3 3679 00055 3604

Standardized Input for Hanford Environmental Impact Statements Part II: Site Description

J. D. Jamison

July 1982

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

**Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute**

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

PACIFIC NORTHWEST LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RLO 1830

Printed in the United States of America
Available from
National Technical Information Service
United States Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151

NTIS Price Codes
Microfiche A01

Printed Copy

Pages	Price Codes
001-025	A02
026-050	A03
051-075	A04
076-100	A05
101-125	A06
126-150	A07
151-175	A08
176-200	A09
201-225	A010
226-250	A011
251-275	A012
276-300	A013

STANDARDIZED INPUT FOR HANFORD
ENVIRONMENTAL IMPACT STATEMENTS
PART II: SITE DESCRIPTION

J. D. Jamison

July 1982

Prepared for
U.S. Department of Energy
under Contract DE-AC06-76RLO 1830
with assistance from
Hanford Engineering Development Laboratory
Rockwell Hanford Company
UNC Nuclear Industries

Pacific Northwest Laboratory
Richland, Washington 99352

CONTENTS

1.0	SUMMARY DESCRIPTION	1.1
1.1	Location and Topography	1.1
1.2	Geology	1.1
1.3	Seismology	1.3
1.4	Hydrology	1.3
1.5	Meteorology	1.4
1.6	Ecology	1.5
1.7	Demography and Land Use	1.6
	1.7.1 Land Use on the Hanford Site	1.6
	1.7.2 Land Use Adjacent to the Site	1.6
	1.7.3 Regional Demography	1.7
	1.7.4 Historic and National Landmarks	1.7
2.0	LOCATION AND PHYSIOGRAPHY	2.1
3.0	GEOLOGY	3.1
3.1	Introduction	3.1
3.2	The Basement Rocks	3.1
3.3	The Columbia River Basalt Group	3.4
3.4	The Ellensburg Formation	3.5
3.5	The Ringold Formation	3.6
3.6	The Hanford Formation	3.7
3.7	Volcanic Ash Deposits	3.8
3.8	Tectonics	3.9
4.0	SEISMOLOGY	4.1
4.1	General Characteristics	4.1
4.2	Regional Features of Seismic Interest	4.1
4.3	Hanford Site Characteristics and Earthquake Effects	4.3
4.4	Earthquake History	4.3

5.0	HYDROLOGY	5.1
5.1	Surface Hydrology	5.1
5.2	Subsurface Hydrology	5.6
5.2.1	The Unconfined Aquifer	5.6
5.2.2	Confined Aquifers	5.15
6.0	METEOROLOGY	6.1
6.1	General Climate	6.1
6.2	Temperature	6.4
6.3	Humidity	6.5
6.4	Wind	6.6
6.5	Precipitation	6.10
6.6	Other Meteorological Phenemona	6.13
7.0	ECOLOGY	7.1
7.1	Aquatic Ecology	7.1
7.1.1	The Columbia River	7.1
7.1.2	Rattlesnake Springs	7.5
7.1.3	Other Aquatic Ecosystems	7.7
7.2	Terrestrial Ecology	7.9
7.2.1	General Characteristics	7.9
7.2.2	Vegetation	7.10
7.2.3	Mammals	7.14
7.2.4	Birds	7.15
7.2.5	Snakes and Lizards	7.16
7.2.6	Insects	7.16
7.2.7	Rare or Endangered Species	7.17
7.2.8	Food Webs and Energy Transfer	7.19
8.0	DEMOGRAPHY AND LAND USE	8.1
8.1	Land Use on the Hanford Site	8.1
8.2	Land Use Adjacent to the Hanford Site	8.3

8.3	Historic Sites and National Landmarks	.	.	.	.	.	.	.	8.3
8.4	Regional Demography	.	.	.	.	.	.	.	8.7
9.0	RADIOLOGICAL CONDITION	.	.	.	.	.	.	.	9.1
9.1	Sources of Radiation in the Environment	.	.	.	.	.	.	.	9.1
9.2	Air	.	.	.	.	.	.	.	9.1
9.3	Water	.	.	.	.	.	.	.	9.3
9.4	Soil and Vegetation	.	.	.	.	.	.	.	9.5
9.5	External Radiation	.	.	.	.	.	.	.	9.11
10.1	Acknowledgments	.	.	.	.	.	.	.	10.1
11.1	REFERENCES	.	.	.	.	.	.	.	11.1
	APPENDIX I--THE 100 N AREA	.	.	.	.	.	.	.	I.1
	APPENDIX II--THE 200 EAST AREA	.	.	.	.	.	.	.	II.1
	APPENDIX III--THE 200 WEST AREA	.	.	.	.	.	.	.	III.1
	APPENDIX IV--THE 300 AREA	.	.	.	.	.	.	.	IV.1
	APPENDIX V--THE 400 AREA	.	.	.	.	.	.	.	V.1

FIGURES

1-1	Map of Hanford Site	1.2
2-1	Location and Topography of the Hanford Site	2.2
3-1	Regional Geologic Map	3.2
3-2	Pasco Basin Stratigraphic Nomenclature	3.3
5-1	Surface Waters on the Hanford Site	5.2
5-2	Columbia River Flow at Hanford	5.3
5-3	Highest Flood on Record-- 2.3×10^4 m ³ /sec	5.7
5-4	Probable Maximum Flood-- 4.1×10^4 m ³ /sec	5.8
5-5	Water Table Elevations--December 1981	5.11
5-6	Gross Beta Activity in Unconfined Groundwater	5.13
5-7	Tritium Distribution in Unconfined Groundwater	5.14
5-8	Nitrate Ion Distribution in Unconfined Groundwater	5.16
6-1	Annual Variation of Extreme Daily Maximum and Minimum Temperatures at the HMS	6.4
6-2	Probability of Yearly High Temperatures at Hanford	6.5
6-3	Probability of Yearly Low Temperature at Hanford	6.6
6-4	Surface Wind Roses for Various Locations on and Surrounding the Hanford Site Based on Five-Year Average	6.8
6-5	Monthly Average Wind Roses for HMS Based on 50-Foot Wind Data 1955-1970	6.9
6-6	Average Monthly Precipitation Amounts at Hanford	6.11
6-7	Total Annual Precipitation Probability Diagram	6.12
6-8	Annual Snow Fall Probability Diagram	6.13
7-1	Food Web of Columbia River	7.2
7-2	Food Web of Gable Mountain Pond and U Pond	7.8

7-3	Distribution of Vegetation Types on the Hanford Site	.	.	.	7.11
7-4	Food Web Centered on Cheatgrass	.	.	.	7.20
7-5	Food Web Centered on Chukar Partridge	.	.	.	7.21
7-6	Food Web Centered on Grasshopper	.	.	.	7.21
8-1	Land Use on the Hanford Site	.	.	.	8.2
8-2	Zoning Status of Area Surrounding the Hanford Site	.	.	.	8.4
8-3	Communities Around the Hanford Site	.	.	.	8.8
9-1	Onsite Environmental Air Sampling Locations--1980	.	.	.	9.2
9-2	Offsite Environmental Air Sampling Locations--1980	.	.	.	9.2
9-3	Soil and Vegetation Sampling Locations	.	.	.	9.8
9-4	Onsite External Penetration Dose Rate Measurement Locations-1980	.	.	.	9.14
9-5	Dosimeter Locations Along Columbia River Shoreline	.	.	.	9.16

TABLES

5-1 Estimated Peak Discharge Rates for Floods on the Columbia

Yakima Basalt Subgroup. These sedimentary deposits, termed the Ellensburg Formation, are thicker and coarser grained in the far western portion of the Columbia Plateau, indicating the Cascade Range as the source area. The Ellensburg deposits include both wind and water-deposited sediments ranging in particle size from sand and gravels through silts and clays. Layers of ash, pumice and other materials of volcanic origin are also part of the Ellensburg Formation (Myers et al. 1979).

Units of the Ellensburg Formation underlie, interfinger, and overlie flows of the Yakima Basalt Subgroup. The lower extent of the formation has been variously defined as the top of the Wanapum Basalt (Mackin 1961), the base of the Wanapum Basalt (Waters 1955, Schmincke 1964), and even the bottom of the Grande Ronde Basalt (Waitt 1979). The upper limit of the Ellensburg Formation is not well defined.

3.5 The Ringold Formation

The Ringold Formation is made up of river-borne sediments deposited upon

Ringold Conglomerate is present throughout most of the Central Pasco Basin except in the area north of Gable Mountain on the Hanford Site, and is greater than 100 m thick in places. This unit is exposed only in the southern part of the White Bluffs and at Coyote Rapids (Myers et al. 1979).

The Upper Ringold Unit is a well-sorted medium to fine sand, silt and clay with minor lenses of fine pebbles. Several beds of caliche (calcium carbonate) are found throughout the unit; one well-developed caliche bed caps the crest of the White Bluffs, marking the upper surface of the unit. More than 120 m of the Upper Ringold are exposed in the White Bluffs. On the Hanford Site, south and west of the Columbia River, the unit is largely eroded away (Myers and Price 1979). Based on magnetic properties of the sediments (Packer and Johnston 1979) and fossil evidence (Gustafson 1978) the Upper Ringold unit is believed to have been deposited between about three and five million years ago.

The Fanglomerate Unit consists of talus, alluvial fans and like materials found on the flanks of anticlinal ridges in the Pasco Basin. It is composed of generally angular particles ranging in size from medium sands to boulders. It is exposed extensively on the northern flank of the Saddle Mountains and to a lesser extent on the southern flank of Gable Mountain. The Fanglomerate Unit is currently included in the Ringold Formation (Grolier and Bingham 1978) on the basis of apparent time equivalency and not similarity of depositional environments.

In the western part of the Hanford Site, the Upper Ringold formation is overlain by wind-deposited fine sand and silt. This silt (loess) is termed early "Palouse" soil, and is considered to have been derived from the surface of the Ringold Formation by wind action during a period of semiarid to arid climatic conditions (Tallman et al. 1979).

3.6 The Hanford Formation (informal name)

During Pleistocene glaciation, eastern Washington was subjected to a number of catastrophic floods resulting from the breakup of ice dams which impounded glacial lakes in Idaho, Montana and northeastern Washington. The sediments deposited in the Pasco Basin by these flood waters are collectively

Basin away from the Yakima Fold hinge zones; they might influence groundwater flow and the age of their most recent movement is not known (Myers et al. 1979).

Faults have been associated with each of the four Yakima Folds in the Pasco Basin. The Saddle Mountain Fault extends along much of the length of the steep (north) limb of the Saddle Mountain Structure. The age of the Saddle Mountain Fault is post-Ringold but pre-Pinedale (Bingham et al. 1970), e.g., at least 12,000 years old. Microearthquake swarms may be associated with the Saddle Mountain Structure, although most epicenter locations lie north of the structure (Malone 1978).

Two faults have been identified in the Gable Mountain-Gable Butte area. One is a northerly-trending reverse fault with about 25 m of offset near the west end of Gable Mountain. The other is a reverse fault of undetermined offset with a sinuous northeasterly to easterly trend, located in the central portion of Gable Mountain. Overlaying sediments dated at greater than 40,000 years ago are not offset, indicating no movement along this second fault within that period of time. One core hole drilled just south of Gable Mountain penetrated two reverse faults with a combined offset of about 50 m. The age of latest movement of these faults is unknown (Myers et al. 1979).

The Rattlesnake Mountain-Wallula Structure contains several known faults. The Rattlesnake Mountain Fault, located on the steep northeastern face of Rattlesnake Mountain, shows about 400 m of displacement. The Badger Mountain Fault shows a maximum offset of 60 m (Myers et al. 1979).

The Wallula Gap Fault is a west-northwest-trending fault that has been mapped and studied in detail (Jones and Fecht 1977, WPPSS 1977). Sand and gravel beds of the Hanford Formation overlie the fault zone and are apparently not deformed (Myers et al. 1979).

4.0 SEISMOLOGY

4.1 General Characteristics

Eastern Washington is a region of low to moderate seismicity which lies between the more seismically active zones of western Montana and western Washington (Jones and Deacon 1966, Rasmussen 1966). The region is designated as Zone 2 seismic probability by the U. S. Coast and Geodetic Survey implying the potential for moderate damage from earthquakes. The seismic risk classification is based on the worst earthquake damage that has been experienced in the approximately 100 years of historic record.

The few faults that have been mapped in the Columbia Plateau appear to be related to structural folds within the basalt. In the Columbia River basalts, folding appears to have been the primary response to tectonic deformation, with faulting of secondary importance.

4.2 Regional Features of Seismic Interest

The Olympic-Wallowa lineament. An Olympic-Wallowa Lineament, although discontinuous and not sharply defined, has been hypothesized as a possible major crustal rupture (Skehan 1966). Along the west side of the Hanford Site, the trace of the lineament corresponds roughly to the axis of Rattlesnake Mountain. The lineament is seen as representing a possible underlying or basement rock feature related to a number of known faults and surface features. A shortened version of this feature, the Rattlesnake Mountain-Wallula alignment, contains several known areas of faulting. Earthquakes have occurred along the alignment but in no greater numbers or concentrations than elsewhere in the vicinity (Myers et al. 1979). In the absence of clear evidence to the contrary, the Washington Public Power Supply System accepted the Rattlesnake-Wallula alignment as a capable structure for purposes of developing seismic design criteria for nuclear generating plants at Hanford (WPPSS 1974).

The Horse-Heaven Hills. The Horse-Heaven Hills are a continuous structure extending from the Cascade Range to the Blue Mountains with significant relief over their entire length. There are several sites of recent fault offset which are generally coincident with the axis of the structure. (Two of these fault

5.0 HYDROLOGY

5.1 Surface Hydrology

The major surface hydrologic feature of the Hanford Site is the Columbia River that runs through or adjoins the Site over approximately 65 km of its length. Additionally, the Yakima River borders part of the southern boundary and there are several ponds and ditches located in the 200 and 300 Areas. Two ephemeral streams located within the Site, Cold and Dry Creeks, have relatively short reaches (on the order of 1 km), but may increase to several times that length during periods of high runoff. Figure 5-1 shows the locations of the surface water areas.

The Columbia River. The Hanford Site lies wholly within the Columbia River basin, with the drainage of the northeastern two-thirds of the Site being directly to the Columbia. The remainder of the surface area of the Site lies within the drainage basin of the Yakima River which empties into the Columbia a few miles downstream from the southern Site boundary.

The reach of the Columbia River that flows through the Hanford Site is the last free-flowing reach of the River within the United States, the rest having been impounded behind dams for electric power generation, flood control and navigation enhancement. The main channel is braided with islands, submerged rock ledges and gravel bars causing repeated pooling and channeling. The river bed material is largely sand, gravel and rocks up to 20 cm in diameter. Small fractions of silts and clays are associated with the sands in areas of low-velocity deposition, becoming more prominent near the upstream faces of the dams (Whetler et al. 1969).

The flow rate of the Hanford reach of the Columbia River varies widely over the course of a year, depending on regional precipitation and snowmelt conditions. Figure 5-2 shows the annual flow variation on the Hanford reach and the corresponding flow variation for 1948, the year of the largest flow recorded in recent times. Much of the peak flow is derived from melting snow in the higher elevations of Idaho, Montana and British Columbia during the late spring or early summer.

FIGURE 5-1. Surface Waters on the Hanford Site

Large daily variations in Columbia flow in the Hanford reach are due to regulation of the power producing Priest Rapids Dam just upstream from the Site boundary. Daily average flow rates during the spring runoff period range from 4,530 to 18,400 m³/second. The flow rates during the late summer through winter low-flow period typically range from 1,020 to 4,530 m³/second.

FIGURE 5-2. Columbia River Flow at Hanford (Paglieri 1975)

The River width varies from 400 to 600 m, depending on flow rate and location, over most of the Hanford reach. The deepest part of the cross section ranges from 3 to 12 m with the average being about 7.5 m. River depth at various locations can vary hourly by as much as 1 to 3 m, depending on the amount of water being released from the upstream dams (USGS 1973).

The Yakima River. The Yakima River, which partially borders the southern side of the Hanford Site, is of minor hydrologic importance on the Hanford Site. No direct withdrawals of water from the river are made for site use, and there is no disposal of site effluents to the river. Runoff from the southwestern one-third of the Site, which is drained by the Yakima, is intermittent. The flow rate of the Yakima River varies from about 35 to 570 m³/second, with a mean of 190 m³/second (USGS 1973).

Ponds and Ditches. There are several ditches and ponds on the Hanford Site that are used for disposal of waste and cooling waters from various processes. The size of the lone natural pond, West Lake, varies with the elevation of the groundwater in that area, which in turn is influenced by the discharge of waste water to the various ponds and ditches. (This subject is treated more fully in Section 5.2.1).

The locations of the process ponds and ditches are shown in Figure 5-1. These surface water bodies are described in greater detail in the Appendices.

Springs and Ephemeral Streams. Rattlesnake Springs is a permanent spring that arises from ground seepage on the Arid Lands Ecology Reserve on the western edge of the Site. The spring flows for approximately 3 km at a flow rate of a few liters per second before disappearing into the ground. The spring is of little hydrologic importance but supports a wide variety of plant and animal life, discussed in Section 7.1.2.

Two ephemeral streams, Cold Creek and Dry Creek, have their origins in the valleys leading off the slopes of Rattlesnake Mountain and the Yakima Ridge in the northwestern corner of the Site. The streams may be up to several kilometers in length, depending on runoff conditions. Both streams disappear into the ground and deliver no water to any of the major bodies of surface water on or near the Site.

Precipitation and Surface Water. The annual precipitation of the Hanford Site averages about 160 mm. The maximum recorded 24-hr precipitation is 48.5 mm (Stone et al. 1972). A probable maximum 24-hr precipitation of 280 mm has been calculated on the basis of historical data. This is the value which can be expected in a region at least once in a million years (U.S. Dept. of Commerce 1966).

Rainfall moisture penetration in the Hanford soils has been measured. Virtually all moisture from rainfall appears to be ultimately evaporated to the atmosphere (ERDA 1975). The high hydraulic conductivity of the surface soils indicate that no flooding of significance would result from local precipitation amounts approaching the 100-yr or 1000-yr rainfall.

Flooding. Flooding of the Columbia River could have a significant impact on Hanford facilities and operations. The magnitude and effect of the Corps of Engineers Standard Project Flood (SPF) and Probable Maximum Flood have been calculated and reported (Corps of Engineers 1969). The Standard Project Flood would be anticipated to occur during the spring snowmelt runoff period following an exceptionally cold and wet and winter season. It was assumed that winter precipitation over the entire Columbia River Basin would be 1.3 times the normal amount, and that unusually rapid melting would occur due to extreme seasonal values for air temperatures, dew point, solar radiation, and wind speed.

The PMF for the upper Columbia River is postulated to result from conditions similar to those described for the SPF. In addition to these conditions, it is assumed that rainfall occurs over the entire river basin, speeding the snowmelt and adding to the total runoff. The dam-regulated PMF is predicted to produce peak discharges at Hanford of $4.1 \times 10^4 \text{ m}^3/\text{sec}$. No estimate of frequency of occurrence is attached to either the PMF or SPF.

The maximum flood of record, which occurred in 1894, resulted from a combination of hydrometeorologic conditions, including heavy snowpack and rapid melting plus rainfall (Corps of Engineers 1969). The estimated peak flow rate in the vicinity of Hanford was $2.1 \times 10^4 \text{ m}^3/\text{sec}$. The largest flow recorded in recent times for the Columbia River below Priest Rapids Dam was $2.0 \times 10^4 \text{ m}^3/\text{sec}$ in 1948 (Leonhart 1979). Based on records of annual peak flows below Priest Rapids dam for the years 1913-1965, a peak flow of about $2.0 \times 10^4 \text{ m}^3/\text{sec}$ is estimated to have a recurrence frequency of once per 100 yrs, while a peak of $2.4 \times 10^4 \text{ m}^3/\text{sec}$ would occur approximately once every 500 yrs (WPPSS 1974). It has been estimated that the maximum flood that would occur in the vicinity of Hanford as a result of earthquake damage to Grand Coulee Dam would approach the regulated PMF flow rate of $4.1 \times 10^4 \text{ m}^3/\text{sec}$ (ERDA 1976). Table 5-1 lists the various peak flood flow rates for comparison. Figures 5-3 and 5-4 show the approximate areal extent of flooding that would result from the highest flood on record and the PMF.

TABLE 5-1. Estimated Peak Discharge Rates for Floods on the Columbia River Below Priest Rapids Dam

<u>Event</u>	<u>Peak Discharge Rate</u>		<u>Reference</u>
	<u>m³/sec</u>	<u>cfs</u>	
Dam-Regulated PMF ^(a)	4.1 x 10 ⁴	1.44 x 10 ⁶	Leonhart 1979
Seismic Damage to Grand Coulee Dam	4.1 x 10 ⁴	1.44 x 10 ⁶	ERDA 1976
500-Year Flood	2.4 x 10 ⁴	8.4 x 10 ⁵	WPPSS 1974
Highest Flood on Record (1894-estimate) ^(b)	2.3 x 10 ⁴	8.0 x 10 ⁵	ERDA 1976
Highest Flood on Record (1894-estimate)	2.1 x 10 ⁴	7.4 x 10 ⁵	Leonhart 1979
Second Highest Flood on Record (1948)	2.0 x 10 ⁴	6.93 x 10 ⁵	Leonhart 1979
100-Year Flood	2.0 x 10 ⁴	6.9 x 10 ⁵	WPPSS 1974

(a) Flooded area shown in Figure 5-4.

(b) Flooded area shown in Figure 5-3.

5.2 Subsurface Hydrology

5.2.1 The Unconfined Aquifer

The unconfined aquifer beneath the Hanford Site is defined as the zone of saturated sediments lying between the water table and the first thick impermeable bed below the water table. The saturated zone includes sand and gravel deposits of both the Ringold and Hanford Formations. In most places on the Site the bottom of the unconfined aquifer is the basalt bedrock; (see Sections 3.5 and 3.7) in others, it is impermeable silt and clay zones of the Ringold Formation.

The widely varying sediment sizes and degrees of sorting and lithification found in the Hanford and Ringold Formations produces a corresponding broad range of hydraulic characteristics. The Ringold Formation consists mainly of fine sand and silts, while the Hanford Formation is largely coarse deposits (sand, gravel and boulders) that have comparatively large interstitial spaces and high hydraulic conductivity (Newcomb et al. 1972).

FIGURE 5-3. Highest Flood on Record-- $2.3 \times 10^4 \text{ m}^3/\text{sec}$
(After ERDA 1976 and Leonhart 1979)

FIGURE 5-4. Probable Maximum Flood-- $4.1 \times 10^4 \text{ m}^3/\text{sec}$
(After ERDA 1976 and Leonhart 1979)

The several channels that were cut by the Columbia River into the upper surface of the Ringold Sediments are regions of very high permeability because of the coarser glacio-fluvial (Hanford Formation) sediments subsequently deposited within them. These ancient, buried river beds (or Paleochannels) have been identified and their hydrologic characteristics studied extensively (Brown and Isaacson 1977).

The unconfined aquifer beneath the Hanford Site has a maximum thickness of about 70 m and extends approximately 50 km from north to south and about 40 km from east to west at its maximum dimensions. The impermeable boundaries of the aquifer are the Rattlesnake Hills, Yakima Ridge and Umtanum Ridge to the west and southwest. Gable Mountain, Gable Butte and other small areas of basalt outcrop above the water table on the Site. The major source of natural recharge of the unconfined aquifer is precipitation on the Rattlesnake Hills, Yakima Ridge and Umtanum Ridge to the south and west. This water percolates underground near the base of the hills and moves into the Hanford area (Bierschenck 1959). The Yakima River also recharges the unconfined aquifer over the reach from the Horn Rapids to Richland. Natural recharge from precipitation falling on the lowland areas of the Site is negligible except where the water table is at or very near the surface, because most moisture from rain or snowfall is returned to the atmosphere by evaporation before deep penetration can occur. Some additional recharge of the unconfined aquifer may be caused by upward leakage from underlying confined aquifers which are sometimes at a higher hydraulic potential. Recharge from irrigation developments in the upper reaches of the Cold Creek Valley augments the natural recharge in that area.

The discharge of waste water from Hanford facilities to surface ponds constitutes an artificial recharge of the unconfined aquifer. These discharges totalling more than 6×10^{11} liters since 1942, (Eddy and Wilbur 1981) are responsible for groundwater "mounds" or local elevations of the water table in the vicinity of the 200 Areas. (The discharges have been greatly reduced in recent years because of the deactivation of all except one production reactor, the improved treatment of waste streams, and the cessation of reactor fuel

reprocessing). These groundwater mounds produce local distortions of the groundwater flow. About one-third of the total waste water discharged to the ground in the 200 Areas is by way of U-Pond and Redox Pond in the 200 West Area. The remaining two-thirds goes to B-Pond and Gable Mountain Pond from the 200 East Area.

The water table, or upper surface of the unconfined groundwater body on the Hanford Site has been mapped using water level data from the numerous wells (Eddy, Cline and Prater 1982). Figure 5-5 shows the water table map with the contour lines linking points of equal hydraulic potential. If the hydraulic conductivity of the aquifer is assumed to be uniform in all directions at a given location, the groundwater flow will be perpendicular to the contour lines and toward lower hydraulic potential (water table elevation). From Figure 5-5 it can be seen that groundwater flow is predominantly north and east toward the Columbia River which is mainly a discharge boundary for the confined aquifer. The average discharge rate from the aquifer into the river has been calculated at about $2.8 \text{ m}^3/\text{sec}$ (Meyers 1978); however, the rate and direction of flow within several kilometers of the river can be affected by the seasonal river level fluctuations (Raymond and Brown 1963).

The artificial recharge sites or groundwater mounds formed by the waste ponds in the 200 Areas are located on a groundwater "saddle" or divide, and the flow direction at any given time is dependent on the amount of recharge and the hydraulic potential at the aquifer boundary (riverbank).

Groundwater Contamination. The liquid wastes disposed of to the ground percolate downward and laterally through 50 to 100 m of unconsolidated sediments. As the wastes move through these sedimentary materials, adsorption and ion exchange reactions take place between minerals in the sediments and the materials in the liquid wastes. Some of the longer-lived radionuclides such as strontium-90, cesium-137 and plutonium-239, are effectively removed by ion-exchange reactions and are retained in the soil column through which the liquid percolates. Other contaminants, including ruthenium-106, cobalt-60, technetium-99, tritium and nitrate ion, are poorly retained by the soil and move downward through the unsaturated soil column at varying rates until they

FIGURE 5-5. Water Table Elevations--December 1981
(after Eddy, Cine and Prater 1981)

eventually enter the groundwater. As they move in the direction of the groundwater flow, the concentrations are further reduced by radioactive decay, ion exchange, and dispersion (dilution) (Eddy, Cline and Prater 1982).

Nearly 850 cased groundwater monitoring wells have been drilled since the beginning of operations at Hanford (McGahn and Damschen 1979). These wells provide the means for sampling the unconfined aquifer to determine the extent and nature of the contamination.

A routine program of sampling and analysis of water from over 300 wells on the Site is conducted to monitor the movement of contaminants in the aquifer. The results of the monitoring program are published yearly. The latest report in this series (Eddy, Cline and Prater 1982) reports the data taken during the period January-December 1981 for gross beta activity, tritium and nitrate concentration. Figure 5-6 shows the distribution and concentration of the gross beta contaminations (calculated as ruthenium-106) in the unconfined groundwater for 1980. The configuration of the 200-Area plumes are not changing significantly from year to year, but their sizes and concentrations are diminishing. In addition to the 200-Area plumes, beta contamination of the groundwater is evident in the 100-B, 100-D and 100-H Areas from past operations, and in the 100-N Area from disposal of liquid waste to the 1301-N trench.

Tritium (^3H) enters the groundwater as a part of the water molecule and is carried along by the groundwater flow, unaffected by the sorption and ion exchange interactions which delay the migration of most other radionuclides. Tritium, therefore, serves as the most accurate indicator of groundwater movement beneath the Hanford Site. Figure 5-7 shows the tritium distribution in the unconfined groundwater. The configuration of the tritium plume illustrates the groundwater movement pattern. The tritium plume has reached the Columbia River east of the 200 Areas, as well as the Washington Public Power Supply System reactor sites and the 400 Area to the southwest. Drinking water obtained from the unconfined aquifer for the facilities in the 400 Area contains an average of about 3.9×10^4 Ci per liter, or about 1% of the DOE 5480.1, Chapter XI, Concentration Guide for tritium.

FIGURE 5-6. Gross Beta Activity in Unconfined Groundwater (after Eddy and Wilbur 1981)

FIGURE 5-7. Tritium Distribution in Unconfined Groundwater (after Eddy, Cline and Prater 1982)

Nonradioactive nitrate (NO_3^-) ion in the unconfined groundwater is evident over much of the Hanford Site. Figure 5-8 shows the distribution and concentrations of nitrate ion. The nitrate ion entered the groundwater largely from the waste disposal ponds in the chemical processing areas (200 East and 200 West), but smaller zones of elevated nitrate concentration from waste disposal persist near the 100-D, 100-F, 100-H, 100-K and 100-N Areas. Residual nitrate contamination north of Gable Mountain is due to agricultural operations prior to 1943.

In addition to gross beta activity, tritium and nitrate analyses, other routine and special analyses are conducted as part of the groundwater monitoring program. The results are published annually in the series of reports entitled: Radiological Status of the Groundwater Beneath the Hanford Project January-December (Year).

5.2.2 Confined Aquifers

The boundary between the confined and unconfined aquifers is the lowermost silt and clay member of the Ringold Formation. A number of confined aquifers lie beneath the Hanford Site. They are composed primarily of permeable lower Ringold Formation sediments and sedimentary interbeds between basalt flows, confined by thick, impermeable basalt layers or fine grained sedimentary deposits such as the lower Ringold silts and clays. In some boundary zones between individual basalt flows, the basalts are highly jointed and fractured and contain breccia, pillow basalt and palagonite complexes (see Section 3.3) through which groundwater can move (LaSala et al. 1973, Gephart et al. 1979).

The upper confined aquifers are interconnected in places to the overlying unconfined aquifer. This connection is thought to occur in areas where the basalts have been extensively eroded and deformed. One such known area on the Site is in the area west of Gable Butte where the basalt flows of the anticlinal ridge were severely eroded by the ancestral Columbia River (Strait and Moore 1981). The Horn Rapids area of the Yakima River is also thought to be another zone where warping and deformation of the basalt layers has breached the confined aquifers resulting in their presumably being recharged from the Yakima River (Ledgerwood and Deju 1976).

FIGURE 5-8. Nitrate Ion Distribution in Unconfined Groundwater (after Eddy, Cline and Prater 1982)

Deep drilling to explore the basalts beneath the Hanford Site has produced an increasing body of data on the confined aquifers in recent years. Much of this information on the individual aquifers is presented in Gephart et al. (1979).

6.0 METEOROLOGY

6.1 General Climatology

The climate of the Hanford region is dominated by the Cascade Mountain range to the west and the prevailing eastward movement of fronts from the Pacific Ocean. The rain shadow on the east side of the Cascades results in relatively low rainfalls. Average annual precipitation is 160 mm (6.25 in.), nearly half falling during the winter season.

Summers are typically sunny, warm and dry. Winters are variable but characteristically mild by comparison with the rest of the inland Pacific Northwest. Frequent changes of weather are caused by Pacific storm systems moving inland; occasionally arctic air masses moving southward from Canada bring periods of cold. The average daily maximum temperatures during January and July are 2.6°C (36.6°F) and 33.2°C (92.8°F), respectively. The average minima for the same months are -5.6°C (21.9°F) and 16.1°C (61.0°F).

High winds are not uncommon at Hanford. They are usually due to squall lines, frontal passages, strong pressure gradients or thunderstorms. Tornadoes or funnel clouds have been observed on the Hanford Site on at least three occasions.

Continuous observation and recording of meteorological data has been carried out at the Hanford Meteorological Station (HMS), located near the 200-West Area since 1945. Climatological conditions on the 200-Area Plateau are significantly different from those on the south end of the Site, especially during the winter months when the incidence of low clouds and fog is much greater at the HMS. The compilation of results of the HMS observations have been published as Climatology of the Hanford Area (Stone et al 1972). Table 6-1 summarizes the averages and extremes of climatic elements at Hanford, based on records through the year 1980. Limited meteorological data is available from the 100-N Area and also from the Washington Public Power Supply System reactor site.

TABLE 6-1a. Averages and Extremes of Climatic Elements at Hanford (based on all available records to and including the year 1980)

TEMPERATURE (°F)										PRECIPITATION (INCHES)										EXTREME AVERAGES OR TOTALS AND YEAR OR SEASON OF OCCURRENCE									
1912-1980 AVERAGES										1912-1980 TOTALS										1912-1980 AVERAGES (%)									
DEGREE DAYS (BASE 65°F)										1912-1980 TOTALS										1912-1980 AVERAGES (%)									
HEATING 1945-1980 TOTALS										COOLING 1960-1980 TOTALS										SNOW - ICE PELLETS (SLEET)									
MEAN MONTHLY										MEAN MONTHLY										MEAN MONTHLY									
YEAR										YEAR										YEAR									
RECORD LOWEST										RECORD LOWEST										RECORD LOWEST									
RECORD HIGHEST										RECORD HIGHEST										RECORD HIGHEST									
DAILY MAXIMUM										DAILY MAXIMUM										DAILY MAXIMUM									
DAILY MINIMUM										DAILY MINIMUM										DAILY MINIMUM									
YEAR										YEAR										YEAR									
RECORD LOWEST										RECORD LOWEST										RECORD LOWEST									
RECORD HIGHEST										RECORD HIGHEST										RECORD HIGHEST									
DAILY MAXIMUM										DAILY MAXIMUM										DAILY MAXIMUM									
DAILY MINIMUM										DAILY MINIMUM										DAILY MINIMUM									
YEAR										YEAR										YEAR									
LOWEST MONTHLY										LOWEST MONTHLY										LOWEST MONTHLY									
HIGHEST MONTHLY										HIGHEST MONTHLY										HIGHEST MONTHLY									
YEAR										YEAR										YEAR									
MEAN MONTHLY										MEAN MONTHLY										MEAN MONTHLY									
YEAR										YEAR										YEAR									
MAX. IN 24 HOURS										MAX. IN 24 HOURS										MAX. IN 24 HOURS									
YEAR										YEAR										YEAR									
MINIMUM MONTHLY										MINIMUM MONTHLY										MINIMUM MONTHLY									
YEAR										YEAR										YEAR									
MAX. MONTHLY										MAX. MONTHLY										MAX. MONTHLY									
YEAR										YEAR										YEAR									
MEAN MONTHLY										MEAN MONTHLY										MEAN MONTHLY									
YEAR										YEAR										YEAR									
MAX. MONTHLY										MAX. MONTHLY										MAX. MONTHLY									
YEAR										YEAR										YEAR									
MINIMUM MONTHLY										MINIMUM MONTHLY										MINIMUM MONTHLY									
YEAR										YEAR										YEAR									
MAX. MONTHLY										MAX. MONTHLY										MAX. MONTHLY									
YEAR										YEAR										YEAR									
MEAN MONTHLY										MEAN MONTHLY										MEAN MONTHLY									
YEAR										YEAR										YEAR									
MAX. MONTHLY										MAX. MONTHLY										MAX. MONTHLY									
YEAR										YEAR										YEAR									
MINIMUM MONTHLY										MINIMUM MONTHLY										MINIMUM MONTHLY									
YEAR										YEAR										YEAR									
MAX. MONTHLY										MAX. MONTHLY										MAX. MONTHLY									
YEAR										YEAR										YEAR									
MEAN MONTHLY										MEAN MONTHLY										MEAN MONTHLY									
YEAR										YEAR										YEAR									
MAX. MONTHLY										MAX. MONTHLY										MAX. MONTHLY									
YEAR										YEAR										YEAR									
MINIMUM MONTHLY										MINIMUM MONTHLY										MINIMUM MONTHLY									
YEAR										YEAR										YEAR									
MAX. MONTHLY										MAX. MONTHLY										MAX. MONTHLY									
YEAR										YEAR										YEAR									
MEAN MONTHLY										MEAN MONTHLY										MEAN MONTHLY									
YEAR										YEAR										YEAR									
MAX. MONTHLY										MAX. MONTHLY										MAX. MONTHLY									
YEAR										YEAR										YEAR									
MINIMUM MONTHLY										MINIMUM MONTHLY										MINIMUM MONTHLY									
YEAR										YEAR										YEAR									
MAX. MONTHLY										MAX. MONTHLY										MAX. MONTHLY									
YEAR										YEAR										YEAR									
MEAN MONTHLY										MEAN MONTHLY										MEAN MONTHLY									
YEAR										YEAR										YEAR									
MAX. MONTHLY										MAX. MONTHLY										MAX. MONTHLY									
YEAR										YEAR										YEAR									
MINIMUM MONTHLY										MINIMUM MONTHLY										MINIMUM MONTHLY									
YEAR										YEAR										YEAR									
MAX. MONTHLY										MAX. MONTHLY										MAX. MONTHLY									
YEAR										YEAR										YEAR									
MEAN MONTHLY										MEAN MONTHLY										MEAN MONTHLY									
YEAR										YEAR										YEAR									
MAX. MONTHLY										MAX. MONTHLY										MAX. MONTHLY									
YEAR										YEAR										YEAR									
MINIMUM MONTHLY										MINIMUM MONTHLY										MINIMUM MONTHLY									
YEAR										YEAR										YEAR									
MAX. MONTHLY										MAX. MONTHLY										MAX. MONTHLY									
YEAR										YEAR										YEAR									
MEAN MONTHLY										MEAN MONTHLY										MEAN MONTHLY									
YEAR										YEAR										YEAR									
MAX. MONTHLY										MAX. MONTHLY										MAX. MONTHLY									
YEAR										YEAR										YEAR									
MINIMUM MONTHLY										MINIMUM MONTHLY										MINIMUM MONTHLY									
YEAR										YEAR										YEAR									
MAX. MONTHLY										MAX. MONTHLY										MAX. MONTHLY									
YEAR										YEAR										YEAR									
MEAN MONTHLY										MEAN MONTHLY										MEAN MONTHLY									
YEAR										YEAR										YEAR									
MAX. MONTHLY										MAX. MONTHLY										MAX. MONTHLY									
YEAR										YEAR										YEAR									
MINIMUM MONTHLY										MINIMUM MONTHLY										MINIMUM MONTHLY									
YEAR										YEAR										YEAR									
MAX. MONTHLY										MAX. MONTHLY										MAX. MONTHLY									
YEAR										YEAR										YEAR									
MEAN MONTHLY										MEAN MONTHLY										MEAN MONTHLY									
YEAR										YEAR										YEAR									
MAX. MONTHLY										MAX. MONTHLY										MAX. MONTHLY									
YEAR										YEAR										YEAR									
MINIMUM MONTHLY										MINIMUM MONTHLY										MINIMUM MONTHLY									
YEAR										YEAR										YEAR									
MAX. MONTHLY										MAX. MONTHLY										MAX. MONTHLY									
YEAR										YEAR										YEAR									
MEAN MONTHLY										MEAN MONTHLY										MEAN MONTHLY									
YEAR										YEAR										YEAR									
MAX. MONTHLY										MAX. MONTHLY										MAX. MONTHLY</									

TABLE 6-1b. Averages and Extremes of Climatic Elements at Hanford (based on all available records to and including the year 1980)

NUMBER OF DAYS (1954-1980)										NUMBER OF DAYS (1945-1980) *										NUMBER OF DAYS (1912-1980)											
CLEAR			CLOUDY			THUNDERSTORMS			HEAVY FOG (VIS. 1/4 MI. OR LESS)			PRECIPITATION 0.10 INCH OR MORE			SNOW 1.0 INCH OR MORE			NUMBER OF DAYS			3 IN. OR MORE SNOW ON GROUND			PEAK GUST 40 MPH OR GREATER			GREATEST ANNUAL (1945-80)				
MEAN MONTHLY	YEAR	LEAST MONTHLY	MEAN MONTHLY	YEAR	LEAST MONTHLY	MEAN MONTHLY	YEAR	LEAST MONTHLY	MEAN MONTHLY	YEAR	LEAST MONTHLY	MEAN MONTHLY	YEAR	LEAST MONTHLY	MEAN MONTHLY	YEAR	LEAST MONTHLY	MEAN MONTHLY	YEAR	LEAST MONTHLY	MEAN MONTHLY	YEAR	LEAST MONTHLY	MEAN MONTHLY	YEAR	LEAST MONTHLY	MEAN MONTHLY	YEAR	LEAST MONTHLY	MEAN MONTHLY	YEAR
3	1963	0	28	1978	17	1983	0	1972	0	1980	3	15	1976	0	1980	3	10	1973	0	1980	3	10	1973	0	1980	3	10	1973	0	1980	
4	1964	0	26	1979	12	1984	0	1973	0	1981	3	11	1981	0	1980	3	11	1981	0	1980	3	10	1973	0	1980	3	10	1973	0	1980	
6	1974	1	17	23	1977	9	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980		
8	1973	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
10	1971	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
12	1972	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
14	1973	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
16	1974	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
18	1975	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
20	1976	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
22	1977	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
24	1978	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
26	1979	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
28	1980	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
30	1981	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
32	1982	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
34	1983	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
36	1984	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
38	1985	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
40	1986	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
42	1987	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
44	1988	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
46	1989	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
48	1990	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
50	1991	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
52	1992	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
54	1993	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
56	1994	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
58	1995	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
60	1996	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
62	1997	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
64	1998	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
66	1999	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
68	2000	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
70	2001	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
72	2002	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
74	2003	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
76	2004	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
78	2005	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
80	2006	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
82	2007	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
84	2008	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
86	2009	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
88	2010	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
90	2011	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981	0	1980	1	5	1981	0	1980	1	4	1979	0	1980	1	4	1979	0	1980
92	2012	1	12	19	1977	6	1976	1	1979	0	1980	1	5	1981																	

6.2 Temperature

The average daily maximum temperature in July, the hottest month of the year, is 33.2°C (91.8°F); the average minimum is 16.1°C (61.0°F). During January, the coldest month, the average maximum is 2.6°C (36.6°F), and the average minimum is -5.6°C (21.9°F). The daily temperature range is about 9.4°C (16.9°F) in January and 16.7°C (30.1°F) in July. Figure 6-1 presents the annual variation of normal and extreme daily maximum and minimum temperatures at the HMS. Based on the history of temperature extremes, the probabilities of occurrence of extreme values of highest and lowest temperature have been developed. The calculated probabilities are illustrated in Figures 6-2 and 6-3.

During the winter, the Hanford area frequently experiences rapid rises of temperature accompanied by moderate west wind. This phenomenon, known as a

FIGURE 6-1. Annual Variation of Extreme Daily Maximum and Minimum Temperatures at the HMS

FIGURE 6-2. Probability of Yearly High Temperatures at Hanford

"chinook wind" has produced temperature variations of up to 12°C (22°F) in one-half hour and is frequently responsible for rapid melting of snow (ERDA 1975).

During much of the year a well defined nocturnal temperature inversion occurs over the Hanford Site, its intensity varying with the season. During the times when it is strongest, early autumn and early spring, the minimum nighttime temperature at the top of the inversion may be 5 to 8°C (9 to 14°F) warmer than at the basin floor.

6.3 Humidity

The relative humidity at the HMS averages 76.4% during January and 32.2% during July. Higher relative humidity values can be expected at locations near the Columbia River and at some locations around the periphery of the Hanford Site due to increased availability of airborne water vapor from the river and irrigated lands.

FIGURE 6-3. Probability of Yearly Low Temperature at Hanford

6.4 Wind

Wind direction at the HMS is influenced by a number of factors. Gravity (drainage) winds caused by movements of air masses of varying density occur regularly in the summer months. Channeling of the winds by surface features has a major part in determining the prevailing wind direction at any given location on the Hanford Site. Although channeling results in the prevailing wind at the HMS being from the WNW or Northwest, the strongest winds are from the southwest.

The highest monthly average wind speed occurs in June, while the lowest monthly average speeds are in November and December. The months of December, January and February typically have periods of several days with very light winds.

Joint wind speed, direction and stability data are available from the HMS and from the meteorology tower at the 100-N Area. Wind data are also available from the Washington Public Power Supply System reactor site and from a network of telemetering stations located so as to define the local topographical effect on surface winds as well as the general surface flow of winds. Figure 6-4 shows the surface wind roses derived from the data collected by the telemetering network. Figure 6-5 displays the average wind speed and direction by month at the HMS. The highest monthly wind speed and peak gusts recorded at the HMS are presented in Table 6-1a. The peak gusts associated with some significant return probabilities are shown in Table 6-2.

Tornadoes are comparatively infrequent in the Pacific Northwest. During the 26-year period, 1950-1975, a total of 21 tornadoes occurred within about 240 km (150 miles) of the Hanford Site (Fujita 1977). Tornadoes or funnel clouds (with bases not reaching the ground) have been observed on the Hanford Site on at least three occasions (June 16, 1948; March 24, 1961; and July 15, 1970). However, the nearest recorded tornado damage was at Yakima, about 70 km (44 miles) west (April 30, 1957) and at Wallula Junction about 80 km (50 miles) southeast (June 26, 1958).

The tornado history of the states of Washington, Idaho and Oregon was evaluated in 1970 (Jaech 1970) to determine the probability of a tornado striking the Exxon Nuclear Company Fuel Fabrication plant. The analysis indicated that the probability of a tornado striking a location in the vicinity of the site is about six chances in a million during any given year. A later independent analysis using data on all reported tornadoes within a 230 km (243 miles) radius of the Exxon plant yielded a similar probability (Fujita 1977).

Tornadoes which do occur in the vicinity tend to be relatively weak. The probable maximum wind speed for tornadoes at Hanford is estimated at about 280 km per hour (175 mph) (Jaech 1970, Fujita 1977).

FIGURE 6-4. Surface Wind Roses for Various Locations on and Surrounding the Hanford Site Based on Five-Year Average (1952-1956). Speeds are given in miles per hour. (the points of the rose represent the directions from which the winds come)

FIGURE 6-5. Monthly Average Wind Roses for HMS Based on 50-Foot Wind Data, 1955-1970 (the numbers in the centers are the percentages of calm winds (top numbers) and variable winds (bottom numbers). The points of the rose represent the directions from which the winds come.

TABLE 6-2. Peak Wind Gust Return Probabilities

Occurrence Probability (per year)	Return Period (yr)	Estimated Wind Speed, mph (km/hr)	
		HMS(a)	Yakima/Walla Walla(b)
10^{-2}	100	87 (140)	88 (142)
2×10^{-3}	500	97 (156)	100 (161)
10^{-3}	1,000	101 (163)	107 (172)
10^{-4}	10,000	---	128 (206)

(a) From: Stone et al (1972), Figure 45, for 40-ft level at the HMS.

(b) From: Fujita (1977), based on 25 yrs of meteorological observations at the Yakima and Walla Walla airports.

6.5 Precipitation

The annual average precipitation at the HMS is about 160 mm (6.25 in.). Forty-four percent of the total falls in the months of November, December and January. The three-month period July through September, contributes only 12%. Figure 6-6 shows the average precipitation amounts at the HMS by month.

About 38% of all the precipitation during the December through February period is in the form of snow, however accumulations of 15 cm (6 in.) or more of snow on the ground, occur only about four days each year. The maximum snow depth recorded at the HMS is 30.7 cm (12.1 in.) in December 1964. However in February 1916, a snow depth of 62.2 cm (24.5 in.) was recorded by a U.S. Weather Bureau Cooperative observer at a site about 16 km (10 miles) ENE of the HMS.

Extrapolation of historical precipitation data indicates that a storm with an expected frequency of recurrence of 100 years could result in a maximum one-hour rainfall of about 21 mm (0.81 in.) with a 24-hr total of 51 mm (1.99 in.). The maximum recorded amounts are 15 mm (0.59 in.) in one hour and 48.5 mm (1.91 in.) in 24 hours. Figure 6-7 gives the probability that total annual precipitation will exceed a given amount; Figure 6-8 provides the probability that maximum snow accumulation will exceed a given depth.

FIGURE 6-6. Average Monthly Precipitation Amounts At Hanford (1912-1280)

FIGURE 6-7. Total Annual Precipitation Probability Diagram

FIGURE 6-8. Annual Snow Fall Probability Diagram

6.6 Other Meteorological Phenemona

Thunderstorms. Thunderstorms may occur during any month of the year in the Hanford area, although most frequently during the months of April through September, and only rarely during November, December and January. On the average, there are 10 days per year when thunder is heard at the HMS, though the number has varied from 3 to 23. The period May through August is the peak season for thunderstorms with an average of 2 days per month when thunder is observed. Severe thunderstorms are rare at Hanford, although lightning strikes have ignited a number of grass fires on the Site.

Hail. Hail is not common at the HMS, being reported only on about 5% of the days when thunderstorms are reported. Hailstone sizes up to 1 cm (0.4 in.) in diameter have been reported, but most are in the 0.5- to 0.75-cm (0.2- to 0.3-in.) size range.

Fog. Although observed in every month of the year, almost 95% of all occurrences are observed during the months of November through February. Fog is reported at the HMS on an average of 38 days each year, of which 25 days are classified as "heavy fog" with visibility reduced to 400 m (1/4 mile) or less. December is the month with highest frequency of fog, with an average of 8 days of fog reported. The frequency and persistence of fog at areas of the Site closer to the Columbia River is believed to be somewhat greater than at the HMS. However, the higher elevations of Rattlesnake Mountain are frequently clear when the HMS and most of the lowland areas of the Site are experiencing fog.

Glaze. Glaze is a coating of ice formed on exposed surfaces by the freezing of supercooled raindrops or drizzle. An average of seven occurrences of glaze are recorded each year at the HMS. Severe instances have the potential for major disruption of traffic and damage to overhead power lines.

Sky Cover and Solar Radiation. There are an average of about 192 days per year with clear or partly cloudy skies. Table 6-1 presents the average and extreme monthly sky cover and solar radiation data recorded at the HMS.

Air Pollution Potential. The Hanford area has a relatively high frequency of stable low-level temperature inversion conditions during the winter. This condition produces a stagnation of the air next to the surface, preventing the normal dispersion of pollutants. An episode of stagnation, defined as an "uninterrupted period of daily average wind speeds of 5 mph or less and/or a peak gust of 15 mph or less," lasting 20 days can be expected about one winter in 20. However a 10-day stagnation period can be expected every other winter season; two of every three seasons can be expected to produce a stagnation period of at least 8 days.

7.0 ECOLOGY

7.1 Aquatic Ecology

The Columbia River is the dominant aquatic ecosystem on the Hanford Site. The fifth largest river in North America, it has a total length of 1955 km from its origin in British Columbia to its mouth at the Pacific Ocean. Numerous dams have been built on the river, with the only free-flowing U. S. section occurring between Priest Rapids Dam and McNary Reservoir. No significant tributaries enter the stream in this section, which is mostly contained within the Hanford Site. The entire Columbia River is exceptionally clean by comparison with other U. S. rivers its size. Other aquatic ecosystems on the Site are Rattlesnake Springs, the 200 Area ponds and ditches, the 100-N disposal trench and the 300-Area process sewer trenches.

7.1.1 The Columbia River

The Columbia River presents a very complex ecosystem due to its size, the number of man-made alterations, the diversity of the biota, and the size and diversity of its drainage basin. Streams in general, especially smaller ones, usually depend upon organic matter from outside sources (such as terrestrial plant debris) to form the base of the aquatic food pyramid. Large rivers, particularly the Columbia with its series of large reservoirs, contain significant populations of primary energy producers (plants) that contribute to the basic energy requirements of the river ecosystem. Phytoplankton (free-floating algae) and periphyton (algae that grow on solid surfaces) are abundant in the Columbia River and provide food for herbivores such as insect larvae and nymphs, which in turn are consumed by carnivorous species. Figure 7-1 is a simplified diagram of the food-web relationships in selected Columbia River biota and represents probable major energy pathways.

Phytoplankton. Diatoms are the dominant algae in the Columbia River, usually representing over 90% of the population. The main genera are typical of those 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 are actually derived from normally stationary algae (periphyton) that

flooding during the spring freshet and daily fluctuating river levels (below Coyote Rapids and 100-D Area). Lemna potamogeton, Elodea and Myriophyllum are among the aquatic plants found in the sloughs.

Zooplankton. The zooplankton populations in the Hanford reach of the Columbia are generally sparse and associated with bottom sediments in slack water areas near the edge of the river. The Cladocera, Alona rectangula, A. affinis and Chydorus sphaericus, predominate in spring, fall and winter; Sida chrystallina and Eurycercis lemallatus are most abundant in summer.

Benthic Species. Benthic organisms are those that are either attached to or live closely associated with the bottom. 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. Other bottom dwelling organisms include limpets (Fisherola nuttali), snails (Physa sp. and Lymnaea sp.), sponge (Spongella lacustris) and crayfish (Pacifasticus leniusculus).

There are seasonal fluctuations in aquatic insect abundance with peak larval abundance in late fall and winter, and greatest adult emergence in spring and summer.

Fish. Forty-four species of fish have been identified in the Hanford reach of the Columbia River (Gray and Dauble 1977). Of these, the salmon (Oncorhynchus tshawytscha, O. nerka and O. kisutch) and steelhead trout (Salmo gairdneri), which use the river as a migration route to and from upstream spawning grounds, are of the greatest economic importance. Both the fall chinook salmon and the steelhead trout also spawn in the Hanford reach. Population estimates of the locally spawning chinook salmon are made annually by means of aerial surveys and enumeration of the number of salmon nests (redds) in the river between Richland and Priest Rapids Dam (Table 7-1). Since 1962, the Hanford reach spawning population has represented about 15 to 20% of the total fall chinook escapement to the river. The destruction of other main-stem Columbia spawning grounds by dams has increased the relative importance of the Hanford reach spawning area (Watson 1970, Watson 1973).

TABLE 7-1. Number of Spawning Fall Chinook Salmon at Hanford, 1947-1980
(population estimate based on 7 fish per redd)

<u>Year</u>	<u>No. of Redds^(a)</u>	<u>Population Estimate</u>
1947	240	1680
1948	785	5500
1949	330	2310
1950	316	2210
1951	314	2200
1952	539	3770
1953	149	1040
1954	157	1100
1955	64	490
1956	92	640
1957	872	6100
1958	1485	10400
1959	281	1970
1960	295	2070
1961	939	6570
1962	1261	8830
1963	1303	9120
1964	1477	10300
1965	1789	12500
1966	3101	21700
1967	3267	22900
1968	3560	24900
1969	4508	31600
1970	3813	26700
1971	3600	25200
1972(b)	876	6130
1973	2965	20800
1974(b)	728	5096
1975	2683	18781
1976	1951	13657
1977	3240	22680
1978	3028	21196
1979	2983	20881
1980	1487	10409

(a) Redd counts obtained by aerial surveys.

(b) Very poor survey conditions probably resulted in substantial undercounting of Redds.

The annual average Hanford reach steelhead spawning population estimates for the years 1962-1971 are about 10,000 fish. The estimated annual sport catch for the period 1963-1968 in the reach of the river from Ringold to the mouth of the Snake River was approximately 2,700 fish (Watson 1973).

The shad, another anadromous species, may also spawn in the Hanford reach of the river. The upstream range of the shad has been increasing since 1956 when fewer than 10 adult shad ascended McNary Dam. Since then the number ascending Priest Rapids Dam has risen to many thousands each year and the young-of-the-year have been collected in the Hanford reach. The shad is not dependent upon 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.

Other fish of importance to sport fishermen are the whitefish, sturgeon, smallmouth bass, crappie, catfish, walleye and perch. Large populations of rough fish including carp, shiners, suckers and squawfish are also present. Fish found in the Hanford reach of the Columbia River are shown in Table 7-2.

7.1.2 Rattlesnake Springs

Rattlesnake Springs is a permanent spring located on the Arid Lands Ecology (ALE) Reserve about 8 km southwest of the 200-West Area. The spring which begins from ground seepage and is subsequently fed by small ground springs along its course, flows for approximately 3 km at a few liters per second before disappearing into the ground. The stream bottom is composed of sand and gravel, with rubble in some areas. The stream is subject to flash flooding in the winter, but still supports a variety of biotic communities.

Some 90 species of algae have been identified at Rattlesnake Springs; slightly over half of the species are diatoms. In the summer, green algae are the second most numerous group and are dominant in terms of biomass production.

Cattails and sedges occur along the stream where it is not shaded, but the dominant macrophyte is watercress, Rorippa nasturtium-aquaticum which seasonally occupies from 2% to 85% of the total stream area (Wolf and Cushing 1972).

TABLE 7-2. Fish Species Collected in the Hanford Reach of the Columbia River
(modified from Gray and Dauble 1977)

Family	Scientific Name	Common Name	Family	Scientific Name	Common Name
Acipenseridae (sturgeons)	<u>Acipenser</u> <u>transmontanus</u>	White sturgeon	Gadidae (codfishes)	<u>Lota</u> <u>lota</u>	Burbot
Catostomidae (suckers)	<u>Catostomus</u> <u>columbianus</u> <u>C. macrocheilus</u> <u>C. platyrhynchus</u>	Bridgelip sucker Largescale sucker Mountain sucker	Gasterosteidae (sticklebacks)	<u>Gasterosteus</u> <u>aculeatus</u>	Threespine stickleback
Centrarchidae (bass, sun- fish and crappie)	<u>Lepomis gibbosus</u> <u>L. macrochirus</u> <u>Micropterus dolomieu</u> <u>M. salmoides</u> <u>Promoxis annularis</u> <u>P. nigromaculatus</u>	Pumpkinseed Bluegill Smallmouth bass Largemouth bass White crappie Black crappie	Ictaluridae (freshwater catfishes)	<u>Ictalurus melas</u> <u>I. natalis</u> <u>I. nebulosus</u> <u>I. punctatus</u>	Black bullhead Yellow bullhead Brown bullhead Channel catfish
Clupeidae (herrings)	<u>Alosa</u> <u>sapidissima</u>	American shad	Percidae (perches)	<u>Perca flavescens</u> <u>Stizostedion vitreum</u> <u>vitreum</u>	Yellow perch Walleye
Cottidae (sculpins)	<u>Cottus asper</u> <u>C. bairdi</u> <u>C. beldingi</u> <u>C. perplexus</u> <u>C. rotheus</u>	Prickley sculpin Mottled sculpin Piute sculpin Reticulate sculpin Torrent sculpin	Percopsidae (troutperches)	<u>Percopsis</u> <u>transmontana</u>	Sand roller
			Petromyzontidae (lampreys)	<u>Entosphenus</u> <u>tridentatus</u> <u>Lampetra ayresi</u>	Pacific lamprey River lamprey
			Salmonidae (trout, salmon, whitefish)	<u>Coregonus</u> <u>Oncorhynchus kisutch</u> <u>O. nerka</u> <u>O. tshawytscha</u> <u>Prosopium williamsoni</u> <u>Salmo clarki</u> <u>S. gairdneri</u> <u>Salvelinus malma</u>	Lake whitefish <u>clupeaformis</u> Coho salmon Sockeye salmon Chinook salmon Mountain whitefish Cutthroat trout ^(a) Rainbow (steelhead) trout Dolly Varden
Cyprinidae (minnows)	<u>Acrocheilus alutaceus</u> <u>Cyrinus caprio</u> <u>Mylocheilus caurinus</u> <u>Ptychocheilus</u> <u>oregonensis</u> <u>Rhinichthys cataractae</u> <u>R. falcatus</u> <u>R. osculus</u> <u>Richardsonium</u> <u>balteatus</u> <u>Tinca tinca</u>	Chiselmouth Carp Peamouth Northern squawfish Longnose dace Leopard dace Speckled dace Redside shiner Tench			

(a) Not collected since construction of McNary Dam in 1954.

Several groups of invertebrates occupy the stream, although the number of species present is highly dependent on the size of the winter floods. Table 7-3 summarizes the major taxonomic groups identified in the Rattlesnake Springs.

7.1.3 Other Aquatic Ecosystems

Several of the waste ponds and ditches on the Hanford Site support aquatic ecosystems. Gable Mountain pond and U-Pond are the most significant and extensively studied of these. The ponds support shoreline vegetation, mainly cattails and rushes. Other primary producers are phytoplanktonic green algae. Figure 7-2 shows the basic food web present in both ponds. Table 7-4 gives the major taxa identified in the ponds.

The aquatic ecosystems supported by the other waste ponds and ditches are of minor interest and have not been extensively studied.

TABLE 7-3. Major Taxa Identified in Rattlesnake Springs

<u>Plants</u>	<u>Animals</u>
Phylum Chlorophyta	Phylum Mollusca
Sub-Division Chlorophyceae	Phylum Annelida
Sub-Division Characeae	Phylum Arthropoda
Phylum Euglenophyta	Class Crustacea
Phylum Chrysophyta	Order Ostracoda
Sub-Division Xanthophyceae	Order Diplostraca
Sub-Division Chrysophyceae	Order Calanoida
Phylum Cyanophyta	Order Cyclopoida
Sub-Division Myxophyceae	Order Amphipoda
Phylum Tracheophyta	Class Insecta
Family Cruciferae	Order Coleoptera
Family Typhaceae	Order Ephemeroptera
Family Cyperaceae	Order Plecoptera
	Order Trichoptera
	Order Diptera
	Order Hemiptera
	Order Odonata

FIGURE 7-2. Food Web of Gable Mountain Pond and U Pond

TABLE 7-4. Major Taxa Identified in Gable Mountain Pond and U Pond

<u>Plants</u>	<u>Animals</u>
Phylum Chlorophyta	Phylum Mollusca
Phylum Tracheophyta	Phylum Annelida
	Phylum Arthropoda
Family Typhacea	
Family Cyperacea	Class Crustacea
Family Najadaceae	Order Diplostraca
Family Haloragidaceae	Order Calanoida
	Order Cyclopoida
	Order Amphipoda
	Class Insecta
	Order Coleoptera
	Order Diptera
	Order Hemiptera
	Order Odonata
	Order Ephemeroptera
	Phylum Chordata
	Class Osteichthyes
	Order Holostei
	Family Cyprinidae

7.2 Terrestrial Ecology

7.2.1 General Characteristics

The Hanford region is frequently described as a "shrub-steppe" because of its resemblance to the steppelands of Central Asia. However, there are major differences between the Hanford temperature and precipitation regime and that of a true steppe. The true steppe receives a major portion of its annual precipitation as summer thunderstorms; the Hanford region receives most of its precipitation during winter. This and other differences have led to the region being variously classified as a cool desert, a winter-wet cool steppe or a mid-latitude desert (Daubenmire 1970). The vegetation types are those that can efficiently utilize the soil moisture stored in winter and withstand the high temperatures and low soil moisture of the summer. The primary productivity is generally quite low, but supports a variety of insect and small animal and bird species.

7.2.2 Vegetation

The vegetation mosaic of the Hanford Site consists of eight major kinds of plant communities identified by the most conspicuous or most abundant plant species:

- Sagebrush/bluebunch wheatgrass
- Sagebrush/cheatgrass or Sagebrush/Sandberg's bluegrass
- Sagebrush-bitterbrush/cheatgrass
- Greasewood/cheatgrass-saltgrass
- Winterfat/Sandberg's bluegrass
- Thyme buckwheat/Sandberg's bluegrass
- Cheatgrass-tumble mustard
- Willow

Figure 7-3 shows the locations on the Site where the communities are dominant. On the Hanford Site, the sagebrush/bluebunch wheatgrass vegetation-type occupies extensive areas in the Rattlesnake Hills, mostly confined to the ALE Reserve. In the absence of fire, sagebrush is the most conspicuous plant, but perennial grasses (bluebunch wheatgrass and Sandberg's bluegrass) contribute most of the plant biomass. In the event of fire, sagebrush is killed but the perennial grasses are not. Over time, sagebrush is expected to return to burned areas, but this is a slow process that probably does not occur during the average human lifetime. Bluebunch wheatgrass is the most important live-stock forage plant on the Hanford Site.

The most broadly distributed vegetation type on the Hanford Site is the sagebrush/cheatgrass or sagebrush/Sandberg's bluegrass association. This vegetation type occurs as a broad zone between the sagebrush/bluebunch wheatgrass type and the sagebrush-bitterbrush/cheatgrass type. The sagebrush/cheatgrass type differs from the sagebrush/bluebunch wheatgrass principally in that wheatgrass is absent, but another important difference is that sagebrush plants also tend to be larger in size and provide more ground cover. Spiny hopsage and rabbitbrush may be intermingled with sagebrush shrubs. Fire can burn through this kind of vegetation, killing sagebrush, but hopsage and rabbitbrush survive burning, sending out new growth during the growing season following the fire. Recovery of this vegetation following fire is not as readily

FIGURE 7-3. Distribution of Vegetation Types on the Hanford Site

apparent as in the sagebrush/bluebunch wheatgrass and Sandberg's bluegrass vegetation because large perennial grasses are scarce. The general paucity of herbaceous cover also tends to favor invasion by tumbleweed, with or without fire. The sagebrush/cheatgrass and sagebrush/Sandberg's bluegrass communities provide very limited forage for livestock or wildlife.

The sagebrush-bitterbrush/cheatgrass type occupies the low elevations in the southeastern sector of the Hanford Site. This vegetation type differs from the sagebrush/cheatgrass type by having bitterbrush intermingled among the

sagebrush shrubs. Also, snow eriogonum, a small shrub, is often locally abundant. The sagebrush-bitterbrush/cheatgrass vegetation type occupies the sandiest soil short of dunes. Fire is especially destructive of this vegetation because sagebrush and bitterbrush are both killed by burning and the sandy soil is especially susceptible to wind erosion when protective vegetation cover is destroyed. The colonization of sandy soils in an arid environment is a slow process, especially if large areas are burned and seed sources are severely reduced. The most efficient early invader of burned areas in the sagebrush-bitterbrush/cheatgrass vegetation type is tumbleweed. Bitterbrush is an important forage plant for mule deer, especially in fall and winter.

The greasewood/cheatgrass-saltgrass type is restricted to a small area of about 100 acres in the vicinity of Rattlesnake Springs. This vegetation type is important because the geographic distribution of greasewood is determined by the presence of a relatively shallow water table. Greasewood has an extensive root system and can extract water from a depth of 12 m at Rattlesnake Springs, remaining succulent throughout the summer when other upland shrubs are dried from summer drought. Greasewood is known to be a salt accumulator. The greasewood/cheatgrass-saltgrass type provides little forage (Rickard and Keough 1968).

The winterfat/Sandberg's bluegrass vegetation-type occupies several thousand acres along the gentle lower slopes of Rattlesnake Hills. For the most part, winterfat is restricted in geographic distribution to the ALE Reserve. In the years prior to government acquisition of the Hanford Site lands, the winterfat areas were used as winter pastures for sheep because winterfat is a nutritious and palatable forage plant for livestock.

The thyme buckwheat/Sandberg's bluegrass type occupies thin, stony soils along ridge crests in the Rattlesnake Hills and Gable Mountain areas. These communities have no potential for agricultural use other than to provide limited forage for livestock and wildlife, but they possess great aesthetic value because of the presence of many species with showy flowers. These species are of substantial botanical interest because of their floristic composition and morphological, physiological and genetic adaptations to living in a stressed environment.

The cheatgrass/tumble mustard type occupies abandoned agricultural fields, especially in the 100 Areas and on the ALE Reserve. This vegetation type is comprised mostly of alien annual plants, i.e., cheatgrass and annual mustards. Over the past 30 years invasion by native perennial grasses and shrubs and colonization by tumbleweed have been resisted. Cheatgrass/tumble mustard communities in the absence of livestock grazing are effective in binding soil against wind and water erosion.

Willow vegetation occurs along the banks of the Columbia River, waste ponds in the 200 Areas, abandoned agricultural irrigation ditches in the 100 Areas and along permanent spring courses in the Rattlesnake Hills. Although the amount of acreage occupied by willow communities is small, their value to wildlife is large. Willows and associated deciduous trees, shrubs and herbaceous plants provide food and nest sites for game and song birds, and summer forage and cover for mule deer. They are also important as nesting sites for several birds of prey that live on the Site (see Section 7.2.4).

The historical pattern of plant succession in the steppe region of Washington has been altered during the past century by the introduction of annual weeds from the steppes of Eurasia. One of the most aggressive of these plants is cheatgrass. Cheatgrass is well adapted to the fall-winter precipitation regime of the area because its seeds are highly viable and seedling growth is more competitive than that of native perennial grasses. Abandoned agricultural fields 30 years old continue to be dominated by cheatgrass; apparently the competition for soil, water, and available essential mineral nutrients is sufficient to exclude other kinds of plants for long periods of time.

Tumbleweed, another exotic plant, has an effective method of seed dispersal. Tumbleweed is not as competitive as cheatgrass in most habitats, but it is a most successful colonizer of habitats where cheatgrass is suppressed by mechanical means or herbicides or in soils with heterogeneous texture. In the absence of physical disturbance, cheatgrass and tumbleweed are not effective in invading pristine steppe communities.

7.2.3 Mammals

The mule deer and elk (Wapiti) are the only big game animals found on the Hanford Site. Most of the mule deer population is found along the Columbia River with smaller concentrations near Gable Mountain and the 200 Areas, at Rattlesnake Springs and in the Snively Ranch area of the Rattlesnake Hills. Deer tagged on the Site as fawns have been taken during hunting season as far away as 50 to 60 km from the Site boundary. The small herd of elk which has become established on the Site since 1971 is believed to have started with a few migrants from the Blue Mountains, some 110 km to the east.

The cottontail rabbit is the only small game mammal, with small populations scattered throughout the Site area. The raccoon is probably the most abundant furbearing mammal on the Hanford Site, mostly confined to shoreline areas of the Columbia River and waste ponds in the 200 Areas. Beaver and muskrats occur in backwater areas of the Columbia River, while muskrats are also found in wasteponds and ditches in the 200 Areas. Mink occur along the Columbia River and weasels are scattered throughout the Hanford area. The coyote is abundant on the Hanford Site as compared to adjacent land areas, although no accurate estimate of population density has been made. The bobcat and badger are present on the Site, but in low numbers.

The jackrabbit is widely distributed on the Hanford Site; however, it is less abundant in the sagebrush/bluebunch wheatgrass vegetation than in the sagebrush/cheatgrass and sagebrush-bitterbrush/cheatgrass vegetation types. The jackrabbit is an important food item for coyotes and raptors.

Porcupines are widely distributed over the Site area but are especially abundant along the Columbia River.

Small mammals are abundant on the Hanford Site, with the Great Basin pocket mouse being the most numerous. Other common small mammals are the deer mouse, ground squirrel, pocket gopher, harvest mouse, house mouse, Norway rat, sagebrush vole, grasshopper mouse, vagrant shrew, least chipmunk, Merriam shrew and woodrat (O'Farrell and Hedlund 1972).

7.2.4 Birds

The steppe region of southeastern Washington is not rich in birds and only a few species nest in the area. The most abundant birds in steppe vegetation are the western meadowlark and the horned lark. The most abundant nesting birds in the riparian vegetation include, among others, magpies, crows, doves, some warblers, and waterfowl.

The chukar partridge is the most important upland game bird on the Hanford Site. Most of the population is concentrated in the Rattlesnake Hills on the ALE Reserve, but local populations exist in the Gable Mountain and White Bluffs Area. The chukar, which was introduced to Washington from Eurasia, is well adapted to the arid rangeland conditions, feeding on herbage, seeds and insects.

Chinese ring-necked pheasants are present on the Hanford Site but in small numbers. Small groups are found along the Columbia River, generally upstream from the old Hanford townsite, Rattlesnake Springs and Snively Spring. The habitat is marginal for pheasants.

California quail are present as scattered local populations along the Columbia River, especially on abandoned farmsteads with orchard and shade trees, and around the waste ponds in the 200 Areas.

Mourning doves are migratory birds that nest throughout the Hanford Site area during the spring months. Most have migrated by October.

Sage grouse are present on the Hanford Site in small numbers. In recent years most sightings occurred in the Rattlesnake Hills on the ALE Reserve. Over the years the sage grouse population declined in southeastern Washington as pristine habitat was converted to dryland wheat and irrigated agriculture fields.

The Canada goose is the most important of the nesting waterfowl on the Hanford Site; the nesting habitat is confined to islands in the free-flowing reach of the Columbia River (Hanson and Eberhart 1971). The Columbia River also provides a resting sanctuary for migratory ducks and Canada geese.

Raptorial birds use the Hanford Site as a refuge from human intrusions, especially during the nesting season. Twenty-six species have been observed on the site with eleven species having been recorded nesting (Fitzner et al. 1981). Trees around abandoned farms in the 100 Areas and abandoned military installations provide nesting habitat for red-tailed hawks, Swainson's hawks and great horned owls (Olendorf 1973). Prairie falcons nest in small numbers on cliffs around the White Bluffs, Gable Mountain and Gable Butte, Rattlesnake Mountain and Umtanum Ridge. Ferruginous hawks nest in trees, on cliffs, or occasionally on the ground. The long-eared owl, short-eared owl, barn owl, burrowing owl, American Kestrel and marsh hawk are also known to nest on the site. The osprey is only an occasional visitor along the Columbia River. The golden eagle and the bald eagle are both winter visitors (Fitzner et al. 1981). The raptorial birds are of particular interest because their ancestral ranges are being steadily reduced by human encroachment. Relatively large areas of uninhabited land, such as the Hanford Site, provide a nesting and foraging ground for raptorial birds.

7.2.5 Snakes and Lizards

Compared to the southwestern United States desert areas, the herpetofauna of the Hanford Site is sparse. The most abundant reptile in low elevation steppe vegetation is the side-blotched lizard. The horned lizard is not common and the sagebrush lizard is scarce. The most abundant snake is the gopher snake, but the yellow-bellied racer and the Pacific rattlesnake are common. The coachwhip snake and the desert night snake are seldom observed (ERDA 1975).

7.2.6 Insects

Leafhoppers (Cacadellidae), aphids (Aphididae) and plant hoppers (Fulgoroidea) are all present, but members of the superfamily Coccidea are the most abundant. The Coccidea are primarily mealybugs (Pseudococcidae), most of which occur in association with bluebunch wheatgrass. Cicadas may periodically be conspicuously present in this area, primarily due to the buzzing "song" produced by the males.

The order Orthoptera contains the well-known family Acrididae (grasshoppers) which are frequently very destructive members of grassland communities.

The grasshopper possessing the greatest potential for outbreak in this area is the migratory grasshopper (Melanoplus sanguinipes). Localized concentrations have occurred at Hanford in the past (Rogers 1973) and will probably continue to do so in the future. These concentrations appear to occur only in the cheatgrass-tumble mustard vegetation.

The order Coleoptera (beetles) constitutes the largest insect order and contains nearly 50% of all known insect species. They are a very diverse group, inhabiting nearly all conceivable types of habitat. Some important predacious beetle families in this area are the ground beetles (Carabidae), tiger beetles (Cicindelidae), checkered beetles (Cleridae), and ladybird beetles (Coccinellidae). The weevils (Curculionidae) are probably the most important group of plant eaters in this order. Sixteen species of darkling beetles occur on the Hanford Site. Two species, Philolithus densicollis and Stenomopha puncticollis, can be particularly abundant. Philolithus is much more abundant in native grasslands than in cheatgrass, while Stenomopha, somewhat less abundant than Philolithus, is less sensitive to vegetation type, and does not occur at low elevations.

The order Hymenoptera (ants, wasps, bees) contains a great number of species that are either predators or parasites, as well as the plant pollinators. The ants (Formicidae), although not abundant on the Hanford Site, apparently occur in all vegetation types. Wasps (specidae and Ichmeumonidae) are very mobile and occur in all vegetation types.

The collembola (springtails) play a dual role, some members feeding on decomposing plant material, others feeding directly on living plant tissue. Collembola are very common in any mulch layer, but are frequently overlooked due to their tiny size. The most abundant collembola species belongs to the family Sminthuriade, sometimes called the globular springtails.

7.2.7 Rare or Endangered Species

Two federally listed threatened or endangered animal species, the bald eagle and the peregrine falcon, are known to occur within the Hanford Site. In addition, the Washington Department of Game, in cooperation with the Nature

Conservancy, is compiling a draft list of "threatened species" and "species of concern." Table 7-5 presents all wildlife species on the State Game Department working list which are known to occur on the Hanford Site (Fickeisen et al. 1980).

TABLE 7-5. Threatened and Endangered Species and Other Species of Concern
(After Fickeisen et al. 1980)

Federally Listed Threatened and Endangered Species(a)

Bald eagle, Haliaeetus leucocephalus alascanus
Peregrine falcon, Falco peregrinus americanus

Species of Concern

Plants(b)

Robinson's onion, Allium robinsonii(c)
Riverbank wormwood, Artemisia lindleyana
Columbia River milkvetch, Astragalus columbianus(c)
Medick milkvetch, Astragalus speirocarpus
Rosy balsamroot, Balsamorhiza rosea
Cryptantha, Cryptantha leucophaea
Cusick's sunflower, Helianthus cusickii
Rorippa, Rorippa calycina var. columbiae
Liverwort monkey flower, Mimulus jungermannioides(c)
Phacelia, Phacelia lenta

Wildlife

Swainson's hawk, Buteo swainsoni
Ferruginous hawk, Buteo regalis
Golden eagle, Aquila chrysaetos
Sandhill crane, Grus canadensis
Sage thrasher, Oreoscoptes montanus
White pelican, Pelecanus erythrorhynchos
Double Crested cormorant, Phalacrocorax auritus
Great blue heron, Ardea herodias
Black-crowned night heron, Nycticorax nycticorax
Whistling swan, Olor columbianus
Goshawk, Accipiter gentilis
Osprey, Pandion haliaetus
Merlin (pigeon hawk), Falco columbarius
Gyr Falcon, Falco rusticolus
Prairie falcon, Falco mexicanus
Sage grouse, Centrocercus urophasianus
Forster's tern, Sterna forsteri
Arctic tern, Sterna paradisaea
Caspian tern, Sterna caspia
Burrowing owl, Athene cunicularia

TABLE 7-5.(continued)

Wildlife (continued)

Western bluebird, Sialia mexicana
 Sage Sparrow, Amphispiza belli
 Pygmy rabbit, Sylvilagus idahoensis
 Merriam's shrew, Sorex merriami
 Silver-haired bat, Lasionycteris noctivagans
 Hoary bat, Lasiurus borealis
 Pallid bat, Antrozous pallidus
 White-tailed jackrabbit, Lepus townsendii
 Northern pocket gopher, Thomomys talpoides limosus
 Ord's kangaroo rat, Dipodomys ordii
 Northern grasshopper mouse, Onychomys leucogaster
 Sagebrush vole, Lagurus curtatus
 Short-tailed weasel, Mustela erminea
 Woodhouse's toad, Bufo woodhousei
 Desert horned lizard, Phrynosoma platyrhinos
 Striped whipsnake, Masticophis taeniatus
 Pacific gopher snake, Pituophis melanoleucus catenifer
 Desert night snake, Hypsiglena torquata
 Columbia River tiger beetle, Cicindela columbica(c)
 Oregon swallowtail, Papilio oregonius

Aquatic Organisms(d)

Chinook salmon, Oncorhynchus tshawytscha(c)
 Coho salmon, Oncorhynchus kisutch(c)
 Sockeye salmon, Oncorhynchus nerka(c)
 Steelhead trout, Salmo gairdneri(c)
 Giant Columbia River limpet, Fisherola nuttalli nuttalli(c)
 Great Columbia River spire snail, Lithoglyphus columbiana(c)

-
- (a) Federal Threatened and Endangered Species List, 50 CRF 17, Federal Register, 10 May 1980.
 - (b) Washington State Working List of Threatened and Endangered Plants (Washington Natural Heritage Data System, 1980).
 - (c) Proposed as Candidates for Federal Listing by U.S. Fish and Wildlife Service.
 - (d) Washington State Department of Game, Wildlife Management Division, Non-Game Program Species of Special Concern (Washington Natural Heritage Data System, 1980).

7.2.8 Food Webs and Energy Transfer

A web of energy and nutrient transfers centering on cheatgrass is shown in Figure 7-4. Although inadvertently introduced to the region, this grass is

FIGURE 7-4. Food Web Centered on Cheatgrass (Arrows indicate direction of energy and mass transfer)

well adapted to the Hanford climate. Physiologically, it is geared for growth under the cool conditions concurrent with Hanford's wet season (Hinds 1974). Consequently, green cheatgrass appears (as seedlings) when few perennials are growing, making it desirable forage for a wide variety of animals, including mule deer, coyotes, and chukars. Mature cheatgrass seeds form important food sources for pocket mice and birds. The dead leaves and stems support a large number of microbiota, including mites, insects, nematodes, and fungi. Similar webs could be constructed around each plant species on the Site. Figures 7-5 and 7-6 illustrate two webs centered on the chukar and the grasshopper.

The edges of all food webs involve the same top carnivores--coyotes, eagles, owls, and so on--and all webs have a transfer into the microbiota, indicated by the transfer to fungi and bacteria. Microbiota are critical for continuous functioning of an ecosystem, but generally they are difficult to discuss with the same degree of understanding as the larger organisms, because they are numerous, small, transient, hard to identify, and difficult to observe in action.

FIGURE 7-5. Food Web Centered on Chukar Partridge (Arrows indicate direction of energy and mass transfer)

FIGURE 7-6. Food Web Centered on Grasshopper (Arrows indicate direction of energy and mass transfer)

8.0 DEMOGRAPHY AND LAND USE

8.1 Land Use on the Hanford Site

The present use of Hanford Site lands is indicated in Figure 8-1. All except one of the 100-Area plutonium production reactors, shown along the Columbia River in the northern part of the Hanford Site, have been deactivated. Fuel reprocessing and waste management activities are located at the 200 Areas, near the center of the Site. The Fast Flux Test Facility (FFTF) and supporting facilities are located in the 400 Area. Also shown is the site leased to the Washington Public Power Supply System for construction of power reactors.

The 300 Area contains a variety of diverse research and development facilities, as well as the fuel fabrication facility for the remaining operational production reactor (100 N). A commercial low level waste burial ground is located just south of the 200 Areas.

Detailed descriptions of the individual areas of the Site are found in the Appendices.

The 310-km² area in the southwestern corner of the Hanford Site, designated the Arid Land Ecology (ALE) Reserve, is set aside for long-term ecological studies. This large area is relatively undisturbed land of desert-steppe terrain ranging in elevation from about 100 m to 1100 m. Studies being conducted for DOE by Pacific Northwest Laboratory (PNL), include effects of rainfall, shade and solar radiation with corresponding variations in soil, plant growth and wildlife.

With the exception of the ALE Reserve and the Columbia River Islands Reserve, other areas of ecological study shown are only temporarily dedicated to that use.

Islands in the upper portion of the Columbia River adjacent to the Hanford Site are excluded from public use by the DOE and are used for wildlife refuge and DOE environmental research.

FIGURE 8-1. Land Use on the Hanford Site

Also to the north and east of the Columbia River is a 236-km² area managed by the Washington State Department of Game where hunting (shotgun and archery) fishing and other recreational activities are permitted during daylight hours. The area between the Columbia River and State Highway 24 is a game refuge managed by the U.S. Bureau of Sport Fisheries and Wildlife, and is closed to the public from the Venita bridge downstream to the 100-H Area.

The Site is served by a network of approximately 430 km of two- and four-lane primary roads, 280 km of secondary gravel roads and 360 km of gravel and unimproved roads.

The DOE-owned railroad system has a capacity of moving approximately 12,000 cars per year over 240 km of Site track. The system includes five main lines, 195 subsidiary lines, and two classification yards.

Barges with capacities up to 3000 tons can navigate the Columbia River from the Pacific Ocean to near the 300 Area.

8.2 Land Use Adjacent to the Hanford Site

Land use within a 50-km (30-mile) radius of the site (illustrated by Figure 8-2) includes residential, suburban, corporate city, agricultural, industrial and commercial, scenic, recreational and general use land areas. The region within 50 km of the site includes areas of Adams, Benton, Franklin, Grant, Walla Walla and Yakima Counties.

The predominant use of lands within the 50-km radius is agricultural, with the nearest farms located along the east bank of the Columbia River in Franklin County. Principal crops are alfalfa, wheat, potatoes, and fruits.

Industrial plants and laboratories located just south of the Hanford Site in north Richland include: Battelle, Pacific Northwest Laboratories, Exxon Nuclear, U.S. Testing Corporation, Washington Public Power Supply System, J. A. Jones shops and offices, and Western Sintering Corporation Plant.

8.3 Historic Sites and National Landmarks

Historic sites entered on the Washington State and/or National Registers of Historic Places or National Register of Historic Landmarks that are on or within approximately 80 km of the site are as follows:

FIGURE 8-2. Zoning Status of Area Surrounding the Hanford Site

Benton County

- Glade Creek Site--southeast of Prosser.
- Rattlesnake Springs Archaeological District--40 km northwest of Richland, DOE Arid Lands Ecology Reserve.
- Ryegrass Archaeological District--right bank of Columbia River, DOE Hanford Site.
- Telegraph Island Petroglyphs--Telegraph Island, Columbia River, vicinity of Patterson.
- Wooded Island Archaeological District--11 km north of Richland, Columbia River.
- Locke Island Archaeological District--Columbia River, approximately 45 km north-northwest of Richland.
- Snively Canyon Archaeological District--Rattlesnake Hills, approximately 40 km northwest of Richland.
- Hanford Island Archaeological District--Columbia River, north of Richland.
- Hanford North Archaeological District--Richland vicinity.
- Benton County Courthouse--Prosser.
- Columbia Park (Bateman) Island--Near Kennewick.
- Coyote Rapids Archaeological District--North of Richland.
- Gable Mountain Archaeological District--North of Richland.
- Wahluke Archaeological District--North of Richland.
- Charles Conway House--Kennewick.

Franklin County

- Tri-Cities Archaeological District--Pasco Vicinity.
- Ainsworth--8 km southeast of Pasco junction of Snake and Columbia Rivers.

- Windust Caves Archaeological District--Ice Harbor Reservoir, Snake River.
- Lyons Ferry Boat--8 km northwest of Starbuck, Palouse River near confluence of Palouse and Snake Rivers.
- Marmes Rock Shelter--confluence of Palouse and Snake Rivers.
- Franklin County Courthouse--Pasco.
- James Moore House--Pasco.
- Allen Rock Shelter--northeast of Pasco.
- Strawberry Island Village--Pasco Vicinity.
- Pasco Carnegie Library--Pasco.
- Burr Cave--North of Walker.
- Palouse Canyon Archaeological District--Lower Palouse River Vicinity.
- Savage Island Archaeological District--21 km north of Richland, Columbia River.

Walla Walla County

- Whitman Mission--11 km west of Walla Walla

Grant County

- Lind Coulee Archaeological Site--located within a 3.9-km radius 5 km northeast of Warden.
- Paris Archaeological Site--Located northwest of Richland.

While further archaeological sites are not of national significance, many less unique sites of archaeological significance are in the area. The Columbia River shoreline, from Vantage in the north downstream to Blalock Island, is rich with Indian artifacts. Many campsites and fishing grounds within the Site boundary were traditionally used as wintering areas from prehistoric times until the civilian residents of the Hanford Site were evacuated in 1943.

8.4 Regional Demography

The population distribution in the area surrounding the Hanford Site is nonuniform. Most of the adjacent area to the east, north and west is farm or range land with scattered farming communities. Figure 8-3 shows the general area surrounding the Site and the locations of towns and population centers within 80 km of the Hanford Meteorological Station (HMS).

The Tri-Cities of Kennewick, Pasco and Richland, which are located to the south and southeast of the Site, comprise the major population center of the area. The three cities and adjacent suburban areas were estimated to have a combined population of approximately 115,000 in 1980 (Sommer et al. 1981). Other population centers of note within the 80 km radius include the cities of Moses Lake, located NNE in the 64- to 80-km (40- to 50-mi) sector and Yakima at about the same distance to the west. The Yakima River Valley, stretching in an arc from the city of Yakima to the Tri-Cities, is a relatively densely populated agricultural area with a number of small towns.

Several population projections for the area surrounding the Hanford Site have been published (References: Yandon and Landstrom 1979, Yandon, Burlison and Rau 1980). The projections generally assume continued population growth based primarily on energy development and irrigated agriculture, with its allied supply and processing industries.

Population distributions centered on the principal research and development areas at Hanford are provided in the Appendices.

Employment. The employment of the labor force in the region surrounding the Hanford Site has been extensively studied in the course of analyzing the social and economic impacts of construction activities, both ongoing and proposed, at Hanford. Tables 8-1 and 8-2 present a summary of the 1981 employment in Benton and Franklin Counties.

FIGURE 8-3. Communities Around the Hanford Site

TABLE 8-1. Employment by Industry in Benton and Franklin Counties, 1981

	<u>1981 Average</u>
Total Manufacturing	9,190
Food and Kindred Products	2,170
Printing and Publishing	330
Chemicals and Allied Products	5,720
Primary and Fabricated Metal Products	340
Stone, Clay and Glass Products	160
Other Manufacturing	470
Mining and Miscellaneous	40
Construction	13,600
Transportation, Communications and Utilities	2,380
Wholesale and Retail Trade	11,530
Finance, Insurance, and Real Estate	1,590
Services	15,540
Government	<u>10,020</u>
Total Nonagricultural Employment	63,890

TABLE 8-2. Labor Force in Benton and Franklin Counties, 1981

Resident Civilian Labor Force	83,270
Employment	75,830
Unemployment	7,440
Percent of Labor Force Unemployed	8.9

From: State of Washington Employment Security Department
Labor Area Summary, March 1982.

9.0 RADIOLOGICAL CONDITION

The radiological condition of the Hanford Site and the surrounding area is studied extensively as part of a continuing program to assess the impact of Hanford operations on the environment. The environmental surveillance program, conducted by the Pacific Northwest Laboratory for the Department of Energy, is designed to evaluate all potentially significant pathways for the release of radioactivity, especially those in which environmental reconcentration of radionuclides is likely to occur and those that may result in direct exposure to the public. Summaries and interpretations of the environmental measurements are published annually. Data presented in this section are taken from the published reports for calendar years 1980 and 1981.

9.1 Sources of Radiation in the Environment

The radiation in the Hanford environment has several components:

- Naturally-occurring long-lived radionuclides, primarily potassium-40
- Uranium, thorium and their decay products
- Direct cosmic radiation
- Radionuclides formed by interaction of cosmic radiation and stable elements in the earth's atmosphere
- Fallout from atmospheric testing of nuclear weapons
- Radionuclides released to the environment from activities at Hanford.

The concentrations of natural and artificially produced radionuclides on and around the Site are measured in air, water, soil and vegetation (see Section 5.2.1 for groundwater monitoring results). Direct radiation is measured continuously at a number of locations with thermoluminescent dosimeters.

9.2 Air

Air samples are taken at a number of onsite and offsite locations (Figures 9-1 and 9-2). Depending on the sampling requirements for a specific location, air is drawn through a high-efficiency filter to collect particulate

FIGURE 9-1. Onsite Environmental Air Sampling Locations--1980

FIGURE 9-2. Offsite Environmental Air Sampling Locations--1980

radioactive material, a silica gel cartridge to collect atmospheric moisture for tritium analysis and/or through an activated charcoal filter to collect gaseous radioiodine. The particulate filters are collected biweekly and analyzed after a delay of 7 days to allow the decay of the short-lived radon and thoron decay products.

Table 9-1 gives a summary of the airborne radioactivity measured during 1980 at various locations on and around the Hanford Site.

A review of the maximum observed concentrations for 1980 revealed no substantial differences when compared to data from previous years. All radionuclide concentrations were negligible in comparison to applicable radionuclide Concentration Guides for uncontrolled areas. There is a tendency for airborne particulate gross beta concentrations to be slightly higher near the operating areas than at distant stations, although the differences are relatively small when compared to changes in concentrations brought about by world-wide fallout from atmospheric nuclear weapons tests and changes in atmospheric conditions (Sula, Blumer and Dirkes 1981).

For 1981, the gross beta emitter concentrations averaged 0.14 ± 0.01 pCi/m³ at the perimeter locations and 0.13 ± 0.02 pCi/m³ at the distant locations. Thus any contribution to the general airborne particulate radioactivity as a result of Hanford operations could not be distinguished from world-wide fallout and naturally-occurring radioactivity (Sula et al. 1982).

9.3 Water

Samples of Columbia River water are routinely collected upstream and downstream from the Hanford Site. The upstream sample location is at Priest Rapids Dam. The downstream locations are at the 300 Area water intake structure and at the Richland city water plant. Samples for radionuclide analysis are taken using two methods. The first passes a continuous flow through a filter and ion exchange resin, while the other is an automatic sampler that collects a small amount of water at regular intervals and produces a composite sample. The filters, resins and composite samples are collected periodically and analyzed for radionuclide content.

TABLE 9-1. Annual Average Airborne Radioactivity Concentrations During 1980--pCi/m³(a)

Sample Location (b)	Radionuclide Concentration, pCi/m ³ (c) (Concentration Guide, pCi/m ³ (d))									
	³ H (2 x 10 ⁵)	⁷ Be (4 x 10 ⁴)	⁹⁰ Sr (30)	⁹⁵ Zr- ⁹⁵ Nb (1000)	¹³¹ I (100)	¹³⁷ Cs (500)	¹⁴⁴ Ce- ¹⁴⁴ Pr (200)	Pu-Total (0.06)	Gross Beta (100)	Gross Alpha (0.03)
100-Area Composite			2.3 x 10 ⁻⁴ ± 1.0 x 10 ⁻⁴	3.8 x 10 ⁻⁴ ± 7.0 x 10 ⁻⁵		(e)	(e)	9.3 x 10 ⁻⁶ ± 3.0 x 10 ⁻⁵	4 x 10 ⁻² ± 6 x 10 ⁻²	
200-E Area (7)	0.81 ± 1.4				2 x 10 ⁻³ ± 1 x 10 ⁻²					1 x 10 ⁻³ ± 1 x 10 ⁻³
200-E Area Composite			5 x 10 ⁻⁴ ± 6 x 10 ⁻⁴	2 x 10 ⁻³ ± 8 x 10 ⁻³		3 x 10 ⁻³ ± 7 x 10 ⁻³	(e)	2 x 10 ⁻⁵ ± 3 x 10 ⁻⁵		
200-W Area (9)									4 x 10 ⁻² ± 5 x 10 ⁻²	
200-W Area Composite							(e)	2 x 10 ⁻⁵ ± 2 x 10 ⁻⁵		
300-Area Composite			1 x 10 ⁻⁴ ± 2 x 10 ⁻⁴	2.5 x 10 ⁻³ ± 1.6 x 10 ⁻³		(e)	(e)	1 x 10 ⁻⁵ ± 3 x 10 ⁻⁵		
400-Area Composite			2 x 10 ⁻⁴ ± 3 x 10 ⁻⁴	1 x 10 ⁻³ ± 8 x 10 ⁻³		(e)	(e)	1 x 10 ⁻⁶ ± 2 x 10 ⁻⁵		
Perimeter	0.70 ± 1.5	0.03 ± 0.05	1.9 x 10 ⁻⁴ ± 2.5 x 10 ⁻⁴	3.3 x 10 ⁻⁴ ± 1 x 10 ⁻²	2 x 10 ⁻³ ± 2 x 10 ⁻²	(e)	(e)	7.2 x 10 ⁻⁶ ± 1.5 x 10 ⁻⁵	4 x 10 ⁻² ± 6 x 10 ⁻²	1 x 10 ⁻³ ± 1 x 10 ⁻³
Downwind Perimeter	0.77 ± 1.6	0.02 ± 0.03	2.0 x 10 ⁻⁴ ± 2.4 x 10 ⁻⁴	1 x 10 ⁻³ ± 1 x 10 ⁻²	2 x 10 ⁻³ ± 2 x 10 ⁻²	(e)	(e)	7.2 x 10 ⁻⁶ ± 1.8 x 10 ⁻⁵		
Distant		0.009 ± 0.12	2.5 x 10 ⁻⁴ ± 4.4 x 10 ⁻⁴	1 x 10 ⁻³ ± 2 x 10 ⁻²	2 x 10 ⁻³ ± 1 x 10 ⁻²	2.4 x 10 ⁻⁴ ± 5.4 x 10 ⁻³	(e)	3.1 x 10 ⁻⁵ ± 1.2 x 10 ⁻⁴	4 x 10 ⁻² ± 7 x 10 ⁻²	

(a) Compiled from data reported in Environmental Surveillance at Hanford for CY-1980, PNL-3728 (Sula and Blumer 1981) and Environmental Status of the Hanford Site for CY-1980, PNL-3729 (Sula, Blumer and Dirkes 1981).

(b) Sample Locations are shown in Figures 9.1 and 9.2. Numbers in parentheses identify the onsite sample location shown in Figure 9.1. Distant stations include Moses Lake, Washtucna, Walla Walla, McNary Dam, and Sunnyside. Perimeter stations are Wahluke #2, Berg Ranch, Othello, Vernita, Wahluke Watermaster, Connel, Cooke Bros., Yakima Barricade, Rattlesnake Springs, ALE, Benton City, Prosser Barricade, Fir Road, Byers Landing, Pettett, Richland, Pasco, 1100 Area, and RRC CP #64. The Downwind Perimeter stations are a subset of the Perimeter group and include: Fir Road, Prosser Barricade, Byers Landing, Pasco, Richland, Pettett, 1100 Area, and RRC CP #64.

(c) Average concentrations include an estimate of the uncertainty of the average at the 95 percent confidence level.

(d) As given in DOE Order 5480.1, Chapter XI for uncontrolled areas.

(e) These averages were reported as negative numbers, implying that the concentration of the radionuclide in the medium is essentially zero. For many sample analyses, it is possible to obtain net values that are less than zero when an instrument or chemical background must be subtracted. Although negative values do not represent a physical reality, they must be included along with the other values when computing the correct average of all values and can result in the average value being a negative number.

Table 9.2 gives the radionuclide concentrations upstream and downstream from the Hanford Site. Only I-129 appeared to be at a higher concentration downstream of the Hanford Site than was observed upstream, indicating a very small possible contribution from Hanford operations (Sula and Blumer 1981). This contribution is attributed to seepage into the river of groundwater from the unconfined aquifer into which process cooling water and low-level liquid wastes have been discharged at the 200 Areas (see section 5.2.1). Since tritium is also present in the unconfined aquifer, there is also some seepage of tritium to the river. However, any contribution to the river concentration was too small to be distinguished from background fluctuations (Sula et al. 1982). As shown in Table 9.2, the downstream concentrations are well below the applicable DOE Concentration Guide for all radionuclides.

Other surface water bodies on the Hanford Site are routinely sampled and analyzed for total alpha and total beta emitter activity and for specific gamma emitters. Two of the ponds, Gable Pond and B-Pond near the 200 East Area, were built in the mid 1950's for disposal of process cooling water and chemical wastes containing low levels of radioactive contamination. The FFTF pond, built in 1978, is a sewage disposal and treatment lagoon and does not receive any radioactive wastes. West Lake is a natural lake and does not receive liquid wastes from site facilities. The four ponds are located outside operating area exclusion fences and are accessible to migrating waterfowl and other animals (Sula, Blumer and Dirkes 1981). Table 9.3 gives concentrations of various radionuclides in the waters of West Lake, Gable Pond, B-Pond and the FFTF pond.

9.4 Soil and Vegetation

Surface soil and vegetation samples are collected annually from the locations shown in Figure 9.3 to establish background concentrations of naturally occurring and fallout radioactivity, and to assess any buildup of radioactivity from site operations. The vegetation samples consist of a representative collection of new growth from perennial vegetation growing in the vicinity of the soil sampling area. Both sets of samples are isotopically analyzed using gamma-ray and alpha spectroscopy. Tables 9.4 and 9.5 give the concentrations of radionuclides in the soil and vegetation samples.

TABLE 9.2. Radionuclide Concentrations in the Columbia River(a)

Radionuclide	Concentration Guide (pCi/liter)	Concentration, pCi/liter ^(b)			
		Upstream		Downstream	
		Maximum	Annual Average	Maximum	Annual Average
Naturally Occurring					
²²⁶ Ra	30	0.28 ± 0.09	0.10 ± 0.25	0.05 ± 0.02	0.04 ± 0.03
²²³ Ra	30	0.17 ± 0.06	0.13 ± 0.10	0.15 ± 0.07	0.10 ± 0.11
U-Nat	2 x 10 ⁴	0.59 ± 0.21	0.40 ± 0.25	0.80 ± 0.28	0.54 ± 0.34
Artificially Produced					
³ H ^(b)	3 x 10 ⁶	420 ± 150	230 ± 310	490 ± 290	265 ± 274
⁵¹ Cr	2 x 10 ⁶	0.29 ± 0.69	0.08 ± 0.61	0.28 ± 0.42	0.09 ± 0.86
⁵⁴ Mn	10 ⁵	0.03 ± 0.09	0.07 ± 0.06	0.03 ± 0.04	0.008 ± 0.07
⁵⁹ Fe	5 x 10 ⁶	0.09 ± 0.20	0.02 ± 0.27	0.07 ± 0.10	0.03 ± 0.19
⁶⁰ Co	3 x 10 ⁴	0.05 ± 0.01	0.01 ± 0.05	0.12 ± 0.02	0.03 ± 0.06
⁹⁰ Sr ^(b)	3 x 10 ²	0.32 ± 0.14	0.24 ± 0.23	0.22 ± 0.14	0.20 ± 0.16
⁹⁵ Nb	10 ⁵	0.07 ± 0.13	0.01 ± 0.08	0.03 ± 0.01	0.01 ± 0.08
⁹⁵ Zr	6 x 10 ⁴	0.05 ± 0.14	0.02 ± 0.22	0.04 ± 0.05	0.02 ± 0.19
¹²⁵ Sb	10 ⁵	0.08 ± 0.08	0.02 ± 0.32	0.07 ± 0.15	0.03 ± 0.22
¹²⁹ I	60	7.4 x 10 ⁻⁶ ± 2.1 x 10 ⁻⁶	5.9 x 10 ⁻⁶ ± 3.2 x 10 ⁻⁶	9.4 x 10 ⁻⁵ ± 3.2 x 10 ⁻⁵	5.4 x 10 ⁻⁵ ± 5.8 x 10 ⁻⁵
¹³¹ I	3 x 10 ²	0.04 ± 0.78	0.02 ± 0.31	0.13 ± 0.14	0.05 ± 0.13
¹³⁷ Cs	2 x 10 ⁴	0.09 ± 0.01	0.01 ± 0.05	0.19 ± 0.04	0.02 ± 0.10
¹⁴⁰ Ba	2 x 10 ⁴	0.12 ± 1.1	0.05 ± 0.63	0.16 ± 1.2	0.07 ± 0.95
¹⁴⁰ La	2 x 10 ⁵	0.07 ± 0.04	0.02 ± 0.11	0.07 ± 0.07	0.03 ± 0.13
²³⁸ Pu	5 x 10 ³	(c)	(c)	(c)	(c)
²³⁹⁻²⁴⁰ Pu	5 x 10 ³	5.4 x 10 ⁻⁴ ± 1.0 x 10 ⁻⁴	3.3 x 10 ⁻⁴ ± 3.7 x 10 ⁻⁴	4.8 x 10 ⁻⁴ ± 6.2 x 10 ⁻⁵	3.2 x 10 ⁻⁴ ± 3.2 x 10 ⁻⁴

(a) Compiled from data for 1980 reported in Sula and Blumer (1981), Tables 3 and 4.

(b) Maximum concentrations include the 2σ counting error. Average concentrations include an estimate of uncertainty at the 95 percent confidence level.

(c) State drinking water standard for ³H and ⁹⁰Sr are 20,000 pCi/l and 8 pCi/l, respectively.

(a) All results reported as less than the detection level for ²³⁸Pu, which was about 3 x 10⁻⁵ pCi/l.

TABLE 9.3. Radionuclide Concentrations in Onsite Ponds During 1980

Sample Location	Date	Concentration pCi/liter ^(a)					Total Alpha Activity	Total Beta Activity
		⁵¹ Cr ^(b)	⁶⁵ Zn	⁹⁰ Sr ^(c)	¹³⁷ Cs ^(d)	²² Na		
West Lake	2/12	35 ± 66	(e)	0.09 ± 1.4	23 ± 7.5	NA	0.23 ± 1.8	13 ± 5.4
	5/6	29 ± 45	2.4 ± 11	2.0 ± 0.27	0.84 ± 5.4	NA	211 ± 14.3	368 ± 45
	8/12	31 ± 26	14 ± 6.3	6.4 ± 0.45	10 ± 3.3	NA	141 ± 8.1	797 ± 30
	11/18	39 ± 110	7.0 ± 16	3.1 ± 0.27	0.83 ± 7.2	NA	104 ± 9.9	502 ± 53
Gable Pond	2/12	52 ± 130	2.7 ± 27	0.41 ± 0.18	110 ± 16	NA	0.49 ± 0.41	24 ± 56
	5/6	4.2 ± 9.8	0.04 ± 2.5	0.60 ± 0.17	61 ± 5.3	NA	0.56 ± 0.28	63 ± 6.5
	8/12	8.9 ± 6.4	(e)	0.52 ± 0.14	47 ± 1.1	NA	0.85 ± 0.33	188 ± 8.8
	11/18	4.0 ± 7.0	(e)	0.37 ± 0.14	23 ± 1.0	NA	0.37 ± 0.37	23 ± 5.6
B Pond	2/12	(e)	(e)	1.7 ± 0.45	12 ± 2.5	NA	0.09 ± 0.32	99 ± 7.3
	5/6	(e)	(e)	6.6 ± 0.17	7.5 ± 0.98	NA	0.93 ± 0.33	23 ± 5.8
	8/12	7.5 ± 6.2	1.1 ± 1.5	40 ± 1.6	32 ± 1.1	NA	0.93 ± 0.37	81 ± 7.1
	9/23	(e)	(e)	19 ± 2.0	7.0 ± 0.79	NA	1.3 ± 0.38	36 ± 5.7
	11/18	5.6 ± 6.2	0.88 ± 1.5	2.6 ± 0.14	30 ± 1.1	NA	0.37 ± 0.41	37 ± 5.8
	12/17	(e)	0.23 ± 4.1	2.6 ± 0.27	107 ± 9.4	NA	0.28 ± 0.29	111 ± 7.3
FFTF Pond	5/6	(e)	1.2 ± 3.7	NA	1.2 ± 1.9	1.4 ± 4.8	0.49 ± 0.41	45 ± 6.1
	8/12	(e)	2.8 ± 3.0	NA	0.38 ± 1.6	0.52 ± 4.7	0.56 ± 0.29	21 ± 4.6
	11/18	13 ± 14	2.7 ± 3.0	NA	(e)	(e)	0.09 ± 0.35	19 ± 3.7

(a) Individual results show the 2σ counting error. No entry indicates the sample was not analyzed for the particular constituent.

(b) Chromium-51, ⁶⁵Zn, and ¹³⁷Cs, based on analysis by gamma-spectrometry. No other artificially produced radionuclides were detected.

(c) Concentration Guide for uncontrolled areas is 300 pCi/l (DOE 5480.1, Chapter XI).

(d) Concentration Guide for uncontrolled areas is 20,000 pCi/l (DOE 5480.1, Chapter XI).

(e) These values were reported as negative numbers, implying that the concentration of the radionuclide in the medium is essentially zero.

NA Radionuclide not analyzed.

After Sula and Blumer 1981. Table 8.

FIGURE 9.3. Soil and Vegetation Sampling Locations

TABLE 9.4. Radionuclide Concentrations in Soil Samples - 1980(a)

Sample Location	Map(b) No.	Concentration, pCi/g (10^{-6} μ Ci/g), Dry weight ^(b)													Total U	58Co	60Co
		40K	224Ra	226Ra	90Sr	95ZrNb	134Cs	137Cs	144Ce	238Pu	239-240Pu						
Riverview	1	10 $\pm$ 1.4	0.92 $\pm$ 0.07	0.57 $\pm$ 0.08	0.001 $\pm$ 0.007	0.05 $\pm$ 0.04	0.03 $\pm$ 0.02	1.1 $\pm$ 0.09	0.37 $\pm$ 0.11	0.0005 $\pm$ 0.0006	0.02 $\pm$ 0.002						
Byers Landing	2	14 $\pm$ 1.3	1.2 $\pm$ 0.08	0.69 $\pm$ 0.09	0.003 $\pm$ 0.007	0.07 $\pm$ 0.04	0.01 $\pm$ 0.02	0.34 $\pm$ 0.05	0.33 $\pm$ 0.11								
Sage Moor	3	17 $\pm$ 1.4	1.2 $\pm$ 0.09	0.75 $\pm$ 0.10	0.02 $\pm$ 0.007	0.05 $\pm$ 0.04	0.004 $\pm$ 0.02	0.55 $\pm$ 0.06	0.36 $\pm$ 0.12	0.007 $\pm$ 0.002	0.008 $\pm$ 0.002						
Taylor Flats #1	4	20 $\pm$ 1.8	1.3 $\pm$ 0.10	1.0 $\pm$ 0.13	0.007 $\pm$ 0.007	(d)	0.04 $\pm$ 0.03	0.09 $\pm$ 0.04	0.22 $\pm$ 0.15	0.007 $\pm$ 0.002	0.003 $\pm$ 0.001	1.4 $\pm$ 0.50					
Taylor Flats #2	5	18 $\pm$ 1.7	0.91 $\pm$ 0.09	0.83 $\pm$ 0.12	0.25 $\pm$ 0.01	0.05 $\pm$ 0.05	(d)	1.4 $\pm$ 0.11	0.39 $\pm$ 0.15	0.005 $\pm$ 0.002	0.03 $\pm$ 0.004	0.61 $\pm$ 0.21					
W. End Fir Road	6	14 $\pm$ 1.3	0.96 $\pm$ 0.08	0.64 $\pm$ 0.09	0.17 $\pm$ 0.007	0.005 $\pm$ 0.04	0.02 $\pm$ 0.02	0.19 $\pm$ 0.04	0.28 $\pm$ 0.12	0.0001 $\pm$ 0.0007	0.008 $\pm$ 0.002	0.46 $\pm$ 0.16					
Ringold	7	11 $\pm$ 1.2	0.79 $\pm$ 0.07	0.45 $\pm$ 0.08	0.07 $\pm$ 0.007	(d)	0.03 $\pm$ 0.03	0.68 $\pm$ 0.07	0.13 $\pm$ 0.10	0.002 $\pm$ 0.001	0.02 $\pm$ 0.003	0.34 $\pm$ 0.12					
Berg Ranch	8	13 $\pm$ 1.3	1.1 $\pm$ 0.08	0.73 $\pm$ 0.10	0.14 $\pm$ 0.007	0.02 $\pm$ 0.04	0.02 $\pm$ 0.02	0.58 $\pm$ 0.06	0.47 $\pm$ 0.12	0.001 $\pm$ 0.0009	0.009 $\pm$ 0.002	0.23 $\pm$ 0.08					
Wahluk #2	9	13 $\pm$ 1.2	0.97 $\pm$ 0.08	0.68 $\pm$ 0.09	0.31 $\pm$ 0.01	0.03 $\pm$ 0.04	0.05 $\pm$ 0.02	0.35 $\pm$ 0.05	0.39 $\pm$ 0.12	0.0007 $\pm$ 0.0008	0.006 $\pm$ 0.002	0.34 $\pm$ 0.12					
Yakima Barricade	10	14 $\pm$ 1.3	1.1 $\pm$ 0.08	0.65 $\pm$ 0.09	0.02 $\pm$ 0.007	0.03 $\pm$ 0.04	0.06 $\pm$ 0.03	0.77 $\pm$ 0.07	0.39 $\pm$ 0.12	0.004 $\pm$ 0.001	0.02 $\pm$ 0.003	0.29 $\pm$ 0.10					
ALE	11	14 $\pm$ 1.5	1.2 $\pm$ 0.10	0.86 $\pm$ 0.12	0.0 $\pm$ 0.007	(d)	0.03 $\pm$ 0.03	1.2 $\pm$ 0.10	0.53 $\pm$ 0.17	0.003 $\pm$ 0.001	0.02 $\pm$ 0.003	0.36 $\pm$ 0.13					
Benton City	12	13 $\pm$ 1.3	1.3 $\pm$ 0.09	0.90 $\pm$ 0.11	0.29 $\pm$ 0.005	0.04 $\pm$ 0.04	0.02 $\pm$ 0.02	1.0 $\pm$ 0.09	0.38 $\pm$ 0.12	0.002 $\pm$ 0.001	0.02 $\pm$ 0.003	0.70 $\pm$ 0.24					
Sunnyside	13	10 $\pm$ 1.4	0.78 $\pm$ 0.09	0.50 $\pm$ 0.10	0.19 $\pm$ 0.02	0.02 $\pm$ 0.06	0.03 $\pm$ 0.03	0.65 $\pm$ 0.08	0.44 $\pm$ 0.17	0.002 $\pm$ 0.001	0.01 $\pm$ 0.003	0.41 $\pm$ 0.14					
Prosser Barricade	14	15 $\pm$ 1.3	0.80 $\pm$ 0.07	0.58 $\pm$ 0.09	0.003 $\pm$ 0.007	0.05 $\pm$ 0.04	0.01 $\pm$ 0.02	0.95 $\pm$ 0.08	0.36 $\pm$ 0.11	0.16 $\pm$ 0.06							
SE of FTF	15				0.9 $\pm$ 0.007	0.02 $\pm$ 0.04	0.04 $\pm$ 0.02	0.40 $\pm$ 0.05	0.40 $\pm$ 0.11	0.002 $\pm$ 0.001	0.007 $\pm$ 0.002	0.03 $\pm$ 0.03					
NE of FTF	16				0.04 $\pm$ 0.01	0.01 $\pm$ 0.04	(d)	0.22 $\pm$ 0.04	0.28 $\pm$ 0.11	0.0003 $\pm$ 0.0009	0.004 $\pm$ 0.002	0.22 $\pm$ 0.08					
Wye Barricade	17				0.23 $\pm$ 0.007	0.06 $\pm$ 0.05	0.02 $\pm$ 0.03	1.1 $\pm$ 0.10	0.28 $\pm$ 0.13	0.0009 $\pm$ 0.0009	0.01 $\pm$ 0.002	0.26 $\pm$ 0.09					
Hanford Township	18				0.23 $\pm$ 0.007	(d)	(d)	1.7 $\pm$ 0.12	0.31 $\pm$ 0.15	0.006 $\pm$ 0.001	0.04 $\pm$ 0.003	0.28 $\pm$ 0.10					
200 ENC	19				0.70 $\pm$ 0.06	0.07 $\pm$ 0.05	0.03 $\pm$ 0.03	28 $\pm$ 0.44	0.43 $\pm$ 0.13	0.002 $\pm$ 0.00006	0.03 $\pm$ 0.002	0.27 $\pm$ 0.10					
200 East Hill	20				0.29 $\pm$ 0.02	(d)	0.003 $\pm$ 0.02	1.2 $\pm$ 0.9	0.34 $\pm$ 0.11	0.29 $\pm$ 0.10							
East of 200 W Area	21				0.83 $\pm$ 0.01	0.01 $\pm$ 0.04	0.009 $\pm$ 0.02	4.8 $\pm$ 0.18	0.34 $\pm$ 0.12	0.01 $\pm$ 0.002	0.63 $\pm$ 0.02	0.62 $\pm$ 0.22					
											(d)	0.007 $\pm$ 0.02					

(a) Compiled from data reported in Environmental Surveillance at Hanford for CY-1980 (Sula and Blumer 1981) and Environmental Status of the Hanford Site for CY-1980 (Sula, Blumer and Dirkes 1981).

(b) Figure 9.3 shows location of sampling sites by number.

(c) Results include the 28 counting error.

(d) These values were reported as negative numbers, implying that the concentration of the radionuclide in the sample is essentially zero.

TABLE 9.5. Radionuclides in Vegetation - 1980(a)

Sample Locations	Map (b) No.	Concentration, pCi/g (10^{-6} μ Ci/g), Dry weight (b)									
		Naturally Occurring	Artificially Produced			137Cs			238Pu	239-240Pu	Total U
		40K	60Co	90Sr	95ZrNb	137Cs	144Ce	238Pu	239-240Pu	Total U	
Riverview	1	8.0 $\pm$ 3.4		0.04 $\pm$ 0.01	(d)	0.02 $\pm$ 0.12	(d)			0.008 $\pm$ 0.01	
Byers Landing	2	30 $\pm$ 6.6		0.06 $\pm$ 0.04	0.08 $\pm$ 0.31	0.18 $\pm$ 0.20	(d)			0.03 $\pm$ 0.02	
Sagemoor	3	17 $\pm$ 3.4		0.05 $\pm$ 0.01	0.08 $\pm$ 0.16	(d)	(d)			0.003 $\pm$ 0.01	
Taylor Flats #1	4	20 $\pm$ 5.2		0.04 $\pm$ 0.01	0.02 $\pm$ 0.26	0.01 $\pm$ 0.15	(d)	0.001 $\pm$ 0.001	0.04 $\pm$ 0.004	0.07 $\pm$ 0.03	
Taylor Flats #2	5	14 $\pm$ 4.3		0.08 $\pm$ 0.05	(d)	0.27 $\pm$ 0.17	0.80 $\pm$ 0.73			0.11 $\pm$ 0.04	
W. End Fir Road	6	17 $\pm$ 5.3			0.04 $\pm$ 0.28	(d)	(d)	0.02 $\pm$ 0.004	0.09 $\pm$ 0.009	0.003 $\pm$ 0.01	
Ringold	7	14 $\pm$ 4.6		0.04 $\pm$ 0.01	0.04 $\pm$ 0.25	0.21 $\pm$ 0.17	0.02 $\pm$ 0.77			0.02 $\pm$ 0.01	
Berg Ranch	8	15 $\pm$ 4.6		0.05 $\pm$ 0.01	0.14 $\pm$ 0.26	0.01 $\pm$ 0.14	0.49 $\pm$ 0.80			0.008 $\pm$ 0.01	
Wahluke #2	9	14 $\pm$ 3.9		0.02 $\pm$ 0.01	0.003 $\pm$ 0.41	(d)	(d)	0.001 $\pm$ 0.004	0.03 $\pm$ 0.008	0.002 $\pm$ 0.01	
Yakima Barricade	10	19 $\pm$ 4.9		0.07 $\pm$ 0.01	(d)	0.18 $\pm$ 0.17	0.15 $\pm$ 0.74			0.01 $\pm$ 0.01	
ALE	11	11 $\pm$ 3.4		0.09 $\pm$ 0.01	(d)	0.03 $\pm$ 0.11	0.16 $\pm$ 0.54	0.02 $\pm$ 0.004	0.15 $\pm$ 0.01	0.07 $\pm$ 0.03	
Benton City	12	17 $\pm$ 5.8		0.08 $\pm$ 0.01	(d)	(d)	(d)	0.01 $\pm$ 0.004	0.10 $\pm$ 0.01	0.03 $\pm$ 0.02	
Sunnyside	13	15 $\pm$ 4.5		0.05 $\pm$ 0.01	0.05 $\pm$ 0.25	0.05 $\pm$ 0.14	(d)			0.02 $\pm$ 0.01	
Prosser Barricade	14	19 $\pm$ 4.2		0.03 $\pm$ 0.01	0.12 $\pm$ 0.21	0.04 $\pm$ 0.11	(d)			0.01 $\pm$ 0.01	
SE of FFTF	15		(d)	0.19 $\pm$ 0.05	0.11 $\pm$ 0.39	0.06 $\pm$ 0.23	(d)			0.01 $\pm$ 0.01	
NE of FFTF	16		(d)	0.03 $\pm$ 0.01	0.0006 $\pm$ 0.20	0.11 $\pm$ 0.13	0.43 $\pm$ 0.60			0.01 $\pm$ 0.01	
Wye Barricade	17		0.02 $\pm$ 0.16	0.03 $\pm$ 0.01	(d)	0.02 $\pm$ 0.15	0.21 $\pm$ 0.80	0.002 $\pm$ 0.0008	0.002 $\pm$ 0.0007	0.02 $\pm$ 0.01	
Hanford Townsite	18		0.05 $\pm$ 0.12	0.12 $\pm$ 0.01	0.003 $\pm$ 0.18	0.32 $\pm$ 0.15	(d)			0.04 $\pm$ 0.20	
299 ENC	19		0.02 $\pm$ 0.17	0.07 $\pm$ 0.01	(d)	0.57 $\pm$ 0.23	0.29 $\pm$ 0.79			0.01 $\pm$ 0.01	
200 East Hill	20		(d)	0.05 $\pm$ 0.01	0.07 $\pm$ 0.20	0.08 $\pm$ 0.12	(d)	0.007 $\pm$ 0.003	0.06 $\pm$ 0.008	0.005 $\pm$ 0.01	
East of 200 West Area	21		0.17 $\pm$ 0.20	0.05 $\pm$ 0.01	(d)	(d)	(d)			0.004 $\pm$ 0.01	

(a) Compiled from data reported in Environmental Surveillance at Hanford for CY-1980 (Sula and Blumer 1981) and Environmental Status of the Hanford Site for CY-1980 (Sula, Blumer and Dirkes 1981).
 (b) Figure 9.3 shows location of sampling sites by number.
 (c) Results include the 26 counting error.
 (d) These values were reported as negative numbers, implying that the concentration of the radionuclide in the sample is essentially zero.

Soil and vegetation radionuclide concentrations observed in 1980 were generally similar to those observed in previous years for both offsite and onsite locations (Sula, Blumer and Dirkes 1981; Sula and Blumer 1981).

9.5 External Radiation

Thermoluminescent dosimeters (TLDs) are used to measure the external dose at several locations on and around the Hanford Site.

The results of the offsite dose measurements made in 1980 are given in Table 9.6. Onsite measurement results are given in Table 9.7 for locations shown in Figure 9.4. These readings are generally consistent with previous years' observations. The 200 Area dosimeters show dose rates above background, with the higher readings primarily due to direct radiation from nearby waste management facilities (Sula, Blumer and Dirkes 1981).

Sula and Blumer (1981) estimated the total annual background dose to members of the general public in the vicinity of the Hanford Site to be about 100 mrem per year. This total includes the average of 69 mrem per year measured by the environmental dosimeters (Table 9.6), plus 6 mrem per year from the fast neutron component of cosmic radiation that the dosimeters do not register, and 25 mrem per year from naturally occurring radionuclides within the human body (primarily potassium-40).

In 1979 a radiological survey of the shore and islands along the Hanford reach of the Columbia River was performed to evaluate the magnitude and distribution of the radioactive contamination present. Low-level contamination was observed over much of the study area, producing an average exposure rate (at 1 m above the surface) of 0.011 mR/hr, about 0.004 mR/hr above the background exposure rate observed upstream of the Hanford Site. Exposure rates in the range of 0.025 to 0.045 mR/hr were observed in ninety-two areas ranging in size from a few square meters up to several thousand square meters. Analysis of soil from these areas showed a mixture of cobalt-60, cesium-137 and europium-152 in approximately equal proportions. Discrete particles of contamination containing 2 to 25 μ Ci of cobalt-60 were also observed along the river, usually in flat, rocky places with little or no vegetation (Sula 1980).

TABLE 9.6. Environmental Radiation Dose Measurements in the Hanford Vicinity

Location (a)	No. of Samples	Dose Rate (mrem/yr)		
		Maximum	Minimum	Average
<u>Perimeter Stations</u>				
Rattlesnake Springs	10	84	55	73 ± 17
ALE	10	84	69	77 ± 11
Benton City	10	73	55	62 ± 14
Yakima Barricade	10	88	69	78 ± 10
Vernita Bridge	10	77	69	73 ± 6
wahluke 2	10	84	73	77 ± 7
Othello	9	69	58	60 ± 7
Connell	11	88	58	70 ± 18
Berg Ranch	10	84	73	76 ± 6
wahluke watermaster	10	80	69	74 ± 6
Cooke Bros.	10	77	62	68 ± 8
Richland	12	77	58	65 ± 10
Pasco	10	80	58	64 ± 14
Byers Landing	11	80	66	71 ± 10
Sagemoor	10	77	66	73 ± 6
Pettett Farm	10	66	47	58 ± 10
Fir Road	10	73	66	68 ± 5
RRC CP 64	11	73	62	67 ± 9
1100 Area	11	91	55	61 ± 21
Prosser Barricade	10	84	69	<u>74 ± 10</u>
				69 ± 16
<u>Distant Stations</u>				
walla walla	11	102	58	65 ± 25
McNary	11	91	66	73 ± 14
Moses Lake	10	77	58	67 ± 13
washtucna	7	80	66	74 ± 11
Sunnyside	10	73	62	<u>66 ± 7</u>
				69 ± 17

(a) Locations are shown in Figure 9.2.
Data From: Sula and Blumer 1981. Table 14.

TABLE 9.7. Onsite External Penetrating Dose Measurements - 1980

Dosimeter Location		Map No. (a)	No. of Measurements	Dose Rate, mrem/y		
				Maximum	Minimum	Average
Operating Areas						
100 Area	100 K	1	10	77	62	68 ± 9
	Below 100 K Retention Basin ^(b)	2	9	405	329	377 ± 49
	100 N	3	11	106	69	86 ± 21
	100 D	4	10	88	69	75 ± 11
	100 Area Fire Station	5	11	77	69	72 ± 6
200 East Area	200 ENC	6	10	164	139	151 ± 16
	200 EEC	7	10	95	80	87 ± 10
	200 ESE	8	10	84	69	77 ± 10
	200 EwC	9	11	77	66	72 ± 6
200 west Area	200 WNE	10	11	77	66	71 ± 8
	200 WEC	11	10	73	66	70 ± 6
	Redox	12	11	88	77	80 ± 7
	200 WwC	13	10	110	95	100 ± 11
300 Area	300 Pond	14	10	212 ^(c)	73	145 ± 119
	3614-A Bldg.	15	10	84	69	72 ± 9
	300 South Gate	16	11	80	66	71 ± 9
	300 SW Gate	17	11	88	66	73 ± 13
	3705 Bldg.	18	10	88	62	72 ± 14
400 Area	400 E	19	11	80	69	72 ± 8
	400 W	20	10	69	55	64 ± 9
	400 S	21	11	73	37	64 ± 19
	400 N	22	11	73	40	66 ± 19
	FFTF North	23	9	80	69	74 ± 8
	FFTF Southeast	24	9	77	69	71 ± 6
Inner East Sector	Hanford	25	9	77	58	70 ± 12
	Wye Barricade	26	9	77	66	71 ± 8

(a) Figure 9.4 shows location of dosimeters by number.

(b) Directly above a known subsurface contamination deposit.

(c) Monthly dose increased in May 1980 due to temporary storage of a radioactive steam generator near the dosimeter location.

Data From: Sula, Blumer and Dirkes 1981. Table 14.

FIGURE 9.4. Onsite External Penetrating Dose Rate Measurement Locations - 1980

Table 9.8 gives the results of shoreline measurements made during 1980 by placing TLDs at some of the areas identified earlier (Figure 9.5)) as having higher dose rates.

Environmental dosimeters are submerged in the Columbia River at two locations (Coyote Rapids and the Richland pump house) to measure the dose potentially received by swimmers in the Columbia River. The average of the dose rates measured in the river is about 0.004 mrem/hr, or about half the background rate on land (Sula and Blumer 1981).

TABLE 9.8. Environmental Radiation Dose Measurements Along the Columbia River Shoreline and Islands

Dosimeter Location	Map No. (a)	No. of Samples (b)	Dose Rate, mrem/y		
			Maximum	Minimum	Average (c)
Upriver 100 B Area	1	9*	0.009	0.006	0.008 ± 0.002
Below 100 B Retention Basin	2	9*	0.025	0.016	0.022 ± 0.005
Above 100 K Boat Ramp	3	11	0.008	0.007	0.008 ± 0.001
100 N Trench Springs	4	11	0.063	0.019	0.030 ± 0.024
Downriver 100 D	5	9*	0.015	0.012	0.013 ± 0.002
Downriver Opposite 100 D	6	11	0.010	0.006	0.008 ± 0.002
Lower End Locke Island	7	9	0.010	0.008	0.009 ± 0.001
White Bluffs Slough	8	9*	0.019	0.014	0.017 ± 0.003
White Bluffs Ferry Landing	9	10	0.009	0.008	0.008 ± 0.0008
Below 100 F	10	11	0.010	0.006	0.008 ± 0.002
Hanford Powerline Crossing	11	11	0.010	0.008	0.009 ± 0.001
Hanford Ferry Landing	12	9	0.009	0.007	0.008 ± 0.001
Hanford Railroad Track	13	11	0.015	0.011	0.013 ± 0.002
Savage Island Slough	14	10*	0.013	0.010	0.012 ± 0.002
Ringold Island	15	11	0.010	0.007	0.008 ± 0.002
Powerline Crossing	16	10	0.012	0.009	0.010 ± 0.002
North End wooded Island	17	9*	0.009	0.005	0.007 ± 0.003
South End wooded Island	18	11	0.011	0.008	0.009 ± 0.002
Island River Mile 344	19	8*	0.016	0.007	0.014 ± 0.007
Island River Mile 333	20	8*	0.011	0.003	0.009 ± 0.005

(a) Figure 9.5 shows locations of dosimeter by number.

(b) Dose measurements at locations with * were initiated in March 1980.

(c) Average $\pm 2\sigma$ uncertainty shown for each location.

Data From: Sula and Blumer 1981. Table 16.

FIGURE 9.5. Dosimeter Locations Along Columbia River Shoreline

10.0 ACKNOWLEDGMENTS

I would like to acknowledge the suggestions and critical reviews provided by Rockwell Hanford Operations, the Hanford Engineering Development Laboratory, and UNC Nuclear Industries in the preparation of this document. W. A. Stone and D. T. Hoitink of the PNL Atmospheric Sciences Department provided the updated meteorological data summaries included in Chapter 6. I would like to thank R. W. Brown, D. G. Watson, J. V. Ramsdell and J. G. Droppo of PNL for their constructive criticism.

11.0 REFERENCES

- Baker, V. R. 1973. Paleohydrology and Sedimentology of Lake Missoula Flooding in Eastern Washington. Geological Society of America Special Paper 144.
- Becker, C. D. 1973. Aquatic Bioenvironmental Studies in the Columbia River at Hanford 1945-1971, A Bibliography with Abstracts. BNWL-1734. Pacific Northwest Laboratory, Richland, Washington.
- Bechtel Corporation. 1970. Site Investigation Report for Fast Flux Test Facility, Richland, Washington, San Francisco, California.
- Bently, R. D. 1977. Western Columbia Plateau Margin Studies, Tieton River to Yakima River. Washington Public Power Supply System Preliminary Safety Analysis Report, Amendment 23, Volume 2A, Subappendix 2R D.
- Bierschenck, W. H. 1959. Aquifer Characteristics and Groundwater Movement at Hanford. HW-60601. General Electric Company, Richland, Washington.
- Bingham, J. W., C. I. Londquist, and E. H. Baltz. 1970. Geologic Investigation of Faulting in the Hanford Region. U.S. Geological Survey Open File Report.
- Blume, John A., and Associates, Engineers. 1971. A Summary Report, Seismic Evaluation and Development of Ground Acceleration and Response Spectra for FFTF Site, JABE-WADCO-03. WADCO, Richland, Washington.
- Brown, R. E. 1960. An Introduction to the Surface of the Ringold Formation Beneath the Hanford Works Area, HW-66289. General Electric Company, Richland, Washington.
- Brown, R. E. 1968. A Study of Reported Faulting in the Pasco Basin. BNWL-662. Pacific Northwest Laboratory, Richland, Washington.
- Brown, R. E. 1969. "Some Suggested Rates of Deformation of the Basalts in the Pasco Basin and Their Implications," in Proceedings of the Columbia River Basalt Symposium. Northwest Scientific Association, Cheney, Washington.
- Brown, R. E. 1970. Interrelationships of Geologic Formations and Processes Affecting Ecology as Exposed at Rattlesnake Springs, Hanford Project, BNWL-D-29. Pacific Northwest Laboratory, Richland, Washington.
- Brown, R. E. 1971. "Volcanic Ash Beds in the Pasco Basin." In: Proceedings. 1971 Meeting Northwest Scientific Association. Moscow, Idaho.
- Brown, D. J., and R. E. Isaacson. 1977. The Hanford Environment as Related to Radioactive Waste Burial Grounds and Transuranium Waste Storage Facilities. ARH-ST-155. Atlantic Richfield Hanford Company, Richland, Washington.

- Coffman, J. L., and C. A. vonHake. 1973. Earthquake History of the United States. Publication 41-1 (revised edition) U.S. Department of Commerce.
- Coombs, H. A., N. G. Milne, O. W. Nuttli, and D. B. Slemmons. 1976. Report of the Review Panel on the December 14, 1872 Earthquake. Washington Public Power Supply System Preliminary Safety Analysis Report, Amendment 23, Appendix 2R A.
- Daubenmire. 1970. Steppe Vegetation of Washington. Agricultural Experiment Station Technical Bulletin No. 62. Pullman, Washington.
- Eddy, P. A., and J. S. Wilbur. 1981. Radiological Status of the Groundwater Beneath the Hanford Site, January-December 1980. PNL-3768. Pacific Northwest Laboratory, Richland, Washington.
- Eddy, P. A., C. S. Cline and L. S. Prater. 1982. Radiological Status of the Groundwater Beneath the Hanford Site, January-December 1981. PNL-4237. Pacific Northwest Laboratory, Richland, Washington.
- Fickeisen, D. H., R. E. Fitzner, R. H. Sauer and J. L. Warren. 1980. Wildlife Usage, Threatened and Endangered Species and Habitat Studies on the Hanford Reach, Columbia River, Washington. Battelle, Pacific Northwest Laboratories, under Contract 23111 04244 for the Seattle District Corps of Engineers.
- Fitzner, R. E., W. H. Rickard, L. L. Cadwell and L. E. Rogers. 1981. Raptors of the Hanford Site and Nearby Areas of South Central Washington. PNL-3212. Pacific Northwest Laboratory, Richland, Washington.
- Fujita, T. T. 1977. Review of Severe Weather Meteorology at Exxon Nuclear Company, Inc. Richland, Washington, University of Chicago, Chicago, Illinois.
- Gray, R. H., and D. D. Dauble. 1977. "Checklist and Relative Abundance of Fish Species of the Hanford Reach of the Columbia River." Northwest Sci. 51(3):208-215.
- Gephart, R. E., R. C. Arnett, R. G. Baca, L. S. Leonhart, F. A. Spane, Jr., D. A. Palombo and S. R. Strait. 1979. Hydrologic Studies within the Columbia Plateau, Washington: An Integration of Current Knowledge. RHO-BWI-ST-5. Rockwell Hanford Operations, Richland, Washington.
- Grolier, M. J. 1965. Geology of Part of the Big Bend Area in the Columbia Plateau, Washington. Ph. D. Dissertation. The Johns Hopkins University, Baltimore, Maryland.
- Grolier, M. J., and J. W. Bingham. 1978. Geology of Parts of Grant, Adams, and Franklin Counties, East-Central Washington. Washington Division of Geology and Earth Resources Bulletin 71, Olympia, Washington.

- Gustafson, E. P. 1978. The Vertebrate Faunas of the Pliocene Ringold Formation, South-Central Washington. Bulletin 25, Museum of Natural History, University of Oregon, Eugene, Oregon.
- Hanson, W. C., and L. E. Eberhart. 1971. "A Columbia River Canada Goose Study." Wildlife Monographs No. 28.
- Herde, K. E. 1948. One Year Study of Radioactivity in Columbia River Fish. HW-11344. Hanford Works, Richland, Washington.
- Hinds, W. T. 1974. An Ecological Assessment of Energy and Carbon Pathways in Swards of Bromus tectorum L. on Contrasting Slope Exposures. BNWL-1822. Pacific Northwest Laboratory, Richland, Washington.
- Jaech, J. L. 1970. Statistical Analysis of Tornado Data for the Three Northwestern States. Jersey Nuclear Company, Richland, Washington.
- Jones, F. O., and R. J. Deacon. 1966. Geology and Tectonic History of the Hanford Area and Its Relation to the Geology and Tectonic History of the State of Washington and the Active Seismic Zones of Western Washington and Western Montana. DUN-1410. Douglas United Nuclear Co., Richland, Washington.
- Jones, M. G., and K. R. Fecht. 1977. Exploratory Trenching Across the Wallula Gap Fault, South-Central Washington. American Geophysical Union Abstracts, 58(12):1248.
- Kipp, K. L., and R. D. Mudd. 1974. Selected Water Table Contour Maps and Well Hydrographs for the Hanford Reservation, 1944-1973. Pacific Northwest Laboratory, Richland, Washington.
- LaSala, A. M., G. C. Doty and F. J. Pearson. 1973. "A Preliminary Evaluation of Regional Groundwater Flow in South-Central Washington". U.S.G.S. Open File Report.
- Ledgerwood, R. K., and R. A. Deju. 1976. Hydrogeology of the Uppermost Confined Aquifers Underlying the Hanford Reservation. ARH-SA-254. Atlantic Richfield Hanford Company, Richland, Washington.
- Ledgerwood, R. K., D. J. Brown, A. C. Waters and C. W. Meyers. 1973. Identification of Basalt Flows in the Pasco Basin. ARH-2768. Atlantic Richfield Hanford Company, Richland, Washington.
- Leonhart, L. S. 1979. Surface Hydrologic Investigations of the Columbia Plateau Region, Washington. RHO-BWI-ST-6. Rockwell Hanford Operations, Richland, Washington.
- Lindberg, T. W., and F. W. Bond. 1979. Geohydrology and Ground-Water Quality Beneath the 300 Area, Hanford Site, Washington. PNL-2949, Pacific Northwest Laboratory, Richland, Washington.

- Mackin, J. H. 1961. A Stratigraphic Section in the Yakima Basalt and the Ellensburg Formation in South-Central Washington. Report of Investigations No. 19, Washington Division of Mines and Geology, Olympia, Washington.
- Malone, S. D. 1978. Annual Technical Report on Earthquake Monitoring of the Hanford Region, Eastern Washington. Geophysics program University of Washington, Seattle, Washington.
- Malone, S. D. 1979. Annual Technical Report on Earthquake Monitoring of the Hanford Region, Eastern Washington. Geophysics program University of Washington, Seattle, Washington.
- McGahn, V. L., and D. W. Damschen. 1979. Hanford Wells. PNL-2894. Pacific Northwest Laboratory, Richland, Washington.
- McKee, B. 1972. Cascadia, the Geologic Evolution of the Pacific Northwest. McGraw-Hill Book Company, New York.
- McMullen, R., and J. Kelleher. 1978. NRC Staff Supplemental Testimony of Richard McMullen and John Kelleher on Geology and Seismology. Washington Public Power Supply System, Inc., Nuclear Project No. 4. Docket STN50-513.
- Meyers, D. A. 1978. Environmental Monitoring Report on the Status of Groundwater Beneath the Hanford Site, January-December 1977. PNL-2624. Pacific Northwest Laboratory, Richland, Washington.
- Mullineaux, D. R., R. E. Wilson, W. F. Ebaugh, R. Fryxell, and M. Rubin. 1977. "Age of the Last Major Scabland Flood of Eastern Washington as Inferred from Associated Ash Beds of Mount St. Helens." Set S. Geological Society of America Abstracts with Programs, 9(7):1105.
- Myers, C. W., S. M. Price, J. A. Caggiano, M. P. Cochran, W. J. Czimer, N. J. Davidson, R. C. Edwards, K. R. Fecht, G. E. Holmes, M. G. Jones, J. R. Kunk, R. D. Landon, R. K. Ledgerwood, J. T. Lillie, P. E. Long, T. H. Mitchell, E. H. Price, S. P. Reidel, and A. M. Tallman. 1979. Geologic Studies of the Columbia Plateau-A Status Report. RHO-BWI-ST-4. Rockwell Hanford Operations, Richland, Washington.
- Newcomb, R. C. 1959. "Some Preliminary Notes on Groundwater in the Columbia River Basalt." Northwest Science, 33(1):1-18.
- Newcomb, R. E., J. R. Strand and F. J. Frank. 1972. Geology and Groundwater Characteristics of the Hanford Reservation of the U.S. Atomic Energy Commission Washington. U.S.G.S. Professional Paper 717.
- O'Farrell, T. P., and J. D. Hedlund. 1972. Distribution and Abundance of Small Mammals on Rattlesnake Mountain. BNWL-1650, Vol. 1 Part 2. Pacific Northwest Laboratory, Richland, Washington.

- Olendorff, R. R. 1973. Raptorial Birds of the U.S. AEC Hanford Reservation, South Central Washington. BNWL-1790. Pacific Northwest Laboratory, Richland, Washington.
- Packer, D. R., and J. M. Johnston, Woodward-Clyde Consultants. 1979. A Preliminary Investigation of the Magnetostratigraphy of the Ringold Formation. RHO-BWI-C-42. Rockwell Hanford Operations, Richland, Washington.
- Paglieri, J. N. 1975. 300 Area Site Description, HEDL-TM 75-13, Hanford Engineering Development Laboratory, Richland, Washington.
- Rasmussen, N. H. 1966. Seismology Report on Washington, Idaho, Northern Oregon and Western Montana, and the Hanford Area, Washington. DUN-1409. Douglas United Nuclear Co., Richland, Washington.
- Rasmussen, N. 1967. Washington State Earthquakes 1840 through 1965. Seismological Society of America Bulletin 57:463.
- Raymond, J. R., and D. J. Brown. 1963. Groundwater Exchange with Fluctuating Rivers. HW-SA-3198. General Electric Company, Richland, Washington.
- Raymond, J. R., and D. D. Tillson. 1968. Evaluation of a Thick Basalt Sequence in South-Central Washington. BNWL-776. Pacific Northwest Laboratory, Richland, Washington.
- Reidel, S. P. 1978. Geology of the Saddle Mountains Between Sentinel Gap and 119 31' Longitude. RHO-BWI-LD-4. Rockwell Hanford Operations, Richland, Washington.
- Rickard, W. H. and R. F. Keough. 1968. "Soil-Plant Relationships of Two Steppe Desert Shrubs." Plant and Soil, 29:205-212.
- Rogers, L. E. 1973. Grasshopper Abundance in an Abandoned Cultivated Field. BNWL-1750, Vol. 1 Part 2. Pacific Northwest Laboratory, Richland, Washington.
- Rumney, G. R. 1968. Climatology and the World's Climates. The MacMillin Company, London.
- Schmincke, H. U. 1964. Petrology, Paleocurrents, and Stratigraphy of the Ellensburg Formation and Interbedded Yakima Basalt Flows, South-Central Washington. Geological Society of America Bulletin 78(3):319.
- Skehan, I. W. 1966. A Continental-Oceanic Crustal Boundary in the Pacific Northwest, AFCRL-65-609.
- Shannon & Wilson, Inc. 1973. Geologic Studies of Columbia River Basalt Structures and Age Deformation. Report to Portland General Electric Company, Portland, Oregon.

- Shannon & Wilson, Inc. 1977. Geologic Evaluation of Structures in the Columbia Plateau. Washington Public Power Supply System Preliminary Safety Analysis Report, Amendment 23, Vol. 2A, Subappendix 2R H.
- Sommer, D. J., R. G. Rau and D. C. Robinson. 1981. Population Estimates for the Areas within a 50-Mile Radius of Four Reference Points on the Hanford Site. PNL-4010. Pacific Northwest Laboratory, Richland, Washington.
- State of Washington. 1978. Geology of Washington. Washington State Department of Natural Resources, Olympia, Washington.
- Stone, W. A., D. E. Jenne and J. M. Thorp. 1972. Climatology of the Hanford Area. BNWL-1605. Pacific Northwest Laboratory, Richland, Washington.
- Strait, S. R., and B. A. Moore. 1981. Aquifer Intercommunication in the Gable Mountain Pond Area, Hanford Site, South-Central Washington. RHO-ST-38. Rockwell Hanford Operations, Richland, Washington.
- Sula, M. J. 1980. Radiological Survey of Exposed Shoreline and Islands of the Columbia River Between Vernita and the Snake River Confluence. PNL-3127. Pacific Northwest Laboratory, Richland, Washington.
- Sula, M. J., and P. J. Blumer. 1981. Environmental Surveillance at Hanford for CY-1980. PNL-3728. Pacific Northwest Laboratory, Richland, Washington.
- Sula, M. J., P. J. Blumer and R. L. Dirkes. 1981. Environmental Status of the Hanford Site for CY-1980. PNL-3729. Pacific Northwest Laboratory, Richland, Washington.
- Sula, M. J., W. D. McCormack, R. L. Dirkes, K. R. Price and P. A. Eddy. 1982. Environmental Surveillance at Hanford for CY-1981. PNL-4211. Pacific Northwest Laboratory, Richland, Washington.
- Swanson, D. A., and T. L. Wright. 1978. Bedrock Geology of the Northern Columbia Plateau and Adjacent Areas. In: The Channeled Scabland: Washington NASA Planetary Geology Program, A Guide to the Geomorphology of the Columbia Basin, Washington, p. 35-57.
- Swanson, D. A., T. L. Wright, P. R. Hooper and R. D. Bently. 1979. Revisions in Stratigraphic Nomenclature of the Columbia River Basalt Group. U.S. Geological Survey Bulletin 1457-H.
- Tallman, A. M., K. R. Fecht, M. C. Marratt, and G. V. Last. 1979. Geology of the Separation Areas, Hanford Site, South-Central Washington. RHO-ST-23. Rockwell Hanford Operations, Richland, Washington.
- UNC Nuclear Industries. 1978. N-Reactor Updated Safety Analysis Report. UNI-M90. Vol. 1, pp. 2.4-7. Richland, Washington.

- U.S. Corps of Engineers. 1969. Memorandum Report - Lower Columbia River Standard Project Flood and Probable Maximum Flood. U.S. Army Engineer Division, North Pacific, Portland, Oregon.
- U.S. Department of Commerce, Environmental Sciences Services Administration, Weather Bureau. 1966. "Probable Maximum Precipitation, Northwest States." Hydro-Meteorological Report No. 43.
- U.S. ERDA. 1975. Final Environmental Statement, Waste Management Operations, Hanford Reservation, Richland, Washington. U.S. Energy Research and Development Administration. ERDA-1538 Vol. 2.
- U.S. ERDA. 1976. Evaluation of Impact of Potential Flooding Criteria on the Hanford Project. RLD-76-4. U.S. Energy Research and Development Administration, Richland, Washington.
- U.S. Fish and Wildlife Service. 1973. Threatened Wildlife in the United States. Bureau of Sport Fisheries and Wildlife, Washington, D.C.
- U.S.G.S. 1973. Water Resources Data for Washington, Part 1, Surface Water Records 1972, U.S. Department of Interior, Geological Survey, 1973.
- Waite, R. B. 1979. Late Cenozoic Deposits, Landforms, Stratigraphy and Tectonism in Kittitas Valley, Washington. U.S. Geological Survey Professional Paper 1127.
- Washington Public Power Supply System. 1973. WPPSS Nuclear Project No. 1 Preliminary Safety Analysis Report, Vol. 2. Richland, Washington.
- Washington Public Power Supply System. 1974. WPPSS Nuclear Project No. 1 Environmental Report. Figure 2.5-3 (Amendment July 1974). Washington Public Power Supply System, Richland, Washington.
- Washington Public Power Supply System. 1977. Preliminary Safety Analysis Report, Amendment 23, Vol. 1 and 2. Washington Public Power Supply System, Inc., Richland, Washington.
- Waters, A. C. 1955. Geomorphology of South-Central Washington, Illustrated by the Yakima East Quadrangle. Geological Society of America Bulletin, Vol. 66 p. 663-684.
- Watkins, N. D. and A. K. Baski. 1974. Magnetostratigraphy and Oroclinal Folding of the Columbia River, Steens and Owyha Basalts in Oregon, Washington and Idaho. American Journal of Science, Vol. 274, p. 148.
- Watson, D. G. 1970. Fall Chinook Salmon Spawning in the Columbia River Near Hanford 1947-1969. BNWL-1515. Pacific Northwest Laboratory, Richland, Washington.

- Watson, D. G. 1973a. "Fall Chinook Salmon Population Census." Pacific Northwest Laboratory Annual Report for 1972 to the USAEC Division of Biomedical and Environmental Research. BNWL-1750, Vol. 1, Part 2. Pacific Northwest Laboratory, Richland, Washington.
- Watson, D. G. 1973b. Estimate of Steelhead Trout Spawning in the Hanford Reach of the Columbia River. Contract No. DACW67-72-C-0100, Pacific Northwest Laboratory, Richland, Washington.
- Watson, D. G., and C. E. Cushing. 1972. "Productivity of Rattlesnake Springs." In: Pacific Northwest Laboratory Annual Report for 1971 to the USAEC Division of Biology and Medicine, Vol. 1, Part 2. BNWL-1650. Pacific Northwest Laboratory, Richland, Washington.
- Westinghouse Hanford Company. 1975. FFTF Final Safety Analysis Report. HEDL-TI-75001 Vol. 1. Hanford Engineering Developing Laboratory, Richland, Washington.
- Whetler, J. T., J. C. Kelley and L. G. Hanson. 1969. "Characteristics of Columbia River Sediment and Sediment Transport." In: Journal of Sedimentary Petrology, 39:1149-1166.
- Wolf, E. G., and C. E. Cushing. 1972. "Productivity of Rattlesnake Springs." In: Pacific Northwest Laboratory Annual Report for 1971 to the USAEC Division of Biology and Medicine, Volume 1, Part 2. BNWL-1650. Pacific Northwest Laboratory, Richland, Washington.
- Wolford, L. V. 1960. Tornado Occurrences in the United States. Technical Paper No. 20, Weather Bureau, U.S. Department of Commerce.
- Yandon, K. E., and D. K. Landstrom. 1979. Supplemental Report on Population Estimates for Hanford High-Level Defense Waste Draft Programmatic Environmental Impact Statement. PNL-3128. Pacific Northwest Laboratory, Richland, Washington.
- Yandon, K. E., J. S. Burlison and R. G. Rau. 1980. Supplemental Report on Population Estimates for Hanford Defense Waste Draft Environmental Impact Statement. PNL-3507. Pacific Northwest Laboratory, Richland, Washington.

APPENDIX I

THE 100 N AREA

APPENDIX I - THE 100 N AREA

I.1 Location and Topography

The 100 N Area is a controlled area of about 0.4 km^2 (90 acres) located next to the Columbia River at river mile 380. The area is about 12 km north of the 200 areas and about 7 km from the nearest Site boundary.

The 100 N Area is located on the bank of the Columbia River at an elevation of about 140 m above msl. The surface slopes up from the river (normal level approximately 120 m) to a maximum of about 145 m. The site is generally flat with no major surface features. The 100 N Area layout is shown in Figure I-1.

I.2 Geology

The Hanford Formation near the surface of the 100 N Area is covered by a thin layer of wind-deposited silt and fine sand. The Hanford Formation consists primarily unconsolidated well-rounded boulders, cobbles and pebbles with the interstitial spaces filled with coarse to medium sand. In places, the deposits are open-work gravels with little or no interstitial filling. The water table is found in these sediments beneath the 100 N Area at a depth of about 20 m. The depth to the top of the Ringold Formation is about 25 m, while the top of the basalt bedrock is approximately 240 m below the surface.

I.3 Seismology

The 100 N Area is located upon generally well compacted sediments, similar to those found under most of the Hanford Site. Steep slopes found on the White Bluffs, Gable Mountain and the Saddle Mountains have the potential for quake-induced land slides, but all are at sufficient distance that there would be no direct effect on the site.

I.4 Hydrology

The free-flowing Hanford reach of the Columbia River borders the 100 N Area on the west. The normal water level at this point on the river is about 120 m. The estimated 100-year maximum flood would result in a river level of 126.5 m. The U.S. Corps of Engineers Probable Maximum Flood (PMF) would result in a river level of 128.9 meters at the 100 N area. (U.S. Corps of Engineers 1969, UNC Nuclear Industries 1978).

FIGURE I-1. 100-N Area Plot Plan

The water table beneath the 100 N Area occurs within the sandy gravels of the Hanford formation at a depth of about 20 meters. The water table is subject to fluctuations as the river level rises and falls, due to the high permeability of the sediments. Ground water movement is generally from the south toward the river in the vicinity of 100 N, however the discharge of process cooling water to the 1301 N has created a groundwater "mound" which locally distorts the flow direction.

I.5 Meteorology

The proximity of the 100 N Area to the Columbia River can be expected to result in generally higher humidity there than at the Hanford Meteorological Station (HMS). As a result, the frequency and persistence of fog may be greater than at the HMS, but no official observations have been made to confirm this. Due to the 100 meter difference in elevation and the effect of topography on surface wind direction, the prevailing winds at the 100 N Area differ from the averages recorded at the HMS. At the 100 N Area, the prevailing wind direction is more west to southwest as compared to northwesterly at the HMS. Table I-1 gives annual average atmospheric dispersion factors around the 100 N Area based on data from the 100 N meteorology tower.

I.6 Ecology

There are no areas of a unique or significantly different ecological character within or nearby the 100 N Area.

The disused areas within the site and the immediate terrain surrounding the 100 N Area are dominated by a cheatgrass/tumble mustard vegetation community.

I.7 Demography and Land Use

Figure I-1 shows the layout of the 100 N Area and the designations of the various facilities. The principal activity in the 100 N Area is the operation of the plutonium-producing 100 N reactor and the generation of electricity using the byproduct steam. The peak daytime (1981) working population of the 100 N Area is about 670.

The nearest residence to the 100 N Area is approximately 19 km to the east. The Richland, Washington city limits are about 40 km to the southeast.

TABLE I-1. Annual Average Atmospheric Dispersion Around the 100 N Area for an 82-m Release Height
(Units are sec/m^3)^(a) (After Sula et al. 1982, Table E.5.)

Direction	Range in Miles (km)									
	0.5 (0.8)	1.5 (2.4)	2.5 (4.0)	3.5 (5.6)	4.5 (7.2)	7.5 (12.0)	15 (24)	25 (40)	35 (56)	45 (72)
N	3.68E-08	1.60E-08	9.02E-09	5.69E-09	4.05E-09	2.49E-09	1.91E-09	1.44E-09	1.10E-09	8.69E-10
NNE	5.24E-08	2.05E-08	1.08E-08	6.64E-09	4.62E-09	2.68E-09	1.94E-09	1.46E-09	1.12E-09	8.90E-10
NE	1.44E-09	4.84E-08	2.35E-08	1.39E-08	9.39E-09	5.02E-09	3.30E-09	2.44E-09	1.87E-09	1.48E-09
ENE	1.21E-07	5.50E-08	2.81E-08	1.70E-08	1.17E-08	6.65E-09	4.72E-09	3.56E-09	2.73E-09	2.17E-09
E	1.14E-09	6.79E-08	3.60E-08	2.20E-08	1.54E-08	9.31E-09	7.43E-09	5.95E-09	4.70E-09	3.79E-09
ESE	1.20E-07	7.12E-08	3.76E-08	2.29E-08	1.59E-08	9.18E-09	6.87E-09	5.41E-09	4.27E-09	3.45E-09
SE	7.91E-08	4.84E-08	2.60E-08	1.60E-08	1.10E-08	5.95E-09	3.81E-09	2.74E-09	2.07E-09	1.63E-09
SSE	7.94E-08	4.40E-08	2.27E-08	1.37E-08	9.28E-09	4.73E-09	2.72E-09	1.85E-09	1.36E-09	1.05E-09
S	9.41E-08	4.26E-08	2.14E-08	1.27E-08	8.58E-09	4.25E-09	2.32E-09	1.55E-09	1.13E-09	8.70E-10
SSW	1.61E-07	5.84E-08	2.82E-08	1.65E-08	1.10E-08	5.38E-09	2.89E-09	1.93E-09	1.41E-09	1.09E-09
SW	7.78E-08	3.33E-08	1.77E-08	1.08E-08	7.49E-09	4.13E-09	2.67E-09	1.89E-09	1.41E-09	1.10E-09
WSW	5.39E-08	2.74E-08	1.62E-08	1.04E-08	7.39E-09	4.34E-09	2.99E-09	2.14E-09	1.59E-09	1.24E-09
W	7.20E-08	3.48E-08	1.97E-08	1.25E-08	8.81E-09	5.20E-09	3.64E-09	2.62E-09	1.95E-09	1.52E-09
WNW	8.53E-08	3.75E-08	2.07E-08	1.29E-08	9.02E-09	5.09E-09	3.39E-09	2.41E-09	1.80E-09	1.40E-09
NW	8.32E-08	3.48E-08	1.90E-08	1.18E-08	8.24E-09	4.62E-09	3.60E-09	2.19E-08	1.64E-09	1.28E-09
NNW	4.68E-08	2.07E-08	1.18E-08	7.43E-09	5.22E-09	2.99E-09	2.04E-09	1.48E-09	1.11E-09	8.69E-10

(a) Calculated from meteorological data collected for the period 2-70 through 1-71.

TABLE I-2. Estimated Distribution of Population Within a 50-Mile Radius of the 100 N Reactor By Population Grid Sector for 1980 (After Sommer et al. 1981)

Compass Direction	Number of People					Totals
	0-10 mi	10-20 mi	20-30 mi	30-40 mi	40-50 mi	
NORTH	36	953	420	1,492	7,583	10,484
NNE	5	285	561	18,531	1,350	20,732
NE	0	624	1,013	2,691	259	4,587
ENE	0	620	5,884	1,129	429	8,062
EAST	0	294	625	2,742	605	4,266
ESE	0	306	1,493	596	247	2,642
SE	0	54	2,113	28,922	5,001	36,090
SSE	0	0	35,127	50,292	3,354	88,773
SOUTH	0	127	4,592	2,041	176	6,936
SSW	0	258	1,676	12,603	625	15,162
SW	0	547	4,946	16,747	469	22,709
WSW	0	680	1,699	8,297	15,274	25,950
WEST	18	395	936	5,149	75,686	82,184
WNW	54	573	377	490	1,598	3,092
NW	74	277	425	515	683	1,974
NNW	64	277	438	1,030	4,696	6,505
TOTALS	251	6,270	62,325	153,267	118,035	340,148

TABLE I-3. Estimated Distribution of Population within a 50-Mile Radius of the 100 N Reactor by Population Grid Sector for the Year 1990 (After Sommer et al. 1981).

Compass Direction	Number of People					Totals
	0-10 mi	10-20 mi	20-30 mi	30-40 mi	40-50 mi	
NORTH	42	1,119	493	1,752	8,901	12,307
NNE	6	336	659	21,755	1,585	24,341
NE	0	769	1,228	3,163	314	5,474
ENE	0	781	7,303	1,401	533	10,018
EAST	0	400	844	3,726	816	5,786
ESE	0	416	2,032	810	319	3,577
SE	0	73	2,841	38,742	6,087	47,743
SSE	0	0	45,015	64,621	4,300	113,936
SOUTH	0	163	5,886	2,617	225	8,891
SSW	0	331	2,118	15,238	734	18,421
SW	0	684	5,771	19,605	544	26,604
WSW	0	837	1,975	9,642	17,750	30,204
WEST	21	462	1,087	5,974	87,901	95,445
WNW	63	672	385	495	1,624	3,239
NW	87	325	478	532	689	2,111
NNW	75	325	515	1,208	5,489	7,612
TOTALS	294	7,693	78,630	191,281	137,811	415,709

APPENDIX II

THE 200 EAST AREA

APPENDIX II - THE 200 EAST AREA

II.1 Location and Topography

The 200 East Area is a controlled area of approximately 8.4 km² located near the middle of the Hanford Site. The 200 East Area is about 10 km from the Columbia River and 18 km from the nearest Site boundaries (to the west, south and east).

The 200 East Area is located on a plateau at an elevation of approximately 200 m above msl. The surface slopes from southwest to northeast, with a maximum difference in elevation across the site of about 25 m. About 4 km north of the area are two basalt outcroppings, Gable Mountain and Gable Butte, which are remnants of an anticlinal Ridge that was severely eroded by the post-glacial floods of the Columbia River. There are no naturally occurring surface water bodies within the 200 East Area. However, process cooling water and aqueous wastes are discharged to an open ditch that carries the effluents to a small impoundment (B-pond) located just east of the Area.

The 200 East Area layout is shown in Figure II-1. The portions of the Area not occupied by structures, storage yards, tank farms or burial grounds are largely vacant with a sparse vegetation cover.

II.2 Geology

The 200 Area plateau, upon which the 200 East Area is located, is a gravel bar deposited by the post-glacial flood waters. A thin surface layer of wind-blown silts and sands cover the Hanford Formation sediments that consist mainly of well-sorted coarse sands. On the east side of the Area, those deposits give way to a slightly silty and pebbly coarse sand. The Hanford Formation sediments are about 70 m thick. They directly overlie the Middle Ringold Formation that consists of well rounded pebbles and cobbles with interstitial spaces filled with medium sand. The upper Ringold Formation is not generally present beneath the 200 East Area, having apparently been eroded away (Tallman et al. 1979).

FIGURE II-1. Detailed map of 200 East Area

The water table beneath the 200 East Area lies near the top of the middle Ringold formation at a depth which varies from about 100 m in the southwest to 55 m in the northeastern portion (Brown and Isaacson 1977). Middle Ringold Formation sediments are unconsolidated and have a relatively high permeability. The depth to basalt bedrock under the 200 East Area is about 120 meters.

II.3 Seismology

The 200 East Area seismic characteristics are typical of the Hanford Site as a whole. The soil characteristics are such that differential compaction or liquifaction as a result of seismic shocks are considered very unlikely (ERDA 1975). There are no slopes within several km of the 200 East Area that could produce landslides during an earthquake.

II.4 Hydrology

There are no naturally-occurring surface water bodies in the 200 East Area. The ditch leading from the site to B-pond is the only surface water. West Lake is a small natural lake located about 4 km north of the area. Gable Mountain pond, formed by the rising of the water table as a result of waste water disposal from the 200 Areas, is about 3 km north.

The Columbia River, 10 km away to the east and north, would not flood the 200 East Area even under the most extreme conditions. The U.S. Corps of Engineers Probable Maximum Flood for the Hanford reach of the Columbia would have peak water levels 60-75 m below the 200 East Area (U.S. Corps of Engineers 1969).

The water table beneath the 200 East Area occurs within the sand and gravel deposits of the middle Ringold Formation at a depth of 55 to 100 meters and slopes toward the river. The natural recharge of the aquifer is from precipitation falling on the slopes of hills to the west of the Hanford Site. However, surface disposal of waste waters from the 200 Areas has created and artificial recharge of the aquifer with local elevation of the water table under the 200 Area plateau.

II.5 Meteorology

The meteorological conditions at the 200 East Areas are monitored at the Hanford Meteorological Station located 3 km west of the site. Table II-1 gives the annual average atmospheric dispersion factors around the 200 Areas based on HMS data.

II.6 Ecology

The 200 Area plateau is dominated by the sagebrush/cheatgrass vegetation community, as are the unoccupied parts of the 200 East Area. Tumbleweed is prominent as an early invader of disturbed ground, and continues in abundance until competition increases from other plants. There are no bodies of water within the 200 East Area that support significant aquatic ecosystems.

II.7 Demography and Land Use

Figure II-1 shows the layout of the 200 East Area and the designations of the various facilities. Principal activities in the 200 East Area include the reprocessing of irradiated plutonium production reactor fuels, fission product separation, criticality research and radioactive waste storage. The peak day time (1981) working population of the 200 East Area is approximately 1650.

The nearest residence to the 200 East Area is approximately 19 km east across the Columbia River. The Richland, Washington, city limits are about 27 km to the southeast.

Tables II-2 and II-3 give the estimated 1980 and 1990 population distributions within 80 km (50 mi) of the 200 East Area.

TABLE II-1. Annual Average Atmospheric Dispersion Around the 200 Areas for an 89-m Release Height (Units are sec/m^3)^(a) (After Sula et al. 1982, Table E.6)

Direction	Range in Miles (km)									
	0.5 (0.8)	1.5 (2.4)	2.5 (4.0)	3.5 (5.6)	4.5 (7.2)	7.5 (12.0)	15 (24)	25 (40)	35 (56)	45 (72)
N	3.29E-08	1.76E-08	1.04E-08	6.91E-09	4.87E-09	2.29E-09	1.08E-09	7.81E-10	6.23E-10	5.10E-10
NNE	4.70E-08	1.90E-08	1.05E-08	6.82E-09	4.76E-09	2.22E-09	1.08E-09	8.11E-10	6.60E-10	5.47E-10
NE	8.05E-08	3.02E-08	1.54E-08	9.44E-09	6.40E-09	2.92E-09	1.50E-09	1.19E-09	9.86E-10	8.26E-10
ENE	7.61E-08	2.84E-08	1.45E-08	8.94E-09	6.07E-09	2.85E-09	1.64E-09	1.37E-09	1.15E-09	9.64E-10
E	4.61E-08	2.28E-08	1.32E-08	8.72E-09	6.17E-09	3.18E-09	2.22E-09	1.95E-09	1.65E-09	1.39E-09
ESE	7.97E-08	4.00E-08	2.17E-08	1.36E-08	9.38E-09	4.77E-09	3.60E-09	3.37E-09	2.93E-09	2.50E-09
SE	1.67E-07	7.60E-08	4.02E-08	2.49E-08	1.70E-08	7.97E-09	4.54E-09	3.73E-09	3.12E-09	2.62E-09
SSE	8.34E-08	4.19E-08	2.47E-08	1.64E-08	1.16E-08	5.42E-09	2.40E-09	1.60E-09	1.22E-09	9.76E-10
S	8.65E-08	4.38E-08	2.55E-08	1.68E-08	1.18E-08	5.40E-09	2.14E-09	1.33E-09	9.81E-10	7.71E-10
SSW	7.93E-08	3.88E-08	2.19E-08	1.42E-08	9.89E-09	4.43E-09	1.65E-09	9.59E-10	6.90E-10	5.35E-10
SW	6.89E-08	4.06E-08	2.36E-08	1.54E-08	1.08E-08	4.82E-09	1.73E-09	9.64E-10	6.79E-10	5.19E-10
WSW	3.74E-08	2.39E-08	1.49E-08	1.01E-08	7.20E-09	3.30E-09	1.24E-09	7.20E-10	5.18E-10	4.02E-10
W	3.72E-08	2.57E-08	1.64E-08	1.13E-08	8.13E-09	3.76E-09	1.44E-09	8.57E-10	6.24E-10	4.87E-10
WNW	3.42E-08	2.37E-08	1.58E-08	1.12E-08	8.09E-09	3.84E-09	1.63E-09	1.07E-09	8.20E-10	6.56E-10
NW	4.17E-08	2.69E-08	1.82E-08	1.29E-08	9.41E-09	4.55E-09	2.08E-09	1.45E-09	1.13E-09	9.10E-10
NNW	2.68E-08	1.57E-08	1.03E-08	7.27E-09	5.27E-09	2.56E-09	1.22E-09	8.79E-10	6.94E-10	5.64E-10

(a) Calculated from meteorological data collected from 1955 through 1970.

TABLE II-2. Estimated Distribution of Population Within a 50 mile Radius of the 200 Area Hanford Meteorological Tower by Population Grid Sector 1980 (After Sommer et al. 1981)

Compass Direction	Number of People					Totals
	0-10 mi	10-20 mi	20-30 mi	30-40 mi	40-50 mi	
NORTH	0	174	1,124	772	1,957	4,027
NNE	0	92	656	5,547	14,822	21,117
NE	0	262	5,930	2,963	596	9,751
ENE	0	235	773	2,366	435	3,809
EAST	0	340	1,329	1,659	588	3,916
ESE	0	283	1,374	230	652	2,539
SE	0	6,757	48,661	50,519	3,474	109,411
SSE	0	1,997	13,161	2,717	5,218	23,093
SOUTH	0	1,532	1,489	195	1,799	5,015
SSW	0	905	5,283	652	129	6,969
SW	0	1,190	19,786	2,182	459	23,617
WSW	5	1,840	5,063	15,088	4,573	26,569
WEST	32	648	949	6,874	78,635	87,138
WNW	73	444	802	833	2,833	4,985
NW	0	555	398	493	1,454	2,900
NNW	0	246	456	864	4,521	6,087
TOTALS	110	17,500	107,234	93,954	122,145	340,943

TABLE II-3. Estimates Distribution of Population Within a 50 mile Radius of the 200 Area Hanford Meteorological Station by Population Grid Sector for the Year 1990 (After Sommer, et al. 1981)

Compass Direction	Number of People					Totals
	0-10 mi	10-20 mi	20-30 mi	30-40 mi	40-50 mi	
NORTH	0	202	1,320	907	2,298	4,727
NNE	0	108	790	6,448	17,482	24,828
NE	0	331	7,360	3,534	713	11,938
ENE	0	320	1,015	3,110	558	5,003
EAST	0	462	1,808	2,258	792	5,320
ESE	0	385	1,869	307	744	3,305
SE	0	8,664	62,866	66,306	4,094	141,930
SSE	0	2,561	16,873	3,483	6,243	29,160
SOUTH	0	1,962	1,909	251	2,114	6,236
SSW	0	1,160	6,757	787	157	8,861
SW	0	1,449	23,003	2,535	534	27,521
WSW	7	2,177	5,884	17,532	5,313	30,913
WEST	40	780	1,103	7,988	91,374	101,285
WNW	94	530	920	924	3,221	5,689
NW	0	652	430	499	1,467	3,048
NNW	0	289	536	1,013	5,268	7,106
TOTALS	141	22,032	134,443	117,882	142,372	416,870

APPENDIX III

THE 200 WEST AREA

APPENDIX III - THE 200 WEST AREA

III.1 Location and Topography

The 200 West Area is a controlled area of approximately 8.2 km² located near the center of the Hanford Site, about 8 km from the Columbia River and about 11 km from the nearest Site boundary.

The 200 West Area is located on a relatively flat plateau at an elevation of approximately 200 m above msl. About 4 to 5 km north and northeast of the area are two basalt outcroppings, Gable Mountain and Gable Butte, which are remnants of an anticlinal ridge that was severely eroded by post glacial floods of the Columbia River. There are no naturally occurring surface water bodies within the 200 West Area. However process cooling water and aqueous wastes are discharged to surface impoundments, creating several artificial ponds within or adjacent to the area.

The 200 West Area layout is shown in Figure III-1. The portions of the area not occupied by structures, burial grounds, tank farms or other facilities are largely vacant land with a sparse vegetation cover.

III.2 Geology

The 200 Area plateau, upon which the 200 West Area is located, is a gravel bar deposited by the ancestral Columbia River. A thin surface layer of wind-blown silts and sands cover the Hanford Formation sediments which consist primarily of slightly silty, coarse to medium sand. Near the surface are some poorly-sorted sediments ranging in size from boulder to silt. The Hanford Formation sediments are about 20 m thick.

Below the Hanford Formation sediments is a layer of wind-deposited silt, derived from the Ringold Formation, and ranging in thickness from 6 m at the north end of the area to 30 m at the south. Near the boundary of this layer with the Ringold Formation is a thin zone of fine sands and silts cemented with calcium carbonate (Tallman et al. 1979).

The Ringold Formation is about 40 meters thick and consists predominantly of well-rounded pebbles and cobbles with the interstitial spaces filled with medium to fine sand and silt. The water table beneath the 200 West Area lies within the Ringold Formation, which has a relatively high permeability. The depth to basalt bedrock is about 110 meters (Brown and Isaacson 1977).

III.3 Seismology

The 200 West Area seismic characteristics are typical of the Hanford Site as a whole. The soil characteristics are such that differential compaction or liquifaction as a result of seismic shocks are considered very unlikely (ERDA 1975). There are no slopes within several km of the 200 West area which could produce land slides during an earthquake.

III.4 Hydrology

There are no naturally-occurring surface water bodies in the 200 West Area. However, there are several ponds and ditches that are created by the discharge of aqueous wastes and process cooling water pumped to the area from the Columbia River. These include T-Pond, U-Pond, Redox Pond, 222-S pond, the 231 Ditch and 216 Z-19 Ditch. The water entering these ponds either evaporates or percolates through the unsaturated soil until it reaches the water table. A complete list of the ponds and ditches, together with these physical dimensions and inventories of radioactive materials, is given in the Final Environmental Statement, Waste Management Operations Hanford Reservation, Richland, Washington (ERDA 1975). The Columbia River, 8 km to the north would not flood the 200 West Area even under the most extreme conditions. The U.S. Corps of Engineers Probable Maximum Flood for the Hanford Reach of the Columbia would have peak water levels 60-70 m below the 200 West Area (U.S. Corps of Engineers 1969).

The water table beneath the 200 West Area occurs within the sand and gravel deposits of the Ringold Formation at a depth of 55 to 82 m. The disposal of waste waters to surface ponds has raised the water table in the vicinity of the 200 Areas.

III.5 Meteorology

The meteorological conditions at the 200 West Area are monitored at the Hanford Meteorological Station located adjacent to the site. Table III-1 gives annual average atmospheric dispersion factors around the 200 Areas based on HMS data.

III.6 Ecology

The 200 Area plateau is dominated by the sagebrush/cheatgrass vegetation community, as are most unoccupied parts of the 200 West Area. Tumbleweed is a prominent early invader of disturbed ground and continues in abundance until competition from other plants increases.

The 200 West Area ponds and ditches support local willow vegetation communities. The larger ponds in and near the 200 West area support simple food webs based mainly on sedimented organic matter. U-pond and Gable pond both support introduced populations of goldfish.

III.7 Demography and Land Use

Figure III-1 shows the layout of the 200 West Area and the designations of the various facilities. Principal activities in the 200 West Area include production of uranium oxide, plutonium purification and conversion and plutonium storage. The peak daytime working (1981) population of the 200 West Area is about 1430.

The nearest residence to the 200 West Area is approximately 16 km to the northwest. The Richland, Washington, city limits are about 34 km to the southeast.

Tables III-2 and III-3 give the estimated 1980 and 1990 population distributions within 80 km (50 mi) of the 200 West Area.

TABLE III-1. Annual Average Atmospheric Dispersion Around the 200 Areas for an 89-m Release Height (Units are sec/m^3)^(a) (After Sula et al. 1982, Table E.6)

Direction	Range in Miles (km)									
	0.5 (0.8)	1.5 (2.4)	2.5 (4.0)	3.5 (5.6)	4.5 (7.2)	7.5 (12.0)	15 (24)	25 (40)	35 (56)	45 (72)
N	3.29E-08	1.76E-08	1.04E-08	6.91E-09	4.87E-09	2.29E-09	1.08E-09	7.81E-10	6.23E-10	5.10E-10
NNE	4.70E-08	1.90E-08	1.05E-08	6.82E-09	4.76E-09	2.22E-09	1.08E-09	8.11E-10	6.60E-10	5.47E-10
NE	8.05E-08	3.02E-08	1.54E-08	9.44E-09	6.40E-09	2.92E-09	1.50E-09	1.19E-09	9.86E-10	8.26E-10
ENE	7.61E-08	2.84E-08	1.45E-08	8.94E-09	6.07E-09	2.85E-09	1.64E-09	1.37E-09	1.15E-09	9.64E-10
E	4.61E-08	2.28E-08	1.32E-08	8.72E-09	6.17E-09	3.18E-09	2.22E-09	1.95E-09	1.65E-09	1.39E-09
ESE	7.97E-08	4.00E-08	2.17E-08	1.36E-08	9.38E-09	4.77E-09	3.60E-09	3.37E-09	2.93E-09	2.50E-09
SE	1.67E-07	7.60E-08	4.02E-08	2.49E-08	1.70E-08	7.97E-09	4.54E-09	3.73E-09	3.12E-09	2.62E-09
SSE	8.34E-08	4.19E-08	2.47E-08	1.64E-08	1.16E-08	5.42E-09	2.40E-09	1.60E-09	1.22E-09	9.76E-10
S	8.65E-08	4.38E-08	2.55E-08	1.68E-08	1.18E-08	5.40E-09	2.14E-09	1.33E-09	9.81E-10	7.71E-10
SSW	7.93E-08	3.88E-08	2.19E-08	1.42E-08	9.89E-09	4.43E-09	1.65E-09	9.59E-10	6.90E-10	5.35E-10
SW	6.89E-08	4.06E-08	2.36E-08	1.54E-08	1.08E-08	4.82E-09	1.73E-09	9.64E-10	6.79E-10	5.19E-10
WSW	3.74E-08	2.39E-08	1.49E-08	1.01E-08	7.20E-09	3.30E-09	1.24E-09	7.20E-10	5.18E-10	4.02E-10
W	3.72E-08	2.57E-08	1.64E-08	1.13E-08	8.13E-09	3.76E-09	1.44E-09	8.57E-10	6.24E-10	4.87E-10
WNW	3.42E-08	2.37E-08	1.58E-08	1.12E-08	8.09E-09	3.84E-09	1.63E-09	1.07E-09	8.20E-10	6.56E-10
NW	4.17E-08	2.69E-08	1.82E-08	1.29E-08	9.41E-09	4.55E-09	2.08E-09	1.45E-09	1.13E-09	9.10E-10
NNW	2.68E-08	1.57E-08	1.03E-08	7.27E-09	5.27E-09	2.56E-09	1.22E-09	8.79E-10	6.94E-10	5.64E-10

(a) Calculated from meteorological data collected from 1955 through 1970.

TABLE III-2. Estimated Distribution of Population Within a 50 mile Radius of the 200 Area Hanford Meteorological Tower by Population Grid Sector 1980 (After Sommer et al. 1981)

Compass Direction	Number of People					Totals
	0-10 mi	10-20 mi	20-30 mi	30-40 mi	40-50 mi	
NORTH	0	174	1,124	772	1,957	4,027
NNE	0	92	656	5,547	14,822	21,117
NE	0	262	5,930	2,963	596	9,751
ENE	0	235	773	2,366	435	3,809
EAST	0	340	1,329	1,659	588	3,916
ESE	0	283	1,374	230	652	2,539
SE	0	6,757	48,661	50,519	3,474	109,411
SSE	0	1,997	13,161	2,717	5,218	23,093
SOUTH	0	1,532	1,489	195	1,799	5,015
SSW	0	905	5,283	652	129	6,969
SW	0	1,190	19,786	2,182	459	23,617
WSW	5	1,840	5,063	15,088	4,573	26,569
WEST	32	648	949	6,874	78,635	87,138
WNW	73	444	802	833	2,833	4,985
NW	0	555	398	493	1,454	2,900
NNW	0	246	456	864	4,521	6,087
TOTALS	110	17,500	107,234	93,954	122,145	340,943

TABLE III-3. Estimates Distribution of Population Within a 50 mile Radius of the 200 Area Hanford Meteorological Station by Population Grid Sector for the Year 1990 (After Sommer, et al. 1981)

Compass Direction	Number of People					Totals
	0-10 mi	10-20 mi	20-30 mi	30-40 mi	40-50 mi	
NORTH	0	202	1,320	907	2,298	4,727
NNE	0	108	790	6,448	17,482	24,828
NE	0	331	7,360	3,534	713	11,938
ENE	0	320	1,015	3,110	558	5,003
EAST	0	462	1,808	2,258	792	5,320
ESE	0	385	1,869	307	744	3,305
SE	0	8,664	62,866	66,306	4,094	141,930
SSE	0	2,561	16,873	3,483	6,243	29,160
SOUTH	0	1,962	1,909	251	2,114	6,236
SSW	0	1,160	6,757	787	157	8,861
SW	0	1,449	23,003	2,535	534	27,521
WSW	7	2,177	5,884	17,532	5,313	30,913
WEST	40	780	1,103	7,988	91,374	101,285
WNW	94	530	920	924	3,221	5,689
NW	0	652	430	499	1,467	3,048
NNW	0	289	536	1,013	5,268	7,106
TOTALS	141	22,032	134,443	117,882	142,372	416,870

APPENDIX IV

THE 300 AREA

APPENDIX IV - THE 300 AREA

IV.1 Location and Topography

The 300 Area is a controlled area of approximately 1.6 km^2 (400 acres) located near the southeast corner of the Hanford Site. The 300 Area is roughly rectangular in shape; it is bounded on the east by the Columbia River and on the west by the Hanford Highway Route 4 south (Stevens Drive extended). The southern site boundary is about 1.7 km north of the Richland city limits and about 11 km north of the city center. Site characteristics relevant to the safety evaluation of activities in the 300 Area have been summarized and published as "300 Area Site Description" (Paglieri 1975).

The 300 Area occupies a relatively flat area on the west bank of the Columbia River. The site elevation is approximately 120 meters above mean sea level (msl), about 15 meters above the average elevation of the adjacent Columbia River. The Hanford Site land surrounding the 300 Area is devoid of prominent surface features. The land surface slopes gently upward to the northwest. Across the river to the east is generally flat, moderately sloping agricultural land, except that approximately 2 km northeast of the 300 Area are bluffs that rise to about 160 m above the river. Approximately 85% of the land in the 300 Area is occupied by structures or facilities. The remaining area is largely vacant with a sparse vegetation cover. A portion of the southeast corner of the 300 Area is irrigated pasture for animals used in biological research activities. Figure IV-1 shows the 300 Area plot plan.

IV.2 Geology

As under the entire Hanford Site, the Columbia River basalt group estimated at more than 3660 m thick, forms the bedrock beneath the 300 Area. The top of the basalt under the 300 Area lies about 60 m below the surface and is overlaid by the Ringold Formation. The Ringold Formation beneath the 300 Area is approximately 46 m thick. The lower 12 m are composed largely of silt and clay with occasional sand and gravel. Above the clay and silt layer is a complex association of gravel and sand with occasional lenses of silt or clay.

FIGURE IV-1. 300 Area Map

Above the Ringold Formation lies 20-25 m of coarse-grained glaciofluvial deposits known as the Pasco Gravels, part of the Hanford Formation. The Pasco Gravels underlying the 300 Area display two cycles of graded bedding. However, the fine-grained portion of the upper cycle is not present, possibly having been eroded away, leaving exposed boulders at the surface. Immediately below the boulders are finer grained sediments typical of another sequence of graded bedding.

Drilling samples, permeability tests and excavations have disclosed the presence of a river channel incised into the Ringold Formation beneath the 300 Area. The channel is filled with coarse glaciofluvial sediments (Pasco Gravels) and is separated from the present channel of the Columbia River by a natural levee of relatively impermeable Ringold Formation sediments. The channel, which has a profile similar in cross section to the present Columbia River channel, merges with the Columbia River about 3.2 km to the north and 1.6 km south of the 300 Area (Lindberg and Bond, 1979).

The surface sediments above the glaciofluvial sediments in the 300 Area are largely wind-transported sands and silts. These sediments were deposited in dunes up to about 3 m in depth that have been largely stabilized by vegetation.

IV.3 Seismology

The sediments, upon which the 300 Area rests, have a high degree of natural compaction. The Pasco Gravels demonstrate a high load-bearing capacity without undue settling. Consequently, differential compaction of the sediments under the 300 Area would be negligible. The likelihood of liquifaction of the sediments as a result of earthquake shocks is also considered remote, based on test results and historic experience with similar soils (ERDA 1975, Bechtel Corp 1970).

The 300 Area would not be affected by earthquake-caused landslides as the site and its immediate surrounding area are relatively flat. The White Bluffs across the Columbia River might be expected to experience some slides during an earthquake, but they are sufficiently distant that no direct impact on the 300 Area is likely. Slides from the bluffs could temporarily divert the

Columbia River flow toward the west side of its channel near the 300 Area, but it is considered unlikely that a significant impoundment of the river would occur (ERDA 1975).

IV.4 Hydrology

The Columbia River which borders the 300 Area has a normal water level of about 104 m above mean sea level (msl). During the spring runoff, the level rises to about 107 m. The estimated 100 year maximum flood would result in a river level of 108.5 m. The U.S. Corps of Engineers Probable Maximum Flood (PMF) would result in a river level of 116.5 ± 1.2 m at the 300 Area (U.S. Corps of Engineers 1969).

The high permeability of the sands and gravels that underlie the site cause rapid infiltration of any precipitation which falls. Flooding of any portion of the 300 Area by rainwater, therefore, is highly improbable. There are no other natural streams or watercourses within or adjacent to the 300 Area.

Groundwater enters the 300 Area from the northwest, west and southwest, flowing into the Columbia River. Throughout most of the 300 Area, the flow is toward the east and southeast. Only in the southern portion of the area is the flow in a northeasterly direction. The water table generally slopes downward from west to east. Variations in the River level, groundwater withdrawal from site wells and discharge of waste water to the process ponds and leaching trenches cause variations in the water table level. The Pasco Gravels and upper Ringold Formation that comprise the unconfined aquifer are highly permeable. The elevation of the water table typically varies from 104.4 m above msl at the west side of the 300 Area to 103.7 m on the east (Lindberg and Bond 1979).

IV.5 Meteorology

The proximity of the 300 Area to the Columbia River can be expected to result in generally higher humidity there than at the HMS. As a result, the frequency and persistence of fog may be greater than at the HMS, however, no official observations have been made to confirm this fact.

Due to the influence of local topography on the surface wind direction, the prevailing conditions at the 300 Area differ substantially from the averages recorded at the HMS. The frequency of northwest winds is lower at the 300 Area than at the HMS, while the frequency of south and southeast winds is greater. Table IV-1 gives the annual average atmospheric dispersion factors around the 300 Area based on meteorological data from the Washington Public Power Supply System reactor site.

IV.6 Ecology

There are no areas of a unique or significantly different ecological character within or near the 300 Area. The 300 Area waste ponds, with a total area of about 12 acres, have previously received liquid waste from 300 Area laboratories and the N reactor fuel fabrication processes. Vascular plants grow down to the waters edge, and the ponds are occasionally used by migrating waterfowl as a resting and feeding stop.

Although largely disturbed from its native state, the 300 Area does include a few acres of unoccupied land with a sparse vegetation cover dominated by sagebrush rabbitbrush and bitterbrush, with an understory of cheatgrass and tumble mustard. The sagebrush/bitterbrush/cheatgrass community is similar to that occupying much of the southeast quarter of the Hanford Site.

IV-7 Demography and Land Use

Figure IV-1 shows the layout of the 300 Area and the designations of the various facilities. Principal activities in the 300 Area facilities include N-Reactor fuel fabrication, reactor fuels research and development, liquid metal technology development, life sciences research and Breeder Reactor Program support. The peak daytime (1981) working population of the 300 Area is about 3100.

The nearest residence to the 300 Area is approximately 1.5 km east across the Columbia River. The Richland, Washington, city limits are about 1.7 km to the south. The northern part of the city, within about 4 km of the 300 Area, is an industrial park. The nearest residences in Richland are about 4.6 km

from the 300 Area boundary. A number of irrigated farms are located immediately across the river from the 300 Area. The nearest city water intake is the Richland city pumping station 6 km downstream from the 300 Area.

Tables IV-2 and IV-3 give the estimated 1980 and 1990 population distributions within 80 km (50 mi) of the 300 Area.

TABLE IV-1. Annual Average Atmospheric Dispersion Around the 300 Area For Ground-Level Release (Units are sec/m^3)^(a) (After Sula et al. 1982, Table E.7)

Direction	Range in Miles (km)									
	0.5 (0.8)	1.5 (2.4)	2.5 (4.0)	3.5 (5.6)	4.5 (7.2)	7.5 (12.0)	15 (24)	25 (40)	35 (56)	45 (72)
N	5.7E-06	8.7E-07	3.9E-07	2.4E-07	1.6E-07	7.9E-08	3.1E-08	1.6E-08	1.0E-08	7.4E-09
NNE	5.0E-06	7.6E-07	3.4E-07	2.1E-07	1.4E-07	6.9E-08	2.7E-08	1.3E-08	8.7E-09	6.3E-09
NE	3.9E-06	5.9E-07	2.6E-07	1.6E-07	1.1E-07	5.3E-08	2.1E-08	1.0E-08	6.7E-09	4.9E-09
ENE	3.6E-06	5.5E-07	2.5E-07	1.5E-07	1.0E-07	5.0E-08	1.9E-08	9.8E-09	6.4E-09	4.6E-09
E	3.4E-06	5.1E-07	2.3E-07	1.4E-07	9.4E-08	4.6E-08	1.8E-08	9.0E-09	5.9E-09	4.3E-09
ESE	5.8E-06	8.8E-07	4.0E-07	2.4E-07	1.7E-07	8.0E-08	3.1E-08	1.6E-08	1.0E-08	7.5E-09
SE	7.2E-07	1.1E-06	4.9E-07	3.0E-07	2.1E-07	1.0E-07	3.9E-08	2.0E-08	1.3E-08	9.3E-09
SSE	7.2E-06	1.1E-06	4.7E-07	2.9E-07	2.0E-07	9.6E-08	3.8E-08	1.9E-08	1.2E-08	9.0E-09
S	5.5E-06	8.4E-07	3.8E-07	2.4E-07	1.6E-07	7.8E-08	3.0E-08	1.5E-08	1.0E-08	7.3E-09
SSW	4.4E-06	6.8E-07	3.1E-07	1.9E-07	1.3E-07	6.3E-08	2.5E-08	1.3E-08	8.2E-09	6.0E-09
SW	3.8E-06	5.9E-07	2.7E-07	1.7E-07	1.1E-07	5.5E-08	2.2E-08	1.1E-08	7.2E-09	5.2E-09
WSW	3.0E-06	4.6E-09	2.1E-07	1.3E-07	8.8E-08	4.3E-08	1.7E-08	8.5E-09	5.6E-09	4.0E-09
W	2.6E-06	4.1E-07	1.8E-07	1.2E-07	7.8E-08	3.8E-08	1.5E-08	7.5E-09	4.9E-09	3.6E-09
WNW	2.9E-06	4.4E-07	2.0E-07	1.2E-07	8.2E-08	4.0E-08	1.5E-08	7.8E-09	5.1E-09	3.7E-09
NW	3.6E-06	5.4E-07	2.4E-07	1.5E-07	1.0E-07	4.9E-08	1.9E-08	9.5E-09	6.2E-09	4.5E-09
NNW	5.4E-06	8.2E-07	3.7E-07	2.2E-07	1.5E-07	7.4E-08	2.9E-08	1.5E-08	9.5E-09	6.9E-09

(a) Calculated from meteorological data collected during the period 4-74 through 3-76.

TABLE IV-2. Estimated Distribution of Population Within a 50 mile Radius of the 300 Area by Population Grid Sector for the Year 1980 (After Sommer, et al. 1981)

Compass Direction	Number of People					Totals
	0-10 mi	10-20 mi	20-30 mi	30-40 mi	40-50 mi	
NORTH	289	241	989	5,655	5,317	12,491
NNE	307	475	841	1,950	2,269	5,842
NE	18	966	2,583	562	205	4,334
ENE	307	465	349	470	238	1,829
EAST	291	114	137	174	687	1,403
ESE	338	288	863	594	17,891	19,974
SE	2,549	26,150	2,922	877	1,235	33,733
SSE	7,161	30,357	1,114	1,117	1,113	40,862
SOUTH	15,561	6,651	96	17,223	5,127	44,658
SSW	11,124	4,034	99	1,209	2,038	18,504
SW	10,066	3,931	706	182	181	15,066
WSW	4,429	1,810	5,531	8,988	621	21,379
WEST	294	984	2,226	16,878	16,293	36,675
WNW	0	0	692	1,543	1,679	3,914
NW	0	0	74	923	785	1,782
NNW	0	0	8	875	1,212	2,095
TOTALS	52,734	76,466	19,230	59,220	56,891	264,541

TABLE IV-3. Estimated Distribution of Population Within a 50 mile Radius of 300 Area By Population Grid Sector for the Year 1990 (After Sommer et al. 1981)

Compass Direction	Number of People					Totals
	0-10 mi	10-20 mi	20-30 mi	30-40 mi	40-50 mi	
NORTH	393	328	1,252	6,995	6,243	15,211
NNE	417	647	1,092	2,415	2,681	7,252
NE	24	1,314	3,515	738	256	5,847
ENE	417	634	476	631	305	2,463
EAST	395	155	180	194	764	1,688
ESE	459	370	963	659	19,882	22,333
SE	3,469	35,104	3,469	988	1,471	44,501
SSE	9,310	38,936	1,425	1,333	1,328	52,332
SOUTH	19,951	8,526	123	20,548	6,117	55,265
SSW	14,260	5,173	128	1,418	2,373	23,352
SW	12,904	5,040	905	229	215	19,293
WSW	5,679	2,319	7,067	10,460	722	26,247
WEST	377	1,261	2,718	19,611	18,932	42,899
WNW	0	0	868	1,815	1,945	4,628
NW	0	0	95	1,084	876	2,055
NNW	0	0	9	1,028	1,422	2,459
TOTALS	68,055	99,807	24,285	70,146	65,532	327,825

APPENDIX V

THE 400 AREA

APPENDIX V - THE 400 AREA

V.1 Location and Topography

The 400 Area is a controlled area of about 0.5 km^2 (130 acres) located in the southeast part of the Hanford Site some 7.2 km from the Columbia River and 6.2 km from the nearest Site boundary.

The 400 Area is located at an elevation of about 170 m above msl. The land around the site slopes gently away to the south and east toward the Columbia and Yakima Rivers. The site is devoid of prominent topographic features. The 400 Area site plan is shown in Figure V-1.

V.2 Geology

The glaciofluvial (Hanford Formation) deposits, upon which the 400 Area is located, extend from the surface to a depth of about 45 m. The surface sediments are coarse sands, merging into the coarse Pasco gravels. The Ringold Formation begins at a depth of 45 m and extends to the basalt bed rock at about 150 m. The water table beneath the 400 Area is in the upper part of the Ringold Formation at a depth of about 50 m (Westinghouse Hanford Company 1975).

V.3 Seismology

The 400 Area was examined carefully to determine the seismic characteristics of the Fast Flux Test Facility (FFTF) Site. The site investigation results are summarized in the Final Safety Analysis Report for the Fast Flux Test Facility (Westinghouse Hanford Company 1975). The site studies disclosed no evidence of surface rupture or displacement by faulting near the site.

V.4 Hydrology

The Probable Maximum Flood (PMF) of the Columbia River would not affect the 400 Area directly. The maximum water level under PMF conditions would be nearly 50 m below the site elevation.

The water table beneath the 400 Area occurs within the upper portion of the Ringold Formation at a depth of about 50 m. The groundwater movement is from west to east toward the Columbia River. A small amount of groundwater is withdrawn from the unconfined aquifer for sanitary use and cooling tower makeup, but the effect on groundwater level is not significant.

FIGURE V-1. 400 Area Site Plan

V.5 Meteorology

The lower elevation of the 400 Area, as compared to the HMS, and local topography produce variations in surface wind conditions. The 400 Area experiences somewhat higher average southwest winds while having a lower frequency of northeasterly winds than does the HMS. Table V-1 gives the annual average atmospheric dispersion factors around the 400 Area based on data from the Washington Public Power Supply System reactor site.

V.6 Ecology

The 400 Area is largely occupied by structures or otherwise disturbed from its natural state by construction activities. The loose sandy soil supports primarily a sagebrush/bitterbrush/cheatgrass vegetation community. There are no areas of unique or distinctive ecological character on the site.

V.7 Demography and Land Use

Figure V-1 shows the layout of the 400 Area and the designations of the various facilities. The principal activity in the 400 Area is breeder reactor research carried on at the Fast Flux Test Facility and the associated Fuels and Materials Examination Facility. The peak daytime (1981) working population of the 400 Area is approximately 1520.

The nearest residence to the 400 Area is approximately 8 km to the southwest. The Richland, Washington city limits are about 11 km to the southeast.

Tables V-2 and V-3 give the estimated 1980 and 1990 population distributions within 80 km (50 mi) of the 400 Area.

TABLE V-1. Annual Average Atmospheric Dispersion Around the 400 Area for a Ground-level Release (Units are sec/m³) (a) (After Sula et al. 1982, Table E.7)

Direction	Range in Miles (km)									
	0.5 (0.8)	1.5 (2.4)	2.5 (4.0)	3.5 (5.6)	4.5 (7.2)	7.5 (12.0)	15 (24)	25 (40)	35 (56)	45 (72)
N	5.7E-06	8.7E-07	3.9E-07	2.4E-07	1.6E-07	7.9E-08	3.1E-08	1.6E-08	1.0E-08	7.4E-09
NNE	5.0E-06	7.6E-07	3.4E-07	2.1E-07	1.4E-07	6.9E-08	2.7E-08	1.3E-08	8.7E-09	6.3E-09
NE	3.9E-06	5.9E-07	2.6E-07	1.6E-07	1.1E-07	5.3E-08	2.1E-08	1.0E-08	6.7E-09	4.9E-09
ENE	3.6E-06	5.5E-07	2.5E-07	1.5E-07	1.0E-07	5.0E-08	1.9E-08	9.8E-09	6.4E-09	4.6E-09
E	3.4E-06	5.1E-07	2.3E-07	1.4E-07	9.4E-08	4.6E-08	1.8E-08	9.0E-09	5.9E-09	4.3E-09
ESE	5.8E-06	8.8E-07	4.0E-07	2.4E-07	1.7E-07	8.0E-08	3.1E-08	1.6E-08	1.0E-08	7.5E-09
SE	7.2E-07	1.1E-06	4.9E-07	3.0E-07	2.1E-07	1.0E-07	3.9E-08	2.0E-08	1.3E-08	9.3E-09
SSE	7.2E-06	1.1E-06	4.7E-07	2.9E-07	2.0E-07	9.6E-08	3.8E-08	1.9E-08	1.2E-08	9.0E-09
S	5.5E-06	8.4E-07	3.8E-07	2.4E-07	1.6E-07	7.8E-08	3.0E-08	1.5E-08	1.0E-08	7.3E-09
SSW	4.4E-06	6.8E-07	3.1E-07	1.9E-07	1.3E-07	6.3E-08	2.5E-08	1.3E-08	8.2E-09	6.0E-09
SW	3.8E-06	5.9E-07	2.7E-07	1.7E-07	1.1E-07	5.5E-08	2.2E-08	1.1E-08	7.2E-09	5.2E-09
WSW	3.0E-06	4.6E-09	2.1E-07	1.3E-07	8.8E-08	4.3E-08	1.7E-08	8.5E-09	5.6E-09	4.0E-09
W	2.6E-06	4.1E-07	1.8E-07	1.2E-07	7.8E-08	3.8E-08	1.5E-08	7.5E-09	4.9E-09	3.6E-09
WNW	2.9E-06	4.4E-07	2.0E-07	1.2E-07	8.2E-08	4.0E-08	1.5E-08	7.8E-09	5.1E-09	3.7E-09
NW	3.6E-06	5.4E-07	2.4E-07	1.5E-07	1.0E-07	4.9E-08	1.9E-08	9.5E-09	6.2E-09	4.5E-09
NNW	5.4E-06	8.2E-07	3.7E-07	2.2E-07	1.5E-07	7.4E-08	2.9E-08	1.5E-08	9.5E-09	6.9E-09

(a) Calculated from meteorological data collected during the period 4-74 through 3-76.

TABLE V-2. Estimated Distribution of Population in 50 mile Radius of the FFTF By Population Grid Sector for the Year 1980
(After Sommers, et al. 1981)

Compass Direction	Number of People					Totals
	0-10 mi	10-20 mi	20-30 mi	30-40 mi	40-50 mi	
NORTH	0	78	859	811	16,267	18,015
NNE	20	343	5,728	2,945	1,021	10,057
NE	114	377	760	1,033	217	2,501
ENE	211	1,041	2,644	492	451	4,839
EAST	229	600	183	169	183	1,364
ESE	229	442	544	292	1,060	2,567
SE	344	25,267	13,654	2,105	952	42,322
SSE	10,829	40,933	5,688	719	2,364	60,533
SOUTH	11,760	9,385	1,525	5,611	15,691	43,972
SSW	1,446	4,550	583	185	1,927	8,691
SW	179	1,538	5,234	535	239	7,725
WSW	0	1,206	7,748	14,956	481	24,391
WEST	0	190	3,339	6,089	17,171	26,789
WNW	0	0	932	1,221	3,176	5,329
NW	0	0	295	903	705	1,903
NNW	0	0	264	1,302	1,182	2,748
TOTALS	25,361	85,950	49,980	39,368	63,087	263,746

TABLE V-3. Estimated Distribution of Population Within a 50-Mile Radius of the FFTF by Population Grid Sector for the Year 1990
(After Sommer, et al. 1981)

Compass Direction	Number of People					Totals
	0-10 mi	10-20 mi	20-30 mi	30-40 mi	40-50 mi	
NORTH	0	107	1,057	968	19,099	21,231
NNE	27	467	7,121	3,517	1,205	12,337
NE	156	513	997	1,293	270	3,229
ENE	288	1,415	3,598	671	611	6,583
EAST	312	817	249	211	208	1,797
ESE	312	602	634	324	1,176	3,048
SE	452	34,069	17,622	2,394	1,252	55,789
SSE	13,881	52,612	7,360	867	2,821	77,541
SOUTH	15,073	12,032	1,955	6,678	18,712	54,450
SSW	1,854	5,832	745	229	2,249	10,909
SW	228	1,971	6,709	638	279	9,825
WSW	0	1,546	9,109	17,380	559	28,594
WEST	0	244	3,946	7,076	19,951	31,217
WNW	0	0	1,149	1,416	3,659	6,224
NW	0	0	346	1,045	750	2,141
NNW	0	0	310	1,528	1,386	3,224
TOTALS	32,583	112,227	62,907	46,235	74,187	328,139

DISTRIBUTION

No of
Copies

No. of
Copies

OFFSITE

27 DOE Technical Information
Center

V. G. Trice
DOE Office of Nuclear Waste
Management
Washington, DC 20545

J. W. Rowen
DOE Office of Nuclear Waste
Management
Washington, DC 20545

E. F. Mastal
DOE Office of Nuclear Waste
Management
Washington, DC 20545

R. Scott
DOE Office of Nuclear Waste
Management
Washington, DC 20545

ONSITE

3 DOE Richland Operations Office

H. E. Ransom
J. L. Daily
P.F.X. Dunigan, Jr.

4 Hanford Engineering Development
Laboratory

G. D. Carpenter
R. W. Dascenzo
G. F. Larson
H. G. Ruppert

5 Rockwell Hanford Operations

S. A. Wiegman (2)
A. R. Hawkins
D. D. Wodrich
W. B. McIntyre

1 UNC Nuclear Industries

P. A. Carlson

50 Pacific Northwest Laboratory

P. E. Bramson
J. B. Brown
K. E. Byers (4)
G. R. Hoenes
D. J. Hoitink
J. D. Jamison (20)
W. E. Kennedy, Jr.
B. A. Napier
T. L. Page
W. H. Rickard
M. J. Sula
J. V. Robinson (4)
R. G. Schreckhise
J. K. Soldat
D. L. Streng
B. E. Vaughan
D. G. Watson
E. C. Watson
Technical Information Library (5)
Publishing Coordination (2)

RECIPIENTS OF PNL-3509 PT 2

If you wish to be on the distribution list for future report revisions, please fill out the form below and return it to J. D. Jamison.

REQUEST FOR REPORT REVISIONS

Name _____

Title and Affiliation _____

Address _____

Date _____ Signature _____

Please fill out this form and mail to:

J. D. Jamison
Battelle, Pacific Northwest Laboratory
P.O. Box 999
Richland, WA 99352