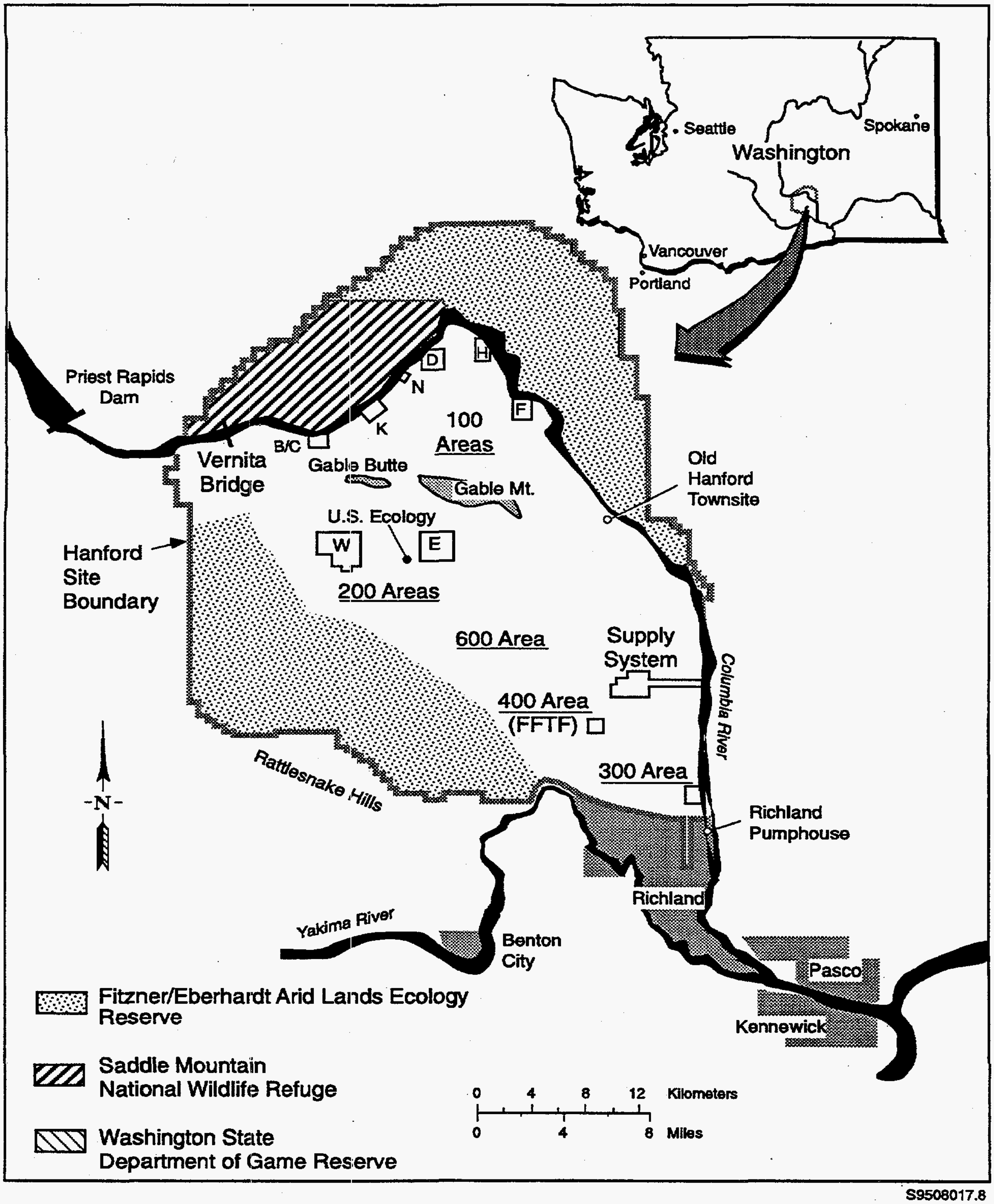

Figure 4.3-8. Sites of Columbia River Monitoring (from Dirkes et al. 1994)

4.3.4 100 Areas Hydrology

Along the Hanford Reach, the water table ranges in depth from 10 to 30 m (33 to 107 ft), and the groundwater flow direction is towards the river. However, during river stages when the river level is above the groundwater table, the flow is away from the river. The water table in the 100 Areas is generally within the Hanford formation, although there are two large areas (Figure 4.3-9) where the water table is within the Ringold Formation (Lindsey 1992). A number of studies on the hydrology of various sites in the 100 Areas discuss the specific hydrologic information available. These reports include 100-B/C Area - Lindberg (1993a); 100-D Area - Lindsey and Jaeger (1993); 100-F Area - Lindsey (1992), Petersen (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).

4.3.5 200 Areas Hydrology

The hydrology of the 200 Areas is strongly influenced by the discharge of large quantities of wastewater to the ground over a 50-year period. Those discharges have caused elevated water levels across much of the Hanford Site, and specific mounds beneath U Pond in the 200 West Area and B Pond in the 200 East Area. Discharges of water to the ground are being greatly reduced, and corresponding decreases in the water table of up to 9 m (29.5 ft) have been measured in the 200 Areas and beyond (Kasza et al. 1994). 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).

Changes vary between the 200 West and 200 East Areas in part because the water table occurs in different units with different hydraulic properties. In the 200 West Area, the water table occurs primarily in Ringold Unit E, while in the 200 East Area, it occurs primarily in the Hanford formation. Ringold Unit E generally has a lower hydraulic conductivity than the Hanford formation. On the north side of the 200 East Area, there is evidence of erosion of the uppermost basalt unit down to the Rattlesnake Ridge Interbed, allowing communication between the unconfined and uppermost confined basalt aquifer (Graham et al. 1984; Jensen 1987).

A number of reports dealing with the hydrogeology of the 200 Areas have been released including the following: Connelly et al. (1992a,b), Jackson (1992), Kasza et al. (1991), Last et al. (1989), Newcomer et al. (1992), and Swanson et al. (1992).

4.3.6 300 Area Hydrology

The unconfined aquifer water table in the 300 Area is generally found in the Ringold Formation at a depth of 9 to 19 m (30 to 62 ft) below ground surface. Fluctuations in the river level strongly affect the groundwater levels and flow in the 300 Area, just as they do in the 100 Areas. Groundwater flows from the northwest, west, and even the southwest to discharge into the Columbia River near the 300 Area. Schalla et al. (1988) and Swanson (1992) have provided more detailed information on the hydrogeology of the 300 Area.

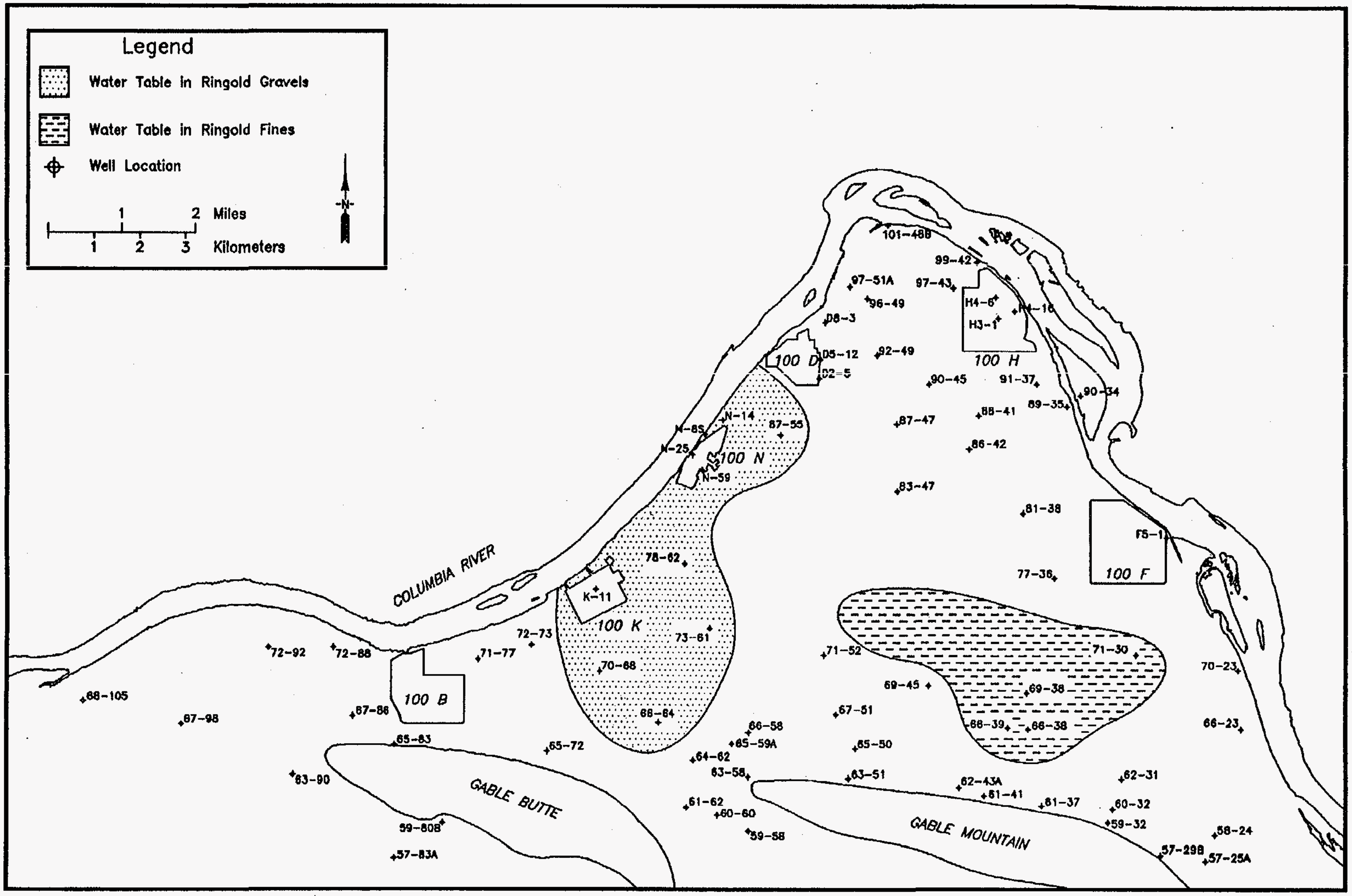

Figure 4.3-9. Geologic Units Intersected by the Water Table in the 100 Areas (modified from Lindsey 1992)

4.3.7 1100 and Richland North Areas Hydrology

The groundwater in the southeastern portion of the Hanford Site is less impacted by Hanford Site operations than by other activities. In addition to natural recharge, artificial recharge is associated with the North Richland recharge basins (used to store Columbia River water for Richland water use) south of the 1100 Area, and irrigated farming near the Richland North Area and west and southwest of the 1100 Area. Although pumping to obtain water also occurs from the unconfined aquifer in these areas, there is a mound in the water table beneath the Richland city system of recharge basins. The Richland city recharge basins are used primarily as a backup system between January and March each year when the filtration plant is closed for maintenance, and during the summer months to augment the city's river-water supply. The water level also rose from December 1990 and December 1991 in the area of the Lamb-Weston Potato-Processing Plant, which uses large amounts of water and, except for plant maintenance during July, operates year-round. The water table in the 1100 Area seems to reflect irrigation cycles connected with agriculture and the growing season (Newcomer et al. 1992).

4.4 Ecology

(Subsection 4.4.3 updated for PNL-6415 Rev. 9)

The Hanford Site encompasses 1450 km^2 (~560 mi^2) of shrub-steppe habitat that is adapted to the region's mid-latitude semiarid climate (Critchfield 1974). The Site encompasses undeveloped land interspersed with industrial development along the western shoreline of the Columbia River and at several locations in the interior of the Site. This land, with restricted public access, provides a buffer for the smaller areas currently used for storage of nuclear materials, waste storage, and waste disposal; only about 6% of the land area has been disturbed and is actively used. Operation of the Site infrastructure contributes to the primary Site mission of clean up.

The Hanford Site is characterized as a shrub-steppe ecosystem (Daubenmire 1970). Such ecosystems are typically dominated by a shrub overstory with a grass understory; in the early 1800s, dominant plants in the area were big sagebrush underlain by perennial Sandberg's bluegrass and bluebunch wheatgrass. With the advent of settlement, livestock grazing and agricultural production contributed to colonization by nonnative plant species that currently dominate many parts of the landscape. Although agriculture and livestock production were the primary subsistence activities at the turn of the century, these activities ceased when the Site was designated in 1943.

The Hanford Site is bordered to the east by the Columbia River. Operation of Priest Rapids Dam upstream of the Site accommodates maintenance of intakes at the Hanford Site and contributes to management of anadromous fish populations. The Columbia River provides habitat for various wildlife and vegetation species as well as recreation and commercial navigation.

Several areas, totaling 655 km^2 (253 mi^2), on the Site have been designated for research or as wildlife refuges. These include the Fitzner/Eberhardt ALE Reserve, the U.S. Fish and Wildlife Service Saddle Mountain National Wildlife Refuge, and the Washington State Department of Fish and Wildlife Wahluke Slope Wildlife Area.

Other descriptions of the ecology of the Hanford Site can be found in DOE (1996a), Cadwell (1994), Downs et al. (1993), ERDA (1975), Jamison (1982), Rogers and Rickard (1977), Sackschewsky et al. (1992), Soll and Soper (1996), Watson et al. (1984), and Weiss and Mitchell (1992).

4.4.1 Terrestrial Ecology

4.4.1.1 Vegetation

The distribution of plant species on the Hanford Site has been significantly altered by human activities in the last 100 years, resulting in large-scale colonization by nonnative species. These introduced plants are now the dominant or most abundant species in many areas. Of the 590 species of vascular plants recorded for the Hanford Site, approximately 20% of all species are considered nonnative (Sackschewsky et al. 1992). The most common species, cheatgrass, is an aggressive colonizer and has become well established across the Site (Rickard and Rogers 1983). Compared with other semiarid regions in North America, primary productivity is relatively low. This difference is attributed to low annual precipitation (16 cm [6.3 in.]), low water-holding capacity of the rooting substrate (sand), and dry summers and cold winters. Many species are adapted to wildfire that frequently burn large areas during the dry summers.

Vegetation and land use areas that occur across the Hanford Site are illustrated in Figure 4.4-1. Vegetation types on the Hanford Site include various combinations of overstory shrubs and native bunchgrass or cheatgrass, areas recovering from fire, grasslands, riparian areas, abandoned old fields, disturbed areas and specialized habitats such as dune fields and basalt outcrops. A list of common plant species in shrub-steppe and riparian areas are presented in Table 4.4-1. A much broader definition of these types including shrublands, grasslands, tree zones, riparian, and unique 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 et al. 1992). Of the shrubland types, sagebrush-dominated communities are the predominant type, with other shrub communities varying with changes in soil and elevation.

The areas botanically characterized as shrub-steppe include remnant native big sagebrush, threetip sagebrush, bitterbrush, gray rabbitbrush, and spiny hopsage. Remnant bluebunch wheatgrass, Sandberg's bluegrass, needle-and-thread grass, Indian ricegrass, and prairie Junegrass also occur in this vegetation type. Heterogeneity of species composition varies with soil, slope, and elevation. Of the vegetation types depicted in Figure 4.4-1, those with a shrub component (i.e., big sagebrush, threetip sagebrush, bitterbrush, spiney hopsage, and rabbitbrush) are considered shrub-steppe. Vegetation types with a significant cheatgrass component are generally of lower habitat quality than those with bunchgrass understories. Areas with winterfat or snow-buckwheat overstories are also generally classified as shrub-steppe. Postfire shrub-steppe on the Columbia River Plain refers to areas impacted by wildfire that are in the process of redeveloping shrub-steppe characteristics.

Grasslands. Most grasses occur as understory in shrub-dominated plant communities. Cheatgrass has replaced many native perennial grass species and is well established in many low-elevation (<244 m [800 ft]) and/or disturbed areas (Rickard and Rogers 1983). Of the native grasses that occur

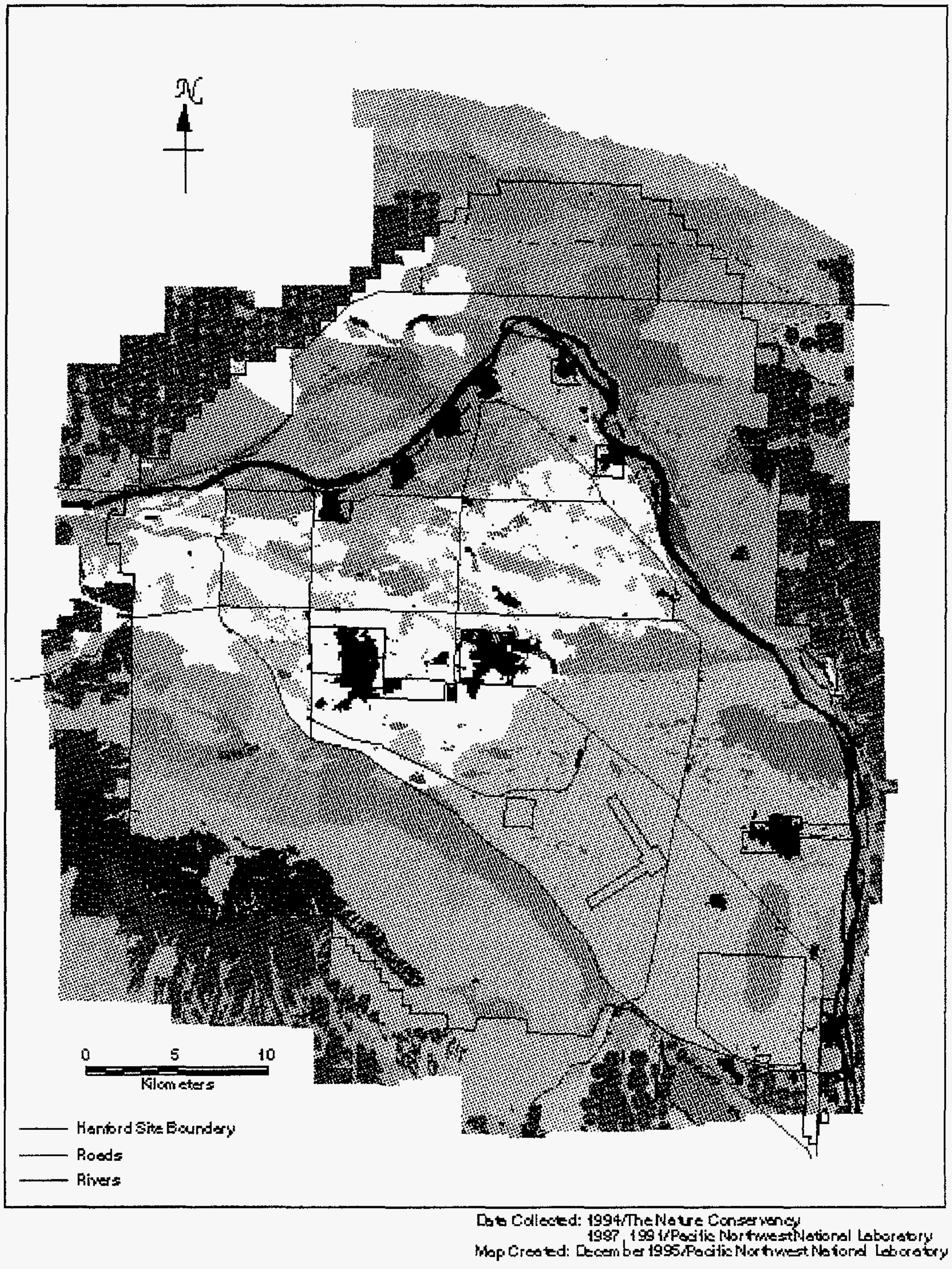

Figure 4.4-1. Distribution of Vegetation Types and Land Use Areas on the Hanford Site

LEGEND

- Post-Fire Shrub-Steppe on the Columbia River Plain
- Rabbitbrush/Bunchgrasses
- Rabbitbrush/Cheatgrass
- Big Sagebrush/Bunchgrasses-Cheatgrass
- Big Sagebrush-Spiny Hopsage/Bunchgrasses-Cheatgrass
- Threetip Sagebrush/Bunchgrasses
- Spiny Hopsage/Bunchgrasses
- Spiny Hopsage/Cheatgrass
- Black Greasewood/Sandberg's Bluegrass
- Winterfat/Bunchgrasses
- Winterfat/Cheatgrass
- Snow Buckwheat/Indian Ricegrass
- Bunchgrasses
- Cheatgrass-Sandberg's Bluegrass
- Planted Non-Native Grass
- Bitterbrush/Bunchgrasses Sand Dune Complex
- Bitterbrush/Cheatgrass
- Alkali Saltgrass-Cheatgrass
- Riparian
- Basalt Outcrops
- Agricultural Areas
- Buildings/Parking Lots/Gravel Pits/Disturbed Areas
- Abandoned Old Fields
- Riverine Wetlands and Associated Deepwater Habitats
- Cliffs (White Bluffs)
- Non-Riverine Wetlands and Associated Deepwater Habitats

Figure 4.4-1. (Cont'd)

Table 4.4-1. Common Vascular Plants on the Hanford Site (Taxonomy follows Hitchcock and Cronquist 1973)

A. Shrub-Steppe Species	Scientific Name
Shrub	
Big sagebrush	*Artemisia tridentata*
Bitterbrush	*Purshia tridentata*
Gray rabbitbrush	*Chrysothamnus nauseosus*
Green rabbitbrush	*Chrysothamnus viscidiflorus*
Snow buckwheat	*Eriogonum niveum*
Spiny hopsage	*Grayia (Atriplex) spinosa*
Threetip sagebrush	*Artemisia tripartita*
Perennial Grasses	
Bluebunch wheatgrass	*Agropyron spicatum*
Bottlebrush squirreltail	*Sitanion hystrix*
Crested wheatgrass	*Agropyron desertorum (cristatum)*[a]
Indian ricegrass	*Oryzopsis hymenoides*
Needle-and-thread grass	*Stipa comata*
Prairie Junegrass	*Koeleria cristata*
Sand dropseed	*Sporobolus cryptandrus*
Sandberg's bluegrass	*Poa sandbergii (secunda)*
Thickspike wheatgrass	*Agropyron dasytachyum*
Perennial Forbs	
Bastard toad flax	*Comandra umbellata*
Buckwheat milkvetch	*Astragalus caricinus*
Carey's balsamroot	*Balsamorhiza careyana*
Cusick's sunflower	*Helianthus cusickii*
Cutleaf ladysfoot mustard	*Thelypodium laciniatum*
Douglas' clusterlily	*Brodiaea douglasii*
Dune scurfpea	*Psoralea lanceolata*
Franklin's sandwort	*Arenaria franklinii*
Gray's desertparsley	*Lomatium grayi*
Hoary aster	*Machaeranthera canescens*
Hoary falseyarrow	*Chaenactis douglasii*
Longleaf phlox	*Phlox longifolia*
Munro's globemallow	*Sphaeralcea munroana*
Pale eveningprimrose	*Oenothera pallida*
Sand beardtongue	*Penstemon acuminatus*
Stalked-pod milkvetch	*Astragalus sclerocarpus*
Threadleaf fleabane	*Erigeron filifolius*

A. Shrub-Steppe Species	Scientific Name
Turpentine spring parsley	*Cymopteris terebinthinus*
Winged dock	*Rumex venosus*
Yarrow	*Achillea millefolium*
Yellow bell	*Fritillaria pudica*
Annual Forbs	
Annual Jacob's ladder	*Polemonium micranthum*
Blue mustard	*Chorispora tenella*[a]
Bur ragweed	*Ambrosia acanthicarpa*
Clasping pepperweed	*Lepidium perfoliatum*
Indian wheat	*Plantago patagonica*
Jagged chickweed	*Holosteum umbellatum*[a]
Jim Hill's tumblemustard	*Sisymbrium altissimum*[a]
Matted cryptantha	*Cryptantha circumscissa*
Pink microsteris	*Microsteris gracilis*
Prickly lettuce	*Lactuca serriola*[a]
Rough wallflower	*Erysimum asperum*
Russian thistle (tumbleweed)	*Salsola kali*[a]
Slender hawksbeard	*Crepis atrabarba*
Spring whitlowgrass	*Draba verna*[a]
Storksbill	*Erodium cicutarium*[a]
Tall willowherb	*Epilobium paniculatum*
Tarweed fiddleneck	*Amsinckia lycopsoides*
Threadleaf scorpion weed	*Phacelia linearis*
Western tansymustard	*Descurainia pinnata*
White cupseed	*Plectritis macrocera*
Whitestem stickleaf	*Mentzelia albicaulis*
Winged cryptantha	*Cryptantha pterocarya*
Yellow salsify	*Tragopogon dubius*[a]
Annual Grasses	
Cheatgrass	*Bromus tectorum*[a]
Slender sixweeks	*Festuca octoflora*
Small sixweeks	*Festuca microstachys*

B. Riparian Species (contd)	Scientific Name
Trees and Shrubs	
Black cottonwood	*Populus trichocarpa*
Black locust	*Robinia pseudo-acacia*
Coyote willow	*Salix exigua*
Dogbane	*Apocynum cannabinum*
Peach, apricot, cherry	*Prunus* spp.
Peachleaf willow	*Salix amygdaloides*
Willow	*Salix* spp.
White Mulberry	*Morus alba*[a]
Perennial Grasses and Forbs	
Bentgrass	*Agrostis* spp. [b]
Blanket flower	*Gaillardia aristata*
Bulrushes	*Scirpus* spp.[b]
Cattail	*Typha latifolia*[b]
Columbia River gumweed	*Grindelia columbiana*
Hairy golden aster	*Heterotheca villosa*
Heartweed	*Polygonum persicaria*
Horsetails	*Equisetum* spp.
Horseweed tickseed	*Coreopsis atkinsoniana*
Lovegrass	*Eragrostis* spp. [b]
Lupine	*Lupinus* spp.
Meadow foxtail	*Alopecurus aequalis* [b]
Pacific sage	*Artemisia campestris*
Prairie sagebrush	*Artemisia ludoviciana*
Reed canary grass	*Phalaris arundinacea*[b]
Rushes	*Juncus* spp.
Russian knapweed	*Centaurea repens*[a]
Sedge	*Carex* spp.[b]
Water speedwell	*Veronica anagallis-aquatica*
Western goldenrod	*Solidago occidentalis*
Wild onion	*Allium* spp.
Wiregrass spikerush	*Eleocharis* spp.[b]
Aquatic Vascular	
Canadian waterweed	*Elodea canadensis*
Columbia yellowcress	*Rorippa columbiae*
Duckweed	*Lemna minor*

B. Riparian Species (contd)	Scientific Name
Aquatic Vascular (contd)	
Pondweed	*Potamogeton* spp.
Spiked water milfoil	*Myriophyllum spicatum*
Watercress	*Rorippa nasturtium-aquaticum*

(a) Introduced
(b) Perennial grasses and graminoids.

on the Site, bluebunch wheatgrass occurs at higher elevations. Sandberg's bluegrass is more widely distributed and occurs within several plant communities. Needle-and-thread grass, Indian ricegrass, and thickspike wheatgrass occur in sandy soils and dune habitats. Species preferring more moist locations include bentgrass, meadow foxtail, lovegrasses, and reed canarygrass (DOE 1996a).

Tree Zones. Trees afford unique attributes of terrestrial habitat on the Hanford Site. Before settlement, the landscape lacked trees. Homesteaders planted trees in association with agricultural areas. Currently, approximately 23 species of trees occur on the Site. The most commonly occurring species are black locust, Russian olive, cottonwood, mulberry, sycamore, and poplar. Many of these nonnative species are aggressive colonizers and have become established along the Columbia River (e.g., cottonwood, poplar, Russian olive), serving as a functional component of the riparian zone (DOE 1996a).

Riparian Areas. Riparian habitat includes sloughs, backwaters, shorelines, islands, and palustrine areas associated with the Columbia River flood plain. Vegetation that occurs along the river shoreline includes emergent water milfoil, water smartweed, pondweed, sedges, reed canarygrass, and bulbous bluegrass. Trees include willow, mulberry, and Siberian elm. Other riparian vegetation occurs in association with perennial springs and seeps and waste-water ponds and ditches on the Hanford Site. Rattlesnake and Snively springs are highly diverse biologic communities (Cushing and Wolf 1984) that support bulrush, spike rush, and cattail. Watercress, which persists at these sites, is also abundant for a large portion of the year. Waste water ponds and ditches are ephemeral, and have contributed to the establishment of cattail, reed canarygrass, willow, cottonwood, and Russian olive in areas otherwise devoid of riparian species.

Riparian (wetland) habitat that occurs in association with the Columbia River includes riffles, gravel bars, oxbow ponds, backwater sloughs, and cobble shorelines. These emergent habitats occur infrequently along the Hanford Reach and have acquired ecological significance because of the net loss of wetland habitat elsewhere within the region. Emergent species include reed canarygrass, common witchgrass, and large barnyard grass. Rushes and sedges occur along the shorelines of the Columbia River and at several sloughs along the Hanford Reach at White Bluffs, below the 100-H Area, downstream of the 100-F Area, and the Hanford Slough.

Unique Habitats. Unique habitats on the Hanford Site include bluffs, dunes, and islands. The White Bluffs, Umtanum Ridge, and Gable Mountain on the Hanford Site include rock outcrops that generally do not occur on the Site. Basalt outcrops are most often occupied by plant communities dominated by buckwheat and Sandberg's bluegrass.

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 are vegetated by bitterbrush, scurfpea, and thickspike wheatgrass.

Island habitat accounts for approximately 474 ha (1170 acres) (Hanson and Browning 1959) and 64.3 km (39.9 mi.) of river shoreline within the main channel of the Hanford Reach. Shoreline riparian vegetation that characterizes the islands includes willow, poplar, Russian olive, and mulberry. Species occurring on the island interior include buckwheat, lupine, mugwort, thickspike wheatgrass, giant wildrye, yarrow, and cheatgrass (Warren 1980). Management of these islands is a shared responsibility of the DOE, the U.S. Fish and Wildlife Service, and the U.S. Bureau of Land Management.

Operable Units. The Hanford Site encompasses more than 1500 waste management units and 4 groundwater contamination plumes that have been grouped into 79 operable units. Each unit has complementary characteristics of such parameters as geography, waste content, type of facility, and relationship of contaminant plumes. In general, the operable units are typified by nonnative or invasive plants. Cheatgrass, Russian thistle, and tumble mustard are invasive species that have colonized many of the disturbed portions of these sites. The 100 Area operable units are characterized by a narrow band of riparian vegetation along the shoreline of the Columbia River, with much of the area shoreward consisting of old agricultural fields, dominated by cheatgrass and tumble mustard. Scattered big sagebrush and gray rabbitbrush also occur throughout the 100 Areas (Landeen et al. 1993). Waste management areas, reactors, and crib sites are generally either barren or vegetated by invasive species including Russian thistle, tumble mustard, and cheatgrass. Russian thistle and gray rabbitbrush that occur in these areas are deep rooted and have the potential to accumulate radionuclides and other buried contaminants, functioning as a pathway to other parts of the ecosystem (Landeen et al. 1993). State threatened, endangered, or sensitive species that have been reported for the 100 Area operable units include Columbia yellowcress, southern mudwort, false pimpernel, shining flatsedge, gray cryptantha, and possibly dense sedge (Landeen et al. 1993).

The undisturbed portions of the 200 Areas are characterized as sagebrush/cheatgrass or Sandberg's bluegrass communities of the 200 Area Plateau. The dominant plants on the 200 Area Plateau are big sagebrush, rabbitbrush, cheatgrass, and Sandberg's bluegrass, with cheatgrass providing half of the total plant cover. Most of the waste disposal and storage sites are covered by nonnative vegetation or are kept in a vegetation-free condition.

Vegetation surveys were conducted at the 300-FF-5 Operable Unit 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). Dominant riparian vegetation in the unit included white mulberry and shrub willow, reed canarygrass, bulbous bluegrass, sedges, and horsetail. Columbia yellowcress, a state species of concern, was identified at 18 locations near this operable unit. Riparian plants have the greatest potential to make root contact with contaminated groundwater.

4.4.1.2 Wildlife

Included in approximately 300 species of terrestrial vertebrates observed on the Hanford Site are approximately 40 species of mammals, 246 species of birds, 5 species of amphibians, and 10 species of reptiles (Landeen et al. 1991, Soll and Soper 1996). All terrestrial habitats, including riparian areas along the Columbia River, shrub- and grasslands, canyons, basalt outcrops, cliffs, and facilities of the operable units are important to terrestrial species.

Many species of insects occur throughout all habitats on the Hanford Site (Soll and Soper 1996). Grasshoppers and darkling beetles are among the more conspicuous of the approximately 1,000 species of insects that have been found on the Hanford Site. Most species of darkling beetle occur throughout the spring to fall, although some species are present during several months in the fall (Rogers and Rickard 1977). Grasshoppers are evident during late spring through fall.

The side-blotched lizard is the most abundant reptile species that occurs on the Hanford Site. Short-horned and sagebrush lizards are reported for the Site, but occur infrequently. The most common snake species include gopher snake, yellow-bellied racer, and Pacific rattlesnake. The Great Basin Spadefoot Toad and Woodhouse's Toad are the only amphibians found on site (Soll and Soper 1996).

Shrubland and Grassland Wildlife. All major groups of terrestrial wildlife, except amphibians, occur in the shrub- and grassland habitat. Species include large game animals like Rocky Mountain elk and mule deer; predators such as coyote, bobcat, and badger; and consumers like deer mice, harvest mice, grasshopper mice, ground squirrels, voles, and black-tailed jackrabbits. The most abundant mammal on the Site is the Great Basin pocket mouse.

Mule deer are reliant 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, which first appeared on the Hanford Site in 1972 (Fitzner and Gray 1991), have increased from approximately 8 animals in 1975 to approximately 300 in 1995. The herd of elk that inhabits the Hanford Site primarily occupy the Fitzner/Eberhardt ALE Reserve and private lands that adjoin the reserve to the north and west, but are occasionally seen on the 200 Area plateau.

Shrub- and grasslands provide nesting and foraging habitat for many passerine bird species. Surveys conducted during 1993 (Cadwell 1994) reported the occurrence of western meadowlarks and horned larks more frequently in shrubland habitats than in other habitats on the Site. Long-billed curlews and vesper sparrows were also noted as commonly occurring species in shrubland habitat. Species that are dependent on undisturbed shrub habitat include sage sparrow, sage thrasher, and loggerhead shrike. Both the sage sparrow and loggerhead shrike tend to roost and nest in sagebrush or bitterbrush that occurs at lower elevations (DOE 1996a). Ground-nesting species that occur in grass-covered uplands include long-billed curlews and burrowing owls. These areas provide nesting and foraging habitat for these species.

Common upland game species that occur in shrub- and grassland habitat include chukar partridge, California quail, and Chinese ring-necked pheasant. Chukar are most numerous in the Rattlesnake Hills, Yakima Ridge, Umtanum Ridge, Saddle Mountains, and Gable Mountain areas of the Hanford

Site. Less common species include western sage grouse, Hungarian partridge, and scaled quail. Western 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. Surveys conducted by the Washington Department of Fish and Wildlife and PNNL during late winter and early spring 1993 did not reveal presence of western sage grouse in sagebrush-steppe habitat of the Fitzner/Eberhardt ALE Reserve (Cadwell 1994).

Among the more common raptor species that use shrub- and grassland habitat are ferruginous hawks, Swainson's hawk, and red-tailed hawk. Northern harriers, sharp-shinned hawks, rough-legged hawks, and golden eagles also occur in these habitats but are not noted as frequently. In 1994, nesting by red-tailed, Swainson's, and ferruginous hawks included 41 nests located across the Hanford Site in relation to high voltage transmission towers, trees, cliffs, and basalt outcrops. In recent years the number of nesting ferruginous hawks on the Hanford Site has increased, as a result in part to their acceptance of steel powerline towers in the open grass- and shrubland habitats.

A cooperative research effort between the PNNL and the Washington Department of Fish and Wildlife is examining home range and habitat use of ferruginous hawks on the Site in an effort to understand the species success in a region where population numbers are, generally, in decline.

Tree Zone Wildlife. Trees occur infrequently on the Hanford Site but provide nesting habitat and thermal cover for many species of mammals and raptors. Raptors use trees for nesting, perching, and roosting. Ferruginous and Swainson's hawks use trees for nesting and perching. Ferruginous hawks on the Site nest primarily in transmission line towers. Bald eagles that occur along the Hanford Reach of the Columbia River use trees for daytime perching and, in some cases, communal night roosts. Great blue herons and black crowned night herons are associated with trees in riparian habitat along the Columbia River and use groves or individual trees for perching, nesting, or rookeries.

Riparian Wildlife. Shoreline riparian communities are seasonally important for a variety of species. Willows trap food for waterfowl (i.e., Canada geese) and birds that use shoreline habitat (i.e., Forster's tern) and provide nesting habitat for passerines (i.e., mourning doves). Terrestrial and aquatic insects are abundant in emergent grasses and provide forage for fish, waterfowl, and shorebirds. Beaver and mule deer rely on shoreline habitat for foraging. Riparian areas provide nesting and foraging habitat and escape cover for many species of birds and mammals.

Mammals that occur primarily in riparian areas include rodents, bats, furbearers (e.g., mink and weasels), porcupine, raccoon, skunk, and mule deer. During the summer months, mule deer rely on riparian vegetation for foraging and periodically cross the Columbia River to access islands or the eastern shorelines. Riparian areas afford suitable habitat for insectivorous bats. The Columbia River and Rattlesnake Springs provide foraging habitat for most species of bats including myotis, small-footed myotis, silver-haired bats, and pallid bats (Becker 1993).

Common bird species that occur in riparian habitats include American robin, black-billed magpie, song sparrow, and dark-eyed junco (Cadwell 1994). Upland gamebirds that use this habitat include ring-necked pheasants and California quail. Predatory birds include common barn owl and great horned owl. Species known or expected to nest in riparian habitat are Brewer's blackbird, mourning dove, black-billed magpie, northern oriole, lazuli bunting, eastern and western kingbird, and western wood peewee. Bald eagles, which have wintered on the Hanford Site since 1960, rely on riparian habitat along the shoreline 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 and Soper 1996). During the fall and winter months, ducks (primarily mallards) and Canada geese rest on the shorelines and islands along the Hanford Reach. 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 white pelicans, double-crested cormorants, and common loons.

Wildlife Occurring in Unique Habitat. Bluffs provide perching, nesting, and escape habitat for several species on the Hanford Site. The White Bluffs and Umtanum Ridge provide nesting habitat for prairie falcons, red-tailed hawks, cliff swallows, bank swallows, and rough-winged swallows. In the past, Canada geese used the lower elevations of White Bluffs for nesting and brooding. Bluff areas provide habitat for sensitive species (i.e., Hoover's desert parsley and peregrine falcon) that otherwise may be subject to impact from frequent or repeated disturbance.

Dune habitat is unique in its association with the surrounding shrub-steppe vegetation type. The uniqueness of the dunes is noted in its vegetation component as well as the geologic formation. The terrain of the Hanford dunes provides habitat for mule deer, burrowing owls, and coyotes as well as many transient species.

Islands afford a unique arrangement of upland and shoreline habitat for avian and terrestrial species. Islands vary in soil type and vegetation and range from narrow cobble benches to extensive dune habitats. With exception for several plant species, the islands accommodate many of the same species that occur in mainland habitats. Operation of Priest Rapids Dam upstream of the Hanford Reach creates daily and seasonal fluctuations in river levels, which may limit community structure and overall shoreline species viability along the shoreline interface.

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 yearly. In recent years downward fluctuations are the result of coyote predation. This predation has been a major cause of the decline of nesting geese in the Hanford Reach. During 1993, 196 of 235 pairs of geese nested successfully in the Hanford Reach, compared with 213 of 286 pairs that nested successfully in 1992 (Cadwell 1994). Control programs have been implemented in the past to control coyote population numbers (Eberhardt, et al. 1979). Islands also accommodate colonial nesting species including California gulls, ring-billed gulls, Forster's terns, and great blue herons. Again, extensive areas ranging from 12 to 20 ha (30 to 50 acres) accommodate colonial nesting species that may range in population size of upwards of 2000 individuals.

Wildlife Occurring at the Operable Units. Insects, reptiles, amphibians, birds, and mammals that occur in the 100, 200, and 300 Area operable units, in general, are typical of species that occur across the Site. During 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).

Landeen et al. (1993) conducted surveys at the 100 Area operable units between 1991 and 1992. One hundred seven bird species were recorded during the 1991/1992 surveys. Of the 29 mammal species known to occur in the 100 Area operable units, 11 were observed during 1991/1992. Species of special concern that use the operable units include the American white pelican, bald eagle, peregrine falcon, mule deer, coyote, Great Basin pocket mouse, black-tailed jackrabbit, and Nuttall's cottontail (Landeen et al. 1993). Exposure pathways for potential contamination of species of special regulatory concern occurring in the 100 Area operable units include flying insect consumption; mud-nest building behavior; vegetation consumption; soil excavation; consumption of vegetation, small mammals, or birds; and consumption of aquatic periphyton (Landeen et al. 1993)(Table 4.4-2).

Surveys were conducted during 1992 to determine the presence of reptile, bird, and mammal species in the 300-FF-5 Operable Unit. Reptiles and amphibians known to occur in the unit include western yellow-bellied racer, gopher snake, side-blotched lizard, sagebrush lizard, the Great Basin spadefoot toad, Woodhouse's toad, bullfrog, and the Pacific tree frog (Brandt et al. 1993).

Fifty-three species of birds, including fourteen riverine and nineteen riparian species (Brandt et al. 1993), were recorded during 1992 surveys of the 300-FF-5 Operable Unit. Seven species listed as candidates for protection under state or federal regulations were observed. These included burrowing owl, common loon, Forster's tern, great blue heron, loggerhead shrike, osprey, and sage sparrow. The most abundant species observed in the unit that occur in shrub-steppe habitat included burrowing owls, western kingbirds, white-crowned sparrows, and western meadowlarks (Brandt et al. 1993). Rock doves and European starlings are nuisance species that occur in the operable units.

Fifteen species of mammals were observed during 1992 surveys of the 300-FF-5 Operable Unit. The most frequently encountered small mammals were house mouse and Great Basin pocket mouse. Other species included deer mouse, western harvest mouse, and grasshopper mouse. Although not observed during 1992 surveys, Townsend's ground squirrel, black-tailed jackrabbit, Nuttall's cottontail, beaver, mule deer, badger, and coyote use the 300 Area Operable Unit.

Species at potential contamination risk during operable unit remediation activities include mule deer, black-tailed jackrabbit, beaver, coyote, raccoon, house mouse, Great Basin pocket mouse, Nuttall's cottontail, beaver, bald eagle, ferruginous hawk, Swainson's hawk, loggerhead shrike, long-billed curlew, great blue heron, sage sparrow, ring-billed gull, mallard, Canada goose, northern harrier, and western meadowlark. Species ecology and pathways relative to contaminant uptake or exposure are included in Table 4.4-2 (Brandt et al. 1993).

Table 4.4-2. Avian and Mammalian Species and Pathways for Contamination in Habitat of the Operable Units

Species	Risk[a]
Birds	
Bald eagle	Salmon, waterfowl ingestion
Burrowing owl	Small mammal, insect ingestion
Canada goose	Vegetation ingestion
Ferruginous hawk	Small/medium mammal ingestion
Forster's tern	Nesting habitat use exposure
Great blue heron	Fish, amphibian, reptile, invertebrate ingestion
Loggerhead shrike	Bird, mammal, insect ingestion
Long-billed curlew	Beetle, insect larvae ingestion
Mallard	Nesting habitat use exposure
Merganser	Fish ingestion
Northern harrier	Small mammal, bird ingestion
Ring-billed gull	Nesting habitat use exposure
Sage sparrow	Insect, seed ingestion
Swainson's hawk	Reptile, mammal ingestion
Western meadowlark	Insect, seed ingestion
Mammals	
Beaver	Willow, cottonwood, forb ingestion
Black-tailed jackrabbit	Yarrow, turpentine bush, mustard, buckwheat, rabbitbrush ingestion
Coyote	Mammal, bird, insect, fruit ingestion
Great Basin pocket mouse	Cheatgrass, seed, insect ingestion
House mouse	Grass, insect ingestion
Mule deer	Forb, shrub, grass ingestion
Nuttall's cottontail	Sagebrush, grass, forb ingestion
Raccoon	Invertebrate, seed, small mammal, bird ingestion

(a) Pathway of exposure.

4.4.2 Aquatic Ecology

There are two types of natural aquatic habitats on the Hanford Site: one is the Columbia River, which flows along the northern and eastern edges of the Hanford Site, and the other is provided by the small spring-streams and seeps located mainly on the Fitzner/Eberhardt ALE Reserve (Figure 4.4-2) in the Rattlesnake Hills. West Pond is created by a rise in the water table in the 200 Areas and is not fed by surface flow; thus, it is alkaline and has a greatly restricted complement of biota.

4.4.2.1 Columbia River

The Columbia River is the dominant aquatic ecosystem on the Hanford Site and supports a large and diverse community of plankton, benthic invertebrates, fish, and other communities. It has a drainage area of about 680,000 km^2 (262,480 mi^2), an estimated average annual discharge of 6600 m^3/s (71,016 ft/s), and a total length of about 2000 km (~1240 mi.) from its origin in British Columbia to its mouth at the Pacific Ocean. The Columbia has been dammed both upstream and downstream from the Hanford Site, and the reach flowing through the area is the last free-flowing, but regulated, reach of the Columbia River in the United States above Bonneville Dam. Plankton populations in the Hanford Reach are influenced by communities that develop in the reservoirs of upstream dams, particularly Priest Rapids Reservoir, and by manipulation of water levels below by dam operations in downstream reservoirs. Phytoplankton and zooplankton populations at Hanford are largely transient, flowing from one reservoir to another. There is generally insufficient time for characteristic endemic groups of phytoplankton and zooplankton to develop in the Hanford Reach. No tributaries enter the Columbia during its passage through the Hanford Site.

Public Law 100-65, passed by Congress in 1988, authorized the study of the Hanford Reach for possible designation as a wild and scenic river. (This law expired and was renewed as Public Law 104-333 in 1996.) In 1994, based on the results of this study, the National Park Service (NPS) (1994) recommended creation of a 41,310-ha (102,000-acre) national wildlife refuge containing the river and its corridor. NPS further recommended that the reach and its corridor be designated as a recreational river in the national wild and scenic rivers system. The refuge and river would be administered by the U.S. Fish and Wildlife Service. Before the plan can become law, it must be endorsed by the secretary of the interior and enacted by Congress. If enacted, the designation would not preclude existing land-use and recreational use of the river for boating, hunting, and fishing but would preclude expansion of agriculture and other non-compatible development within the refuge and river corridor (NPS 1994). Establishing the lands adjacent to the river as a national wildlife refuge would increase protection to all habitat types within and along the reach, protect both terrestrial and aquatic resources, and benefit the entire Hanford Reach ecosystem (NPS 1994; Geist 1995).

The Columbia River is a very complex ecosystem because of its size, the number of alterations, the biotic diversity, and size and diversity of its drainage basin. Streams in general, especially smaller ones, usually depend on organic matter from outside sources (terrestrial plant debris) to provide energy for the ecosystem. Large rivers, particularly the Columbia River with its series of large reservoirs, contain significant populations of primary energy producers (algae and plants) that contribute to the basic energy requirements of the biota. Phytoplankton (free-floating algae) and periphyton (sessile algae) are abundant in the Columbia River and provide food for herbivores such as immature insects, which in turn are consumed by carnivorous species.

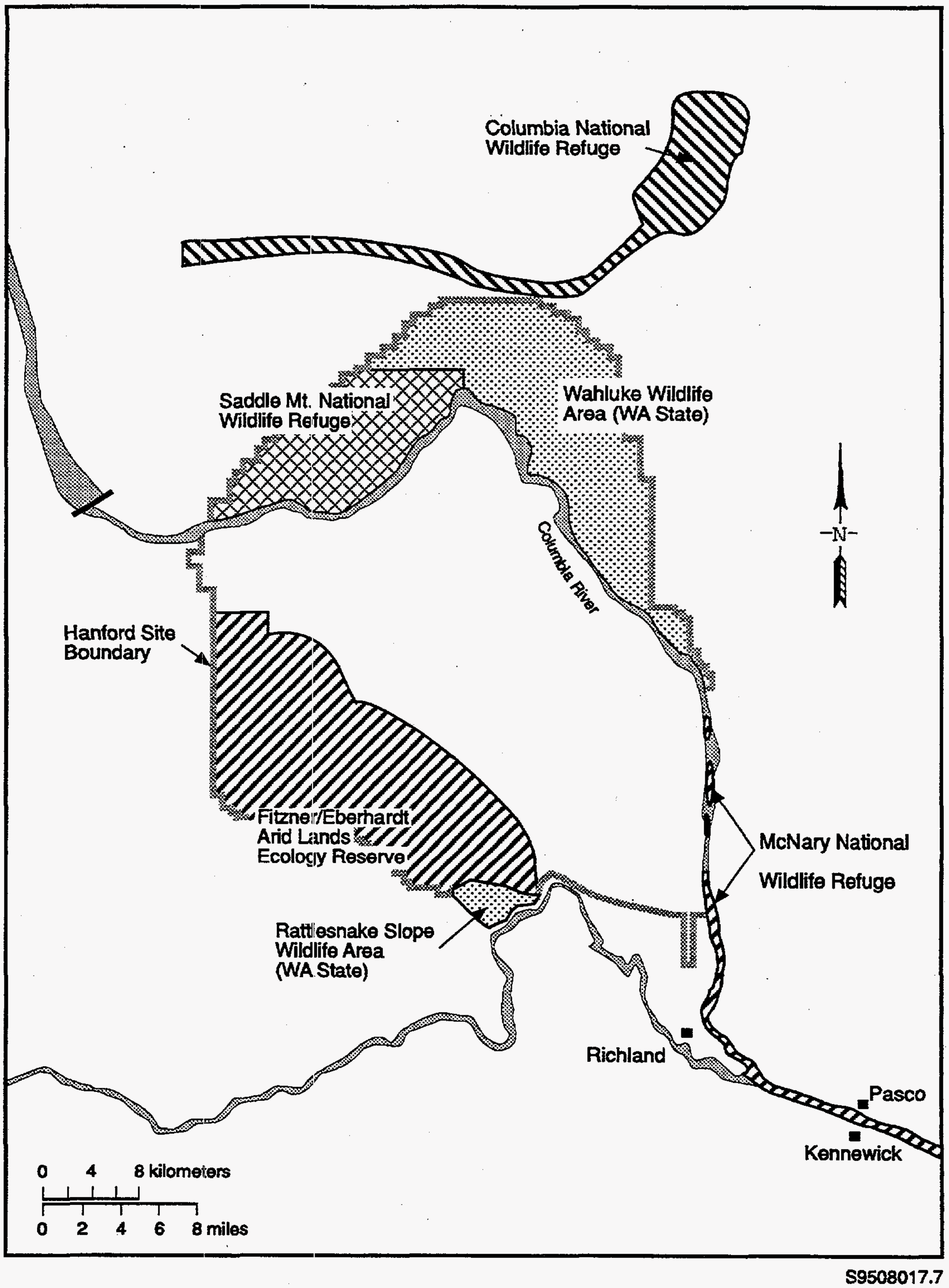

Figure 4.4-2. National and State Wildlife Refuges near the Hanford Site

Phytoplankton. Phytoplankton species identified from the Hanford Reach include diatoms, golden or yellow-brown algae, green algae, blue-green algae, red algae, and dinoflagellates. Diatoms are the dominant algae in the Columbia River phytoplankton, usually representing more than 90% 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 the 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 are detached and suspended by current and frequent fluctuations of the water level.

The peak concentration of phytoplankton is observed in April and May, with a secondary peak in late summer/early autumn (Cushing 1967a). The spring pulse in phytoplankton density is probably related to increasing light and water temperature rather than to availability of nutrients, because phosphate and nitrate nutrient concentrations are never limiting. Minimum numbers are present in December and January. Green algae (*Chlorophyta*) and blue-green algae (*Cyanophyta*) occur in the phytoplankton community during warmer months but in substantially fewer numbers than diatoms. Diversity indices, carbon uptake, and chlorophyll-a concentrations for the phytoplankton at various times and locations can be found in Beak Consultants Inc. (1980), Neitzel et al. (1982a), and Wolf et al. (1976).

Periphyton. Communities of periphytic species ("benthic microflora") develop on suitable solid substrata wherever there is sufficient light for photosynthesis. Peaks of production occur in spring and late summer (Cushing 1967b). Dominant genera are the diatoms *Achnanthes, Asterionella, Cocconeis, Fragilaria, Gomphonema, Melosira, Nitzchia, 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 Hanford Slough. Macrophytes are also present along gently sloping shorelines that are subject to flooding during the spring freshet and daily fluctuating river levels (below Coyote Rapids and the 100-D Area). Commonly found plants include *Lemna, Potamogeton, Elodea*, and *Myriophyllum*. Where they exist, macrophytes have considerable ecological value. They provide food and shelter for juvenile fish and spawning areas for some species of warmwater game fish. However, should some of the exotic macrophytes increase to nuisance levels, they may encourage increased sedimentation of fine particulate matter. These changes could have a significant impact on trophic relationships of the Columbia River.

Zooplankton. The zooplankton populations in the Hanford Reach of the Columbia River are generally sparse. In the open-water regions, crustacean zooplankters are dominant; dominant genera are *Bosmina, Diaptomus*, and *Cyclops*. Densities are lowest in winter and highest in the summer, with summer peaks dominated by *Bosmina* and ranging up to 160,650 organisms/m^3 (4,500 organisms/ft^3). Winter densities are generally <1785 organisms/m^3 (<50 organisms/ft^3). *Diaptomus* and *Cyclops* dominate 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 limpets, snails, sponges, and crayfish. 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 are important food items for nearly all juvenile and adult fish. There is a close relationship between food organisms in the stomach contents and those in the benthic and invertebrate drift communities.

Fish. Gray and Dauble (1977) list 43 species of fish in the Hanford Reach of the Columbia River. The brown bullhead (*Ictalurus nebulosus*) has been collected since 1977, bringing the total number of fish species identified in the Hanford Reach to 44 (Table 4.4-3). Of these species, chinook salmon, sockeye salmon, coho salmon, and steelhead trout use the river as a migration route to and from upstream spawning areas and are of the greatest economic importance. Both fall chinook salmon and steelhead trout also spawn in the Hanford Reach. The relative contribution of upper-river bright stocks to fall chinook salmon runs in the Columbia River increased from about 24% of the total in the early 1980s, to 50% to 60% of the total by 1988 (Dauble and Watson 1990). The destruction of other mainstream Columbia spawning grounds by dams has increased the relative importance of the Hanford Reach spawning (Watson 1970, 1973).

Upper estimates of the annual average Hanford Reach steelhead spawning population based on dam counts for the years 1962 to 1971 were about 10,000 fish. The estimated annual sport catch for the period from 1963 to 1968 in the reach of the river from Ringold to the mouth of the Snake River was approximately 2700 fish (Watson 1973).

Shad, another anadromous species, may also spawn in the Hanford Reach. The upstream range of the shad has been increasing since 1956 when <10 adult shad ascended McNary Dam. Since then, the number ascending Priest Rapids Dam, immediately upstream of Hanford, has risen to many thousands each year, and young-of-the-year have been collected in the Hanford Reach. The shad is not dependent on specific current and bottom conditions required by the salmonids for spawning and has apparently found favorable conditions for reproduction throughout much of the Columbia and Snake Rivers.

Studies were initiated in the spring of 1993 to evaluate the potential for use of water storage facilities at the former 100-K Area fuel production site for fish production. These studies were initiated because of suggestions made to the Westinghouse Technology Acquisition offices and following a formal agreement among the U.S. Department of Energy, Richland Operations Office (DOE-RL), Westinghouse Hanford (WHC), Tri-Cities Economic Development Council (TRIDEC), the Washington Department of Fisheries (WDF), and Pacific Northwest National Laboratory (PNNL). Pilot studies at the facility indicated that juvenile fall chinook salmon could be transported to the 100-K facility and successfully held prior to outplanting in the Columbia River (Dauble et al. 1993).[a]

(a) Dauble, D. D., G. A. Martenson, D. F. Herborn, and B. N. Anderson. 1994. *K Basin Fisheries Investigations: FY 94 Summary of Activities*. Letter Report to Pacific Northwest Laboratory, Richland, Washington.

Table 4.4-3. Fish Species in the Hanford Reach of the Columbia River

Common Name	Scientific Name
American shad	*Alosa sapidissima*
Black bullhead	*Ameiurus melas*
Black crappie	*Pomoxis nigromaculatus*
Bluegill	*Lepomis macrochirus*
Bridgelip sucker	*Catostomus columbianus*
Brown bullhead	*Ictalurus nebulosus*
Burbot	*Lota lota*
Carp	*Cyprinus carpio*
Channel catfish	*Ictalurus punctatus*
Chinook salmon	*Oncorhynchus tshawytscha*
Chiselmouth	*Acrocheilus alutaceus*
Coho salmon	*Oncorhynchus kisutch*
Cutthroat trout	*Oncorhynchus clarki*
Dolly Varden	*Salvelinus malma*
Lake whitefish	*Coregonus clupeaformis*
Largemouth bass	*Micropterus salmoides*
Largescale sucker	*Catostomus macrocheilus*
Leopard dace	*Rhinichthys falcatus*
Longnose dace	*Rhinichthys cataractae*
Mottled sculpin	*Cottus bairdi*
Mountain sucker	*Catostomus platyrhynchus*
Mountain whitefish	*Prosopium williamsoni*
Northern squawfish	*Ptychocheilus oregonensis*
Pacific lamprey	*Entosphenus tridentatus*
Peamouth	*Mylocheilus caurinus*
Piute sculpin	*Cottus beldingi*
Prickley sculpin	*Cottus asper*
Pumpkinseed	*Lepomis gibbosus*
Rainbow trout (steelhead)	*Oncorhynchus mykiss*
Redside shiner	*Richardsonius balteatus*
Reticulate sculpin	*Cottus perplexus*
River lamprey	*Lampetra ayresi*
Sand roller	*Percopsis transmontana*
Smallmouth bass	*Micropterus dolomieui*
Sockeye salmon	*Oncorhynchus nerka*
Speckled dace	*Rhinichthys osculus*
Tench	*Tinca tinca*
Threespine stickleback	*Gasterosteus aculeatus*
Torrent sculpin	*Cottus rotheus*
Walleye	*Stizostedion vitreum vitreum*
White crappie	*Pomoxis annularis*
White sturgeon	*Acipenser transmontanus*
Yellow perch	*Perca flavescens*
Yellow bullhead	*Ictalurus natalis*

Other fisheries studies at the 100-K water treatment facility include the Yakama Indian Nation's (YIN's) expansion of fall chinook salmon rearing activities to include raising 500,000 salmon in 14 net pens. These fish were successfully reared at K Basin and released directly to the Columbia River via a pipeline. Approximately 75,000 larval walleye and 27,000 juvenile channel catfish were released into other basins at the facility as part of a collaborative agreement between the Washington Department of Fisheries and Wildlife, DOE, and WHC. The YIN reared up to 1 million fall chinook salmon at the 100-K facility in the spring of 1995 using two of the basins and up to 28 net pens. The Nez Perce Nation transferred some sturgeon to a hatchery facility upstream of Lower Granite Reservoir on the Snake River to be used as brood stock for future supplementation of depleted Snake River stocks.

Other fish of importance to sport fishermen are mountain whitefish, white sturgeon, smallmouth bass, crappie, catfish, walleye, and yellow perch. Large populations of rough fish are also present, including carp, redside shiner, suckers, and northern squawfish.

4.4.2.2 Spring Streams

Small spring streams, such as Rattlesnake and Snively Springs, contain diverse biotic communities and are extremely productive (Cushing and Wolf 1984). Dense blooms of watercress occur that are not lost until one of the major flash floods occurs. 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.

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^3/s (0.4 ft^3/s) (Cushing and Wolf 1982). Water temperature ranges from 2° to 22°C (36° to 72°F). Mean annual total alkalinities (as $CaCO_3$), 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 Site. Snively Springs, located farther west and at a higher elevation than Rattlesnake Springs, apparently does not contribute to the flow of Rattlesnake Springs (Brown 1970), but probably flows to the west and off the Hanford Site. The major rooted aquatic plant, which in places may cover the entire width of the stream, is watercress (*Rorippa nasturtium-aquaticum*). Isolated patches of bulrush (*Scirpus* sp.), spike rush (*Eleocharis* sp.), and cattail (*Typha latifolia*) occupy $<5\%$ of the stream bed.

Primary productivity at Rattlesnake Springs is greatest during the spring and coincident with the maximum periphyton standing crop. Net primary productivity averaged 0.9 $g/cm^2/d$ organic matter during 1969 and 1970; the spring maximum was 2.2 $g/cm^2/d$. 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/DWm^2/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 of these spring-streams that would appear to preclude significant autochthonous production (Mize 1993).

An inventory of the many springs occurring on the Rattlesnake Hills has been published by Schwab et al. (1979). Limited physical and chemical data are included for each site.

4.4.2.3 Wetlands

Several habitats on the Hanford Site could be considered wetlands. The largest wetland habitat is the riparian zone bordering the Columbia River. The extent of this zone varies but includes extensive stands of willows, grasses, various aquatic macrophytes, and other plants. The zone is extensively impacted by both seasonal water-level fluctuations and daily variations related to power generation at Priest Rapids Dam immediately upstream of the Site.

Other extensive areas of wetlands can be found within the Saddle Mountain National Wildlife Refuge and the Wahluke Wildlife Area; these two areas encompass all the lands extending from the north bank of the Columbia River northward to the Site boundary and east of the Columbia River down to Ringold Springs. Wetland habitat in these areas consists of fairly large pond habitat resulting from irrigation runoff (see Figure 4.3-1). These ponds have extensive stands of cattails (*Typha* sp.) and other emergent aquatic vegetation surrounding the open-water regions. They are extensively used as resting sites by waterfowl.

Some wetland habitat exists in the riparian zones of some of the larger spring streams on the Fitzner/Eberhardt ALE Reserve of the Hanford Site (see earlier description). These are not extensive and usually amount to less than a hectare in size, although the riparian zone along Rattlesnake Springs is probably about 2 km (1.2 mi.) in length and consists of peachleaf willows, cattails, and other plants.

The U.S. Fish and Wildlife Service has published a series of 1:24,000 maps that show the locations of wetlands. An accompanying booklet describes how to use these maps. Four sets of these maps, covering the Hanford Site, and the instructional booklet for their use are available. They are located at 1) the office of D. A. Neitzel, Sigma 5 Building/Room 2216 (PNNL); 2) the Consolidated Information Center Library, Washington State University, Tri-Cities Campus; 3) the office of the Richland Office NEPA Compliance Officer; and 4) the environmental restoration contractor.

4.4.2.4 Temporary Water Bodies

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. The majority of these have been taken out of service and have been backfilled with the cessation of activities (except West Pond); while present, however, they form established aquatic ecosystems complete with representative flora and fauna (Emery and McShane 1980). The temporary wastewater ponds and ditches had been in place for as long as two decades. Rickard et al. (1981) discussed the ecology of Gable Mountain Pond, one of the former major lentic sites. Emery and McShane (1980) presented ecological characteristics of all the temporary sites. The ponds develop luxuriant riparian communities and become quite attractive to autumn and spring migrating birds; several species nest near the ponds. Section 4.3.1.7 describes those sites still active.

4.4.3 Threatened and Endangered Species

Threatened and endangered plants and animals identified on the Hanford Site, as listed by the federal government (50 CFR 17) and Washington State (Washington Natural Heritage Program 1994), are shown in Table 4.4-4. No plants or mammals on the federal list of threatened and endangered wildlife and plants (50 CFR 17) are known to occur on the Hanford Site. There are, however, three species of birds on the federal list of threatened and endangered species and several species of both plants and animals that are under consideration for formal listing by the federal government and Washington State (refer to Figure 4.4-1 for locations of species discussed in this section.) Under a proposed rule (61 FR [Federal Register] 7595), the U.S. Fish and Wildlife Service has consolidated its categorizing of candidate species from three designations to one. Consequently, a number of candidate species found at Hanford have been dropped from federal listing.

Pristine shrub-steppe habitat is considered priority habitat by Washington because of its relative scarcity in the state, and because of its requirement as nesting/breeding habitat by several state and federal species of concern. Several recent publications describing the distribution of threatened and endangered species on the Hanford Site have been prepared by Becker (1993), Cadwell (1994), Downs et al. (1993), Fitzner et al. (1994), Frest and Johannes (1993), and Pabst (1995).

4.4.3.1 Plants

Six species of plants are included in the Washington State listing as threatened or endangered (Washington Natural Heritage Program 1994): Columbia milk-vetch (*Astragalus columbianus*), Dwarf evening primrose (*Oenothera pygmaea*), and Hoover's desert parsley (*Lomatium tuberosum*) are listed as threatened; Columbia yellowcress (*Rorippa columbiae*) and northern wormwood (*Artemisia campestris* ssp. *borealis* var. *wormskioldii*) are designated endangered. Columbia milk-vetch occurs on dry-land benches along the Columbia River near Priest Rapids Dam, Midway, and Vernita; it also has been found atop Umtanum Ridge and in Cold Creek Valley near the present vineyards and on Yakima Ridge (Fitzner/Eberhardt ALE Reserve). Dwarf evening primrose has been found north of Gable Mountain, near the Vernita Bridge, Ringold, and on mechanically disturbed areas (i.e., the gravel pit near the Wye Barricade). Hoover's desert parsley grows on steep talus slopes near Priest Rapids Dam, Midway, and Vernita. Yellowcress occurs in the wetted zone of the water's edge along the Hanford Reach. Northern wormwood is known to occur near Beverly and could inhabit the northern shoreline of the Columbia River across from the 100 Areas. Three additional species will be listed as threatened or endangered in the updated Washington Natural Heritage Program listing expected to be published in August 1997 (WNHP personal communication). Two of these, Umtanum desert buckwheat and White Bluffs bladderpod, occur only on the Hanford Site and no where else in the world. The third species, loeflingia, occurs north of Gable Mountain.

Table 4.4-4. Federally or Washington State Listed Threatened (T) and Endangered (E) Species Occurring or Potentially Occurring on the Hanford Site

Common Name	Scientific Name	Federal	State
Plants			
Columbia milk-vetch	*Astragalus columbianus*		T
Columbia yellowcress	*Rorippa columbiae*		E
Dwarf evening primrose	*Oenothera pygmaea*		T
Hoover's desert parsley	*Lomatium tuberosum*		T
Loeflingia	*Loeflingia squarrosa* var. *squarrosa*		T*
Northern wormwood[a]	*Artemisia campestris borealis* var. *wormskioldii*		E
Umtanum desert buckwheat	*Eriogonum codium*		E*
White Bluffs bladderpod	*Lesquerella tuplashensis*		E*
White eatonella	*Eatonella nivea*		T
Birds			
Aleutian Canada goose[b]	*Branta canadensis leucopareia*	T	E
American white pelican	*Pelecanus erythrorhychos*		E
Bald eagle	*Haliaeetus leucocephalus*	T	T
Ferruginous hawk	*Buteo regalis*		T
Peregrine falcon[b]	*Falco peregrinus*	E	E
Sandhill crane[b]	*Grus canadensis*		E
Mammals			
Pygmy rabbit[a]	*Brachylagus idahoensis*		E

(a) Likely not currently occurring on the site.
(b) Incidental occurrence.
* Species will be added to the updated WNHP list that is expected to be published in August 1997 (Personal communication, Sandy Norwood, WNHP)

4.4.3.2 Animals

The federal government lists the Aleutian Canada goose (*Branta canadensis leucopareia*) and the bald eagle (*Haliaeetus leucocephalus*) as threatened and the peregrine falcon (*Falco peregrinus*) as endangered. The State of Washington lists, in addition to the peregrine falcon, the Aleutian Canada goose, white pelican (*Pelecanus erythrorhynchos*), sandhill crane (*Grus canadensis*), and pygmy rabbit (*Brachylagus idahoensis*) as endangered and the ferruginous hawk (*Buteo regalis*) and the bald eagle as threatened. The peregrine falcon is a casual migrant to the Hanford Site and does not nest there. The bald eagle is a regular winter resident and forages on dead salmon and waterfowl along the Columbia River; it does not nest on the Hanford Site, although it has attempted to for the past several years. Access controls are in place along the river at certain times of the year to prevent the disturbance of eagles. Washington State Bald Eagle Protection Rules were issued in 1986 (Washington Administrative

Code [WAC]-232-12-292). DOE has prepared a site management plan (Fitzner and Weiss 1994) to mitigate eagle disturbance. This document constitutes a biological assessment for those activities implemented in accordance with the plan and, unless there are extenuating circumstances associated with a given project, the document fulfills the requirements of Section 7(a)(2) of the Endangered Species Act of 1973 for bald eagles and peregrine falcons. Section 7(a) of the Endangered Species Act of 1973 also requires consultation with the U.S. Department of the Interior and the state of Washington when any action is taken that may destroy, adversely modify, or jeopardize the existence of bald eagle or other endangered species' habitat. An increased use of power poles for nesting sites by the ferruginous hawk on the Hanford Site has been noted.

Table 4.4-5 lists the designated candidate species under consideration for possible addition to the threatened or endangered list by Washington State.

Table 4.4-6 lists Washington State plant species that are of concern and are currently listed as sensitive or are in one of three monitor groups (Washington Natural Heritage Program in press).

4.4.4 Special Ecological Considerations in the 100 Areas

In the 100 Areas, cheatgrass is prevalent because of the extensive perturbation of soils in these areas. The characteristic communities found are cheatgrass-tumble mustard, sagebrush/cheatgrass, or Sandberg's bluegrass, sagebrush-bitterbrush/cheatgrass, and willow-riparian vegetation near the Columbia River shoreline. California quail and Chinese ring-necked pheasants are more likely to be found near the Columbia River, and several mammals, such as raccoons, beavers, and porcupines, are more likely to be present near the Columbia River.

Table 4.4-5. Washington State Candidate Species Potentially Found on the Hanford Site

Common Name	Scientific Name
Molluscs	
Columbia pebble snail	*Fluminicola (= Lithoglyphus)* columbiana
Shortfaced lanx	*Fisherola* (= *Lanx*) *nuttalli*
Insects	
Columbia River tiger beetle[(b)]	*Cicindela columbica*
Juniper hairstreak	*Mitoura siva*
Silver-bordered bog fritillary	*Boloria selene atrocastalis*
Birds	
Burrowing owl	*Athene cunicularia*
Common loon	*Gavia immer*
Flammulated owl[(a)]	*Otus flammeolus*
Golden eagle	*Aquila chrysaetos*
Lewis' woodpecker[(a)]	*Melanerpes lewis*
Loggerhead shrike	*Lanius ludovicianus*
Long-billed curlew	*Numenius americanus*
Northern goshawk[(a)]	*Accipter gentilis*
Sage sparrow	*Amphispiza belli*
Sage thrasher	*Oreoscoptes montanus*
Trumpeter swan[(b)]	*Cygnus buccinator*
Western sage grouse[(a)]	*Centrocercus urophasianus phaios*
Merlin	*Falco columbarius*
Reptiles	
Striped whipsnake	*Masticophis taeniatus*
Mammals	
Merriam's shrew	*Sorex merriami*
Pacific western big-eared bat[(b)]	*Corynorhinus townsendii*[(c)]
Washington ground squirrel	*Spermophilus washingtoni*

(a) Reported, but seldom observed on the Hanford Site.
(b) Probable, but not observed, on the Hanford Site.
(c) Formally known as *Plecotus townsendii.*

Table 4.4-6. Washington State Plant Species of Concern Occurring on the Hanford Site

COMMON NAME	SPECIES	1994 State Status[(a)]	Proposed State[(b)]
Ammania	*Ammania robusta*	-	R1
Annual Paintbrush	*Castilleja exilis*	-	R1
Bristly Combseed	*Pectocarya setosa*	S	W
Bristly cryptantha	*Cryptantha spiculifera (= C. interrupta)*	M2	S
Brittle prickly-pear	*Opuntia fragilis*	-	R1
Canadian St. John's wort	*Hypericum majus*	M1	S
Chaffweed	*Centunculus minimus*	-	R1
Columbia river mugwort	*Artemesia lindleyana*	M3	W
Crouching milkvetch	*Astragalus succumbens*	M3	W
Desert Cryptantha	*Cryptantha scoparia*	-	R1
Desert dodder	*Cuscuta denticulata*	M1	S
Desert eveningprimrose	*Oenothera cespitosa*	S	S
Dr. Bill's Locoweed	*Astragalus conjunctus var. novum*	-	R1
False pimpernel	*Lindernia dubia anagallidea*	S	R2
Fuzzy beardtongue	*Penstemon eriantherus whitedii*	M3	R1
Geyer's milkvetch	*Astragalus geyeri*	S	S
Gray cryptantha	*Cryptantha leucophaea*	S	S
Great Basin Gilia	*Gilia leptomeria*	-	R1
Hedge Hog Cactus	*Pediocactus simpsonii var. robustior (=P. nigrispinus)*	-	R1
Kittitas Larkspur	*Delphinium multiplex*	M3	W
Palouse thistle	*Cirsium brevifolium*	M3	W
Piper's daisy	*Erigeron piperianus*	S	S
Purple Mat	*Nama densum var. parviflorum*	-	R1
Robinson's onion	*Allium robinsonii*	M3	W
Rosy balsamroot	*Balsamorhiza rosea*	M3	W
Rosy calyptridium	*Calyptridium roseum*	-	S
Scilla onion	*Allium scilloides*	M3	W
Shining flatsedge	*Cyperus bipartitus (rivularis)*	S	S
Small-flowered eveningprimrose	*Camissonia (Oenothera) minor*	-	R1
Small-flowered Hemicarpha	*Lipocarpha (=Hemicarpha) aristulata*	-	R1
Smooth cliffbrake	*Pellaea glabella simplex*	M3	W
Southern mudwort	*Limosella acaulis*	S	W
Stalked-pod milkvetch	*Astragalus sclerocarpus*	M3	W
Suksdorf's monkeyflower	*Mimulus suksdorfii*	S	S
Toothcup	*Rotala ramosior*	-	R1
Winged combseed	*Pectocarya linearis*	-	R1

Table 4.4-6 (contd)

The following species have been reported as occurring on the Hanford Site, but the known collections are questionable in terms of location or identification, and have not been recently collected on the Hanford Site.

Coyote tobacco	*Nicotiana attenuata*	S	S
Dense sedge	*Carex densa*	S	S
Few-flowered collinsia	*Collinsia sparsiflora var. bruciae*	S	S
Medic milkvetch	*Astragalus speirocarpus*	M3	W
Palouse milkvetch	*Astragalus arrectus*	S	S
Thompson's sandwort	*Arenaria franklinii thompsonii*	M2	R2

(a) Status Definitions in WNHP (1994) :

S = Sensitive, i.e. taxa that are vulnerable or declining, and could become threatened or endangered without active management or removal of threats.

M1 = Monitor Group 1. Taxa for which there are insufficient data to support listing as endangered, threatened, or sensitive.

M2 = Monitor Group 2. Taxa with unresolved taxonomic questions, once resolved, these taxa could qualify for listing as endangered, threatened, or sensitive.

M3 = Monitor Group 3. Taxa that are more abundant and/or less threatened than previously assumed, but are continuing to be monitored and the status is regularly evaluated.

(b) The revised WNHP listing (publication expected in August 1997, Personal communication, Sandy Norwood, WNHP) includes a number of additional Hanford Site species, and will include a change in status classification terminology. In general Review Group 1 (R1) corresponds to the former M1 classification, Review Group 2 (R2) corresponds to the former M2 classification, and Watch List (W) corresponds to the former M3 category.

4.5 Cultural, Archaeological, and Historical Resources

(All subsections of 4.5 updated for PNL-6415 Rev. 9)

With construction of dams elsewhere in the Columbia River system, the Hanford Reach is one of the most archaeologically rich areas in the western Columbia Plateau. It contains numerous well-preserved archaeological sites representing prehistoric, contact, and historic periods and is still thought of as a homeland by many Native American people. Historic period resources include sites, buildings, and structures from the pre-Hanford Site, Manhattan Project, and Cold War eras. Sitewide management of Hanford's cultural resources follows the Hanford Cultural Resources Management Plan (Chatters 1989).

There are more than 830 cultural resource sites and isolated finds recorded in the files of the Hanford Cultural Resources Laboratory (HCRL). Forty-nine of them are listed in the National Register of Historic Places (National Register) including 1 reactor building, 2 single archaeological sites, the 2 Rattlesnake Spring sites, and 44 archaeological sites in six archaeological districts (Table 4.5-1). In addition to the National Register sites and districts already listed in the National Register, several National Register nominations are pending (Table 4.5-2) and nine individual archaeological sites have been determined to be eligible for listing.

A programmatic agreement that addresses management of the built environment (buildings and structures) constructed during the Manhattan Project and Cold War periods was completed and accepted by Department of Energy, Advisory Council on Historic Preservation, and Washington State Historic Preservation Officer in 1996 (DOE 1996b). Using 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, the Department of Energy identified a Register-eligible Hanford Site Manhattan Project and Cold War Era Historic District which served to organize and delineate the evaluation and mitigation of Hanford's built environment. This process resulted in the selection of 185 buildings, structures and complexes as contributing properties within the historic district recommended for mitigation. 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 requirement. Approximately 900 buildings and structures were identified as either contributing properties not selected for mitigation or as non-contributing properties, and will be documented in a database maintained by the Department of Energy. Four hundred and fifty- five buildings and structures have been inventoried and recorded on Washington State Historic Property Inventory Forms.

Cultural resource reviews are conducted before Hanford Site projects that entail disturbing ground and/or altering or demolishing existing structures are begun. These reviews ensure that prehistoric and historic sites and existing structures eligible for the National Register of Historic Places are not adversely impacted by proposed projects. (For Manhattan Project/Cold War era properties, refer to Appendix C, Table 1, Programmatic Agreement for the Built Environment on the Hanford Site, 96-EAP-154, for the list of buildings/structures eligible for the National Register as contributing properties within the Historic District recommended for mitigation.)

4.5.1 Native American Cultural Resources

In prehistoric and early historic times, the Hanford Reach of the Columbia River was populated by Native Americans of various tribal affiliations. The Wanapum and the Chamnapum bands dwelt along the Columbia River from south of Richland upstream to Vantage (Relander 1956; Spier 1936). Some of their descendants still live nearby at Priest Rapids (Wanapum), others are included in the Yakama and Umatilla Reservations. Palus people, who lived on the lower Snake River, joined the Wanapum and Chamnapum to fish the Hanford Reach of the Columbia River and some inhabited the river's east bank (Relander 1956; Trafzer and Scheuerman 1986). Descendants of the Palus now live on the Coville Reservation. The Nez Perce, Walla Walla, and Umatilla people also made periodic visits to fish in the area. Descendants of these people retain traditional secular and religious ties to the region and many have knowledge of the ceremonies and lifeways of their ancestral culture.

Table 4.5-1. Historic Properties Listed in the National Register of Historic Places and the Archaeological Sites Within Them

Property Name	Site(s) Included
Hanford Island Archaeological Site	45BN121
Hanford North Archaeological District	45BN124 through 45BN134, 45BN178
Locke Island Archaeological District	45BN137 through 45BN140, 45BN176, 45GR302a, 45GR302b, 45GR302c, 45GR303 through 45GR305
Paris Archaeological Site	45GR317
Rattlesnake Springs Sites	45BN170 and 45BN171
Ryegrass Archaeological District	45BN149 through 45BN151
Savage Island Archaeological District	45BN116 through 45BN119, 45FR257 through 45FR262
Snively Canyon Archaeological District	45BN172 and 45BN173
Wooded Island Archaeological District	45BN107 through 45BN112
105-B Reactor	N/A[a]

(a) N/A = not applicable.

Table 4.5-2. Historic Properties Nominated, or Prepared for Nomination, to the National Register of Historic Places

Property Name	Site(s) Included
Coyote Rapids A.D.[a,b]	45BN152, 45GR312 through 45GR314
Gable Mountain/Gable Butte Archaeological Site[a,b]	45BN348 through 45BN363, 45BN402 through 45BN410
Hanford South A.D.[b,c]	45BN026 through 45BN036; 45BN040 through 45BN045; 45BN101 through 45BN112; 45BN162 through 45BN168; 45BN191, 45BN192; 45FR019 through 45FR025; 45FR251 through 45FR253, and 45FR308
Wahluke A.D.[b,c]	45BN141 through 45BN148; 45GR306A, 45GR306B, 45GR307C

(a) Nominated; renomination pending.
(b) Listed on the Washington State Register of Historic Places.
(c) Nominated; nomination process discontinued.

The *Washani* religion, which has ancient roots and had its start on the Hanford Site, is still practiced by many people such as the Wanapum, and those on the Yakama, Umatilla, Warm Springs, and Nez Perce Reservations. Native plant and animal foods, some of which can be found on the Hanford Site, are used in the ceremonies performed by tribal members. Tribes have expressed an interest in renewing their use of these resources, and the Department of Energy is assisting them in this effort. Certain landforms, especially Rattlesnake Mountain, Gable Mountain, Gable Butte, Goose Egg Hill, and various sites along and including the Columbia River, remain sacred to them.

4.5.2 Archaeological Resources

People have inhabited the Middle Columbia River region since the end of the glacial period. More than 10,000 years of prehistoric human activity in this largely arid environment have left extensive archaeological deposits along the river shores (Chatters 1989; Greengo 1982; Leonhardy and Rice 1970). Well-watered areas inland from the river also show evidence of concentrated human activity (Chatters 1982, 1989; Daugherty 1952; Greene 1975; Leonhardy and Rice 1970; Rice 1980), and recent surveys have indicated extensive, although dispersed, use of arid lowlands for hunting. Graves are common in various settings, and spirit quest monuments are still found on high, rocky summits of the mountains and buttes (Rice 1968a). Throughout most of the region, hydroelectric development, agricultural activities, and domestic and industrial construction have destroyed or covered the majority of these deposits. Amateur artifact collectors have had an immeasurable impact on what remains. By virtue of their inclusion in the Hanford Site from which the public is restricted, archaeological deposits found in the Hanford Reach of the Columbia River and on adjacent plateaus and mountains have been spared some of the disturbances that have befallen other sites. The Hanford Site is thus a *de facto* reserve of archaeological information of the kind and quality that have been lost elsewhere in the region.

More than 300 prehistoric archaeological sites and isolated finds have been recorded on Hanford, of which almost 50 contain prehistoric and historic components. Prehistoric archaeological sites common to the Hanford Site include remains of numerous pit house villages, various types of open campsites, cemeteries, spirit quest monuments (rock cairns), hunting camps, game drive complexes, and quarries in nearby mountains and rocky bluffs (Rice 1968a,b 1980); hunting/kill sites in lowland stabilized dunes; and small temporary camps near perennial sources of water located away from the river (Rice 1968b).

Many recorded sites were found during four archaeological reconnaissance projects conducted between 1926 and 1968 (Drucker 1948; Krieger 1928; Rice 1968a,b). Much of this early archaeological survey and reconnaissance activity concentrated on islands and on a strip of land approximately 400-m (1312-ft) wide on either side of the river (Rice 1980). Reconnaissance of several project-specific areas and other selected locations conducted through the mid-1980s added to the recorded site inventories. Systematic archaeological surveys conducted from the middle 1980s through 1996 are responsible for much of the remainder (Chatters 1989; Chatters and Cadoret 1990; Chatters and Gard 1992; Chatters et al. 1990, 1991, 1992; Last et al. 1993, Andrefsky et al.1996).

The Mid-Columbia Archaeological Society (MCAS) conducted minor test excavations at several sites on the river banks and islands (Rice 1980) and a larger scale test at site 45BN157 (Den Beste and Den Beste 1976). The University of Idaho also excavated a portion of site 45BN179 (Rice 1980) and collaborated with the MCAS on its other work. Test excavations were conducted at other sites to determine National Register eligibility (Table 4.5-3).

During his reconnaissance of the Hanford Site in 1968, Rice (1968b) inspected portions of Gable Mountain, Gable Butte, Snively Canyon, Rattlesnake Mountain, and Rattlesnake Springs. Rice also inspected additional portions of Gable Mountain and part of Gable Butte in the late 1980s (Rice 1987). Some reconnaissance of the BWIP Reference Repository Location (Rice 1984), a proposed land exchange in T. 22 N., R. 27 E., Section 33 (Rice 1981), and three narrow transportation and utility corridors (ERTEC 1982; Morgan 1981; Smith et al. 1977) were also conducted. Other large-scale proposed project areas have been completed in recent years, including the 100 Areas from 1991 through 1993 and 1995 (Chatters et al. 1992; Wright 1993), McGee Ranch (Gard and Poet 1992), the Laser Interferometer Gravitational Wave Observatory Project, the North Slope Waste Sites Project, the Environmental Restoration Disposal Facility, and the Washington State University 600 Area Block Survey. To date, approximately 8% of the Hanford Site has been surveyed.

4.5.3 Historic Archaeological Resources

The first Euroamericans who came onto the Hanford Site were Lewis and Clark, who traveled along the Columbia and Snake Rivers during their 1803 to 1806 exploration of the Louisiana Territory. They were followed by fur trappers, military units, and miners who passed through on their way to more productive 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. Cattle ranches were established in the 1880s, and farmers soon followed. Several small, thriving towns, including Hanford, White Bluffs, and Ringold, grew up along the riverbanks in the early twentieth century. Other ferries were established at Wahluke and Richmond. The towns and nearly all other structures were razed after the U.S. Government acquired the land for the Hanford Engineer Works in 1943 (Chatters 1989; ERTEC 1981; Rice 1980).

About 470 historic archaeological sites and isolated finds have been recorded on Hanford. Forty-eight archaeological sites contain both historic and prehistoric components. Numerous historic properties, associated with the pre-Hanford Site era, have also been recorded. Properties from this period include semi-subterranean structures near McGee Ranch; the Hanford Irrigation and Power Company's pumping plant at Coyote Rapids; the Hanford Irrigation Ditch; the former Hanford Townsite, pumping plant, and high school; Wahluke Ferry; the White Bluffs Townsite and bank; the Richmond Ferry; Arrowsmith Townsite; a cabin at East White Bluffs ferry landing; the White Bluffs road; the Chicago, Milwaukee, St. Paul, and Pacific Railroad (Priest Rapids-Hanford Line) and associated whistle stops; and Bruggeman's fruit warehouse (Rice 1980). Historic archaeological sites, including an assortment of farmsteads, corrals, and dumps, have been recorded by the HCRL since 1987. ERTEC Northwest was responsible for minor test excavations at some of the historic sites, including the former Hanford Townsite (Table 4.5-3). Resources from the pre-Hanford Site period are scattered over the entire Hanford Site and include numerous areas of gold mine tailings along the riverbanks of the Columbia and remains of homesteads, agricultural fields, ranches, and irrigation-related features.

Table 4.5-3. Test Excavations Conducted on the Hanford Site

Property Name	Excavation Conducted By
45BN090	Western Washington University, Hanford Cultural Resources Laboratory
45BN149	Mid-Columbia Archaeological Society
45BN157A	Mid-Columbia Archaeological Society, University of Idaho, Columbia Basin College
45BN163 and 45BN164	Hanford Cultural Resources Laboratory
45BN179 and 45BN180	University of Idaho
45BN257	Rice
45BN307	ERTEC, Northwest Inc.
45BN423	Hanford Cultural Resources Laboratory
45BN432 and 45BN433	Hanford Cultural Resources Laboratory
45BN447	Hanford Cultural Resources Laboratory
45FR266h	University of Idaho
45GR302A	Mid-Columbia Archaeological Society
45GR306	Central Washington University, Hanford Cultural Resources Laboratory
45GR306B	Mid-Columbia Archaeological Society
45GR317	Mid-Columbia Archaeological Society
45GR318	Mid-Columbia Archaeological Society

4.5.4 Historic Architectural Resources

Historic architectural resources documented from the Manhattan Project and Cold War eras include buildings and structures primarily found in the 100, 200, 300, 400, and 600 Areas. The most important of these are the plutonium production and test reactors, and chemical separation and fuel fabrication/ processing facilities. The first reactors, 100-B, 100-D, and 100-F, were constructed during the Manhattan Project. Plutonium for the first atomic explosion and the bomb that destroyed Nagasaki to end World War II were produced in the 100-B Facility. 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.

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 sitewide (DOE 1997). To date, 455 Manhattan Project and Cold War facilities have been inventoried and recorded on historic property inventory forms. 185 Manhattan Project and Cold War buildings/structures and complexes have been determined eligible for the National Register as contributing properties within the Historic District recommended for mitigation.

4.5.5 100 Areas

Intensive field surveys were completed in the 100 Areas from 1991 to 1995. Much of the surface area within the 100 Area operable units has been disturbed by the industrial activities that have taken place during the past 50 years. However, numerous prehistoric and historic archaeological sites have been encountered, and many are potentially eligible for the National Register. The 100 Areas were the locations of nine plutonium production reactors and their ancillary and support facilities. The production reactors functioned to irradiate uranium fuel elements, the essential second step in the plutonium production process. A complete inventory of 100 Area 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 determined eligible for the National Register as contributing properties within the Historic District recommended for mitigation.

100-B/C Area. Three archaeological sites can be identified from area literature (Rice 1968a, 1980); all lie partially within the 100-B/C Area. Thirty-five sites and isolated finds were recorded in the B/C Area during archaeological surveys competed in 1995. The remains of Haven Station, a small stop on the former Chicago, Milwaukee, and Saint Paul Railroad, is located to the west of the reactor compound. One archaeological site and the remains of the small community of Haven lie on the opposite bank of the Columbia River. Many sites related to hunting and religious activities are located at the west end of Gable Butte, due south of the 100 B/C Area. These sites are part of the proposed Gable Mountain/Gable Butte Cultural District nomination.

Two archaeological sites located in the general area near 100 B/C have been investigated. Test excavations conducted in 1991 at one hunting site revealed large quantities of deer and mountain sheep bone and projectile points dating from 500 to 1500 years old. A second archaeological site 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 prehistory.

The 105-B Reactor was the first full-scale plutonium production reactor and is designated as a National Historic Mechanical Engineering Landmark. It is also listed in the National Register, was recently named as a National Civil Engineering Landmark, and was given the Nuclear Historic Landmark Award. A total of fourteen buildings and structures within the reactor compound have been recorded on historic property inventory forms. Of that number, ten properties have been determined eligible for the National Register as contributing properties within the Historic District recommended for mitigation. These include 105-B reactor, 181-B River Pumphouse, 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.

100-D/DR Area. One hundred and six known archaeological sites lie within 2 km (1.2 mi.) of the 100-D/DR reactor compound, three on the northern bank and the remainder on the southern bank. The Wahluke Archaeological District is located north of the reactor compound area. Twenty-seven sites located south of the reactor compound may be potentially eligible for the National Register because of their association with a traditional cultural property. Most of the remaining sites represent early Euroamerican settlement activities. The former community of Wahluke, which was at the landing of a ferry of the same name, is also situated on the river's north bank.

All of 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 DR Reactor buildings. Both reactors were determined eligible for the National Register as contributing properties within the Historic District, but were not recommended for mitigation. The 185/189-D buildings and adjoining facilities, all part of the 190-D complex, have been determined eligible for the National Register and were documented to Historic American Engineering Record standards.

100-F Area. The 100-F Area is situated on a segment of the Columbia River that contains many cultural sites. According to Relander (1956), camps and villages of the Wanapum people extended from the Old Hanford Townsite upstream to the former White Bluffs Townsite. Eighty-one archaeological sites have been recorded near the 100-F Area through 1995. Sites of particular importance include a cemetery, a National Register site, and a site that appears to contain artifact deposits dating to at least 6000 years ago.

The principal historic site in the vicinity is the East White Bluffs ferry landing and former townsite. This location was the upriver terminus of shipping during the early- and mid-19th 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 river boats. The first store and ferry of the mid-Columbia region were located at the ferry landing (ERTEC 1981). A log cabin, thought by some to have been a blacksmith shop in the mid-19th century, still stands there. Test excavations, conducted at the cabin by the University of Idaho, revealed historic and prehistoric elements. The structure has been recorded according to standards of the Historic American Buildings Survey (Rice 1976). The only remaining structure associated with the White Bluffs Townsite (near the railroad) is the White Bluffs Bank.

Three Manhattan Project/Cold War era buildings/structures have been inventoried in this area, including the 105-F Reactor building. The 108-F Biology Laboratory, originally a chemical pumphouse, has been determined eligible for the National Register as a contributing property within the Historic District recommended for mitigation.

100-H Area. As of 1995, there have been 40 archaeological sites recorded within 2 km (1.2 mi.) of the area. Included in this group are two historic Wanapum cemeteries, six camps (one with an associated cemetery), and three housepit villages. The largest village contains approximately 100 housepits and numerous storage caches. It appears to have been occupied from 2500 years ago to historic times (Rice 1968a). The cemeteries, camps, and villages are included in the Locke Island Archaeological District.

Historic sites in the vicinity recorded during 1992, 1993, and 1995 and include 20th century farmsteads, household dumps, and military encampments. None have yet been evaluated for eligibility to the National Register.

Four Cold War era buildings/structures were inventoried in the 100-H Area. Of that number, only the 105-H Reactor was determined eligible for the National Register as a contributing property within the Historic District. The reactor, however, was not recommended for mitigation.

100-K Area. Events took place at this locality that were of great significance to Native American people in the interior Northwest. It was here, in the mid-19th century, that Smohalla, Prophet of the Wanapum people, held the first *Washat*, the dance ceremony that has become central to the Seven Drums or Dreamer religion (Relander 1956). As a result of Smohalla's personal abilities, the religion spread to many neighboring tribes and is now practiced in some form by members of the Colville, Nez Perce, Umatilla, Wanapum, Warm Springs, and Yakama Tribes.

An archaeological survey of the 100-K Area in 1991 revealed five previously unrecorded archaeological sites. Archaeological surveys conducted during 1995 of areas not surveyed in 1991 resulted in documentation of 31 additional prehistoric and historic sites. Two sites are believed to date to the Cascade Phase (9000 to 4000 years ago). More importantly, a group of pithouses with associated long house and sweat lodge were identified that may have been the site of Smohalla's first *Washat* dance. Two National Register Districts are located near the 100-K Area, the Coyote Rapids Archaeological District and the Ryegrass Archaeological District and two individual archaeological sites have been determined to be eligible for listing in the National Register.

Historic farmstead sites are widely scattered throughout the nearby area. Two important linear features, the Hanford Irrigation Ditch and the former Chicago, Milwaukee, and St. Paul Railroad, are also present in the 100-K Area. Remnants of the Allard community and the Allard Pumphouse at Coyote Rapids are located west of the K Reactor compound.

Thirty-eight buildings/structures have been inventoried in the 100-K Reactor Area, including the 105-KE and KW Reactor buildings. Of that number, thirteen have been determined eligible for the National Register as contributing properties within the Historic District recommended for mitigation. These include the 105-KW Reactor, 190-KW Main Pumphouse, 107-KW Retention Basin, 183-KW Filter Plant, and 181-KW River Pump House.

100-N Area. Thirty-one archaeological sites have been recorded within 2 km (1.2 mi.) of the 100-N Area perimeter. Four of these sites are either listed, or considered eligible for listing, on the National Register. Three sites, two housepit villages and one cemetery, 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 (Chatters et al 1990). 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; see also Rice 1980), which do not purport to produce complete inventories of the areas covered. Intensive surveys of areas surrounding 100-N were conducted during 1991 and 1995.

Three areas near the 100-N Area are known to have been of some importance to the Wanapum Tribe. The knobs and kettles surrounding the area may have been called *Moolimooli*, which means Little Stacked Hills. Coyote Rapids, which is a short distance upstream, was called *Moon*, or Water Swirl Place. Gable Mountain (called *Nookshai* or Otter) and Gable Butte, which lie to the south of the river, are sacred mountains where youths would go on overnight vigils seeking guardian spirits (Relander 1956). Sites of religious importance may exist near the 100-N compound.

The most common evidence of historic activities now found near the 100-N Area consists of historic archaeological sites where farmsteads once stood. Sixty-six Cold War era buildings and structures have been inventoried in the 100-N Area. The 100-N Reactor, completed in 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. Twenty-nine 100-N Area buildings/structures have been determined eligible for the National Register as contributing properties within the Historic District recommended for mitigation. These include the 105-N Reactor, 109-N Heat Exchanger Building, 1112-N Guard Station, 181-N River Water Pump House, 183-N Water Filter Plant, 184-N Plant Service Power House, and 185-N Export Powerhouse (WPPSS).

4.5.6 200 Areas

An archaeological survey has been conducted of all undeveloped portions of the 200 East and 200 West Areas. The only evaluated historic site is the White Bluffs freight road that crosses diagonally through the 200 West Area. The road, which was formerly a Native American trail, has been in continuous use since antiquity and has played a role in Euroamerican immigration, development, agriculture, and Hanford Site operations. This property has been determined by the SHPO to be eligible for the National Register, although the segment that passes through the 200 West Area is considered to be a noncontributing element. A 100-m (328 ft) easement has been created to protect the road from uncontrolled disturbance.

The 200 Areas were the locations of the chemical separations (processing) plants and their ancillary and support facilities. The plants functioned to dissolve the irradiated fuel elements to separate out the plutonium, the essential third step in the nuclear process. Historic property inventory forms have been completed for seventy-two buildings/structures in the 200 Area. Of that number, fifty-eight have been determined eligible for the National Register as contributing properties within the Historic District recommended for mitigation. These include the 234-5Z Plutonium Finishing Plant, 236-Z Plutonium Reclamation Facility, 242-Z Water Treatment Facility, 231-Z Plutonium Metallurgical Laboratory, 225-B Encapsulation Building, 221-T Plant, 202-A Purex Plant, 222-S Redox Plant, 212-N Lag Storage Facility, 282-E Pumphouse and Reservoir Building, 283-E Water Filtration Plant, and 284-W Power House and Steam Plant. The 232-Z Waste Incinerator Facility and the 233-S Plutonium Concentration Building, determined eligible for the National Register, have been documented to Historic American Engineering Record standards.

4.5.7 300 Area

Much of the 300 Area has been highly disturbed by industrial activities. Five recorded archaeological sites including campsites, housepits, and a historic trash scatter are located at least partially within the 300 Area; many more may be located in subsurface deposits. Twenty-seven archaeological sites and thirteen isolated artifacts have been recorded within 2 km (1.2 mi.) of the 300 Area fence. The historic sites contain debris scatters and road beds associated with farmsteads. One archaeological site has been tested and is recognized as eligible for listing in the National Register. Several sites in this area are in the Hanford South Archaeological District, which is listed in the State Register.

One documented locality with great importance to the historic Wanapum Tribe is located near the 300 Area. Certain areas surrounding the 300 Area have been found to be of great importance to the

Native Americans and are fenced.

As the Area that was the location of the uranium fuel fabrication plants that manufactured fuel to be irradiated in the Hanford reactors, the 300 Area provided the first essential step in the plutonium production process. The 300 Area was also the location of most of the Site's research and development laboratories. One hundred fifty-eight buildings/structures in the 300 Area have been inventoried on historic property inventory forms. Of that number, forty-seven buildings/structures have been determined eligible for the National Register as contributing properties within the Historic District recommended for mitigation. This total includes the 313 Fuels Fabrication Facility, 305 Test Pile, 318 High Temperature Lattice Test Reactor, 321 Separation Building, 325 Radiochemistry Laboratory, 333 Fuel Cladding Facility, 3706 Radiochemistry Laboratory, and the 3760 Hanford Technical Library.

4.5.8 400 Area

Most of the 400 Area has been so disrupted by construction activities that archaeologists surveying the site in 1978 were able to find only 30 acres that were undisturbed (Rice et al. 1978). They found no cultural resources in those 30 acres. No archaeological sites are known to be located within 2 km (1.2 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 of 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 have been determined eligible for the National Register as contributing properties within the Historic District recommended for mitigation. 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.

4.5.9 600 Area

The 600 Area contains a diverse wealth of cultural resources and traditional cultural properties representing a full range of human activity across the Hanford Site. Project-driven surveys have been conducted throughout the area but much of the 600 Area remains unsurveyed. Several National Register Districts are located within the 600 Area including the Hanford Archaeological Site, the Hanford North Archaeological District, the Paris Archaeological Site, Rattlesnake Springs Sites, Savage Island Archaeological District, Snively Basin Archaeological District, and the Wooded Island Archaeological District. The McGee Ranch/Cold Creek Valley District has been determined to be eligible for listing on the National Register and the Gable Mountain Cultural District is pending nomination to the National Register. Areas of traditional cultural importance include Rattlesnake Mountain and foothills, the Columbia River, and Gable Mountain and Butte.

The 600 Area contains facilities that served more than one specific Site Area such as roads and railroads (and support structures). Former townsites, farmsteads, and connecting roads are widely scattered throughout the 600 Area. Fifteen buildings/structures, including the underground missile storage facility, have been inventoried at the former Nike launch and control center (H-52) in the Fitzner/Eberhardt Arid Lands Ecology (ALE) Reserve. The 622 Meteorological Complex, located near 200 West, includes seven inventoried properties. Both complexes have been determined eligible for the National Register as contributing properties within the Historic District recommended for mitigation. Four other 600 Area properties, 604 Yakima Patrol Checking Station, 604-A Sentry House, 607 Batch Plant, 618-10 Solid Waste Burial Trench, have also been determined eligible for the National Register as contributing properties within the Historic District recommended for mitigation.

Five anti-aircraft artillery sites located in the 600 Area have been determined eligible for the National Register. The Central Shops complex located in the 600 Area was determined ineligible for the National Register.

4.5.10 700 Area

The 700 Area was the location of the central administrative functions during the early Hanford period. Most of the 700 Area has been highly disturbed by industrial activities. Buildings and structures have been inventoried in this area and several have been identified as eligible for listing in the National Register.

4.5.11 1100 Area

Historic cultural resources have been identified in or near the 1100 Area. These include remains of farmsteads, homesteads, and agricultural structures pre-dating the Hanford Site. All of these historic sites will be evaluated for National Register eligibility before the start of proposed projects that could impact them. Buildings or structures have been inventoried in this area and several have been identified as eligible for listing in the National Register.

4.5.12 North Richland Area

Archaeological surveys conducted adjacent to the North Richland Area have been confined to a narrow strip along the Columbia River (Cleveland et al. 1976; Drucker 1948; Rice 1968a; Thoms 1983). Twelve sites are within 2 km (1.2 mi.) of the area. Many of these sites are included in the Hanford South Archaeological District, which was nominated for listing in the National Register in 1983.

During World War II, the North Richland Area was the locale for a camp that housed Hanford Site construction personnel. No historic archaeological sites have been recorded for this area, but homesteads and remnants of the former North Richland Townsite, Manhattan Project/Cold War construction camp, and industrial facilities associated with the 1950s Camp Hanford are found there. Seventeen former Camp Hanford industrial buildings/structures in North Richland have been inventoried and determined not eligible for the National Register.

4.6 Socioeconomics

(All subsections of 4.6 were updated for PNL-6415 Rev. 9, with the exception of section 4.6.4)

Activity on the Hanford Site plays a dominant role in the socioeconomics of the Tri-Cities and other parts of Benton and Franklin Counties. 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.

4.6.1 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) Supply System in its construction and operation of nuclear power plants; and 3) the agricultural community, including a substantial food-processing component. With the exception of a minor amount of agricultural commodities sold to local-area consumers, the goods and services produced by these sectors are exported outside the Tri-Cities. In addition to the direct employment and payrolls, these major sectors also support a sizable number of jobs in the local economy through their procurement of equipment, supplies, and business services.

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. The second component is tourism. The Tri-Cities area has increased its convention business substantially in recent years, in addition to recreational travel. The final component in the economic base relates to the local purchasing power generated not from current employees but from retired former employees. Government transfer payments in the form of pension benefits constitute a significant proportion of total spendable income in the local economy.

4.6.1.1 DOE Contractors (Hanford)

Nearly 20% of the nonagricultural jobs in Benton and Franklin counties in 1996 were at the Hanford site. An average of 13,500 employees worked for the Department of Energy and its Hanford contractors in 1996. This number is down from over 18,000 in 1994 due to downsizing activities, which has reduced employment at Hanford by 4,800 through FY 1996.

In addition to downsizing by Hanford contractors in 1996, DOE created a new Project Hanford Team in an effort to produce cleanup results more cost effectively over a shorter time period, and to help diversify and stabilize the Tri-Cities economy. This team is made up of the Fluor Daniel Hanford Company, which is the overall management contractor, six major subcontractors, and six newly created "enterprise companies." Fluor Daniel is responsible for integrating and directing cleanup tasks. The actual cleanup work is conducted by the six subcontractors. The "enterprise companies" will provide services to the six major subcontractors.

As of December 31, 1996, the official employment count for Hanford was 11,413, which includes Fluor, the six major subcontractors, Pacific Northwest National Laboratory, Bechtel, Hanford Environmental Health Foundation, ICF Kaiser, and local DOE employees. The "enterprise companies", which have a combined employment of just over 2,000, are not included in this count.

The fact that such a large portion of the Tri-Cities employment is at Hanford has had an impact on other areas of employment for many years. Previous studies have revealed that each Hanford job supports about 1.2 additional jobs in the local service sector of Benton and Franklin Counties and about 1.5 additional jobs in the state's service sector (Scott et al. 1987). Similarly, each dollar of Hanford income supports about $2.10 of total local incomes and about $2.40 of total state-wide incomes. Based on these multipliers, Hanford directly or indirectly accounts for more than 40% of all jobs in Benton and Franklin Counties.

The total wage payroll for the Hanford Site was estimated at $521 million in 1996, which accounted for a significant percentage of the payroll dollars earned in the area. This source of income has a direct impact on area businesses and services, as the bulk of Hanford employees live in Benton and Franklin counties. Based on employee residence records as of December 1996, 93% of the direct employment of Hanford live in Benton and Franklin Counties. Approximately 76% of Hanford employees reside in Richland, Pasco, or Kennewick. More than 37% are Richland residents, 9% are Pasco residents, and 30% live in Kennewick. Residents of other areas of Benton and Franklin Counties, including West Richland, Benton City, and Prosser, account for about 17% of total Hanford employment.

4.6.1.2 Washington Public Power Supply System

Although activity related to nuclear power construction ceased with the completion of the WNP-2 reactor in 1983, the Supply System continues to be a major employer in the Tri-Cities area. Headquarters personnel based in Richland oversee the operation of one generating facility and perform a variety of functions related to a standby generating facility. Decommissioning of two mothballed nuclear power plants (WNP-1 and WNP-4), which were never completed or refueled, began in 1995. In 1996, the Supply System employed around 44 people at the two plants, less than half of the 90 people that were employed there in 1994, due to decommissioning activities. As part of an effort to reduce electricity production costs, the Supply System headquarters has decreased the size of its workforce from over 1,900 in 1994 to 1,164 at the end of 1996. Supply System activities generated a payroll of approximately $81 million during 1996.

4.6.1.3 Agriculture

In 1995, agricultural production in the bi-county area generated about 9,739 wage and salary jobs, or about 12% of the area's total employment, as represented by the employees covered by unemployment insurance. Seasonal farm workers are not included in that total but are estimated by the U.S. Department of Labor for the agricultural areas in the state of Washington. In 1996, seasonal farm workers in Benton, Franklin, and Walla Walla Counties averaged 7,033, ranging from 1,788 workers during the winter pruning season to 17,257 workers at the peak of harvest. An estimated average 6,150 seasonal workers were classified as local (ranging from 1,653 to 14,388); an average of 375 were classified as intrastate (ranging from 0 to 1,311) and an average of 508 were classified as interstate (ranging from 8 to 1,558). The weighted seasonal wage for 1996 ranged from $5.35/hr to $6.75/hr, with an average of $6.06/hr (U.S. Department of Labor 1996).

According to the U.S. Department of Commerce's Regional Economic Information System, about 2,173 people were classified as farm proprietors in 1994. Farm proprietors' income, according to this same source, was estimated to be $69 million.

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 farm supply and equipment sales. Although formally classified as a manufacturing activity, food processing is a natural extension of the farm sector. More than 20 food processors in Benton and

Franklin Counties produce such items as potato products, canned fruits and vegetables, wine, and animal feed.

4.6.1.4 Other Major Employers

In 1996, the five largest non-Hanford employers employed approximately 4,570 people in Benton and Franklin Counties. These companies include: 1) Lamb Weston, which employed 1,340, 2) Burlington Northern Santa FE (BNSF) Railroad, which employed 375, 3) Siemens Power Corporation, which employed 830, 4) Boise Cascade/Paper Group, which employed 525 (although Boise Cascade's Wallula mill lies outside both Benton and Franklin Counties, most of its workforce resides in the Tri-Cities), and 5) Iowa Beef Processing Inc., which employed 1,500 (like Boise Cascade, this company lies outside of Benton and Franklin Counties, but most of the workforce resides in the area).

4.6.1.5 Tourism

An increase in the number of visitors to the Tri-Cites over the last several years has resulted in tourism playing an increasing role in helping to diversify and stabilize the area economy. The Tri-Cities Visitors and Convention Bureau reported 206 conventions and events were held in the Tri-Cities in 1996, which drew 63,540 people and generated an estimated $21 million in local revenue. The number of convention delegates is up 45% from 1995 and is over 5 times the number of delegates that visited in 1989.

Overall tourism expenditures in the Tri-Cities were roughly $184 million in 1995, up from $173 million in 1994. Travel-generated employment in Benton and Franklin Counties was about 3,220 with an estimated $34 million in payroll, up from an estimated 2,740 employed and a $30 million payroll in 1994 (Washington State Community, Trade and Economic Development).

4.6.1.6 Retirees

Although Benton and Franklin Counties have a relatively young population (approximately 55% under the age of 35), 16,958 people over the age of 65 resided in Benton and Franklin Counties in 1996. The portion of the total population 65 years and older in Benton and Franklin Counties accounts for 9.7% of the total population, slightly below that of the state of Washington (11.5%). This segment of the population supports the local economy on the basis of income received from government transfer payments and pensions, private pension benefits, and prior individual savings.

Although information on private pensions and savings is not available, data are available regarding the magnitude of government transfer payments. The U.S. Department of Commerce's Regional Economic Information System has estimated transfer payments by various programs at the county level. A summary of estimated major government pension benefits received by the residents of Benton and Franklin Counties in 1994 is shown in Table 4.6-1. About two-thirds of Social Security payments go to retired workers; the remainder are for disability and other payments. The historical importance of government activity in the Tri-Cities area is reflected in the relative magnitude of the government employee pension benefits as compared to total payments.

Table 4.6-1. Government Retirement Payments in Benton and Franklin Counties, 1994 (millions of dollars)[a]

	Benton County	Franklin County	Total
Social Security (including survivors and disability)	148.0	38.5	186.5
Railroad retirement	3.9	4.0	7.9
Federal civilian retirement	12.7	2.6	15.3
Veterans pension and military retirement	20.5	3.9	24.4
State and local employee retirement	28.9	5.7	34.6
Total	214.0	54.7	268.7

(a) U.S. Department of Commerce (1996).

4.6.2 Employment and Income

Nonagricultural employment in the Tri-Cities grew steadily from 1988 to 1994. However, the total annual average employment fell in 1995 and again in 1996. Table 4.6-2 provides a breakdown of nonagricultural wage and salary workers employed in Benton and Franklin Counties in 1995 and 1996 (Washington State Employment Security 1996). There was an average of 69,600 jobs in the Tri-Cities in 1996, down 2,700 from 1995. The bulk of the decrease came in the services sector, which lost 1,900 jobs. Within this sector, research services averaged 12,900 in 1996, down from a peak of 17,400 in 1994, mostly due to Hanford downsizing. All other sectors experienced job losses in 1996 except the transportation, communication, and public utility sector, which remained even. Employment in construction fell 300, manufacturing dropped 200, and government, trade, and the finance, insurance, and real estate sectors each dropped 100 (Washington State Employment Security 1996).

Three measures of area income are presented in this section: total personal income, per capita income, and median household income. Total personal income is comprised of all forms of income received by the populace, including wages, dividends, and other revenues. Per capita income is roughly 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 an income greater than the median and half have less. The source for total personal income and per capita income was the U.S. Department of Commerce's Regional Economic Information System, while median income figures for Washington State were provided by the Office of Financial Management (OFM) (OFM 1996b).

In 1994, the total personal income for Benton County was $2,851 million, Franklin County was $726 million, and the state of Washington was $120.4 billion. Per capita income in 1994 for Benton County was $22,053, Franklin County was $16,999, and Washington State was $22,526. Median household income in 1994 for Benton County was estimated to be $43,684, Franklin County was estimated at $31,121, and the state of Washington was estimated at $38,094.

Table 4.6-2. Nonagricultural Workers in Benton and Franklin Counties, 1995 and 1996

Industry	1995 Annual Average	1996 Annual Average	% Change 1995-1996
Nonagricultural wage laborers	72,300	69,600	-3.7
Manufacturing	6,000	5,800	-3.3
Construction	4,300	4,000	-7.0
Public utilities	2,900	2,900	0.0
Wholesale and retail trade	15,500	15,400	-0.7
Finance, insurance, and real estate	2,300	2,200	-4.4
Services	27,800	25,900	-6.8
Government	13,500	13,400	-0.7

4.6.3 Demography

Estimates for 1996 placed population totals for Benton and Franklin Counties at 131,000 and 43,700, respectively (OFM 1996b). When compared to the 1990 census data in which Benton County had 112,560 residents and Franklin County's population totaled 37,473, the current population totals reflect the continued growth occurring in these two counties. When compared to 1995 estimates, however, growth seems to be stabilizing, as the Benton County estimate remained unchanged from 1995 and the Franklin County estimate was down 300 people.

Within each county, the 1996 estimates distributed the Tri-Cities population as follows: Richland 35,990; Pasco 22,370; and Kennewick 48,010. The combined populations of Benton City, Prosser, and West Richland totaled 13,665 in 1996. The unincorporated population of Benton County was 33,335. In Franklin County, incorporated areas other than Pasco have a total population of 3,263. The unincorporated population of Franklin County was 18,067 (OFM 1996b).

The 1996 estimates of racial categories by the OFM (OFM 1996b) indicate that in Benton and Franklin Counties, Asians represent a lower proportion and individuals of Hispanic origin represent a higher proportion of the racial distribution than those in the state of Washington. Countywide, Benton and Franklin Counties exhibit varying racial distributions, as indicated by the data in Table 4.6-3.

Benton and Franklin Counties accounted for 3.2% of Washington State's population (OFM 1996a). In 1996, the population demographics of Benton and Franklin Counties are quite similar to those found within the state of Washington. The population in Benton and Franklin Counties under the age of 35 is 54.5%, compared to 50.7% for the state of Washington. In general, the population of Benton and Franklin Counties is somewhat younger than that of Washington State. The 0- to 14-year old age group accounts for 26.6% of the total bi-county population as compared to 22.7% for Washington State. In 1996, the 65-year old and older age group constituted 9.7% of the population of Benton and Franklin Counties compared to 11.5% for the state of Washington.

Table 4.6-3. Population Estimates by Race and Hispanic Origin, 1996[(a)]

Area	Total	White/ Caucasian	Black/ African American	Indian, Eskimo, and Aleut	Asian and Pacific Islander	Hispanic Origin[(b)]
Washington State	5,516,800	4,872,813 88.3%	191,296 3.5%	109,766 2.0%	342,925 6.2%	337,706 6.1%
Benton and Franklin Counties[(c)]	174,700	163,376 93.5%	3,313 1.9%	1,689 1.0%	6,320 3.6%	34,202 19.6%
Benton County[(c)]	131,000	124,206 94.8%	1,644 1.3%	1,198 0.9%	3,951 3.0%	15,138 11.6%
Franklin County[(c)]	43,700	39,170 89.6%	1,669 3.8%	491 1.1%	2,369 5.4%	19,064 43.6%

(a) From OFM 1996b - Population Estimates by Race and Hispanic Origin by County, April 1, 1996; Racial Classifications Based on OMB Directive 15.

(b) 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.

(c) Percentage figures refer to county, not state, populations.

4.6.4 Environmental Justice

Environmental justice refers to fair treatment of all races, cultures, and income levels with respect to laws, policies, and government actions. Executive Order (E.O.) 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, directs federal agencies to identify and address, as appropriate, disproportionately high and adverse human health or environmental effects of their programs, policies, and activities on minority and low-income populations.

Minority populations are defined as all nonwhite individuals, plus all individuals of Hispanic origin, as reported in the 1990 census. Low-income persons are defined as living in households in the 1990 Census that reported an annual income less than the United States official poverty level. The poverty level varies by size and relationship of the members of the household. The 1990 Census states poverty level was $12,674 for a family of 4. Nationally, in 1990, 24.2% of all persons were minorities and 13.1% of all households had incomes less than the poverty level.

The distribution of minority populations residing in various areas surrounding the Hanford Site in 1990 is shown in Table 4.6-4. The table shows minority populations within an 80-km (50-mi) radius. For comparison, minority populations are also shown for those counties with boundaries at least partially within the circle. Counties included in the circle are Benton, Franklin, Walla Walla, Adams, Grant, Kittitas, Yakima, and Klickitat in Washington State; and Umatilla in Oregon.

The racial and ethnic composition of minorities surrounding the Hanford Site is also illustrated in Table 4.6-4. At the time of the 1990 census, Hispanics composed nearly 81% of the minority population surrounding the Hanford Site. The Site is also surrounded by a relatively large percentage (about 8%) of Native Americans because of the presence of the Yakama Indian Reservation and tribal headquarters in Toppenish, Washington.

Table 4.6-5 demonstrates the number of low-income households in the area surrounding the Hanford Site. Block groups containing 50% or more low-income households lie largely south of the Site.

Table 4.6-4. Distribution of Minority Populations in Counties Surrounding the Hanford Site, 1990

Population within 80 km (50 mi.) of center of Site	383,934
Minority population within 80 km (50 mi.) of center of Site	95,042
American Indian, Eskimo, or Aleut population	7,913
Asian or Pacific Islander population	5,296
African American population	4,331
Other race	568
Hispanic origin population[a]	76,933
Percentage of minority population within 80 km (50 mi.) of center of Site	25
Population in counties surrounding the Site	565,871
Minority population in counties surrounding the Site	116,610
Percent of minority population in counties surrounding the Site	21

(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.

Table 4.6-5. Distribution of Low-Income Households in Counties Surrounding the Hanford Site, 1990

Households within 80 km (50 mi.) of the Site	136,496
Low-income households within 80 km (50 mi.) of the Site	57,667
Percentage of low-income households within 80 km (50 mi.) of the Site	42
Households in counties surrounding the Site	204,501
Low-income households in counties surrounding the Site	86,693
Percent of low-income households in counties surrounding the Site	42

Figures 4.6-1 and 4.6-2 show the geographic distribution of minority and low-income population within census block groups (areas defined for monitoring census data of approximately 250 to 550 housing units) that are within 80 km (50 mi.) of the 200 East Area (approximately the center of the

Hanford Site).

There is not yet an agreed-upon standard within the emerging federal guidance on environmental justice for what constitutes an area that has a minority or low-income population large enough to act as a test for disproportionate impact. For example, it has not been decided in the case of minority residents whether the standard ought to be 50% minority residents, more than the national average of minority residents (24.2%), more than the state average, or some other number that takes into account other regional population characteristics. It is even more problematic to define low-income residents, since less income is needed to maintain a given living standard in areas with a relatively low cost of living. Several different definitions have been proposed, but each potential definition has strengths and weaknesses.

Therefore, Figures 4.6-1 and 4.6-2 each employs a graduated shading scheme that indicates those areas of small and roughly equal numbers of housing units that have heavy concentrations of minority and low-income residents as well as those areas that have lighter concentrations of such residents. Shaded areas generally indicate those census block groups that have more than the national average percentages of minority and low-income populations, with heavier shading showing heavier concentrations. There are no residents within the irregularly shaped census block shown in the center of Figures 4.6-1 and 4.6-2 that contains the 200 East location. This block is the Hanford Site.

4.6.5 Housing

In 1996, 91% of all housing (44,488 total units) in the Tri-Cities were occupied. Single-unit housing, which represents nearly 58% of the total units, had a 95% occupancy rate throughout the Tri-Cities. Multiple-unit housing, defined as housing with two or more units, had an occupancy rate of 85%. Representing 11% of the housing unit types, mobile homes had the lowest occupancy rate at 84%. Pasco had the lowest occupancy rate in all categories of housing with 89%, followed by Kennewick with 90%, and Richland with 92%. In 1995, 95% of all housing units in the Tri-Cities were occupied, but the combination of staff reductions by Hanford employers and a surge in single family housing and apartment construction toward the end of 1995 and early 1996 has had an impact on occupancy rates in 1996. The most significant drop was in multiple-unit housing which had a 94% occupancy rate in 1995. Table 4.6-6 shows a detailed listing of total units and occupancy rate by type in the Tri-Cities.

Table 4.6-6. Total Units and Occupancy Rates, 1995 Estimates[(a)]

City	All Units	Rate %	Single Units	Rate %	Multiple Units	Rate %	Manufactured Homes	Rate %
Richland	15,859	92	10,722	96	4,284	84	853	88
Pasco	8,419	89	4,104	95	2,956	85	1,359	83
Kennewick	20,210	90	10,887	95	6,660	85	2,241	84
Total for Tri-Cities	44,488	91	27,713	95	13,900	85	4,875	84

(a) OFM 1996b.

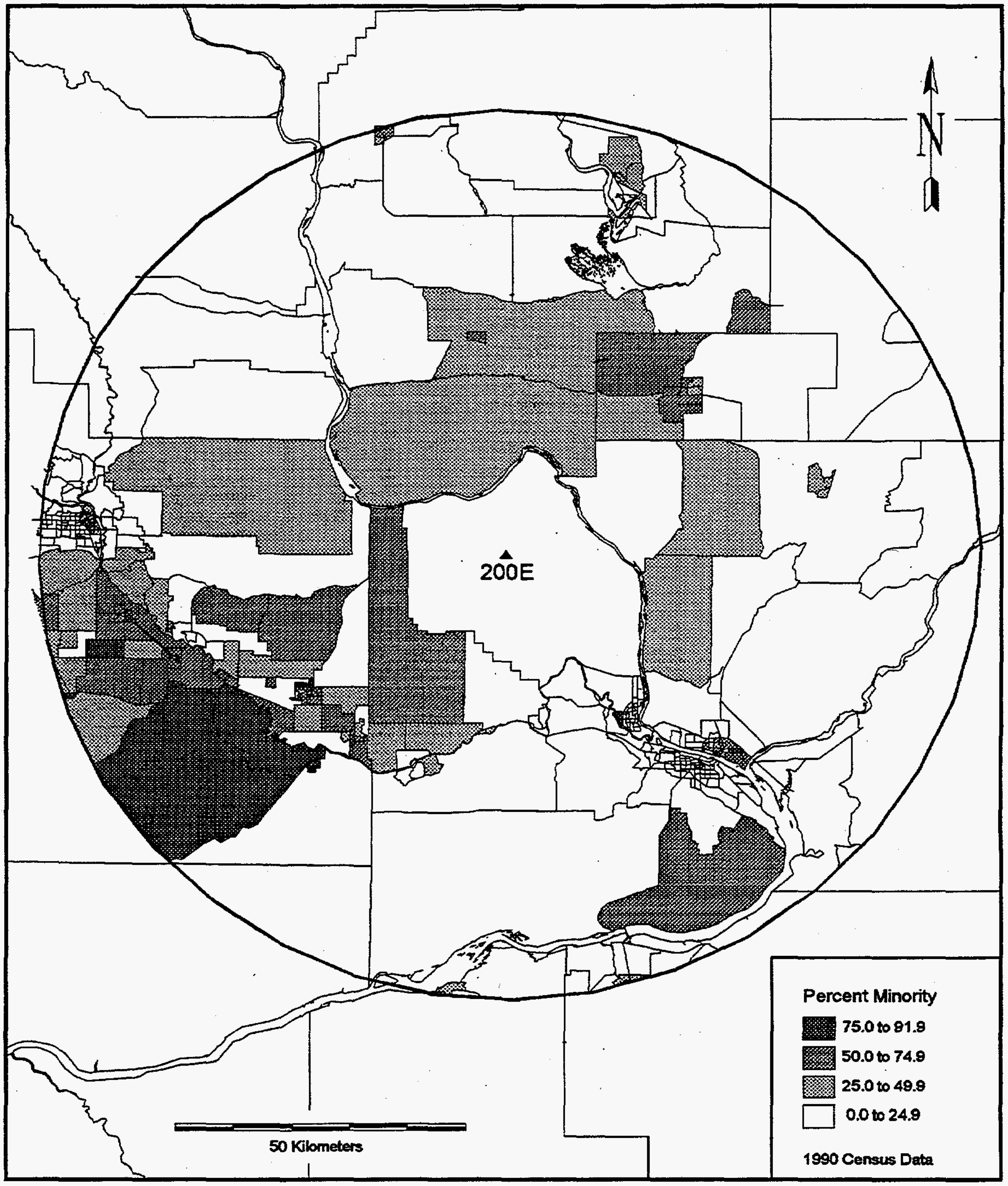

Figure 4.6-1. Distribution of Minority Populations Within 80 km (50 mi.) of the Hanford Site

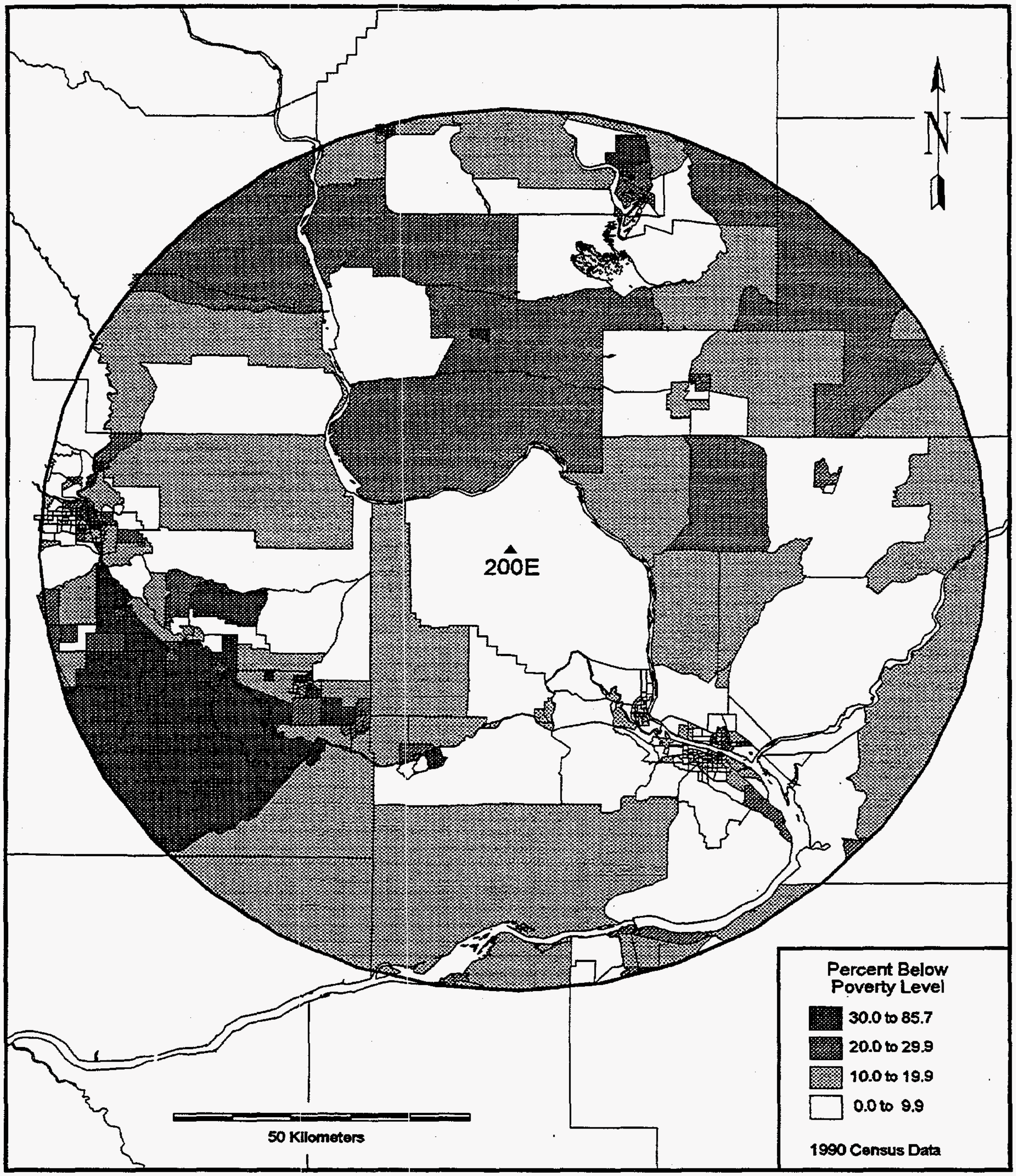

Figure 4.6-2. Distribution of Low-Income Populations Within 80 km (50 mi.) of the Hanford Site

4.6.6 Transportation

The Tri-Cities serve as a regional transportation and distribution center with major air, land, and river connections. The Tri-Cities have direct rail service, provided by BNSF and Union Pacific, that connects the area to more than 35 states. Union Pacific operates the largest fleet of refrigerated rail cars in the United States and is essential to food processors, which ship frozen food from this area. Passenger rail service is provided by Amtrak, which has a station in Pasco.

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. The average shipping time from the Tri-Cities to these deep-water ports by barge is 36 hours (Evergreen Community Development Association 1986).

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 access to destinations anywhere in the world. Delta Airlines, SkyWest Airlines and Horizon Air offer 33 flights into and out of the Tri-Cities on a daily basis connecting to domestic and international flights through Salt Lake City, Seattle and Portland. There are two runways: a main and minor crosswind. 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, such as the Boeing 727-200 and Douglas DC-9. The Tri-Cities Airport handled about 175,376 passengers (enplanements) in 1996. 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. Air freight shippers that service the region include Airborne out of Richland, United Parcel Service from Kennewick, and Federal Express out of the Tri-Cities airport in Pasco.

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, I-182, I-84 and I-90. Interstate-82 is 8 km (5 mi.) south-southwest of the Site. Interstate-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 Interstate-84. I-84, located south of the site in Oregon, is a major corridor leading to Portland, Oregon. SR 224, 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, which continues south through the Tri-Cities. SR 14 connects with I-90 at Vantage, Washington, and provides ready access to I-84 at several locations along the Oregon and Washington border. SRs 240 and 24 traverse the Hanford Site and are maintained by Washington State. Other roads within the Site are maintained by the DOE.

4.6.7 Educational Services

Primary and secondary education in the Tri-Cities area are served by the Richland, Pasco, Kennewick, and Kiona-Benton School Districts. The combined 1996 fall enrollment for all districts was approximately 31,970 students, an increase of 3.3% from the 1995 total of 30,940 students. The 1996 total includes approximately 8,943 from the Richland School District, 7,954 students from the Pasco School District, about 13,625 students from the Kennewick School District, and 1,701 from Kiona-Benton. In 1996, Richland was operating over capacity at the elementary level, at capacity at their middle schools and slightly under at the high school level. A bond issue was recently passed to build a new elementary school, which should open in about two years. Pasco was at capacity for primary education but had room for more students at the secondary level. Pasco also passed an elementary school bond issue, and will replace two schools, remodel one, and build a new one. Kennewick and Kiona-Benton schools are operating at capacity.

Post-secondary education in the Tri-Cities area is provided by a junior college, Columbia Basin College (CBC), and the Washington State University, Tri-Cities branch campus (WSU-TC). WSU-TC offers a variety of upper-division, undergraduate, and graduate degree programs. The 1996 fall/ winter enrollment was approximately 6,505 at CBC and 1,296 at WSU-TC. Many of the programs offered by these two institutions are geared towards the vocational and technical needs of the area. Currently, 27 associate degree programs are available at CBC, and WSU-TC offers 10 undergraduate and 16 graduate programs, plus access to 8 more graduate programs via satellite.

4.6.8 Health Care and Human Services

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

Kadlec Medical Center, located in Richland, has 125 beds and functioned at 54.2% capacity with 6,255 total admissions in 1996. Non-Medicare/Medicaid patients accounted for 62%, or 3,863 of their annual admissions in 1996. An average stay of 3.97 days per admission was reported for 1996.

Kennewick General Hospital maintained a 45% occupancy rate of its 70 beds with 4,880 annual admissions in 1996. Non-Medicare/Medicaid patients in 1996 represented 48% of its total admissions. An average stay of 3.0 days per admission was reported in 1996.

Our Lady of Lourdes Hospital operates a 132-bed Health Center, located in Pasco, providing acute, subacute, skilled nursing and rehabilitation, and alcohol and chemical dependency services. Our Lady of Lourdes also operates the Carondolet Psychiatric Care Center, a 32-bed psychiatric hospital located in Richland. They also provide a significant amount of outpatient and home health services. For their fiscal year ending June 30, 1996, Our Lady of Lourdes had a total of 4,398 admissions and 120,145 outpatient visits. 35.5% of Lourdes' admissions were non-Medicare/Medicaid. Lourdes had an average acute care length of stay of 3.1 days.

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; the Child Protective Service; emergency medical service; a senior companion program; and vocational rehabilitation.

The Tri-Cities are also served by a large number of private agencies and voluntary human services organizations. The United Way, an umbrella fund-raising organization, incorporates 23 participating agencies offering 46 programs. These member agencies had a cumulative budget total of $21.3 million in 1996.[a] In addition, there were 470 organizations that received funds as part of the United Way-Franklin County donor designation program.

4.6.9 Police and Fire Protection

Police protection in Benton and Franklin Counties is provided by Benton and Franklin Counties' sheriff departments, local municipal police departments, and the Washington State Patrol Division with headquarters in Kennewick. Table 4.6-7 shows the number of commissioned officers and patrol cars in each department in April 1997. The Kennewick Municipal Police Department maintains the largest staff of commissioned officers with 74.

Table 4.6-7. Police Personnel in the Tri-Cities, 1997[a]

Area	Commissioned Officers	Reserve Officers	Patrol Cars
Kennewick Municipal	74	13	22
Pasco Municipal	44	22	15
Richland Municipal	50	13	13
West Richland Municipal	11	8	9
Benton County Sheriff	43	20	55
Franklin County Sheriff	21	20	21

(a) Source: Personal communication with each department office, April 1997.

Table 4.6-8 indicates the number of firefighting personnel, both paid and unpaid, on the staffs of fire districts in the area.

The Hanford Fire Department, with 93 firefighters, is trained to dispose of hazardous waste and to fight chemical fires. During the 24-hour duty period, the 1100 Area and 300 Area have 6 firefighters; 300 Area has 7; 200 East and 200 West Areas have 8; the 100 Areas have 5; and the 400 Area, which includes the Supply System, has 6. To perform their responsibilities, each station has access to a Hazardous Material Response Vehicle that is equipped with chemical fire-extinguishing equipment, an attack truck that carries foam and Purple-K dry chemical, a mobile air truck that provides air for gas masks, and a transport tanker that supplies water to six brushfire trucks.

(a) Personal communication with Jim Ball, President of Benton-Franklin United Way, 1996.

Table 4.6-8. Fire Protection Personnel in the Tri-Cities, 1997[a]

Station[b]	Fire Fighting Personnel	Volunteers	Total	Service Area
Kennewick	63	0	63	City of Kennewick
Pasco	30	0	30	City of Pasco
Richland	48	0	48	City of Richland
BCRFD 1	6	94	100	Kennewick Area
BCRFD 2	3	26	29	Benton City
BCRFD 4	4	32	36	West Richland

(a) Source: Personal communication with each department office, April 1997.
(b) BCRFD = Benton County Rural Fire Department.

4.6.10 Parks and Recreation

The convergence of the Columbia, Snake, and Yakima Rivers offers the 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. While 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. In 1996, nearly 2 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, which attracted more than 4.3 million visitors in 1996. 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 the indoor and outdoor facilities available, some of which are listed in Table 4.6-9. Numerous tennis courts, ball fields, and golf courses offer outdoor recreation to residents and tourists. 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.

Table 4.6-9. Examples of Physical Recreational Facilities Available in the Tri-Cities

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.
Bowling	Lanes in each city including Fiesta Bowling Center, Celebrity Bowl, Columbia Lanes, and Go-Bowl.
Camping	Several hundred campsites within driving distance from the Tri-Cities area, including Fishhook Park and Sun Lakes.
Fishing	Steelhead, sturgeon, trout, walleye, bass, and crappie fishing in the lakes and rivers near the Tri-Cities.
Golf	6 public courses including Canyon Lakes, Horn Rapids, and West Richland Municipal, two private courses, and a number of driving ranges and pro shops are available.
Hunting	Duck, geese, pheasant, and quail hunting. Deer and elk hunting in the Blue Mountains and the Cascade Range.
Roller skating	Roller skating in Richland, Kennewick, and Prosser.
Swimming	Private and public swimming pools in the area. Boating, water-skiing, and swimming on the Columbia River.
Tennis	20 outdoor city courts, with additional outdoor courts located at area schools.
Walking/Bicycling	The region has over 32 miles of paved bike/hike paths.

4.6.11 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 draw a large portion of the 50.6 billion L (13.43 billion gal) used in 1996 from the Columbia River. Each city operates its own supply and treatment system. The Richland water supply system derives about two-thirds of its water directly from the Columbia River, while the remainder is split between a well field in North Richland and groundwater wells. The city of Richland's total usage in 1996 was 28 billion L (7.4 billion gal). This usage represents approximately 65% of the maximum supply capacity. The city of Pasco system also draws from the Columbia River for its water needs. In 1996, Pasco consumed 9 billion L (2.41 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 provide approximately 43% of the total maximum supply of 30 billion L (8 billion gal). Total 1996 usage in Kennewick was 12.9 billion L (3.41 billion gal).

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 is designed to treat a total capacity of 113.5 million L/d (30 million gal/d) and processed an average flow of 76.4 million L/d (20.2 million gal/d) in 1996. Kennewick's waste treatment system processed an average 19.3 million L/d (5.13 million gal/d), while the system is capable of treating 32.9 million L/d (8.7 million gal/d). Pasco's waste treatment system processed an average 4.5 million L/d (1.2 million gal/d) while the system is capable of treating 60.4 million L/d (16 million gal/d).

In the Tri-Cities, electricity is provided by the Benton County Public Utility District, Benton Rural Electrical Association, Franklin County Public Utility District, and City of Richland Energy Services Department. All the power that these utilities provide in the local area is purchased from the Bonneville Power Administration (BPA), a federal power marketing agency. The average rate for residential customers served by the four local utilities is approximately $0.048/kWh. Total electrical consumption in 1996 was 3.13 billion kWh. Electrical power for the Hanford Site is purchased wholesale from BPA. Energy requirements for the Site during FY 1996 exceeded 332 million kWh for a total cost of $9.4 million. Additionally, the Site spends about $0.03/kWh for electrical transportation and distribution within the Hanford reservation.

Natural gas, provided by the Cascade Natural Gas Corporation, serves a small portion of residents, with 7,600 residential customers in December 1996. The average annual gas bill for residential customers is $576.

In the Pacific Northwest, hydropower, and to a lesser extent, coal and nuclear power, constitute the region's electrical generation system. The system is capable of delivering approximately 20,300 average megawatts of guaranteed energy. Of that, approximately 62% is derived from hydropower, 16% from coal, and less than 7% from nuclear plants. One commercial nuclear power plant, WNP-2, remains in service in the Pacific Northwest, with an average generating capability of 833 megawatts. The Trojan nuclear power plant, in Oregon, was permanently shut down on January 4, 1993.

The region's electrical power system, more than any other system in the nation, is dominated by hydropower. In a given peak demand hour, the hydropower system is capable of providing nearly 30,000 megawatts of capacity. Variable precipitation and limited storage capabilities alter the system's output from 12,300 average megawatt under critical water conditions to 20,000 average megawatt in record high-water years. The Pacific Northwest system's reliance on hydroelectric power means that it is more constrained by the seasonal variations in peak demand than in meeting momentary peak demand.

Additional constraints on hydroelectric production are measures designed to protect and enhance the production of salmon, as many salmon runs have dwindled to the point of being threatened or endangered. These measures, outlined by the Northwest Power Planning Council's (NPPC) Columbia River Basin Fish and Wildlife Program, include minimum flow levels and a "water budget," which refers to water in the Columbia and Snake Rivers that is released to speed the migration of young fish to the sea. Generation capacity of the hydroelectric system is decreased with these measures, as less water is available to pass through the turbines.

Throughout the 1980s, the Pacific Northwest had more electric power than it required and was operating with a surplus. This surplus has been exhausted, however, and there is only enough power supplied by the system to meet regional electricity needs. In the 1991 Northwest Power Plan, the NPPC set a goal of purchasing more than 1500 megawatts of energy savings by the year 2000 to help the existing system meet with rising electricity demand. NPPC estimates that the Pacific Northwest will need an additional 2000 megawatts over 1991 consumption by the turn of the century.

4.6.12 Land Use

The Hanford Site encompasses 1,450 km^2 (560 mi^2) and includes several DOE operational areas. The entire Hanford Site has been designated a National Environmental Research Park. The major areas on the Site are as follows:

- The 100 Areas, bordering on the right bank (south shore) of the Columbia River, are the sites of eight retired plutonium production reactors and the N Reactor. The facilities in the 100 Areas are being placed in a stabilized state for ultimate decommissioning. The N Reactor Deactivation Program covers the period from FY 1992 through FY 1997. The 100 Areas occupy about 11 km^2 (4 mi^2).

- The 200 West and 200 East Areas are located on a plateau about 8 and 11 km (5 and 7 mi.), respectively, from the Columbia River. These areas have been dedicated for some time to fuel reprocessing and waste management and disposal activities. The 200 Areas cover about 16 km^2 (6 mi^2).

- The 300 Area, located just north of the city of Richland, is the site of nuclear research and development. This area covers 1.5 km^2 (0.6 mi^2).

- The 400 Area is about 8 km (5 mi.) north of the 300 Area and is the site of the FFTF used in the testing of breeder reactor systems. In December 1993, the Secretary of Energy ordered the FFTF to be shut down, with a goal to reach a radiologically and industrially safe shutdown in approximately 5 years. Defueling of FFTF, which was the first major phase of deactivation, was completed in April 1995, four and a half months ahead of schedule. The next several phases are currently under way, however, DOE is also studying whether the shutdown reactor should be revived for the purposes of producing tritium for defense purposes, the production of medical isotopes, and burning weapons-grade plutonium. Also included in this area is the Fuels and Materials Examination Facility.

- The 600 Area includes all of the Hanford Site not occupied by the 100, 200, 300, or 400 Areas. Land uses within the 600 Area include the following:

    1. 310 km^2 (120 mi^2), known as the Fitzner/Eberhardt ALE Reserve, is set aside for ecological studies. Management of this area has been transferred to the U.S. Fish and Wildlife Service while the land is still being held by the U.S. Department of Energy. ALE will continue to serve as a research natural area and will also be used by a consortium of educational and scientific groups for public education programs.

    2. 0.4 km^2 (0.2 mi^2) is leased by Washington State, a part of which is used for commercial low-level radioactive waste disposal.

    3. 4.4 km^2 (1.6 mi^2) is used by the Supply System for nuclear power plants.

4. 2.6 km^2 (1 mi^2) is held by Washington State as a potential site for the disposal of nonradioactive hazardous wastes.

5. about 130 km^2 (50 mi^2) is under revocable use permit to the U.S. Fish and Wildlife Service for a wildlife refuge.

6. 225 km^2 (87 mi^2) is under revocable use permit to the Washington State Department of Fish and Wildlife for recreational game management (the Wahluke Wildlife Area).

7. support facilities for the controlled access areas.

An area of 665 km^2 (257 mi^2) has been designated for Fitzner/Eberhardt ALE Reserve, the U.S. Fish and Wildlife Service, wildlife refuges, and the Washington State Department of Game management area (DOE 1986).

The area known as the Hanford Reach includes the quarter-mile strip of public land on either side of the Columbia River in addition to the Saddle Mountain National Wildlife Refuge and the Wahluke Wildlife Area on the Wahluke Slope. The Hanford Reach is the last free-flowing, nontidal segment of the Columbia River in the United States. In 1988, Congress passed Public Law 100-65, known as the Comprehensive River Conservation Study Act, which required the Secretary of the Interior to prepare a study in consultation with the Secretary of Energy to evaluate the outstanding feature of the Reach and its immediate environment (see Section 6.2.6). Also, alternatives for preserving those features were examined, including the designation of the Reach as part of the National Wild and Scenic Rivers System. The results of the study can be found in the two-volume report, *Hanford Reach of the Columbia River - Comprehensive River Conservation Study and Environmental Impact Statement* (U.S. Department of Interior 1994). The preferred alternative was to designate the lands in the Hanford Reach as a wildlife refuge with a recreational river designation for the river. (Public Law 100-65 expired and was renewed as Public Law 104-333 in 1996).

The Columbia River, which is adjacent to and runs through the Hanford Site, provides access to the public for boating, water skiing, fishing, and hunting of upland game birds and migratory waterfowl. Some land access along the shore and on certain islands is available for public use.

Land use in other areas includes urban and industrial development, irrigated and dry-land farming, and grazing. In 1995, wheat represented the largest single crop in terms of area planted in Benton and Franklin Counties. Total acreage planted in the two counties 249,000 and 46,500 acres for winter and spring wheat, respectively. Alfalfa, apples, asparagus, cherries, corn, grapes, and potatoes are other major crops in Benton and Franklin Counties.

In 1992, the Columbia Basin Project, a major irrigation project to the north of the Tri-Cities, produced gross crop returns of $552 million, representing 12.5% of all crops grown in Washington State. In 1992, the average gross crop value per irrigated acre was $1042. The largest percentage of irrigated acres produced alfalfa hay (26.1% of irrigated acres), wheat (20.2%), and feed-grain corn (5.8%). Other significant crops are apples, dry beans, potatoes, and sweet corn.

4.6.13 Visual Resources

With the exception of Rattlesnake Mountain, the land near the Hanford Site is generally flat with little relief. Rattlesnake Mountain, rising to 1,060 m (3,477 ft) above mean sea level, forms the western boundary of the Site, and Gable Mountain and Gable Butte are the highest land forms within the Site. The view towards Rattlesnake Mountain is visually pleasing, especially in 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 Site and forming the eastern boundary, is generally considered scenic, with its contrasting blue against a background of brown basaltic rocks and desert sagebrush. 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 strong feature of the landscape.

4.7 Noise

(Section 4.7 was last updated in PNL-6415 Rev. 7, September 1995)

Noise is technically defined as sound waves, that are unwanted and perceived as a nuisance by humans. 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. 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 pressure levels outside the range of human hearing are not considered noise in a regulatory sense, even though wildlife may be able to 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 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.

4.7.1 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 indicated that the potential to violate federal or state standards is remote or unrealistic.

4.7.2 Environmental Noise Regulations

The Noise Control Act of 1972 and its subsequent amendments (Quiet Communities Act of 1978 and 40 CFR 201-211) direct the regulation of environmental noise to the state. 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 defined the regulation of environmental noise levels. Maximum noise levels are defined for the zoning of the area in accord with 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) or Class B (commercial). Maximum noise levels are established based on the EDNA classification of the receiving area and the source area (Table 4.7-1).

4.7.3 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 State Route 240 through the Hanford Site. These data are not concerned with background levels of noise and are not reviewed here. There are two sources of measured environmental noise at Hanford. Environmental noise measurements were made in 1981 during site characterization for the Skagit/Hanford Nuclear Power Plant Site (NRC 1982). Measurements were also made 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. Site characterization studies performed in 1987 included measurement of back-ground environmental noise levels at five locations on the Hanford Site. Additionally, certain activities such as well drilling and sampling have the potential for producing noise in the field apart from major permanent facilities.

Recently, the potential impact of traffic noise resulting from Hanford Site activities has been evaluated for a draft EIS addressing the siting of the proposed New Production Reactor (NPR) (DOE 1991). While this EIS does not include any new baseline measurements, it does address the traffic component of noise and provides modeled "baseline" measurements of traffic noise for the Hanford Site and adjacent communities.

Table 4.7-1. Applicable State Noise Limitations for the Hanford Site Based on Source and Receptor EDNA Designation (values are dBA)

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

4.7.3.1 Skagit/Hanford Data

Pre-construction measurements of environmental noise were taken in June 1981 on the Hanford Site (NRC 1982). Fifteen sites were monitored, and noise levels ranged from 30 to 60.5 dBA (L_{eq}). The values for isolated areas ranged from 30 to 38.8 dBA. Measurements taken around the sites where the

Supply System was constructing nuclear power plants (WNP-1, WNP-2, and WNP-4) ranged from 50.6 to 64 dBA. Measurements taken along the Columbia River near the intake structures for WNP-2 were 47.7 and 52.1 dBA compared with more remote river noise levels of 45.9 dBA (measured about 4.8 km [3 mi.] upstream of the intake structures). Community noise levels in North Richland (Horn Rapids Road and Highway 12) were 60.5 BA.

4.7.3.2 BWIP Data

Background noise levels were determined at five locations within the Hanford Site (Figure 4.7-1). Noise levels are expressed as L_{eqs} for 24 hours (L_{eq-24}). Sample location, date, and L_{eq}-24 are listed in Table 4.7-2. Wind was identified as the primary contributor to background noise levels, with winds exceeding 19 km/h (12 mi./h) significantly affecting noise levels. Background noise levels in undeveloped areas at Hanford can best be described as a mean L_{eq}-24 of 24 to 36 dBA. Periods of high wind, which normally occur in the spring, would elevate background noise levels.

4.7.3.3 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 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 modeled. Noise levels were expressed in L_{eq} for 1-hour periods in dBA at a receptor located 15 m (49 ft) from the road edge (Table 4.7-3). Adverse community responses would not be expected at increases of 5 dBA over background noise levels.

4.7.3.4 Noise Levels of Hanford Field Activities

In the interest of protecting Hanford workers and complying with Occupational Safety and Health Administration (OSHA) standards for noise in the workplace, HEHF has monitored noise levels resulting from several routine operations performed at Hanford. Occupational sources of noise propagated in the field have been summarized in Table 4.7-4. These levels are reported here because operations such as well sampling are conducted in the field away from established industrial areas and have the potential for disturbing sensitive wildlife.

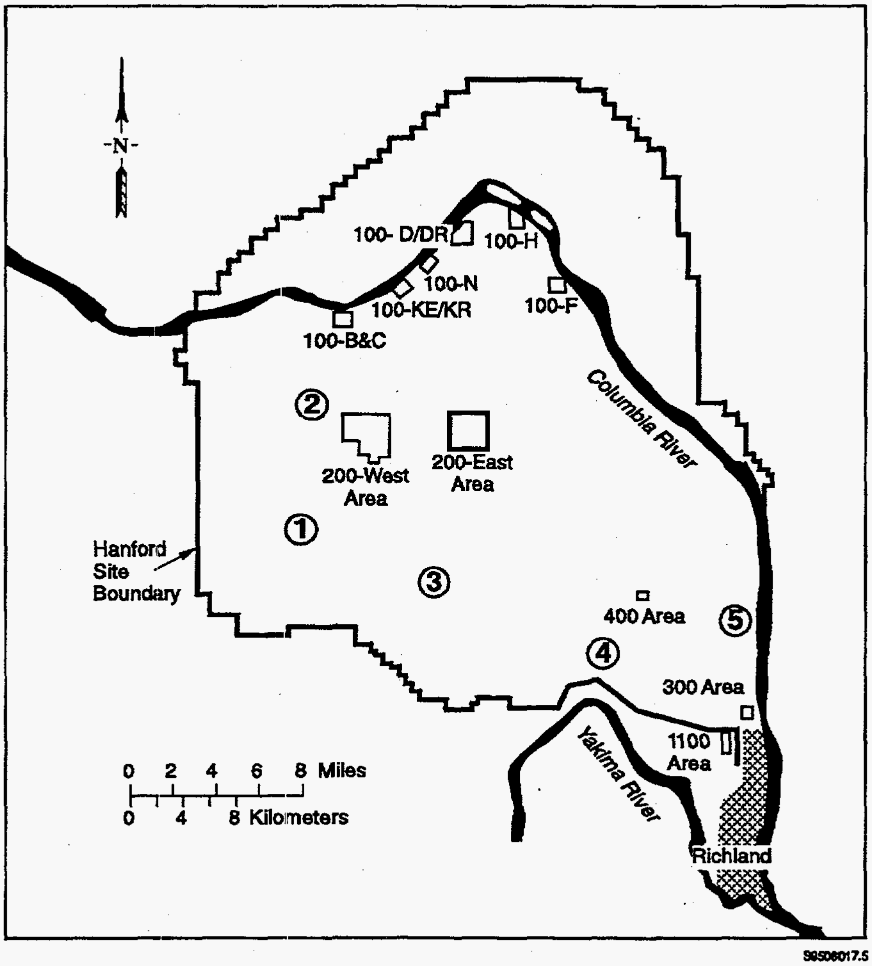

Figure 4.7-1. Location of Background Noise Measurements (see Table 4.7-2)

Table 4.7-2. Background Noise Levels Measured at Isolated Areas

Site	Location			Date	L_{eq}-24 (dBA)
	Section	Range	Township		
1	9	R25E	T12N	07-10-87	41.7
				07-11-87	40.7
				07-12-87	36.0
				07-13-87	37.2
				07-14-87	35.6
2	26	R25E	T13N	07-25-87	43.9
				07-26-87	38.8
				07-27-87	43.8
				07-28-87	37.7
				07-29-87	43.2
3	18	R26E	T12N	08-08-87	39.0
				08-09-87	35.4
				08-10-87	51.4[(a)]
				08-11-87	56.7[(a)]
				08-12-87	36.0
4	34	R27E	T11N	09-09-87	35.2
				09-10-87	34.8
				09-11-87	36.0
				09-12-87	33.2
				09-13-87	37.3
5	14	R28E	T11N	10-15-87	40.8
				10-16-87	36.8
				10-17-87	33.7
				10-18-87	31.3
				10-19-87	35.9

(a) L_{eq} includes grader noise.

Table 4.7-3. Modeled Noise Resulting from Automobile Traffic at Hanford in Association with the New Production Reactor Environmental Impact Statement (DOE 1991)[a]

Location[b]	Scenario	Traffic flow (Vehicles/h) Baseline	Traffic flow (Vehicles/h) Maximum[c]	Noise levels (L_{eq}-1 h in dBA) Baseline noise levels	Noise levels (L_{eq}-1 h in dBA) Modeled noise levels[c]	Maximum increase (dBA)
Construction Phase						
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
Operation Phase						
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.

Table 4.7-4. Monitored Levels of Noise Propagated from Outdoor Activities at the Hanford Site[a]

Activity	Average Noise Level	Maximum Noise Level	Year Measured	Distance
Water wagon operation[a]	104.5	111.9	1984	On staff member
Well sampling[a]	74.8 - 78.2		1987	On staff member
Truck[a]	78 - 83		1989	On staff member
Compressor[b]	88 - 90			.3 m (1 ft) from truck
Generator[b]	93 - 95			.3 m (1 ft) from truck
Well drilling, Well 32-2[a]	98 - 102	102	1987	23 m (75 ft)
Well drilling, Well 32-3[a]	105 - 11	120 - 125	1987	15 m (49 ft)
Well drilling, Well 33-29[a]	89 - 91		1987	15 m (49 ft)
Pile driver[a]	118 - 119		1981	1.5 m (5 ft)
Tank farm filter building[a]	86		1976	9.0 m (30 ft)

(a) Noise levels measured in a weight dB (dBA)
(b) Noise levels measured in decibels (dB).

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6.0 Statutory and Regulatory Requirements

(All sections of Chapter 6.0 updated for PNL-6415 Rev. 9)

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, and DOE directives. 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 Department of Health (DOH). In addition, the Benton County Clean Air Authority (BCCAA) 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
- existing environmental permits covering activities at the Hanford Site
- environmental standards for protection of the public.

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.

- DOE's NEPA web site at URL: http://tis-nt.eh.doe.gov/nepa/
- Council on Environmental Quality's (CEQ's) web site at URL: http//www.whitehouse.gov/CEQ/

The *National Environmental Policy Act Compliance Guide* (DOE 1994), issued by the DOE Office of Environment, Safety and Health, contains useful information including copies of relevant executive orders. The document, *Environmental Compliance* (WHC 1996), contains a detailed listing and discussion of environmental compliance and permit requirements at Hanford.

(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.)

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 satisfies NEPA. DOE has adopted the CEQ regulations as part of its NEPA implementing procedures (40 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 EIS must list "all Federal permits, licenses, and other entitlements which must be obtained in implementing the proposal." 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 have been discussed in recent Hanford Site EISs, and Chapter 6.0 of these EISs has evolved into a chapter on "Statutory and Regulatory Requirements." Given the large number of applicable environmental regulations, the rapidly changing character of environmental regulation, and the public's interest in environmental regulation, this practice is likely to continue.

Chapter 6 of Hanford Site EISs should include the list called for by 40 CFR 1502.25(b). The list should also include significant permits that will be needed from state and local government agencies. Chapter 6 should also include descriptive discussions of applicable requirements including requirements which do not have associated permit requirements. 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 Chapter 5 of the EIS and any recreational fisheries aspects of the affected environment should be discussed in Chapter 4 of the EIS.

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. The intent here is to present a reasonably complete discussion of federal and state environmental laws, regulations, permits, 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 by deleting irrelevant parts and by adding some specificity with respect to the proposed action. It is planned that Chapter 6 of this document will be revised on a regular basis because of the rapidly changing nature of federal environmental laws and regulations.

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

Environmental regulation of federal facilities is governed by federal law. 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 the 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. The 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 under federal waivers of sovereign immunity. Ecology has also delegated various air compliance responsibilities to the BCCAA.

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).

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). 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 (WSR).

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 (16 USC 1531 et seq.).

Section 309 of the CAA directs the 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 concern, 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 the EPA rating definitions can be found at 61 FR 15251, April 5, 1996. The fact that EPA rates EISs should be known by the EIS preparers so that the EIS will be prepared in such a fashion as to avoid an unfavorable rating. EPA's comments on the draft EIS are answered 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 Endangered Species Act, and other environmental review laws and executive orders. The three preceding statutes should be cited in Chapter 6. Environmental impacts associated with the laws should be discussed in Chapter 5.

6.1 Federal Environmental Laws

Significant federal environmental laws applicable to the Hanford Site include the following:

- American Antiquities Act (16 USC 431 to 433)
- American Indian Religious Freedom Act (42 USC 1996)
- Archaeological and Historic Preservation Act (16 USC 469 to 469c)
- Archaeological Resources Protection Act (ARPA) (16 USC 470aa to 470ll)
- Bald and Golden Eagle Protection Act (16 USC 668 to 668c)
- Clean Air Act (CAA) (42 USC 7401 to 7642)
- Clean Water Act (CWA) (33 USC 1251 to 1387)
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act (SARA) (42 USC 9601 to 9675)
- Comprehensive River Conservation Study Act (PL 100-605)

- Endangered Species Act (16 USC 1531 to 1544)
- Federal Facilities Compliance Act (FFCA) (42 USC 6901)
- Fish and Wildlife Coordination Act (16 USC 661 to 667c)
- Migratory Bird Treaty Act (16 USC 703 to 712)
- National Historic Preservation Act (NHPA) (16 USC 470 to 470w-6)
- Native American Graves Protection and Repatriation Act (25 USC 3001 to 3013)
- National Environmental Policy Act (NEPA) (42 USC 4321 to 4347)
- Resource Conservation and Recovery Act (RCRA) of 1976 as amended by the Hazardous and Solid Waste Amendments (42 USC 6901 to 6991i) of 1984
- Safe Drinking Water Act (SDWA) (42 USC 300f to 300j-11)
- Toxic Substances Control Act (TSCA) (15 USC 2601 to 2692)

In addition, the Atomic Energy Act (AEA) (42 USC 2011 to 2286), the Low-Level Radioactive Waste Policy Act (LLWPA) (42 USC 2021b to 2021i), and the Nuclear Waste Policy Act (NWPA) (42 USC 10101 to 10270), while not environmental laws per se, contain provisions under which environmental regulations applicable to the Hanford Site may be or have been promulgated.

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 specific exceptions are created by Congress. Exceptions with respect to environmental regulation have been created by Congress and provisions in several federal laws give to the states specific authority to regulate federal environmental activities. 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 FFCA 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 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 U.S. Department of Energy (DOE) 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. The CAA amendments of 1990 have resulted in extensive revisions of federal and state air quality regulations. Specifically, a large list of hazardous air pollutants will be brought under regulation and a more uniform state regulatory and permitting system under state implementation plans

(SIPs) will result. Also, federal and state regulations relating to hazardous waste management continue to be promulgated under RCRA at a rapid rate.

Several of the more important existing federal and state environmental regulations are discussed briefly below. These regulations are grouped according to areas of environmental interest.

6.2.1 Air Quality

- 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 (NAAQSs) for air pollutants including sulfur oxides, particulate matter, carbon monoxide, ozone, nitrogen dioxide, and lead. These standards are not directly enforceable; but other, enforceable regulations are based on these standards. Washington's ambient air standards are at Washington Administrative Code (WAC) 173-470 through 173-481 and include standards for radionuclides and fluorides.

- 40 CFR 51-52, State Implementation Plans. 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 from stationary sources and include state permit requirements (see 40 CFR 70 below).

- 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); also 40 CFR 61 Subpart H, "National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities." EPA hazardous emission standards in 40 CFR 61 provide for the control of the emission of hazardous pollutants to the atmosphere, and standards in 40 CFR 61 Subpart H apply specifically to the emission of radionuclides from DOE facilities. Approval to construct a new facility or to modify an existing one may be required (under 40 CFR 61.07) by these regulations. EPA has delegated interim authority to the State of Washington to implement and enforce 40 CFR 61 Subpart H, but has not yet delegated this construction approval authority (60 FR [Federal Register] 39263, August 2, 1995). The list of hazardous air pollutants presently regulated under 40 CFR 61 will be expanded pursuant to the CAA amendments of 1990 to include the 189 hazardous air pollutants listed in the amendments. New emission standards for hazardous air pollutants designated in the 1990 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 that will replace the existing fragmented programs. All major sources of air pollutants including hazardous air pollutants will be covered. EPA granted interim approval to Washington's operating permit program in November 1994 (59 FR 55813). Washington's operating permit regulations appear at WAC 173-401. An operating permit application for the Hanford Site (DOE/RL-95-07) was submitted to the Washington State Department of Ecology (Ecology) in May 1995.

- WAC 173-400 through 173-495, Washington State Air Pollution Control Regulations; General Regulation 1, BCCAA. Ecology air pollution control regulations, promulgated under the Washington CAA (Revised Code of Washington [RCW] 70.94), appear in WAC 173-400 through 173-495. 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 BCCAA. However, except for certain air pollution sources (e.g., asbestos removal, fugitive dust, and open burning) administered by the BCCAA, 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.

6.2.2 Water Quality

- 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 National Pollutant Discharge Elimination System (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 now apply to the discharge of storm waters (40 CFR 122.26) and the discharge of runoff waters from construction areas over 2 ha (5 acres) in size into waters of the United States. NPDES permits may be required by 40 CFR 122. EPA has not yet 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.

- 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, the 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 apply to DOE activities that are proposed to take place either in wetlands or in floodplains.

- 33 CFR 322-323, 40 CFR 230-233. 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 216 program. DOE has agreed to meet the requirements of this program at the Hanford Site for discharges of liquids to the ground.

- RCW 75.20.100, "Construction Projects in State Waters." WAC 220-110. As a matter of comity, DOE will obtain hydraulic project approval from the Washington State Department of Fish and Wildlife to construct any form of hydraulic project or perform work that will divert, obstruct, or change the natural flow of the Columbia River.

- WAC 332-30, "Aquatic Land Management." Where applicable, DOE will obtain an aquatic landuse 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. DOE 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 Solids

- 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 may be granted. Ecology has been authorized by EPA to administer the RCRA program and all but the land disposal restriction and waste minimization provisions of the Hazardous and Solid Waste Amendments.

- 40 CFR 280-281, Underground Storage Tanks. EPA regulations in 40 CFR 280-281 apply to underground storage tanks and may require permits for new and existing tanks containing petroleum or substances regulated under CERCLA (except for hazardous wastes regulated under RCRA). EPA has authorized Washington State to administer this program under RCW 90.76 and WAC 173-360.

- 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. On November 3, 1989, (54 FR 41015) the Hanford Site was placed on the EPA's National Priorities List (NPL). 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 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. The agreement can be found at URL: http://www.hanford.gov/tpa/html/tpa-toc.htm.

- WAC 173-303, "Dangerous Waste Regulations." The 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.

6.2.4 Species Protection

- 50 CFR 10-24, 222, 225-227, 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 these species on the Hanford Site. Regulations in 50 CFR 222, 225-227, 402, and 450-453 apply to endangered or threatened species. In addition, the Fish and Wildlife Coordination Act requires consultation with the U.S. Fish and Wildlife Service if any body of water over 4 ha (10 acres) in size is to be modified by a federal 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

- 36 CFR 800, 36 CFR 79, 43 CFR 3, and 43 CFR 7, Historic Preservation Regulations. Requirements of the NHPA in 36 CFR 60 and 36 CFR 800; the American Antiquities Act in 25 CFR 261 and 43 CFR 3; the ARPA and the American Indian Religious Freedom Act in 43 CFR 7; and the Native American Graves Protection and Repatriation Act in 43 CFR 10 apply to the protection of historic and cultural properties, including both existing properties and those discovered during excavation and construction.

6.2.6 Land Use

The Comprehensive River Conservation Study Act (PL 100-605) required the Secretary of the Interior, in consultation with the Secretary of Energy, to conduct a study of the Hanford Reach of the

Columbia River that included identification and evaluation of geologic, scenic, historic, cultural, recreational, fish, wildlife, and natural features of the Hanford Reach. The Secretary of the Interior was also directed by Congress to examine alternatives for the preservation of these features. A final study report was published in June 1994: *Hanford Reach of the Columbia River, Comprehensive River Conservation Study and Environmental Impact Statement* (see 59 FR 44430, August 29, 1994). This study proposed that Congress designate the Hanford Reach of the Columbia River and land within one quarter mile of the river as a new National Wildlife Refuge and National Wild and Scenic River. The Act provides that until November 4, 1996, federal agencies planning new projects within one quarter mile of the river are to consult and coordinate with the Secretary of the Interior.

In August 1996, DOE issued the Draft Hanford Remedial Action Environmental Impact Statement and Comprehensive Land Use Plan (DOE/EIS-0222D). The EIS can be viewed at URL: http://www.hanford.gov/eis/hraeis/hraeis.htm.

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 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 1500-1508 provide for the preparation of environmental documentation on any federal action impacting the environment, and require federal agencies to prepare an environmental impact statement (EIS) on any major federal action significantly affecting the quality of the human environment.

- 10 CFR 830, "Nuclear Safety Management." Part 830 governs the conduct of DOE management and operating contractors and other persons at DOE nuclear facilities.

- 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 implement NEPA and the CEQ's NEPA regulations in 40 CFR 1500-1508.

- 49 CFR 171-179, Hazardous Materials Regulations. Department of Transportation regulations in 49 CFR 171-179 apply to the handling, packaging, labeling, and shipment of hazardous materials offsite, including radioactive materials and wastes.

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 Chapter 6 of a Hanford EIS. 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. 11987	Exotic Organisms
E.O. 11988	Floodplain Management
E.O. 11990	Protection of Wetlands
E.O. 12088	Federal Compliance with Pollution Control Standards
E.O. 12144	Environmental Effects Abroad of Major Federal Actions
E.O. 12580 (as amended by E.O. 13016)	Superfund Implementation
E.O. 12843	Procurement Requirements and Policies for Federal Agencies for Ozone Depleting Substances
E.O. 12856	Federal Compliance with Right-to-Know Laws and Pollution Prevention Requirements
E.O. 12873	Federal Acquisition, Recycling, and Waste Prevention
E.O. 12898	Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations
E.O. 12902	Energy Efficiency and Water Conservation at Federal Facilities
E.O. 12962	Recreational Fisheries
E.O. 12969	Federal Acquisition and Community Right-to-Know
E.O. 13045	Protection of Children from Environmental Health Risks and Safety Risks

E.O.s can be accessed at the following URLs:

- http://es.inel.gov/program/exec/exec.html
- http://library.whitehouse.gov/?request=ExecutiveOrder.

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 the following URLs:

- http://www.hr.doe.gov/refshelf.html
- http://www.explorer.doe.gov:1776/htmls/directives.html.

At the Hanford Site, active DOE and RL directives are maintained on HANINFO. DOE directives have been extensively revised and consolidated over the past two years. New directives are classified in the new series directives.

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.

DOE directives cover 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 regulatory bodies, as well as other DOE directives, are incorporated by reference into DOE directives.

6.5 Permits

The DOE holds an NPDES permit (permit no. WA-000374-3) from EPA Region 10 for the discharge of nonradioactive liquids to the Columbia River. On June 28, 1985, the DOE applied for renewal of this permit. The original permit is still in effect pending renewal. An NPDES permit (permit no. WA-002592-7) was issued in October 1994 for the 300 Area Treated Effluent Disposal Facility.

EPA Region 10 issued a stormwater discharge permit (permit no. WA-R-00-A17F) to DOE/RL in 1992.

Ecology issued a waste discharge permit (permit no. ST-4502) to DOE/RL under WAC 173-216 for the 200 Area Treated Effluent Disposal Facility in April 1995. A waste discharge permit (permit no. ST-4500) for additional discharges to the ground in the 200 Area under WAC 173-216 was issued by Ecology in June 1995 for the Effluent Treatment Facility. Both of these permits were modified in 1997. Ecology issued waste discharge permit no. ST-4501 for the 400 Area secondary cooling water discharge in July 1996. Ecology issued the following waste discharge permits in May 1997:

- ST-4503 for the 183-N backwash discharge pond;
- ST-4507 for the 100-N sewage lagoon; and

- ST-4508 for hydrotest, maintenance, and construction discharges.

DOE/RL holds a PSD permit (permit no. PSD-X80-14) from EPA Region 10 for the discharge of oxides of nitrogen to the atmosphere from the Plutonium-Uranium Extraction (PUREX) and Uranium Oxide (UO_3) Plants.

DOE/RL holds approvals for construction of air emission facilities and approvals of alternate air emission limits issued by the BCCAA.

DOE/RL received a radioactive air emissions license (license no. FF-01) from the Washington Department of Health (DOH) on August 15, 1993, covering radioactive emissions from Hanford Site operations.

DOE/RL holds interim status for the operation of hazardous waste management facilities at Hanford by virtue of having submitted a RCRA Part A application to EPA on November 18, 1980. On November 6, 1985, DOE submitted a RCRA Part B application to EPA Region 10 and to Ecology for the treatment, storage, and disposal of hazardous wastes at Hanford. A final status RCRA permit covering several units at the Hanford Site became effective in September 1994. The permit was modified on November 26, 1996. The permit has two parts, a dangerous waste portion issued by Ecology (permit number WA7890008967) to DOE and three Hanford contractors and a Hazardous and Solid Waste Amendments portion issued by EPA Region 10 to DOE only. The permit will be amended over a period of years to add additional interim status units.

DOE/RL submitted an air operating permit application to the State of Washington in 1995.

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 right.

Additional information on environmental documents at Hanford is available in Thompson (1996). This report will be updated annually.

6.6 Environmental Standards for Protection of the Public

Numerical standards for protection of the public from releases to the environment have been set by the EPA and appear in the CFR.

Standards in 40 CFR 61.92 apply to releases of radionuclides to the atmosphere from DOE facilities and state that:

> Emissions of radionuclides (other than radon-220 and radon-222) to the ambient air from Department of Energy facilities shall not exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent of 10 mrem/yr.

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 millirem/year. Maximum contaminant levels in community water systems of 5 pCi/L of combined radium-226 and radium-228, and maximum contaminant levels of 15 pCi/L of gross alpha particle activity, including radium-226 but excluding radon and uranium, are specified in 40 CFR 141.15.

EPA regulations in 40 CFR 264 contain numerical standards for protection of the public from releases of hazardous wastes from hazardous waste disposal sites.

References

Thompson, S. A. 1996. *Annual Hanford Site Environmental Permitting Status Report*. DOE/RL-96-63, Revision 0, U.S. Department of Energy, Richland, Washington.

U.S. Department of Energy (DOE). 1994. *National Environmental Policy Act Compliance Guide Volume II (Reference Book). Washington, DC.*

Westinghouse Hanford Company (WHC). 1996. *Environmental Compliance*. WHC-CM-7-5, Westinghouse Hanford Company, Richland, Washington.

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