**Environmental
Characterization of Two
Potential Locations at
Hanford for a New
Production Reactor**

September 1984

**Prepared for the U.S. Department of Energy
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**Pacific Northwest Laboratory
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ENVIRONMENTAL CHARACTERIZATION OF TWO
POTENTIAL LOCATIONS AT HANFORD FOR A
NEW PRODUCTION REACTOR

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ENVIRONMENTAL CHARACTERIZATION OF TWO POTENTIAL LOCATIONS AT HANFORD FOR A NEW PRODUCTION REACTOR

1.D INTRODUCTION

This report describes various environmental aspects of two areas on the Hanford Site that are potential locations for a New Production Reactor (NPR). The area known as the Skagit Hanford Site is considered the primary or reference site. The second area, termed the Firehouse Site, is considered the alternate site.

The scope of this report encompasses an environmental characterization of these two potential NPR locations. It does not include an assessment of impacts of locating an NPR at either area. The information contained in this report will likely be used, along with similar data being developed for the Idaho Falls and Savannah River sites, in a follow-on study evaluating the siting of various reactor types at each of the three government reservations (Hanford, Idaho Falls, and Savannah River).

The body of this environmental characterization report covers eight subject areas, each in a separate chapter:

- geography and demography
- ecology
- meteorology
- hydrology
- geology
- cultural resources assessment
- economic and social effects of station construction and operation
- environmental monitoring.

Each chapter addresses both the Skagit/Hanford and Firehouse sites, where appropriate (i.e., environmental monitoring is a Hanford Site-wide activity and would not necessarily differ significantly between the two locations). In

addition, to the degree possible, the most recent information available on the various environmental aspects is presented. References are listed at the end of each chapter.^(a)

In addition, two documents are referred to throughout this report. These had been prepared to support a license application (later withdrawn) by Puget Sound Power & Light Company for construction of two commercial reactors at Hanford:

- Puget Sound Power & Light Company. 1981. Skagit/Hanford Units 1 and 2, Application for Site Certification/Environmental Report. Docket Nos. 50-522 and STN 50-523, Seattle, Washington.
- U.S. Nuclear Regulatory Commission and Washington State Energy Facility Site Evaluation Council. 1982. Draft Environmental Statement Related to the Construction of Skagit/Hanford Nuclear Project, Units 1 and 2. NUREG/0894, Washington, D.C.

Various appendixes are also included in this environmental characterization report. The material provides extensive supplemental information likely to be useful in the follow-on site characterization study.

(a) In some cases a copy of the reference document has been included when it was more efficient to do so than to incorporate the information contained in the reference in the text of the chapter.

2.0 GEOGRAPHY AND DEMOGRAPHY

In this chapter, geographic and demographic characteristics of the reference Skagit/Hanford Site and the alternate Firehouse Site are described.

2.1 SITE LOCATION AND DESCRIPTION

Both the Skagit/Hanford and the Firehouse sites are located on the U.S. Department of Energy's (DOE) Hanford Site, as shown in Figure 2.1. The Hanford Site is situated within the semiarid Pasco Basin, which makes up part of the Columbia Plateau in southeastern Washington State. The site occupies an area of about 1,480 km² (570 mi²) and is approximately 48 km (30 mi) north to south and 38 km (24 mi) east to west. The Hanford Site overlies the structural low point of the Pasco Basin and is bounded to the southwest, west, and north by large ridges that trend eastward and southeasterly from the Cascade Range, enter the Pasco Basin and die out within its confines. The site is bounded to the north and east by the Columbia River and the steep bluffs of the Ringold Formation. The Yakima River flows near the southern boundary of the site.

A thin mantle of wind-blown silts and sands covering layers of coarse sands and gravels constitutes the Hanford Formation underlying the site. The Hanford Formation, which is up to 60 m (200 ft) thick, resulted from catastrophic floods (Tallman et al. 1979) that occurred during the last ice age (Pleistocene). Sands, silts, and gravels of the Ringold Formation lying beneath the Hanford Formation gravels were deposited up to 300 m (1000 ft) thick during the Pleistocene. Beneath these younger sediments lies an accumulation of basaltic lava of the Columbia River basalt group that extruded over periods extending from 6 to 16 million years ago. Borehold measurements indicate the total basaltic lava accumulation beneath the Hanford Site is greater than 3,650 m (12,000 ft) thick (U.S. DOE 1982b).

On the Hanford Site, principal DOE operational areas are identified by area numbers; access to these areas is controlled and limited (U.S. DOE 1982a). The five major areas are as follows:

FIGURE 2.1. Location of Skagit/Hanford and Firehouse Sites Within the Hanford Site

- The 100 Areas, bordered to the north by the south shore of the Columbia River, house eight nonoperating plutonium production reactors and one operating dual-purpose (electrical power generation and plutonium production) reactor. The 100 Areas occupy about 1,090 ha (2,690 acres).
- The 200 Areas, located on a plateau about 11 km (7 mi) from the Columbia River, are the sites of fuel reprocessing as well as waste processing and management facilities. The 200 Areas cover about 1,560 ha (3,860 acres).
- The 300 Area, located 9 km (6 mi) north of the City of Richland, is the site of nuclear research and development and fuel fabrication. The 300 Area covers 152 ha (375 acres).
- The 400 Area is about 11 km (7 mi) north of the 300 Area and is the site of the Fast Flux Test Facility used in the testing of breeder reactor systems.
- The 600 Area includes all of the Hanford Site not occupied by the 100, 200, 300, or 400 areas. The 600 Area covers 145,000 ha (358,000 acres). Both the Skagit/Hanford and the Firehouse Sites are located within the 600 Areas.

Land use in areas surrounding the Hanford Site includes urban and industrial development, irrigated and dry-land farming, and grazing. Principal agricultural crops include hay, wheat, potatoes, corn, apples, soft fruit, hops, grapes, and vegetables. In recent years wine grapes have gained in importance. Industries in the nearby Tri-Cities are mainly those related to agriculture and energy production.

2.1.1 Skagit/Hanford Site

The reference Skagit/Hanford Site is the location of the now abandoned Puget Sound Power & Light Company (PSP&L) Skagit/Hanford Nuclear Project (S/HNP). Because the S/HNP envisioned twin reactors, the location of the NPR was taken to be the midpoint between the two reactors. Coordinates of that portion are:

<u>Latitude and Longitude</u>	<u>Universal Transverse Mercator</u>	<u>Lambert Coordinates (State of Washington) (ft)</u>
N46°29'15"	N5150900M	N422710
W119°25'57"	E313300 M	E2268840

The Skagit/Hanford Site is legally described as Section 33, the south half of Section 28, the west quarter of Section 34, and the west half of the southwest quarter of Section 27, all within Township 12N, Range 27E, Benton County. The site is approximately 8 km (5 mi) west of the Washington Public Power Supply System's Nuclear Project No. 2 Unit. It is approximately 13 km (8 mi) west of the Columbia River at River Mile 352, 11 km (7 mi) north of the Yakima River Horn Rapids Dam, and 19 km (12 mi) northwest of the City of Richland.

The Skagit/Hanford Site grade level varies between approximately 158 m (520 ft) and 165 m (540 ft) above mean sea level. This site has no major features; further, no public roads or railroads cross the site. The total area of the site is roughly 3.2 km^2 (2.0 mi^2).

Additional information on the Skagit/Hanford Site can be found in Section 4.2 of the draft environmental statement on the S/HNP (U.S. NRC 1982) and in Section 2.1.1 of the application for site certification/environmental report for the S/HNP (PSP&L 1981).

2.1.2 Firehouse Site

The alternative location for the NPR is the Firehouse Site, so-named because of the firehouse situated in the southwestern corner that serves the northern part of the Hanford Site.

A specific detailed survey to locate the midpoint of this site has not been performed. However, the approximate coordinates are N46°36' (latitude) and W119°33' (longitude). The legal description of the site is Section 3 within Township 13N, Range 26E, Benton County, and Section 34, Township 14N, Range 26, Benton County.

The site is bordered on the south by Route 1, and Route 4N passes from the southwestern corner through the northern border in a north-northeasterly

direction. The site is located approximately 4.8 km (3 mi) south of the Columbia River at River Mile 380, 4.8 km (3 mi) west of the White Bluffs Townsite, and 14 km (9 mi) northwest of the Hanford Townsite.

The Firehouse Site grade level varies between 158 m (520 ft) and 134 m (440 ft) above mean sea level; the terrain is gently sloping in a north-south direction. There are no major features on the site, although the Hanford Ditch (a canal constructed to provide irrigation water for orchards in and around the White Bluffs Townsite) cuts through the northwest corner. No public roads or railroads cross the site. The area of the Firehouse Site is 3.2 km² (20 mi²).

2.2 POPULATION DISTRIBUTION

The major population centers within a 50-mile radius of the Hanford Site are shown in Figure 2.2. The Tri-Cities area of Richland, Kennewick, Pasco, and West Richland lies southeast of Hanford and is both the largest population center and the center nearest to the site. Other major population centers include Yakima and the Yakima Valley towns to the west, Umatilla to the south, and Moses Lake to the north. The cities of Ellensburg and Walla Walla lie just beyond the 50-mile radius. Portions of Adams, Benton, Franklin, Grant, Kittitas, Walla Walla, Yakima, Morrow, and Umatilla Counties are contained within 50 miles of the Hanford Site. Both the primary and second NPR sites are indicated in Figure 2.2.

Because of the highly developed transportation network between the Tri-Cities and the Hanford Site, the Tri-Cities Standard Metropolitan Statistical Area (SMSA) is the area most likely to exhibit population impacts for both the primary and secondary NPR sites. Historical population figures for the Tri-Cities SMSA, which consists of Benton and Franklin Counties, are presented in Table 2.1. Population in the area grew 54.8 percent between the 1970 and 1980 census years, and growth continued through 1981. In 1982 the population declined, following the end of several thousand construction jobs at the WPPSS plants. During the period shown in Table 2.1, most of the population growth occurred in Benton County, with the population of the City of Kennewick more

FIGURE 2.2. Communities Within a 50-Mile Radius of the Hanford Site

TABLE 2.1. Historical Population Estimates for the Tri-Cities SMSA, 1970-1982^(a)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Tri-Cities SMSA	93,356	93,499	93,722	95,289	99,319	104,922	114,040	120,169	130,805	139,203	144,469	148,260	143,910
Benton County	67,540	67,069	67,214	68,264	71,850	77,054	84,341	90,365	98,238	104,941	109,444	112,010	108,724
Benton City	1,070	1,093	1,090	1,100	1,125	1,315	1,422	1,583	1,917	1,900	2,087	2,150	1,870
Kennewick	15,212	15,400	15,580	16,200	16,800	18,253	21,301	23,638	26,564	29,810	34,397	34,700	35,350
Prosser	2,954	2,975	2,990	3,050	3,100	3,104	3,150	3,335	3,400	3,788	4,049	4,120	4,170
Richland	26,290	26,300	26,350	26,600	28,000	28,600	30,009	31,050	32,350	35,550	33,578	33,700	33,550
West Richland	1,143	1,143	1,159	1,225	1,247	1,477	1,561	2,024	2,311	2,641	2,938	3,783	3,934
Franklin County	25,816	26,430	26,508	27,025	27,469	27,868	29,699	29,804	32,567	34,262	35,025	36,250	35,186
Pasco	13,920	13,920	14,000	14,050	14,100	14,450	14,618	15,375	16,000	16,370	18,425	18,700	19,050

(a) The use of HARC data for intercensal figures is necessary for consistency with mandated scenarios. Intercensal estimates are also available from the Washington State Office of Financial Management (1980).

Source: Bureau of the Census (1972, 1982) for 1970 and 1980.
Battelle, Human Affairs Research Centers for other years.

than doubling for the period. Franklin County had slower, but steady, growth during the 1970 to 1981 period, and, like Benton County, exhibited a slight decline in population in 1982.

Table 2.2 gives the age distribution for the Tri-Cities SMSA for the census years 1970 and 1980. The most significant changes over the period are the decrease in the number of school-aged children and the increase in adults between 25 and 34 years old as percentages of total population. The increase in the adults was probably tied to the construction job activity that occurred at Hanford in the 1970s.

TABLE 2.2. Age Distribution for the Tri-Cities SMSA, 1970 and 1980 (percent of total population)

<u>Age Range</u>	<u>1970</u>	<u>1980</u>
0 to 14 years	31	26
15 to 24 years	18	18
25 to 34 years	12	19
35 to 44 years	12	12
45 to 54 years	12	10
55 to 64 years	9	8
65 to 74 years	2	5
75 years and over	2	2

Source: Bureau of the Census (1972, 1982).

2.2.1 Population Within Ten Miles

Figure 2.3 shows the estimated 1980 population within a 10-mile radius that uses the Skagit/Hanford Site as the geographic center of reference. Population estimates are shown for 16 compass direction sections and for rings representing distances of 1, 2, 3, 4, 5, and 10 miles from the site. The estimates shown for 1980 are based on a house count conducted in 1981 (PSP&L 1981). As these data indicate, the nearest residence was 7.5 miles away. Based on average household data for the area, it was estimated that 357 people

RING IN MILES	0-1	1-2	2-3	3-4	4-5	5-10	Total 0-10
POPULATION	0	0	0	0	0	357	357

Source: Puget Sound Power & Light Company (1981).

FIGURE 2.3. Population Within 10 Miles of the Skagit/Hanford Site, 1980

resided within 10 miles of the site, all in southerly to easterly directions. These 357 people represented about 0.13 percent of the approximately 280,000 residents living within the 50-mile radius.

Projected population within 10 miles of the site for the census years 1990 through 2030 is shown in Figures 2.4 through 2.8. These population projections are based on county-level forecasts for the states of Washington and Oregon and are taken directly from the Skagit/Hanford Site certification study (PSP&L 1981). The projection calculations assume that, after the year 2000, population growth will gradually stabilize within a 50-mile radius of the NPR Site. For each of the census years from 2010 to 2030 it was estimated that the rate of population increase would decline by one-half of the rate prevalent in the preceding decade. No major land use changes were projected for the Hanford Site and population growth is expected to be concentrated in areas that actually had residents in 1980 (PSP&L 1981). These projections assume that WNP-1 and WNP-4 are still under construction and, therefore, are probably high estimates of future population.

Given the above procedure, projections for population within 10 miles of the primary NPR site are 513 in 1990, 639 in 2000, 683 in 2010, 691 in 2020, and 691 in 2030. Based on these projections, the population within 10 miles of the NPR will increase 93.6 percent between 1980 and 2030.

2.2.2. Population Between Ten and Fifty Miles

Figure 2.9 gives the sector estimates of the 1980 population living between 10 and 50 miles from the primary NPR site. These estimates are based on 1980 Census of Population data for blocks, tracts, and enumeration districts, and show that approximately 279,000 people lived between 10 and 50 miles from the site in 1980 (Bureau of the Census 1982). As indicated in Figure 2.9, the bulk of the population within 30 miles was concentrated in the Tri-Cities area in the southeast and south-southeast sectors. Other major concentrations of population were in the 40- and 50-mile ring. The 1980 population distribution for the Firehouse Site is given in Table 2.3.

RING IN MILES	0-1	1-2	2-3	3-4	4-5	5-10	Total 0-10
POPULATION	0	0	0	0	0	513	513

Source: Puget Sound Power & Light Company (1981).

FIGURE 2.4. Population Within 10 Miles of the Skagit/Hanford Site, 1990

RING IN MILES	0-1	1-2	2-3	3-4	4-5	5-10	Total 0-10
POPULATION	0	0	0	0	0	639	639

Source: Puget Sound Power & Light Company (1981).

FIGURE 2.5. Population Within 10 Miles of the Skagit/Hanford Site, 2000

RING IN MILES	0-1	1-2	2-3	3-4	4-5	5-10	Total 0-10
POPULATION	0	0	0	0	0	683	683

Source: Puget Sound Power & Light Company (1981).

FIGURE 2.6. Population Within 10 Miles of the Skagit/Hanford Site, 2010

RING IN MILES	0-1	1-2	2-3	3-4	4-5	5-10	Total 0-10
POPULATION	0	0	0	0	0	691	691

Source: Puget Sound Power & Light Company (1981).

FIGURE 2.7. Population Within 10 Miles of the Skagit/Hanford Site, 2020

RING IN MILES	0-1	1-2	2-3	3-4	4-5	5-10	Total 0-10
POPULATION	0	0	0	0	0	691	691

Source: Puget Sound Power & Light Company (1981).

FIGURE 2.8. Population Within 10 Miles of the Skagit/Hanford Site, 2030

TABLE 2.3. Distribution of 1980 Population Within a 50-Mile Radius of the Firehouse Site^(a)

Compass Direction	0-10 Miles	10-20 Miles	20-30 Miles	30-40 Miles	40-50 Miles	Totals
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	305	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	4,597	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	75,636	82,184
WNW	54	573	377	490	1,598	3,042
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

(a) The 100-N Reactor was used as the geographic center of reference.

Source: Sommer, Rau and Robinson (1981).

RING IN MILES	10-20	20-30	30-40	40-50	Total 10-50	Total 0-50
POPULATION	53,532	115,691	30,284	79,364	278,871	279,228

Source: Puget Sound Power & Light Company (1981).

FIGURE 2.9. Population Between 10 and 50 Miles from the Skagit/Hanford Site, 1980

Figures 2.10 through 2.14 give the population projections for the 10- to 50-mile area surrounding the Skagit/Hanford Site. These projections were estimated in a manner similar to the projections within 10 miles of the site, and use the same assumptions discussed in Section 2.2.1. In particular, they assume that WNP-1 and WNP-4 are currently under construction; hence, the projections are probably high estimates of future population. In addition, the distribution of population growth is assumed to be equal throughout each of the counties included within the 50-mile radius, with the major exceptions of Benton and Franklin Counties, which are nearest the site. Based on interviews with local planners and city officials and a review of land use and annexation plans, a number of areas within the Tri-Cities are identified as having high growth potential. These areas include the Horn Rapids Triangle in Richland, the Horn-Willamette area in West Richland, and northwest Pasco near the new I-182 bridge. For the projections for 1990 to 2030, the enumeration districts and census blocks corresponding to these areas were assumed to grow at twice the rate of the remainder of the metropolitan area. Several areas were projected to sustain growth from 2000 to 2010. However, after 2010, all areas were projected to stabilize and generally parallel the overall metropolitan area growth rates (PSP&L 1981).

Following this methodology, the 10- to 50-mile population would be 339,000 in 1990, 393,000 in 2000, 426,000 in 2010, 432,000 in 2020, and 433,000 in 2030. The 2030 projected population represents a 55.2 percent increase over the 1980 population. The 1990 projected population distribution for the Firehouse Site is given in Table 2.4.

2.2.3 Transient Population

The transient population of both the Skagit/Hanford and Firehouse sites consists of agricultural workers, industrial and construction workers, and sportspersons engaged in hunting and fishing. The transiency of agricultural workers and sportspersons is seasonal, while the transiency of industrial and construction workers varies daily and by the amount of available work. Table 2.5 lists the total transient population within 10 miles of the Skagit/Hanford Site by location, direction, and distance. Industrial and construction workers make up the bulk of the transient population and are the

RING IN MILES	10-20	20-30	30-40	40-50	Total 10-50	Total 0-50
POPULATION	73,150	142,928	35,143	87,943	339,164	339,677

Source: Puget Sound Power & Light Company (1981).

FIGURE 2.10. Population Between 10 and 50 Miles from the Skagit/Hanford Site, 1990

RING IN MILES	10-20	20-30	30-40	40-50	Total 10-50	Total 0-50
POPULATION	88,631	162,952	40,713	101,058	393,354	393,993

Source: Puget Sound Power & Light Company (1981).

FIGURE 2.11. Population Between 10 and 50 Miles from the Skagit/Hanford Site, 2000

RING IN MILES	10-20	20-30	30-40	40-50	Total 10-50	Total 0-50
POPULATION	99,134	172,985	43,308	110,703	426,130	426,813

Source: Puget Sound Power & Light Company (1981).

FIGURE 2.12. Population Between 10 and 50 Miles from the Skagit/Hanford Site, 2010

RING IN MILES	10-20	20-30	30-40	40-50	Total 10-50	Total 0-50
POPULATION	101,063	174,882	43,924	112,288	432,157	432,848

Source: Puget Sound Power & Light Company (1981).

FIGURE 2.13. Population Between 10 and 50 Miles from the Skagit/Hanford Site, 2020

RING IN MILES	10-20	20-30	30-40	40-50	Total 10-50	Total 0-50
POPULATION	101,240	175,063	44,004	112,488	432,795	433,486

Source: Puget Sound Power & Light Company (1981).

FIGURE 2.14. Population Between 10 and 50 Miles from the Skagit/Hanford Site, 2030

TABLE 2.4. Projected 1990 Population Distribution Within a 50-Mile Radius of the Firehouse Site^(a)

<u>Compass Direction</u>	<u>0-10 Miles</u>	<u>10-20 Miles</u>	<u>20-30 Miles</u>	<u>30-40 Miles</u>	<u>40-50 Miles</u>	<u>Totals</u>
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	3,161	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	1,037	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

(a) The 100-N Reactor was used as the geographic center of reference.

Source: Sommer, Rau and Robinson (1981).

TABLE 2.5. Transient Population Within 10 Miles
of the Skagit/Hanford Site

<u>Location</u>	<u>Peak Transient Population</u>	<u>Equivalent Permanent Population</u>	<u>Distance in Miles</u>	<u>Direction</u>
WNP-2	295	76	4.5-5	ESE
Refueling	200	14		
FFTF	1,187	305	4.5-5	SE
200 East	2,069	533	5-8.8	NW
200 West	1,361	351	8.5-10	WNW
H. J. Ashe Substation	1 ^(a)	<1	5	E
Central Landfill	2	<1	2	NW
Arid Lands Ecology	24	6	8.5-10	SW
Rattlesnake Mountain Observatory	35	12	8.5-10	SW
Migrant Workers	300	75	8.5-10	NNE-ESE
Fishermen	14,000 ^(b)	14	6-10	NE-2
Hunters	2,910 ^(b)	3	8.5-10	ENE-E

(a) Nine crew members report daily to the substation for work assignment.

(b) Person days per year.

Source: Puget Sound Power & Light Company (1981).

group whose numbers are the most variable over time. The 100-N reactor is the major source of industrial employment within 5 miles of the Firehouse Site, with 993 workers in 1981.

With the delay of WNP-1 and the termination of WNP-4, WNP-2 is the remaining Washington Public Power Supply System plant attracting transient workers. If WNP-1 were restarted, however, about 5500 construction workers could be expected within 10 miles of the Skagit/Hanford Site until plant completion, when transient population figures would be similar to those for WNP-2. No increase in workers is projected for WNP-4. The Fast Flux Test Facility (FFTF), operated by Westinghouse Hanford Company for DOE, has a transient work

force of 1,187. The 200-East and 200-West Areas in the northwest quadrant of Hanford employ a total of 3,430 persons. Workers in these two areas are employed by DOE or its contractors.

The Arid Lands Ecology (ALE) Reserve and the Rattlesnake Mountain observatory are located southwest of the Skagit/Hanford Site. The ALE Reserve employs 24 persons, while the observatory has a normal daytime staff of 19 persons. However, as many as 35 people may be present at the observatory on a given day, and several persons may be staying overnight (PSP&L 1981). The H. J. Ashe Electrical Substation is located 4.5 miles east of the Skagit/Hanford Site, and is operated by the Bonneville Power Administration as part of its transmission system. Workers at the substation consist of one operator who works eight hours per day, five days per week, and nine additional crew members who report daily for work assignments. The central landfill located 2.5 miles north-northwest of the site employs two workers eight hours per day, five days per week (PSP&L 1981).

No agricultural activity exists on the Hanford Site itself but there is farming across the Columbia River to the northeast and southeast of the Skagit/Hanford Site. Migrant farm workers may be present in these areas within 8 to 10 miles. Most of the migrant workers are present in the spring and early summer; a 1981 survey (PSP&L) indicated that up to 300 migrants may be working within the 10-mile radius during those months.

Fishing and hunting are the primary recreational activities found within 10 miles of the Skagit/Hanford Site, and are focused on the Columbia and Yakima Rivers. The number of sportspersons varies with the season, weather, day of the week, and time of day. The area is used most heavily for both hunting and fishing on weekends and holidays in the early morning hours. The main hunting season is from mid-October through January; it was estimated that during the season, 10 hunters are present on weekdays and 50 hunters are present on weekends and holidays, on average. Most of the hunters are in the 8- to 10-mile range from the site, east and east-northeast at the Wahluke Game Hunting Area. The main fishing season is from June to November; and it was estimated that 50 people on weekdays and 100 people on weekends are fishing within 10 miles of the Skagit/Hanford Site. Some fishing takes place on the Columbia River south

of the Ringold Fish Hatchery toward Richland. It was estimated that the peak number of persons hunting or fishing in the area did not exceed 1000 at a given time (PSP&L 1981).

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3.0 ECOLOGY

This chapter presents a detailed description of the terrestrial and aquatic plants and animals found on the Hanford Site and in the nearby Columbia River. Species known to inhabit both the Skagit/Hanford and Firehouse sites are characterized in terms of their abundance, habitats, interrelationships, and subjectivity to human intervention.

3.1 TERRESTRIAL ECOLOGY

3.1.1 Plants and Habitat Description of the Skagit/Hanford Site

The Skagit/Hanford (primary) site is located mostly in the sagebrush-bitterbrush/ cheatgrass plant community and extends slightly into the sagebrush/ cheatgrass community (Figure 3.1). The sagebrush-bitterbrush/ cheatgrass community occurs on sandy soils and stabilizes old sand dunes. Sagebrush dominates low areas between sand dunes, while bitterbrush occurs primarily on the dune tops. Associated shrubs of this community are gray rabbitbrush, green rabbitbrush, hopsage, and snowy buckwheat. The grasses include Sandberg bluegrass, Indian rice grass, thick-spike wheatgrass and needle-and-thread grass. The common forbs include terpenate cymopterus, long-leaf phlox, stalked-pod milkvetch, Lyall's milkvetch, Carey's balsamroot, pale evening primrose, lance-leaf scurf-pea, winged cryptantha, spring draba, and western tansy mustard. Starvation cactus is also common in the sagebrush-bitterbrush/cheatgrass community (PSP&L 1981).

The western edge of the primary site extends into the sagebrush/ cheatgrass plant community. This community is dominated by sagebrush and cheatgrass, with scattered hopsage and rabbitbrush interspersed with sagebrush. The understory is dominated by cheatgrass with Sandberg bluegrass being common. The most abundant perennial forbs are long-leaf phlox and Carey's balsamroot. The annuals include six-week fescue, spring draba, jagged chickweed, Indian-wheat and western tansy mustard (PSP&L 1981). The important plant species associated with the primary site are tabulated in Appendix A. Cline et al. (1977) report on the plants and soil of a sagebrush community on the Hanford Site. They also characterized the sagebrush/cheatgrass community.

FIGURE 3.1. Major Vegetation Types of the Hanford Site (from Cline et al. 1977)

The average understory cover was 38 percent. Cheatgrass, an annual grass, was the dominant species, providing 18 percent of the herbaceous cover. Sagebrush was the conspicuous shrub, providing 15 to 20 percent of the total cover. Biomass production of the herbaceous species was approximately 40 g/m².

Much of the primary site has been burned in the past. These range fires have eliminated sagebrush, bitterbrush, and hopsage. The resulting plant communities are strongly dominated by cheatgrass. Species that were found in the sagebrush or sagebrush-bitterbrush dominated communities before fires are usually well represented, but diversity appears lower in burned-over areas (PSP&L 1981, p 2.2-2).

In the past, some of the primary site consisted of active sand dunes. Vegetation has stabilized most of these dunes but, in some areas, vegetation is sparse and the sand is actively moving. The blowouts are distinctive in the types of plants they contain. Perennial forbs predominate, including gray cryptantha, Franklin's sandwort, sand-dune penstemon, silverleaf phacelia, and lance-leaf scurf-pea. These areas are not dominated by cheatgrass or shrubs, although small amounts of cheatgrass may be present, and an occasional bitterbrush may be found. A few annual forbs, such as annual burweed, are found in this community (PSP&L 1981, p. 2.2-2).

3.1.2 Soils of the Skagit/Hanford Site

Hajek (1966) provides a detailed description of the soils on the Hanford Site; specific soil types are presented in Figure 3.2. The soils in the vicinity of the primary site are generally sandy with little potential for cropland use without irrigation. Four types are found: Rugers sand, Burbank loam sand, ephrata sandy loam, and dune sand. Detailed characteristics of these soils are presented in Appendix A.

The soils in the sagebrush/cheatgrass community are sandy loams dominated by sand, followed by silt and clay. Clay-sized particles are scarce, making up only 1 percent of the texture size classes. This implies that the moisture-holding capacity and cation exchange of the site's soil profile are low. Also, sandy soils are subject to serious wind erosion when disturbed. The pH of the surface soils is alkaline, and alkalinity increases with profile depth. Soluble salts are low, indicating that salinity (excess salts) is not

FIGURE 3.2. Soil Types of the Hanford Reservation

a hindrance to plant growth, at least in the upper soil. Organic matter is low, indicative of low soil nitrogen levels.

Glad (1981) described the soil chemistry of the sagebrush-bitterbrush/cheatgrass vegetation community as characteristic of Rupert sand with scattered dune sand. Data on sixteen parameters, including pH, bicarbonate, conductivity, sulfate, chlorine, fluoride and ten elemental concentrations, are summarized in Appendix A.

3.1.3 Wildlife of the Skagit/Hanford Site

3.1.3.1 Invertebrates

Numerous studies have been conducted on invertebrate inhabiting the Hanford Site (Rogers and Woodley 1978; Rogers et al. 1977; Rogers and Rickard 1975; Rogers 1979; Fitzner et al. 1979; Rogers and Fitzner 1980). Table 3.1 provides a list of the major insect taxa and the shrubs with which they are most commonly associated on the 200-Area plateau.

Rogers (1978) studied darkling beetles and provides extensive data on their abundance across the Hanford Site. Rogers and Fitzner (1980) provide additional data on darkling beetles within 2 miles of the primary site and near Washington Public Power Supply System's nuclear power plant site No. 1. The plant community here was a sagebrush-bitterbrush/cheatgrass community. Additional data were collected in a sagebrush/cheatgrass community on the 200 Area plateau. The data on darkling beetles from these two plant communities probably typify the species expected on the primary site. Because all naturally occurring animal populations are dynamic (ever-changing), the studies conducted today would not necessarily yield data of the same nature as that collected by Rogers and Fitzner (1980). Year-to-year variations in temperature and humidity will affect abundance and distribution of insects.

The ant populations of the Hanford 300 area waste burial grounds were characterized by Fitzner et al. (1979). The species encountered were Solenopsis molesta, Pogonomyrmex owyheei, Formica subpolita, and Formica manni. The habits of each species are provided in Fitzner et al. (1979). Ants are of some concern in radioactive waste management, since they can

TABLE 3.1. Relative Abundance (Percent) of Insect Taxa Collected from Sagebrush, Rabbitbrush, and Hopsage (Rogers 1979)

<u>Taxa</u>	<u>Sagebrush</u>	<u>Rabbitbrush</u>	<u>Hopsage</u>
Hemiptera (true bugs)	44.6	11.7	6.4
Homoptera (bugs)	33.0	31.2	6.1
Orthoptera (grasshoppers)	7.3	24.0	21.8
Araneida (spiders)	6.5	20.7	21.3
Hymenoptera (ants, bees, wasps)	4.2	2.9	5.8
Coleoptera (beetles)	1.7	1.9	27.4
Lepidoptera (butterflies, moths)	1.2	6.1	5.3
Diptera (flies)	1.1	1.2	5.3
Neuroptera (lace wings)	0.3	0.3	0.3
Other	0.1	0.1	0.3

excavate soil to a depth of several meters. Buried waste can thus be transported from shallow waste burial sites to the surface. Grasshopper abundance has been examined by Rogers (1976).

Specific details on insect abundance and location are noted in Appendix A (Tables A.5 through A.7).

3.1.3.2 Reptiles and Amphibians

The Hanford Site is not rich in cold-blooded vertebrates. Table 3.2 lists 21 species that may occur on the site; of these, only 11 have been observed (Rogers and Rickard 1977, p. 3.37). Trapping studies using drift fencing and pit-traps indicate that green racers (Coluber constrictor mormon) and gopher snakes (Pituophis melanoleucus) occur in about equal numbers on the 200 Area Plateau. Striped whipsnake (Masticophis taeniatus), desert night snake (Hypsiglena torquata) and Northern Pacific rattlesnake (Crotalus viridis) also can be expected on the primary site; however, these species have fairly specific habitat requirements that limit their distribution.

Lizards may be the most important group of cold-blooded vertebrates from a density and biomass consideration. Species observed on the 200 Area Plateau (Rogers and Rickard 1977, p. 3.35) are the side-blotched lizard (Uta stansburiana), sagebrush lizard (Sceloporus graciosus) and pigmy short-horned

TABLE 3.2. Amphibian and Reptile Species Observed on the Hanford Reservation (Rogers and Rickard 1977)

<u>Common Name</u>	<u>Scientific Name</u>	<u>Occurrence</u>
<u>Amphibians</u>		
Great Basin Spadefoot Toad	<u>Scaphiopus intermontanus</u>	U ^(a)
Western Toad	<u>Bufo boreas</u>	U
Pacific Treefrog	<u>Hyla regilla</u>	
<u>Reptiles</u>		
Sagebrush Lizard	<u>Sceloporus graciosus</u>	U
Side-blotched Lizard	<u>Uta stansburiana</u>	C
Pigmy Short-horned Lizard	<u>Phrynosoma douglassi</u>	U
Striped Whipsnake	<u>Masticophis taeniatus</u>	O
Western Yellow-bellied Racer	<u>Coluber constrictor</u>	C
Gopher Snake	<u>Pituophis melanoleucus</u>	C
Desert Night Snake	<u>Hypsiglena torquata</u>	R
Northern Pacific Rattlesnake	<u>Crotalus viridis</u>	C
<u>Reptiles and amphibians for which sightings have not yet occurred</u>		
Long-toed Salamander	<u>Ambystoma macrodactylum</u>	
Tiger Salamander	<u>Ambystoma tigrinum</u>	
Woodhouse's Toad	<u>Bufo woodhousei</u>	
Leopard Frog	<u>Rana pipiens</u>	
Bullfrog	<u>Rana catesbeiana</u>	
Painted Turtle	<u>Chrysemys picta</u>	
Western Fence Lizard	<u>Sceloporus occidentalis</u>	
Western Skink	<u>Eumeces skiltonianus</u>	
Common Garter Snake	<u>Thamnophis sirtalis</u>	
Western Terrestrial Garter Snake	<u>Thamnophis elegans</u>	

(a) U=Uncommon, C = Common, R = Rare

lizard (Phrynosoma douglassi). The sagebrush and pigmy short-horned lizard are restricted primarily to sandy areas, while the side-blotched lizard is more widespread. Figure 3.3 provides a graphic representation of population levels, hatching dates, and dates of hibernation for the sagebrush and side-blotched lizard. By using 20 x 20 m (400-m²) pit-trapping grids, density estimates of side-blotched lizards on the 200 Area Plateau were estimated to range from 15 to 25 lizards per hectare. Because the average weight of an

FIGURE 3.3. Seasonal Variations in Lizard Populations (Rogers and Rickard 1977)

individual lizard was 3.5 g, density estimates ranged from 52.5 to 87.5 g of lizard biomass per hectare.

Amphibians on the Hanford Site are found primarily on the Columbia River shoreline and near waste ponds associated with the 200 Areas.

3.1.3.3 Mammals

Thirty-nine mammalian species, listed in Table 3.3, are reported to inhabit the Hanford Site; twelve of these are bats.

Small mammals have been studied intensively on the 200 Area Plateau near the B-C crib and a nearby control area (Hedlund and Rogers 1976). The Great Basin pocket mouse is by far the most pervasive species found on the Skagit/Hanford site. Table 3.4 provides the percentage composition of small mammal populations inhabiting a sagebrush-bitterbrush/cheatgrass community near the Washington Public Power Supply System's nuclear power plants and populations inhabiting a sagebrush/cheatgrass association on the 200 Area

TABLE 3.3. Mammals of the Hanford Reservation (Rogers and Rickard 1977)

<u>Common Name</u>	<u>Scientific Name</u>
Vagrant shrew	<u>Sorex vagrans</u>
Black-tailed hare	<u>Lepus californicus</u>
White-tailed hare	<u>Lepus townsendii</u>
Nuttall cottontail	<u>Sylvilagus nuttallii</u>
Townsend ground squirrel	<u>Citellus townsendii</u>
Northern pocket gopher	<u>Thomomys talpoides</u>
Great Basin pocket mouse	<u>Perognathus parvus</u>
Beaver	<u>Castor canadensis</u>
Western harvest mouse	<u>Reithrodontomys megalotis</u>
Deer mouse	<u>Peromyscus maniculatus</u>
Northern grasshopper mouse	<u>Onychomys leucogaster</u>
Bushy-tailed wood rat	<u>Neotoma cinerea</u>
Sagebrush vole	<u>Lagurus curtatus</u>
Montana meadow mouse	<u>Microtus Montanus</u>
Muskrat	<u>Ondatra zibethica</u>
Norway rat	<u>Rattus novegicus</u>
House mouse	<u>Mus musculus</u>
Porcupine	<u>Erethizon dorsatum</u>
Coyote	<u>Canis latrans</u>
Raccoon	<u>Procyon lotor</u>
Mink	<u>Mustela vison</u>
Long-tailed weasel	<u>Mustela frenata</u>
Badger	<u>Taxidea taxus</u>
Striped skunk	<u>Mephitis mephitis</u>
Bobcat	<u>Lynx rufus</u>
Mule deer	<u>Odocoileus hemionus</u>
Elk	<u>Cervus canadensis</u>
Little brown myotis bat	<u>Myotis lucifugus</u>
Fringed myotis bat	<u>Myotis thysanodes</u>
California myotis bat	<u>Myotis californicus</u>
Small-footed myotis bat	<u>Myotis subulatus</u>
Hairy-winged myotis bat	<u>Myotis volans</u>
Long-eared myotis	<u>bat Myotis erotis</u>
Hoary bat	<u>Lasiurus cinereus</u>
Silvery-haired bat	<u>Lasionycteris noctivagans</u>
Big brown bat	<u>Eptesicus fuscus</u>
Western pipistrelle bat	<u>Pipistrellus hesperus</u>
Pallid bat	<u>Antrozous pallidus</u>
Lump-nosed bat	<u>Plecotus townsendii</u>

Plateau. Additional data pertinent to the primary site are available in Rickard and Gano (1979).

Eight medium-sized mammals are known to inhabit the Hanford Site. These are muskrat, beaver, porcupine, jackrabbit, cottontail, coyote, badger, and

TABLE 3.4. Percentage Composition of Small Mammal Populations Inhabiting Common Habitat Types of the Hanford Site

	Habitat	
	Sagebrush ^(a) Cheatgrass	Sagebrush-Bitterbursh/ ^(b) Cheatgrass
Pocket Mouse (<u>Perognathus parvus</u>)	93% ^(c)	83%/418 ^(d)
Deer Mouse (<u>Peromyscus maniculatus</u>)	6%	13%/65
N. Grasshopper mouse (<u>Onychomys leucogaster</u>)	1%	3%/15
W. Harvest Mouse (<u>Reithrodontomys megalotis</u>)	---	2%/8
Sagebrush vole (<u>Lagurus curtatus</u>)	4%	---
Mountain vole (<u>Microtus montanus</u>)	---	---

(a) Adapted from Rogers and Rickard 1977.

(b) References adapted from WPPSS 1980.

(c) Percent of total capture; actual numbers captured not presented.

(d) Percent of total capture/actual numbers captured.

raccoon (Rogers and Rickard 1977, p. 3.10-3.11). The muskrat, beaver, and raccoon are associated with riparian habitats and the Columbia River. Porcupines occur throughout the Hanford Site but are most abundant in areas containing trees. The Columbia River shoreline and waste ponds contain trees used by this species.

Jackrabbits occur over most of the Hanford Site, and are abundant in the primary site. This species has been documented as a vector of radioactive materials away from waste burial sites. During the late 1950s or early 60s, burrowing animals (probably badgers or coyotes) exposed buried radioactive salts, creating a salt lick for other wildlife species. Jackrabbits were attracted to this salt lick and thus ingested radioactivity. This radioactive material was excreted in urine and deposited as fecal pellets over distances

up to 1.6 km from the waste burial sites (O'Farrell et al. 1973). Uresk et al. (1975) provide data on the foods eaten by jackrabbits.

Cottontail rabbits occur throughout the 200 Area Plateau (Rogers and Rickard 1977, p. 3.11). They are less abundant than jackrabbits and are associated more with riparian habitats and irrigated areas. They are commonly associated with the irrigated lawns of the 100-N Area.

Coyotes and badgers are often observed on the primary site. They both dig burrows and are potential agents for uncovering buried radioactive wastes. Both species feed primarily on small mammals. Springer (1977) and Stoel (1976) provide information on movement patterns and food habits of coyotes. Coyote movements vary seasonally, with individuals sometimes being very limited in range while at other times their movements are extensive. The foods of coyotes are predominately small rodents (Great Basin pocket mice, microtines) and lagomorphs.

Two large mammals, the mule deer and elk, occur on the Hanford Site. Elk are found primarily on the ALE reserve (Rattlesnake Hills) while deer range over the entire site. Deer are abundant within certain habitats, especially along the Columbia River, near Gable Mountain, and in Snively Canyon. The Hanford herd is not totally confined to the site boundaries; one deer was shot by a hunter 113 km north of the Hanford Site (Eberhardt et al. 1979).

Dietary habits of Hanford deer are reported by Uresk and Uresk (1980). They identified 44 food items in fecal pellets. The composition of pellets collected for three study sites on the 200 Area Plateau are listed in Table 3.5. These data suggest that mule deer inhabiting the Hanford Reservation can serve as a pathway for movement of radioactive material from low-level radioactive waste management areas to man. Uresk and Uresk (1980) found maximum levels of ^{137}Cs in fecal pellets of 100 pCi/g and 128 pCi/g for the B-Pond and Gable Mountain Pond areas, respectively. Maximum ^{90}Sr values found in deer pellets at B-Pond were 107 pCi/g and 184 pCi/g at Gable Mountain Pond. These values indicate that mule deer can consume radioactive materials through forage plants growing in radioactive waste management sites.

TABLE 3.5. Botanical Composition of Fecal Pellets Collected from Mule Deer During 1976 from Three Habitats on the Hanford Site (Uresk and Uresk 1980)

	B-C Cribs (N=20)	B Pond (N=40)	Gable Pond (N=40)
	$\bar{x} \pm SE$	$\bar{x} \pm SE$	$\bar{x} \pm SE$
<u>Grasses and Grass-like Plants</u>			
Needle-and-thread (<i>Stipa comata</i>)	<0.5		
Sandberg bluegrass (<i>Poa sandbergii</i>)	<0.5	0.6±0.3	<0.5
Bluebunch wheatgrass (<i>Agropyron spicatum</i>)			<0.5
Canary grass (<i>Phalaris arundinacea</i>)			0.6±0.6
Three-awn (<i>Aristida</i> spp.)			<0.5
Cheatgrass (<i>Bromus tectorum</i>)	<0.5	1.7±0.6	3.4±1.1
Carex (<i>Carex</i> spp.)		<0.5	<0.5
Horsetail (<i>Equisetum</i> spp.)		<0.5	2.1±1.1
Barnyard grass (<i>Echinochloa crusgallii</i>)		6.8±1.3	
Muhly grass (<i>Muhlenbergia</i> sp.)			<0.5
Indian ricegrass (<i>Oryzopsis hymenoides</i>)			<0.5
Old withchgrass (<i>Panicum</i> sp.)		<0.5	<0.5
Cattail (<i>Typha latifolia</i>)			<0.5
Sand dropseed (<i>Sporobolus cryptandrus</i>)		<0.5	
<u>Forbs</u>			
Astragalus (<i>Astragalus</i> spp.)	<0.5	<0.5	1.9±1.7
Bassia (<i>Bassia hyssopsfolia</i>)			4.4±1.6
Tansy mustard (<i>Descurainia pinnata</i>)		<0.5	
Wild lettuce (<i>Lactuca scariola</i>)			1.9±0.7
Bladderpod (<i>Lesquerella</i> sp.)			<0.5
Lupine (<i>Lupinus</i> spp.)		<0.5	<0.5
White sweet clover (<i>Melilotus alba</i>)	3.5±2.2 ^(a)		23.2±3.9
Microsteris (<i>Microsteris</i> sp.)		<0.5	
Evening-primrose (<i>Oenothera</i> spp.)	8.7±3.5	0.9±0.7	<0.5
Phlox (<i>Phlox longiflora</i>)			<0.5
Prickly pear (<i>Opuntia polycantha</i>)		<0.5	
Indian wheat (<i>Plantago purshii</i>)			<0.5
Willow-weed (<i>Epilobium paniculatum</i>)		<0.5	<0.5
Russian thistle (<i>Salsola kali</i>)	2.9±0.7	75.5±4.0	5.2±2.2
Jim Hill mustard (<i>Sisymbrium altissimum</i>)			<0.5
Goldenrod (<i>Solidago</i> spp.)	1.4±0.4 ^(a)	6.1±1.9	39.7±5.4
Globe mallow (<i>Sphaeralcea munroana</i>)	<0.5	10.9±4.4	1.8±1.0
Buttercup (<i>Ranunculus</i> spp.)			<0.5
Common mullen (<i>Verbascum thapsus</i>)	<0.5 ^(a)	1.9±1.9	
<u>Shrubs</u>			
Big sagebrush (<i>Artemisia tridentata</i>)			<0.5
Bitterbrush (<i>Purshia tridentata</i>)	79.4±7.3		2.2±2.2
Gray Rabbitbrush (<i>Chrysothamnus nauseosus</i>)		<0.5	
Hopsage (<i>Atriplex spinosa</i>)			<0.5
Willow (<i>Salix</i> spp.)	18.1±5.8 ^(a)	8.3±2.8	32.3±5.3

a. These plants are not expected to occur in the B-C Cribs area, which indicates deer would move into this area primarily from the B Pond site.

TABLE 3.5. (contd)

	<u>B-C Cribs (N=20)</u>	<u>B Pond (N=40)</u>	<u>Gable Pond (N=40)</u>
<u>Trees</u>			
Russian Olive (<u>Elaeagnus angustifolia</u>)		10.9±4.4	
<u>Others</u>			
Moss			<0.5
Seeds	1.2±1.2	4.5±1.6	1.6±0.6
Unknown forb			<0.5
Unknown grass		<0.5	<0.5
Unknown sedge		<0.5	<0.5

3.1.3.4 Birds

The primary site is totally dry land and thus provides no habitat for birds associated with wetland habitats. Rogers and Rickard (1977) list only 29 species known to breed in the shrub-steppe habitat of the Hanford Reservation (Appendix A). Three additional species were listed as winter residents. Only three of the breeding species are abundant enough to be considered an important part of the functioning of the shrub-steppe ecosystem. These include the horned lark, western meadow lark and sage sparrow. The sage sparrow is rare in the primary site, due to the low density of big sagebrush, an important plant necessary for nesting.

The low numbers of species present limits the complexity of the primary site bird community. This lack of complexity is probably due to the hot, dry summers and cold, wet winters characteristic of Hanford. Rickard and Gano (1979) provide some additional data on relative abundances of birds near the primary site. Their study was conducted adjacent to the Washington Public Power and Supply System's nuclear power plants 1 and 4. It indicated that the three most common breeding bird species were the western meadowlark, horned larks and white-crowned sparrows which were abundant during the winter. Sage sparrows were common, but less than half as abundant as the former species. Surveys revealed that the next most abundant species were loggerhead shrike, common nighthawk, mourning dove, burrowing owl, and long-billed curlew.

3.1.4 Important Species of the Skagit/Hanford Site

A species is considered to be "important" if one or more of the following criteria applies: 1) the species is commercially or recreationally valuable, 2) the species is threatened or endangered, 3) the species affects the well-being of some important species within the first two criteria, and 4) the species is critical to the structure and function of the ecological system or is a biological indicator of radionuclides in the environment (U.S. NRC 1976, pp. 2.3-2.4).

The only important species providing sport hunting is the mule deer. Other huntable species occur on the primary site (i.e. cottontail, chukar, pheasant, California quail, mourning dove) but in low numbers, and are not likely to travel offsite where they would be available to hunters. Eberhardt et al. (1979) reveal that deer from Hanford do travel offsite and are occasionally shot by hunters.

Mule deer are also the most important species to consider regarding transfer of radioactivity to man. Eberhardt et al. (1982) provide a discussion of the potential transfer of radionuclide contaminated deer meat to man. There appears to be "little potential for ingestion by man of ¹³⁷Cs originating from the 200 Areas."

Several animal species have been involved in the nuisance spread of radioactivity on the Hanford Site. Section 3.1.3.3 of this report discusses mammalian species. Fitzner et al. (1980) report on several cases where birds of prey ingested contaminated prey and carried their remains to the bird nest site or roosting area.

3.1.5 Unique and Sensitive Habitats of the Skagit/Hanford Site

The primary site has been examined for rare and endangered plant and animal species. Two plant species listed as sensitive^(a) by the Washington

(a) The designation "sensitive" includes species with small populations or localized distribution within the state whose populations and habitats will be jeopardized if current land use practices continue.

Natural Heritage Program (1981) are Astragalus sclerocarpus and Cryptantha leucophaea; these plants occur in the primary site (PSP&L 1981). These species occur in sandy habitats such as sand blowouts. These habitats are important to the preservation of these plant species.

Three pairs of nesting curlews were observed at two locations on the primary site (PSP&L 1981). Curlews utilize shortgrass habitats dominated by cheatgrass and Poa. These habitats are not unique botanically; however, the integrity of the plant community is important for curlew nesting. The long-billed curlew is a candidate for threatened or endangered status by the U.S. Fish and Wildlife Service (Federal Register, 50 CFR Part 17, 1982). Nesting areas should be afforded protection due to the rarity of this species.

3.1.6 Threatened or Endangered Species of the Primary Site

The only federally listed threatened or endangered species known to occur on the primary site is the bald eagle (Haliaeetus leucacephalus alascanus). Three species common to the Hanford Site--the Swainson's Hawk (Buteo swainsoni), ferruginous hawk (Buteo regalis) and long-billed curlew (Numenius americanus)--are being reviewed for listing as threatened or endangered species (Federal Register, 1982). The Swainson's hawk and long-billed curlew are common on the primary site and nest within it.

Species of concern to the Washington State Department of Game, and which are known to occur on the Skagit/Hanford Site, are listed in Table 3.6.

3.1.7 Plants and Habitat Description of the Firehouse Site

The sagebrush/cheatgrass-sandberg-bluegrass plant community occurs over most of the proposed secondary site. This plant community is dominant over most of the 20D Area Plateau (Rogers and Rickard 1977). A list of plants occurring on the 20D Area Plateau was compiled by Price and Rickard (1973), and additional species were identified by Cline et al. (1975). These species are listed in Appendix A. Climatic influences, fire, man's past activities and microtopography alter structure of vegetation in the secondary site. Scars from past fires, vehicle traffic, and grazing have altered plant communities by favoring cheatgrass (Bromus tectorum).

Microhabitat influences are evident on the northeast end of the firehouse site. This part of the site includes a portion of a 60D-acre area of knob and kettle

TABLE 3.6. Animal Species of Concern for Washington State (Washington State Department of Game 1983)

<u>Common Name</u>	<u>Scientific Name</u>	<u>Status</u>
<u>Amphibians</u>		
Woodhouse's toad	<u>Bufo woodhousei</u>	PM ^(a)
<u>Reptiles</u>		
Sagebrush lizard	<u>Sceloporus graciosus</u>	PM
Striped whipsnake	<u>Masticophis taeniatus</u>	PM
Desert night snake	<u>Hypsiglena torquata</u>	PM
<u>Birds</u>		
Golden eagle	<u>Aquila chrysaetos</u>	PS ^(b)
Prairie falcon	<u>Falco mexicanus</u>	PS
Burrowing owl	<u>Athene cunicularia</u>	PS
Loggerhead shrike	<u>Lanius ludovicianus</u>	PS
Sage sparrow	<u>Amphispiza belli</u>	
<u>Mammals</u>		
Pallid bat	<u>Antrozous pallidus</u>	PS
Northern grasshopper mouse	<u>Onychomys leucogaster</u>	PM
Sagebrush vole	<u>Lagurus curtatus</u>	PS

(a) PS = a species proposed for state sensitive classification.

(b) PM = a species proposed for state monitor classification.

topography. Rickard (1975) described this site as a thin veneer of fine textured soil mixed with large amounts of river-washed gravels, cobbles, and boulders. These knobs rise 15-20 feet higher than the swales or kettles. This topography scarcely reaches the proposed secondary site, but is worth mentioning due to the influence it may have on vegetation structure and plant community composition. Table 3.7 lists the species composition, canopy-cover and frequency of vascular plants in the undulating topography.

3.1.8 Soils of the Firehouse Site

The soils associated with the secondary site are sandier than soils at higher elevations on the Hanford Reservation (Hajek 1966). The sandy soils

TABLE 3.7. Species Composition, Canopy-cover and Frequency of Vascular Plants on Gently Undulating Topography Typical of Firehouse Site (Rickard 1975)

	<u>Species</u>	<u>% Frequency</u>	<u>% Cover</u>
Cheatgrass	<u>Bromus tectorum</u>	100	39
Sandberg's Bluegrass	<u>Poa sandbergii</u>	100	17
Microsteris	<u>Miscrosteris gracilis</u>	48	1
Jim Hill Mustard	<u>Sisymbrium altissimum</u>	16	2
Draba	<u>Draba verna</u>	28	0.7
Tansy Mustard	<u>Desurainia pinnata</u>	48	1
Russian Thistle	<u>Salsola Kali</u> ^(a)	<u>48</u>	<u>1</u>
Total Cover %		---	62

(a) seedlings

have low water holding capacity and limited cation exchange capacity. The low water holding capacity provides for deeper penetration of water than would occur if the soils were less sandy. On the Hanford Reservation, water penetration seldom exceeds 9 feet. Because plant roots rarely grow in the absence of moisture, one can expect that roots will not penetrate much beyond this 9-foot level (Rickard and Klepper 1976). The low cation exchange capacity of the soils reveal that only small quantities of minerals are held in the root zone for plant growth and thus play only a minor role in growth.

The dispersal of radioactive wastes can potentially occur through resuspension by wind, especially with soils that are very sandy, wind erodible, and where vegetation cover is sparse, and by action of soil water.

3.1.9 Wildlife of the Firehouse Site

3.1.9.1 Invertebrates

The most comprehensive study dealing with the insects most likely associated with shrubs on the secondary site was conducted several miles south on the 200 Area Plateau (Rogers 1979). In this report, insect taxa collected

from sagebrush, rabbitbrush, and hopsage are listed according to their relative abundance (Table 3.1). Rogers (1978) also provides abundance data for darkling beetles, an important group of ground dwelling beetles common throughout the Hanford Reservation (Appendix A). The darkling beetle data were collected nearby on the 200 Area Plateau at the B-C Crib waste burial site and the REDOX pond area. Grasshopper abundance was examined at these same sites; data on population density for 16 species are found in Appendix A.

3.1.9.2 Reptiles and Amphibians

The reptiles and amphibians at both the primary and secondary sites are expected to be comparable and typical of those found throughout the Hanford Reservation. Section 3.1.3.2 provides a discussion of the reptiles and amphibians of the Hanford Reservation; Table 3.2 provides a list of species observed.

3.1.9.3 Mammals

A good discussion of the mammals expected on the Firehouse Site is presented in Section 3.1.3.3 of this report.

3.1.9.4 Birds

Section 3.1.3.4 of this report provides a discussion of the bird species known to inhabit the shrub-steppe habitat of the Hanford Reservation. Table A.8 provides a list of 32 species of birds present during the different seasons of the year.

3.1.10 Important Species of the Firehouse Site

Important species of the Firehouse Site are the same as those of the Skagit/Hanford Site. These are discussed in Section 3.1.4 of this report.

3.1.11 Unique and Sensitive Habitats of the Firehouse Site

No unique or sensitive habitats are known to occur directly within the Firehouse Site. This site, however, has not been thoroughly examined for rare or endangered plant species. Thus, small pockets of habitat containing a rare and endangered plant may be present. Field reconnaissance is suggested for 1984. The area should be walked by several botanists skilled at identifying rare species.

3.1.12 Threatened or Endangered Species of the Firehouse Site

Section 3.1.6 of this report lists the federally threatened or endangered species that occur on the Hanford Reservation. That discussion applies also to the secondary site wildlife species.

3.2 AQUATIC ECOLOGY

3.2.1 Habitats

The Columbia River is the major surface water and aquatic habitat on the Hanford Reservation. The physical and hydrological characteristics of the Columbia are described in Section 5.1.1 of this report.

Other surface waters on the Hanford Site include several artificial ponds and ditches used for the disposal of low-level radioactive liquid wastes, certain industrial pollutants, and process cooling water (U.S. ERDA 1975, p. II.3-16). These waters are located mainly in or near the 200 Areas. They lie northwest of the Skagit/Hanford Site and to the south of the Firehouse Site. The major aquatic habitats are Gable Mountain Pond, B-Pond, U-Pond, and West Pond (Figure 3.4). The physical and chemical characteristics of these ponds are given in Table 3.8 and their dimensions are shown in Figures 3.5 through 3.8.

Gable Mountain Pond, shown in Figure 3.5, is the largest [71 acres (28.7 ha)] and was created in 1957 to receive cooling water from the PUREX Plant in 200 West Area. It contains low levels of actinides and mixed fission products.

B-Pond was constructed in 1945 to receive cooling water from 200 East encapsulation facility and the PUREX plant. This pond, shown in Figure 3.6, has an area of about 40 acres (16.2 ha) and contains small amounts of actinides and mixed fission products.

U-Pond (Figure 3.7) has an area of 14 acres (5.7 ha) and was built in 1944 to receive low-level liquid effluents from plutonium processing facilities. It has also received contaminated laundry effluents and

FIGURE 3.4. Surface Water Bodies Including Ephemeral Streams on the Hanford Site (U.S. DOE 1982; Meinhardt and Frostenson 1979)

TABLE 3.8. Physical and Chemical Characteristics of Ponds on the Hanford Site (Emery and McShane 1980)

	Gable Pond	B-Pond	U-Pond	West Pond
Surface area (m ²) [acres]	287,300 [71.0]	149,200 [36.9]	56,700 [14.0]	77,800 [19.2]
Volume (m ³) [acre-ft]	431,000 [350]	233,200 [190]	22,700 [18.4]	31,100 [25.1]
Mean depth (m) [ft]	1.5 [4.9]	1.6 [5.2]	0.4 [1.3]	0.4 [1.3]
Retention time (hrs)	504 ± 211	424 ± 183	37 ± 4	---(a)
Temperature Range (°C)	0-25.3	0-25.0	0-28.4	0-25.5
Isolation Range (Langley's)	20-253	20-253	20-253	20-253
Seston (mg/l)	14.5 ± 10.9	12.2 ± 17.4	24.0 ± 8.9	21.6 ± 9.6
Sedimentation Rate (mg/cm ² per day)	2.43 ± 0.76	0.81 ± 0.51	2.24 ± 1.42	11.20 ± 6.50
pH Range	7.8-8.7	7.0-9.0	7.0-9.5	9.7-10.0
Alkalinity (mg/l as CaCO ₃)	58.4 ± 6.1	57.1 ± 4.8	95.2 ± 6.5	9009 ± 1923
Diss. O ₂ Range (mg/l)	7.9-12.7	8.1-13.8	9.0-13.00	8.0-13.8
Hardness (mg/l as CaCO ₃)	67.4 ± 6.0	68.0 ± 4.2	72.4 ± 14.1	121.8 ± 7.6
Conductivity (μmhos/cm @ 25°C)	1327 ± 104	1251 ± 170	1553 ± 132	229,698 ± 42,292
Total NO ₃ -NO ₂ -N (mg/l)	0.18 ± 0.07	3.65 ± 1.33	0.28 ± 0.08	---
Total NH ₃ -N (mg/l)	0.38 ± 0.10	1.04 ± 0.51	0.45 ± 0.20	2.61 ± 0.40
Ortho PO ₄ -P (μg/l)	1.0 ± 0.1	4.5 ± 4.2	57.8 ± 25.1	2050 ± 180
Total PO ₄ -P (μg/l)	38.0 ± 10.0	40.0 ± 10.0	123.0 ± 56.0	2160 ± 140
Total SiO ₂ -Si (mg/l)	0.99 ± 0.22	1.53 ± 0.41	0.80 ± 0.43	0.23 ± 0.21

(a) No data available

Note: Means are shown with 95% confidence values (i.e., mean ± confidence value = 95% confidence interval about the mean).

evaporator water. The radioactive materials in this pond include transuranic elements and other actinides, along with activation and mixed fission products.

The ponds and ditches in the 200 Areas have contributed to the rise in the water table; West Pond (Figure 3.8) was created in 1957 by the flooding

FIGURE 3.5. Gable Mountain Pond (Meinhardt and Frostenson 1979)

of a depression by groundwater. Wastewater from the 200 Areas has never been discharged directly to this pond but it does contain low amounts of radioactivity of unknown origin (Meinhardt and Frostenson 1979). The water quality of this pond differs from that of the other ponds in its much higher conductivity, alkalinity, phosphorous levels, and pH (see Table 3.8). The area of West Pond is about 19 acres (7.7 ha).

Rattlesnake Springs on the western side of the Hanford Reservation forms a small surface stream that flows for about 2.5 km (1.6 mi) before disappearing into the ground, as a result of seepage and evapotranspiration. Base flow of this stream is about $0.01 \text{ m}^3/\text{sec}$ (0.4 cfs) (Cushing and Wolf 1982, p. 404). Water temperature ranges from 2 to 22°C (36 to 72°F). Mean annual total alkalinity (as CaCO_3), nitrate nitrogen, phosphate phosphorous, and total dissolved solids are 127, 0.3, 0.18, and 217 mg/l (Cushing et al.

FIGURE 3.6. B-Pond, and B-3-3 and A-29 Ditches (Meinhardt and Frostenson 1979)

1980; Cushing and Wolf in press). The sodium content of the spring water is about 7 ppm (Brown 1970, p. 27).

3.2.2 Plants and Invertebrates of the Hanford Reach

Two groups of aquatic biota--plankton and benthic organisms--are discussed in this section.

3.2.2.1 Plankton

Plankton populations in the flowing Hanford Reach of the Columbia River are generally divided into four communities:

- phytoplankton - small, mostly microscopic aquatic plants (e.g., photosynthetic organisms) floating or drifting in the water column.

FIGURE 3.7. U-Pond, and Z-19 and U-14 Ditches (Meinhardt and Frostenson 1979)

- periphyton - a mixture of organisms, usually small but densely set, attached to underwater substrates, objects, or rooted aquatic plants associated with the river bottom or margins. This community is not planktonic but contributes to the phytoplankton in the Hanford Reach.
- macrophytes - large, mostly macroscopic aquatic plants (e.g., photosynthetic organisms), usually rooted to the river bottom or margins, and either submerged, emergent or floating. Again, this group is not part of the plankton, but is included here for case in discussion.

FIGURE 3.8. West Pond (Meinhardt and Frostenson 1979)

- zooplankton - small, mostly microscopic animals (e.g., nonphotosynthetic) floating or drifting in the water column.

Plankton populations generally represent a low-trophic level in aquatic ecosystems, and are predominately primary producers. However, lower trophic levels must obtain their energy from exogenous and/or endogenous sources. Streams in general, and especially smaller ones, depend greatly on allochthonous (outside the system) input of organic matter to drive the energetics of the system. Large rivers, particularly the present-day Columbia River with its interconnected reservoir series, contain a large population of autochthonous (inside the system) primary producers such as phytoplankton and periphyton that contribute the basic energy needs (WPPSS 1977, p. 2.2-3 and 4). The primary producers, in turn, are utilized by secondary producers (e.g., benthic invertebrates, zooplankton, and fish).

Plankton populations in the Hanford Reach are influenced by communities that develop in the reservoirs of upstream dams, particularly Priest Rapids Reservoir, and manipulation of water levels below by dam operations in

downstream reservoirs. Phytoplankton and zooplankton populations at Hanford are largely transient, flowing from one reservoir to another. There is generally insufficient time for characteristic edemic groups of phytoplankton and zooplankton to develop in the Hanford Reach.

3.2.2.1.1 Phytoplankton. Phytoplankton species identified from the Hanford Reach include diatoms, golden or yellow-brown algae, green algae, blue-green algae, red algae, and dinoflagellates. A complete list of these species is shown in Table A.10. The taxonomic list has gradually increased over the last decade as identification became more precise and less common species were added.

Phytoplankton in the Hanford Reach are derived from upstream reservoirs and from periphyton above the collection site. Early studies indicated that phytoplankton were well mixed in the water column in the Hanford Reach, and that sampling variations did not indicate meaningful differences in the phytoplankton community (Wolf et al. 1976, p. 2-9). Thus, phytoplankton sampling is not a problem in terms of station or depth.

Diatoms (Chrysophyta, Bacillariophyceae) is the dominant algal group in the Columbia River, usually representing over 90% of the algae (PSP&L 1981, p. 2.2-17; WPPSS 1977, p. 2.2-4; Neitzel et al. 1982a, p. 498). The main genera include Asterionella, Cyclotella, Fragilaria, Melosira, Stephanodiscus and Synedra (Neitzel et al. 1982a, p. 498). Diatoms not only contribute the greatest number of species, but account for the highest percentage of total unit densities among the major algae divisions (Table A.11).

The diatoms of the phytoplankton community in the Hanford Reach are dominated by lentic forms that originate in upstream impoundments. The phytoplankton also contains a number of species derived from the periphyton or sessile algae. Daily fluctuations of water level from the operation of Priest Rapids Dam above the Hanford Reach (Becker et al. 1981, Figure 8; Fickeisen et al. 1980a, p. 4-24) may explain the presence of many periphytic algae in phytoplankton drift samples. Periphytic algae attached to rocks and other substrates along the river margin may be exposed when water levels fall,

become partially dried, and then detach and be carried away when the water level rises.

Green algae (Chlorophyta) and blue-green algae (Cyanophyta) occasionally occur in the phytoplankton community during warmer months, but in substantially fewer numbers than the diatoms. Characteristically, the composition of phytoplanktonic species will vary from season to season and from year to year as indicated in Figure 3.9.

FIGURE 3.9. Phytoplankton Unit Densities in the Hanford Reach of the Columbia River, September 1974 - March 1980. Data from September 1974 through July 1978 from Page and Neitzel (1978) and Page et al. (1979); from September 1978 through March 1980 from Beak Consultants, Inc. (1980)

The spring pulse in phytoplankton density is probably related to increasing light and water temperature rather than to availability of nutrients as PO_4 and NO_3 (WPPSS 1977, p. 2.2-4; PSP&L 1981, p. 2.2-17). Although these nutrients decrease in the spring due to both phytoplankton uptake and increased dilution associated with spring flows, they do not appear to decrease to concentrations limiting growth of algae at any time of the year (loc. cit.).

The most recent data on phytoplankton in the Hanford Reach were collected at RM 352 (RKM 566) from September 1978 to March 1980. During this period the five most abundant species of algae were Cyclotella glomerata (Sept., Oct. and Nov. 1978; Aug. and Sept. 1979), Stephanodiscus hantzschii (Dec. 1978; Apr., Jan., Feb. and March 1980), Melosira italica (May and June 1979), Cyclotella camensis (July 1979), and C. pseudostelligera (Oct. 1979) (Beak Consultants Inc. 1980, p. 2.5). Most of these forms are small centric diatoms (5-15 μm diameter, 2-3 μm thick). In contrast, the previously dominant diatoms, at RM 352 (RKM 566) were Asterionella formosa (prevalent in spring), Cyclotella spp. (prevalent in most summers) (prevalent in fall and winter) and Synedra spp. and Melosira spp. (prevalent in summer) (Page and Neitzel 1978a, p. 2.5; Page et al. 1979a, pp. 2.4 and 2.5). The differences in species composition in recent studies may be due to examination of samples at slightly greater magnification, which reveal more of the very small concentric diatoms such as Stephanodiscus (Beak Consultants Inc. 1980, p. 2.5). It was also noted that phytoplankton densities at RM 352 (RKM 566) were higher for September 1978 to March 1980 than noted previously ranging from 7.9×10^5 units/liter in November 1979 to 16.0×10^6 units/liter in April 1979 (Beak Consultants Inc. 1980, p. 2.5 and Figure 2.1).

The community structure and production of phytoplankton can be measured in units other than total numbers and dried weights. Such parameters include diversity indices, carbon uptake and chlorophyll *a* concentrations. Information on these values are given for RM 380 (RKM 611) during 1973 and 1974 by Wolf et al. (1976), and for RM 352 (RKM 566) during 1973 through 1980 by Beak Consultants Inc. (1980) and Neitzel et al. (1982). Phytoplankton production values will fluctuate seasonally with such factors as light intensity, water temperature, and current velocities and may show wide year to year variations.

The diversity index is based primarily on the number of species and their relative abundance. The diversity index, and two of its associated parameters (index of relative abundance and species richness) through 1979 at RM 352 (RKM 566) is shown in Figure 3.10, as an example. Diversity indices were higher in the summer, fall and early winter and spring when phytoplankton densities were highest (Beak Consultants Inc. 1980, p. 2.7).

Carbon uptake is essentially a measurement of photosynthetic activity (i.e., productivity); hence, it is influenced by light and temperature. Rate of carbon uptake at RM 352 (RKM 566) can be used to indicate general values for the Hanford Reach. Carbon uptake was measured on 12 dates from 1974 through 1976. Productivity ranged from 0.020 to less than 0.001 mg ^{14}C /hour (Neitzel et al. 1982, pp. 498-501). Carbon uptake is near zero during the winter (January, February, and March) but reaches 0.033 mg C/liter hour in June and September (loc. cit.). Uptake data are typical of rivers in a temperate climate. Uptake values increase seasonally at the surface of the river in late February, rise steadily to peak in July, remain high through mid-September, and then decline to the winter minimum. Mid-depth and bottom uptake values are less than those at surface because of the influence of depth on light penetration, attenuation of light by particulate materials, and other physical properties of the water (loc. cit.).

Peak chlorophyll a concentrations at RM 380 (RKM 611) occurred in June and July. Unlike primary productivity, the summer chlorophyll a peak did not last long. Even though the chlorophyll a decreased in August, September and October, primary productivity was relatively stable. Apparently, during this period, phytoplankton organisms were more efficient in fixing carbon per gram of available chlorophyll a (Neitzel et al. 1982, p. 501).

Chlorophyll a concentration estimates at RM 352 (RKM 566) ranged from less than 1 mg/m³ to greater than 24 mg/m³. Chlorophyll a concentrations peaked in late spring-early summer and were lowest in late fall-early winter (Neitzel et al. 1982, p. 502). All maximum chlorophyll a concentrations measured at RM 352 (RKM 566) were greater than concentrations measured at RM 380 (RKM 611).

FIGURE 3.10. Species Diversity Index (H'), the Index of Relative Abundance (J'), and Species Richness (S) for Phytoplankton Samples at RM352 (RKM566), September 1978-March 1980 (Beak Consultants, Inc. 1980)

3.2.2.1.2 Periphyton. The periphyton community in the Hanford Reach occurs on solid substrates wherever light is sufficient for photosynthesis; hence, they are often called "benthic microflora". This community is composed primarily of diatoms, which may be attached, or entangled from the river drift. Dominant genera are the diatoms Achnanthes, Asterionella, Cocconeis, Fragillaria, Gomphonema, Melosira, Nitzschia, Stephanadiscus and Synedra (Page and Neitzel 1978b, p. 4.1-4.36; Page et al. 1979b, p. 4.1-4.27; Beak Consultants Inc. 1980, p. 4.7-4.12; Neitzel et al. 1982). One set of samples taken in June 1979 was dominated by filamentous blue-green algae, genera Schizothrix and Entophysalis (Beak Consultants Inc. 1980, p. 4.9; Neitzel et al. 1982, p. 502).

In studies conducted at RM 352 (RKM 566) from March 1977 to March 1980, the number of periphyton (microflora) units/cm² varied seasonally, with maxima in winter and minima in summer. The lowest average density was 4,652 units/cm² in June 1977, and the higher average density was 1,146,250 units/cm² in March 1979 (Neitzel et al. 1982, p. 502). Organic matter estimates also varied seasonally, with a low of 0.2 g/m² in June 1978 and a high of 21.0 g/m² in September 1977 (loc. cit.). However, chlorophyll a estimates did not show clear seasonal trends (loc. cit.).

Comparisons were made at RM 352 (RKM 566) between productivity of phytoplankton and periphyton. There was no obvious relationship between dominant taxa in phytoplankton or periphyton samples on 13 comparable dates. However, practically all taxa were present in samples of both communities. Chlorophyll a estimates from periphyton were generally higher than those from phytoplankton, ranging from 0.1 to 31 times greater and averaging 6 times greater (Neitzel et al. 1982, p. 502-503). The comparisons indicated greater production of periphyton than phytoplankton even though phytoplankton densities were greater. A possible cause was that more dead algae cells from planktonic and benthic origin were present in the drifting phytoplankton community due to mixing by river currents and diurnal river level fluctuations (loc. cit.).

In past years during operation of plutonium production reactors at Hanford (1944-1971), concentrations of radionuclides in the Columbia River

were monitored in planktonic and benthic communities (Coopey 1953a; Cushing and Watson 1966; Cushing 1967a; Watson et al. 1971; Cushing et al. 1981). Primary emphasis was on uptake and cycling of radionuclides between Columbia River biota, but some early data on phytoplankton and periphyton production are given in these reports.

3.2.2.1.3 Macrophytes. Fluctuating water levels, strong currents, and rocky substrates inhibit the development of a rooted macrophyte community in the Hanford Reach. Rooted macrophytes are generally restricted to isolated slack-water areas in the main river channel and to muddy bottom areas of sloughs. Where they exist, macrophytes have considerable ecological value. They provide food and shelter for juvenile fish and spawning areas for some species of warm-water game fish. Macrophyte species that have been identified in the Hanford Reach are listed in Table 3.9. A comprehensive discussion of riparian zone vegetation, portions of which are innundated by periodic high flows, is given by Fickeisen et al. (1980a, Section 4), and Fickeisen et al. (1980b, Section 4).

The most common macrophyte likely to occur along the shoreline at Hanford is the curled leaf pondweed, Potamogeton crispus. Pondweed is common among quiet pools and is most visible at reduced flows after summer growth. Patches of emergent macrophytes, including rushes (Juncus spp.), sedges (Carex spp.), and cattails (Typha latifolia) also occur at various shoreline locations where currents and silt deposits permit. Isolated pools may contain green floating mats of duckweed (Lemna spp.)

3.2.2.1.4 Zooplankton. A complete list of zooplankton species known to occur in the Hanford Reach is given in Table A.12. Many organisms may be encountered in zooplankton samples. From a strict viewpoint, "zooplankton" includes only the Rotifera and Arthropoda while the other organisms listed belong with the benthic fauna although they may enter the river drift. Information on zooplankton in the Hanford Reach is provided by Coopey (1953a, 1953b; Page and Neitzel 1976, Section 3; Page and Neitzel 1978c, Section 3; Beak Consultants Inc. 1980, Section 3; Neitzel et al. 1982b). Zooplankton species identified in McNary Reservoir, which may be typical of reservoir populations in the mid-Columbia River, are listed by Scarola (1968).

TABLE 3.9. Macrophytes Identified in the Hanford Reach, Columbia River (Fickeisen et al. 1980a; PSP&L 1981)

<u>Family</u>	<u>Species</u>	<u>Common Name</u>
Ceratophyllaceae	<u>Ceratophyllum demersum</u>	Coontail
Cruciferae	<u>Rorippa calycina</u>	Rorippa (watercress)
	<u>R. islandica</u>	Rorippa (watercress)
	<u>R. nasturtium-aquaticum</u>	Rorippa (watercress)
Cyperaceae	<u>Carex athrostachya</u>	Carex (sedge)
	<u>Scirpus validus</u>	Bulrush
Halogaceae	<u>Myriophyllum</u> spp.	Water milfoil
Hydrocharitaceae	<u>Elodea canadensis</u>	Elodea, waterweed
Juncaceae	<u>Juncus articulatus</u>	Rush
	<u>J. balticus</u>	Rush
Lemnaceae	<u>Lemna</u> spp.	Duckweed
Jajadaceae	<u>Potamogeton crispus</u>	Curly pondweed,
	<u>p. pectinatus</u>	curled leaf pondweek pondweed
Polygonaceae	<u>Polygonum persicaria</u>	Buckweat
Typhaceae	<u>Typha latifolia</u>	<u>Cattail</u>

The crustacean-zooplankton community at RM 380 (RKM 611) consisted of 12 identified species during 1973 and 1974 (Page and Neitzel 1976, Table 3.5). Bosmina longirostris was the most abundant cladoceran and dominant zooplankter from June to October when Diaptomus ashlandi became dominant, and remained so until June 1974. Before January 1974, Cyclops bicuspidatus thomasi was third in abundance, but it increased to second in abundance during the January-February thaw and became dominant in June 1974. Daphnia spp. were fourth most abundant, but at only about 10% of the total zooplankton community present (Figure 3.11).

Other invertebrates than crustacea were taken in zooplankton samples. Larvae of aquatic insects usually were less than 5% of the organisms collected, peaking in mid-July at about 7 larvae/m³ (Neitzel et al. 1982b, p.

FIGURE 3.11. Relative Abundance of Dominant Zooplankton Species in the Columbia River at RM352 (RKM522) and RM380 (RKM611) (PSP&L 1981; Neitzel et al. 1982b)

114). This peak corresponded with maximum abundance of insect larvae in the benthos. Drift insects represented only about 0.08% of all zooplankton.

The zooplankton community at RM 352 (RKM 566) consisted of 58 identified taxa from 1974 to March 1980. Three crustacean genera dominated: Bosmina, Diaptomus and Cyclops (Figure 3.11). Bosmina generally dominated in July, August and September samples; Diaptomus in December and January; and Cyclops in March and June. Insect larvae were numerically significant only in March 1975 and September 1976 samples.

Part of the increased taxa at RM 352 (RKM 566) was probably due to improvements in identification from 1975 to 1980, which permitted more organisms to be identified to lower taxonomic levels, and not to an actual higher species diversity (Beak Consultants Inc. 1980).

Zooplankton densities generally followed a trend of winter minimums, and late spring and early-summer maximums (Figure 3.12). Average number of zooplankters ranged from 1500 organisms/m³ in mid-July to less than 30

FIGURE 3.12. Columbia River Zooplankton Density RM352 (RKM566) and RM 380 (RKM611) (PSP&L 1981; Neitzel et al. 1982b)

organisms/m³ in November and December at RM 380 (RKM 611). Average numbers of zooplankters ranged from less than 10 organisms/m³ in December 1974 to 4702 organisms/m³ in June 1977 at RM 352 (RKM 566).

Zooplankton densities may be affected by total river flow. The density increase in 1977 (Figure 3.12) was likely influenced by extremely low river discharges that year (Beak Consultants Inc. 1980, p. 3.5). Reduced flows caused higher plankton densities by increasing residence time of water in reservoirs, so that reproduction was enhanced and net export of cells was decreased.

3.2.2.2 Benthic Organisms

Benthic organisms are those that live in or on the bottom substrates of lakes, reservoirs, and streams. Benthic communities are divided into macrofauna and microflora. The macrofauna, discussed in this section, are large nonphotosynthetic organisms such as insect larvae, annelids, and snails. The microflora are small photosynthetic organisms representing primarily the periphyton. The benthic communities of the river are a primary food source for many macroinvertebrates and fish.

Early studies of benthic organisms in the Hanford Reach were conducted by Davis and Cooper (1951) from Fall 1948 to Spring 1950 and by Roebuck et al.

(1954) in Spring 1951 to Spring 1953. The data collected were from shallow shoreline areas, and were restricted by the available sampling gear.

Benthic organisms in the Hanford Reach are discussed in several reports on site assessment studies. Studies conducted at RM 380 (RKM 611) in 1973 and 1974 are summarized by Wolf (1976, Section 4). Studies conducted at RM 352 (RKM 566) are summarized by Page and Neitzel (1978c, Section 4) and Beak Consultants Inc. (1980, Section 4). Benthic organisms can be measured in terms of numbers per square meter or in biomass (grams) per square meter. Considerable variation can be expected in species diversity, numbers, and biomass from site to site at a given time and at a single site at different seasons. This is due to natural factors. For example, the life cycle of aquatic insects includes egg deposition, larval feeding and growth, pupation and adult emergence. Some insects pass through this cycle only once annually; others repeat it twice or more annually. Their peak abundance in the benthos occurs after eggs hatch and larvae are present in bottom substrates.

The macrofaunal composition of the Hanford Reach is diverse (Table A.13). Two taxa dominate: midge fly larvae (Chironomidae) and caddisfly larvae (Trichoptera). Other taxa include black fly larvae (Simuliidae), annelids, molluscs, a crayfish (Pacifasticus leniusculus), a freshwater sponge (Spongilla lacustris), and water mites.

Population densities change seasonally and annually. Total numbers are usually lowest in June and July (corresponding with the spring emergence of adult aquatic insects), increase dramatically in September and October (aquatic insects eggs hatch into larvae), and are moderately high from December through April (overwintering population levels). Average numerical densities for September, December, March and June in samples collected between 1973-1980 were $53,656/m^2$, $33,580/m^2$, $6,984/m^2$ and $5,944/m^2$, respectively (Figure 3.13). Precise comparisons between years are usually unfeasible because of differences in sample sites, collection dates, duration of colonization (of collection units), and methods of collection.

Mean total biomass of benthic macrofauna usually peaks in December while the lowest biomass occurs in March, and coincides with high December and low March populations of Trichoptera (primarily hydropsyche cockerelli). On

FIGURE 3.13. Seasonal Densities of Columbia River Macrobenthic Fauna (PSP&L 1982)

occasions, Simuliidae, Chironomidae, and molluscs will constitute significant portions of the benthic biomass.

Stomach contents of fish collected in the Hanford Reach from June 1973 through March 1980 (See Section 3.2.4) that benthic invertebrates are important food items for nearly all juvenile and adult fish. There is a close relationship between food organisms in the stomach contents and those in the benthic and invertebrate drift communities.

3.2.3 Biota of Ponds and Small Streams

The plants and animals of the wastewater ponds and ditches have been described and summarized in several reports (Cushing and Watson 1974; Meinhardt and Frostenson 1979; Emery and McShane 1980; Rickard, et al. 1981; Jamison 1982). Detailed lists of the species observed are presented in Appendix A (Tables A.14 through A.16).

Most of the algae is periphytic (attached) in most of the surface waters although unattached filamentous green algae is at times abundant in U-Pond. The average depth of the ponds and ditches is less than 3 meters and light penetration sufficient to support plant life can reach much of the bottom area. Blue-green algae (Cyanophyta), green algae (Chlorophyta) and diatoms (Chrysophyta) are present in all systems. The algae Cladophora is one of the more abundant green algae and is present both as attached and floating masses (Cushing et al. 1976).

Among the zooplankters, waterfleas (Cladocera) and scuds (Malacostraca) are found in Gable Mountain, U-, and B-Ponds. Both plant and animal plankton were sparse in Gable Mountain Pond (Cushing et al. 1976, p. 8D) and U-Pond and B-Pond.

The bottom invertebrates in most of the wastewater ponds and ditches include segmented worms; larvae of midgeflies, mayflies, caddisflies, damselflies, dragonflies; predaceous diving beetles, water boatmen; back-swimmers; and waterstriders.

The major aquatic macrophytes common to Gable Mountain, B- and U-Ponds and several of the ditches include pondweed, cattail, and bulrush. Hornwort and water milfoil are also abundant in Gable Mountain Pond (Emery and McShane

1980). Cottonwoods (Populus) grow along shore at Gable Mountain Pond and U-Pond; willows (Salix) are found along U-Pond.

The aquatic food web is shown schematically in Figure 3.14. The ponds and ditches serve as food and water sources for birds and mammals, and can potentially contribute to the transfer of pollutants to the human food chain.

Rattlesnake Springs, near the western side of the Hanford Reservation, creates a small stream about 2.5 km long. It is of ecological importance because it provides a source of water to terrestrial animals in an otherwise arid part of the reservation. Snively Springs, located further west and at a higher elevation than Rattlesnake Springs apparently does not contribute to

FIGURE 3.14. Food Web of Gable Mountain Pond and U Pond (U.S. ERDA 1975)

the flow of Rattlesnake Springs, (Brown 1970, p. 26) but probably flows to the west and off the Reservation.

The autotrophic communities in the spring system are primarily periphytic; diatoms are the primary algae group (Cushing and Wolf, in press). Achnanthes lanceolata, Gomphonema intricatum and Melosira varians are the most abundant. A total of 90 algal species have been identified from the springs, with Chrysophyta (diatoms) the most abundant (49 species) and Chlorophyta (green algae) the next most abundant (23 species) (Lippert and Cushing 1973, p. 6.15). The major rooted aquatic plant, which in places may cover the entire width of the stream, is watercress (Rorippa nasturtium-aquaticum). Isolated patches of bulrush (Scirpus sp.), spike rush (Eleocharis sp.), and cattail (Typha latifolia) occupy less than 5 percent of the streambed.

In studies of leaf breakdown at Rattlesnake Springs, midgefly (Chironomidae) larvae were the dominant benthic organisms (Cushing et al. 1974, p. 91-94); also represented were larvae of blackflies (Simuliidae), caddisflies (Trichoptera), and damselflies (Odonata); and scuds (Amphipoda) (Cushing et al. 1973, p. 93). Waterstriders (Gerris sp.), backswimmers (Notonecta sp.), water beetles (Hydaticus sp. and Agabetes sp.), mayflies (Ephemeroptera), and snails (Tyrolus sp.) have also been reported (Cushing and Wolf 1971).

No fish are present in the springs.

Primary productivity at Rattlesnake Springs was greatest during the spring and coincident with the maximum periphyton standing crop (loc. cit.). Net primary productivity averaged $0.9 \text{ gCm}^{-2} \text{ d}^{-1}$ during 1969-1970; the spring maximum was $2.2 \text{ gCm}^{-2} \text{ d}^{-1}$. Seasonal productivity and respiration rates are shown in Figure 3.15, and are within the ranges reported for arid region streams. Although Rattlesnake Springs was a net exporter of organic matter during much of the growing season, it is subject to flash floods and severe scouring and denuding of the stream bed during winter and early spring, making it an importer of organic materials on an annual basis (Cushing and Wolf, in press).

FIGURE 3.15. Seasonal Gross (P_g) and net (P_n) Primary Productivity and Respiration (R) Rates for Rattlesnake Springs (Cushing and Wolf, in press)

3.2.4 Fish Populations

3.2.4.1 Species Present

Forty-four species of fish have been identified from the free-flowing Hanford Reach of the Columbia River (Gray and Dauble, 1977, p. 211-212). Of these, 39 are resident species present during the entire year, while seven are anadromous species present only during certain seasons and stages of their life cycle. The indigenous species native to the Columbia River are limited. Fifteen of the fish species listed were introduced to the Columbia River from other areas, many before 1900 (Smith 1896; Wydoski and Whitney 1979). Fish species found in the Hanford Reach are listed in Table A.17.

The anadromous species, which typically spawn in fresh water but grow to sexual maturity in the sea, are American shad, Pacific lamprey, river lamprey, coho salmon, sockeye salmon, chinook salmon, and rainbow (steelhead) trout. The salmonids are generally considered to be sensitive to environmental changes; hence they are species of concern in the Columbia River system (Schwiebert 1977; Collins et al. 1975).

Fourteen species of fish are generally considered as important species in the Hanford Reach. Criteria for designating a species as important are given in Section 3.1.4. In addition, 316 (a) EPA defines representative, important species as those species that represent, in terms of their biological requirements, a balanced, indigenous community of shellfish, fish, and wildlife in the body of water into which a discharge is made. The EPA definition specifically includes those species that are:

- commercially or recreationally valuable
- threatened or endangered
- critical to the structure and function of an ecological system (e.g., habitat formers)
- potentially capable of becoming localized nuisance species
- necessary (e.g., in the food chain) for the well-being of species listed immediately above
- representative of the thermal requirements of important species but which themselves may not be important.

Although other species of fish found in the Hanford Reach may qualify for designation as "important", the species listed in Table 3.10 closely conform to these criteria.

3.2.4.2 Important Anadromous Fishes

Important anadromous fish utilizing the Hanford Reach include chinook, coho and sockeye salmon, steelhead trout (a seaward migrating form of rainbow trout), and American shad. These species are regionally important as recreational and commercial resources. The salmonids are also internationally important because of their extensive feeding migrations in the sea where they enter the commercial fisheries of Canada and Japan.

TABLE 3.10. Fish Species Designated as Important for the Hanford Reach, Columbia River

<u>Common Name</u>	<u>Scientific Name</u>
Adadromous Species	
chinook salmon	<u>Oncorhynchus tshawytscha</u>
coho salmon	<u>Oncorhynchus kisutch</u>
sockeye salmon	<u>Oncorhynchus nerka</u>
rainbow (steelhead trout)	<u>Salmo gairdneri</u>
Resident Species, Indigenous	
white sturgeon	<u>Acipenser transmontanus</u>
largescale sucker	<u>Catostomus macrocheilus</u>
prickly sculpin	<u>Cottus asper</u>
northern squawfish	<u>Ptychocheilus oregonensis</u>
mountain whitefish	<u>Prosopium willlamsoni</u>
Resident Species, Introduced	
smallmouth bass	<u>Micropterus dolomieu</u>
yellow perch	<u>Perca flavescens</u>

Sources: U.S. DOE (1982), PSP&L (1981)

The free-flowing Hanford Reach serves as a migration route for salmon and steelhead that spawn upstream. In addition, it is the last major spawning ground for fall chinook salmon and steelhead trout in the main-stem Columbia River. Shad also spawn in the Hanford Reach.

Considerable research has been conducted on salmonid resources of the Columbia River, and runs are partly maintained with an extensive artificial propagation (hatchery) program supported by the federal government and the states of Idaho, Oregon and Washington. In recent years, an average of 123,500 adult salmonids produce 14 million outmigrants that originate in or pass through the Hanford Reach annually. These fish represent a combined sport and commercial value of \$3 million annually (Fickeisen et al. 1980, p. 2-15).

Anadromous salmonids have similar life cycles, but each species and often races within a species mature at different rates, resulting in differences in timing of the upriver spawning migration (Figure 3.16). Some adult salmon will be in the Hanford Reach each month of the year. The greatest numbers pass through during spring to early fall. The fewest occur from December

FIGURE 3.16. Timing of Salmonid Migrations Near the Hanford Site Columbia River (Adapted from PSP&L 1981, Amendment 4)

through February when only adult steelhead are present. Peak adult upstream migration periods at Hanford are normally as follows:

Sockeye:	June-August
Chinook:	
Spring:	April to mid-June
Summer:	mid-June to mid-August
Fall:	mid-August to November
Coho:	September-October
Steelhead:	August-October

Adult salmonids generally migrate upstream close to the banks of large rivers. Studies of migration routes in the Hanford Reach show that the fish usually prefer the east-northeast shore (left bank), which is opposite the intake and discharge ports of the closed and currently operating Hanford plants (Monan et al. 1970; Coutant 1973, p. 7-13; Becker 1973, p. 856). This migration path generally persists from Richland upstream to Priest Rapids Dam.

Chinook salmon: Spring and summer races of chinook salmon pass through the Hanford Reach to spawn primarily in tributaries of the mainstem river above Hanford, including the Wenatchee, Okanogan, Entiat and Methow Rivers (Fulton 1968). Adult spring- and summer-run chinook salmon move through the Hanford Reach from April through mid-June and mid-June to mid-August, respectively. Part of the adult fall chinook pass through the Hanford Reach to upstream spawning areas in mid-August to November; another portion of the run spawns in the Hanford Reach during September, October, and November.

Generally, juvenile spring and summer chinook salmon produced above Hanford migrate seaward as large fingerlings in their second year of life (1-age group), while juvenile fall chinook above and in the Hanford area migrate seaward as small fingerlings in their first year of life (0-age group) (Major and Mighell 1969, p. 352-353; Bell 1973, Chapter 5, p. 4-6). Downstream movement of 1-age group spring chinook salmon through Hanford occurs from April to September but peaks in May (Table 3.11). An estimated 170,000 (in 1965) to 1.6 million (in 1975) spring chinook salmon fingerlings and 1.4 to 2.3 million summer and fall chinook salmon fingerlings pass downstream of Priest Rapids Dam annually (Sims and Miller 1976, Table 1). Hatchery releases contribute the major part of the spring chinook salmon

TABLE 3.11. Median (Peak) Outmigration Dates for Juvenile Salmon Passing Priest Rapids Dam (from Hovland et al. 1982, p. 9; Weitkamp and McEntree 1982, p.12)

<u>Year</u>	<u>Spring Chinook</u>	<u>Fall & Summer Chinook</u>	<u>Sockeye</u>	<u>Coho</u>	<u>Steelhead</u>
1965	May 19	Aug. 11	May 3	May 12	May 20
1966	May 17	Aug. 12	May 1	April 29	May 25
1967	May 23	Aug. 8	May 1	May 20	May 18
1976	May 14	Aug. 11	May 19	May 19	May 14
1977	May 17		May 14	May 25	May 17
1979	May 19		May 21	May 23	May 18
1980	May 12		May 14	May 25	May 10
1981	May 15	Aug. 12	May 14	May 21	May 15
1982	May 7		May 18	May 19	May 11

outmigration originating above Priest Rapids Dam. Juvenile salmon from upriver areas travel from Priest Rapids Dam to McNary Dam (the Hanford Reach plus Lake Wallula) in 7 to 15 days, depending on river flow (Faurat 1979, p. 8). The fall run of chinook salmon ascending fishways at Bonneville Dam (RM 145) has been about 200,000 individuals annually the last ten years (1969-1978). Nearly half of these are harvested by the Indian fishery between Bonneville and McNary Dams (RM 2929) (Fickeisen et al. 1980, p. 2-4).

Total numbers of fall chinook salmon passing McNary Dam averaged 44,000 fish from 1968 to 1978, but declined to 31,200, 29,900 and 21,100 fish in 1979, 1980, and 1981, respectively. Above McNary Dam the run may enter the Snake River and pass Ice Harbor Dam, pass on up the Columbia River over Priest Rapids Dam, or spawns in the Hanford Reach (fall chinook salmon only). Total numbers of fall chinook salmon passing Ice Harbor Dam averaged 7,300 fish from 1968 to 1978, but declined drastically after 1973 to less than 1,200 fish in 1979, 1980, and 1981, respectively. Total numbers of fall chinook salmon

passing Priest Rapids Dam averaged 6,300 fish from 1968 to 1978, and was 4,900, 6,000 and 3,800 fish in 1979, 1980 and 1981, respectively (ODFW and WDF 1983, Table 26). Additionally, some fish enter the Yakima River. Estimates of numbers of adult fall chinook salmon using the mid-Columbia area are in Table 3.12.

Fall chinook salmon spawn primarily in tributaries of the lower Columbia River and main river in the Hanford Reach. Spawning at Hanford takes place from September to mid-November, peaking in late October and early November (Watson 1976, p. 4-6). Fall chinook salmon spawning in the Hanford Reach has increased markedly since 1960 with the construction of Priest Rapids Dam, probably as a result of the barrier to upstream movement created by the dam and the upstream translocation of main-stem spawning populations whose spawning grounds were eliminated by dams constructed below Hanford (Watson 1970, p. 36).

Annual surveys of fall chinook salmon redds have been made at Hanford since 1947 (Figure 3.17). The number of redds increased dramatically from 1960 to 1969 and, except for greatly reduced abundance in 1972 and 1974, has remained relatively consistent since then. There is no evidence that maximum use of available spawning grounds has been reached in the Hanford area, thereby limiting further increase in the spawning population. Estimates of the total number of fall chinook salmon using the Hanford Reach annually are in Table 3.13.

Several separate areas in the Hanford Reach have suitable substrates and currents for spawning of adult salmonids (Figure 3.18). The numbers of redds counted annually at each spawning area are in Table 3.14. Major spawning areas are at Vernita Bar (36% average contribution) below Priest Rapids Dam (RM 396), a possible partial barrier to upstream migration, and near Locke Island (RM 375) (20% average contribution) (Table 3.15).

Eggs develop in the gravel of the Hanford Reach from late fall through the winter, when seasonal water temperatures are low. Fry typically emerge from March through June. Peak numbers of 0-age fall chinook salmon fry occur in shoreline areas at Hanford from April through May (Becker 1970, p. 6; Gray

FIGURE 3.12. Annual Estimates of Adult Fall Chinook Using the Hanford Reach

Year	McNary Dam (a) Count	Ice Harbor Dam (b) Count	Yakima River Escapement (c)	Priest Rapids Dam (d) Count	Interdam Population (Estimate)	Peak Hanford Redd Count (e)
1960	47,337			10,687		295
1961	41,200		87	11,108		939
1962	44,116	30,049	15	10,082	3,970	1,261
1963	57,363	13,537	324	17,563	25,936	1,303
1964	58,593	11,097	120	14,760	32,616	1,477
1965	76,326	12,354	198	21,149	42,625	1,789
1966	75,119	15,018	405	18,821	40,875	3,101
1967	73,087	19,022	531	12,375	41,159	3,267
1968	72,757	24,377	186	11,031	37,163	3,569
1969	79,375	17,507	2,487	12,367	47,014	4,508
1970	61,554	10,385	1,830	16,372	32,967	3,813
1971	69,718	11,004	2,090	10,591	46,033	3,600
1972	49,307	9,436	1,480	5,782	32,611	876
1973	73,253	8,353	2,200	10,083	52,617	2,965
1974	62,009	2,814	1,860	7,618	49,717	728
1975	68,719	2,558	2,060	13,365	50,736	2,683
1976	87,991	1,474	2,640	10,774	73,103	1,951
1977	84,370	1,756	2,531	6,856	73,227	3,240
1978	44,145	1,609	1,324	6,523	34,689	3,028
1979	49,961	2,074	1,499	7,727	38,661	2,983
1980	38,910	1,744	1,167	8,442	27,557	1,487
1981	33,148	2,111	N.A.			4,866

(a) U.S. Army Corps of Engineers 1982, Table 67.

(b) U.S. Army Corps of Engineers 1982, Table 85.

(c) Watson 1970; D.G. Watson, Battelle, Pacific Northwest Laboratories, personal communication

(d) Grant County Public Utility District 1978.

(e) Watson 1976; D.G. Watson, Battelle, Pacific Northwest Laboratories, communication.

FIGURE 3.17. Hanford Reach Fall Chinook Salmon Redd Observations, 1947 Through 1979
(Based on Watson 1970, 1976 and D.G. Watson personal communication,
Pacific Northwest Laboratory)

TABLE 3.13. Calculation of Average Fall Chinook Interdam Population and Estimate of the Number of Fish Utilizing Hanford Reach 1962-1980 (Modified from PSP&L 1981)

Dam Counts ⁽⁵⁾	
McNary	64,562
Ice Harbor	10,325
Priest Rapids	11,699
Interdam Population ⁽⁵⁾	
Yakima spawners	42,225 ⁽¹⁾
Hanford spawners	1,313 ^(1,2)
Ringold Springs	17,548 ^(1,3)
Priest Rapids (volunteers)	500
	380
Unaccounted (including sports catch and natural mortalities)	22,797 ^(1,4)

Note:

- (1) Numbers with inherent inaccuracies.
- (2) Assumption of 3 fish per redd (Watson 1970, p. 4).
- (3) Assumption of 7 fish per redd (Watson 1970, p. 4).
- (4) Represents 35 percent of the McNary count, but varies from to year.
- (5) From Table 3.12.

and Dauble 1979a, Fig. 5.2, 1979b, Fig 2). In addition to these fish, juvenile fall chinook salmon are released from the hatchery and rearing facility above the Hanford Reach, and from the Ringold rearing station at the lower part of the Hanford Reach.

Backwater sloughs and shoreline indentations are important rearing sites for newly emergent fall chinook salmon fry (0-age group). Currents are reduced in these locations and food organisms may be more readily available to fry than in the swift current of the main stream. However, chinook fry are also vulnerable to periodic changes in water level resulting from peaking power operations at Priest Rapids Dam (Becker et al. 1981, p. 44). The residence time of 0-age group fry in shoreline areas is relatively brief because fry of fall chinook salmon in the mid-Columbia River characteristically migrate to the sea in their first year (loc. cit.). In June, increased temperatures and high flows may stimulate down-stream movement of 0-age group fry from the Hanford environs. While small numbers of chinook

FIGURE 3.18. Fall Chinook Salmon Spawning Areas Within the Hanford Reach
(Based on Watson 1976)

TABLE 3.14. Fall Chinook Salmon Redd Distribution in the Hanford Reach by Spawning Area, 1947 Through 1982 (Watson 1970, p. 9; Watson 1976, p. 4-6; D.G. Watson, Battelle, Pacific Northwest Laboratories, Personal Communication November 1983)

Year	Number of Redds								Adult Fall Chinook Passage	
	RM 354 (Ringold)	RM 365 to 368	RM 371 (White Bluffs)	RM 373 to 376	RM 383 (Coyote Rapids)	RM 393 (Midway)	Other	Total	Bonneville Dam (Aug 1-Dec 31)	McNary Dam (Aug 14-Oct 31)
1947	0	15	25	10	0	75	115	240	307,955	
1948	120	330	38	219	0	25	53	785	310,590	
1949	45	50	6	195	0	1	33	330	180,981	
1950	24	43	38	151	3	46	11	316	250,482	
1951	5	10	45	151	5	95	3	314	137,617	
1952	73	101	40	221	3	78	23	539	220,396	
1953	7	5	16	38	0	83	0	149	104,371	
1954	4	5	8	127	0	6	7	157	106,784	13,476
1955	0	12	0	47	0	4	1	64	105,318	16,426
1956	0	3	7	59	0	17	6	92	136,268	11,290
1957 ⁽¹⁾	17	88	39	290	42	100	1	577	131,813	70,607
1958 ⁽¹⁾	32	105	99	332	130	176	48	922	249,314	97,528
1959	1	0	36	101	32	111	0	281	194,943	55,730
1960	0	31	22	99	38	105	0	295	101,232	47,337
1961	0	27	43	201	23	640	4	939	116,824	41,200
1962	6	195	66	456	1	535	2	1261	118,024	44,116
1963	0	283	127	506	14	370	3	1303	139,075	57,363
1964	5	163	111	510	37	624	27	1477	172,463	58,593
1965	4	262	211	588	54	659	11	1789	157,694	76,326
1966	10	279	267	1206	37	1300	2	3101	155,445	75,119
1967	28	388	273	1192	17	1340	29	3267	185,643	73,087

TABLE 3.14. (contd)

Year	Number of Redds								Adult Fall Chinook Passage	
	RM 354 (Ringold)	RM 365 to 368	RM 371 (White Bluffs)	RM 373 to 376	RM 383 (Coyote Rapids)	RM 393 (Midway)	Other	Total	Bonneville Dam (Aug 1-Dec 31)	McNary Dam (Aug 14-Oct 31)
1968	117	595	188	1069	52	1520	39	3595	159,048	72,757
1969	265	820	427	1446	50	1500	0	4508	231,828	79,375
1970	107	615	302	1180	72	1528	9	3813	208,902	61,554
1971	182	560	416	1071	10	1361	0	3600	202,274	69,718
1972	88	247	147	259	4	131	0	876	137,486	49,307
1973	137	458	179	1273	62	856	0	2965	211,127	73,253
1974	104	156	49	238	5	173	3	728	186,328	62,009
1975	95	458	291	752	91	995	1	2683	277,111	68,719
1976	25	313	185	647	182	599	0	1951	325,312	87,991
1977	15	473	355	1577	48	772	0	3240	206,126	84,370
1978	18	216	326	1389	80	999	0	3028	200,414	44,145
1979	67	396	297	1151	92	980	0	2983	190,627	49,961
1980	30	157	64	346	35	855	0	1487	153,466	38,910
1981	82	421	275	1875	80	2132	0	4866	193,712	33,148
1982	9	368	290	1978	168	2159	16	4988	219,923	56,869

(1) 1957 and 1958 counts were corrected. The original values were the sum of all redds observed, i.e. the sum of all survey counts.

TABLE 3.15. Relative Utilization of Major Fall Chinook Spawning Grounds in the Hanford Reach

Spawning Area	Section	10 Year Average # Redds (1967-1976)	Contribution Per Area
1. Wooded Island/ Ringold	RM 347-354	103	3.9
2. --	RM 365-368	259	9.8
3. White Bluffs	RM 371	183	6.9
4. --	RM 373-374	235	8.9
5. Locke Island	RM 375	530	20.1
6. --	RM 376	111	4.2
7. --	RM 377	226	8.6
8. Coyote Rapids	RM 383	51	1.9
9. Vernita Bar	RM 393-395	943	35.7
TOTAL 10 Year Average		2,639	100.0
Range		623-3,981 Redds	

Source: PSP&L (1981, Amendment 4)

salmon these fry may be present in nearshore areas in July, virtually all are absent in August when seasonal water temperatures peak.

Peak movement through the Hanford Reach of 0-age group fall and summer chinook salmon from upstream tributaries and hatcheries typically occurs in August (Sims and Miller 1976, Table 2; Hovland et al. 1982, p. 9). Peak outmigration of 1-age group spring chinook salmon from upstream occurs near mid-May (Hovland et al. 1982). Outmigrants passing through the Hanford Reach from upriver tributaries and hatcheries are typically larger than those produced locally. These upriver fish generally pass through the area rapidly and do not linger at nearshore sites.

Two rearing facilities contribute juvenile fall chinook directly to the Hanford Reach: the hatchery and spawning channel at Priest Rapids Dam, above Hanford, and the Ringold Rearing Ponds in the lower reaches of Hanford. Available production data from these facilities are given in Figures A.1 and A.2.

Feeding and growth is important for 0-age fall chinook salmon in the Hanford Reach. Based on frequency of occurrence and volume, various stages of aquatic insects, mainly caddisfly (Trichoptera) and midge fly (Chironomidae) are the major food items (Becker 1972 p. 391; Gray and Dauble 1977a, p. 5.7; Gray and Dauble 1978, p. 5.5). Feeding trends are related to seasonal availability of various food organisms.

Because 1-age fingerlings are larger than 0-age fry, their food habits may differ. Adult caddisfly and midge fly pupae represent the greatest food items by number and volume of transitory spring chinook salmon smolts (Gray and Dauble 1979a, p. 5.7; Gray and Dauble 1977b, p. 5.6). Caddisfly larvae, fish, spiders and midge fly larvae and adults are also taken. Salmon smolts may prey on salmon fry (loc. cit.).

Columbia River salmonids are cold-water species and are relatively sensitive to water temperatures exceeding 20°C. Preferred temperatures are reported to range from 12.0°C (53.6°F) to 13.0°C (55.4°F) for juvenile chinook salmon acclimated to 20.0°C (68°F) (Brett 1952, p. 291) and 17.3°C (63.1°F) for adults (Spigarelli 1975). The incipient upper lethal temperature (1 week exposure) for juvenile chinook salmon is 25.1°C (77.2°F) (Brett 1952, p. 305). Chinook salmon may be able to avoid temperatures that exceed the preferred temperatures. Juvenile chinook salmon in laboratory tests avoid simulated thermal discharges at a current velocity of 2.0 fps when the thermal discharge greatly exceed ambient temperatures (Gray et al. 1977, p. 369). Other observations suggest that adult chinook salmon in the Columbia River will cease upstream migration at water temperatures above 21.1°C (70.0°F) (EPA 1971, p. 17).

Median (50% mortality) resistant times to death for young spring chinook salmon range from 205 min at a 22.5°C (72.5°F) exposure and 5°C (41°F) acclimation to 12,300 min at 25°C (77.0°F) exposure and 24°C (75.2°F)

acclimation (Brett 1952, p. 316). The lethal threshold (10% mortality) of 19.5°C (67.7°F) at 13.0°C (55.4°F) acclimation for chinook salmon fingerlings at 2-wk exposures (Snyder and Blahm 1970, p. 893). Another study lists an upper lethal threshold (50% mortality) of 24.2-24.4°C (75.6°-76.1°F) at acclimations of 11.0-20.0°C (51.8-68.0°F) (Blahm and McConnel 1970).

Precise upper limits have not been defined for adult chinook salmon, but experiments with precocious males (jack salmon) suggest that the incipient lethal temperature for fish acclimated to 15.3-19.6°C (59.5-67.3°F) ambient Columbia River water is 21.0-22.0°C (69.8-71.6°F) (Coutant 1970a). For adult chinook salmon in the Hanford Reach, water temperatures are crucial during spawning. Temperatures are normally about 15.0-16.0°C (59.0-60.8°F) when spawning begins in the fall, but they were as high as 19.3°C (66.8°F) during early October 1958 when spawning had apparently started.

The effect of a thermal effluent discharge in midstream on juvenile chinook salmon outmigrants will depend on several factors including the timing of the outmigration, distribution of the fish in the water column, the thermal increment encountered, and the duration of exposure.

Data on the timing of the chinook salmon outmigration from the Hanford Reach were presented previously. Peak numbers of 0-age fry occur in shoreline areas from late April through May (Becker 1970, p. 6; Gray and Dauble 1979a, Fig. 5.2, 1979b, Fig. 5.2). Downstream movement of 1-age chinook fingerlings over Priest Rapids Dam occurred from April to September in 1967. The timing of the outmigration is now somewhat later than the timing before extensive dam construction. For example, the 1-age group outmigrants appeared at Byers Landing (RM 346) in June 1955 and composed 93% of the catch in July (Mains and Smith 1964, p. 28-29). Impoundment of the upper Columbia River is considered responsible for delayed outmigration rates in recent years (Park 1969, p. 315-317; Raymond 1968, p. 358).

Most (60-75%) movement of chinook salmon smolts occurred at night at Priest Rapids Dam (Sims and Miller 1977, p. 12), as it did in 1955 (70%) at Beyers Landing (Mains and Smith 1964, p. 29-30). However, some outmigrants pass downriver at all times of the day. Horizontal and vertical distribution of outmigrants in the water column of the Hanford Reach is known primarily

from 1955 studies of Mains and Smith (1964), before construction of Priest Rapids Dam. Stations closest to the banks accounted for the heaviest catches per unit of effort (50-60%), although numerous fish were taken at all stations across the rest of the river (40-50%). The outmigrant chinooks also preferred the surface zone, with 44% of the catch near the surface, 28% at mid-depth and 30% at the bottom (Mains and Smith 1964, p. 42). Recent (1983) studies on the distribution of 1-age salmonids passing seaward at Hanford were conducted at PNL, and these data are being analyzed.

The duration of exposure is related to an acute encounter when a fish enters a thermal effluent in a flowing river, passes downstream through the effluent and returns to ambient river temperature. Experimental data on this phenomena is given by Dean (1973) for juveniles of three salmonid species, including chinook salmon. Additional experimental studies on plume exposures were conducted at PNL in 1983, and these data are being analyzed. Coutant (1972) discussed the scientific basis for water temperature standards at power plants, including the relationship between effects and duration of exposure of fish entrained in thermal discharge plumes.

3.2.4.2.2 Coho salmon

Coho salmon do not spawn in the Hanford Reach but migrate through it to and from upstream spawning areas, primarily the Wenatchee River system. Generally, coho spawning and fry development occurs in smaller rivers and moderately-sized tributary streams in the lower Columbia River (Fulton 1970, p. 12). After hatching, juvenile coho salmon remain in freshwater nursery area for one to three years before migrating to the sea as smolts measuring 4-7 inches (Wydowski and Whitney 1979, p. 56-58).

From 1954 through 1981, the main adult coho salmon spawning migration at McNary Dam occurred from August through October, with the peak movement in September (U.S. Army Corps of Engineers, 1982 Table 69). Adult counts at Priest Rapids Dam have declined significantly in recent years. Counts ranged from 1,336 to 11,648 adults annually from 1966 to 1976, but dropped to less than a thousand for most years after that time. The coho salmon run characteristically contains a high proportion of precocious males ("jacks") (Bilton et al. 1982).

Outmigrant coho salmon, primarily 1-age fish, appear at Priest Rapids Dam from April to September with peaks occurring usually in May (Sims and Miller 1976, p. 9; Faurot 1979, p. 9; Olson 1981, p. 17). Coho move into gatewell collectors at Priest Rapids Dam primarily at night (Olson 1981, p. 18-19). Downstream migration rate of all salmonids including coho from Priest Rapids Dam to McNary Dam ranged from 7 to 15 days in 1977 with fastest travel at higher river flows (Faurot 1979, p. 8). Passage through the Hanford Reach must be relatively rapid since outmigration would be slowed by Lake Wallula, the impoundment behind McNary Dam.

Some coho salmon smolts may stay in the Hanford Reach, a tendency noted only recently. In Spring 1978, several coho salmon were collected at Hanford that appeared to be 2-year old residents (Gray and Dauble 1979b, p. 5.10). However, these fish may have moved up from Lake Wallula, downstream of Hanford.

Numbers of coho salmon smolts passing through the Hanford Reach are variable, and depend on fluctuations in natural production and on artificial propagation, primarily at the Leavenworth Hatchery, Wenatchee River system in recent years (Sims and Miller 1976, p. 9). Annual gatewell catches at Priest Rapids Dam, a program now supported by Grant County Public Utility District, do not accurately indicate the size of the outmigration. This is because gatewell sampling does not collect outmigrants passing over the spillway, and spillway discharges vary widely from year to year. Also, collecting effort has been inconsistent from year to year. However, an estimated 600,000 juvenile coho salmon passed Priest Rapids Dam in 1976 (Sims and Miller 1976, p. 6). This estimate is only about half that of the runs that occurred in the late 1960s (Park and Bentley 1968).

Analysis of stomach contents of juvenile coho salmon collected at Hanford showed a varied diet consisting of fish larvae, midge fly larvae and pupae, and caddisfly larvae and adults (Gray and Dauble 1979b, p. 5.11).

Adult coho salmon generally prefer temperatures from 11.4 to 16.6°C (52.5 to 61.9°F) (Brett 1952, p. 293; Reutter and Herdendorf 1974, Spigarelli 1975). Coho salmon, like other species of Pacific salmon, generally avoid temperatures above 15°C (59°F) (Brett 1952, p. 293). Elevation of

environmental temperatures above 21.0°C (69.8°F) may be directly lethal to adult salmon and steelhead during long-term (about 1 week) exposures (Coutant 1970a, p. 10). Geometric mean time to death for adult coho salmon ranged from 13 minutes at 30°C (86°F) to 42 min at 26°C (78.8°F) (Coutant 1970a, Figure 5).

The upper incipient lethal temperature for juvenile coho salmon acclimated at 5 to 23°C (41 to 73.2°F) is 22.9 to 25°C (73.2 to 77.0°F) (Brett 1952, Figure 24). Median times to death (50% mortality) range from 1000 min at exposure to 23°C (73.4°F) to 9000 min at exposure to 25°C (77.0°F), depending on acclimation level (Brett 1952, Figure 8, Table 4). The lethal threshold (10% mortality) for juvenile coho salmon acclimated at temperatures of 10 to 14°C (50 to 57.2°F) ranged from 14 to 23.7°C (57.2 to 74.7°F) (Blahm and McConnel 1970).

Loss of equilibrium and lethal temperatures of juvenile coho salmon acclimated to 5 and 15°C (41.0 and 59°F) and exposed to progressively increasing temperatures will vary with the rate of increase (Becker and Genoway 1979, p. 248). Resistance times of juvenile coho salmon acclimated to 10, 15 and 20°C (50, 59 and 68°F) varied from 100,000 to less than 100 minutes (Dean 1973, p. 38).

Elevated temperatures also produce secondary effects among coho salmon. For example, rheotactic response may be altered by sudden small changes in temperature during fry and smolt outmigration (Keenleyside and Hoare 1954, p. 82). As it does with other anadromous species of salmonids, temperature influences the growth and smolting of juvenile coho salmon (Clarke et al. 1981, p. 113; Wedemeyer et al. 1980, p. 6-7). Also, sublethal heat stress results in a number of physiological responses (Wedemeyer 1973). Outbreaks of a number of fish diseases, including the bacterial disease columnaris (Holt et al. 1975; Becker and Fujihara 1978, p. 25-27) are influenced by elevated temperatures.

3.2.4.2.3 Sockeye salmon

Sockeye salmon do not spawn in the Hanford Reach but migrate through it to upstream spawning areas. Adults typically spawn in tributary or outlet streams of lakes, or along lake shores, from August through November.

Juveniles live 1 to 3 years in lakes before migrating seaward in early spring. Virtually all sockeye salmon adults entering the Columbia River are destined for its upper reaches where the main production areas are Lake Wenatchee, on the Wenatchee River and Lake Osoyoos on the Okanogan River (Allen 1977, p. 29). Adult sockeye salmon typically migrate upriver in relatively shallow water near the shore (Becker 1962), but there is little knowledge of their migration routes in the mid-Columbia River.

The last large runs of adult sockeye salmon passed McNary Dam in 1966, 1967 and 1968 when the run averaged 127,000 fish. Since that time McNary Dam counts have averaged 40,000 fish (U.S. Army Corps of Engineers 1982, Table 68). There has been no meaningful commercial harvest in the lower Columbia River in recent years. Discrepancies exist between the counts of adult sockeye salmon at Priest Rapids Dam and the counts at McNary Dam. Adult sockeye salmon pass through the Hanford Reach primarily from June to early September, with the upstream migration peaking in July (U.S. Army Corps of Engineers 1982, Table 68).

Sockeye salmon fry emerge in April and May and enter lakes to feed. Peak outmigration of juvenile sockeye salmon at Priest Rapids Dam occurs in May (Table 3.11). Juveniles enter the gatewells at Priest Rapids Dam at all hours of the day, but in greatest numbers during the afternoon (Olson 1981, Figure 6). In terms of relative abundance, the numbers of juvenile sockeye salmon outmigrants are close to that of juvenile chinook salmon outmigrants in gatewell collections at Priest Rapids Dam (Olson 1981, Table 2).

Numbers of sockeye salmon juveniles passing downstream each year through the Hanford Reach depends on natural reproduction of upstream stocks. Estimates of sockeye salmon juveniles passing Priest Rapids Dam ranged from 1.0 to 4.0 million from 1965 to 1967, and were 1.6 million in 1976 (Sims and Miller 1976, Table 1). A few juvenile sockeye salmon have been collected in the Hanford Reach have been made in June and July (Gray and Dauble 1978, p. 515; Page et al. 1982, Table 2). The Hanford area is transitory habitat for juvenile sockeye salmon and this section of the river is not an important feeding area for outmigrants.

Sockeye salmon juveniles feed primarily on zooplankton and phytoplankton in their lake nursery areas (Foerster 1968, p. 166-167). They feed on plankton more than juveniles of other species of Pacific salmon. Analysis of gut contents of a few sockeye salmon outmigrants taken at Hanford (RM 352) showed primarily midge fly and caddisfly pupae (Gray and Dauble 1979a, Table 5.5).

Juvenile sockeye salmon prefer temperatures of 12 to 14°C (53.6 to 57.2°F) regardless of acclimation level, and generally avoid temperatures above 15°C (59°C), as do other species of Pacific Salmon (Brett 1952, p. 293). One field study showed a preferred range of 10.6 to 12.8°C (51.1 to 55.0°F) (Horak and Tanner, 1964). The optimum temperature for growth of fingerling sockeye salmon is near 15°C (59°F) (Brett 1971, p. 99). The temperature preference for kokanee salmon (landlocked sockeye salmon) is 10-15°C (50-59°C) (Scott and Crossman 1973, p. 169.).

The upper incipient lethal temperature for juvenile sockeye salmon acclimated from 5 to 23°C (41 to 73.2°F) is 22 to 24°C (71.6 to 75.2°F) (Brett 1952, Figure 22). Medium times to death (50% mortality) range from 100 minutes at 5°C (41°F) acclimation and exposure to 22.5°C (72.5°F) to 675 minutes at 23°C (73.4°F) acclimation and exposure to 26.5°C (79.7°F) (Brett 1952, Table 4). Adult sockeye salmon can survive an average of 3.2 days at 22.2°C (72°F) and 11.7 days at 20.0°C (68°F) (EPA 1971, p. 41-42).

Elevated temperatures may delay the upstream migration of sockeye salmon. Adults congregate in colder tributary streams near Bonneville and Rock Island Dams when Columbia River temperatures reached 21.7 to 23.9°C (71.1 to 75.0°F) (Fish and Hanavan 1948). Water temperatures above 21.1°C (70°F) block migration of sockeye salmon into the Okanogan River (Major and Mighell 1967, p. 145).

Elevated temperatures also produce secondary effects among sockeye salmon. In the Columbia River system, high temperatures are related to outbreaks of a bacterial disease, columnaris (Holt et al. 1975, Becker and Fujihara 1978, p. 25-27). Juvenile sockeye salmon stressed by abrupt exposure to elevated temperatures are more susceptible to predation (Sylvester 1972).

3.2.4.2.4 Steelhead or rainbow trout. The steelhead trout is an anadromous form of the rainbow trout. Resident and anadromous forms both occur in the Hanford Reach. The steelhead trout spawns in freshwater but may not die afterward as do Pacific salmon (genus Oncorhynchus). Steelhead and rainbow trout both have sport and commercial value, and the former contributes to the Indian gill net fishery in the lower Columbia River on its return from the ocean.

On the basis of the timing of the adult migration in the lower Columbia River, steelhead trout are classified either as winter or summer run. The summer run, which enters the river from May to October, migrates upriver to tributaries above Bonneville Dam (Fulton 1970, p. 3).

Adult steelhead trout show peak periods of migration through the Hanford Reach, but a sizeable population is present the year around. An upriver run of steelhead occurs over McNary Dam from April through October, but the peak movement occurs in August and September (U.S. Army Corps of Engineers 1982, Table 70). The average migration of steelhead trout over the McNary Dam from 1971 to 1981 was 11,000 in August and 24,000 in September (loc. cit.). Many of these fish are destined for the Snake River as well as the mid-Columbia River. In some months (October, April, May) more steelhead pass over Priest Rapids and Ice Harbor Dams then come upriver over McNary Dam. This may indicate late fall and winter residence in Lake Wallula and the Hanford Reach (Watson 1973, p. 3).

Numbers of adult steelhead trout passing Priest Rapids Dam ranged from 2,000 to 11,000 from 1971 to 1980 and averaged 7,000 fish (Table 3.16). The average number from 1962 to 1971 at the same location was 9,700 (Watson 1973, Table 1), indicating sustained population levels with some year-to-year variations. The peak run of adult steelhead trout over Priest Rapids Dam occurs in September of most years. Steelhead and rainbow trout have been collected in small numbers from the Hanford Reach at RM 366 (RKM 588) and 352 (RKM 566) during most months (Gray and Dauble 1976a, Figure 5.13; Gray and Dauble 1979b, Figure 5.14). In addition to McNary and Ice Harbor runs, each year about 10,000 to 15,000 steelhead trout enter the Yakima River, about 4,000 to 5,000 enter the Walla Walla River, and about 2,700 are taken by sport

TABLE 3.16. Adult Salmon Counts at the Priest Rapids Dam Fishway
(Olson 1981, p. 40)

Year	Spring Chinook	Summer Chinook	Fall Chinook	Sockeye	Coho	Steelhead	Total Salmonids
1960	8,534	20,852	10,687	58,201	58	7,827	66,133
1961	8,385	18,245	11,108	19,793	88	8,559	66,178
1962	7,993	20,824	10,082	28,575	601	9,324	77,399
1963	7,597	18,511	17,563	64,883	29	9,344	177,927
1964	9,814	26,489	14,760	79,072	60	6,009	136,204
1965	5,718	24,936	21,149	48,340	440	9,041	109,632
1966	13,358	29,736	18,821	170,071	11,903	13,006	252,930
1967	10,307	26,256	12,375	123,786	8,879	7,354	188,937
1968	10,739	26,544	11,031	108,308	13,212	10,524	180,358
1969	7,142	21,277	12,367	39,240	1,351	6,650	88,027
1970	5,789	21,641	16,372	77,419	4,971	5,558	131,750
1971	5,086	20,481	10,591	73,837	7,738	11,102	128,835
1972	8,775	18,083	5,782	44,927	5,225	6,429	89,221
1973	9,967	14,351	10,083	54,480	1,576	6,999	97,456
1974	11,127	13,703	7,618	35,434	1,781	3,089	72,752
1975	8,170	22,205	13,865	55,210	2,193	2,462	103,605
1976	13,306	19,344	10,774	32,810	2,275	9,248	87,757
1977	21,217	19,605	6,856	95,413	370	9,803	153,264
1978	21,427	22,580	6,523	17,529	597	4,545	73,201
1979	7,750	22,689	7,727	45,662	311	8,409	86,947
1980	11,136	18,708	8,441	52,039	318	8,524	99,166
1981*	14,467	11,633	5,417	51,460	300	8,925	92,202
1982*	8,664	8,762	12,462	40,461	1,631	10,893	82,873

* Condensed Daily Fish Count Report,
U. S. Army Engineer District, Portland, OR

fishermen. Assuming a 20% mortality also, for fish unaccounted for, the average annual number of steelhead trout spawning in the Hanford Reach was about 10,000 for the 1962-1971 period (Watson 1973, p. 6-7). In recent years, steelhead trout are also reared and released at the Ringold Hatchery [RM 354 (RKM 569)] and a significant sport fishery occurs on returns to this facility (Allen 1977, p. 25, 27).

Steelhead trout mature in the ocean at ages of 3 to 6 years, spawn in the Columbia River from late December through May and eggs incubate in the gravel through June (Bell 1973, Chapter 5, p. 12-13). Steelhead spawn from February through May from the mouth of the Yakima River to Priest Rapids Dam (Fickeisen

et al. 1980, p. 2-19). Gravid females have been collected in late April and early May, spent males in August, and a spent female in February in the Hanford Reach (Gray and Dauble 1976a, p. 5-20; Gray and Dauble 1977b, p. 5.8. Steelhead may survive spawning. Repeat spawnings ranging from 5 to 31.3 percent are reported in some British Columbia streams (Withler 1966, p. 365). Repeat spawners in Washington State compose from 4.4 to 14% of the run (Wydowski and Whitney 1979, p. 44-45).

Only a few steelhead trout redds have been observed in the Hanford Reach. However, there are several sites with apparently suitable conditions for successful spawning. Few emergent steelhead trout fry have been collected despite extensive effort (Fickeisen et al. 1980, p. 2-19). On the basis of the best available information for the Hanford Reach, the estimated natural production of steelhead trout fry is 1.6 million (loc. cit.).

Estimates of steelhead trout spawners in the Hanford Reach by direct observation and redd enumeration is complicated by high flows and turbidities during the late winter spawning season. Possible spawning areas for steelhead trout are scattered throughout the area (Figure 3.18).

Releases of juvenile steelhead trout occur annually at Ringold rearing facility operated by the Washington State Departments of Game and Fisheries. About 160,000 smolts are released each year from the Ringold facility (RM 354). The releases represent about 25% of the of steelhead trout reared artificially from the Hanford area upstream to Wenatchee (Washington State Department of Game, 1971 to 1979). Most releases from Ringold facilities remain in the general area for about a month, and a few overwinter in the Hanford Reach (Gray and Dauble 1978, p. 5.12).

Juvenile steelhead trout characteristically spend one to three years in freshwater and move seaward through the Columbia River during the spring and summer (Bell 1973, p. 12-13). The outmigration of juvenile steelhead trout from above Priest Rapids Dam generally occurs from mid-April to early July, with a peak movement in May (Table 3.11). Juvenile outmigrants were collected at Hanford from April through June with peak catches in May (Gray and Dauble 1977a, Fig. 5.12; 1978, Fig. 5.11; 1979a, Fig. 5.11). However, markings indicated that most of these fish were produced at upriver hatcheries. The

hatchery contribution may be reflected in outmigration patterns (Park and Bentley 1968). Estimated of steelhead trout outmigrants at Priest Rapids Dam in 1965, 1966, 1967 and 1976 were 270,000, 240,000, 266,000 and 400,000, respectively (Sims and Miller 1976, Table 1).

Therefore, the total number of juvenile steelhead trout passing seaward from the Hanford Reach each year is between 2.0 and 2.2 million (sum of natural and artificial production at Hanford plus the outmigration at Priest Rapids Dam) (Fickeisen et al. 1980, p. 2-21). The variation in this estimate reflects changes in abundance of juveniles passing Priest Rapids Dam and of juveniles produced at the Ringold facilities.

Diel movements of juvenile salmonid outmigrants tends to vary, for reasons that remain unclear. Catches at Priest Rapids Dam first indicated that most (61%) entered the intake gatewells after dark (Sims and Miller 1977, p. 13). Recent studies indicate variable movement rates at night and a strong movement after sunrise (Olson 1981, p. 19-20). Most outmigration (76%) of steelhead trout smolts from impounded waters occurs at night, and the portion of fish collected in the lighted surface zone (0-7.3 m) declines from day (74%) to night (36%), reflecting this movement (Smith 1974, p. 42-45). Most steelhead smolts passing Priest Rapids Dam probably move directly through the free-flowing Hanford Reach to Lake Wallula.

Juvenile steelhead and rainbow trout in freshwater streams exist on foods associated with the bottom, such as aquatic insects, amphipods, aquatic worms, fish eggs, and occasionally small fish. Diets change seasonally depending on availability of food items (Wydoski and Whitney 1979, p. 46). At Hanford, fish and caddisflies (adults and larvae) were food major items of juvenile rainbow trout collected near the N-Reactor (Gray and Dauble 1976a, Table 5.3), as well terrestrial insects (spiders and beetles). Analysis of stomach contents from fish collected near RM 352 revealed caddisfly larvae, pupae, and adults, midgefly pupae, other insects and fish as major food items (Gray and Dauble 1979b, Table 5.14). The summer emergence of adult caddisflies in the Hanford Reach is reflected in stomach contents of these fish. Adult steelhead trout do not actively feed during their upstream migration, but they will take salmon eggs, worms and artificial lures. Guts of adult steelhead collected at Hanford were empty and atrophied.

Most adult steelhead trout collected at Hanford were 3 to 4 years old. Except for hatchery releases (Ringold), most fish displayed two freshwater annuli on their scales, indicating that they wintered 2 years in the river before outmigrating as smolts. Most fish returning to Washington streams have been at sea for 2 years and weigh 5 to 10 pounds (Wydowski and Whitney 1979, p. 44). Adult size is generally related to the length of residence and feeding conditions in the ocean.

Adult rainbow trout prefer temperatures ranging from 10.8 to 22.5°C (52.1 to 72.5°F) depending on acclimation temperature, season and life stage. In one early study, the final preferred temperature was 13°C (55.4°F) (Garside and Tate 1958, p. 565).

Juvenile rainbow trout prefer temperatures between 11.6 to 22.0°C (57.8 to 71.6°F) at acclimation temperatures between 6.0° to 24.0°C (42.8 to 75.2°F) (Cherry et al. 1975, Table 1).

Given a choice, rainbow trout (and other salmonids) may avoid potentially lethal temperatures. The upper avoidance temperature of adult rainbow trout is 25°C (77°F) when they are acclimated to 24°C (75.2°F), and 13°C (55.4°F) when acclimated to 6°C (42.8°F) (Cherry et al. 1975, Table 2); fingerlings avoid 22.0°C (71.6°F) when reared at 15-20°C (29-68°F) (McCauley and Pond 1971, p. 1802-1804). The upper lethal temperature limit for steelhead and rainbow trout will vary with acclimation level, physiological condition of the fish, and environmental factors. In one study, juvenile rainbow trout acclimated to 11°C (51.8°F) died at 24°C (75.2°) at exposures of 24 hours, but all survived at 22°C (71.6°F) (Black 1953, p. 199). In another study, juvenile rainbow trout acclimated to 20°C (68°F) exposed to 27°C (80.6°F) died in 423 or 363 minutes, depending on whether they were reared in soft or hard water (Craigie 1963, p. 828). The maximum acclimation temperature is 17°C (80.6°F) (Charlon et al. 1970, p. 88). The apparent upper lethal threshold for adult steelhead trout in the Hanford Reach is 21°C (69.8°F) (Coutant 1970a, p. 10).

Elevated temperatures will generally increase the rate of embryonic development of eggs deposited by most species of salmonids, as long the

temperature does not exceed lethal limits. Rainbow trout eggs hatch at the following rate when incubated at increasing temperatures: 80 days at 4.4°C (40°F), 48 days 7.2°C (45°F), 31 days at 10°C (50°F), 24 days at 12.8°C (55°F), and 19 days at 15.6°C (60°F) (Leitritz and Lewis 1976, p. 76).

Secondary effects of high water temperatures have also been reported. Migrating steelhead trout (and other adult salmonids) may cease upstream movement in the Columbia River when temperatures exceed 21.1°C (70°F) (EPA 1971, p. 17). The migration paths of adult steelhead in the Snake River remained the same with seasonal changes of river temperature from 3.0 to 23.5°C (37.4 to 74.3°F) however, migration rates increased from 1 km/day at 0-11°C (32-51.9°F) to 5 km/day at 18.5°C (65.3°F) and to 16 km/day at 21°C (69.8°F) (Falter and Ringe 1974, p. 55-56). A rapid increase in temperature from 10 to 20°C (50-68°F) in three minutes can cause a number of sublethal physiological effects but recovery occurs in 24-28 hours (Wedemeyer 1973, p. 831-834). Exposure to thermal shock may induce selective predation on juvenile rainbow trout over different exposure times. The highest temperatures showed effects after the shortest exposures. The lowest temperature of 26°C induced significant predation after exposures of 64, 90 and 120 minutes but not after 16 to 32 min (Coutant 1973, p. 968-969).

Temperature is also a factor in susceptibility of salmonids to many infectious pathogens. In one study, experimental infections of juvenile steelhead trout with the bacterial disease columnaris was related to temperature. No mortality occurred below 9.4°C (49°F), but 96 to 100% mortality occurred in groups held at different temperatures above 12.2°C (54°F) (Holt et al. 1975, p. 1555). The same study found that all steelhead trout held as controls at 23.3°C (74°F) died in 13 days with no evidence of infection (loc. cit).

3.2.4.3 Important Resident Species

Important resident species in the Hanford Reach include the white sturgeon, large scale sucker, prickly sculpin, northern squawfish, mountain whitefish, smallmouth bass and yellow perch.

3.2.4.3.1 White Sturgeon. The white sturgeon is the largest North American freshwater fish. It occurs along the Pacific Coast from Monterey,

California, to Cook Inlet in northwestern Alaska (Wydoski and Whitney 1979, p. 17). White sturgeon occur throughout most of the Columbia River and its tributaries (Scott and Crossman 1973, p. 97). Although some individuals are found in the ocean and ascend rivers to spawn, white sturgeon are not truly anadromous. In earlier years, sturgeon in the Columbia River appeared to migrate upstream during the fall and early winter, and downstream in late winter and spring (Bajkov 1951, p. 20). However, many individuals remain in freshwater throughout their long life; movement of those in the Columbia River above Bonneville Dam is now restricted by hydroelectric dams, although some may move upstream or downstream through the navigation locks.

Female white sturgeon do not mature until 15 years old at a length of about 64 inches (165 cm) and a weight of 60-70 lbs (Stockley 1981, p. 2). White sturgeon spawn primarily in May and June when temperatures reach between 8.9 and 16.7°C (48 and 62°F) (loc. cit). Adults survive spawning but spawn again only after increasing intervals of 2-11 years. White sturgeon spawn in fast-flowing rocky areas of river at least 10 ft (3 meters) deep and broadcast their eggs in large grayish masses. The eggs become sticky when exposed to water and adhere to any material contacted (loc. cit).

A female sturgeon can produce several million eggs, and the number of eggs produced increases geometrically as the fish grows (Stockley 1981, Figure 1). A female sturgeon with maturing ovaries, if subjected to stress, may absorb her eggs and lose a spawning cycle (Stockley 1981, p. 2). Eggs hatch in 1 to 2 weeks depending on water temperature. Collections of post-larval white sturgeon in the Columbia River, including the Hanford Reach, are rare. In the lower Columbia River, yolk-sac fry were collected in May 1979, 1980 and 1981 with drift trawls in from 30 to 65 feet (9 to 20 meters) of water (Stockley 1981, p. 2). In the Hanford Reach, catches of immature white sturgeon near RM 352 occurred in April, May and August (Gray and Dauble 1979b). Only one juvenile white sturgeon was collected on traveling screens during various impingement studies conducted at the Washington Public Power Supply Systems Hanford Generating Plant and N Reactor from 1974 through 1977 (Gray et al. 1975, Page et al. 1975, 1976a, 1977a). A study of sturgeon movement in

the Snake River failed to locate fish less than 18 inches (46 cm long, although effort to locate small individuals was limited (Coon et al. 1977, p. 34).

No spawning white sturgeon spawning has been detected in the Hanford Reach, but all bottom types and currents generally reported as favorable for spawning are present (Fickeisen et al. 1980, p. 2-25). White sturgeon are found in deeper holes in the Columbia River (Wydoski and Whitney 1979, p. 17), and may spawn in certain areas of the Hanford Reach: below Priest Rapids Dam (RM 396), below Coyote Rapids (RM 383), at White Bluffs (RM 370), and below Ringold (Fickeisen et al. 1980, Figure 10).

Sturgeon fry begin to search for small planktonic crustaceans as soon as their yolk sac is absorbed, then seek various insect larvae as they become larger. When about 1 year old (7-9 inches long; 18-23 cm). They become bottom feeders and eat organisms such as molluscs, crayfish, fish and carrion. Sturgeon have poor eyesite and feed by touch and smell. They are equipped with four sensitive barbels and root in the mud with their snouts when feeding although food consists mainly of animal matter, sturgeon are opportunistic and will try any available food (Galbreath 1979, p. 5). White sturgeon in the Snake River have had reduced growth rates in recent years, presumably because dams have eliminated or greatly reduced upriver runs of anadromous salmonids and lampreys. The spawned-out carcasses of these fish are important sturgeon food (Coon et al. 1977, p. 60-61). Because of lesser amounts of food available, white sturgeon above Bonneville Dam grow more slowly than those below (Galbreath 1979, p. 6).

Stomach contents of white sturgeon collected in the Hanford Reach show a variety of bottom organisms. In one study, fish collected near the N-Reactor (RM 380) and showed that crayfish and snails were commonly ingested (Gray and Dauble 1976a, Table 5.24). In another study, fish collected at RM 352 showed that the main food items were fish, midge-fly larvae, caddisfly larvae, and crayfish (Gray and Dauble 1977a, Table 5.21).

White sturgeon collected in the Hanford Reach from 1973 through 1978 ranged from 45 to 158 cm long. A small white sturgeon about 20 cm long was observed just above Wooded Island (RM 350). Young sturgeon reach a length of

51 cm is about 5 years. All evidence indicates that a viable spawning population of white sturgeon is present in the Hanford Reach (Fickeisen et al. 1980, p. 2-27).

White sturgeon movement in the Hanford Reach was studied in 1975 and 1976. Water temperatures appeared to influence diel and seasonal movements. As temperatures dropped below 13°C (55.4°F) in October, sturgeon long-distant movement slowed and only local movement occurred until temperatures increased above 13°C (55.4°F) in June (Haynes 1978, p. 59). During summer, sturgeon moved into warmed shallow areas in late afternoon and evening, and back to cool, main-channel areas in early morning (loc. cit.). These movements were probably related to feeding.

No thermal studies have been conducted with white sturgeon. Temperature preference is inferred only from movement data (Haynes 1978, loc. cit.) and spawning timing. In Sacramento River, California, sturgeon spawn when temperatures range from 7.8 to 17.8°C (46.0 to 64.0°F), with a peak at 14.4°C (57.9°F) (Kohlhorst 1976, p. 352). Spawning in the Columbia River occurs from May through July at 8.9 to 17.2°C (48 to 63°F) (Wydowski and Whitney 1979, p. 18). White sturgeon have been caught at temperatures of 0 to 23.3°C (32 to 74°F) (Scott and Crossman 1973, p. 98). For assessment purposes, the thermal tolerance of white sturgeon may be similar to that of chinook and coho salmon.

3.2.4.3.2 Largescale sucker. The largescale sucker is an abundant and highly prolific resident of Pacific Coast drainage systems in Oregon, Washington and British Columbia (Scott and Crossman 1973, p. 545). The largescale sucker inhabits both lakes and streams throughout the State of Washington (Wydowski and Whitney 1979, p. 97), and is often considered to be a nuisance when abundant. The largescale sucker is very common in the Hanford Reach. It was the fourth most abundant species collected near the N-Reactor (RM 380) in 1973 to 1974 (Gray and Dauble 1976a, Figure 5.5). It was the second most common resident fish species collected in other parts of the Columbia River at Hanford (Gray and Dauble 1979b, Figure 5.7). In other studies, the largescale sucker was the most abundant resident species (by number) collected by boat electroshocker in other parts of the Columbia River at Hanford (Beak 1980, Page et al. 1982). The largescale sucker apparently resides and feeds throughout the various widths and depths of the Columbia

River at Hanford. Mark-recapture studies at RM 361 in 1981 gave a population estimate of $\pm 4,961 \pm 9,422$ fish per 1000 M of shoreline in June and $12,343 \pm 6,721$ in July (Page et al. 1982, p. 20). Their large numbers could constitute serious food competition with young and adults of salmonid fishes (Scott and Crossman 1973, p. 546).

The largescale sucker spawns in the spring throughout its range, usually in deeper sandy areas of streams but at times on gravelly or sandy shoals in lakes (Scott and Crossman 1973, p. 545). In the Hanford Reach, wide variation occurs in spawning condition adults collected near the N Reactor from 1975 through 1977 (Gray and Dauble 1979a, Figure 5.3). Water temperatures at Hanford ranged from 6.0 to 10.0°C (42.8 to 50°F) at initiation of spawning and were 12.0 to 15.°C (53.6 to 59°F) at peak spawning in May and June. A female may deposit as many as 20,000 eggs, which are adhesive, demersal, and about 2.5 mm diameter before fertilization (Scott and Crossman 1973, p. 545-546).

Eggs of the largescale sucker hatch in about 2 weeks. Fry remain in the gravel or near the surface of sand for a few weeks until they become pelagic (Scott and Crossman 1973, p. 546; Wydowski and Whitney 1979, p. 98). In the Hanford Reach, fry appear near the shoreline at sizes of 12 to 18 mm at depths less than 1 m. Inshore water temperatures in locations sheltered from the current are warmer than those in mid-channel and these areas are sought by juvenile suckers. Largescale sucker fry and juveniles are collected in shoreline pools where water temperatures range to 23.3°C (73.9°F). Yearling largescale suckers are common in large slough areas rather than the main river (Dauble 1978, p. 61-69).

Sucker fry, when they are pelagic, eat small zooplankton but they change their diet to insect larvae and some diatoms and other plant material when they become bottom dwellers (Wydowski and Whitney 1979, p. 98). Adults feed on a variety of bottom organisms including algae and plant remains, cladocerans, copepods, and aquatic insect larvae. Periphyton (attached algae) is the primary dietary component of largescale sucker of all ages at Hanford (Dauble 1978, Table 7, 9, Figure 18; Gray and Dauble 1976a, p. 5-13) in contrast to an apparent larger invertebrate diet component elsewhere in its range.

Depending on geographical location, the largescale sucker matures in 3 to 6 years; males mature about 1 year earlier than females (Scott and Crossman 1973, p. 546; Brown 1971, p. 126). A largescale sucker can live as long as 11 years and reach a length of 24 inches and a weight of 7 pounds (Wydowski and Whitney 1979, p. 98). In the Hanford Reach, most females mature in 6 or 7 years at about 40 cm length, while males mature 1 year earlier at about 37 cm length (Dauble 1978, p. 17-26). Growth rates decline rapidly after maturity. The maximum age of largescale sucker collected at Hanford was 15 years (loc. cit.).

For juvenile largescale sucker acclimated to 19°C (66.2°F) and abruptly exposed to various temperature increases for 24 hours, the median death point (50% mortality) is 29.4°C (84.9°F) (Black 1953, p. 207). Largescale sucker were collected at Hanford and exposed to a gradual temperature increase to determine critical thermal maximum (CTM) values. The CTM values for adults acclimated from 4.5 to 21.0°C (40.1 to 69.8°F) ranged from 26.9 to 32.6°C (80.4 to 90.6°F) (Dauble 1978, p. 71-72).

Prickly sculpin. The prickly sculpin is generally found along coastal areas of Washington State, but penetrates more than 400 miles upstream in the Columbia River (Scott and Crossman 1973, p. 824; Wydowski and Whitney 1979, p. 160). It is generally found on bottoms of sand, gravel or rubble. At Hanford, adult prickly sculpin are common in nearshore areas, particularly among crevices in cobble bottoms.

The prickly sculpin has been collected near the N-Reactor throughout the year, and was the sixth most common species at this site, with peak numbers observed in June (Gray and Dauble 1976a, Figure 5.7). At RM 252 (RKM 566) sculpins were collected mainly by hoop net in late spring (Gray and Dauble 1979b, Figure 5.5). The prickly sculpin uses its protective coloration for concealment and is often in open areas; small specimens are generally in vegetated areas in shallow water (Wydowski and Whitney 1979, p. 160).

Sculpin larvae appear in the Hanford Reach from mid-April through July at temperatures from 9.0 to 17.0°C (48.2 to 62.6°F) (Page et al. 1982, p. 21). The temperature range for naturally spawning prickly sculpin is 8.0 to 13.0°C (46.4 to 55.4°F) (Krejsa 1967). Nests are usually under rocks and logs

in areas with low water velocities (≤ 1 cfs), and often in man-made objects such as cans, sheet metal, car bodies etc. (Wydowski and Whitney 1979, p. 161). The adhesive eggs are deposited on the under-surface of objects and fertilized. After spawning, the female leaves and the male guards the eggs. Fecundity varies with size of the female, ranging from 280 to 7,410 eggs for mature females from 60 to 160 mm long (loc. cit.).

The eggs hatch in 15 to 16 days at 12°C (53.6°F), and the larvae are 5-7 mm long (Scott and Crossman 1973, p. 825). Larvae remain pelagic for 30 to 35 days before metamorphosis when they sink to the bottom (loc. cit.). In rivers, these pelagic larvae are carried downstream by currents. Sculpin larvae dominate midstream ichthyoplankton drift in the Hanford Reach. Larvae of the prickly sculpin comprised more than 95% of the total larvae fish collected at RM 352 in 1979 (Beak Consultants Inc. 1981; Table 3.5) and at RM 361 (RKM 581) in 1981 (Page et al. 1982, p. 21). Peak densities, however, were relatively low, up to only 0.18 larvae/m³ (Page et al. 1982, Figure 5.31).

Prickly sculpin fry occur in nearshore areas at Hanford in mid-summer. Typical habitat is mud or sand bottom with some submerged or emergent vegetative cover.

Aquatic insect larvae, especially midgefly and caddisfly larvae, and other bottom invertebrates form the major food supply of prickly sculpin (Scott and Crossman 1979, p. 825). Planktonic crustaceans are also important for small fish about 30 mm long. In the Hanford Reach, prickly sculpin feed primarily on caddisfly and midgefly larvae, but also eat crayfish and other benthic invertebrates (Gray and Dauble 1976a, p. 5-15; Gray and Dauble 1979b, p. 5.7). Prickly sculpin also feed on fish eggs, and on young salmonids and other small fish. Several fish species, including white sturgeon, smallmouth bass, squawfish, and bullheads also feed on prickly sculpin (Gray and Dauble 1976a, Section 5).

Prickly sculpin may reach a maximum of 10 years age, but normal life expectancy is probably 5 to 6 years (Bond 1963, p. 30-31). They mature as early as 2 years, but some may not spawn until 4 years old (Wydowski and Whitney 1979, p. 161).

Prickly sculpin, in various parts of their range, are usually found at 10.0 to 17.8°C (50 to 64°F), but they have been found at temperatures as high as 27.8°C (82°F) (loc. cit. p. 160). The species may be relatively sensitive to elevated temperatures. Prickly sculpins acclimated to 19.0°C (66.2°F) died after 24 hour exposure to water heated to 26.5°C (79.7°F); all fish survived at 22.8°C (73°F) but half of the test group died at 24.1°C (75.4°F) (Black 1954, p. 199). Sculpins acclimated to 14.0°C (57.2°F) and exposed to a 1°C daily increase in temperature underwent first mortality at 30.2°C (86.4°F) (Bond 1963, p. 57-58). Prickly sculpin eggs reared in the laboratory underwent over 50% mortality at 15.0°C (59.0°F) and total mortality at 18.0°C (64.4°F) (Krejsa 1967).

3.2.4.3.4 Northern squawfish. The northern squawfish is abundant in the Columbia River system. They inhabit lakes and areas of slow to moderate currents in streams (Wydowski and Whitney 1979, p. 85). Northern squawfish are present throughout the year near the N-Reactor (RM 380) (Gray and Dauble 1976a, Figure 5.22) and RM 352 (Gray and Dauble 1979b, Figure 5.23). Depending on collection method, they rank first to third in abundance of all species captured in the Hanford Reach.

Northern squawfish spawn in the Hanford Reach from late June to early August when water temperatures range from about 14.0 to 18.0 (57.2 to 64.4°F) (Gray and Dauble 1977a, p. 5.10; Gray and Dauble 1978, p. 5.6; Gray and Dauble 1979a, p. 5.10; Gray and Dauble 1979b, p. 5.3).

Spawning northern squawfish may gather in large numbers but build no nests. Eggs and sperm are released near the bottom over gravelly areas in lakes and streams and the eggs, which are adhesive and demersal, settle in the gravel (Scott and Crossman 1973, p. 489; Brown 1971, p. 105; Patten and Rodman 1969, p. 109-111). The eggs hatch in about 1 week at 15.6 to 20°C (60.1 to 68°F) (loc. cit., Jeppson and Platts 1959, p. 201). A female will produce 6,700 to 83,000 eggs, depending on size.

Based on collections from 1974 through 1978, fry of northern squawfish first appear at Hanford in late July with a peak abundance in September or October (Gray and Dauble 1976a, Figure 5.22; Gray and Dauble 1979b, Figure 5.23).

Population levels appear highest after spawning and after fry enter the population in late summer. Fry abundance near the N-Reactor peaked in September 1973 and yearling abundance occurred in May 1973 and 1974 (loc. cit.). Northern squawfish fry are common in shallow vegetated pools with mud and rock bottom where temperatures are warmer than in main river channel. Large numbers of fry occur in slough areas at Hanford during the spring and summer, frequently in association with fry of the reidside shiner and peamouth chub.

Small northern squawfish 4-10 inches (25-102 mm) long feed primarily on insects. Adults are piscivorous and large individuals feed exclusively on fish and crayfish (Wydowski and Whitney 1979, p. 86); they can be serious predators on juvenile salmonids (Thompson 1959, p. 57-58) and may compete with trout and salmon for food (Jeppson and Platts 1959, p. 199). Because of this habit and their low food value, the northern squawfish is often considered an undesirable species.

The major food items of 311 fish taken at Hanford near the N-Reactor were adult caddisflies (13% occurrence), crayfish 6% and fish 5% (Gray and Dauble 1976a, Table 5.3). Analysis of gut contents from northern squawfish collected at other sites in the Hanford Reach showed that fish, caddisfly adults and larvae, and crayfish were the most abundant food items. There was evidence of northern squawfish predation on juvenile percids, catostomids, cottids, centrarchids, cyprinids, percopsids and salmonids (Gray and Dauble 1977b, 1978a). Northern squawfish fry (2.0 to 3.4 cm fork length) seined in October and November 1976 near RM 352 contained chironomid pupae in 70% of the stomachs examined; chironomid adults (22%) and chironomid larvae (17%) were the next most common items (Gray and Dauble 1978b p. 5.7).

Northern squawfish are reported to live 19 years, and to reach a length of 25 inches (360 mm) and a weight up to 29 lbs (13 kg) (Brown 1971, p. 106; Wydowski and Whitney 1979, p. 85; Scott and Crossman 1973, p. 489). They reportedly become sexually mature in 5 to 6 years. At Hanford, northern squawfish up to 15 years old were collected near RM 352. Females mature in 5 to 6 years at 32 cm fork length, and males mature about 1 year earlier at 25 cm fork length (Gray and Dauble 1977b, p. 5.10). Most large squawfish in the Hanford area are females. Annual growth rates are greatest from 1 to 5 years.

The northern squawfish is relatively tolerant of warmed water. They prefer the highest temperatures 20.0 to 22.8°C (68-73°F) that occur in Lake Washington (Wydowski and Whitney 1979, p. 85). All northern squawfish acclimated to 19-22°C (66.2-71.6°F) died after 24 hour exposure to water heated to 32°C (89.6°F); all fish survived at 26.4°C (79.5°F), but half of the test group died at 29.3°C (84.8°F) (Black 1954, p. 199). Juvenile northern squawfish are regularly seen at Hanford in nearshore areas where temperatures reach 23.3°C (73.9°F).

3.2.4.3.5 Mountain whitefish. The mountain whitefish is common in Washington (Wydowski and Whitney 1979, p. 35). In the Hanford Reach, the mountain whitefish is abundant and present the year around. They are not fished commercially, and sport fishing is usually limited to the winter (Fickeisen et al. 1980, p. 2-23). The area above Vernita Bridge (RM 392) where mountain whitefish spawn in winter, is a popular fishing sport (loc. cit.). Whitefish reportedly make up nearly 14% of the sport catch in the lower Hanford Reach (Honstead et al. 1971).

Mountain whitefish spawn in the late fall or early winter over gravel or gravel and rubble, but the exact time of spawning varies over its range (Scott and Crossman 1973, p. 293). In the Hanford Reach, spawning occurs from late November through early January when water temperatures average 3 to 8°C (37.4 to 46.4°F) (Gray and Dauble 1977b, p. 5.7; Gray and Dauble 1978, p. 5.9; Gray and Dauble 1979a, p. 5.1); this is somewhat later than spawning times reported elsewhere (Gray and Dauble 1979b, p. 5.8). Specific spawning sites have not been documented at Hanford. Mountain whitefish spawn over gravel or rubble riffle areas of streams (Brown 1952, p. 110-111) but little preference of bottom type was found in laboratory tests (Stalnaker and Gresswell 1974, p. 13). Eggs are deposited adjacent to strong currents at depths of 0.1 to 1.2 m or more, usually at dusk or night (Brown 1952, p. 111; Stalnaker and Gresswell 1974, p. 10-11). Based on substrate composition and collection of gravid females, several potential spawning areas have been visualized for the Hanford Reach (Fickeisen et al. 1980, Figure 9).

Mountain whitefish tend to move upstream to spawn. Before construction of Priest Rapids Dam, mountain whitefish migrated upstream from Hanford as far

as Crab Creek (RM 411). Upstream movement above Priest Rapids Dam is not well defined but they do migrate up to the dam and from the Columbia River into the lower Yakima River (Cushing and Watson 1966, p. 564-568). Mountain whitefish become sexually mature when 3 to 4 years old. A gravid female produces, on the average, 5,000 eggs but the number of eggs increase with female size. One female 19.5 inches (495 mm) long weighed 3 pounds and carried 24,000 eggs (Scott and Crossman 1971, p. 293). The eggs are adhesive and stick to sand and gravel. Eggs hatch in 35 to 40 days at 11.1°C (52°F). In nature, most eggs hatch in March (Brown 1971, p. 45).

Mountain whitefish fry usually appear annually in the Hanford Reach from early April through May (Gray and Dauble 1979a, p. 5.1; Gray and Dauble 1979b, p. 5.8). Fry measuring 14 to 23 mm are found in shallow nearshore pools in early April. However, they disappear from these areas by early June when approaching 40 mm in length. Extensive collections in the Hanford Area from 1973 through 1978 revealed no 0+ to 1-year mountain whitefish (Fickeisen et al. 1980, p. 2-25). They may move downstream into Lake Wallula or may be in areas of the river that can not affectively be sampled. In other areas juveniles tend to move downstream before the end of their first year (Pettit and Wallace 1975, p. 73-75). Young mountain whitefish over 1 year and older, occur in the Hanford Reach the year around with peak abundance from October through January.

The mountain whitefish is primarily a bottom feeder consuming a variety of organisms, especially aquatic insect larvae such as mayflies, stoneflies, caddisflies, and midges, small molluscs and sometime larvae fish (Scott and Crossman 1971, p. 294).

Mountain whitefish prefer cool temperatures. They spawn during winter at temperatures between 1.7 and 7.2°C (35 and 45°F) (Brown 1971, p. 45). The upper optimum temperature for successful egg development is 6°C (42.8°F); development is disrupted and abnormal fry are produced at 9°C (48.2°F); all eggs die within 2 weeks at 12°C (53.6°F) (Rajagopal 1979, p. 155-156). No upper lethal limits have been determined experimentally for adult mountain whitefish.

3.2.4.3.6 Smallmouth bass. The smallmouth bass was originally restricted to fresh waters in east-central North America. Smallmouth bass were introduced to the Yakima River in 1925, and spread into the Columbia and Snake River (Robbins and MacCrimmon 1974). In Washington, smallmouth bass are most numerous in the Columbia and Snake River systems (Wydowski and Whitney 1979, p. 126).

Smallmouth bass are now abundant in sloughs and slack water areas of the Hanford Reach. Much of the area was closed to public access until recently and fishing pressure on spawning populations of smallmouth bass in various sloughs at Hanford was low. Smallmouth bass were transplanted from the Hanford Reach to the lower Yakima River in the mid-1950s but some of these fish returned to the capture site (Henderson and Foster 1956, p. 116-119). The Hanford Reach of the Columbia River between Vernita RM 363 was opened to the public in 1978.

The Washington State Department of Game recognized the importance of slough areas at Hanford for bass spawning and closed them to fishing in 1979 (Fickeisen et al. 1980, p. 2-27).

Smallmouth bass usually inhabit cool, clear streams or lakes with some currents. Smallmouth bass in the Snake River are usually found over broken rocky substrate, few over solid rock substrate and none over sand (Munther 1970, p. 4.4). Smallmouth bass have a definite home range and do not travel long distances. In the Snake River, most of the fish tagged (76%) remained in the same pool or location where they were originally tagged (loc. cit.). Most of the other fish moved less than three quarters of a mile.

Smallmouth bass prefer water temperatures of 21.1 to 26.7°C (70 to 80°F) (Wydowski and Whitney 1979, p. 126). In the Snake River they do not occur in shallow water (<8 feet deep) when temperatures drop below 15.6°C (60°F). Distribution in the Snake River changed daily. At night, smallmouth bass remained motionless on broken rock substrate in quiet water; in early morning they were always feeding near the edge of a current (Munther 1970, p. 48-49).

Smallmouth bass usually mature when 3 or 4 years old. Spawning occurs over a period of 6-10 days in late spring and early summer. Nest building and spawning commences over a range of temperatures from 12.8 to 20°C (55 to 68°F)

but most eggs are deposited at 16.1-18.3°C (61 to 65°F) (Scott and Crossman 1971, p. 730). Smallmouth bass eggs incubated at constant temperatures of 12.8 and 23.9°C (55 and 75°F) hatched at 9-10 days and 2-3 days, respectively (Webster 1948, p. 46). In the Columbia River, smallmouth bass spawn in sloughs at temperatures of 12.8-15.6°C (55 to 60°F) when the water is warmer than in the main river channel at 7.2-10.0°C (45 to 50°F) (Henderson and Foster 1976, p. 119). Spawning in April and May was generally unsuccessful if the Columbia River rose in the spring and flooded nest sites in the sloughs with cool water (loc. cit.).

During spawning, the male builds a nest 1-6 feet (30.5 - 183 cm) in diameter on a sandy, gravel, or rocky bottom, usually near the protection of rocks, logs or rarely dense vegetation. Eggs are deposited and fertilized in brief (5 sec) acts that take place repeatedly for about 2 hours. Eggs per female depend on fish size, and range from 5,000 to 14,000. Eggs are demersal and adhesive. The male guards the nest, fans the eggs, and guards the fry after they hatch (Scott and Crossman 1971, p. 730). Often 40% of the nests fail. About 2000 fry result from most successful nests. Sudden shifts of temperature, changes in water level, and fungal infections kill many eggs. Smallmouth bass fry disperse among rocks and vegetation near the shore when about 1 inch (2.5 cm) long.

Smallmouth bass in the Columbia River grow at rates equal to or faster than that of bass in other areas of United States (Wydowski and Whitney 1979, p. 127). Mature bass collected at Hanford in 1952 ranged to 8 years of age and 19 inches (48 cm) in length (Henderson and Foster 1956, p. 120-123).

Smallmouth bass fry eat small crustaceans. When about 1-2 inches (2.5 - 5.0 cm) long, they change to a diet of insects and small fish. Adult bass feed on insects, crayfish, fish, frogs, and fish eggs.

Studies on reproduction of smallmouth bass in the Hanford Reach confirmed that spawning occurs in at least three large sloughs: Hanford Slough (RM 362), 100-F Slough (RM 368) and White Bluffs Slough (RM 370) (Montgomery et al. 1980, Figure 2). Fluctuating water levels caused by peaking operations at Priest Rapids Dam appear to impact smallmouth bass spawning by alternately flooding and dewatering nest sites. Cold river water entering warmed slough

areas can cause temperature changes up to 10°C during the spawning period. In addition, changing water levels trap smallmouth bass fry and juveniles in temporary ponds where they are lost from desiccation, thermal stress, malnutrition, and predation (loc. cit., p. 303-34; Becker et al. 1981, p. 45-46).

Experimental transfer of smallmouth bass eggs from 11.7 to 25.0°C (53 to 77°F) and from 18.3°C (65°F) to 10.0°C and 23.9°C (50 and 75°F) caused no adverse effects (Webster 1948, p. 43).

Final preferred temperature for smallmouth bass under experimental and field conditions are 28°C (82.4°F) and 20.3 - 21.3°C (68.5 to 70.3°F), respectively (Ferguson 1958; p. 612-616). Maximum growth rate of juveniles grown at various constant temperatures occurs at 26°C (78.8°F), while fish held at 35°C (95°F) lost weight (Horning and Pearson 1973, p. 1228-1229). Preferred temperatures of smallmouth bass acclimated under rising (spring) thermal regimes range from 20.2°C (68.3°F), at 15°C (59°F) acclimation, to 29.4°C (85°F) at 33°C (91.4°F) acclimation Cherry et al. 1977, Table 1). Smallmouth bass acclimated to 23.3°C (74°F) and subject to a rapid increase in temperature loose their equilibrium at 38.3°C (101°F) (Reutter and Herdendorf 1976. Smallmouth bass fry acclimated to 30 and 35°C (86 and 95°F) cannot swim at higher temperatures (Larimore and Duever 1968, p. 182).

3.2.4.3.7 Yellow perch. The yellow perch was introduced to Washington in 1890, and it subsequently became established throughout the state (Wydowski and Whitney 1979, p. 146). Its preferred habitat is cool, clear lakes or slow-moving streams with abundant vegetation. However, the yellow perch is extremely adaptable and reproduces readily under a range of conditions not necessarily favorable to good growth (Brown 1971, p. 173). Yellow perch usually occur in loose schools associated with the bottom. Fingerling yellow perch occur in shallow, inshore waters but move to open and deep water in the fall. Adults are active during daytime in the summer but rest on the bottom at night, and generally do not move great distances (Wydowski and Whitney 1979, p. 146).

Yellow perch have been collected by various gear throughout the Hanford Reach. Peak catches of adults near RM 352 occurred from August through

October (Gray and Dauble 1979b, Figure 5.20). Adult yellow perch are sometimes common in slough areas or large pools adjacent to the main river, particularly at sites containing curled-leaf pondweed.

Yellow-perch are spring spawners. Spawning in Washington State usually occurs in April and May when water temperatures reach 7.2 to 11.1°C (45 to 52°F) (Wydowski and Whitney 1979, p. 146). At this time males and females school separately. Spawning takes place over various sand, gravel, or rubble bottom, and on submerged vegetation and brush. Eggs are deposited in a ribbonlike, gelatinous masses. Egg masses are semi-buoyant and undulate with water movement. The number of eggs produced ranges from 10,000 to 40,000 and is related to age of the female. Eggs require 10 to 20 days for incubation. No parental care is given the egg or young (Brown 1971, p. 173; Scott and Crossman 1973, p. 757-758; Ney 1978, p. 3). The egg incubation period depends on water temperature and rate of warming. Hatching will occur 2 to 3 weeks after fertilization at typical spring temperatures of 8-15°C (46.4 - 59°F) (Ney 1978, p. 3).

In the Hanford Reach near RM 352 (RKM 566), gravid females were collected from mid-November through January and ripe males from September through mid-February (Gray and Dauble 1977a, p. 5.16; 1977b, p. 5.6; 1978, p. 5.13; 1979a, p. 5.12. However, the maturity index for female yellow perch was highest in early April (Gray and Dauble 1979a, p. 5.12). The presence of newly hatched fry near N-Reactor (Page et al. 1977, Table 3) and RM 352 (Gray and Dauble 1978, p. 5.13; 1979b, p. 510) in June and July suggests that some yellow perch at Hanford spawn in spring, but probably later than reported elsewhere.

Yellow perch are about 0.2-0.3 inches (4.5-7.0 mm) total length when hatched. Larvae are initially photopositive and pelagic, becoming demersed at lengths of about 1.0 -1.6 inches (25-40 mm) (Ney 1978, p. 3). Growth is rapid at first; and young yellow perch often form large, compact schools (Scott and Crossman, 1971, p. 758). At Hanford, appearance of young yellow perch is sporadic. No fry were collected near N-Reactor from March 1973 through June 1974 (Gray and Dauble 1976a, Table 5.1), but over 2515 perch fry were collected on traveling screens at HGP water intake over a 3 week period in

June and July 1977 (Page et al. 1977a, p. 6, Table 3). Young of the year yellow perch were collected at Hanford Slough in July 1981 (Page et al. 1982, p. 23-24).

The food of adult yellow perch consists of aquatic invertebrates or small fish. Young feed heavily on zooplankton. Feeding occurs all day in deep water and during twilight hours near the surface and in shallow water near shore (Brown 1971, p. 173). Their high reproductive potential, voracious appetite and effectiveness in feeding can, in some areas, lead to severe competition with more valued species. These characteristics may produce stunted populations where adult yellow perch never exceed 6 inches (152 mm) in length (Scott and Crossman 1973, p. 760).

Adult yellow perch in the Hanford Reach at RM 352 feed primarily on caddisfly larvae and fish (Gray and Dauble 1977b, Table 5.20; 1977b, Table 5.14; 1979a, p. 5.13). Young of the year show greater dependence on the smaller midge fly larvae, and zooplankton. Most yellow perch collected at Hanford were age 1 to 3 years, but some individuals were 6 years old (Gray and Dauble 1978a, Table 5.45). Some males mature after one year, but most fish mature in about three years.

Yellow perch in nature are usually found at temperatures of 19-21°C (66.2 - 69.8°F); young fish show an upper preferred temperature of 24.2°C (75.6°F) and older fish show an upper preferred temperature of 21.0°C (69.8°F) when acclimated to 30°C (86.0°F) (Ferguson 1958, p. 607-611). Another study indicates that juvenile yellow perch prefer temperatures between 14.4 and 28.0°C (58 and 82.4°F), depending on seasonal environmental temperatures (Barans and Tubb 1973, p. 1699). Peak growth of yellow perch occurs at 28°C (82.4°F) (McCormick 1976). Optimum temperatures for hatching of yellow perch are 10.1 - 18°C (50.2 - 64.4°F) and for swim-up larvae, 13.1 - 18.0°C (55.6 - 64.4°F) (Hokanson and Kleiner 1974).

Under experimental conditions, yellow perch acclimated to 22-24°C (71.6 - 75.2°F) and abruptly exposed to elevated temperatures for 24 hr underwent total mortality at 29.1 - 29.8°C (84.4 - 85.6°F), 50% mortality at 29.2°C (84.5°F) and all survived at 28.9°C (84°F) (Black 1953, p. 199). Another study showed that upper lethal temperatures (ULT) of yellow perch depended on

acclimation (A) temperature as follows: 5°C (41°F) A, 21.3°C (70.3°F) ULT; 10°C (50°F) A, 25°C (77°F) ULT; 15°C (59°F) A, 27.7°C (81.8°F) ULT; 25°C (77°F) A, 29.7°C (85.5°F) ULT (Brett 1956, p. 77). Yellow perch acclimated to 22°C (71.6°F) and subject to a rapidly increasing temperature undergo loss of equilibrium at 35°C (95°F) (Reutter and Herdendorf 1976).

3.2.4.4 Ichthyoplankton

Ichthyoplankton are defined herein as small, larvae fish that are present in the downstream drift and are taken by fine-mesh nets during plankton sampling. The occurrence of small, larvae fish as planktonic organisms is indicative of a temporary pelagic life of a particular species. Ichthyoplankton are apt to be exposed to heat and chemicals if they are entrained in power plant cooling systems or in the cooling water discharge plumes.

In studies conducted from June 1973 to June 1974 in the Hanford Reach at RM 380 indicated that ichthyoplankton were neither major or frequent components of the mid-river drift (Page et al. 1976, p. 5-24). Ichthyoplankton were collected only in May and July. In another study, one unidentified ichthyoplankter was collected incidentally in a zooplankton sample near RM 352 in June 1975 (Gray and Dauble 1977a, p. 5.20). Ichthyoplankton tows were subsequently made monthly near RM 350 from September 1978 to March 1980. Only a few yolk-sac and post-yolk sac larvae of the prickly sculpin were collected from May through July 1979; peak densities were 0.14 larvae/m³ (Beak Consultants Inc. 1980, p. 3.6, Table 3.5).

Additional ichthyoplankton samples were collected twice monthly from April 1981 through April 1982 at RM 361.5. Five species of fish were collected in midstream tows (Puget Power 1982, p. 2.2-32a). Peak abundance (0.17 larvae/m³) occurred in May and June 1981. About 95% (211 of 222) of the larvae were prickly sculpin, two were shad, one was a carp, and one was chinook salmon alevin (loc. cit., Table 2.2-21c). Because of low densities and composition of relatively unimportant species, ichthyoplankton were not thought to be of major importance to the ecology of the Hanford Reach (loc. cit., p. 2.2-32a, 32b).

3.2.4.5 Important Columbia River Habitats. The Hanford Reach, because of its length, volume, and free-flow characteristics, has aquatic communities that are largely different from those found in the impounded portion of the Columbia River. The Hanford Reach is characterized by cobble and rock substrate and swift currents. A portion of the reach includes the Ringold formation substrate (a conglomerate of gravel and rock). Much of the shoreline is steep and includes a narrow strip of cobble beach next to the water. In some areas, particularly along the left (east) bank near Ringold, bluffs extend into the river. There are 21 islands present from Richland to Priest Rapids Dam, each with cobble and/or sandy shorelines (Fickeisen et al. 1980, p. 2-1).

The rocky substrate and swift to moderate currents provide critical habitats for present populations of chinook salmon, steelhead trout and mountain whitefish. White sturgeon also prefer flowing water for reproduction. Smallmouth bass utilize the waters of the mainstem as adults (loc. cit., p. 2-1).

There are a number of sloughs and backwater areas on both sides of the Hanford Reach. These have largely rocky substrates but may also contain sand, mud and silt substrates. Water in the sloughs warms earlier in the spring than in the mainstem river and summer temperatures often exceed 30°C because of insolation. The rocky areas of the sloughs serve as spawning habitats for smallmouth bass and bullhead. Other centrarchids such as largemouth bass, bluegill and pumpkinseed sunfish spawn along shallow shorelines of the quieter waters of the sloughs. The warm water, weak currents and substrate of the sloughs make them important nursery areas for juvenile salmonids. The sloughs are also important nursery areas for centrarchids, bullheads, suckers and cyprinids. Sculpins are abundant in rocky areas of some sloughs.

Some areas in the Hanford Reach of the Columbia River are critical habitats for populations of valued or important fish species. The spawning areas used by adult chinook salmon are critical habitats. Spawning areas used by steelhead trout, although less well known, are also critical habitats. Certain areas in the Hanford Reach have been tentatively identified as spawning sites for white sturgeon (Fickeisen et al. 1980, Figure 10) and

mountain whitefish (loc. cit., Figure 9). These four species spawn in the main channel where observation of site selection and spawning activity is difficult. The salmonids dig redds and deposit their eggs in the gravel. Hence, chinook salmon and steelhead trout require sites with gravel of suitable composition for digging and for maintaining intergravel water flow after egg deposition.

Certain sloughs and backwater areas in the Hanford Reach are valuable habitats for reproduction of smallmouth bass (Fickeisen et al. 1980, Figure 11). Particularly important areas are the Hanford Slough (RM 362), 100-F Slough (RM 368) and White Bluffs Slough (RM 370). Similar areas are important as feeding and nursery areas for 0-age chinook salmon prior to spring outmigration and for many species of resident fish (Fickeisen et al. 1980, p. 2-1; PSP&L 1982, p. 2.2-22). The suitability of these areas for juvenile fish is adversely affected by fluctuating flows from Priest Rapids Dam (Becker et al. 1981, p. 18-37).

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4.0 METEOROLOGY

This chapter presents a summary of the meteorological characteristics pertinent to the Skagit/Hanford Site. Although no data have been collected at the proposed site itself, meteorological data are collected at a number of locations on the Hanford Site.

Complete climatological data are available for the Hanford Meteorology Station (HMS), located about 15 km (9.3 mi) northwest of the Skagit/Hanford Site. Data have been collected at the HMS since 1945, and temperature and precipitation data from a nearby location are available for the period from 1912 through 1943. A summary of these data, for the period through 1980, has been compiled by Stone et al. (1983). Sections, Figures, and Tables referred to here without further elaboration are from Stone et al. The summary also contains wind data for several locations on and near the Hanford Site. One location for which supplementary wind data are available is the Wye Barricade, which is about 2.5 km (1.6 mi) east-southeast of the Skagit/Hanford Site.

The general climatological characteristics of the Skagit/Hanford Site should be adequately described by the HMS summary, although there are some systematic differences where specific climatic elements are concerned. In particular, the HMS summary correctly indicates that the region experiences frequent periods of low wind speeds and has a low annual average wind speed, but comparisons of hourly wind data and wind roses for the HMS and the Wye Barricade indicate that the HMS winds are not particularly representative of the proposed site.

The WNP-2 site, approximately 7.2 km (4.5 mi) east-southeast of the proposed NPR site, is another source of meteorological data that could be used to characterize the climatology of the proposed NPR site. Data from WNP-2 were used in the draft environmental impact statement (U.S. NRC 1982) for the Skagit/Hanford Nuclear Project plants that were considered originally for the site. However, use of these data to characterize the Skagit/Hanford Site climatology is not recommended because 1) the longer period of record for the HMS data provides a better basis for making a statement about the general climatological characteristics of the region, and 2) wind data for WNP-2 and

the Wye Barricade indicate that the winds at WNP-2 differ significantly from those at the proposed NPR site.

With these considerations, it is recommended that the HMS climatological summary (Stone et al. 1983) be used as the primary source of information for characterizing the atmosphere for general purposes. The narrative on page iii of the summary describes the factors that influence the climate at Hanford and gives a synopsis of the normal and extreme meteorological conditions. The description should adequately represent the climate at the proposed site except for winds. Some differences are to be expected in detailed values presented, but the magnitudes of the differences will be inconsequential in the current context.

4.1 WIND DATA

The wind data that are most representative of the winds at the proposed site should be those for the Wye Barricade. Measurements at this location are made at a height of 9.1 m (30 ft) above ground. The data for the period October 19, 1979, through April 25, 1982, are summarized in Table A.IV-1 and Figure A.IV-1 (Station 12). These summaries, which approximate annual averages, would be appropriate for characterizing the initial transport and diffusion of effluents released at ground level.

Additional Wye Barricade wind data summaries for the data collection period ending January 31, 1984, are presented in Appendix B. These summaries include both monthly and annual joint frequency distributions of wind direction, wind speeds, and atmospheric stability.

Comparison of the wind rose for Station 12 (Wye Barricade) with those for the HMS and Station 14 (WNP-2) in Figure A.IV-1 illustrates that the winds at those sites are not fully representative of the winds at the Skagit/Hanford Site. Hour-by-hour comparisons of the winds for a 10-month period show that significant differences^(a) exist between the Wye Barricade and HMS winds more

(a) For this purpose, a significant difference is defined as a direction difference of 90° or more, or a magnitude of the vector difference between two winds that exceeds 80% of the average of the two wind speeds.

than 29% of the time and between the Wye Barricade and WNP-2 winds more than 20% of the time.

The wind data for the HMS in Tables 41, 42, and 43 indicate the potential variations of the wind joint frequency distributions in the vertical and by months for the Skagit/Hanford Site. However, the strong northwesterly winds shown for the HMS during the summer months are the result of drainage winds that may not extend to the proposed site. The HMS wind data provide the best available estimates of extreme wind events.

The HMS narrative summary table on page iv shows that winds exceeding 50 kts (25.5 m/s or 57 mph) occur throughout the year. The direction of the wind during peak gusts (generally from the southwest or south-southwest) indicates that the highest winds are associated with synoptic scale storms. Figure 35 indicates that the expected return interval for a wind of 50 kts or above at the 15.2-m (50-ft) level at the HMS is about 1.4 years. The estimated return periods at the 60- and 122-m (200- and 400-ft) levels are just over 1 year.

Thunderstorms and summertime afternoon drainage winds are also associated with high winds. On average, 10 thunderstorms occur each year. They have occurred in all seasons, but are most frequent during the summer months. The winds during thunderstorms show no directional preference. The strong drainage winds occurring during the summer are generally northwesterly. The period of record of wind data for the Wye Barricade is too short to permit good estimates of the frequency of occurrence of high winds.

Table 40 of the HMS climatological summary lists tornadoes since 1916 within a radius of approximately 161 km (100 mi) of the HMS. An independent list of tornadoes since 1948 occurring within a 161-km radius of the proposed NPR site was obtained in a search of the National Severe Storms Forecast Center (NSSFC) tornado data base.

There are several discrepancies between the lists. The NSSFC list includes a tornado on May 22, 1964, that is not in the HMS data summary; records at National Weather Service offices in the area indicate that the tornado did occur. The HMS list includes a tornado near Colfax, Washington, on August 30, 1971, and the NSSFC list notes one in about the same location on December 30, 1971. The date of the tornado in the NSSFC list is incorrect. Similarly, the tornado on August 18, 1978, in the NSSFC list actually occurred on August 15,

1978, as shown in the HMS list. Finally, the HMS records list the occurrence on August 9, 1982, as a funnel cloud. It was initially reported as a tornado, but no evidence could be found to indicate that the cloud made contact with the ground. Resolving the discrepancies in this manner and treating the 1972 Spokane, Washington, and the 1978 Hatton, Washington, tornadoes as single events because of their proximities in time and space leaves a combined list of 22 tornado events between 1916 and August 1982. Two additional tornadoes have occurred since August 1982. On September 13, 1982, a tornado occurred between Touchet and Lowden, Washington, and on April 23, 1983, one occurred between Connell and Eltopia, Washington.

Given the data in the NSSFC data base and version 2.0 of the NRC computer program TORNADO (Schreck and Sandusky 1982), the tornado recurrence interval at the proposed NPR site is 98,460 years. This is consistent, within the uncertainties of estimating rare events from a limited data base, with the 146,000-year recurrence interval for HMS estimated by Daubek in 1970 (Stone et al. 1983). The maximum wind speed estimated for a tornado at the Skagit/Hanford Site is 98.3 m/s (220 mph). The rotational component of the speed is estimated to be 77.8 m/s (174 mph), and the translation component is estimated at 20.6 m/s (46 mph). The total pressure drop is estimated to be 12.05 psi, with a maximum rate of decrease of 0.47 psi.

4.2 TEMPERATURE, PRECIPITATION AND HUMIDITY

Diurnal and monthly averages and extremes of temperature, dewpoint, and humidity are contained in the tables in the narrative portion of the HMS summary on pages iv and v. They are also discussed in Section VII, and additional detail is provided in Tables 27, 28, 29, and 30, and in Figure 24.

Section IV of the climate summary discusses precipitation. The information presented is specific to the HMS site, but trends and precipitation amounts should be approximately correct for the Skagit/Hanford Site. Table 10 gives monthly precipitation totals for the period from 1912 through 1980 and the monthly averages for the period. The frequency of precipitation and precipitation rates are described in Table 11, 12, 13, and 14, and in Figures 14, 15, and 16. The probability of extreme precipitation is covered in Figures 36, 37, and 18 (snow), and in Table 61.

Table 15 compares precipitation averages for the HMS and Richland, Washington, which is about 39 km (24 mi) to the southeast of the HMS. During the winter months--November through March--Richland receives about 10% more precipitation than does the HMS. For the remaining months, the monthly averages are about the same for the two locations. This seasonal difference may be attributable to a seasonal variation in the type of precipitation and to a sheltering effect of Rattlesnake Mountain, which lies along the southwest edge of the Hanford Site. The available data are not adequate to determine whether the precipitation pattern at the Skagit/Hanford Site follows HMS or Richland more closely.

Precipitation wind roses have not been prepared for the proposed NPR site. No precipitation data are available for the site. Tables 21 and 22 give the wind direction and speed frequencies, respectively, during periods of precipitation at the HMS.

4.3 ATMOSPHERIC DIFFUSION

Wind data for the Wye Barricade contained in the summary are applicable to the Skagit/Hanford Site, but are not sufficient for full evaluation of atmospheric transport and diffusion at the site. Joint frequency distributions of wind and stability for the Wye Barricade using Wye Barricade winds and stability determined at the HMS tower are included in Appendix B.

Seasonal variations of the wind direction and speed frequency distributions for the HMS by stability class are contained in Table 50, 51, and 52. The stability class definitions used in preparing these tables were determined on the basis of numerous atmospheric diffusion tests conducted at Hanford and do not correspond directly to the stability class definitions in Regulatory Guide 1.23 (U.S. NRC 1974).

The probabilities of extended periods with temperature inversions at Hanford are discussed by Stone, Jenne, and Thorp (1972). Given an initial observation of inversion conditions between 1 and 61 m (3 and 200 ft), the probability of inversion persistence for more than 12 hours varies from a low of about 0.1 from May through August to high of about 0.64 in September and

October. The probability that an inversion will persist more than 24 hours reaches a maximum of slightly more than 0.02 in January and February.

The depth of the atmospheric mixing layer is monitored continuously at the HMS using an acoustic sounder. The mixing layer depth data summarized for the 22-month period from March 25, 1982, through January 31, 1984, are presented in Appendix C.

4.4 AIR QUALITY

The discussion of air quality in the S/HNP draft environmental impact statement (U.S. NRC 1982, Section 4.2.10.2) reflects the current conditions in the Columbia Basin, except for the oxides of nitrogen (NO_x).

Chemical processing of reactor fuel at Hanford was resumed in November 1983 for the first time since 1972. The fuel processing facilities are located about 11 km (7 mi) northwest of the Skagit/Hanford Site. Releases of NO_x are associated with fuel processing. Ramsdell (1981) reports on the observed NO_x levels in the vicinity of the processing facility during the last period of operation (1968-1969). Recent NO_x measurements made prior to the facility restart indicate a background concentration of less than 0.007 ppm (Sula et al. 1983). During renovation of the facilities prior to resumption of fuel processing, NO_x emission control has been upgraded. As a result, even with fuel processing, the ambient NO_x concentrations are expected to remain within permissible federal and Washington State limits (U.S. DOE 1982).

4.5 METEOROLOGICAL INSTRUMENTATION

The meteorological instrumentation on the tower at the HMS through 1982 is described in Section XII of the climatological summary; the instrumentation in the telemetry network is described in Appendix IV. The wind instruments described do not meet the criteria outlined in Regulatory Guide 1.23 (U.S. NRC 1974). The instruments described have been replaced by more sensitive instruments that meet the criteria. Similarly, the temperature sensors on the

tower have been replaced by platinum resistance sensors. In addition, a Doppler acoustic sounder has been used to estimate mixing depths since the late 1970s.

The meteorological instrumentation on the Hanford Site is currently being upgraded. The telemetry network is being increased to permit better evaluation of trajectories of effluents after they pass the site boundaries. Three 61-m (200-ft) towers and three additional acoustic sounders are being added to the network to permit better definition of the stability and wind structure over the site. The data from all of this instrumentation will be relayed to computers for use in evaluating the consequences of routine and accidental releases to the atmosphere.

4.6 REFERENCES

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5.0 HYDROLOGY

In this chapter, hydrologic characteristics of the Skagit/Hanford and Firehouse sites are provided. Section 5.1 provides a description of surface water hydrology; Section 5.2 characterizes the groundwater hydrology. The descriptions are directed primarily to the Skagit/Hanford Site. However, the more general parts apply to the Firehouse Site as well. Where conditions are different, a description for the Firehouse Site is also given.

5.1 SURFACE WATER HYDROLOGY

The main surface water that could be affected or influenced by the plant construction and operation is the Columbia River. Hence, it is discussed in some detail in Section 5.1.1. Watershed characteristics, river water quality, and effluent discharges are then discussed.

5.1.1 Columbia River Hydrologic and Physical Characteristics

5.1.1.1 Tributaries, Major Dams, and Water Intakes

The Columbia River and its tributaries, shown in Figure 5.1, drain an area of approximately 259,000 square miles. The river originates at Columbia Lake in British Columbia, flows northwesterly paralleling the Rocky Mountains for about 190 miles, then turns southward flowing 271 miles to the international border. In the United States the river flows southward across the state of Washington to the Washington-Oregon state line. The river then flows westward along the Washington-Oregon state line through the Cascade Coast Ranges to its mouth in the Pacific Ocean near Astoria, Oregon. The Columbia River is about 1200 miles in length.

The stretch of the Columbia River nearest the Skagit/Hanford Site is known as the Hanford Reach. It stretches from Priest Rapids Dam (River Mile 397.1) to the head of Lake Wallula (RM 354). The Hanford Reach is the last free-flowing reach of the Columbia River in the United States (Rickel 1981). The main river channel in this reach is braided around the island reaches, and submerged rock ledges and gravel bars cause repeated pooling and channeling. River bed material is typically sand, gravel and cobbles as large as 8 inches in diameter. The river channel varies from 1200 to 1800 feet wide

LEGEND

- PROJECT EXISTING OR UNDER CONSTRUCTION, FEDERAL
- PROJECT EXISTING OR UNDER CONSTRUCTION, NON-FEDERAL
- MAJOR IRRIGATION AREAS
- MAJOR FLOOD DAMAGE AREAS
- NATURAL LAKE WITH STORAGE CONTROL

SCALE IN MILES

25 0 25 50 75 100 125 150

PACIFIC OCEAN

COLUMBIA

COLUMBIA RIVER DRAINAGE BASIN

CANADA

UNITED STATES

CALIFORNIA

OREGON

NEVADA

IDAHO

WYOMING

UTAH

ARIZONA

NEW MEXICO

TEXAS

OKLAHOMA

KANSAS

MISSOURI

ILLINOIS

INDIANA

MICHIGAN

OHIO

PENNSYLVANIA

DELAWARE

MARYLAND

VIRGINIA

NORTH CAROLINA

SOUTH CAROLINA

GEORGIA

FLORIDA

ALABAMA

LOUISIANA

MISSISSIPPI

ARIZONA

NEW MEXICO

UTAH

WYOMING

NEVADA

OREGON

CALIFORNIA

TEXAS

OKLAHOMA

KANSAS

MISSOURI

ILLINOIS

INDIANA

MICHIGAN

OHIO

PENNSYLVANIA

DELAWARE

MARYLAND

VIRGINIA

NORTH CAROLINA

SOUTH CAROLINA

GEORGIA

FLORIDA

ALABAMA

LOUISIANA

MISSISSIPPI

ARIZONA

NEW MEXICO

UTAH

WYOMING

NEVADA

OREGON

CALIFORNIA

TEXAS

OKLAHOMA

KANSAS

MISSOURI

 

Source: PSP&L (1982)

during low-water and normal high-water flows. The depth varies from about 23 feet to 45 feet during normal high-water and flood high-water flows, respectively. Flow velocities vary from 3 fps to more than 11 fps, depending on flow and location.

Major tributaries of the Columbia River are summarized in Table 5.1. The largest tributary is the Snake River, about 30 river miles downstream of the Hanford Reach. The Snake River has a drainage area of 108,500 square miles and an average annual discharge of 56,380 ft³/sec (USGS 1979). The Yakima

TABLE 5.1. Location of Significant Structures and Landmarks on Columbia River

<u>Description</u>	<u>River Mile</u>
River Mouth	0.0
Cowlitz River	
Lewis River	
Willamette River	
Bonneville Dam	146.1
The Dalles Dam	191.4
Deschutes River	
John Day Dam	215.6
John Day River	
McNary Dam	292.0
Walla Walla River	
Snake River	324.2
Yakima River	335.2
WNP-2 Intake and Discharge	351.75
Proposed WNP-1 and 4 Intake and Discharge	352.85
<u>Skagit/Hanford Nuclear Project Intake and Discharge</u> (approximate)	361.5
Existing Hanford Generating Plant	380.0
Priest Rapids Dam	397.1
Wanapum Dam	415.8
Rock Island Dam	453.4
Wenatchee River	468.4
Rocky Reach Dam	473.7
Chelan River	503.3
Wells Dam	515.6
Methow River	
Okanogan River	
Chief Joseph Dam	545.1
Grand Coulee Dam	596.6
Spokane River	638.9
United States-Canadian Boundary	745.0

Source: Pacific Northwest River Basin Commission (1962)

River is the nearest major tributary to the Hanford Reservation. The river mouth is about 19 miles downstream of the Hanford Reach. It has a drainage area of 5,615 square miles.

Eleven multipurpose reservoir projects listed in Table 5.1 have been constructed on the Columbia River within the United States during the past 40 years. The reservoirs provide for electrical power generation, navigation, irrigation, recreation and flood control. Seven dams are located upstream of the Hanford Reach and four dams are located downstream. Figure 5.2 shows these dams in relationship to the Hanford Reach. McNary Dam, the closest downstream dam, is about 62 miles. It began operation in 1953. The maximum pool elevation is 340 feet above mean sea level (MSL) and has a maximum storage volume of 1,350,000 acre-feet. Priest Rapids Dam forms the upstream boundary to the Hanford Reach. It began operation in 1960. The maximum pool elevation is 488 feet above MSL and has a maximum storage capacity of 227,000 acre-feet. Grand Coulee Dam, located 200 miles upstream of the Hanford Reach, is the largest dam. The dam began operation in 1941. The maximum pool elevation is 1288 feet above MSL, and the maximum storage capacity is 9,402,000 acre-feet.

The Columbia River is regulated on both an hourly and seasonal basis to meet the fluctuating demand for power. The annual variation in power demand is not large, with the winter demand being only about 20 percent greater than the summer demand. The natural streamflow pattern of the Columbia River does not coincide with the demand for electrical power, requiring that the streamflow be regulated by storage reservoirs so it more nearly coincides with the power demand. Water is stored in the high runoff months of April through July for release during the remainder of the year. Daily fluctuation in flow depends on the power demand, the volume of water in the river, and irrigation depletions. Typically, the power demand rises (increase in river flow) from baseload at 0600 hours to the peak demand at 0800 hours, after which the demand stays fairly level until 2000 hours, when it decreases to baseload.

Columbia River surface water users are listed in Tables 5.2 through 5.4 and shown in Figure 5.3. Surface water is withdrawn from the Columbia River primarily for irrigation, livestock, domestic and commercial uses. Within

FIGURE 5.2. Schematic Representation of the Hydraulic Regime of the Columbia River Showing Major Dams (U.S. Army Corps of Engineers)

TABLE 5.2. Surface Water Rights Claims 50 Miles Downstream from Skagit/Hanford Nuclear Project^(a)
(Washington State DOE 1981a)

Name	Location		Withdrawal ^(b) Section	Rate (cfs)	Use Type ^(c)
	Township	Range			
Melvin H. McInturf	12	28	36	0.92	I
Max C. Kinne	12	28	36	0.80	I
Washington State Dept. of Natural Resources	12	28	36	0.64	S/I/O
Donald M. Huntzinger	12	28	25	3.20	S/I
Washington State Dept. of Game ^(d)	12	28	23	0.86	I
Washington State Dept. of Game ^(d)	12	28	3	1.90	I
Charles A. Rohrmann	11	28	24	1.20	I
John P. Kohler	10	28	36	2.00	I
Norton T. Hildreth	10	28	35	0.02	D/I
E. W. Christopherson	10	28	25		I
John R. Carver	10	28	25	0.01	D
Industrial Properties, Inc.	10	28	24		D/I
Benton Co. Parks & Recr. Dept.	9	29	35	0.28	I
Benton Co. Parks & Recr. Dept.	9	29	35	0.40	I
Benton Co. Parks & Recr. Dept.	9	29	35	0.60	I
Benton Co. Parks & Recr. Dept.	9	29	35	0.20	I
Benton Co. Parks & Recr. Dept.	9	29	29	0.40	I
Benton Co. Parks & Recr. Dept.	9	29	29	0.08	I
Benton Co. Parks & Recr. Dept.	9	29	28	0.08	I
Trinity Lutheran Church	9	29	25	0.01	D
Robert H. Lindsey	9	29	21		D/I
Alvin A. Harris	9	29	18		D/S/I
John P. Kohler	9	28	1	1.20	I
Irving L. Winter	8	30	14		D/I
Total				14.80	

(a) The surface water rights claims were recorded before 1974 under different water laws. Location specified only by township, range, and section. These users are not shown on Figure 2.11.

(b) Minimum permitted withdrawal was calculated using average withdrawal rates assumed by Washington State Dept. of Ecology: 0.01 cfs and 0.02 cfs for domestic use and per acre of irrigation, respectively.

(c) I = irrigation, S = livestock, D = domestic, O = other.

(d) Possibly duplicated by a water use permit.

TABLE 5.3. Surface Water Permits 50 Miles Downstream
From Skagit/Hanford Nuclear Project^(a)

No. (b)	Name	Location			Rate (cfs)	Withdrawal ^c Use Type	Radial Distance from Station	Miles Down- stream from Discharge
		Township	Range	Section				
01	WA State Dept. of Game	12	28	3	1.9	I	8	3.5
02	WA State Dept. of Game	12	28	23	0.86	I	8	6
03	WA Public Power Supply System	11	28	2	2.0	D	7	9.5
04	WA Public Power Supply System	11	28	2	88.0	F/P	7	9.5
05	L. L. Bailie	11	28	24	2.0	I	9	12.5
06	H. D. Lloyd	11	28	24	0.99	I	9	13
07	Central Premix Concrete Co.	11	28	26	1.78	C-I	8	13.5
08	Battelle Memorial Institute	10	28	14	4.4	I	12	18.5
09	University of Washington	10	28	23	1.75	I	13	20
10	City of Richland	10	28	24	0.67	D	13	20
11	Ivan L. Huffman	10	28	25	0.01	I	13.5	20
12	City of Richland	10	28	25	31.0	D	14	20.5
13	City of Richland	10	28	25	23.25	D	14	20.5
14	City of Richland	10	28	25	31.0	D	14	20.5
15	R. J. Sloat	10	28	25	0.01	I	13.5	20.5
16	City of Richland	10	28	36	23.25	D	14.5	21
17	City of Richland	10	28	36	17.0	D	14.5	21
18	City of Kennewick	9	30	31	55.7	D	24	32.5
19	City of Pasco	9	30	31	35.0	D	23.5	33
20	Franklin Co. Irrigation Dist.	9	29	18	83.0	I	17.5	25.5
21	Franklin Co. Bo	9	29	20	0.448	I	19.5	27
22	Franklin Co. Bo	9	29	20	0.672	I	19.5	27.5
23	Franklin Co. Irrigation Dist.	9	29	27	83.0	I	22	30
24	Benton Co. Parks & Recr. Dept.	9	29	35	0.5	I	22.5	31.5
25	G. C. Walkley	9	28	1	2.32	I	16	23
26	E. C. Watts	9	28	1	0.01	D	16	22.5
27	E. C. Watts	9	28	1	0.3	I	16	22.5
28	H. S. Petty	9	28	1	0.48	I	16	23
29	W. H. & M. Ketchersid	9	28	1	1.66	I	16	22.5
30	L. Horrigan	9	28	11	2.54	I	16.5	24
31	L. Horrigan	9	28	12	2.54	I	16.5	24
32	Premix Concrete, Inc.	9	28	12	1.1	C-I	17	24.5
33	City of Richland	9	28	13	2.0	I	17.5	25
34	U.S. Bureau of Reclamation	8	31	20	80.0	I	31	40.5
35	U.S. Bureau of Reclamation	8	31	20	8.5	I	31	40.5
36	Port of Pasco	8	30	4	14.5	F	26	35
37	Allied Chemical and Dye Co.	8	30	14	3.55	F/HE	28	38
38	F. J. Henckel	8	30	14	0.015	I	28	38
39	Chevron Chemical Co.	8	30	23	3.77	C-I/HE	29	39
40	Chevron Chemical Co.	8	30	23	40.0	HE/F	29	39
41	Phillips Pacific Chemical Co.	8	30	24	82.0	C-I	30	39.5
42	Phillips Pacific Chemical Co.	8	30	24	20.0	C-I	30	39.5
43	Gilbert Garn, et al.	7	31	3	59.4	I	35	43.5
44	Esmieu, Louis P. and Stephen A.	7	31	3	227.0	I	35	43.5
45	V. L. Layton	7	31	5	1.0	I	33	43.5
46	Boise Cascade Corp.	7	31	9	20.68	C-I	36	44.5
47	Boise Cascade Corp.	7	31	10	24.5	C-I/F	36	44.5
48	Hoyt Stark Berry	7	31	15	179.8	I	37	45.5
49	U.S. Corps of Engineers	6	31	4	0.24	I	39.5	49.5
	Total				1266.10			

(a) Washington State DOE (1981b).

(b) Number keyed to Figure 5.3.

TABLE 5.4. Surface Water Applications as of May 18, 1981^(a)

Letter (b)	Name	Location			Withdrawal Rate (cfs)	Use Type ^(c)	Radial Distance from Station	Miles Down- stream from Discharge
		Township	Range	Section				
A	Peter Kiewit Son's	11	28	2	1.0	Env. Qual.	7	10
B	Port of Benton	10	28	14	0.33	I	12	18.5
C	C. W. Lindenmeier, et al.	10	28	25	0.02	I	14	20.5
D	Lewis G. Zirkle, Jr.	10	28	25	0.01	I	14	20.5
E	James O. Henrie	10	28	25	0.01	I	14	20.5
F	City of Richland	10	28	25	58.43	0	14	20.5
G	B. Kristofferson	10	28	25	0.08	I	14	20.5
H	Fredric W. Albaugh	10	28	25	0.11	D/I	14	20.5
I	Columbia Irrigation Dist.	9	29	30	8.0	I	19.5	27.5
J	Columbia Irrigation Dist.	9	29	36	186.0	I	22.5	31.5
K	Burlington Northern	7	31	3	13.33	I	35.5	43.5
Total					267.32			

(a) Washington State DOE (1981b).

(b) Letter Keyed to Figure 5.3.

(c) I = irrigation, D = domestic.

50 miles downstream of Hanford there are 49 surface water permits for withdrawal of a total of about 1266 cfs (Table 5.3). In addition there are 24 surface-water rights claims amounting to 14.8 cfs (Table 5.2) and 11 surface-water withdrawal applications as of 1981 amounting to about 267 cfs.

5.1.1.2 Columbia River Flows

The U.S. Geological Survey (USGS) operates a river gaging station just downstream of Priest Rapids Dam (RM 394.5). Historical discharge data are summarized in Table 5.5 for the period of record from 1917 through 1979 (USGS 1979). For the 62 years of record, the average discharge below Priest Rapids Dam was 119,870 cfs. The maximum discharge, observed on June 12, 1948, was 692,600 cfs, and the minimum discharge of 4,120 cfs was observed on February 10, 1932. The minimum discharge at Priest Rapids Dam is administratively set at 36,000 cfs by the Federal Energy Regulatory Commission (FERC).

Irrigation depletion and power regulation have altered the discharge characteristics of the Columbia River in the Hanford Reach. The Bonneville Power Administration has adjusted the 1929 to 1968 historical discharge data to reflect the 1980 level of irrigation depletion and dam regulation. The adjusted monthly average discharge data are summarized in Table 5.6 and shown in Figure 5.4. These data were used to calculate the adjusted flow duration curves in Figure 5.5, flow frequency curves in Figure 5.6, and dependable yield data in Table 5.7. The adjusted average discharge (1980 conditions) for the Columbia River below Priest Rapids Dam is 117,214 cfs. The adjusted average discharge that is equalled or exceeded 50 percent of the time is 115,752 cfs.

The minimum instantaneous flow recorded at the USGS gaging station below Priest Rapids Dam (RM 394.5) was 4120 cfs on February 10, 1932. The low flow was the result of activities connected with regulation of the river near Wenatchee, Washington. The minimum daily average flow of 20,000 cfs occurred on January 31, 1937 (WPPSS 1981). The minimum 30-day average monthly flow of 20,400 cfs occurred during February 1937 (Hutchinson 1981).

The Grant County Public Utility District, the operator of Priest Rapids Dam, has been required to maintain a minimum flow of 36,000 cfs under its FERC license since operation of the dam began in 1960. Table 5.8 summarizes the

TABLE 5.5. Historical Discharge Data

	Columbia River below Priest Rapids Dam
Gauge number ^(a)	12-4728-00
River mile ^(a)	394.5
Drainage area (mi ²) ^(a)	96,000
Period of record ^(a)	1917-1979
Average discharge (cfs) ^(a)	119,870
Maximum discharge (cfs)	
° Instantaneous	692,600
° 1-day average	690,000
° 30-day average	607,000
° Annual average	160,000
Minimum discharge (cfs)	
° Instantaneous	4,120
° 1-day average	20,000
° 30-day average	20,400
° Annual average	78,000

(a) USGS (1979).

(b) Hutchinson (1981).

TABLE 5.6. Summary of Historical Flow Data (1929-1968) for the Columbia River at Priest Rapids Dam Adjusted to the 1980 Level of Irrigation Depletion and Dam Regulation (in cfs)

	<u>Oct.</u>	<u>Nov.</u>	<u>Dec.</u>	<u>Jan.</u>	<u>Feb.</u>	<u>March</u>	<u>April</u>	<u>May</u>	<u>June</u>	<u>July</u>	<u>Aug.</u>	<u>Sep.</u>
Mean Monthly Flow	83,671	87,562	114,180	190,952	140,581	109,839	109,501	169,160	134,613	92,394	96,584	77,773
Standard Deviation	11,968	13,080	17,886	47,884	32,185	18,718	31,556	65,648	63,958	21,128	19,689	10,499

Maximum Monthly Flow = 326,948 (occurring in June of 1948)

Minimum Monthly Flow = 54,441 (occurring in June of 1952)

Maximum Annual Flow = 162,661 (occurring in 1934)

Minimum Annual Flow = 87,856 (occurring in 1930)

The Regulated Average Annual Flow = 117,214

The Regulated Flow which is equalled or exceeded 50% of the time = 115,752

Source: Walters (1981)

FIGURE 5.4. Adjusted Average Monthly Flow Below Prist Rapids Dam
Source: PSP&L (1982)

FIGURE 5.5. Adjusted Monthly and Annual Flow Duration Below Priest Rapids Dam

FIGURE 5.6. Flow Frequency Below Priest Rapids Dam

TABLE 5.7. Dependable Yield for Columbia River Below
Priest Rapids Dam (1980 Conditions)

Consecutive Years	Lowest Average Flow (cfs)	Percent of 1929-1969 Average
1	87856	75.0
2	89647	76.5
3	90531	77.2
4	94201	80.4
5	96018	81.9
6	97474	83.2
7	98064	83.7
8	99361	84.8
9	98256	83.8
10	99122	84.6
11	100052	85.4
12	101291	86.4
13	102978	87.9
14	104512	89.2
15	105261	89.8
16	104395	89.1
17	103684	88.5
18	104308	89.0
19	105303	89.8
20	107464	91.7
21	107835	92.0
22	108637	92.7
23	110537	94.3
24	111181	94.9
25	111147	94.8
26	112038	95.6
27	112825	96.3
28	114490	97.7
29	114851	98.0
30	114744	97.9
31	115288	98.4
32	116010	99.0
33	116739	99.6
34	116334	99.2
35	116182	99.1
36	116251	99.2
37	116733	99.6
38	116709	99.6
39	117158	100.0
40	117214	100.0

Source: Walters (1981)

TABLE 5.8. Low Flow Data for Columbia River Below Priest Rapids Dam (USGS Station No. 12472800 at River Mile 394.5)

<u>Water Year</u>	<u>Minimum Average Daily Flow (cfs)</u>	<u>Minimum Instantaneous Flow (cfs)</u>
1979	50,500	34,800
1978	39,000	28,300
1977	38,400	35,500
1976	39,300	32,100
1975	43,500	38,300
1974	37,800	36,400
1973	38,000	35,800
1972	45,900	36,100
1971	37,100	34,800
1970	38,400	36,100
1969	38,500	36,100
1968	38,200	35,600
1967	38,000	36,000
1966	37,600	36,300
1965	38,100	34,800
1964	38,700	36,900
1963	51,100	37,300
1962	36,400	35,300
1961	44,100	37,200
1960	52,100	40,100

Source: USGS (1979)

minimum average daily and minimum instantaneous flows at the USGS gaging station below Priest Rapids Dam from 1960 through 1979 (USGS 1979). The minimum average daily flow has exceeded 36,000 cfs since 1960; however, the minimum instantaneous flow of less than 36,000 cfs has occurred in 9 of the 20 years (1960-1979) (USGS 1979). Low flow recurrence intervals for a 20-year period of record (1960-1979) are given in Table 5.9. The 7-day, 10-year low flow based on data collected since Priest Rapids Dam became operational is 47,899 cfs.

TABLE 5.9. Low Flow Recurrence Intervals for the Columbia River Below Priest Rapids Dam ^a (1960-1980)

Recurrence Interval (Years)	Lowest Mean Flow in cfs for the Following Number of Consecutive Days In Year Ending on March 31		
	<u>1-Day</u>	<u>7-Day</u>	<u>30-Day</u>
2	41993	61788	70136
5	38006	53012	60604
10	35576	47899	55018
20	33392	43458	50144

(a) Determined by a Log Pearson Type III Analysis.

5.1.1.3 Columbia River Floods

Most major Columbia River floods result from melting of the winter snow-pack during late spring and early summer. Localized rainfall can augment the snowmelt runoff but is not the dominant flood factor. Snowmelt floods rise gradually to a peak, and high flows last for a considerable time. Warm winter rainstorms covering a large area can cause flooding at lower elevations. Such floods are relatively rare, but are compounded by snowmelt, frozen ground and ice in streams. Convective storms can also cause floods. These storms are generally localized, but can be accompanied by intense rainfall of short

duration. Peak discharges from these convective storms may result in extensive local flooding, but have little effect on major streams (PNRBC 1971).

The largest known flood on the Columbia River occurred on June 7, 1894, with an estimated maximum discharge of 740,000 cfs below Priest Rapids Dam (USGS 1979). The flood resulted from the rapid melting of an abnormally large snowpack. The second largest flood occurred on June 12, 1948. It also resulted from snowmelt and produced a peak discharge of 692,600 cfs below Priest Rapids Dam. Other floods include those of June 6, 1956 (533,900 cfs), June 9, 1961 (547,400 cfs), and June 24, 1924 (525,300 cfs).

Flood frequency curves for the Columbia River at Trinidad are shown in Figure 5.7. Trinidad is located about 46.5 miles upstream of Priest Rapids Dam, but is considered to be applicable to Priest Rapids Dam because no major tributary inflows occur between these two locations. The curves show unregulated flow conditions and flows regulated by dams as of 1975 with estimated 1985 level of depletion (Merkle 1979). Water surface elevation-discharge curve for the Columbia River at the Old Hanford Townsite (RM 361.5) is shown in Figure 5.8 (Walters 1981). The flood of June 7, 1894, would have resulted in a water surface elevation of 388 ft MSL at RM 361.5.

5.1.1.4 Columbia River Erosion and Sedimentation

The drainage basin of the Columbia River contains a wide variety of igneous, metamorphic and sedimentary rocks, and unconsolidated surficial deposits. Sediment derived from this diverse geologic and physiographic region is transported to the Pacific Ocean (Whetten et al. 1979). Sediments obtained from Grand Coulee, Rocky Reach, Wanapum, and Priest Rapids reservoirs are largely fine-grained nonvolcanic sediments that are carried in suspension. Many of the sediments are probably eroded from surficial deposits, which are primarily of glacial and eolian origin. The sediments in three lower Columbia River reservoirs and from Bonneville to the mouth are coarse and of andesitic volcanic origin. Erosion tends to be rapid because, for the most part, the andesitic formations are poorly consolidated and the local relief is quite high (Whetten et al. 1979).

FIGURE 5.7. Flood Frequency Curves for the Columbia River at Trinidad (Annual Peaks)
Source: PSP&L (1982)

FIGURE 5.8. Water Elevation in Columbia River at River Mile 361.5
Source: PSP&L (1982)

Concentrations of suspended sediment carried by the Columbia River vary considerably throughout the year because of the seasonal contribution by tributaries. In a given period, the great bulk of the sediment may be transported during a few days or weeks of unusually high discharge related to flooding. During the floods on the lower Columbia in December 1964, the maximum suspended-sediment concentrations of most rivers in the basin were approximately 10 times higher than peak concentrations of an average year. Sediment discharges for the flood period were generally several times greater than for the entire 1963 water year, the previous year of maximum recorded sediment discharge. Dams along the Columbia and Snake Rivers normally interrupt the transport of suspended sediment as well as the bedload during the slack water. During high water the sediment is resuspended. Thus, most of the suspended sediment is discharged to the Pacific Ocean during the late spring and early summer at the time of maximum water discharge (Whetten et al. 1979).

Except in the lower reaches from Bonneville Dam to the mouth, little sediment has accumulated on the bed of the Columbia River. Some sediment is present in Bonneville and Grand Coulee Reservoirs (and seasonally in other reservoirs), but the bed in most stretches of the river between reservoirs has been either scoured to bedrock or covered with a thin deposit of coarse gravel. In the reservoirs, much of the sand-size and finer sediment deposited during the low- to medium-discharge period from August through April is flushed through the dams during high discharges. Bedload sediment transport is appreciable only in the lower Columbia, and the amount of sediment transported is probably small, perhaps on the order of 10 percent of the total sediment load exclusive of dissolved materials. This estimate is based on the small amount of sediment transported on the bed of Bonneville Reservoir as calculated from rates of sand wave movement. Sediment transported as bedload is estimated at less than 1 million tons per year. In 1914, Van Winkle estimated that 7 million tons of suspended matter were transported past Cascade Locks (Bonneville) in 1910-1911. In 1966, Hidaka et al. stated that the Columbia River transported 8 million tons of suspended sediment past Vancouver, Washington, near the mouth of the Willamette River in 1962-1963 (Whetten et al. 1979).

Table 5.10 gives particle-size data for eight of the reservoirs of the Columbia River, based on 152 samples from near the center of the channel. Table 5.11 shows the mineral composition of the sediment while Table 5.12 shows the chemical composition (Stottlemire 1972).

Results from cation-exchange-capacity (CEC) determinations on sized sediments from the Columbia River and major tributaries are shown in Table 5.13 (Glenn et al. 1973). A comparison of these data with data for streams throughout the continental United States indicates that sediments from the Columbia River and major tributaries have CEC values that generally are comparable to CEC values for other stream sediments in western and midwestern areas (Glenn et al. 1973). The CEC values provide a measure of the capacity of the sediments to adsorb positively charged species in the water, including various radionuclides.

5.1.2 Local Site Watershed Characteristics

The Skagit/Hanford Site is located within a small watershed (1200 acres) that lies in a small drainage basin on the Hanford Reservation. The watershed and drainage basin boundaries are shown in Figure 5.9. The drainage basin contains the WPPSS Nuclear Projects No. 1, 2 and 4. The upper boundary of the watershed lies on the divide that separates the Yakima River and Columbia River basins. The watershed ranges in elevation from about 516 feet to 530 feet MSL. There are no perennial streams in or near the watershed. The reference site is fairly level with many shallow depressions and low ridges (Figure 5.10).

There are no well-defined drainage channels within the reference site watershed. General drainage patterns within the watershed and drainage basin are shown in Figure 5.11.

5.1.3 Columbia River Water Quality

Water quality for the Hanford Reach of the Columbia River is very good. The state of Washington has designated the Hanford Reach as Class A, which means the water is suitable for all uses including drinking water, recreation, and wildlife. State water quality standards are given in Table 5.14, and recent measurements of water quality parameters are shown in Table 5.15.

TABLE 5.10. Particle-Size Distribution of Undispersed and Dispersed Sediments From Columbia River Size Classes

Type of Analysis: A, not dispersed mechanically or chemically;
B, dispersed mechanically and chemically

(Size limits and range in microns)

Size Class Number and Limits	Location	Type of Analysis	Percent in Size Range				2*
			61-31	31-16	16-4	4-2	
7 (62-31)	Pasco	A	93.8	4.0	0.7	0.6	0.9
	McNary Dam	A	92.2	5.3	1.4	.1	1.0
	The Dalles	A	89.0	8.9	1.3	.1	.7
	Hood River	A	90.8	7.3	.5	.5	.9
	Hood River	B	86.4	9.5	1.4	1.1	1.6
	Bonneville Dam	A	92.8	5.2	1.3	.0	.7
	Vancouver	A	92.5	6.5	.6	.1	.3
	St. Helens	A	90.8	8.0	.8	.1	.3
8 (31-16)	McNary Dam	A	10.8	83.7	3.7	1.8	.0
	The Dalles	A	7.4	86.4	4.4	.5	1.3
	Hood River	A	9.8	84.1	5.5	.2	.4
	Bonneville Dam	A	12.3	82.7	3.6	.1	1.3
	Vancouver	A	8.7	85.4	5.2	.2	.5
	St. Helens	A	9.6	84.7	4.7	.3	.7
9 (16-4)	Pasco	A	.0	22.9	68.1	5.1	3.9
	McNary Dam	A	.0	11.0	84.6	1.1	3.5
	McNary Dam	B	.0	7.3	81.5	5.5	5.7
	The Dalles	A	.0	10.9	82.1	4.0	3.0
	Hood River	A	.0	.0	90.5	7.6	1.9
	Bonneville Dam	A	.5	9.1	85.1	2.5	2.8
	Vancouver	A	.0	8.8	83.7	5.9	3.6
	St. Helens	A	.0	5.1	87.4	.0	7.5
10 (4-2)	McNary Dam	A	.0	3.7	40.3	46.7	9.1
	McNary Dam	B	.0	.0	11.6	52.2	36.2
	The Dalles	A	.0	.0	24.3	60.4	15.3
	The Dalles	B	1.0	1.4	2.0	70.6	25.0
	Vancouver	A	.0	.0	32.0	56.3	11.7
11 (2*)	McNary Dam	A	.0	.0	.0	34.6	65.4
	McNary Dam	B	1.1	.2	13.8	10.3	74.6
	The Dalles	A	.0	.0	.0	30.1	69.9
	Hood River	A	.0	.0	.5	9.1	90.4
	Hood River	B	.0	.0	.7	10.1	89.2
	Vancouver	A	.0	.0	.5	19.7	79.8
	St. Helens	A	.0	.0	.0	6.1	93.9
	St. Helens	B	.0	.0	.1	7.9	92.0

*Less than.

Source: Stottlemire (1972)

TABLE 5.11 Mineral Composition of Bottom Sediments From Columbia River Reservoirs

Bulk-Mineral Composition (in %) of Bottom Sediments from Columbia River Reservoirs
Determined Petrographically by Point-Counting Thin Sections. Approximately
250 grains counted per sample. $\bar{x}$ =mean, s=standard deviation

Constituent	Bonneville		The Dalles		McNary		Priest Rapids - Wanapum - Rocky Reach		Grand Coulee		Ice Harbor (c)	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Quartz	29	9.0	29	9.3	34	9.0	41	6.5	37	10.4	45	5.2
Plagioclase	18	5.2	17	5.9	15	6.8	12	3.5	5	0.6	8	4.1
K-feldspar	10	4.3	13	6.6	12	5.1	11	2.7	12	9.9	11	3.9
Lithic Fragments	35	12.5	32	20.4	29	11.9	21	10.9	28	9.3	16	7.5
Opaque minerals	4	4.5	5	2.9	4	3.2	13	5.3	15	2.7	3	1.5
Mafic minerals (a)	5	3.2	4	3.1	6	5.3	2	1.7	3	1.7	18	5.0
Number of samples	19		6		15		12		3		19	

(a) Largely orthopyroxene (hypersthene), clinopyroxene (augite), hornblende, and biotite.

Heavy-Mineral (SG Greater than 3.17) Composition (in %) of Bottom Sediments from Columbia River Reservoirs
Determined Petrographically by Point-Counting Grain Mounts in Hyrax (n=1.67).
Approximately 250 grains counted per sample. $\bar{x}$ =mean, s=standard deviation

Constituent	Bonneville		The Dalles		McNary		Priest Rapids - Wanapum - Rocky Reach		Grand Coulee		Ice Harbor (c)	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Orthopyroxene (a)	27	10.0	10	7.3	6	3.2	5	2.4	5	3.5	2	1.5
Clinopyroxene (b)	38	9.1	47	9.8	30	7.7	20	10.1	14	3.5	12	6.0
Hornblende	22	11.9	32	9.9	44	10.0	58	13.1	57	3.6	72	7.8
Epidote	2	2.9	1	0.8	2	1.8	3	3.1	3	1.7	1	1.3
Garnet	6	5.2	6	3.3	9	6.8	7	4.5	9	7.0	4	2.8
Sphene	1	1.0	2	1.0	3	1.1	5	1.9	9	2.4	5	2.3
Zircon	1	1.3	1	1.0	4	4.5	2	1.5	3	1.3	3	1.7
Apatite	1	0.8	1	0.8	1	1.0	1	0.7	0	--	1	0.3
Other	tr		tr		tr		tr		tr		tr	
Number of samples	19		6		15		12		4		9	

(a) Large hypersthene.

(b) Largely augite.

(c) Reservoir on Snake River.

Source: Stottlemire (1972)

TABLE 5.12 Chemical Composition in Bottom Sediments From Columbia River Reservoirs

Chemical Composition of Major-Element Oxides (in weight %) in Bottom Sediments from Columbia River Reservoirs. Analysis by x-ray emission spectrography (MnO and TiO₂ by optical emission spectrography), x=mean, s=standard deviation

Constituent	Bonneville		The Dalles		McNary		Priest Rapids - Wanapum - Rocky Reach		Grand Coulee		Ice Harbor**	
	x	s	x	s	x	s	x	s	x	s	x	s
SiO ₂	68.5	4.3	65.2	3.4	67.6	4.8	66.2	3.3	58.4	2.9	62.3	2.0
TiO ₂	0.8	0.2	0.8	0.1	0.8	0.2	0.7	0.2	0.8	0.1	1.1	0.1
Al ₂ O ₃	13.3	1.1	14.1	1.4	13.6	0.8	14.4	0.8	17.0	1.9	14.9	1.4
FeO as Fe ₂ O ₃	5.1	1.3	5.7	0.9	4.8	1.3	3.3	0.8	5.1	0.6	4.6	0.7
Fe ₂ O ₃												
MnO	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.3	0.4
MgO	2.1	0.5	2.1	0.2	1.8	0.4	2.1	0.4	2.6	0.5	2.1	0.2
CaO	3.2	1.0	3.7	0.5	3.2	1.0	3.5	0.3	2.6	0.3	3.7	0.9
Na ₂ O	3.0	0.2	2.7	0.3	2.8	0.3	3.5	0.3	2.5	0.2	2.9	0.2
K ₂ O	2.1	0.3	2.0	0.2	2.2	0.2	2.1	0.1	3.1	0.3	2.3	0.3
B ₂ O	nd		nd		nd		nd		nd		nd	
CO ₂	nd		nd		nd		nd		nd		nd	
Total	98.2		96.4		96.9		95.9		92.3		94.2	
Number of samples	21		11		15		12		6		9	

Chemical Composition of Minor Elements (ppm) in Bottom Sediments from Columbia River Reservoirs. Analysis by optical emission spectrography (E. Bingham, analyst). x=mean, s=standard deviation

Constituent	Bonneville		The Dalles		McNary		Priest Rapids - Wanapum - Rocky Reach		Grand Coulee		Ice Harbor**	
	x	s	x	s	x	s	x	s	x	s	x	s
B	20	5*	20	10*	30	10	30	10*	50	10*	30	10*
Ba	1720	430	1600	270	1410	330	860	60	970	190	860	90
Co	10	10*	10	10*	10	10*	10	10*	20	10*	20	10*
Cr	50	10	50	10*	50	20	40	10	40	10	30	10*
Cu	20	10	40	10	40	10	40	10	90	20	50	10
Ga	20	10*	20	10*	20	10*	20	10*	20	10	20	10*
Ni	30	10	30	10*	30	10*	40	10	50	10*	30	10*
Pb	20	10*	40	20	40	20	70	50	570	170	30	10
Sc	20	10*	20	10*	20	10*	20	10*	20	10*	30	10*
Sr	430	70	430	80	450	110	360	110	280	30	300	50
V	90	50	120	30	60	50	100	40	90	10	130	30
Y	40	10*	50	10	50	10	50	10	120	20	60	10*
Zr	150	40	180	40	190	50	190	40	180	30	280	90
Number of samples	21		11		15		12		6		9	

*Less than.

**Reservoir on Snake River

Source: Stottlemire (1972)

TABLE 5.13. Cation-Exchange Capacities (in Milliequivalent per 100 Grams) of Sized Sediments From Columbia River and Tributary Locations

Type of sample:

1. Bulk sample as received for analysis. CEC computed algebraically by combining the results of CEC analyses on type 2 and 3 samples, where available, using the weight percent of material for each type as weighting factors.
2. Bulk sample after material finer than the lower limit of the size class has been removed by decantation.
3. Material finer than the lower limit of the size class.
4. Bulk sample after treatment with cesium chloride followed by decantation and removal of material finer than the lower limit of the size class.
5. Material from type 4 sample is finer than lower limit of size class.

If type 4 or 5 samples are not listed for size classes greater than 62 microns at a location, or if a dashed line is shown, no analyses were necessary; that is, no additional fines or floating organic matter were present. Size limit (in parentheses) are given in microns.

Location	Type of Sample	Size Class and Limits											Total
		1 (4000- 2000)	2 (2000- 1000)	3 (1000- 500)	4 (500- 250)	5 (250- 125)	6 (125- 62)	7 (62- 31)	8 (31- 16)	9 (16- 4)	10 (4- 2)	11 (2*)	
Columbia River near: Pasco	1	3.0	3.2	9.0	2.9	2.8	3.3	3.5	9.2	18.7	22.3	35.0	113.7
	2	3.0	3.2	9.5	2.8	2.7	2.8	--	--	--	22.6	--	
	3	6.7	6.7	29.3	18.0	18.1	14.9	--	--	--	20.0	--	
	4	2.9	2.9	8.4	2.7	2.6	2.7	--	--	--	--	--	
	5	10.2	10.2	26.4	18.8	19.6	5.9	--	--	--	--	--	
McNary Dam	1	12.6	8.5	4.1	2.6	5.0	9.5	5.2	8.7	16.8	31.7	44.8	149.5
	2	8.4	5.9	3.9	2.2	4.2	6.3	--	--	--	32.1	--	
	3	28.3	53.5	50.6	37.5	32.3	30.0	--	--	--	28.7	--	
	4	8.3	5.8	3.9	--	--	--	--	--	--	--	--	
	5	14.0	12.3	3.5	--	--	--	--	--	--	--	--	
The Dalles	1	(1)	(1)	23.1	4.3	5.3	9.9	6.0	9.3	17.6	34.4	47.8	157.7
	2	(1)	(1)	6.7	3.8	4.9	8.2	--	--	--	34.7	--	
	3	(1)	(1)	48.5	25.9	34.3	40.9	--	--	--	32.5	--	
Hood River	1	13.3	3.5	2.4	2.3	3.1	10.4	5.7	8.0	14.3	32.8	41.7	137.7
	2	13.2	3.5	2.3	2.1	2.8	8.1	--	--	--	--	40.8	
	3	14.2	10.3	36.0	29.5	39.6	42.3	--	--	--	--	42.3	
	4	12.5	3.2	--	--	--	--	--	--	--	--	--	
	5	25.6	107.5	--	--	--	--	--	--	--	--	--	
Bonneville Dam	1	18.4	10.2	3.4	2.1	4.2	9.1	5.9	9.5	17.2	31.6	41.0	152.6
	2	14.4	9.5	3.3	2.1	3.7	7.5	--	--	--	32.1	--	
	3	53.0	39.5	32.3	10.4	22.3	25.8	--	--	--	22.8	--	
Vancouver	1	2.0	1.6	2.4	3.0	4.1	8.1	5.1	9.3	18.3	29.6	42.0	125.5
	2	2.0	1.6	2.3	2.9	3.8	6.4	5.0	--	--	30.0	--	
	3	10.5	20.2	21.2	32.0	17.0	36.2	8.4	--	--	25.3	--	
	4	1.9	--	--	--	--	--	--	--	--	--	--	
	5	9.8	--	--	--	--	--	--	--	--	--	--	

TABLE 5.13. (contd)

Location	Type of Sample	Size Class and Limits											Total
		1 (4000- 2000)	2 (2000- 1000)	3 (1000- 500)	4 (500- 250)	5 (250- 125)	6 (125- 62)	7 (62- 31)	8 (31- 16)	9 (16- 4)	10 (4- 2)	11 (2*)	
St. Helens	1	2.0	2.6	2.6	2.2	3.0	12.6	6.8	10.2	17.1	26.3	33.4	110.0
	2	2.0	--	2.6	2.2	2.8	8.8	--	--	--	27.1	--	
	3	--	--	8.0	19.0	29.2	36.7	--	--	--	22.0	--	
Mean	1	8.6	4.9	6.8	2.8	3.9	9.0	5.4	9.2	17.1	29.8	40.8	
	1	7.1	3.5	7.6	1.7	1.0	2.9	1.0	.7	1.4	4.2	5.1	
Standard Deviation	(2)	7.0	4.1	4.2	2.6	3.5	6.8	5.4	9.2	17.1	30.2	40.7	
	(2)	5.6	2.9	2.4	.6	.8	2.0	1.0	.7	1.4	4.1	6.1	
Snake River	1	11.4	10.9	7.4	3.7	4.2	7.0	5.6	8.7	17.0	30.0	47.6	153.5
	2	11.4	10.8	7.0	3.6	4.1	5.7	--	--	--	30.1	--	
	3	17.0	12.9	31.7	9.5	17.6	32.5	--	--	--	26.8	--	
	4	10.7	10.4	7.0	3.5	--	--	--	--	--	--	--	
	5	19.3	21.8	8.2	12.4	--	--	--	--	--	--	--	
Willamette River	1	6.5	8.0	7.2	9.3	12.0	15.9	12.7	18.0	24.7	34.3	44.6	193.2
	2	6.4	7.8	7.0	9.2	11.5	14.4	--	--	--	34.8	--	
	3	36.0	30.4	37.2	33.3	34.4	35.9	--	--	--	29.2	--	
	4	6.4	7.4	6.9	9.2	11.4	14.4	--	--	--	--	--	
	5	16.3	22.4	23.8	21.0	20.7	25.6	--	--	--	--	--	

(1) Insufficient material for analysis.

(2) Calculated using CEC data from sample types 4, 2, or 1, in that order of preference.

*Less than.

Source: Glenn (1973)

FIGURE 5.9. Local Water Sheds
Source: PSP&L (1981)

FIGURE 5.10. Natural Site Topography
Source: PSP&L (1981)

FIGURE 5.11. Skagit/Hanford Nuclear Project Watershed
Source: PSP&L (1981)

TABLE 5.14. Washington State Water Quality Standards for the Hanford Reach of the Columbia River (Sula et al. 1983)

Parameter	Permissible Levels
Fecal Coliform Organism	1) ≤ 100 organisms/100 ml (median) 2) $\leq 10\mu$ of samples may exceed 200 organisms/100 ml
Dissolved Oxygen	> 8 mg/l
Temperature	1) $\leq 20^{\circ}\text{C}$ (68°F) due to human activities 2) Increases not to exceed $34/T + 9$, where T = highest existing temperature in $^{\circ}\text{C}$ outside of mixing zone
pH	1) 6.5 to 8.5 range 2) < 0.5 unit induced variation
Turbidity	≤ 5 NTU ^(a) over background turbidity
Toxic, Radioactive, or Deleterious Materials	Concentrations shall be below those of public health significance, or which cause acute or chronic toxic conditions to the aquatic biota, or which may adversely affect any water use.
Aesthetic Value	Shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch or taste.

(a) NTU = Nephelometric Turbidity Units--Standard Candle.

TABLE 5.15. Columbia River Water Quality (Sula et al. 1983)

Analysis	Units	No. of Samples	Vernita Bridge (Upstream)			No. of Samples	Richland (Downstream)			State Standard ^(h)
			Max.	Min.	Annual Average ^(a)		Max.	Min.	Annual Average ^(a)	
<u>Environmental Surveillance Sampling Program</u>										
Dissolved O ₂	mg/l	49	17	6.8	12 ± 1.2	48	17	6.8	11 ± 1.3	8 (minimum)
Turbidity	NTU ^(c)	51	8.7	0.1	2.5 ± 0.8	49	7.4	1.0	2.9 ± 0.9	5 ± background
pH		48	8.0	6.0	N/A	49	7.7	5.4	N/A	8.5 - 6.5
Fecal Coliform	#/100 ml	11	110	0	5.0 ^(d)	10	240	2	7.0 ^(d)	100
Total Coliform	#/100 ml	10	2400	2	79 ^(d)	10	240	4	33 ^(d)	
BOD ^(e)	mg/l	11	7.1	1.0	3.2 ± 2.2	11	7.2	0.8	3.3 ± 2.2	
Nitrogen (as NO ₃)	mg/l	52	0.92	0.10	0.22 ± 0.08	52	7.6	0.10	0.58 ± 0.68	
<u>USGS Sampling Program</u>										
Temperature	°C	343	20.2	1.8	10.7 ± 0.6	350	21.0	2.0	10.9 ± 0.6	20 (maximum)
Dissolved O ₂	mg/l	5	14.1	11.6	12 ± 2	4	12	10	11 ± 1	8 (minimum)
Turbidity	NTU ^(c)	6	2.6	0.6	1.4 ± 0.7	3	3.5	0.6	2.4 ± 1.8	5 ± background
pH		6	9.0	7.7	N/A	4	8.1	7.7	N/A	8.5 - 6.5
Fecal Coliform	#/100 ml	5	8	<1	3 ^(d)	3	5	<1	2 ^(d)	100
Suspended Solids, 105°C	mg/l	6	7	<1	4 ± 1.9	4	11	3	6 ± 3	
Dissolved Solids, 180°C	mg/l	6	93	58	76 ± 12.1	4	88	64	78 ± 12	
Specific Conductance	µmhos	6	150	113	130 ± 11.4	4	148	122	135 ± 189	
Hardness, as CaCO ₃	mg/l	6	76	55	65 ± 7.7	4	77	55	66 ± 12	
Phosphorus, total	mg/l	6	0.060	<0.010	0.03 ± 0.020	4	0.050	0.020	0.032 ± 0.015	
Chloride, dissolved	mg/l	6	1.6	0.8	1.2 ± 0.2	4	1.4	0.9	1.1 ± 0.2	
Chromium total ^(f)	ng/l	3	20	20	20 ± 0	4	10	<10	10 ± 0	
Iron, total ^(f)	mg/l	3	360	120	223 ± 142	4	230	60	145 ± 92.6	
Nitrogen, Kjeldahl	mg/l	4	0.49	0.22	0.36 ± 0.12	4	0.70	0.34	0.50 ± 0.15	

(a) Average ± two standard error terms (95% confidence interval).

(b) See Appendix A.

(c) Nephelometric Turbidity Units.

(d) Annual median.

(e) Biological Oxygen Demand.

(f) Total - total recoverable with standard analytical method.

N/A Not Applicable.

TABLE 5.15. (contd)

300 Area/Richland													
Year	Month												Annual Average
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Standard Deviation
1972	13.0	13.2	11.1	10.4	10.5	--	11.9	11.1	9.9	9.0	9.0	9.7	10.8
1973	11.2	9.5	8.8	9.8	9.6	9.6	10.8	11.3	10.9	10.1	--	10.1	10.2
1974	8.5	10.2	10.3	10.5	11.9	12.4	11.7	10.6	10.2	10.4	10.6	11.1	10.7
1975	11.8	12.4	13.1	13.6	13.2	11.6	11.4	10.5	10.6	10.7	10.4	12.0	11.8
1976	13.6	13.2	13.7	12.8	10.9	11.2	--	10.0	11.0	11.5	6.7	11.6	11.5
1977	--	14.0	13.6	13.4	11.2	11.1	10.1	11.4	10.3	11.5	15.7	11.7	12.2
1978	-- -- NO DATA -- --												
1979	10.1	15.9	11.5	13.2	12.5	--	11.0	8.5	9.0	9.6	--	9.0	11.0
1980	11.9	9.0	13.3	12.5	11.2	10.0	9.5	9.6	9.2	9.0	9.3	10.4	10.4
Average 1972-1977, 1979-1980	11.4	12.2	11.9	12.0	11.4	11.0	10.9	10.4	10.1	10.2	10.3	10.7	11.1
Std. Dev.	1.7	2.4	1.8	1.5	1.1	1.0	0.9	1.0	0.7	1.0	3.0	1.1	--
Minimum Daily (observed)	6.1	5.5	7.7	8.1	8.5	9.0	8.3	3.0	8.5	8.1	6.7	8.7	--
Maximum Daily (observed)	14.7	16.8	19.0	14.1	14.0	13.6	14.1	13.2	12.4	14.0	11.7	12.8	

Monthly variations in dissolved oxygen, pH, and turbidity are given in Tables 5.16, 5.17, and 5.18, respectively. Metal concentrations are shown in Table 5.19.

Suspended sediment concentrations in the Hanford Reach vary widely throughout the year because of seasonal differences in the contribution of tributaries (U.S. ERDA 1975, p. II.3.D-8). During low flows the dams along the Columbia intercept much of the suspended sediment; during high flows part of these deposited materials are resuspended and washed out of the dam reservoirs. The concentration of suspended material in river water ranges from about 300 g/l in April, or nearly a 100-fold variation during the year (Wildung 1971, p. 7) (Table 5.20). The clay fraction ($<2.0\mu$) accounts for a major part of the suspended particle load during the spring flows (Table 5.21) and the concentration of particles 0.5μ in diameter greatly exceeds the total (53μ diameter) particulate concentrations during other seasons. The total carbon content of the suspended material is greatest in the fall and least in the spring (Table 5.22) and probably reflects the greater fraction of phytoplankton in the suspended load during the fall. The variation in mineral composition of the suspended particulates do not vary greatly seasonally. The relative concentrations of minerals in suspended sediments are shown in Table 5.23. In the fractions $>0.5\mu$ diameter feldspar, amphibole, mica-illite and chlorite are the most abundant.

Columbia River temperatures have been recorded for a number of years at the Vernita Bridge (RM 391) just upstream from the Hanford Reservation and Richland, Washington (RM 339), just downstream of the reservation. The monthly average temperatures at these locations range from 3.2°C (37.8°F) in February to 19.3°C (66.7°F) in August (Tables 5.24 and 5.25). The minimum and maximum daily temperatures are 0.0°C (32.0°F) and 21.5°C (70.7°F) (PSP&L 1982, p. 2.4-6). A diurnal temperature variation of about 1.2°C (2.2°F) in spring and summer, and 0.6°C (1.1°F) in fall and winter can be expected from the diurnal reservoir discharge variations from Priest Rapids Dam (PSP&L 1982, p. 2.4-6b). The establishment of dams in the Columbia upstream from Hanford delays the annual peak river temperature arrival dates in direct proportion to the increase in travel time due to the dam (US ERDA 1975, p. II.3-D-5).

TABLE 5.16. Monthly Average Values of Dissolved Oxygen (mg/l) at Vernita Bridge and at 300 Area/Richland (PSP&L 1982)

A. Vernita Bridge														
Year	Month												Annual Average	Standard Deviation
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec		
1972	12.5	13.4	10.8	10.8	10.8	--	--	12.0	10.9	19.2	9.2	6.6	11.6	3.3
1973	10.3	9.0	9.2	10.5	10.2	10.5	11.3	12.6	11.0	10.4	--	10.4	10.5	1.0
1974	10.0	9.8	10.5	11.0	12.5	11.7	11.3	11.4	10.7	10.6	10.7	10.8	10.9	0.8
1975	11.8	12.9	13.2	13.9	13.2	11.4	11.5	10.5	10.5	10.6	10.9	12.1	11.9	1.2
1976	13.7	14.8	14.5	12.8	--	10.0	--	11.7	10.9	10.8	5.8	11.5	11.7	2.6
1977	12.6	13.5	13.6	13.6	12.0	11.0	10.6	10.2	10.1	10.5	10.4	11.8	11.7	1.4
1978	14.1	14.3	13.3	13.5	12.0	12.9	12.0	10.9	--	9.9	10.9	11.7	12.3	1.4
1979	13.0	15.9	13.0	13.5	12.7	8.6	10.6	10.0	10.1	9.9	--	9.6	11.5	2.2
Average 1972-1979	12.2	13.0	12.3	12.5	11.9	10.9	11.2	11.2	10.6	11.5	9.7	10.6	11.5	
Std. Dev.	1.5	2.4	1.8	1.4	1.1	1.4	0.5	0.9	0.4	3.1	2.0	1.8	--	--
Minimum Daily (observed)	6.3	8.4	8.6	9.5	9.3	6.0	9.0	9.2	7.4	8.0	5.8	4.0	--	--
Maximum Daily (observed)	17.0	15.9	15.8	14.4	15.0	14.1	15.2	14.1	13.0	11.7	11.5	12.6	--	--

TABLE 5.16. (contd)

B. 300 Area/Richland

Year	Month												Annual Average	Standard Deviation
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec		
1972	7.9	7.9	7.9	8.3	8.4	8.2	8.2	8.1	8.0	8.0	7.9	7.8	8.1	0.2
1973	7.9	8.1	8.1	7.9	8.4	8.5	8.2	8.3	8.3	8.1	8.0	7.9	8.1	0.2
1974	8.0	7.8	7.9	7.8	7.8	7.9	7.8	7.8	8.0	7.8	7.7	7.9	7.9	0.1
1975	8.0	8.1	8.0	8.2	8.1	7.9	8.0	8.0	8.1	8.2	7.8	7.7	8.0	0.2
1976	7.6	7.6	7.6	7.8	7.4	7.5	--	7.5	8.1	8.2	7.8	7.7	7.7	0.3
1977	7.4	8.1	7.7	7.9	8.1	7.8	8.1	8.4	8.1	8.4	7.7	--	8.0	0.3
1978	----NO DATA----													
1979	7.4	7.5	7.6	7.5	7.9	--	7.3	7.7	7.7	7.6	7.9	8.1	7.7	0.2
1980	7.2	7.5	7.7	7.7	7.6	7.4	7.7	7.4	7.5	7.2	7.2	7.4	7.5	0.2
Average 1972-1977, 1979-1980	7.7	7.8	7.8	7.9	8.0	7.9	7.9	7.9	8.0	7.9	7.8	7.8	7.9	
Std. Dev.	0.3	0.3	0.2	0.3	0.4	0.4	0.3	0.4	0.3	0.4	0.2	0.2	--	--
Minimum Daily (observed)	7.1	7.1	6.7	7.2	7.1	6.9	7.2	7.1	7.1	7.1	7.0	7.0	--	--
Maximum Daily (observed)	8.6	8.4	8.8	8.9	9.1	9.4	8.8	8.7	11.3	9.0	8.6	8.3	--	--

TABLE 5.17. Monthly Numerical Average of pH at Vernita Bridge and at 300 Area/Richland (PSP&L 1982)

A. Vernita Bridge

Year	Month												Annual Average	Standard Deviation
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec		
1972	8.1	7.9	7.9	8.4	8.4	8.3	8.0	8.2	8.2	8.0	8.0	8.0	8.1	0.2
1973	8.0	8.0	8.1	8.1	8.5	8.8	8.4	8.5	8.5	8.4	8.5	8.4	8.3	0.2
1974	8.4	8.0	8.2	8.2	8.3	8.0	8.0	8.4	8.1	8.0	7.9	7.9	8.1	0.2
1975	7.9	8.2	8.0	8.2	8.2	8.1	8.1	8.0	8.3	8.2	8.1	7.8	8.1	0.1
1976	7.6	7.5	8.3	8.1	--	7.6	--	8.2	8.0	8.0	7.7	7.9	7.9	0.3
1977	7.7	7.8	7.5	7.7	7.9	7.7	7.9	7.9	7.9	8.5	8.0	--	7.9	0.2
1978	8.5	8.1	7.6	7.5	7.4	7.4	7.8	7.5	8.0	7.5	7.6	7.5	7.7	0.3
1979	7.9	7.6	7.7	7.7	7.8	7.8	7.6	7.7	7.6	7.9	8.0	7.7	7.8	0.1
Average 1972-1979	8.0	7.9	7.9	8.0	8.1	8.0	8.0	8.1	8.1	8.1	8.0	7.9	8.0	
Std. Dev.	0.3	0.2	0.3	0.3	0.4	0.4	0.2	0.3	0.3	0.3	0.3	0.3	--	--
Minimum Daily (observed)	7.3	7.1	7.1	7.3	7.2	7.2	7.2	7.2	7.2	7.2	7.3	7.3	--	--
Maximum Daily (observed)	8.7	8.5	9.2	8.7	9.1	9.2	8.8	8.6	8.7	10.0	8.8	8.6	--	--

TABLE 5.17. (contd)

B. 300 Area/Richland

Year	Month												Annual Average	Standard Deviation
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec		
1972	1.6	2.7	6.4	6.3	6.1	16.3	5.0	4.1	2.9	1.9	1.2	1.4	4.7	4.2
1973	1.6	0.9	2.6	1.7	1.7	1.9	1.6	1.3	1.0	1.4	0.9	0.9	1.5	0.5
1974	4.9	14.7	6.3	6.1	5.6	6.5	3.1	1.6	1.5	1.4	1.1	1.3	4.5	3.9
1975	1.5	1.1	.9	1.8	3.6	--	2.0	2.2	1.6	1.5	1.1	1.9	1.7	0.7
1976	1.5	3.3	3.8	3.6	3.9	2.8	--	2.2	1.6	1.4	1.4	1.5	2.5	1.0
1977	1.5	3.0	3.6	2.3	2.5	2.3	2.0	2.6	1.7	1.8	1.9	--	2.3	2.6
1978	-----NO DATA-----													
1979	1.5	1.4	1.3	2.1	1.5	--	1.5	3.5	3.3	3.1	2.6	1.4	2.1	0.9
1980	1.6	1.0	2.9	1.6	6.9	2.8	1.4	1.9	1.7	1.4	1.8	2.1	2.3	1.6
Average 1972-1977, 1979-1980	2.0	3.5	3.5	3.2	4.0	5.4	2.4	2.4	1.9	1.7	1.5	1.5	2.7	
Std. Dev.	1.2	4.6	2.0	2.0	2.0	5.6	1.3	0.9	0.8	0.6	0.6	0.4	--	--
Minimum Daily (observed)	0.4	0.6	0.4	0.7	1.2	1.0	0.8	0.8	0.8	0.8	0.6	0.1	--	--
Maximum Daily (observed)	9.7	23.0	13.0	9.0	18.0	30.0	8.0	8.0	6.2	6.7	4.6	6.0	--	--

TABLE 5.18. Monthly Average Values of Turbidity (NTU) at Vernita Bridge and at 300 Area/Richland (PSP&L)

A. Vernita Bridge

Year	Month												Annual Average	Standard Deviation
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec		
1972	1.3	2.5	7.1	7.4	5.8	18.7	5.7	3.7	3.8	1.2	1.2	1.3	5.0	4.7
1973	1.4	1.2	3.1	1.8	1.8	1.8	1.7	1.1	1.0	0.9	0.8	1.0	1.5	0.6
1974	3.8	17.3	6.2	6.1	6.4	5.6	3.1	1.6	1.4	1.4	1.1	1.2	4.6	4.3
1975	1.3	1.2	0.7	1.6	4.0	--	2.3	2.2	1.4	1.3	1.1	2.3	1.8	0.9
1976	1.6	2.4	4.3	3.4	--	3.8	--	1.8	1.5	1.5	1.3	1.5	2.3	1.1
1977	2.5	3.1	2.4	2.8	2.3	2.2	2.1	2.3	1.5	1.4	1.3	--	2.2	0.5
1978	1.8	1.3	2.3	1.7	2.0	1.8	2.1	1.5	1.6	1.1	1.6	1.3	1.6	1.1
1979	1.5	0.9	1.2	1.7	1.6	1.6	1.6	1.8	1.4	0.7	2.7	1.4	1.5	0.5
Average 1972-1979	1.9	3.7	3.4	3.3	3.4	5.1	2.7	2.0	1.7	1.2	1.4	1.4	2.6	
Std. Dev.	0.8	5.1	2.1	2.1	1.9	5.7	1.3	0.7	0.8	0.3	0.5	0.4	--	--
Minimum Daily (observed)	0.6	0.5	0.4	1.0	1.2	1.4	1.4	1.0	0.8	0.08	0.5	0.7	--	--
Maximum Daily (observed)	7.5	24.0	12.0	10.0	9.0	28.0	7.3	5.0	5.0	2.3	4.5	6.5	--	--

TABLE 5.18. (contd)

B. 300 Area/Richland

Year	Month												Annual Average	Standard Deviation
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec		
1972	1.6	2.7	6.4	6.3	6.1	16.3	5.0	4.1	2.9	1.9	1.2	1.4	4.7	4.2
1973	1.6	0.9	2.6	1.7	1.7	1.9	1.6	1.3	1.0	1.4	0.9	0.9	1.5	0.5
1974	4.9	14.7	6.3	6.1	5.6	6.5	3.1	1.6	1.5	1.4	1.1	1.3	4.5	3.9
1975	1.5	1.1	.9	1.8	3.6	--	2.0	2.2	1.6	1.5	1.1	1.9	1.7	0.7
1976	1.5	3.3	3.8	3.6	3.9	2.8	--	2.2	1.6	1.4	1.4	1.5	2.5	1.0
1977	1.5	3.0	3.6	2.3	2.5	2.3	2.0	2.6	1.7	1.8	1.9	--	2.3	2.6
1978	-----NO DATA-----													
1979	1.5	1.4	1.3	2.1	1.5	--	1.5	3.5	3.3	3.1	2.6	1.4	2.1	0.9
1980	1.6	1.0	2.9	1.6	6.9	2.8	1.4	1.9	1.7	1.4	1.8	2.1	2.3	1.6
Average 1972-1977, 1979-1980	2.0	3.5	3.5	3.2	4.0	5.4	2.4	2.4	1.9	1.7	1.5	1.5	2.7	
Std. Dev.	1.2	4.6	2.0	2.0	2.0	5.6	1.3	0.9	0.8	0.6	0.6	0.4	--	--
Minimum Daily (observed)	0.4	0.6	0.4	0.7	1.2	1.0	0.8	0.8	0.8	0.8	0.6	0.1	--	--
Maximum Daily (observed)	9.7	23.0	13.0	9.0	18.0	30.0	8.0	8.0	6.2	6.7	4.6	6.0	--	--

TABLE 5.19. Mean and Extreme Concentrations of Metals and Other Water Quality Parameters Measured at Vernita Bridge and Richland During Water Years 1979-1980 (PSP&L 1982)

		1979 WY (2) Vernita Bridge			1980 WY (2) Vernita Bridge			1979 WY (2) Richland, WA			6/80-1/81 (1) Near Richland, WA		
		Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Iron (total)	b	80	98	130	40	98	150	90	132	180	28	50	95
Iron (dissolved)	b	10	40	100	10	12	20	--	--	--	3	15	39
Copper (total)	b	4	6	12	1	9	19	2	10	19	1	4	16
Copper (dissolved)	b	0	0	1	0	1	3	--	--	--	1	2	7
Nickel (total)	b	--	--	--	1	6	9	--	--	--	1	2	10
Nickel (dissolved)	b	--	--	--	0	1	4	--	--	--	1	1.3	3.4
Zinc (total)	b	10	38	70	10	35	90	20	32	40	5	14	29
Zinc (dissolved)	b	4	16	30	3	8	20	--	--	--	5	10	23
Lead (total)	b	8	33	73	4	7	14	27	75	130	1	3	24
Lead (dissolved)	b	0	5	12	1	2	3	--	--	--	1	1	2
Cadmium (total)	b	1	1	3	0	1	2	0	2	7	0.1	0.7	8.4
Cadmium (dissolved)	b	1	1	2	1	1	1	--	--	--	0.1	0.5	6.8
Chromium (total)	b	0	0	0	0	6	20	0	5	20	0.5	0.6	1.8
Chromium (dissolved)	b	0	0	0	0	0	0	--	--	--	0.5	0.5	0.8
Mercury (total)	b	0.0	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.3	0.2	0.8	4.1
Mercury (dissolved)	b	0.0	0.0	0.0	0.0	0.1	0.5	--	--	--	0.2	0.3	1.0
Phosphorus (total)	a	0.01	0.03	0.05	0.01	0.04	0.11	0.01	0.02	0.04	0.022	0.027	0.035
Calcium (dissolved)	a	17	20	23	15	20	24	17	19	22	16.2	18.3	2.4
Magnesium (dissolved)	a	1.3	4.1	5.2	3.7	4.4	5.4	3.7	4.4	5.2	3.2	3.8	4.9
Sodium (dissolved)	a	1.8	2.2	2.7	2.0	2.3	3.0	2.0	2.2	2.3	1.2	2.0	2.4
Sulfate (dissolved)	a	8.3	12.8	16.0	9.0	13.0	17.0	10.0	11.8	13.0	8.9	11.8	16.7
Barium (total)	b	30	37	40	0	125	200	--	--	--	--	--	--
Nitrate (total)	a	0.00	0.08	0.12	0.12	0.13	0.14	0.01	0.07	0.15	0.01	0.14	0.29
Specific Conductance	c	109	135	156	109	135	156	120	134	150	122	139	169
Alkalinity	a	43	54	62	47	56	65	45	54	60	53	58	63
Chloride (dissolved)	a	0.9	1.3	2.1	0.7	1.2	2.5	1.1	1.8	2.5	1.0	1.1	1.8
Bicarbonate	a	--	--	--	--	62	--	--	--	--	--	--	--
Dissolved Solids	a	67	75	90	--	--	--	67	77	86	54	90	119

NOTES: a. Units are mg/l.
b. Units are ug/l.
c. Units are micromhos.
Outliers excluded from analysis.

Sources: (1) Unpublished chemical analyses made by Battelle Memorial Institute, Pacific Northwest Laboratories on behalf of the Washington Public Power Supply System.

TABLE 5.20. Seasonal Changes in the Concentration of Particulate Matter ($<53\mu$) in River Water (Wildung et al. 1972)

<u>Time of Sampling</u>	<u>Concentration^(a) of Suspended Particulate Matter</u>
	$\mu\text{g/l}$
November	310
February	2002
April	34680
June	5788
August	3726

(a) Based on oven dry (60C) weight.

TABLE 5.21. Seasonal Changes in the Size Distribution of Particulate Matter Isolated From River Water (Wildung et al. 1972)

<u>Equivalent Spherical Diameter</u>	<u>Particle Size Distribution^(a)</u>				
	<u>November</u>	<u>February</u>	<u>April</u>	<u>June</u>	<u>August</u>
μ	$\%$				
53 to 2.0	70	85	37	78	86
2.0 to 0.5	14	8	39	16	7
0.5 to 0.2	9	5	16	4	5
<0.2	7	2	8	2	2

(a) Based on oven dry (60C) weight and expressed as a percentage of total recovered particulate matter ($<53\mu$).

TABLE 5.22. Seasonal Changes in the Carbon Content of Particulate Matter (<53 μ) Isolated From River Water (Wildung et al. 1972)

<u>Time of Sampling</u>	<u>Contents^(a)</u>		
	<u>C</u>		
	<u>Ash</u>	<u>Total Sample</u>	<u>Ash-Free Sample</u>
	----- % -----		
November	65.7	14.4	42.0
February	80.4	7.8	39.7
April	92.1	1.5	19.4
June	86.8	2.8	20.8
August	75.0	7.7	30.9

(a) Based on oven dry (60C) weight.

Maximum heating of the free-flowing Hanford Reach of the Columbia during August and September is about 0.5 to 0.75°C (0.9 to 1.35°F), due primarily to insolation.

5.1.4 Effluents Discharged to the Hanford Reach of the Columbia River

Fifteen liquid effluent lines from Hanford facilities discharge their contents directly to the Columbia River. Pertinent data on quantities and constituents for each discharge are given in Table 5.26, and a summary of annual amounts of the principal chemical discharges is given in Table 5.27 (WPPSS 1978).

At present, the only thermal discharges of sufficient magnitude to affect Columbia River temperatures occur either from the 100-N Reactor or from the associated WPPSS Hanford Generating Project (HGP) when the 100-N Reactor is operating (WPPSS 1978).

The largest heated effluent arising from this operation is the cooling water from the HGP (RM 380), which has a thermal capacity of 3780 MW (megawatts) and an electrical capacity of 860 MW. The cooling water flow rate is 940 to 1260 cfs depending on incoming river temperature, and is discharged at

TABLE 5.23. Relative Abundance of Minerals in Size Fractions of Suspended Particulate Matter Isolated From River Water (Wildung et al. 1972)

Equivalent Spherical Diameter (Microns)	Relative Abundance ^(b) of					
	Quartz	Feldspar	Amphibole	Mica-illite	Chlorite	Montmorillonite
53 to 2.0	2	3	3	3	3	1
2.0 to 0.5	2	3	3	3	3	1
0.5 to 0.2	2	1	3	2	2	2
0.2	1	2	3	2	2	2

(a) April

(b) Relative mineral abundance designated as: 1) trace (2-10%); 2) intermediate (5-25%); 3) abundant (>25%)

TABLE 5.24. Monthly Average Water Temperature in °C, at Vernita Bridge, WA^(a)
(USGS Station No. 12472900)(b) (PSP&L 1982)

Year	Month												Annual Average	Standard Deviation
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec		
1961(c)	5.4	4.7	4.7	7.4	10.4	13.7	17.3	18.9	17.8	14.9	10.4	6.6	11.0	5.3
1962(c)	4.1	3.6	3.6	6.5	10.0	13.7	16.1	17.4	17.1	14.8	11.9	8.9	10.6	5.3
1963(c)	5.3	3.8	4.6	6.5	10.4	14.0	16.6	18.4	18.3	16.3	11.9	7.7	11.2	5.5
1964(c)	5.5	4.6	4.7	7.2	9.7	12.8	15.3	17.1	16.3	14.6	10.8	6.3	10.4	4.7
1965(c)	4.4	3.3	4.1	6.6	10.0	13.3	16.1	18.4	17.3	15.3	11.9	7.8	10.7	5.4
1966(c)	4.8	4.1	4.5	7.8	10.6	12.4	15.3	17.5	17.5	14.6	11.6	8.4	10.8	4.9
1967(c)	5.9	5.7	5.0	6.8	10.1	13.3	16.1	18.5	18.2	15.4	11.3	7.2	11.1	5.1
1968(c)	4.6	3.3	4.6	7.1	11.1	13.4	16.1	17.5	17.2	14.2	10.9	6.8	10.6	5.2
1969(c)	2.4	1.5	3.4	7.2	10.8	14.6	17.1	18.2	17.7	14.8	11.5	7.6	10.6	6.1
1970(c)	4.3	4.1	4.8	6.8	10.9	14.8	18.0	19.2	17.5	15.2	10.6	6.2	11.0	5.7
1971(c)	4.0	3.5	3.6	6.6	10.7	12.6	15.3	18.4	17.2	15.2	11.3	6.8	10.4	5.4
1972(c)	3.6	1.9	4.0	7.2	10.6	12.9	15.2	17.3	16.8	15.4	11.3	7.3	10.3	5.4
1973(c)	2.3	2.9	4.8	7.7	12.5	15.4	17.6	18.8	17.8	15.2	10.3	7.7	11.1	6.0
1974(c)	4.0	3.0	4.9	7.7	10.8	13.6	17.2	18.7	18.4	15.5	11.8	8.6	11.2	5.6
1975(d)	4.4	2.3	3.3	5.9	9.8	13.7	17.2	18.0	18.6	15.7	11.6	6.7	10.6	6.0
1976(d)	3.6	3.0	3.9	6.6	10.3	12.9	15.7	17.9	17.3	14.8	11.4	7.2	10.4	5.4
1977(d)	3.9	3.4	4.3	7.8	10.7	14.8	16.5	19.2	17.8	15.3	10.6	6.8	10.9	5.7
1978(d)	3.9	2.4	4.0	6.6	10.4	--	17.1	18.7	18.0	15.5	10.0	--	--	--
1979(d)	--	0.9	3.0	6.3	10.7	14.5	17.5	19.4	19.4	17.1	12.7	7.8	--	--
1980(e)	3.8	2.0	3.9	7.1	10.9	13.8	16.9	18.3	18.0	15.7	12.4	8.2	10.9	5.8
Averages 1961-1980	4.2	3.2	4.2	7.0	10.6	13.7	16.5	18.3	17.7	15.3	11.3	7.4	10.8	--
Std. Dev.	0.9	1.1	0.6	0.5	0.6	0.8	0.8	0.7	0.7	0.6	0.7	0.8	--	--
Minimum Daily(c-f)	0.5	0.0	1.5	4.0	7.5	10.6	13.1	16.5	15.3	12.2	7.7	2.3	--	--
Maximum Daily(c-f)	7.6	6.2	6.9	10.1	14.6	17.1	19.5	20.5	20.0	18.7	14.4	10.9	--	--

(a) Recorded values adjusted by computer-simulation to compensate for measurement errors and missing data (1961-1974).

(b) Pilot to October 1971 published as 12472800 "at Vernita Ferry".

TABLE 5.25. Monthly Average Water Temperature in °C, at Richland, WA^(a)
(USGS Station No. 1247352) (PSP&L 1982)

Year	Month												Annual Average	Standard Deviation
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec		
1965(b)	6.1	5.4	6.3	9.1	11.0	14.2	17.3	19.8	18.5	16.4	12.6	8.4	12.1	5.1
1966(b)	5.9	6.2	6.8	10.3	12.1	13.5	16.2	18.8	19.4	15.6	12.6	9.5	12.2	4.7
1967(b)	7.4	7.0	6.6	8.8	12.0	13.9	17.0	20.2	19.4	16.1	12.0	7.8	12.4	4.9
1968(b)	5.7	5.0	6.0	8.8	12.8	14.3	17.0	18.7	18.3	15.0	11.4	7.4	11.7	5.0
1969(b)	2.7	1.9	4.3	8.0	11.4	15.3	17.9	19.3	18.6	15.2	11.7	7.0	11.1	6.3
1970(b)	5.3	4.9	5.7	7.9	11.7	15.4	19.0	19.9	17.5	14.9	10.6	5.9	11.6	5.6
1971(b)	4.2	3.4	3.8	7.0	11.1	12.9	16.4	19.5	17.8	15.0	10.7	6.2	10.7	5.7
1972(b)	3.3	2.2	3.7	7.0	11.0	13.3	15.5	18.1	16.9	14.0	10.5	6.1	10.1	5.6
1973(b)	3.2	3.0	4.7	7.8	12.9	15.6	18.3	19.6	18.3	15.0	9.9	7.6	11.3	6.1
1974(b)	3.2	3.2	5.2	8.2	11.3	13.7	17.4	19.4	18.8	15.4	11.5	7.9	11.3	5.8
1975(c)	4.6	2.8	3.9	6.9	10.7	14.3	18.3	18.8	18.8	15.3	10.6	6.9	11.0	6.0
1976(c)	4.0	3.4	4.5	7.2	10.9	13.5	16.3	18.3	17.5	14.7	11.0	6.8	10.7	5.4
1977(c)	3.7	3.4	4.9	8.9	11.6	15.8	17.5	19.8	17.8	15.4	10.4	6.6	11.3	5.9
1978(c)	4.2	2.8	4.7	7.3	11.0	14.7	17.5	19.3	18.1	15.4	9.6	5.6	10.9	6.0
1979(c)	1.5	2.0	4.1	6.5	11.4	15.3	18.4	19.9	19.6	16.9	--	7.0	--	--
1980(d)	3.5	2.4	4.4	8.3	11.6	14.1	17.4	18.6	17.4	15.5	9.3	7.8	10.6	5.6
Averages 1965-1980	4.3	3.7	4.5	8.0	11.5	14.4	17.3	19.3	18.3	15.4	11.0	7.2	11.3	--
Std. Dev.	1.5	1.5	1.0	1.0	0.6	0.9	0.9	0.6	0.8	0.7	1.0	1.0	--	--
Minimum Daily(b-e)	0.2	0.5	2.4	4.0	8.0	11.0	14.0	17.0	14.6	11.1	7.0	2.4	--	--
Maximum Daily(b-e)	8.3	8.3	8.6	12.8	15.0	17.7	21.0	21.5	21.1	18.5	15.9	11.3	--	--

(a) Recorded values adjusted by computer-simulation to compensate for measurement errors and missing data (1961-1974).

TABLE 5.26. Discharge Lines to Columbia River From Hanford Reservation

Area	Discharge Lines	Discharge Rates, cfs	or	Quantities
100-B/C	12-in. steel pipe			6,000 gallons
100-B/C	42-in. steel pipe	2.2		
100-Ke and KW		1.1		500 gallons 3 times a year
100-Ke and KW	Two 84-in. steel pipes	1.1		
100-N				75,000 gallons 3 times a day
100-N	3- by 4-ft concrete chute	1.1		
100-N	42-in. steel pipe	0.01		
100-N	66-in. pipe to 12-ft concrete flume on riverbank	140		
100-N	102-in. steel pipe	300 (extremes 140 and 410 cfs)		
WPPSS (HGP)	132-in. steel pipe	940 (river greater than 25°C) 1260 (river less than 25°C)		
100-D/DR	12-in. steel pipe			6,000 gallons once a month
100-D/DR	Two 42-in. steel pipes	4.4 (2.2 to 22)		
300	24-in. concrete pipe terminating as a 30-in. half-round corrugated metal pipe	2.2 (average)		6 to 12/day batches of 12,000 gallons
300	36-in. steel pipe	0.01		
300	12-in. steel pipe	1.1 (0.04 to 2.3)		
100-B/C WPPSS (HGP)	24-in. concrete pipe terminating as a 30-in.	940 (river greater than 25°C)		11,111 gallons

TABLE 5.26. (contd)

Area	Use	Temperature	Other Potential Water Quality Effects
100-B/C	Backflush pump inlet screens	Ambient	None - untreated raw river water
100-B/C	Drains and filter backwash	2.8°C, above ambient	Total Solids, Turbidity, Aluminum, Sulfate Chloride
100-Ke and KM	Backflush pump inlet screens	Ambient	None-untreated river water
100-Ke and KM	Drains, overflow and cooling water for compressors and pumps	2.8°C above ambient	Total Solids, Turbidity, Aluminum, Sulfate, Chloride, Chlorine (0.25 mg/l)
100-N	Backflush pump inlet screens	Ambient	None- untreated river water
100-N	Overflow from filtered water and raw water storage tanks, condensate from medium pressure steam system, filter backwash	11 to 20°C above ambient	Total Solids, Ammonia (as well as radioactive waste) Chlorine (0.05 mg/l) Turbidity
100-N	Filtered water overflow, and waste from floor drains	6 to 8°C above ambient	Sulfate, Chloride, Chlorine (0.05 mg/l)
100-N	Turbine condenser cooling water and graphite heat exchanger cooling water	16°C above	Aluminum, Turbidity
100-N	Steam condenser cooling water	5.5°C above ambient	Turbidity, Ammonia, Sulfate, Iron, Sodium, (occasionally 0.3 mg/l) orthophosphate), Chlorine - 2 to 40 ppb.
WPPSS (NGP)	Steam condenser cooling water	15 to 20°C above ambient	(Same as above)
100-D/DR	Backflush pump inlet screens once a month	Ambient	None - untreated river water
100-D/DR	Filter backwash and process coolant and wash water, hydraulic test loop water	2.8°C above ambient	Total Solids, Turbidity, Aluminum Sulfate, Chloride, Chlorine (0.74 mg/l) (maximum 2.2 mg/l)
300	Filter backwash (from water treatment plant)	Ambient	Total Solids, Turbidity, Aluminum, Sulfate, "Separon" (a proprietary polyacrylamide filter aid) Chlorine (0.5 mg/l)
300	Air conditioner cooling water and floor drains	25°C above	Aluminum, Sulfate, Chlorine (0.5 mg/l)
300	Drainage from roof and parking lot, tanks for aquatic organisms	2 to 3°C above ambient	Total Solids, Turbidity, Organic Nitrogen

Source: WPPSS, 1978

15 to 20°C (59 to 68°F) above ambient river temperature (Table 5.26). The calculated temperature increment for complete mixing (about 2.5 miles downstream) at the minimum river flow rate of 36,000 cfs would be 0.6°C (1.0°F) (WPPSS 1978).

During operation, the N Reactor, immediately downstream from HGP, discharges a cooling water stream of about 140 cfs, with a temperature up to 16°C (28.8°F) above ambient river temperature, to the river. This discharge increases the river temperature by only 0.06°C (0.11°F) at the minimum river flow rate of 36,000 cfs and 0.02°C (0.04°F) at the approximate average river flow rate of 120,000 cfs (WPPSS 1978).

Chemicals are released to the Columbia River at three locations: 1) the 100-N Area, 2) the 100-K Area, and 3) the 300 Area. The primary source of chemicals released to the river, as shown in Table 5.27, is the 100-N Reactor operation. In addition to these chemicals, impurities removed from the river water by the treatment plants also are returned to the river. The intermittent filter backwash contains suspended solids, principally an aluminum hydroxide floc, plus an accumulation of suspended solids removed from the raw river water during the filtration process. Several of the smaller effluent streams, consisting largely of treated water, may contain free chlorine at concentrations up to a maximum of 1 mg/l. Other chemical concentrations in treated water are mostly the result of use of alum (aluminum sulfate) and small quantities of polyacrylamide filter aids in the water filtration plant (WPPSS 1978).

A summary of the 1980 NPDES monitoring report data for the 100-N and 100-K area discharges is presented in Table 5.28 (Greger 1981). Chemical parameters of the low-volume waste sampled from March 1980 through February 1981 at the WPPSS Hanford Generating Project are presented in Table 5.29 (WPPSS 1981b).

The production reactors that were cooled directly with river water have been shut down. Nevertheless, the Hanford Reservation still has several sources of low-level radioactive effluents. These include cooling water at 100-N, animal farm waste at 100-F and 300 Areas, and tritium migrating to the river with groundwater from the 200 Area disposal sites (WPPSS 1978).

TABLE 5.27. Total Annual Direct Chemical Discharge From
Hanford Reservation to Columbia River

<u>Materials</u>	<u>Existing Quantity from 100 and 300 Areas (tons)</u>
Aluminum Sulfate	260
Chlorine	20
Polyacrylamide	0.8
Salt (rock)	22
Sodium Dichromate	2
Sulfuric Acid	650
Ammonium Hydroxide	60
Hydrazine	8
Morpholine	1.5
Sodium Hydroxide	230

Source: WPPSS (1978)

TABLE 5.28. Summary of NPDES Monitoring Report Data for 100-N and 100-K Areas
(CY 1980)

Sample Parameter		NPDES Discharges					
		003	004	005	006	007	009
Flow (MGD)	Max.	0.06	2.9	1.9	0.38	2.6	473
	Avg.	0.03	1.7	1.1	0.23	0.40	340
	Total/yr.	1.1	630	410	85	150	1.5E5
Temp. (°F)	Max.	--	74	136	64	--	70
	Avg.	--	60	63	53	--	56
pH	Max.	--	8.2	8.9	8.4	--	8.9
	Min.	--	7.5	7.4	7.5	--	8.0
Total Suspended Solids ^a (mg/l)	Max.	7.7	9.8	57.1	19.6	15.7	--
	Avg.	4.4	3.6	3.0	3.4	5.9	--
Oil and Grease (mg/l)	Max.	--	--	4.2	3.7	--	--
	Avg.	--	--	1.6	1.4	--	--

(a) The analytical results for Total Suspended Solids are biased high, especially for Discharge 005, due to the ash fallout from Mt. St. Helens during 1980.

Source: Greger (1981)

TABLE 5.29. Low-Volume Waste Sampled at the Hanford
Generating Project (March 1980-February 1981)

<u>Sample Parameters</u>		<u>Max.</u>	<u>Avg.</u>	<u>Min.</u>
pH	--	--	--	--
	--	8.7	--	6.2
Suspended Solids	#/day	4.46	0.43	--
	mg/l	3.1	0.93	0.5
Oil and Grease	#/day	1.01	0.31	--
	mg/l	1.8	0.59	0.5
Total Iron	#/day	0.2	0.041	--
	mg/l	0.25	0.082	0.05
Total Copper	#/day	0.1	0.029	--
	mg/l	0.2	0.058	0.01

Source: WPPSS (1981b)

5.2 GROUNDWATER

The Pasco Basin is the appropriate hydrologic boundary to use in assessing the groundwater impact of this project (Figure 5.12). A detailed description of the geohydrologic units that underlie the Hanford Site is found in Gephart (1979). Table 5.30, reproduced from that document, shows the generalized lithologic and hydrologic characteristics of the units. Figure 5.13 is a map showing the locations of the wells on the Hanford Site used to develop this description.

The geological formations at the Skagit/Hanford and Firehouse sites have been divided into seven geohydrologic units according to hydrologic character and properties (Figure 5.14). The vadose zone or unsaturated zone, the unconfined glaciofluvial aquifer, and the upper confining layer are the only geohydrologic units on which the potential NPR facilities could have an impact.

FIGURE 5.12. Pasco Basin Location Map

5.2.1 Unsaturated Zone

The unsaturated (vadose) zone lies between the ground surface and the water table. Characteristically, this zone contains liquid water under less than atmospheric pressure, and water vapor and air or other gases usually at atmospheric pressure. In parts of this zone, interstices may be temporarily filled with water. The springs that issue from the flanks of the Rattlesnake Hills are also classified as belonging to the vadose zone. A more detailed

TABLE 5.30. Major Geologic Units in the Hanford Region and Their Hydrologic Character(a)

Stratigraphic	Bed or Flow Unit	General Lithologic Character	Average Thickness in Feet	Hydrologic Character	Aquifer
Alluvium, Colluvium, and Eolian Sediments		Sands, silts, and clays modified by wind erosion	Dunes to 50	Occur everywhere above the water table.	Dry
Glaciofluvial Sands and Gravels (Hanford Formation)	Touchet Silts	Fine-grained facies of the glacio-fluvial deposits. Bedded in quiet water.		Occur above the water table except between the high terrace plateaus and the Columbia River. Has very high transmissivity and storage.	Occasionally an Unconfined Aquifer or Dry
	Pasco Gravels	Predominantly coarse-grained gravels. Cobbles and sands with cut and fill.	0-400		
	Palouse Soil	Calcareous sand and silt eolian deposit mainly derived from Ringold formation	0-80	Above water table when present.	Dry
Ringold Formation	Upper Ringold	Locally capped by caliche. Mostly Well-bedded fluvial silts and sands with some gravels.		Sand and gravel beds have very high hydraulic conductivity and storage. Some beds of silty clay or clay are essentially impermeable.	Unconfined Aquifer
	Middle Ringold	Sands and gravels well-sorted, compact, but variably cemented.	0-400		
	Lower Ringold	Silts and clays with interbedded gravels and sands. Clay is characteristically blue, but may be green, brown, or tan.	0-400		Aquiclude
Columbia River	Saddle Mountains	Basalt flows with interflow zones. Several sedimentary interbeds of Ellensburg formation are present.	900	Flows are dense with low-hydraulic conductivity. Interflows and interbeds have higher hydraulic conductivity and transmissivity.	Confined Aquifers
	Wanapum	Basalt flows with interflow zones. Few interbeds of Ellensburg formation are present.	1,000		
	Grande Ronde	Basalt flows with interflow zones. Interbeds of Ellensburg formation are infrequently and very thin when present.	3,000		

(a) Gephart et al. (1979)

GEOLOGIC UNITS		GENERALIZED LITHOLOGY	DEPTH (feet)	GEO-HYDROLOGIC UNITS
MISSOULA		WELL SORTED SAND	0	UNSATURATED ZONE
PRE-MISSOULA			100	
		POORLY SORTED SAND AND GRAVEL	Water Table	GLACIO-FLUVIAL AQUIFER
RINGOLD FORMATION	UNIT IV	INTERBEDDED SILT AND GRAVEL	200	UPPER CONFINING LAYER
		POORLY BEDDED SAND AND GRAVEL	300	UPPER CONFINED AQUIFER
	UNIT III		400	
	UNIT II	SILT AND CLAY	500	LOWER CONFINING LAYER
		SAND AND GRAVEL		
	UNIT I	SILT AND CLAY	600	LOWER CONFINED AQUIFER
		SAND AND GRAVEL	700	
SADDLE MOUNTAIN BASALT		BASALT		

FIGURE 5.14. Generalized Geologic and Geohydrologic Column (PSP&L 1981)

discussion of the vadose zone based on work done at the reference site is contained in Appendix D of this report.

Within the Hanford Site, the unsaturated zone ranges in thickness from less than 1 m near the Columbia River to over 115 m (1 to 350 ft) beneath the 200 Area plateau and is bounded by the land surface and the water table. The thickest unsaturated zone located in the eastern portion of the Pasco Basin has been encountered during the drilling of a well in the NW1/4, SW1/4, Section 27, T11N, R29E where the water table was reached at a depth of 150 m (456 ft) below the surface. The unsaturated zone is composed of sediments of the Hanford and/or Ringold Formations, depending on the position of the water table in a given area at a given time.

5.2.2 Unconfined Aquifer

The unconfined aquifer consists of the Hanford and Ringold Formations, except along the Columbia River where Holocene alluvium is thick enough to extend below the water table. Table 5.30 shows the representative hydraulic properties of the unconfined aquifer. Large differences in hydraulic conductivity appear between the Hanford Formation and the middle Ringold unit. The two major geologic units of the unconfined aquifer. The Hanford Formation normally exhibits a hydraulic conductivity between 330 and 3300 m/day (1000 and 10,000 ft/day); whereas the middle Ringold averages 43 m/day (130 ft/day). Field measured hydraulic conductivity values were determined from pump tests on wells in the vicinity of the reference site and are shown in Table 5.31. The great range of conductivities reported in the Ringold Formation may be due in part to the reworking of older Ringold sediments by streams of Hanford or glaciofluvial age which removed finer grained sediments and cementation, thereby increasing the overall hydraulic conductivity of the formation. This situation may exist at Wells 699-31-31 and 699-24-33 (Figure 5.13) where hydraulic conductivities are in excess of 2300 m/day (7000 ft/day). These permeable channels are reflected in the groundwater flow pattern of the region.

There are limited data available on storage coefficients and specific yields at the Hanford Site. Those presented in Table 5.32 are extracted from reports and are estimates for the unconfined aquifer. Newcomb et al. (1972) provide an areal estimate of 0.11 for the storage coefficient in the 200 West

TABLE 5.31. Results of Pumping Tests Completed Within the Unconfined Aquifer

Source of Data (a)	Hanford Test Site Coordinates (b)	Test Interval (c)	Hydraulic Conductivity (ft/day)	Transmissivity (ft ² /day)	Remarks
2	699-8-17	MR	640	35,000	8-hour test
1	699-17-5	MR	17	750	8-hour test
3	699-20-20	MR	150	30,000	No drawdown data 3-hour recovery
2	699-20-34	LR		8	Short duration, poor well construction
1	699-24-33	MR-H	8,600	373,000	Data as reported
2	699-26-15	MR	200	9,500	6-hour test
3	699-15-26 ^(d)	MR	320	7,100	8-hour test

(a) Sources of Data:

- 1) Bierschenk (1959);
- 2) Deju (1974); and
- 3) Kipp and Mudd (1973).

(b) Refer to McGhan and Damschen (1979) for explanation of Hanford Site Coordinate.

(c) Tested Interval:

- H - Hanford Formation
- MR - Middle member of Ringold Formation
- LR - Lower member of Ringold Formation

(d) Former designation 699-14-27.

TABLE 5.32. Representative Hydraulic Properties of the Unconfined Aquifer(a)

<u>Stratigraphic Interval</u>	<u>Hydraulic Conductivity (feet per day)</u>	
Hanford Formation	500	- 20,000
Undifferentiated Hanford and Middle Ringold Unit	100	- 7,000
Middle Ringold Unit	20	- 600
Lower Ringold Unit	0.11	- 10

<u>Region</u>	<u>Transmissivity (square feet per day)</u>
North of Gable Butte and Gable Mountain	4,000 - 25,000
On the Flank of Gable Butte and Gable Mountain and Along Paleochannels	40,000 - 600,000
Other Areas on the Hanford Site	2,000 - 40,000

<u>Storage Coefficients</u>	
Throughout the Unconfined Aquifer	0.01 - 0.1

(a) Gephart et al. (1979).

area. This estimate is based on the growth of the groundwater mounds between 1948 and 1953 and the water disposal rate during this period. The range of values estimated for the Hanford unconfined aquifer was 0.006 to 0.35, but the general quality of measurement was poor.

The base of the aquifer is defined by either the silt and clay sediment of the lower Ringold unit or the basalt surface. The thickness of the aquifer ranges from zero to 100 m (0 to 300 ft). Where the Hanford Formation extends below the water table, it is generally composed of coarse sand, gravel, and cobbles with occasional finer grained sediments. The Ringold Formation is divided into an upper, middle and lower unit, each having different textures as previously noted in Table 5.30. The unconfined aquifer is dominated by the middle Ringold, composed of sorted sands and gravels with a wide range of cementation. The degree of cementing controls the hydraulic properties of this unit; i.e., the less the unit is cemented, the higher its hydraulic conductivity.

The lateral boundaries of the unconfined aquifer are identified by the anticlinal basalt structures which rim the Pasco Basin. These include the Saddle Mountains to the north, Umtanum and Yakima Ridges on the west, Rattlesnake and Horse Heaven Hills on the south, and on the east by a broad monocline. The water table lies within the basalt in areas where the unconfined aquifer thins over bedrock; the most notable of these sites being Gable Mountain and Gable Butte located just south of the alternate site.

5.2.2.1 Water Level Changes

The groundwater tables for 1944 and 1980 for the Hanford Site reflect the direction of groundwater flow and the effects of natural and artificial recharge and withdrawal. The water level elevations in the glaciofluvial aquifer at the reference site range from 121.63 m (400.09 ft) msl at the northeastern edge of the site to 121.11 m (399.39 ft) msl at the southern edge. The water table at the reference site in 1944 had a measured elevation of 115.5 m (385 ft) msl, which is 6 m (20 ft) below the present water table, indicating the impact of artificial recharge on and near the Hanford Site.

Artificial recharge and groundwater withdrawal, that would affect the reference site, occur within the glaciofluvial aquifer from waste injection

operations in the 200 East and 200 West Areas of the Hanford Site, from irrigation in the Cold Creek Valley, and from withdrawal of water at Hanford Site facilities. The historical sequence of water table maps representing the years 1980, 1978, 1973, 1968, and 1944 (Figures 5.15 through 5.19) illustrates the water table changes which have occurred since Hanford began operations in 1944. Comparison of the 1944 water table map (Figure 5.19) with the 1973 map (Figure 5.17) shows a 10 m (30 ft) increase in water table elevation beneath B pond. Following 1973, the water table elevation gradually declines (compare Figures 5.17 and 5.15) due to the closing of the PUREX plant. Restarting of PUREX in late 1983 is expected to cause water levels to rise again in response to increased discharges of water.

Another groundwater mound is centered below the U Pond where water levels have risen approximately 28 m (85 ft) over the past 35 years. Decreased disposal to this facility following 1972 has not reduced groundwater elevations significantly (Figure 5.15). This may be due in part to increased irrigation in the Cold Creek Valley west of the Hanford Site boundary which recharges into this area. The combined effects have resulted in a regional increase in groundwater gradient from 0.75 to 0.95 m/km (4 to 5 ft/mi) in 1944 to 1.32 to 1.52 m/km (7 to 8 ft/mi) in 1980.

5.2.3 Confined Aquifers

The confined aquifers underlying the Hanford Site have been combined into one of three major groups according to the basalt flows in which they lie: Saddle Mountains; Wanapum; or Grand Ronde basalts. The aquifers lying within each basalt sequence tend to have similar hydrologic properties, with groundwater flow occurring primarily horizontally in the interbeds between the individual flows and vertically where fractures or other structures are present. Although understanding the confined aquifer system is essential to understanding the regional hydrology, these aquifers play a minor role in the siting of the proposed facility. Because of this, comments on the confined system are restricted to the uppermost sequence of confined aquifers, those of the Saddle Mountains basalt.

FIGURE 5.15. Water Table Map for the Hanford Reservation for 1980

FIGURE 5.16. Water Table Map for the Hanford Reservation for 1978

FIGURE 5.17. Water Table Map for the Hanford Reservation for 1973

FIGURE 5.18. Water Table Map for the Hanford Reservation for 1968

FIGURE 5.19. Water Table Map for the Hanford Reservation for 1944

Groundwater in the Saddle Mountains confined aquifers occurs principally in the interbeds and interflows separating individual basalt flows. Flow rates are relatively small; hydraulic conductivities range between 0.3 and 33 m/day (1 and 100 ft/day) (Gephart et al. 1979). The groundwater flow in these aquifers is generally to the southeast across the Pasco Basin with discharge to the Columbia River. Figure 5.20 is a potentiometric map for the uppermost confined aquifer based on data through 1970. This map depicts the general groundwater flow and also shows that, in places, the hydraulic potential in the confined aquifer is greater than in the overlying unconfined aquifer (compare Figures 5.15 and 5.20). The main exception to this is in the vicinity of the 200 Area groundwater mounds discussed earlier.

5.2.4 Alternate Site

Groundwater beneath the alternate site flows through sands and gravels of the Hanford and Ringold Formations. Flow direction is predominantly to the north and east toward the Columbia River. Composition of these hydrogeologic units is similar at this site to the reference location.

Depth to groundwater is about 38 m (125 ft) below land surface. There are no significant recharge sources in the vicinity of the alternate site. Near the Columbia River, local mounding to the water table occurs in response to waste water discharges at 100 N Area.

Yield characteristics of wells near the alternate site show a wide range of capacity. Glaciofluvial channels near the north side of Gable Mountain yield large quantities of water to wells. Monitoring wells drilled to the west of the alternate site yield limited amounts of water (<10 gpm).

5.2.5 Groundwater Usage

Minor amounts of groundwater are being produced from wells at the Fast Flux Test Facility (FFTF) and at WNP-1, -2, -4. These are the major production wells at the Hanford Site. The WNP facilities have a reported groundwater usage of 946 m^3 (9,250,000 gal) per month or 22.7 μpm (6 gpm) (WPPSS 1981), most of which comes from aquifer interbeds in the basalts. These amounts of water withdrawal will have little or no impact on the reference and alternate sites.

FIGURE 5.20. Uppermost Confined Aquifer Potential Map

5.2.6 Groundwater Quality

The chemical quality of the groundwater in the unconfined aquifer has been determined at numerous locations from 1975 to the present. Complete inorganic chemical analyses, including trace elements, are available for 79 wells.

Nitrate ion, which is a waste product from the manufacturing and chemical separation operations, is monitored over the entire Hanford Site (Eddy et al. 1983). Maps of the nitrate ion concentration near the surface of the unconfined aquifer are published each year. Nitrate concentrations under the proposed site currently range from less than 10.0 mg/l to as great as 25 mg/l depending upon location (Figure 5.21).

The radiological status of the groundwater near the surface of the unconfined aquifer is monitored regularly and reported annually (Eddy et al. 1983). A plot of the tritium plume is shown in Figure 5.22. Because ruthenium (^{106}Ru), tritium (^3H), and nitrate (NO_3), are not readily adsorbed on the soil, they are used to trace groundwater movement. Tritium concentrations at the primary site are less than 60 pCi/ml. At the alternate site, tritium concentrations are less than 30 pCi/ml. The gross beta plume does not extend under either the reference or alternate sites.

5.3 REFERENCES

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FIGURE 5.21. Nitrate Ion Distribution in Unconfined Ground Water

FIGURE 5.22. Tritium Distribution in Unconfined Ground Water

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6.0 GEOLOGY

This chapter briefly describes the geologic setting and character of the region and area containing the two proposed NPR sites. The regional setting, site topographic expression, structure, stratigraphy, and seismicity are characterized.

The general discussions given apply to both sites, unless noted otherwise, because of their proximity on the Hanford Site. The few local and site-specific differences are described in more detail in the references at the end of the chapter.

Geologic studies of the Pasco Basin are being carried out continually under the Basalt Waste Isolation Project (BWIP). These studies are refining conceptual models of the local geology and seismology. However, much of the information is yet unpublished and therefore not referenceable. In the future, this material will be incorporated into the existing data base as it becomes available.

6.1 REGIONAL SETTING

The geologic region containing the reference and alternate sites covers a portion of the Pacific Northwest that includes Washington, Oregon, and adjoining areas of Idaho and British Columbia. The physiographic pattern of the study region, a part of the North American Cordilleran system, is a complex arrangement of mountain ranges, plateaus, and basins (Figure 6.1). These features are the result of extensive Cenozoic (the past 65 million years) volcanic activity and the accumulation of thick sedimentary deposits in the structurally negative areas.

The reference and alternate sites are centrally located in the Pasco Basin, which is near the center of the Columbia Plateau. To the east and north, the plateau is bounded by old, PreCambrian (ended about 570 million years before present (mybp)) and Paleozoic (about 225 to 570 mybp) rocks. To the west and south, almost all deposits are Cenozoic (from 0.01 to 65 mybp). The Columbia Plateau was formed during Miocene time (5 to 23 mybp) when vast outpourings of basalt lava blanketed central Washington (U.S. NRC 1982).

FIGURE 6.1. Principal Physiographic Elements of the Pacific Northwest (Blume and Associates 1970)

Bounding the Columbia Plateau on the west are the Cascade Mountains, the dominant physiographic feature in the region. Topography in the plateau country east of the Cascade Mountains is relatively subdued compared with surrounding mountainous regions. The major topographic features of the plateau are generally east-west trending folds, anticlinal ridges and monoclines, and

intervening basins. These structures are transected by rivers that locally have cut deep gorges into the layered basalt sequence.

6.2 SITE TOPOGRAPHY

The topography of the reference and alternate sites has been created by the geologic structures within the study region and the erosion of surficial geologic materials. The Pasco Basin is a gently undulating plain mantled with Pleistocene glaciofluvial flood deposits and Holocene eolian deposits. This low-relief plain is bounded on three sides by the pronounced topographic/structural ridges of the Saddle Mountains to the north, Umtanum and Yakima Ridges to the west, and the Rattlesnake and Horse Heaven Hills to the south. The eastern topographic boundary of the basin is indistinct, with major relief being sand dunes and coulees.

The Skagit/Hanford Site has an average elevation of 158 m (520 ft) above mean sea level (msl), and is situated in a slight depression with a local topographic relief of about 6 m (20 ft). The local topography is further characterized by active sand dunes: a small dune several hundred meters northwest of the site and a larger, east-northeast trending dune east of the site. The dunes are migrating north-eastward, away from the site, and are not expected to change site topography (U.S. NRC 1982).

6.3 STRUCTURE

Geologic structures in the region of the Skagit/Hanford Site have been produced by tectonic deformation of the original near-horizontal basalt flows. Deformation began in the upper Miocene prior to cessation of the basaltic lava outpourings. The downwarping of the Pasco Basin and the formation of prominent folds, anticlines, and monoclines was well developed in late Miocene time (10.5 mybp). The basin was filled by Ringold sediments and later by Pliocene-Pleistocene gravels of the Hanford Formation.

The basin is bounded by prominent ridges: the Saddle Mountains to the north, Umtanum and Yakima Ridges to the west, and Rattlesnake Hills and Horse Heaven Hills to the south. To the east, the buried basalt surface slopes gradually upward, forming a gradational boundary. Gable Mountain and Gable

Butte are asymmetrical anticlines of basalt protruding through the surficial materials. The Umtanum and Yakima Ridges plunge beneath the Quaternary-Tertiary sediments of the basin and die out beneath it. Evidence exists that Gable Mountain and Gable Butte are structural extensions of Umtanum Ridge. The Firehouse Site lies within the same regional geologic framework as the Skagit/Hanford Site, but to the north of the Umtanum Ridge/Gable Mountain anticline.

Faults associated with the Gable Mountain anticline include the South and Central faults. Movement has been inferred to have occurred on the south fault in late Pleistocene time on the basis of deformation observed in clastic dikes present along the fault. The Central fault has displaced overlying Missoula Gravels (dated at 13,000 to 17,500 ybp) a maximum of 0.06 m (0.2 ft) (Myers and Price 1979).

6.4 STRATIGRAPHY

The stratigraphy of the Pasco Basin consists of three basic units of highly contrasting lithology and origin. The lowermost identifiable unit in the region is one of basalt flows, which are overlain in the Pasco Basin by the sands, silts, and gravels of the Ringold Formation. Above the Ringold Formation are the uncemented gravels of the Hanford Formation, which are covered within 1.5 to 3 m (5 to 10 ft) of the ground surface by eolian sand.

The basalt flows of the plateau are generally separated by interbeds of volcanoclastic sediments. Most of the younger flows have been named and age-dated, and their areal extent has been mapped. The stratigraphic section illustrating the succession of flows and overlying formations is shown in Figure 6.2. Total thickness of basalt at the Pasco Basin is at least 3,000 m (10,000 ft) (Blume and Associates 1971a,b); only the upper portion of these flows has been studied in detail. Age determinations of basalt flows range from lower Miocene (16.5 mybp) to upper Miocene (6 mybp) (Myers and Price 1979).

The Ringold Formation consists of fine to coarse sediments containing gravels deposited by a through-flowing stream during the late Miocene and early Pliocene (10.5 to 3.3 mybp). Its thickness over the site area is about 152 m (500 ft) (PSP&L 1981, Amendment 23).

The Hanford Formation unconformably overlies the Ringold Formation in the Pasco Basin. The formation consists of uncemented granular material ranging in size from boulders to silt. The uppermost gravels are assigned an age of 13,000 ybp, and the age of the lowermost is uncertain but could be as old as 3.3 mybp. The Hanford Formation is about 60 m (200 ft) thick at the Skagit/Hanford Site (PSP&L 1981).

6.5 SEISMICITY

Historically, eastern Washington has been a region of low seismicity in comparison with western Washington and many other areas of western North America. The historical record for the Pasco Basin region is probably complete for earthquakes of modified Mercalli intensity (MMI) VII and greater that have occurred since about 1870 (WPPSS 1981). This record indicates that earthquakes with MMI VII or greater (potentially destructive) occur at a rate of about two per century within a circular area with a radius of 110 km (68.3 mi) centered at the site. The largest historic earthquake in this zone is the Milton-Freewater earthquake of 1936, with MMI VII or ML 6.1 (WPPSS 1979).

Existing faults include the Wallula Fault zone, which coincides with the southern boundary of the basin and aligns with a fault along the north slope of Rattlesnake Mountain. This trend is part of the Olympic Wallowa linement, extending northwest to the Olympic Peninsula. The existence of the linement as an alignment of topographic features is well established, but its structural and tectonic significance is doubtful (U.S. NRC 1982).

Closest to the sites is a probable fault extending about 6.4 km (4 mi) along the southwest flank of a buried easterly segment of the Umtanum Ridge-Gable Mountain structural trend. Other faults are associated with Gable Mountain, Saddle Mountain, Umtanum Ridge, and the northeast margin of the Horse Heaven Hills (Blume and Associates 1971a,b). Only one fault has been designated as capable, although studies are continuing.

Since 1969, abundant swarms of microearthquakes (ML 3.0) in the Hanford (Pasco Basin) region have been thoroughly monitored and analyzed. About

80 percent of these shocks have had focal depths less than 3 km (1.9 mi) and may be nontectonic in nature; the remainder have occurred as deep as 25 km (15 mi) and may be caused by north-south crustal compression.

The only mapped fault in the Pasco Basin deemed to be capable according to NRC criteria is the Central fault, situated on the Gable Mountain-Umtanum Ridge structural trend (WPPSS 1979), which is located about 12.9 km (8 mi) northwest of the site. Other late Pleistocene faults have been mapped along this and other structural trends. Although none of these faults has a proven tectonic origin or seismogenic potential, the maximum earthquake magnitude that could reasonably be associated with them has been calculated to be approximately ML 5 (WPPSS 1979). The Central fault lies approximately 6.4 km (4 mi) south of the Firehouse Site and may be a factor determining the suitability of that site.

There is no well-defined correlation between macroseismic activity within the 110-km (68.3-mi) region about the site and geologic structures such as faults, grabens or fold axes. Larger magnitude, deep focus earthquakes in the Pacific Northwest are generally confined to the western side of the Cascade Mountains, where activity is centered in the Puget Sound Lowland and the northern portion of the Willamette Valley of Oregon. These zones are both within the Puget-Willamette Trough tectonic province. Activity within the Puget-Willamette province has not significantly affected the proposed sites due to the distance of about 225 km (140 mi), which separates them at their closest approach (WPPSS 1979).

With two exceptions, the entire region east of the Cascades is characterized by low seismicity, and by widely scattered epicenters of low intensity. A clustering of epicenters occurs in the Chelan area in the vicinity of the common boundaries of the Northern Cascade, Okanogan Highland, and Columbia Basin tectonic provinces. A second clustering of epicenters occurs in the Walla Walla Basin area, near the boundary of the Columbia Basin and Blue Mountains tectonic provinces. There is no known correlation between these zones and known structures (WPPSS 1979).

Although there is no well-defined correlation of macroearthquake activity with tectonic structures northwest of the Milton-Freewater epicentral region, the presence of the Wallula Gap Fault (capable) within the zone of the Rattlesnake-Wallula alignment and associated structures makes this zone the most significant for determining the earthquake potential at the site. No significant faults other than the Wallula Gap Fault are recognized to be associated with this structural zone.

The Wallula Gap Fault has been positively mapped for only 5 miles. Bingham et al. (1970), on the basis of reconnaissance mapping, have inferred that the fault extends for at least 19 km (12 mi) southeastward of the Gap, and that it may be related to a youthful linear feature trending southeast beyond that point.

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7.0 CULTURAL RESOURCES ASSESSMENT

As required by the provisions of the National Environmental Policy Act, Executive Order 11593, and the amended National Historic Preservation Act, an archaeological assessment of both potential NPR sites was performed as part of the environmental characterization effort. This section documents the information obtained, and analyses performed, by Dr. David G. Rice,^(a) who determined the archaeological and cultural aspects of the Skagit/Hanford and Firehouse sites.

Between November 22 and December 12, 1983, a literature search/records check was conducted. In addition to cultural resource reports and records in Dr. Rice's possession, information was obtained from the Washington Archaeological Research Center, the Washington State Office of Archaeology and Historic Preservation, and the U.S. DOE Richland Operations Office. Information on pre-Hanford Reservation history was derived from the Richland Public Library, the University of Washington Library, Seattle District, U.S. Army Corps of Engineers, and the U.S. DOE Richland Operations Office. Other researchers doing work in the area were also consulted. Federal Register listings through June 1983 were checked for additions to the National Register of Historic Places.

An archaeological field survey was carried out between November 25 and November 28, 1983. Because preliminary research disclosed that most of the Skagit/Hanford Site was previously and recently surveyed for cultural resources, the field efforts were focused at the Firehouse Site. Field methods employed on-the-ground linear transects (north-south) at 65-yard intervals. Rodent burrows and unvegetated ground surfaces were more intensively examined at transect intervals of 10 yards. Subsurface probes were made with a shovel and immediately backfilled; none of these probes produced evidence of archaeological material. Locational control on the ground was accomplished by use of high-resolution aerial photographs at a scale of 2 inches to a mile. Compass readings were used for maintaining direction while making transects. Archaeological and historical literature were reviewed prior to field studies to

(a) Rice Consulting Service, Seattle, Washington.

help guide the survey efforts. The type of archaeological survey employed in this study is described by King (1978, pp. 36-37) as a "non-exclusive comprehensive survey with background research and subsurface testing." This means that background research including records checks and a literature search were conducted prior to on-the-ground field work; that the survey conducted was comprehensive and did not exclude portions of the study area; and that limited subsurface shovel tests were made. The results of these investigations are summarized by study location in the following subsections.

7.1 FIREHOUSE SITE

Within this study area no prehistoric archaeological sites were identified. Lithic material suitable for the production of artifacts was found, but occurred naturally in flood gravel deposits. Even though there is the potential for isolated prehistoric finds, these finds are not apt to be extensive because of the distance from water (minimum of 1.5 miles) in a xerophytic environmental setting.

Historical research indicates that the upland flats of the study area served as grazing lands for Indian horses during the 19th century. An 1880-81 Indian trail (Figure 7.1) was identified as crossing the study area. Field reconnaissance failed to clearly identify the trail on the ground because it appears to coincide with the Hanford No. 1-Ashe Bonneville Power Administration 500-kV power transmission line. The trail also could have been obliterated by herds of grazing livestock late in the 19th century.

The history of 20th century pre-Hanford Reservation land use identifies grazing as the primary usage (U.S. Army Corps of Engineers 1947). When the Hanford Reservation was established in 1943, the study area was nearly evenly owned by the state and the Milwaukee Railroad, with one small private ownership. The most prominent cultural feature relating to early 20th century Euroamerican settlement is the Hanford Ditch (45-BN-309H), which cuts across the northwest corner of the study area (Figure 7.2). It was constructed between 1906-08 by the Priest Rapids Irrigation Company, and enlarged by its successor, the Hanford Irrigation and Power Company. This historic site is

FIGURE 7.1. Old Indian Trail Passing Through the Firehouse Site [Government Land Office plat map (1880-1881).]

- (1) Ryegrass Archaeological District
- (2) Hanford Generating Plant Sites (45-BN-179 & 180)
- (3) The Hanford Ditch
- (4) The Old White Bluffs Wagon Road

FIGURE 7.2. Relationship of Firehouse Site to Identified Cultural Resources [USGS Coyote Rapids Quadrangle (1965), scale: 1 inch = 1 mile]

likely to be eligible for listing on the National Register of Historic Places and appears to meet criteria outlined in 36 CFR Part 60.

Several cultural resource sites were identified in the general vicinity of the study area. They include the Ryegrass Archaeological District (listed on the National Register) (Rice 1980), archaeological sites at the Hanford Generating Plant (45-BN-179 and 180) (Rice 1980), and the Old White Bluffs wagon road to the Yakima River. These are also indicated in Figure 7.2.

7.2 SKAGIT/HANFORD SITE

Previous investigations (Rice 1981) identified a prehistoric archaeological site (45-BN-266) (Figure 7.3) within the study area. The site consisted of a lithic scatter and contained no temporally diagnostic artifacts. The archaeological material was collected, leaving no site to be impacted.

The history of 20th century pre-Hanford Reservation land use indicates that grazing was also the primary usage of this study area (U.S. Army Corps of Engineers 1947). When the Hanford Reservation was established in 1943, the study area was evenly divided between Government and private lands. An historic homestead (45-BN-305H) was identified (ERTEC Northwest 1981) at the northeast corner of this study area. There is some evidence that the homestead was a base for livestock grazing and may have served as a sheep ranch. Figure 7.3 shows the site location. No standing structures remain at the site.

Figure 7.4 illustrated the portions of the study area surveyed in 1981 by ERTEC Northwest. Because Section 33 was previously surveyed by Rice (1981), survey efforts at this study site covered the gaps in the ERTEC survey. No additional archaeological sites or materials were observed.

Significant cultural resources in the vicinity of the study area have been previously identified by Rice (1980) and are illustrated in relation to the study site in Figure 7.5. These include the Hanford North Archaeological District, the Hanford Island Site, the Savage Island Archaeological District, and the Wooded Island Archaeological District. All of these sites are listed on the National Register of Historic Places.

- (1) Prehistoric Indian Lithic Scatter (45-BN-266)
- (2) Historic pre-Hanford Reservation Homestead (45-BN-305H)

FIGURE 7.3. Relationship of Skagit/Hanford Site to Identified Cultural Resources
[USGS Richland Quadrangle (1951), scale: 1 inch = 1 mile)

FIGURE 7.4. Survey Units Selected and Walked by ERTEC Northwest in Late 1981 Using 50-Foot Interval Transects
(ERTEC Northwest 1981, p. 7)

FIGURE 7.5. Significant Cultural Resources in the Skagit/Hanford Site Vicinity (ERTEC Northwest 1981)

7.3 CONCLUSIONS

Cultural resource sites are legally significant if they meet the criteria of eligibility for listing on the National Register (36 CRF Part 60). No sites listed on the National Register are located within either of the study areas. Nearby National Register sites and districts have been identified and located. The Hanford Ditch (45-BN-309H) is the only potentially significant cultural resource site located by this study. It is likely that the Hanford Ditch meets the criteria of eligibility for listing on the National Register. If the Firehouse Site is selected for the new production reactor, then a formal determination of eligibility should be made in consultation with the Washington State Historic Preservation Officer pursuant to 36 CFR Part 800. None of the other sites identified within the bounds of the study areas warrants further consideration. National Register sites outside the study areas would need to be considered in the design and construction of associated facilities if either study area is selected for the new production reactor.

Because the Hanford Ditch (45-BN-309H) is an historical archaeological site of linear character and is located within one study area and nearby the other, it is appropriate to discuss proper mitigation of adverse impacts related to the siting and construction of a new production reactor. Avoidance is the preferred management action and should not be difficult because the historic site is rather remote to likely construction for major facilities. However, if the Hanford Ditch is determined eligible for the National Register, it is probable that the mitigation for adverse effects would consist only of more detailed mapping, a structural analysis, and detailed research into its history. National Register status does not mean that the site cannot be disturbed, but only that it must be considered during planning for a project, including consultation with the Advisory Council on Historic Preservation pursuant to Section 106 of the National Historic Preservation Act.

From a research standpoint it is curious that so few prehistoric archaeological sites are found on upland flats which include the study areas. The landforms have been available for human use and habitation for 9000 or 10,000 years. Evidently the resources, particularly water, to support significant human activity were lacking. The only type of human activity

recorded within these areas is transient, including trails and roads. Even in historical times water was the key to development and settlement. The Hanford Ditch takes on special significance as a recent adaptation to a longstanding arid environment.

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8.0 BASELINE ECONOMIC AND SOCIAL CONDITIONS FOR THE NPR IMPACT AREA

This chapter presents the characterization of the baseline economic and social conditions for the NPR impact area of Benton and Franklin Counties. The baseline socioeconomic situation is for the future years corresponding to the NPR construction and operation schedule, and provides the baseline from which impacts from NPR can be projected. This chapter covers only the development of estimates of the Tri-Cities economy without NPR (baseline condition); the impacts of the NPR are not analyzed.

Because the future cannot be known with certainty, four different scenarios of the baseline socioeconomic conditions are developed in Section 8.2. Each scenario makes different assumptions about future Tri-Cities area employment levels based on historical trends and current information about future trends. In Section 8.1 the current socioeconomic situation in the Tri-Cities is discussed in the context of available historical economic and social data. (Historical population data are given in Section 2.2.) The following analysis applies to both the primary and secondary NPR sites.

8.1 HISTORICAL SOCIOECONOMIC DATA FOR THE IMPACT AREA

The primary socioeconomic impact area associated with the construction and operation of the NPR is the Tri-Cities SMSA, composed of Benton and Franklin Counties. This section presents historical data on the economy and social condition of the Tri-Cities area, concentrating on the period from 1970 to 1982. Socioeconomic characteristics covered include employment, labor force characteristics, income, housing, education, public services, recreation, transportation, and public revenues. (Historical population data are presented in Section 2.2.) For some of these categories, such as public services, recreation, and transportation, historical time series are not available; for these categories the most recent available information is used. When available, 1983 data are added to the time series data for 1970 to 1982.

8.1.1 Employment

This section examines employment trends in the Tri-Cities from 1969 to 1982. Major trends are dealt with first, followed by a short section on other employment trends of smaller impact.

Table 8.1 shows Tri-Cities agricultural and manufacturing employment by sector from 1969 to 1981. Table 8.2 contains calculated average annual growth rates.^(a) From 1969 to 1981 wage and salary employment in the Tri-Cities SMSA grew from 33,108 to 72,253 (Table 8.1), for an average annual growth rate of over 6.5 percent, making this area one of the fastest-growing regions in the nation. This growth developed in phases, with different sectors dominating in different years.

1969 to 1973

Total wage and salary employment in the Tri-Cities grew at an annual average rate of 3.3 percent from 1969 to 1973. The largest contributors in this period were the agriculture and Construction sectors, with 11.7 percent and 11.5 percent average annual growth rates, respectively, over the four-year period (Table 8.2). The significant growth in employment in agriculture can be attributed to a continuing increase in productive acreage resulting from irrigation projects sponsored by the Bureau of Reclamation. Irrigated acreage in Benton and Franklin Counties increased at an annual rate of 3.3 percent (Table 8.3) over this period, a growth rate large enough to more than offset the lower labor requirements per volume of agricultural output resulting from technological improvements.

1973 to 1977

During the period 1973 to 1977, the biggest impact on Tri-Cities employment was the beginning of work on the Washington Public Power Supply System (WPPSS) nuclear power plant projects. Local employment at WPPSS falls under two major categories shown in Table 8.2: Construction and Services (for design and engineering). Other jobs directly related to the Supply System are

(a) Actual historical employment figures used in the baseline scenarios are contained in Table 8.8. The figures in Table 8.1 are used for historical perspective and not as a starting point for scenario projections.

TABLE B.1. Employment by Type and Broad Industrial Categories for the Tri-Cities SMSA, 1969 - 1981

	1969 ^(a)	1970 ^(a)	1971 ^(a)	1972 ^(a)	1973 ^(a)	1974 ^(a)	1975 ^(b)	1976 ^(b)	1977 ^(b)	1978 ^(b)	1979 ^(b)	1980 ^(b)	1981 ^(b)
Total Employment ^(c)	37,499	38,700	38,536	39,630	42,406	46,426	51,423	55,602	60,508	67,766	74,421	74,709	78,904
Number of Proprietors	4,391	4,354	4,479	4,500	4,576	4,714	4,960	5,195	5,595	6,003	6,430	6,613	6,651
Farm Proprietors	2,453	2,407	2,362	2,318	2,302	2,287	2,253	2,256	2,314	2,449	2,513	2,578	2,678
Nonfarm Proprietors	1,938	1,947	2,117	2,182	2,274	2,427	2,707	2,939	3,281	3,554	3,917	4,035	3,973
Total Wage and Salary Employment	33,108	34,346	34,057	35,130	37,830	41,712	46,463	50,407	54,913	61,763	67,991	68,096	72,253
Farm	2,222	2,718	2,869	2,959	3,550	4,270	4,638	5,611	4,203	4,204	4,847	4,850	5,183
Nonfarm	30,886	31,628	31,188	32,171	34,280	37,442	41,825	44,796	50,710	57,559	63,144	63,246	67,070
Agricultural Services, Forestry, Fishing, Other ^(d)	(D)	(D)	(D)	368	398	459	(D)	(D)	(D)	(D)	1,104	(D)	(D)
Mining	(D)	(D)	(D)	(L)	(L)	(L)	(D)	(D)	(D)	(D)	80	(D)	(D)
Construction	1,976	1,758	1,695	2,376	3,124	4,004	5,493	5,432	7,519	9,374	11,289	10,063	13,539
Manufacturing	5,514	5,543	5,259	5,334	5,699	6,079	6,903	7,303	8,024	8,887	9,293	9,132	9,116
Non-durable Manufacturing	4,987	5,078	4,788	4,822	5,043	5,339	5,954	6,373	7,057	7,874	8,344	8,192	8,230
Durable Manufacturing	527	465	471	512	656	740	949	930	967	1,013	949	940	886
Transportation and Public Utilities	1,624	1,655	1,634	1,685	1,808	1,810	1,797	1,878	2,055	2,356	2,442	2,479	2,459
Wholesale Trade	833	886	857	867	1,120	1,020	1,392	1,555	1,630	1,935	2,130	1,907	1,917
Retail Trade	4,629	4,834	4,947	5,084	5,241	5,509	5,678	6,606	7,481	8,625	9,385	9,426	9,813
Finance, Insurance and Real Estate	702	700	732	868	899	980	956	1,139	1,382	1,531	1,730	1,733	1,639
Services	9,067	9,390	9,148	8,948	9,132	10,012	10,900	11,838	13,250	14,713	15,424	16,338	16,380
Government	6,222	6,518	6,539	6,544	7,022	7,557	8,087	8,321	8,493	9,074	10,267	10,868	10,982
Federal, Civilian	813	830	767	739	777	835	890	929	971	1,012	1,061	1,117	1,076
Federal, Military	594	595	661	615	635	625	612	603	536	568	600	620	685
State and Local	4,815	5,093	5,111	5,190	5,610	6,097	6,585	6,789	6,986	7,494	8,606	9,131	9,221

Source: Regional Economic Information System BEA 1982.

(a) Estimates based on 1967 SIC.

(b) Estimated based on 1972 SIC.

(c) Consists of wage and salary jobs plus number of proprietors.

(d) Includes number of jobs held by U.S. residents working for international organizations in the U.S. Primary source for private non-farm employment: ES-202 covered wages - Washington Employment Security Department.

(D) Not shown to avoid disclosure of confidential data. Data are included in totals.

(L) Less than 10 wage and salary jobs.

TABLE 8.2. Calculated Average Annual Growth in Employment: Tri-Cities SMSA
(percent)

<u>Employment by Place of Work</u>	<u>1969- 1981</u>	<u>1969- 1973</u>	<u>1973- 1977</u>	<u>1977- 1980</u>	<u>1980- 1981</u>
Total Employment	6.2	3.1	8.9	7.0	5.5
Number Proprietors	3.5	1.0	5.0	5.6	0.6
Farm Proprietors	0.7	-1.6	0.1	3.6	3.8
Nonfarm Proprietors	6.0	4.0	9.2	6.9	-1.5
Total Wage & Salary Employment	6.5	3.3	9.3	7.2	5.9
Farm	7.1	11.7	4.2	4.8	6.6
Nonfarm	6.5	2.6	9.8	7.4	5.9
Agricultural, Forestry					
Services, Fisheries, Other	NA	NA	NA	NA	NA
Mining	NA	NA	NA	NA	NA
Construction	16.0	11.5	22.0	9.7	29.7
Manufacturing	4.2	0.8	8.6	4.3	-0.2
Transportation, Public	3.5	2.7	3.2	6.3	-0.8
Utilities					
Wholesale Trade	6.9	7.4	9.4	5.2	0.5
Retail Trade	6.3	3.1	8.9	7.7	4.0
Finance, Insurance, and	7.1	6.2	10.8	7.5	-5.6
Real Estate					
Services	4.9	0.2	9.3	7.0	0.3
Government	4.7	3.0	4.8	8.2	1.0
Federal, Civilian	2.3	-1.1	5.6	4.7	-3.7
Federal, Military	1.2	1.7	-4.2	4.9	10.0
State and Local	5.4	3.8	5.5	8.9	1.0

Source: Calculated from Table 8.1.

reflected in the Transportation and Public Utilities category. With the issuance of the construction permit for WNP-2 in March 1973 and the State Site Certifications for WNP-1 and WNP-4 in August 1975, construction employment grew at a rate of 22.0 percent per year during this period. Overall employment growth in the Tri-Cities increased at an average annual rate of 8.9 percent.

Employment by DOE and its contractors grew from 7,570 in 1973 to 12,300 in 1977 (Table 8.4), increasing 62 percent over the period, or over 12.1 percent per year. DOE-generated employment falls primarily into the Chemicals and Allied Products, Services, Construction, and Federal Government employment categories. These significant increases fueled demand for housing (real

TABLE 8.3. Irrigated Acreage in Benton and Franklin Counties, 1969-1982

<u>Year</u>	<u>Benton County</u>	<u>Franklin County</u>	<u>Benton Franklin Combined</u>
1969	74,184	128,899	203,083
1970	79,937	132,608	212,545
1971	85,690	135,899	221,589
1972	91,443	136,743	228,186
1973	97,200	134,274	231,474
1974	107,296	140,768	248,064
1975	118,441	141,787	260,228
1976	132,739	142,426	275,165
1977	143,264	144,902	288,166
1978	151,911	145,984	297,895
1979	156,313	146,291	302,604
1980	159,000	148,631	307,631
1981	160,991	150,335	311,326
1982	161,593	151,599	313,192

Source: Benton County Extension Office (1983), Clement et al. (1974).

TABLE 8.4. Tri-Cities DOE and Supply System Employment, 1973-1982

<u>Year</u>	<u>Supply System Corporate Staff and Contractors (WNP-1, 2, 4)</u>	<u>DOE and Contractors</u>
1973	530	7,570
1974	1,115	8,700
1975	1,946	9,800
1976	2,954	10,680
1977	3,412	12,300
1978	7,097	11,750
1979	8,926	12,000
1980	7,935	12,100
1981	11,728	11,880
1982	8,841	11,500

Source: McGinnis and Schau (1983).

estate) and for services, and led to annual growth rates in these sectors of 10.8 percent and 9.3 percent, respectively (Table 8.2). Employment growth rates in virtually all sectors increased during this period, with the exceptions of military and agricultural employment. Despite continuing increases in acreage, technological developments and changes in crop mix slowed growth in farm employment.

1977 to 1980

Tri-Cities employment continued to grow rapidly between 1977 and 1979, then slowed in 1980. The area's annual employment growth rate for wage and salary employment was 7.2 percent, but that figure is based on 11.8 percent growth from 1977 to 1978, 9.6 percent growth from 1978 to 1979, and 0.2 percent growth from 1979 to 1980 (Table 8.1). Strong growth continued in agriculture, construction, retail trade, real estate, and services, as well as state and local government. Declines were noted in durable manufacturing, and the growth rate in wholesale trade was nearly halved over the 1973 to 1977 period. One of the reasons for the stagnant economy in 1980 was the large number of labor disputes that year. The number of employees involved in labor disputes averaged over the total year (1,040) represented 12 percent of construction employment or 13 percent of total WPPSS employment for that year (Washington Employment Security 1983). These disputes by construction workers were felt throughout the Tri-Cities economy, particularly affecting the wholesale and retail trade sectors.

1980 to 1982

Employment during the 1980 to 1981 period showed declines in several sectors. Annual average growth in Construction between 1980 and 1981 was 29.7 percent and accounted for the majority of the total employment gains that year (Table 8.2). Overall growth in wage and salary employment was 5.9 percent, with Government and Retail Trade posting modest gains; Manufacturing and Utilities modest declines; and employment in Finance, Insurance and Real Estate declines of 5.6 percent.

From 1981 to 1982, employment in the Tri-Cities began to decline. In the fourth quarter of 1981, the WNP-4 project (20 percent complete) was mothballed and then terminated (January 1982), a decision based on the Supply System's

inability to finance the remaining construction and uncertainty regarding the future need for power. Still, moderate increases in payrolls on other WPPSS sites mitigated some of the impact from the halt in construction at WNP-4. In late April 1982, WNP-1 (62 percent complete) was mothballed for at least 5 years.. Construction on the WNP-2 project was completed in the second quarter of 1983 and the facility is currently awaiting its fuel load. As a result of these actions, the WPPSS workforce is expected to lose 10,000 of the 13,500 jobs held in June 1981 within 2 years (McGinnis and Schau 1983).

Nearly all non-manufacturing sectors of the Tri-Cities economy experienced a decline from 1981 to 1982. Construction employment fell over 38 percent, while Government, Services, Wholesale and Retail Trade, and Transportation and Public Utilities all experienced declines between 2.9 and 7.8 percent. Finance, Insurance and Real Estate employment, however, increased 4.9 percent, and Manufacturing increased 2.4 percent (McGinnis and Schau 1983).

Other Historical Trends

Local manufacturing has been a mainstay of the Tri-Cities economy. The Chemicals and Allied Products category provides local support to DOE Hanford contractors and off-Hanford firms that produce agricultural chemicals for local consumption and export. It and the Food and Kindred Products category have provided fairly steady growth between 1971 and 1980. Local manufacturing has maintained its share of employment due to increases in chemicals, food, and other manufacturing categories. Manufacturing jobs in Walla Walla County also add to the Tri-Cities local economy because an estimated 75 percent of workers employed in the Burbank-Wallula area of that county commute daily from the Tri-Cities (Washington State Employment Security 1982).

Between 1980 and 1982, employment in the Food and Kindred Products sector declined; however, opportunities in this area are expected to be increased by the opening of several new wineries in the area. The performance of the Chemicals and Allied Products sector continues to be strong. The increase in Transportation and Public Utilities employment from 1975 to 1982 would have been higher except for pervasive losses in the railroads. Some of the lower

growth since 1980 can also be attributed to a decline in population growth and the restructuring of local industry.

Federal government budgets represent the single largest source of primary economic activity in the area. The recent changes in emphasis of DOE programs is expected to lead to changes in the mix of employment demands, with relative declines in the Business Services sector, and increases in Chemicals and Allied Products (Washington State Employment Security 1982). The federal budget for Hanford for fiscal year (FY) 1982 was \$756 million, and \$844 million for FY 1983 (Washington State Employment Security 1983).

8.1.2 Labor Force Characteristics

The labor force of the Tri-Cities has several interesting characteristics. Local occupational studies conducted in 1980 and 1981 examined local employment in the Mining, Construction, Manufacturing, Finance, Insurance and Real Estate, Federal Government, and Services sectors. The studies showed 3,010 engineers, 740 scientists, 2,240 technicians, and 260 computer specialists were employed in these sectors. The ratio of the number of locally-employed engineers to total non-farm employment is 220 percent of the national average (Washington State Employment Security 1982). This highly technical labor force composition reflects the emphasis on research and development work associated with Hanford activities.

Table 8.5 gives the labor force mix by age, race, and sex for the Tri-Cities and Walla Walla County area for 1970 and projections for 1984. Several changes are shown over this period. The percentage of the total labor force represented by women is expected to grow from 37 percent in 1970 to 45 percent of the projected total work force in 1984. The racial mix is also expected to change, with 98 percent of the 1970 work force composed of whites, compared to a projected 94 percent share of whites in 1984. The largest change will occur in the Other Race category, with a jump from under 1 percent in 1970 to 5 percent in 1984. The fastest growing racial groups within the region during this period have been Hispanics and Asians. Part of this was the result of immigration to meet seasonal agricultural demands, but the larger part was due to an inflow of workers from Asian countries. Washington State ranked third among the 50 states in Indochinese resettlement during this period, with the Tri-Cities gaining a healthy share of the state total.

TABLE 8.5. Resident Civilian Labor Force by Age, Sex, and Race for Benton, Franklin, and Walla Walla Counties

Age	Total		Sex		Race		
	Number	Percent	Male	Female	White	Black	Other
<u>1984 Projections</u>	100,240	100.0	55,100	45,140	93,970	1,230	5,040
16-17	3,540	3.5	1,900	1,640	3,110	50	380
18-19	3,990	4.0	1,910	2,080	3,670	50	270
20-24	12,370	12.4	6,570	5,800	11,380	150	850
25-34	32,180	32.1	17,820	14,360	30,650	380	1,150
35-44	22,840	22.8	11,860	10,980	21,370	280	1,190
45-64	22,780	22.7	13,440	9,340	21,410	260	1,100
65 and older	2,540	2.5	1,600	940	2,380	60	100
<u>1970 Census</u>	54,975	100.0	34,661	20,314	53,863	703	409
16-17	2,484	4.5	1,421	1,063	2,432	27	25
18-19	3,031	5.5	1,632	1,399	2,979	24	28
20-24	5,822	10.6	3,360	2,462	5,669	92	61
25-34	10,095	18.4	6,629	3,466	9,824	178	93
35-44	11,497	20.9	7,237	4,260	11,297	105	95
45-64	20,036	36.4	13,037	6,990	19,701	237	98
65 and older	2,010	3.7	1,345	665	1,961	40	9

Source: Washington State Employment Security (1983).

Finally, the most interesting change in the labor force has been in the age distribution. In 1970, the largest labor force age category for both men and women was the 45 to 64 age range, with 38 percent of all male workers and 34 percent of all female workers within that range. By 1984, a significant shift will occur, with the most workers now in the 25 to 34 age bracket; 32 percent of both the male and female labor force will fall within that range. In 1970, only 19 percent and 17 percent of male and female workers, respectively, were in the younger category. By 1984, the percentage of the labor force aged 45 to 64 will have fallen to 23 percent.

The most significant cause of this shift in the age distribution of the labor force is the dramatic increase in construction employment that accompanied the WPPSS nuclear projects. These projects attracted large numbers of mobile, younger, male construction workers to the area throughout the late 1970s and into the early 1980s, altering the age structure of the resident labor force.

Unemployment

Table 8.6 shows total civilian labor force unemployment rates in the Tri-Cities between 1973 and 1982. Unemployment in the Tri-Cities and surrounding communities has generally averaged higher than the state or nation due to the seasonal variability in the Agricultural and Food Processing sectors. Despite the rapid growth in employment at WPPSS and other industries in the area, unemployment remained a problem in the region, especially for unskilled labor (Washington State Employment Security 1982). It was said that "it seemed for every 10 jobs created, eleven persons would enter the local labor market to compete for these positions" (Washington State Employment Security 1982, p. 10). The labor force grew 7.2 percent between 1978 and 1981, primarily from in-migration. Although job opportunities grew significantly during the late 1970s, this in-migration caused the unemployment rate to increase.

Insured unemployment for the Tri-Cities area for 1982 was 4,946 workers. Of this total, 32.5 percent were female and 67.5 percent were male (Washington State Employment Security 1983). The increase in the unemployment rate since 1981 reflects the national recession, declining employment in agriculture, and the decisions to mothball and terminate WNP-1 and WNP-4. The recent increase

TABLE 8.6. Total Tri-Cities Civilian Labor Force Unemployment, 1973-1982^(a)

Year	Resident Civilian Labor Force	Employment	Total Unemployment	Annual Unemployment Rate
1973	42,520	38,960	3,560	8.4
1974	45,270	42,300	2,970	6.6
1975	49,190	45,550	3,640	7.4
1976	55,800	51,800	4,000	7.2
1977	60,400	55,500	4,900	8.1
1978	68,670	64,340	4,330	6.3
1979	75,450	70,480	4,970	6.6
1980	79,810	72,000	7,810	9.8
1981	83,000	75,600	7,400	8.9
1982	81,400	69,800	11,600	14.3

(a) These values vary slightly from figures in Table 8.1. The figures from this table are used for scenario development in Section 8.2.

Source: McGinnis and Schau (1983).

in unemployment has hit the construction industry hardest, although trade and services have also been significantly affected (Washington State Employment Security 1983). This is reflected in the high unemployment rate of males in the area; nationally the unemployment rate for adult females is higher than that for adult males. Some out-migration of labor has occurred; however, the continuing high level of unemployment indicates that significant numbers of unemployed workers are remaining in the area.

The recent unemployment situation in the Tri-Cities and Walla Walla County is shown in Tables 8.7 and 8.8, where the number of applicants and the number of nonagricultural job openings by major occupational title are given for October 1981 through March 1983. This information gives some indication of the structure of unemployment in the area. The largest numbers of unemployed workers applying for job services occurred in the Construction, Services, Clerical, and Professional categories, with 10 percent or more of total applicants in each of the periods. In 1981 to 1982, there were roughly twice as many job openings as applicants in the Tri-Cities, while openings

TABLE 8.7. Applicants and Job Openings for Selected Occupations in the Tri-Cities Job Service Centers

Occupational Title	October 1982 through March 1983				October 1981 through March 1982			
	Applicants Registered: Active (End of Period)	Nonagricultural Openings Received	Ratio of Openings to Applicants (percent)	Ratio of Applicants from Category to Total Applications (percent)	Applicants Registered: Active (End of Period)	Nonagricultural Openings Received	Ratio of Openings to Applicants (percent)	Ratio of Applicants from Category to Total Applications (percent)
Professional, Technical, Manager	382	60	16	13	114	173	152	14
Clerical	458	134	29	15	160	330	206	19
Sales	116	75	65	4	36	270	750	4
Services	293	206	70	10	164	264	161	19
Agriculture, Fisheries, Forestry	91	25	27	3	37	27	73	4
Food Processing	99	124	125	3	20	363	1,815	2
Machine Trades	116	32	28	4	51	32	63	6
Benchwork	29	34	117	1	11	8	73	1
Structure Work	1,057	81	8	36	112	91	81	13
Miscellaneous	274	159	58	9	94	185	197	11
No Occupational Code	42	37	88	1	26	5	19	3
TOTAL	2,957	967	33	100	825	1,748	212	100

Source: Washington State Employment Security, 1983 (Raw Data).

TABLE 8.8. Applicants and Job Openings for Selected Occupations in the Walla Walla Job Service Center

Occupational Title	October 1982 through March 1983				October 1981 through March 1982			
	Applicants Registered: Active (End of Period)	Nonagricultural Openings Received	Ratio of Openings to Applicants (percent)	Ratio of Applicants from Category to Total Application (percent)	Applicants Registered: Active (End of Period)	Nonagricultural Openings Received	Ratio of Openings to Applicants (percent)	Ratio of Applicants from Category to Total Application (percent)
Professional, Technical, Manager	73	28	38	11	58	26	45	12
Clerical	100	53	53	15	68	75	110	14
Sales	26	32	123	4	15	16	107	3
Services	96	85	89	15	83	73	88	18
Agriculture, Fisheries, Forestry	36	5	14	5	34	29	85	7
Food Processing	54	61	113	8	8	125	1,563	2
Machine Trades	48	9	19	7	42	11	26	9
Benchwork	9	6	67	1	4	0	0	1
Structural Work	136	17	13	21	77	38	49	16
Miscellaneous	70	29	14	11	58	54	93	12
No Occupational Code	9	5	56	1	26	0	0	5
TOTAL	657	330	50	100	473	447	95	100

Source: Washington State Employment Security, 1983 (Raw Data).

were available for 95 percent of Walla Walla County applicants. The Food Processing, Sales, and Clerical categories had the largest number of openings per applicant, while Machine Trades, and Agriculture, Fisheries and Forestry had the lowest ratios.

In the 1982 to 1983 period, the overall ratio of openings to applicant fell dramatically, from 212 percent to 33 percent in the Tri-Cities, and from 95 percent to 50 percent in Walla Walla County. The largest opening-to-applicant ratios for this period in the Tri-Cities were in Food Processing, Benchwork, Services, and Sales. The lowest ratios were in the Professional, Technical and Manager, and Construction categories. The largest ratios in Walla Walla County for the 1982 to 1983 period were in Sales, Food Processing, and Services, and the lowest ratios were in Construction, Agriculture, Fisheries and Forestry, and Machine Trades.

The most dramatic shifts in the ratios of openings to applicants again appeared in the construction sector. In the 1981 to 1982 period, the Tri-Cities figures showed 81 percent as many openings as applicants in construction (structural work) and Walla Walla had 49 percent. In 1982 to 1983, however, the ratios fell to 8 percent and 13 percent, respectively. Of the almost 1200 registered job services applicants in construction, 70 were placed in the 98 job openings received. This category alone accounted for one-third of total applications for the area, more than double the 15 percent of total construction applications in 1981 to 1982.

There are several possible reasons that over 1200 construction workers remained in the area after the decisions to terminate WPPSS construction were made in the fourth quarter of 1981 and second quarter 1982. The most important is probably the depressed nature of the construction industry nationwide. Another is the relatively unskilled nature of construction workers drawn to the Tri-Cities area. A significant number of WPPSS construction workers were young, relatively inexperienced laborers with few specific skills. The unfavorable employment conditions nationally give construction workers more incentive to remain in the locale of their current union, since "travelers" are generally hired only after local union members are employed.

Other occupational categories with significant numbers of applicants over available openings in the 1982 to 1983 period were the Professional, Technical and Manager, Clerical, and Services categories. Between the 1981 to 1982 and 1982 to 1983 periods, the share of total applicants in some of the categories actually fell. For example, during the 1981 to 1982 period 19 percent of all applicants were in the services trade; this share fell to 10 percent in 1982 to 1983. Similarly, clerical applicants fell from 19 percent to 15 percent. However, in every occupational category the total number of job applicants was greater in 1982 to 1983 than in 1981 to 1982.

Seasonality of Employment

Another major characteristic of unemployment in the Tri-Cities area is the large degree of seasonality in the agricultural sector. Table 8.9 shows monthly employment figures for Benton and Franklin Counties for 1979 to 1982. Covered agricultural employment in June is three times higher than employment in December. The bulk of this seasonal employment is filled by migrant workers, with thousands of positions filled through the issuing of clearance orders from as far away as Texas. Local residents employed in agriculture tend to concentrate in the food processing occupational categories.

The seasonal agricultural work consists of a variety of jobs, each with different requirements throughout the year. The major crops employing migrant workers include asparagus (early spring to mid-April), hops (early spring to prepare the fields, and then harvesting for 1-1/2 months starting in September), and the orchards (apples and cherries start after the hops, with workers moving up the Yakima Valley picking from September through November). Other tasks include thinning of the apple trees in the summer, pruning grapevines in November through February, harvesting field corn and wheat, and the tedious work of moving hoses associated with low technology irrigation. Recently, the demands for labor to prune fruit trees and grapevines have been increasing.

8.1.3 Income

This section examines trends in labor and proprietor income by major sectors. Table 8.10 presents income data for the period 1969 to 1980, and Table 8.11 shows calculated growth rates in the sectors covered in Table 8.10.

TABLE 8.9. Seasonality of Employment: Covered Agriculture in Benton and Franklin Counties, 1979-1981

		Ave	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Benton	1979	2,236	725	1,057	1,588	1,325	1,492	5,335	2,798	2,723	3,083	2,224	1,387	1,155
Franklin	1979	1,011	514	817	1,077	1,057	997	1,239	1,124	1,099	1,176	1,185	704	569
	Total	3,247	1,239	1,874	2,665	2,382	2,489	6,574	3,922	3,822	4,259	3,409	2,091	1,724
Benton	1980	2,824	1,335	1,449	2,040	2,349	2,692	4,713	3,715	3,455	3,672	3,184	1,469	1,240
Franklin	1980	933	472	721	832	997	836	1,163	1,069	1,132	1,176	1,337	937	853
	Total	3,757	1,807	2,170	2,872	3,346	3,528	5,878	4,784	4,587	4,848	4,521	2,406	2,093
Benton	1981	3,073	1,541	1,851	2,433	2,564	2,872	6,052	3,488	3,217	3,637	3,326	1,913	1,773
Franklin	1981	943	648	670	801	906	1,087	1,002	1,084	1,197	1,091	1,149	717	702
	Total	4,016	2,189	2,521	3,234	3,470	3,959	7,054	4,572	4,414	4,728	4,475	2,630	2,475

Source: Washington State Employment Security, 1983.

TABLE 8.10. Total Labor and Proprietors Personal Income by Major Sources for the Tri-Cities SMSA (in thousands of dollars)^(a)

	1969 ^(a)	1970 ^(b)	1971 ^(b)	1972 ^(b)	1973 ^(b)	1974 ^(b)	1975 ^(b)	1976 ^(b)	1977 ^(b)	1978 ^(b)	1979 ^(b)	1980 ^(b)
Wage and Salary Income	227.0	244.8	250.8	276.5	319.8	385.9	485.0	554.9	696.5	865.4	1,026.3	1,091.6
Other Labor Income ^(d)	9.5	10.9	11.6	13.5	15.6	19.2	26.4	32.6	42.2	52.5	64.2	72.9
Proprietor Income ^(d)	43.7	37.9	41.5	53.2	80.2	94.6	81.4	79.5	57.9	81.3	71.7	95.6
Farm	20.2	14.0	16.8	26.9	51.1	63.6	44.7	32.8	5.2	19.7	3.1	25.0
Non-Farm ^(d)	23.6	23.9	24.8	26.3	29.1	31.0	36.7	46.7	52.8	61.7	68.6	70.7
By Industry												
Farm	27.9	24.0	26.8	37.8	65.7	82.2	66.9	61.0	31.0	47.1	36.8	62.7
Non-Farm	252.4	269.6	277.0	305.4	349.9	417.6	525.9	606.0	765.5	952.1	1,125.4	1,197.4
Agricultural Services, Forestry, Other ^(e)	(D)	(D)	(D)	2.3	2.5	3.2	(D)	(D)	(D)	(D)	8.6	(D)
Mining	(D)	(D)	(D)	0.9	0.2	0.2	(D)	(D)	(D)	(D)	1.6	(D)
Construction	25.1	23.7	25.0	35.6	48.3	63.5	100.8	106.7	169.3	229.4	287.6	252.1
Manufacturing	53.9	55.5	54.2	59.3	65.9	78.9	100.4	115.1	137.6	165.7	194.3	210.4
Non-Durable Manufacturing	49.4	51.3	49.4	53.3	57.3	68.1	82.7	99.3	121.2	146.9	174.9	188.9
Durable Manufacturing	4.5	4.2	4.8	6.0	8.6	10.8	17.7	15.7	16.4	18.8	19.4	21.4
Transportation	14.5	16.2	17.3	20.0	23.2	24.8	26.4	31.5	38.2	46.3	53.3	57.3
Wholesale Trade	7.4	8.0	8.0	8.8	9.7	21.0	17.6	20.2	22.6	29.7	36.6	34.5
Retail Trade	26.9	29.7	31.4	34.5	37.7	42.8	47.0	56.2	65.4	78.8	90.7	97.8
Financial, Insurance, Real Estate	6.2	6.0	6.8	8.0	8.3	8.7	9.5	12.8	17.6	22.9	27.1	28.8
Services	77.8	84.5	85.4	86.8	94.7	113.6	136.7	162.7	200.9	247.2	279.0	332.3
Government	38.6	44.0	46.4	49.3	50.4	69.7	83.1	95.3	107.2	123.1	146.6	173.4
Federal, Civilian	8.1	9.5	9.5	9.9	11.0	12.7	15.1	17.1	19.7	21.8	23.7	26.2
State and Local	29.1	32.9	35.2	37.4	46.2	54.9	65.8	76.8	86.1	99.7	121.2	145.3
Per Capita Personal Income	3.6	3.8	4.0	4.4	5.2	6.0	6.6	7.0	7.8	8.9	9.7	10.3

Source: Regional Economic Information System BEA (1982).

(a) Consists of wage and salary disbursements. Other labor income, and proprietors' income. Primary source for private nonfarm wages: ES-202 covered wages Washington employment security department.

(b) Estimates based on 1967 SIC.

(c) Estimates based on 1972 SIC.

(d) Includes the capital consumption adjustment for non-farm proprietors.

(e) Includes wages and salaries of U.S. residents working for international organizations in the U.S.

(f) The estimates for federal military earnings have been revised for the year 1977-80.

(D) Not shown to avoid disclosure of confidential information, data are included in totals.

(L) Less than \$50,000 data are included in totals.

TABLE 8.11. Calculated Growth in Income: Tri-Cities SMSA (percent)^(a)

	<u>1969-</u> <u>1980</u>	<u>1969-</u> <u>1973</u>	<u>1973-</u> <u>1977</u>	<u>1977-</u> <u>1980</u>	<u>1973-</u> <u>1980</u>
<u>Total Labor and Proprietors Income</u>					
Wage and Salary Income	14.3	8.6	19.5	15.0	17.5
Other Labor Income	18.5	12.4	24.9	18.2	22.0
Proprietor Income	7.1	15.2	-8.1	16.7	2.5
Farm	1.9	23.2	-57.1	52.3	-10.2
Non-Farm	10.0	5.2	14.9	9.7	12.7
<u>By Industry</u>					
Farm	7.4	21.4	-18.8	23.5	-0.7
Non-Farm	14.2	8.2	19.6	14.9	17.6
Construction	21.0	16.4	31.4	13.3	23.6
Manufacturing	12.4	5.0	18.4	14.2	16.6
Non-Durable	12.2	3.7	18.7	14.8	17.0
Durable	14.2	16.2	16.1	8.9	13.0
Transportation and Public Utilities	12.5	11.8	12.5	13.5	12.9
Wholesale Trade	14.0	6.8	21.1	14.1	18.1
Retail Trade	11.7	8.4	13.8	13.4	13.6
Financial, Insurance, Real Estate	14.0	7.3	18.8	16.4	17.8
Services	13.2	4.9	18.8	16.8	17.9
Government	13.7	10.8	14.8	16.0	15.3
Federal, Civilian	10.7	7.7	14.6	9.5	12.4
State and Local Government	14.6	11.6	15.6	17.4	16.4
Per Capita Personal Income	9.6	9.2	10.1	9.3	9.8
Inflation	6.6	4.6	7.1	8.8	7.8

Source: Calculated from Table 8.10.

Inflation rate from Economic Report of the President 1983, Table B-3.
Implicit Price Deflators for Gross National Product, Total Personal
Consumption Expenditures Deflator, p. 166.

(a) Data not available for the Agricultural Services, Forestry and Other, and Mining categories.

While the overall annual average growth rate in current income over the period was over 14 percent compared to annual growth in inflation of 6.6 percent, the growth has not been steady and has come from a variety of sources. The following discussion details these trends.

1969 to 1973

Over the four-year period from 1969 to 1973, overall wage and salary income in the Tri-Cities SMSA grew at an annual average rate of 8.6 percent,

compared to a 4.6 percent annual growth in inflation (Table 8.11). The sector with the largest average income growth was Agriculture, with annual average growth of 21.4 percent. Construction and Durable Manufacturing had average annual growth rates of 16.4 percent and 16.2 percent, respectively, and Transportation and Public Utilities grew at a rate of 11.8 percent per year. The period showed 8.4 and 10.8 percent growth rates, respectively, in Retail Trade and Government, and 7.3 percent growth in Real Estate. Per capita personal income increased from \$3,600, to \$5,200, a total growth of 9.2 percent per year. With inflation growth over this period of 4.6 percent per year, real per capita income grew roughly 4.6 percent per year.

1973 to 1977

Annual income growth over the period 1973 to 1977 was 19.5 percent, a rate which is over twice the rate of the 1969 to 1973 period and over twice the 7.1 percent inflation rate for this period. Construction income showed the greatest increase, growing at an annual growth rate of 31.4 percent. At the Farm income declined 18.8 percent per year over the period, due to a sharp increase in farm income in 1974 and a sharp decline in 1977. Many categories showed annual increases of more than 15 percent, including Manufacturing, Wholesale Trade, Services, and Finance, Insurance and Real Estate. Both Federal Civilian, and State and Local Government income experienced strong growth, while military income declined at an annual average rate of 10.1 percent. Per capita personal income grew 10.1 percent per year. Although this annual increase is larger than during the 1969 to 1973 period, per capita income did not keep pace with total income growth, reflecting the in-migration of workers in excess of available jobs. Real per capita income increased about 3.0 percent per year, which was less than the rate of the 1969 to 1973 period.

1977 to 1980

During the three-year period from 1977 to 1980, wage and salary income increased 15.0 percent. During this period, the annual inflation rate was 8.8 percent. The largest contributing sector was Agriculture, with 23.5 percent annual average growth over the period. Real Estate posted a 16.4 percent gain in income per year, and Manufacturing, Wholesale Trade, Services, and Govern-

ment each showed 14 percent or greater annual gains. Construction grew at an average annual rate of 13.3 percent over the period. All income categories had growth rates higher than the inflation rate for the 1977 to 1980 period. Per capita income grew 9.3 percent over the period. Inflation during this period was 8.8 percent, so real per capita income increased roughly 0.5 percent per year.

With reductions in total wage and salary employment, trade sector employment also fell. Adverse impacts were reduced because a portion of the activity within the trade sector is due to consumers outside the immediate Tri-Cities area, and because some of the local wholesale trade is linked to the export of agricultural food commodities (Washington State Employment Security, 1983).

8.1.4 Housing

Following the increases in population and employment that accompanied the WPPSS projects in the mid-1970s, the number of housing units also increased from 1970 to 1982, a total of 94.3 percent. Table 8.12 gives the historical number of housing units by type for Benton and Franklin Counties. The number of housing units began escalating in 1973, growing at an annual average rate of 7.8 percent through 1981. Since 1981, the annual average rate of growth has slowed to levels closer to the 1.6 percent rate that occurred prior to 1973. During the 1970 to 1982 period the number of mobile homes increased at the fastest rate (16.1 percent), followed by multi-family units (8.4 percent), and single-family homes (6.7 percent).

In 1982, single-family homes accounted for 69 percent of total housing units, multi-family units accounted for 20 percent, and mobile homes accounted for the remaining 11 percent. The single-family share was 76 percent in 1970, while the multi-family and mobile home shares were 19 and 5 percent, respectively. In periods of rapid growth in population and employment, as occurred in the Tri-Cities area, it is expected that the number of multi-family and mobile homes would grow more rapidly than the number of single-family homes.

Table 8.13 shows the number of housing units for the cities of Kennewick, Richland, and Pasco for 1975 to 1982. For all the years and types of housing shown, Kennewick had more housing units than the other two cities. Kennewick

TABLE 8.12. Number of Housing Units for Benton and Franklin Counties, 1970-1982

<u>Year</u>	<u>Single-Family Units</u>	<u>Multi-Family Units</u>	<u>Mobile Homes</u>	<u>Total Housing Units</u>
1970	22,798	5,568	1,605	29,971
1971	22,668	5,724	1,646	30,038
1972	22,725	5,759	1,663	30,146
1973	23,137	5,997	1,787	30,922
1974	24,336	6,379	1,995	32,710
1975	26,018	6,932	2,309	35,259
1976	28,804	7,857	2,953	39,614
1977	30,690	8,540	3,418	42,648
1978	34,038	9,703	4,437	48,178
1979	36,718	10,680	5,360	52,758
1980	38,409	11,327	5,996	55,732
1981	39,478	11,443	6,294	57,215
1982	40,186	11,648	6,406	58,240

Sources: Bureau of the Census (1972).
 Bureau of the Census (1982).
 Office of Financial Management (1982).
 Battelle Human Affairs Research Centers (1983).

also had a disproportionately large number of housing units compared with its corresponding share of the population. In 1975, Kennewick had 30 percent of the total Tri-Cities population, but 39 percent of the housing; in 1982 the proportions were 40 percent and 45 percent, respectively. Richland had a smaller proportion of housing than population, while Pasco had nearly equal proportions for both population and housing. From 1975 to 1981, Kennewick's annual average growth rates for each of the three types of housing were higher than the corresponding rates for Richland and Pasco, particularly for single-family units. This corresponds with Kennewick's rapid population growth for the same period. Growth in the number of mobile homes was the most similar among the three cities, while Pasco had a lower annual average growth rate in multi-family units than either Kennewick or Richland, which were similar. All three cities have experienced sharp declines in housing growth since 1981.

Vacancy rates for the Tri-Cities are presented in Table 8.14. Except for declines in 1978, vacancy rates for all types of housing have generally increased since 1975, with sharp rises after 1980. Multi-family units throughout the area have been hit hardest by increased vacancy rates,

TABLE 8.13. Number of Housing Units in Richland, Kennewick, and Pasco, 1975-1982

<u>All Housing Units</u>	<u>Richland</u>	<u>Kennewick</u>	<u>Pasco</u>
1975	10,969	11,807	7,689
1976	12,339	13,663	8,755
1977	13,561	16,267	9,500
1978	14,636	18,642	10,108
1979	15,139	20,008	10,880
1980	15,458	21,059	11,081
1981	15,912	22,247	11,876
1982	15,887	22,460	11,385
<u>Single-Family Units</u>			
1975	9,301	9,473	5,977
1976	10,370	9,812	6,165
1977	9,054	10,804	6,198
1978	9,523	11,567	6,691
1979	9,727	12,054	6,686
1980	10,156	12,699	6,805
1981	10,312	12,972	7,031
1982	10,192	13,555	6,749
<u>Multi-Family Units</u> ^(a)			
1975	1,151	1,368	924
1976	1,369	2,453	1,399
1977	3,795	3,658	1,999
1978	4,230	4,670	1,812
1979	4,340	5,592	2,405
1980	4,369	5,624	2,216
1981	4,443	6,404	2,820
1982	4,504	6,057	2,726
<u>Mobile Homes</u>			
1975	517	966	788
1976	600	1,398	1,191
1977	712	1,805	1,303
1978	883	2,405	1,605
1979	1,072	2,362	1,789
1980	933	2,736	2,060
1981	1,157	2,871	2,025
1982	1,191	2,848	1,410

(a) Includes condominiums.

Source: Tri-Cities Real Estate Research Council (1982).

TABLE 8.14. Vacancy Rates for the Tri-Cities, 1975-1983 (percent)

	<u>Tri-Cities SMSA</u>	<u>Richland</u>	<u>Kennewick</u>	<u>Pasco</u>
<u>All Housing Units</u>				
1975	0.6	0.7	0.7	0.3
1976	0.8	0.7	0.9	0.8
1977	1.7	0.8	2.1	2.1
1978	1.3	1.1	1.4	1.5
1979	2.0	1.7	2.3	1.9
1980	2.8	3.7	2.5	1.9
1981	4.3	3.5	5.3	3.4
1982	5.1	4.9	5.7	4.4
1983	8.6	9.1	8.7	7.7
<u>Single-Family Units</u>				
1975	0.5	0.7	0.4	0.3
1976	0.6	0.4	1.0	0.5
1977	0.9	0.3	1.2	1.1
1978	0.9	1.1	0.9	0.9
1979	1.2	1.1	1.2	1.0
1980	1.2	1.4	1.2	1.1
1981	1.5	1.5	1.5	1.7
1982	2.5	2.5	2.7	1.9
1983	3.6	4.2	3.7	2.5
<u>Multi-Family Units^(a)</u>				
1975	1.6	1.2	2.7	0.3
1976	1.8	3.2	0.9	2.1
1977	4.1	2.2	5.3	5.3
1978	2.7	1.4	3.2	4.4
1979	4.4	3.1	5.2	5.2
1980	7.0	9.7	5.5	5.5
1981	11.4	8.4	14.4	9.2
1982	12.1	10.9	13.8	10.1
1983	19.1	19.7	19.9	16.4
<u>Mobile Homes</u>				
1975	0.7	0.4	0.7	0.8
1976	0.6	0.0	0.1	1.1
1977	0.9	0.0	0.8	1.6
1978	0.6	0.2	0.6	0.9
1979	0.9	1.0	0.8	0.8
1980	1.6	1.5	2.2	1.0
1981	2.1	3.3	2.1	1.4
1982	3.2	2.0	2.6	4.9
1983	8.8	5.7	7.3	13.0

(a) Includes condominiums.

Source: Federal Home Loan Bank (1983).

followed by mobile homes, and lastly, single-family units. In 1983, Richland had the highest vacancy rate for single-family homes (4.2 percent), Kennewick had the highest rate for multi-family homes (19.9 percent), and Pasco had the highest rate for mobile homes (13.0 percent). Using the 8.6 percent vacancy estimate for all housing units for the entire Tri-Cities SMSA, there were about 5,000 vacant housing units in 1983.^(a)

8.1.5 Education

In 1981, the Tri-Cities area was served by 12 public school districts, 9 private schools, 8 vocational schools, a community college, and the Joint Center for Graduate Study, which offers undergraduate and graduate degrees through several Washington and Oregon universities. Public school enrollment for Benton and Franklin Counties is given in Table 8.17 for the years 1970 to 1983 (where available). Total enrollment for Benton and Franklin Counties combined increased 10.2 percent, from 24,579 in 1970 to 27,075 in 1982. Enrollments in both counties were falling prior to 1974, increasing through 1981, then falling again in 1982 and 1983. Franklin County enrollments varied less than Benton County enrollments. Table 8.15 also gives the enrollments for Richland,

TABLE 8.15. Public School Enrollment in the Tri-Cities SMSA, 1970-1983

<u>Year</u>	<u>Benton County</u>	<u>Franklin County</u>	<u>Richland</u>	<u>Kennewick</u>	<u>Pasco</u>
1970	18,002	6,577	7,322	7,598	5,152
1971	17,760	6,425	7,224	7,418	5,006
1972	17,602	6,234	7,160	7,376	4,869
1973	17,475	6,015	7,036	7,401	4,655
1974	17,838	5,981	7,206	7,565	4,565
1975	18,823	6,302	7,321	8,212	4,816
1976	19,832	6,431	7,757	8,576	4,946
1977	20,776	6,282	7,993	9,224	4,907
1978	21,592	6,383	8,201	9,658	4,991
1979	21,840	6,464	8,071	9,927	5,058
1980	21,288	6,438	7,833	9,688	5,096
1981	21,727	6,590	7,760	10,045	5,249
1982	20,552	6,523	7,087	9,578	5,114
1983	NA	NA	7,050	10,089	5,330

Sources: Pacific Northwest Laboratory.
Educational Service District 123 (1983).

(a) Estimated using the 1982 total for housing units (58,240 units) from Table 8.12.

Kennewick, and Pasco. Kennewick had both the most students and experienced the most growth during the 1970 to 1983 period. The teacher-to-student ratio in elementary through high school classes is approximately 1 to 23 in Pasco, 1 to 21 in Kennewick, and 1 to 22 in Richland.

Table 8.16 gives the 1981 estimates of public school capacity and enrollment. All the districts except Kennewick had significant amounts of unused capacity and even Kennewick had some unused capacity. Because enrollment has declined since 1981, additional unused capacity is available in 1983. The districts are experiencing fewer facility strains than in the mid-1970s, although some have used portable classrooms to accommodate temporary expansion needs. In the past 3 years, the area has seen the construction of two new high schools, four new elementary schools, and the expansion of existing buildings to add classrooms (U.S. Department of Energy 1982).

Public school expenditures are presented in Table 8.17 for 1970 to 1981. Both total expenditures and expenditures per student fell from 1970 to 1972, increased steadily through 1980, then fell again in 1981. Broken down by county, expenditures increased at an annual average rate of 4.9 percent in Benton County and 2.6 percent in Franklin County between 1972 and 1980. Part of the increase was due to increased enrollment and part was due to increased expenditures per student. Expenditures per student grew at an average annual rate of 2.2 percent in Benton County and 1.4 percent in Franklin County from 1970 to 1981. Expenditures for education generally kept up with the changing enrollment patterns that followed the changing population growth patterns in the Tri-Cities area during the 1970 to 1982 period.

8.1.6 Public Services

Public services discussed in this section include public utilities, public safety, health care and human services, and libraries, historical and cultural resources. Because historical data are not readily available for these categories, only the most recent data will be presented here. Information on government expenditures for public services is covered in Section 8.1.9.

TABLE 8.16. Enrollments and Capacities of School Districts in the Immediate Tri-Cities Area, 1981

<u>School District</u>	<u>Enrollment</u>	<u>Capacity</u>	<u>Non-Utilized Capacity</u>
Columbia (No. 400)	886	1,129	243
Finley (No. 503)	902	1,163	261
Kennewick (No. 017)	10,604	11,290	686
Kiona-Benton (No. 052)	1,163	1,625	462
Pasco (No. 001)	5,535	7,016	1,481
Richland (No. 400)	8,308	10,103	1,795

Source: Puget Sound Power & Light (1981).

TABLE 8.17. School District Expenditures in Benton and Franklin Counties, 1970 to 1981 (dollars)

<u>Year</u>	<u>Benton-Franklin Total Expenditures</u>	<u>Expenditure per Student</u>
1970	44,572,169	1,813
1971	41,946,001	1,734
1972	39,359,327	1,651
1973	41,550,143	1,769
1974	43,003,553	1,805
1975	46,182,910	1,838
1976	51,307,339	1,954
1977	55,825,772	2,063
1978	59,433,278	2,125
1979	62,643,395	2,213
1980	62,885,628	2,268
1981	58,499,186	2,066

Source: Battelle, Human Affairs Research Centers (1983).

Public Utilities

The water systems of Benton City, Kennewick, Prosser, Richland, West Richland, and Pasco were operating at less than capacity in 1981. The City of Richland has the largest water supply system capacity in the area with an ability to supply 178.8 million liters per day (mld) while experiencing a maximum daily usage of 140.0 mld; it was operating at 84 percent of capacity in 1981. Pasco has a water supply capacity of 73.8 mld and treatment capacity of 70.0 mld, while experiencing a maximum daily use of 56.0 mld in 1980. Kennewick's water treatment facility is designed for 113.6 mld and was operating at 28.4 mld, with wells producing 54.9 mld, for a total system capacity of 83.3 mld. Maximum daily use in Kennewick in 1981 was 64.3 mld. The three smaller cities in the study area have municipal water systems that supply water in excess of 22.7 mld while experiencing a maximum daily usage total somewhat larger than 15.1 mld in 1981 (PSP&L 1982).

The major incorporated areas of Benton and Franklin Counties are served by municipal waste-water treatment systems, whereas the unincorporated areas are served by onsite septic systems. The Kennewick system is running at about 73 percent of capacity and the Pasco system is running at about 26 percent of capacity. Richland's waste-water treatment plant is running near capacity and a new treatment plant is currently under construction, which should be on line in 1987 with capacity to serve 65,000 people. Both West Richland and Benton City are operating waste-water disposal systems at capacity and are moving to improve the situation. Prosser is operating well within system capacity limits, but has been violating Federal clean water standards (PSP&L 1982).

Solid waste disposal is currently supplied largely by the local governments through contractual agreements with private disposal companies; the City of Richland is the only jurisdiction to operate its own solid waste disposal service. Wastes collected in Richland are disposed in a sanitary landfill operated by the city in the Horn Rapids area. Wastes from Kennewick, Benton City, West Richland, and Pasco are disposed in the sanitary landfill operated by the City of Pasco. Current capacity in these landfills is adequate to meet existing and future needs through 1990 (PSP&L 1982).

Public Safety

Police protection in the Tri-Cities SMSA is provided by the Benton and Franklin County sheriff departments, local municipal police departments, and the Washington State Patrol division headquartered in Kennewick. Table 8.18 gives the number of staff and patrol cars for the major jurisdictions. The larger cities of Richland, Kennewick, and Pasco maintain the largest police personnel staffs with 55, 56, and 37 people, respectively. Of the incorporated areas, West Richland maintains the largest staff per thousand population (2.4 per 1000), whereas Kennewick and Richland have the lowest (1.6 per 1000). A ratio of 2.0 per 1000 is generally considered an appropriate level of service. Nearly all of the other municipal staffing levels are near the 2.0 per 1000 residents ratio, while the Benton County sheriffs are understaffed with a 0.7 per 1000 residents ratio (PSP&L 1982).

The police staffs in the Tri-Cities area have increased over recent years with population growth, as have the number of police calls. When the rate of crime per hundred thousand residents is compared for SMSAs in Washington State, the Tri-Cities has substantially lower rates than either Yakima or Spokane or the state as a whole. Table 8.19 gives the type and number of crimes in the Tri-Cities SMSA for 1980 (PSP&L 1982).

Jail facilities in the study area include county jails in both Benton and Franklin Counties, and city jails in Richland, Kennewick, and Pasco. In 1981, available jail facilities were inadequate; state-mandated improvements in

TABLE 8.18. Police Personnel in the Tri-Cities Area, 1981

<u>Type</u>	<u>Staff</u>	<u>Patrol Cars</u>
Benton City Municipal	5	2
Kennewick Municipal	56	17
Pasco Municipal	37	8
Richland Municipal	55	9
West Richland Municipal	9	3
County Sheriff, Benton County	25	16
County Sheriff, Franklin County	32	N/A

Source: PSP&L (1981).

TABLE 8.19. Type and Number of Crimes in the Tri-Cities SMSA, 1980

Area	Type and Number of Crimes						Mtr. Veh. Theft
	Murder and Manslaughter	Rape	Robbery	Assault	Burglary	Larceny- Theft	
Tri-Cities SMSA	6	39	76	314	1973	5,957	422
Kennewick	--	8	20	36	525	2,176	115
Pasco	4	10	39	111	560	1,510	115
Richland	1	4	8	83	400	1,369	70

Source: PSP&L (1981).

Benton County resulted in construction of a new 109-bed county jail scheduled to replace the existing 33-bed jail in 1983. Completion of this facility will alleviate prisoner overloads at the Benton County, Franklin County, Richland, and Kennewick jails. A juvenile justice center run jointly by Benton and Franklin County is located in Kennewick and has a capacity of 28 live-in juveniles.

Fire protection in the area is provided by municipal fire departments, and by fire protection units for specific service areas in Benton and Franklin Counties. The departments serving the area are listed in Table 8.20 along with data on staff size, and the service area covered. Only Pasco and Richland maintain exclusively full-time non-volunteer fire departments (PSP&L 1981). Mutual aid agreements have been established among the five incorporated areas in Benton County, Pasco, and rural areas of Benton and Franklin Counties to supply fire protection service. The mutual aid agreements allow jurisdictions to reinforce each other during emergency situations. Each specific fire protection unit is capable of offering better fire protection service because of the availability of backup personnel and equipment from the neighboring fire protection units.

Health Care and Human Services

Numerous health care facilities and services are offered within the Tri-Cities area. Four general hospitals, located in Richland, Kennewick, Pasco, and Prosser offer a total of 351 beds. Other facilities include a bi-

TABLE 8.20. Fire Protection Personnel Within the Tri-Cities Area, 1981

Fire Protec- tion Unit	Staff			Service Area
	Full Time	Volunteers	Total	
Kennewick	33	15	48	City
Pasco.	26	0	26	City
Richland	42	0	42	City
BCRFD No. 1	1	126	127	Kennewick Area
BCRFD No. 2	1	17	18	Benton City
BCRFD No. 3	1	11	12	Prosser Area
BCRFD No. 4	1	17	18	West Richland
BCRFD No. 5	1	68	69	Southeast of Prosser
FCRFD No. 3	3	65	68	Surrounds City of Pasco

Note: There are mutual aid agreements among all fire districts in the area. The "Tri-Cities Mutual Aid Agreement" (September 15, 1980) includes the cities of Pasco, Kennewick, Richland, BCRFDs Nos. 1, 2, 3, FCRFD No. 3, Walla Walla County, and the Rockwell Hanford Fire Protection Department.

Source: PSP&L (1981).

county medical health facility operated by the Benton-Franklin District Health Department, a medical clinic in Benton City, the Hanford Environmental Health Facility in Richland, and 4 minor emergency clinics. There is a large range of medical specialties among the approximately 125 physicians and 50 dentists in the Tri-Cities area. Seven nursing homes serve the area with a total of 411 beds. The Mid-Columbia Mental Health Center is the primary source of mental health services and currently provides direct service to 3 percent of the population, with approximately one practicing psychiatrist or psychologist for each 10,000 residents. Services include treatment for drugs, crisis intervention, family-planning programs, and some services for the developmentally disabled. Maximum inpatient capacity for the center will be reached with a population of 140,000 in the immediate Tri-Cities area, but outpatient services are more flexible and are influenced primarily by revenue availability and demand for services.

A broad range of social services is offered in the Tri-Cities area. Benton and Franklin Counties cooperatively provide extension programs, health services, and emergency services. State human service offices in the Tri-Cities

include the job services offices of the Employment Security Department, Food Stamp offices, the Division of Developmental Disabilities, financial and Medical Assistance, the Child Protective Service, emergency medical service, a senior companion program, vocational rehabilitation and various farm workers programs. The federal government maintains local Social Security offices.

In addition to these public human services programs, the area is also served by a large number of private agencies and voluntary human service organizations. Various organizations provide counseling programs on family problems, family planning, alcohol abuse, legal aid, behavioral difficulties, child placement, and aid to persons affected by various physical, emotional, and learning disabilities (PSP&L 1981). Table 8.21 lists several specific programs available in these areas.

Libraries and Historical and Cultural Sites

The Mid-Columbia Library District serves Benton and Franklin Counties from a main library located in Kennewick and maintains branch libraries in Benton City, West Richland, and Pasco. A bookmobile maintains a scheduled route throughout the rural areas of the library district, offering service to residents outside the incorporated areas. The cities of Richland and Prosser have their own library systems. Increased usage of library services has created a need for better facilities in West Richland and Benton City. Although population served by the Mid-Columbia District increased by more than 28,000 persons between 1977 and 1980, library material increased by only 2500 volumes (PSP&L 1982). Total Mid-Columbia volumes were 218,086 in 1980.

The Columbia River was one of the most densely inhabited regions of aboriginal North America. Sites along the Hanford reach of the Columbia are the only remaining archaeological evidence of the early cultures. Nine archaeological properties on the Hanford Reservation are listed in the National Register of Historic Places. Controlled access to the Hanford Site provides protection to the remaining sites. The known archaeological sites nearest the primary NPR site are some of the Rattlesnake Springs sites. Table 8.22 lists the historic places in counties adjacent to the Hanford Reservation.

8.1.7 Recreation

Many opportunities for both indoor and outdoor recreation are available in the Tri-Cities area as shown in Table 8.23. The Tri-City Court Club in

TABLE 8.21. Examples of Human Services Facilities and Organizations in the Tri-City SMSA

<u>Facility or Organization</u>	<u>Descriptive Comments</u>
911 Emergency Dispatch Center	Provides immediate referral to emergency information and dispatch of ambulance, fire, police, etc., services.
Benton-Franklin Association for Retarded Citizens	Counseling, recreation, transportation and referral services for learning-disabled individuals.
Benton-Franklin Developmental Center	Provides services and programs for developmentally disadvantaged children.
Catholic Family Services Lutheran Social Services of Washington	Provides foster care programs, family and individual counseling programs and adoptive services.
Children's Home Society of Washington	Residential treatment facilities and programs for emotionally disturbed children.
Columbia Industries	Assists the physically and mentally disabled towards meaningful employment through vocational evaluation, work training, job placement and sheltered employment.
Benton-Franklin Council on Aging	Program to provide meals, household assistance, health care and information and transportation services.
Evergreen Legal Services	Free legal aid program for civil cases involving low-income persons.
Good Shepherd Home	A residential treatment program for adolescent girls with behavior problems.
A Woman's Place	Crisis phone and temporary residence for women and their children who are victims of domestic violence.
Planned Parenthood of Benton-Franklin Counties	Family planning education, information and assistance programs.
Tri-Cities Chaplaincy	Chaplaincy service to those with life-threatening illnesses and their families, including a hospice program.
Tri-Cities Food Bank	Provides food for those in need.

Source: United Way (1983).

TABLE 8.22. Washington State Register of Historic Places in Counties
Adjacent to the Hanford Site (State of Washington 1981c)

Adams County

Dr. Frank R. B. Burroughs House, Ritzville^(a)
Stephen Devenish Rank, Ritzville vicinity
Nelson H. Greene House, Ritzville^(a)
Othello Museum and Arts Center, Othello
Seivers Brothers Ranchhouse and Barn, Lind vicinity^(a)
Strap Iron Corral, Hooper vicinity^(a)
Zion Congregational Church, Ritzville

Benton County

Benton County Courthouse, Prosser^(a)
Columbia Park (Bateman) Island, Kennewick vicinity
Coyote Rapids Archaeological District, Richland vicinity
Gable Mountain Archaeological Site, Richland vicinity
Glade Creek Site, Prosser vicinity^(a)
Hanford Island Archaeological Site, Richland vicinity^(a)
Hanford North Archaeological District, Richland vicinity^(a)
Locke Island Archaeological District, Richland vicinity^(a)
Rattlesnake Springs Sites, Richland vicinity^(a)
Ryegrass Archaeological District, Richland vicinity^(a)
Snively Canyon Archaeological District, Ringold vicinity^(a)
Telegraph Island Petroglyphs, Paterson vicinity^(a)
Wahluke Archaeological District, Richland vicinity
Wooded Island Archaeological District, Richland vicinity^(a)
Charles Conway House, Kennewick

Franklin County

Ainsworth, Pasco vicinity
Allen Rockshelter, Pasco vicinity^(a)
Burr Cave, Walker vicinity^(a)
Franklin County Courthouse, Pasco^(a)
Marmes Rockshelter, Lyons Ferry vicinity^(a)
James Moore House, Pasco^(a)
Palouse Canyon Archaeological District, Lower Palouse River vicinity
Pasco Carnegie Library, Pasco
Savage Island Archaeological District, Ringold vicinity^(a)
Strawberry Island Village, Pasco vicinity^(a)
Tri-Cities Archaeological District, Pasco vicinity
Windust Caves Archaeological District, Ice Harbor Reservoir, Snake River

Grant County

Grant County Courthouse, Ephrata^(a)
Lind Coulee Archaeological Site, Warden vicinity^(a)
Mesa 36, Soap Lake vicinity^(a)
Paris Archaeological Site, Vernita vicinity^(a)
Wilson Creek State Bank, Wilson Creek^(a)

(a) Also listed in the National Register of Historic Places (State of Washington 1981c).

Source: U.S. Department of Energy 1982.

TABLE 8.23. Examples of Physical Recreational Facilities Available in the Tri-Cities Area

<u>Physical Activity</u>	<u>Descriptive Comments</u>
Tennis	62 outdoor courts (e.g., Sylvester Park, Howard Amon Park, Pasco High School). Indoor courts at Tri-City Court Club and the Columbia Basin Racquet Club.
Golf	Six courses including Tri-City Country Club, Canyon Lakes and West Richland Municipal Golf Course. Several driving ranges and pro shops are also available.
Bowling	Lanes in each city including Atomic Bowling Center, Clover Leaf Lanes and Columbia Lanes.
Swimming	Private (e.g., Ranchette Estates) and public (e.g., Kennewick) swimming pools in the area. Boating, water-skiing and swimming on the Columbia River in the Tri-Cities area.
Ball	Baseball fields and basketball courts are located throughout the Tri-Cities including such places as Badger Canyon, Craighill Playgrounds, Stevens Playground and Lewis and Clark School. Soccer and football fields are also located in various areas.
Skating	Roller-skating, ice-skating and skateboard facilities.
Camping	Several hundred campsites within driving distance from the Tri-Cities area including Levy Park, Fishhook Park and Sun Lakes.
Fishing	Steelhead, sturgeon, trout, and crappie fishing in the lakes and rivers near the Tri-Cities area.
Hunting	Duck, geese, pheasant and quail hunting. Deer and elk hunting in the Blue Mountains and the Cascade Range.

Source: PSP&L (1981).

Kennewick and the Columbia Basin Racquet Club in Richland have indoor tennis and racquetball courts, pools, and exercise equipment. Several exercise clubs are also in business. Bowling lanes are available in each of the cities. Private and public swimming pools and ice-skating and roller-skating rinks are

also available. More than 15 movie theaters are found in the Tri-Cities, as well as several playhouses, a light opera company, the Mid-Columbia Symphony, and several art galleries.

Numerous tennis courts, ball fields, and six golf courses offer outdoor recreation to area residents and tourists. Camping sites and fishing areas are abundant within short driving distances of the Tri-Cities. The Columbia River Basin is also a popular area for migratory waterfowl and upland game bird hunting, and the Blue Mountains to the east and Cascades to the west offer opportunities for big game hunting, as well as hiking and skiing. Boating, auto racing, and hydroplane racing are also popular in the area. There are 134 outdoor recreation sites under local jurisdiction, 18 state sites, and 7 federal sites in Benton and Franklin Counties (PSP&L 1982).

8.1.8 Transportation

The Tri-Cities serves as a regional transportation and distribution center with major air, land, and river connections. The Tri-Cities Regional Airport, located in Pasco, provides passenger and freight service to other major cities. The Richland Airport has facilities for commuter and private air traffic, while the Kennewick Airport is limited to serving small private aircraft. Commercial rail service is based in Pasco and includes a passenger station and a major switching yard for freight traffic. Rail service within the Hanford Site is controlled and maintained by DOE. Port facilities for barge traffic on the Columbia River are available at each of the three cities. All three cities are also served by Greyhound bus service.

Primary roads in the area include Routes 12, 395, 260, and 17, and Interstate-82 currently under construction. Routes 240 and 24, which traverse the Hanford Reservation, are maintained by the State of Washington while other secondary roads within the Reservation are maintained by DOE. Bridges across the Columbia River currently exist at Vernita in the northwest corner of the Hanford Site and at two locations connecting Kennewick and Pasco. Currently, a new bridge is being constructed across the Columbia; it will connect Richland to West Pasco as part of the I-182 project. This bridge will reduce traffic congestion over the Yakima River bridge connecting Richland and Kennewick and should increase population growth in Pasco (U.S. Department of

Energy 1982). Major transportation facilities near and within the Hanford Reservation are shown in Figure 8.1.

Existing travel patterns and characteristics in the Tri-Cities area are heavily influenced by commuter travel generated on or near the Hanford Reservation. The recent history of traffic volumes on streets in the impact area has been one of growth since the mid-1970s, and has generally been parallel with the pattern of employment associated with Hanford. Traffic growth on the Yakima River Bridge (the "causeway"), for example, mirrors the year-by-year trend of combined DOE and WPPSS employment even to the 1980 "notch" in traffic volume (a sharp decrease) that occurred during the labor strikes. Traffic volumes on Stevens Drive and the Bypass Highway are similar. Traffic volumes peaked in 1981.

Most of the arterials serving the Tri-Cities area are two lanes wide; exceptions are Route 4, George Washington Way, Stevens Drive, and the Bypass Highway. Traffic along the routes serving Hanford exhibit some unusual and extreme characteristics. Peak hour traffic near the Hanford Reservation forms a much larger portion of daily traffic (15 to 20 percent) than the portion of peak hour traffic to daily traffic found in other urban areas. Average vehicle occupancy in the area varies from 1.5 to 1.7 persons per car, well above the more usual 1.2 found in other areas. The southbound peak hour traffic volumes on the Route 240 bridge across the Yakima River (the "causeway") approached 2,000 cars per lane per hour in 1981, which is near or at maximum capacity (PSP&L 1982).

Traffic congestion is heaviest during the evening peak hours. The most serious street capacity deficiencies in 1981, which was the peak traffic year, were observed at the intersection of the Bypass Highway with Van Giesen Street, and just north of the Yakima River Bridge where traffic from the Bypass Highway and George Washington Way merges. Current transit service is provided by crew buses serving the Hanford Reservation (but not including construction workers) and a local charter bus operation that also serves the Reservation (PSP&L 1982). The Ben Franklin Transit System, a publicly-owned urban transit operation established in 1981, provides general daytime transportation service throughout the Tri-Cities and also runs an express service for contractors on the outskirts of the Reservation.

FIGURE 8.1. Major Transportation Routes in the Tri-Cities Area Serving the Hanford Reservation

8.1.9 Public Revenues

Table 8.24 compares the 1983 budget revenues and expenditures for all funds for the cities of Richland, Kennewick, and Pasco. An examination of

TABLE 8.24. Estimated Revenues and Expenditures, All Funds 1983 Budget for Tri-Cities Dollars and Percent of Total Receipts and Expenditures

<u>Revenues</u>	<u>Richland</u>	<u>Kennewick</u>	<u>Pasco</u>
Service Charges	24,039,102 (36.4)	1,984,795 (7.1)	3,968,617 (32%)
Taxes	5,744,315 (8.7)	5,800,550 (20.8)	4,340,675 (35)
Intergovernmental Revs.	9,821,412 (14.8)	4,710,420 (16.8)	1,736,270 (14)
Licenses and Permits	342,500 (0.5)	279,000 (1.0)	124,019 (1)
Fines and Forfeitures	322,500 (0.5)		248,039 (2)
Miscellaneous and Interest	2,368,644 (3.6)	2,203,519 (7.9)	620,096 (5)
Utilities		4,305,000 (15.4)	
Nonrevenue Receipts	1,097,080 (1.5)		
Intergovernmental Servs (R)/ Interfund Transfers (K)	1,549,356 (2.5)	2,220,942 (8.0)	
Beginning Fund Bal (R)/ Cask (K)/Resources Forward (P)	20,729,907 (31.4)	6,424,136 (23.0)	1,364,212 (11)
Total Revenue	66,155,316	27,928,362	13,401,929
<hr/>			
<u>Expenditures</u>			
Personal Services	13,196,812 (20.0)	7,971,141 (28.5)	4,417,144 (35.6)
Supplies	113,025 (1.7)	854,521 (3.1)	357,236 (2.9)
Debt Service	2,926,485 (4.4)	2,222,991 (8.0)	487,081 (3.9)
Service and charges	28,513,036 (43.1)	4,005,880 (14.3)	2,556,820 (20.6)
Capital Outlays	3,524,356 (5.3)	6,877,250 (24.6)	1,654,417 (13.3)
Council & Admin. Conting. (R)/ Ending Fund Balance (K) P)	15,504,403 (23.5)	3,775,637 (13.5)	2,578,989 (20.8)
Transfers (R,K)/Gov't Services (P)	1,319,999 (2.0)	2,220,942 (8.0)	350,243 (2.8)
Total Expenditures	66,115,316	27,928,362	12,401,929

these shows several interesting differences in methods of raising and dispersing funds, and the overall size of the budgets for the cities.

Richland's total 1983 budget is \$66,155,316 while Kennewick's is \$27,928,352, or 42 percent of Richland's, despite similarly sized populations between the two cities. Pasco's budget is \$12,401,929. The major source of the disparity in budget size is the fact that Richland owns and operates four utilities: water, sewer, garbage, and electric. Kennewick and Pasco, on the other hand, operate only two: water and sewer. Further, Richland's electric utility fund alone for 1983 is \$32 million, overshadowing Kennewick's total utility fund of \$4 million. This amount accounts for virtually all of the difference in total budgets between the cities.

Other interesting differences occur in the manner in which the cities raise funds. Taxes account for 21 percent of Kennewick revenues and 35 percent of Pasco revenues, but only 9 percent of Richland revenues are attributable to taxes. However, service charges represent 36 percent of Richland revenues and only 7 percent of Kennewick's. Intergovernmental revenues, largely state and federal revenue sharing and grants distributed by a formula based on population, represent 14.8 percent of Richland's revenues, 18.8 percent of Kennewick's revenues, and 14 percent in Pasco. Funds raised from licenses and permits and miscellaneous sources are also roughly comparable. The funds marked "Beginning Fund Balance" in Richland, "Cash" in Kennewick, and "Resources Forward" in Pasco represent roughly comparable funds. These funds enable certain revenues to equal expenditures, a requirement set out by state law. The use of such funds also allows city disbursements to proceed smoothly throughout the year despite the "chunkiness" in certain revenues.

Revenue sources particularly vulnerable to shifts in population, employment, and the business sector include some tax revenues (sales tax and business license tax), building permit revenues, and some state-shared revenues. The special revenues derived from the WPPSS construction were used by Richland's government mainly for special projects, so basic services and revenues were not greatly affected by the shift in WPPSS fortunes.

Expenditures in major city budget categories were roughly comparable among the three cities with the major exception of services and charges, where

43 percent of Richland's budget fund services; Kennewick's service charges account for only 14 percent of outlays. Again, Richland's electric utility accounts for most of the difference.

Few of these expenditure categories vary greatly with economic conditions or population. Funding for police and fire protection (Table 8.25) increased rapidly from 1978 to 1981, but increased gradually (or fell slightly for fire) between 1981 and 1983, even though the population fell.

Tables 8.26, 8.27, and 8.28 show local government revenues and expenditures for the current or general funds for the three cities (Richland, Kennewick, and Pasco, respectively) for 1981 to 1983.^(a) These funds represent operational revenues and expenditures. They are a suitable basis for analysis because they tend not to fluctuate based on one-time events and, therefore, better portray the underlying fiscal structure of the area.

TABLE 8.25. Tri-Cities Police and Fire Protection, 1978 and 1983

City		Personnel			Officers per 1000 Residents			Budget (million \$)		
		1978	1981	1983	1978	1981	1983	1978	1981	1983
Richland	Police	51	55	55	1.6	1.6	1.7	1.25	2.0	2.5
	Fire	38	42	42.5	1.2	1.2	1.3	1.1	1.6	1.65
Kennewick	Police	35	56	58	1.3	1.6	1.6	1.2	2.1	2.5
	Fire	30 ft ^(a) 14 Vol	33 ft 15 Vol	37	1.1 ^(b)	0.95 ^(b)	1.0	0.84	1.2	1.4
Pasco	Police	38	37	39	2.4	2.0	2.0	0.90	1.36	1.55
	Fire	26	26	27	1.6	1.4	1.4	0.66	0.84	1.02

(a) FT denotes full-time personnel.

(b) Based on number of full-time personnel.

Source: Richland, Pasco, Kennewick City Budgets (1978, 1981, 1983).

(a) The term "actual" budget refers to actual receipts and expenditures tallied after the end of the financial year. "Preliminary" budgets are proposed, but not yet approved by the Council. "Adopted" (or "final") budgets have been approved by the City Council, and "revised" budgets are revised midway through the financial year with adjustments and corrections made for known contracts, outlays, etc.

TABLE 8.26. City of Richland General Fund Revenues and Expenditures
(dollars)

<u>Revenues</u>	<u>1981 Actual</u>	<u>1982 Revised</u>	<u>1983 Final</u>
General Property Tax	1,492,079	1,665,915	1,851,729
Retail Sales and Use Tax	751,046	847,000	906,000
Other Taxes	1,745,830	1,885,117	2,226,908
Licenses and Permits	342,434	286,833	342,500
Charges for Services	627,140	450,579	501,850
Fines and Forfeitures	238,015	300,000	320,000
Intergovernmental Revenues	3,118,129	3,187,742	3,321,409
Miscellaneous Revenue	763,002	406,804	301,346
Nonrevenue Receipts	<u>4,617</u>	<u>35,660</u>	<u>39,000</u>
Total Current Revenue	9,082,292	9,065,650	9,810,742
Beginning Fund Balance	<u>1,915,844</u>	<u>2,011,932</u>	<u>1,312,482</u>
Total Available Revenue	10,998,136	11,077,582	11,123,224
<u>Expenditures</u>			
Personal Services	6,028,174	6,377,903	7,235,993
Supplies	236,761	259,072	273,994
Charges and Services	1,916,557	1,893,871	1,863,108
Capital Outlay	95,303	242,657	148,814
Debt Service and Reserves	-17,006	17,337	171,503
Transfer from General Fund	692,403	948,407	865,542
Admin. and Council Contingency	<u>0</u>	<u>25,853</u>	<u>56,527</u>
Total Requirements	8,986,204	9,765,100	11,123,224
Ending Fund Balance	2,011,932	1,312,482	0

Source: City of Richland Budget (1983).

TABLE 8.27. City of Kennewick, Current Fund Revenues and Expenditures

<u>Revenues</u>	<u>1981 Actual</u>	<u>1982 Budgeted</u>	<u>1983 Adopted</u>
Property Taxes	1,709,905	1,976,000	2,216,000
Retail Sales and Use Taxes	1,507,467	1,750,000	1,450,000
Business and Utility Taxes	1,258,842	1,388,000	1,575,000
Other Taxes	347,614	350,000	355,000
Licenses and permits	355,061	331,300	279,000
Intergovernmental Revenue	946,165	1,132,125	1,054,531
Charges for Services	717,391	872,025	909,200
Fines and Forfeitures	318,360	300,000	310,000
Miscellaneous Revenue	481,428	404,200	352,500
Nonrevenue Receipts	0	17,515	16,500
Other Financing Sources	<u>439,223</u>	<u>749,401</u>	<u>561,415</u>
Total Current Expense Revenue	8,081,556	9,270,566	9,079,146
Cash on hand and Begin. Fund Bal.	<u>732,359</u>	<u>850,570</u>	<u>865,000</u>
Total Current Expense Fund	8,813,915	10,121,136	9,944,146
<u>Expenditures</u>			
Personal Services and Benefits	4,825,171	5,600,777	5,806,101
Capital Outlay	201,023	349,870	130,250
Debt Service	260,868	380,393	398,400
Supplies	164,111	215,080	228,821
Other Services and Charges	1,762,594	2,196,258	2,099,326
Interfund Transfers	746,000	988,100	972,277
Ending Fund Balance	<u>0</u>	<u>390,658</u>	<u>308,971</u>
Total Current Expense	7,959,767	10,121,136	9,944,146

Source: City of Kennewick Budget (1983).

TABLE 8.28. City of Pasco, General Fund Revenues and Expenditures

<u>Revenues</u>	<u>1981 Actual</u>	<u>1982 Revised</u>	<u>1983 Final</u>
Real and Personal Property Taxes	715,036	764,000	950,000
Retail Sales and Use Taxes	709,188	650,000	654,000
Other Taxes	882,491	1,148,800	1,344,900
Licenses and Permits	124,334	142,000	107,000
Intergovernmental Revenue	917,649	781,900	640,625
Charges for Services	121,656	137,755	135,900
Fines and Forfeitures	162,319	165,000	150,000
Miscellaneous Revenue	730,045	621,201	561,550
Intragovernmental Services	<u>0</u>	<u>0</u>	<u>257,692</u>
Total Current Revenues for Fund	4,362,718	4,410,656	4,801,667
Est. Cash Plus Begin. Balance	<u>0</u>	<u>295,247</u>	<u>175,249</u>
Total for Fund	4,362,718	4,705,903	4,976,916

<u>Expenditures</u>	<u>1982 Revised Budget</u>	<u>1983 Prelim. Budget</u>
City Council	39,580	35,954
Municipal Court	118,971	132,164
City Manager	89,454	89,818
City Attorney	76,860	80,494
Police	1,467,477	1,547,913
Fire	943,780	1,022,116
Parks/Recreation	466,011	499,324
Community Development	187,328	192,240
Engineering	194,042	196,072
Administration Services	609,643	584,400
Miscellaneous Nondepartmental	505,188	405,113
Library	<u>177,990</u>	<u>191,308</u>
Total General Fund	4,876,324	4,976,916

Source: City of Pasco Budget (1983).

Within Richland's general fund (Table 8.26), the most volatile revenue categories over the period 1981 to 1983 have been Licenses and Permits, Charges for Services, and Miscellaneous Revenue, all of which fell in 1982 and rose again in 1983. The largest of component changes included declines in the demand for engineering services, in zoning and subdivision fees, in interest in loans, in leases and rentals, and a substantial decline in building permit revenues. Revenue categories experiencing growth over the period included all tax categories, Fines and Forfeitures, Intergovernmental Revenues, and Non-revenue Receipts.

Kennewick's current fund revenues and expenditures are detailed in Table 8.27. Categories showing variable or declining revenues for the 1981 to 1983 period, include Retail Sales and Use Taxes, Licenses and Permits, Miscellaneous Revenues, and the category "Other Financing Sources". Sources of these variations include changes in sales tax laws on food, and declines in building permits, construction engineering revenues, and interest on investments. Categories experiencing growth in revenues include Property Taxes, Business and Utility Taxes, Other Taxes, and Charges for Services.

Pasco's general fund revenues and expenditures for 1981 to 1983 are shown in Table 8.28. Major revenue categories with variable or declining trends include Retail Sales and Use Taxes, Licenses and Permits, Intergovernmental Revenues, and Miscellaneous Revenues. Sources for these variations include changes in the sales tax laws and collections, variation in building permits, large declines in federal grants, variations in liquor board profits, and declines in interest on investments, rents and surplus sales. Growth sectors included Real and Personal Property Taxes, Other Taxes, and Intragovernmental Services.

Table 8.29 shows a time series of total revenues and tax revenues for current operating funds for Richland, Kennewick, and Pasco for the period 1975 to 1981, and per capita revenues by source.^(a) Average annual growth rates

(a) Figures on city budget revenues from Table 8.29 are not strictly comparable with the figures in Tables 8.24, 8.26, 8.27 and 8.28. The figures for Tables 8.24 and 8.26 to 8.28 are derived directly from the 1983 city budgets. Table 8.29 is based on a time series from the Auditor of the State of Washington. There are no checks provided between the two sources to ensure compatibility, so the reader should avoid comparisons. Similar problems occur with Tables 8.31 and 8.32. are also given.

TABLE 8.29. Per Capita Revenue for the Tri-Cities, 1975-1981 (in 1981 dollars)

	Year	Property Taxes	Per Capita Revenue	Excise Tax	Per Capita Revenue	Business Taxes	Per Capita Revenue	Total Taxes	Per Capita Revenue	Total Revenue	Per Capita Revenue
Richland											
	1975	1,127,773	39	714,311	25	1,186,853	41	3,029,168	106	6,723,771	235
	1976	1,225,289	41	877,159	29	1,458,893	49	3,561,460	119	6,486,771	216
	1977	1,539,241	50	1,082,263	35	1,446,631	47	4,074,362	131	8,515,293	274
	1978	1,678,449	52	1,271,365	39	1,574,337	49	4,753,595	147	13,104,340	405
	1979	1,525,870	45	973,755	29	1,811,779	54	4,514,010	135	9,754,866	291
	1980	1,669,183	50	903,877	27	1,650,385	49	4,379,341	130	10,503,969	313
	1981	1,887,934	56	954,829	28	1,614,112	48	4,725,497	140	10,047,436	298
Annual Growth Rate 1975 to 1979 (%)	7.6	3.6		7.7	3.7	10.6	6.9	10.0	6.0	9.3	5.3
Annual Growth Rate 1975 to 1981 (%)	8.6	6.0		4.8	1.9	5.1	2.6	7.4	4.6	6.7	4.0
Kennewick											
	1975	780,485	43	988,205	54	384,269	21	2,152,959	118	4,597,510	252
	1976	835,850	39	1,480,891	70	555,886	26	2,872,627	135	5,265,342	247
	1977	1,432,496	61	1,462,512	62	927,001	39	3,984,221	169	8,643,419	366
	1978	1,484,381	56	1,719,650	65	891,816	34	4,356,483	164	9,462,548	356
	1979	1,573,490	53	1,707,519	57	1,092,791	37	4,702,609	158	9,608,454	322
	1980	1,683,750	49	1,583,352	46	1,191,949	35	4,806,887	140	9,280,832	270
	1981	1,910,249	55	1,507,467	43	630,500	18	4,395,828	127	8,921,356	257
Annual Growth Rate to 1979(%)	17.5	5.2		13.7	1.4	26.1	14.2	19.5	7.3	18.4	6.1
Annual Growth Rate to 1981(%)	14.9	4.1		7.0	-3.8	8.3	-2.6	11.9	1.2	11.0	0.3
Pasco											
	1975	668,711	46	921,795	64	469,375	32	2,074,127	144	5,306,397	367
	1976	704,458	48	1,133,045	78	524,203	36	2,388,408	163	4,576,314	313
	1977	935,002	61	1,056,583	69	565,842	37	2,589,434	168	4,599,194	299
	1978	963,008	60	1,238,152	77	558,833	35	2,796,488	175	5,861,985	366
	1979	1,002,333	61	1,181,691	72	624,517	38	2,856,926	175	6,332,112	387
	1980	938,170	51	1,105,284	60	601,919	33	2,796,248	152	5,151,100	299
	1981	1,009,402	54	1,072,953	57	669,902	36	2,964,842	159	5,362,343	287
Annual Growth Rate to 1979(%)	10.1	7.1		6.2	2.9	7.1	4.3	8.0	4.9	4.4	1.3
Annual Growth Rate to 1981(%)	6.9	2.7		2.5	-1.9	5.9	2.0	6.0	1.7	0.2	-4.1
Tri-Cities Combined											
	1975	2,576,969	42	2,624,311	43	2,040,497	33	7,256,254	118	16,627,677	271
	1976	2,765,598	42	3,491,094	53	2,538,983	39	8,822,495	134	16,328,427	248
	1977	3,906,735	56	3,601,358	51	2,939,474	42	10,648,017	152	21,757,906	311
	1978	4,125,838	55	4,229,168	56	3,024,986	40	11,906,566	159	28,428,873	379
	1979	4,101,692	51	3,862,966	48	3,529,087	44	12,073,544	151	25,695,433	322
	1980	4,291,103	58	3,592,514	42	3,444,253	40	11,982,476	139	25,299,901	293
	1981	4,797,585	55	3,535,249	41	2,914,514	33	12,086,167	139	24,331,135	279
Annual Growth Rate to 1979(%)	11.6	4.9		9.7	2.8	13.2	7.2	12.7	6.2	10.9	4.3
Annual Growth Rate to 1981(%)	10.4	4.5		5.0	-0.8	5.9	0	8.5	2.7	6.3	0.5

Source: Washington State Office of the State Auditor, 1975-1981.

Although these data come from the same publications, some fairly wide variations between years occur. Some possible causes include effects on property, retail sales, and excise tax revenues due to city annexations of county property, changes in interest rates, changes in taxing rates (food tax, property tax, etc.) and special project levies.

Table 8.29 shows that real per capita revenues in the Tri-Cities fell initially, and then rose dramatically for two periods, and then fell again. Between 1975 and 1981, per capita total revenues grew at an average annual rate of 4 percent in Richland, 0.3 percent in Kennewick, fell 4.1 percent in Pasco, for an overall Tri-Cities growth of 0.5 percent. Analysis of total real revenues shows a 6.7 percent per annum growth in total revenues in Richland, 11.0 percent growth in Kennewick, 0.2 percent growth in Pasco, and 6.3 percent over the combined Tri-Cities. In each case, total revenues grew more rapidly than did per capita revenue. This holds true for each tax revenue source for each of the three cities.

Breaking revenues down by tax source shows fairly substantial rises in property tax revenues over the period. Property tax revenues rose at average annual rates equal to 8.6 percent in Richland, 14.9 percent in Kennewick, and 6.9 percent in Pasco. Per capita property taxes in each city rose, but at a slower rate. Similar patterns exist for the other tax revenues. The largest growth occurred in Kennewick's property, business, and excise taxes, Richland's property taxes, and Pasco's property taxes. In all cities per capita growth was greatest in the Property Taxes revenue category.

Examining the growth rates calculated for the sub-period 1975 to 1979 shows that growth in revenues (and in per capita revenues) from most sources was greater in the early part of the period, and slowed or declined thereafter. (The only exception is property tax revenues in Richland.) Some declines were particularly dramatic, including business taxes in Kennewick and Richland. Kennewick had 29.9 percent growth through 1979, declining to 8.6 percent over the entire period. Richland had 11.1 percent in the early period and 5.3 percent growth overall. Property taxes in Pasco grew 11 percent in the early period and 7.0 percent overall. Excise taxes showed considerable variation between the periods throughout the area. Growth rates through 1979 were

roughly twice what they were from 1975 to 1981, and per capita revenues from this source actually declined in Kennewick and Pasco as well as in the combined Tri-Cities as a whole.

Examining the tax revenues from these cities shows that a higher proportion of Richland's revenues derive from business taxes, and that revenues from this source became an increased share of total revenues for Kennewick over this period. Also, although per capita revenues were highest in Pasco at the beginning of the period, by 1981 the more rapid and consistent growth in per capita revenues for Richland and Kennewick left all three cities at approximately the same level.

The high growth in revenues in Richland and Kennewick reflects the rapid expansion of activities at the Hanford site over this period. Prior to this, population and employment were growing more rapidly in Franklin County than in Benton County. However, with the imminent completion (1985-1986) of the bridge connecting Pasco with Richland, Pasco stands to share more equally in Hanford-related activities in the future.

Table 8.30 shows the percentage each tax revenue source contributes to total top revenues, and the share that taxes contribute toward current operating revenues for Richland, Kennewick, and Pasco, 1975-1981. The data in Table 8.30 demonstrate that contributions from property taxes remained fairly stable over the period in all cities, and that roughly one-third of total tax collections derive from property taxes. Richland consistently receives a smaller share of total tax revenues from excise taxes, with the difference made up in business tax collections (which are higher than those in Kennewick and Pasco). Table 8.30 also shows that excise taxes as a share of total taxes have been decreasing over time in each of the three cities. Business taxes have shown much more variation as a share of total taxes in Richland and Kennewick than they have in Pasco. This may be related to the more direct involvement of these cities in the secondary effects related to the WPPSS activities. Tax contributions as a share of total operating revenues have averaged 45 percent in Richland, and in Kennewick around 49 percent. Disregarding the 1975 figure, taxes have contributed an average of 51 percent of total operating revenues in Pasco.

TABLE 8.30. Revenue Source Shares: 1975-1981. Richland, Pasco, Kennewick (as a share of operating revenues)

	Property Taxes share of total Taxes (%)	Excise Taxes Share of Total Taxes (%)	Business Taxes Share of Total Taxes (%)	Taxes as share of total operating revenues (%)
Richland				
1975	37	24	39	45
1976	34	25	41	55
1977	38	27	36	48
1978	35	27	33	36
1979	34	22	40	46
1980	38	21	39	42
1981	40	20	34	47
Kennewick				
1975	36	46	18	47
1976	29	52	19	55
1977	36	37	23	46
1978	34	39	20	46
1979	33	36	23	49
1980	35	33	25	52
1981	43	34	14	49
Pasco				
1975	32	44	23	39
1976	29	47	22	52
1977	36	41	22	56
1978	34	44	20	48
1979	35	41	22	45
1980	34	40	22	51
1981	34	36	23	55

Source: Calculated from Table 8.29

County Revenues

Table 8.31 shows current expense revenues for Benton and Franklin County for 1983. The major source of revenues for both counties is taxes. Over 61 percent of total current expense revenues in Benton County and 47 percent in Franklin County derive from taxes. Benton County relies more heavily upon tax revenues, with the major sources being property taxes (33 percent) and retail sales and use taxes (23 percent). As a share of total tax revenues, property taxes account for 53 percent, retail sales for 38 percent, and penalties for 8 percent in Benton County. Franklin County's most important contributors are property taxes at 64 percent of total taxes collected, retail sales taxes (17 percent) and penalties (19 percent).

Table 8.32 shows a time series of real and per capita county tax revenues by source; these categories represent major stable county revenue sources. Table 8.33 calculates the share each of the various sources contributes to total operating revenues. These figures show that since 1975 property taxes have been contributing decreasing shares of total taxes in Benton County, while the share deriving from excise taxes has been increasing. Further, total

TABLE 8.31. County Budgets: Benton and Franklin Counties, Current Expense Revenues, 1983

	Benton	Source as Share of Total Taxes (%)	Source as Share of Total Operating Revenue (%)	Franklin	Source as Share of Total Taxes (%)	Source as Share of Total Operating Revenue (%)
Property Taxes	3,000,000	53	32.7	1,390,809	64	30.1
Retail Sales & Use Tax	2,150,000	38	23.4	360,000	17	7.8
Excise Tax	60,000	1	0.7	7,000	0	0.1
Penalties on Delinquent Tax	428,000	8	4.7	400,000	19	8.7
Other Taxes	10			5,000		
TOTAL TAXES	5,638,010		61.4	2,162,809		46.8
License and Permits	94,650		1.0	75,000		1.6
State Shared Revenues and Grants	905,881		9.9	710,687		15.4
Miscellaneous and Interest Revenue	1,200,300		13.1	384,666		8.3
All Other Revenue Sources	<u>1,342,005</u>		<u>14.6</u>	<u>1,288,619</u>		<u>27.9</u>
Total Budgeted Revenues	\$9,180,846			\$4,618,708		

(a) Figures in parentheses are percentages of total operating revenue.

Source: Benton County Budget, 1983

Franklin County Budget, 1983

TABLE 8.32. Per Capita Revenue for Benton/Franklin Counties, 1975-1981 (in 1981 dollars)

	<u>Year</u>	<u>Property Taxes</u>	<u>Per Capita Revenue</u>	<u>Excise Tax</u>	<u>Per Capita Revenue</u>	<u>Total Taxes</u>	<u>Per Capita Revenue</u>	<u>Total Revenue</u>	<u>Per Capita Revenue</u>
Benton County									
	1975	2,586,822	34	1,657,056	22	4,370,750	57	8,736,543	113
	1976	2,650,098	31	1,810,452	21	4,581,187	54	11,604,481	138
	1977	3,144,684	35	1,673,816	19	4,955,697	55	10,613,215	117
	1978	3,330,944	34	3,332,423	34	6,839,207	70	13,134,110	134
	1979	3,372,405	32	4,509,694	43	8,036,075	77	14,660,784	140
	1980	3,627,004	33	3,590,590	33	7,413,348	68	14,819,489	135
	1981	3,694,838	33	3,561,368	32	7,561,793	68	15,117,687	136
Franklin County									
	1975	2,003,983	72	347,271	12	2,453,191	88	5,616,338	202
	1976	1,914,246	64	373,498	13	2,401,937	81	6,201,233	209
	1977	2,101,432	71	430,907	14	2,636,728	88	6,947,018	233
	1978	2,126,489	65	486,524	15	2,722,830	84	7,388,057	227
	1979	2,199,683	64	450,949	13	2,805,665	82	6,713,179	196
	1980	2,127,074	61	374,298	11	2,662,547	76	7,215,452	206
	1981	2,232,681	62	376,154	10	2,950,322	81	6,701,836	185

Source: Washington State Office of the State Auditor, 1975-1981.

taxes as a share of total revenues collected grew significantly between 1976 and 1979, and returned to 1975 levels in 1980 and 1981.

Franklin County figures in Table 8.33 show that property taxes are the major contributor of total tax revenues, but that the share declined between 1975 and 1981. The share of total taxes contributed by excise taxes grew between 1975 and 1978, but has fallen since then. The share of taxes represented by other sources has increased from 4 percent in 1975 to 11 percent in 1981. As a proportion of total revenues collected, taxes fell from 1975 to 1977, but have generally risen since that time.

TABLE 8.33. Benton/Franklin County Revenue Source Shares, 1975-1981
(Operating Revenues)

	<u>Property Taxes</u> <u>share of total</u> <u>Taxes (%)</u>	<u>Excise Taxes</u> <u>Share of Total</u> <u>Taxes (%)</u>	<u>Other Taxes</u> <u>Share of Total</u> <u>Taxes (%)</u>	<u>Taxes as share</u> <u>of total operating</u> <u>revenues (%)</u>
Benton County				
1975	60	38	2	50
1976	58	40	2	39
1977	63	34	3	47
1978	49	49	2	52
1979	42	56	2	55
1980	48	48	4	50
1981	49	47	4	50
Franklin County				
1975	82	14	4	44
1976	80	16	4	39
1977	80	16	4	38
1978	78	18	4	37
1979	78	16	6	42
1980	80	14	6	37
1981	76	13	11	44

Source: Calculated from Table 8.32.

Comparing Benton and Franklin County revenue sources shows that Franklin County has traditionally garnered a larger share of total tax revenues from property taxes than has Benton County, although the reliance on this revenue source in both counties has fallen since 1975. Excise taxes have been a more important contributor in Benton County (roughly 40 to 50 percent of tax

revenues) than in Franklin County (13 to 18 percent). In each year, Benton County's tax receipts made up a larger portion of the total operating revenue than in Franklin County.

In general, operating revenues grew more rapidly in Benton than in Franklin County between 1975 and 1981--9.1 percent compared to 2.9 percent (Table 8.32). Per capita revenues also increased rapidly in Benton County, while decreasing in Franklin County. Benton County received about 85 percent of the total revenue increase over the period (and about 80 percent of the two-county population increase) suggesting that Benton County residents received a larger share of revenue benefits over the period 1975 to 1981. With the opening of the I-182 bridge to Pasco it is possible that Franklin County will share revenue benefits from Hanford projects to a larger extent.

8.2 ALTERNATIVE BASELINE SCENARIOS

To measure the socioeconomic impacts of construction and operation of the NPR, a baseline for comparison is necessary. Because the future socioeconomic condition of the Hanford area cannot be known with certainty for the years coinciding with the NPR construction and operating schedules, four different baseline socioeconomic scenarios are developed. The scenarios are based on different assumptions about the level of primary employment in Benton and Franklin counties, projected without potential NPR employment. From the projected primary employment for each of the scenarios, estimates of secondary employment, population, and other socioeconomic impacts are made.

8.2.1 Methodology and Assumptions

Although assumptions about primary employment differ for each baseline scenario, some assumptions and methodological approaches are common to all four. All of the scenarios divide primary employment into three major categories, based on historical trends: WPPSS and its contractors, DOE and its contractors, and agriculture. Each of the four scenarios will be developed from estimates of employment for these three categories; then, using common multipliers, secondary employment effects and socioeconomic impacts will be estimated. All of the scenarios concentrate on the 1983 to 2010 period.

Because there is little chance of replacing, in the short run, the approximately 10,000 WPPSS jobs that have been lost between 1981 and 1984, and because this means there is somewhat less uncertainty about what will happen in the Tri-Cities economy during that time, all four baseline scenarios will rely on the same employment projections through 1984, and two of the scenarios share 1985 figures. The estimated primary and secondary employment impacts for these years are shown in Table 8.34. Primary sector jobs are projected to decrease until 1985, when a modest increase is estimated. A decline of 3,219 primary sector jobs between 1981 and 1982 was accompanied by an actual reduction in total employment of 5,800 jobs. This suggests that for every 10 jobs lost in the primary sector, an additional 8 jobs were lost in the secondary sector. From this observation a primary sector-based total employment multiplier of 1.8 was used to estimate the total employment figures for 1982 to 1985 shown in Table 8.34.

The population estimates in Table 8.34 are based on the assumptions that, during periods of declining employment, 25 percent of the workers losing their jobs leave the area, and that the average family size of the workers leaving the area is three. Population multipliers based on historical trends are not used because population multipliers observed during periods of increasing employment are not likely to be relevant during periods of declining employment, because population decreases more slowly during downturns than it increases during periods of increasing employment. Because most of the workers losing WPPSS jobs are construction workers who are relatively more mobile than other workers, a 25 percent out-migration rate is used. An average family size of three is used instead of the average construction worker household size of 3.4 (suggested by the socioeconomic literature), because single workers and workers with small families are more likely to migrate than workers with large families.

The loss in economic activity from 1981 to 1985 in the Benton and Franklin County area is significant, and will leave the area with excess capacity in housing and public services. Considerable growth would have to take place after 1985 before the area could begin to feel the pressures of growth experienced in the mid-1970s. All four baseline scenarios assume that the Supply System, DOE, and agriculture will continue to be the main economic

TABLE 8.34. Projected Primary and Secondary Employment in Benton and Frankling
Counties: 1981-1985

	Number of Workers					Average Annual Rate of Change
	1981	1982	1983	1984	1985	
Primary Sector						
WPPSS and contractors	11,728	8,841	4,376	920	920	-63.6%
OOE and contractors	11,880	11,500	12,485	12,485	12,485	1.2%
Agriculture	4,850	4,898	4,947	4,997	5,047	1.0%
TOTAL	28,458	25,239	21,808	18,402	18,452	-10.8%
Difference between years		-3,219	-3,431	-3,406	+50	
Secondary Sector	47,142	44,561	41,816	39,091	39,131	-4.9%
Total Employment	75,600	69,800	63,624	57,493	57,583	-6.8%
Total Population	148,260	143,910	139,278	134,680	134,950	-2.4%

Source: Battelle, Human Affairs Research Centers (1983).

drivers, but each scenario makes different assumptions about the future growth of these three sectors. The scenarios will be referred to in the remainder of this discussion as Scenarios A through D.

8.2.2 Scenario A

Baseline Scenario A predicts a low growth rate for all three primary employment sectors for the period 1985 to 208. The key assumptions that determine primary sector employment under this scenario are as follows:

1. The expected level of employment at WPPSS for 1985 (920 workers) will remain constant until 208. This implies that no further work is done on either WNP-1 or WNP-4.
2. Agricultural employment continues to grow at the moderate 1.0 percent per year rate assumed for the 1981 to 1985 period.
3. DOE and its contractor employment continues to grow at the moderate 1.2 percent per year rate assumed for the 1981 to 1985 period.

The projected total primary employment for each year from 1985 to 2010 for Scenario A is given in Table 8.35. The assumptions listed above result in about a 1.1 percent per year increase in primary employment over the forecast period.

The primary sector employment growth shown in Table 8.35 is used to project growth in total employment for the 1985 to 2010 period. Because even the 2010 total primary employment figure of 24,253 workers generated by Scenario A does not exceed the 28,500 workers employed in 1981, a multiplier of 1.8 is assumed to apply throughout the forecast period. This total employment multiplier is based on the ratio of the expected decrease in total employment between 1981 and 1985 of 18,017 persons to the expected decrease in primary employment between 1981 and 1985 of 10,006 jobs (Table 8.34). That is, for every 10 jobs added in the primary sector, it is expected that 8 secondary sector jobs would also be added to the Tri-Cities area economy. This is a conservative assumption, as 12 secondary jobs for every 10 primary jobs were added from 1973 to 1981. The secondary employment, total employment, and population projections under Scenario A are also shown in Table 8.35.

TABLE 8.35. Baseline Employment and Population Using Scenario A, 1985-2010

Year	WPPSS and its Contractors	DOE and its Contractors	Agriculture	Total	Secondary Sector Employment	Total Employment	Population
1985	920	12,485	5,047	18,452	39,131	57,583	134,945
1986	920	12,638	5,098	18,653	39,293	57,946	135,226
1987	920	12,788	5,149	18,857	39,455	58,312	135,501
1988	920	12,943	5,201	19,063	39,620	58,683	135,779
1989	920	13,099	5,253	19,272	39,787	59,059	136,061
1990	920	13,257	5,306	19,483	39,955	59,438	136,346
1991	920	13,417	5,359	19,696	40,126	59,822	136,634
1992	920	13,579	5,413	19,912	40,299	60,211	136,925
1993	920	13,743	5,467	20,130	40,474	60,604	137,220
1994	920	13,909	5,522	20,351	40,651	61,002	137,518
1995	920	14,077	5,578	20,575	40,829	61,404	137,820
1996	920	14,247	5,634	20,801	41,009	61,810	138,125
1997	920	14,419	5,690	21,029	41,193	62,222	138,433
1998	920	14,593	5,748	21,260	41,378	62,638	138,745
1999	920	14,769	5,805	21,494	41,565	63,059	139,061
2000	920	14,947	5,864	21,731	41,754	63,485	139,381
2001	920	15,128	5,923	21,970	41,946	63,916	139,704
2002	920	15,310	5,982	22,213	42,139	64,352	140,031
2003	920	15,495	6,042	22,458	42,335	64,793	140,361
2004	920	15,682	6,103	22,705	42,534	65,239	140,696
2005	920	15,872	6,164	22,956	42,734	65,690	141,034
2006	920	16,063	6,226	23,210	42,937	66,147	141,377
2007	920	16,257	6,289	23,466	43,142	66,608	141,723
2008	920	16,453	6,352	23,725	43,350	67,075	142,073
2009	920	16,652	6,416	23,988	43,560	67,548	142,428
2010	920	16,853	6,480	24,253	43,773	68,026	142,786

Source: Battelle, Human Affairs Research Center (1983).

Under Scenario A, the Tri-Cities baseline economy is projected to grow slowly during the 1981 to 2010 period. Total employment in the Tri-Cities SMSA will grow at an average annual rate of 0.7 percent, the lowest rate for any of the four baseline scenarios. The population multiplier of 0.75 is based on the observed relationship between total employment and population in 1981 to 1982; that is, the ratio of the decrease in population from 1981 to 1982 and the decrease in total employment during that year is 0.75. This conservative multiplier is used because employment does not reach 1981 levels throughout the forecast period in this scenario. These assumptions yield an annual rate of population increase between 1985 and 2010 of about 0.2 percent.

The low baseline economic growth predicted with the Scenario A assumptions will probably result in continued excess capacity in Tri-Cities area housing and schools. The persistence of low population growth into the 1990s could create fiscal problems for local governments accustomed to the revenue levels associated with the higher employment and population levels of 1981. Public revenues may not be sufficient for the maintenance of public service capacity, such as roads, water, and sewage systems, built during the WPPSS construction period. Revenue shortages could lead to higher local taxes, special levies, and long-term borrowing.

8.2.3 Scenario B

Scenario B projects a higher level of economic activity than Scenario A and is defined by the following assumptions about primary sector employment:

1. WNP-1 will be restarted in 1986 to 1987 and completed by 1991.
2. Agricultural employment will grow at an average annual rate of 6 percent until 1991, and at 3 percent thereafter until 2008.
3. DOE-related employment will grow at an average annual rate of 5 percent until 1991, and at 2 percent thereafter until 2008.

The assumption regarding the WNP-1 restart is based on internal studies conducted by the Supply System, and on publicity indicating that the restart costs may be too high in the 1990s for serious consideration. The 6 percent growth rate in the agricultural sector is based on the possibility of the development of another half million acres of irrigated farmland as a result of

the proposed second phase of the Columbia Basin project. This rate falls between the 8.7 percent average annual agricultural growth rate for 1967 to 1973 and the 4.2 percent rate for 1973 to 1981 (Battelle, Human Affairs Research Centers 1983). The DOE-related growth rate is based on DOE estimates of increased use of DOE facilities and contractors at Hanford for defense research. DOE employment growth was approximately 5 percent from 1970 to 1981.

Primary, secondary, and total employment for Scenario B are shown in Table 8.36. Rapid growth in WPPSS employment due to the restart in WNP-1 construction, plus strong steady growth in the DOE and agriculture sectors brings primary employment up to the 1981 peak of 28,500 workers in 1995. Under the Scenario B assumptions, primary employment will exceed 39,000 workers by 2010, a 39.4 percent increase over the 1981 peak level.

Recognizing the slack in the regional economy in 1985 caused by the reduction in primary sector employment from 28,500 in 1981 to 18,500 in 1985, it is assumed that, from 1985 onward, increases in the primary sector employment of up to 28,500 jobs would use the 1.8 total employment multiplier (explained under Scenario A). Increases beyond 28,500 jobs are assumed to have a 2.2 multiplier effect on total employment. The 2.2 multiplier used for the period 1996 to 2010 is derived from the experience of the WPPSS construction period, 1973 to 1981. Under these assumptions, growth in primary sector employment after 1995 has a higher rate of associated secondary sector growth compared with the period from 1985 to 1995.

For similar reasons it is assumed that the smaller population multiplier of 0.75 applies during the period when primary sector employment is returning to the former high level of 1981, and a larger population multiplier of 1.2 applies after that level is reached in 1995. The 1.2 multiplier is based on pre-WPPSS experience from 1965 to 1973 (Battelle, Human Affairs Research Centers, 1983). During that period, total population increased by 7,830 persons while total employment increased by 6,790. The level of moderate growth assumed under Scenario B is likely to more closely match the growth prior to the WPPSS construction period than the rapid growth that accompanied construction.

TABLE 8.36. Baseline Employment and Population Using Scenario B, 1985-2010

Year	WPPSS and its Contractors	DOE and its Contractors	Agriculture	Total	Secondary Sector Employment	Total Employment	Population
1985	920	12,485	5,047	18,452	39,131	57,583	134,954
1986	1,450	13,125	5,359	19,934	40,317	60,251	136,955
1987	5,800	13,798	5,690	25,289	44,600	69,889	144,183
1988	7,000	14,506	6,042	27,548	46,408	73,956	147,233
1989	5,600	15,249	6,416	27,265	46,182	73,447	147,233
1990	4,700	16,031	6,813	27,544	46,404	73,948	147,233
1991	1,600	16,853	7,234	25,687	44,919	70,606	144,726
1992	1,600	17,193	7,454	26,248	45,367	71,615	145,483
1993	1,600	17,541	7,681	26,822	45,827	72,649	146,259
1994	1,600	17,895	7,915	27,410	46,298	73,708	147,053
1995	1,600	18,257	8,156	28,013	46,780	74,793	147,866
1996	1,600	18,625	8,405	28,630	47,521	76,151	149,496
1997	1,600	19,002	8,661	29,262	48,279	77,541	151,165
1998	1,600	19,386	8,924	29,910	49,056	78,966	152,875
1999	1,600	19,777	9,196	30,573	49,853	80,426	154,626
2000	1,600	20,177	9,476	31,253	50,668	81,921	165,420
2001	1,600	20,584	9,765	31,949	51,503	83,452	158,258
2002	1,600	21,000	10,062	32,662	52,359	85,021	160,141
2003	1,600	21,424	10,369	33,393	53,236	86,629	162,070
2004	1,600	21,857	10,684	34,142	54,134	88,276	164,046
2005	1,600	22,299	11,010	34,909	55,054	89,963	166,071
2006	1,600	22,749	11,345	35,694	55,998	91,692	168,145
2007	1,600	23,209	11,691	36,499	56,964	93,463	170,271
2008	1,600	23,678	12,047	37,324	57,954	95,278	172,448
2009	1,600	24,156	12,414	38,169	58,968	97,137	174,680
2010	1,600	24,644	12,792	39,036	60,006	99,042	176,966

Source: Battelle, Human Affairs Research Centers (1983).

The projections shown in Table 8.36 imply that the excess capacity in housing, school, and public services developed from 1981 to 1985 would disappear in the 1990s. Increased public revenues that would accompany the restart of WNP-1, as well as the expansion of the DOE and agricultural sectors, should allow local government to expand public services as needed to keep pace with the economic expansion between 1995 and 2008. The rapid employment and population growth of the WNP-1 restart should not cause an exhaustion of current capacity, because it will peak in 1990 and then decrease in 1991. The steady growth of the other primary employment sectors will not match the 1981 peak until 1995, after which the moderate pace of growth should allow for a smooth increase in the capacity of the Tri-Cities infrastructure.

8.2.4 Scenario C

Scenarios C and D are calculated using a slightly different method than the one used for Scenarios A and B. The same assumptions about agricultural and WPPSS employment used in Scenario B are used for C and D, but instead of calculating future growth rates for total DOE employment based on general estimated DOE employment, the employment growth rate is calculated based on the estimated future employment generated by specific DOE projects. To do this, DOE employment is divided into employment growth for existing DOE projects and employment growth for new DOE projects. The key assumptions defining Scenario C are as follows:

1. WNP-1 will be restarted in 1986 to 1987 and completed in 1991.
2. Agricultural employment will grow at an average annual rate of 6 percent until 1991, and at a 3 percent rate from 1992 to 2008.
3. Existing DOE employment will grow at an average annual rate of 1.2 percent, while employment in new DOE projects will grow an average of 4 percent per year.

Primary, secondary, and total employment for Scenario C are shown in Table 8.37. The restart of WNP-1 again causes a primary employment bulge in the late 1980s; then steady growth to 2010 leads to a primary employment total of over 34,000 workers. The same total employment and population multipliers of 2.2 and 1.2, respectively, used in the later years of Scenario B are used.

TABLE 8.37. Baseline Employment and Population Using Scenario C, 1985-2010

Year	WPPSS and its Contractors	DOE and its Contractors	Agriculture	Total	Secondary Sector Employment	Total Employment	Population
1985	920	13,785	5,047	19,752	37,831	57,583	134,954
1986	1,450	13,988	5,359	20,797	39,085	59,882	137,713
1987	5,800	14,194	5,690	25,684	44,949	70,633	150,614
1988	7,000	14,405	6,042	20,454	40,765	61,219	143,554
1989	5,600	14,620	6,416	26,636	48,183	74,819	159,874
1990	4,700	14,839	6,813	26,352	47,956	74,308	159,491
1991	1,600	15,062	7,234	23,896	45,991	69,887	156,175
1992	1,600	15,290	7,454	24,344	46,529	70,873	157,161
1993	1,600	15,522	7,681	24,803	47,080	71,883	158,373
1994	1,600	15,759	7,915	25,274	47,645	72,919	159,616
1995	1,600	16,001	8,156	25,757	48,225	73,982	160,892
1996	1,600	16,248	8,405	26,253	48,820	75,073	162,201
1997	1,600	16,500	8,661	26,761	49,429	76,190	163,541
1998	1,600	16,758	8,924	27,282	50,054	77,336	164,916
1999	1,600	17,020	9,196	27,816	50,694	78,510	166,325
2000	1,600	17,288	9,476	28,364	50,694	79,058	166,983
2001	1,600	17,563	9,765	28,928	51,370	80,298	168,471
2002	1,600	17,842	10,062	29,504	52,061	81,565	169,991
2003	1,600	18,129	10,369	30,098	52,774	82,872	171,559
2004	1,600	18,421	10,684	30,705	53,502	84,207	173,161
2005	1,600	18,720	11,010	31,330	54,252	85,582	174,811
2006	1,600	19,025	11,345	31,970	55,020	86,990	176,219
2007	1,600	19,338	11,691	32,629	55,811	88,440	177,959
2008	1,600	19,657	12,047	33,304	56,621	89,925	179,741
2009	1,600	19,984	12,414	33,998	57,454	91,452	181,573
2010	1,600	20,319	12,792	34,711	58,310	93,021	183,456

Source: Pacific Northwest Laboratory

The out-migration rate remains at 25 percent for the years in which population decreases after completion of the WNP-1 plant (Section 8.2.1). The projections for Scenario C are fairly close to those for Scenario B.

Table 8.38 shows the steps used to derive the DOE primary employment figures contained in Table 8.37. Existing DOE programs and contractor employment was assumed to grow 1.2 percent per year, the rate of DOE employment

TABLE 8.38. DOE Employment for Scenario C, 1985-2010

<u>Year</u>	<u>Employment in Existing DOE Pro- jects and Contracts</u>	<u>Employment in New DOE Projects</u>	<u>Total DOE Employment</u>
1985	12,485	1,300	13,785
1986	12,636	1,352	13,988
1987	12,788	1,406	14,194
1988	12,943	1,462	14,405
1989	13,099	1,521	14,620
1990	13,257	1,582	14,839
1991	13,417	1,645	15,062
1992	13,579	1,711	15,290
1993	13,743	1,779	15,522
1994	13,909	1,850	15,759
1995	14,077	1,924	16,001
1996	14,247	2,001	16,248
1997	14,419	2,081	16,500
1998	14,593	2,165	16,758
1999	14,769	2,251	17,020
2000	14,947	2,341	17,288
2001	15,128	2,435	17,563
2002	15,310	2,532	17,842
2003	15,495	2,634	18,129
2004	15,682	2,739	18,421
2005	15,872	2,848	18,720
2006	16,063	2,962	19,025
2007	16,257	3,081	19,338
2008	16,453	3,204	19,657
2009	16,652	3,332	19,984
2010	16,853	2,466	20,319

Source: Pacific Northwest Laboratory

growth assumed for the 1981 to 1985 period when few DOE projects were under construction. From 1973 to 1977 DOE employment grew at a rapid 9.7 percent annual average rate, but since 1977 growth has been much slower, even declining in some years (see Table 8.4). Because most of the rapid DOE growth will occur in the construction of new projects, the growth rate of existing programs was assigned the lower 1.2 percent rate. Future employment growth in new DOE projects of 4 percent is based on an analysis of the construction and operation employment requirements and time schedules of the presently planned DOE projects that are most likely to be implemented: B-Plant Immobilization Pilot Plant (BIPP); 100 Area Decommissioning (100 D&D); Fuels and Materials Examination Facility (FMEF); Breeder Reprocessing Engineering Test Facility (BRET); Secure Automated Fabrication (SAF); Fusion Materials Irradiation Test Facility (FMIT); Process Facility Modification (PFM, to the Plutonium and Uranium Extraction Plant; PUREX); Waste Receiving and Processing Facility (WRAP); and the Special Isotope Separation Facility (SIS). Since many of the projects are only in the development stages, employment estimates used are preliminary. Because the scheduling of these projects tended to complement each other, employment growth was reasonably steady from 1985 to 1998.

Under the assumptions for Scenario C, the 1981 peak primary employment level of 28,500 will be reached in 1995. Once again, growth after this point is steady and Tri-Cities area government should be able to adjust its level of public services gradually. Primary employment is over 34,000 in 2010, and total employment reaches 93,000. Population between 1985 and 2010 is projected to increase 35.9 percent. The information currently available on the timing of the more likely new DOE projects shows a good dispersion of mainly medium and smaller projects, so that there is no year when construction of several projects combines to form a single employment impact equal to that of the WNP-1 restart.

8.2.5 Scenario D

Scenario D depicts the largest socioeconomic baseline condition for the Tri-Cities SMSA with the following key assumptions:

1. WNP-1 will be restarted in 1986-87 and completed in 1991.

2. Agriculture employment will grow at an average annual rate of 6 percent until 1991, and at 3 percent thereafter.
3. Existing DOE employment will grow at an average annual rate of 1.2 percent until 1990 and 2.2 percent thereafter. Employment from new DOE projects will grow at an average annual rate of 8 percent.

As show in Table 8.39, the WPPSS and agricultural primary employment sectors are the same as those assumed in Scenarios B and C, and the approach for calculating the DOE sector is the same as that used under Scenario C. In Scenario D, however, all of the currently planned DOE construction projects are assumed to be implemented instead of only the most likely ones covered in Scenario C. In addition to the facilities listed in Section 8.2.4, the Basalt Waste Isolation Project (BWIP), and the Hanford Defense Waste Project are assumed to be constructed. Available information about the timing of these projects and their employment levels suggest an average annual employment growth rate of 8 percent through 1998.

Because there is generally a 5- to 8-year lag time between the conception of a project idea and implementation, it is not unreasonable to assume that projects that would begin construction after 1998 have not even been proposed. The projects planned for 1985 to 1998 represent an assortment of different sized projects, although no single project is as large as WNP-1 in terms of construction employment. It is assumed that a similar assortment of projects will occur from 1998 to 2010 and the 8 percent is assumed to carry through the 1985 to 2010 period. The calculation of total DOE employment is shown in Table 8.40.

According to Scenario D, the 1981 peak employment level will not be regained until 1995. The economy, however, will be operating close to this peak from 1987 to 1995, and it is likely that public services, education and housing in the Tri-Cities will be triggered into growth. Total primary employment will reach a high of 45,763 in 2010, with corresponding total employment and population levels of 115,417 and 204,565, respectively.

TABLE 8.39. Baseline Employment and Population Using Scenario D, 1985-2010

Year	WPPSS and its Contractors	DOE and its Contractors	Agriculture	Total	Secondary Sector Employment	Total Employment	Population
1985	920	14,045	5,047	20,012	37,571	57,583	134,954
1986	1,450	14,321	5,359	21,130	38,912	60,042	137,905
1987	5,800	14,608	5,690	26,098	44,874	70,972	148,835
1988	7,000	14,908	6,042	27,950	47,096	75,046	153,724
1989	5,600	15,221	6,416	27,237	46,526	73,763	152,762
1990	4,700	15,679	6,813	27,192	46,490	73,682	152,701
1991	1,600	16,158	7,234	24,992	44,730	69,722	149,731
1992	1,600	16,657	7,454	25,711	45,593	71,304	151,629
1993	1,600	17,177	7,681	26,458	46,489	72,947	153,601
1994	1,600	17,723	7,915	27,238	47,425	74,663	155,660
1995	1,600	18,294	8,156	28,050	48,399	76,449	157,803
1996	1,600	18,891	8,405	28,896	49,414	78,310	160,036
1997	1,600	19,518	8,661	29,779	50,474	80,253	162,368
1998	1,600	20,176	8,924	30,700	51,579	82,279	164,799
1999	1,600	20,865	9,196	31,661	52,732	84,393	167,336
2000	1,600	21,591	9,476	32,667	53,939	86,606	169,992
2001	1,600	22,352	9,765	33,952	55,481	89,433	173,384
2002	1,600	23,154	10,062	34,816	56,518	91,334	175,665
2003	1,600	23,998	10,369	35,967	57,899	93,866	178,703
2004	1,600	24,887	10,684	37,171	59,344	96,515	181,882
2005	1,600	25,826	11,010	38,436	60,862	99,298	185,222
2006	1,600	26,816	11,345	39,761	62,452	102,213	188,720
2007	1,600	27,861	11,691	41,152	64,121	105,273	192,392
2008	1,600	28,965	12,047	42,612	65,873	108,485	196,246
2009	1,600	30,134	12,414	44,148	67,716	111,864	200,301
2010	1,600	31,371	12,792	45,763	69,654	115,417	204,565

Source: Pacific Northwest Laboratory

TABLE 8.40. DOE Employment for Scenario D, 1985-2010

<u>Year</u>	<u>Employment in Existing DOE Pro- jects and Contracts</u>	<u>Employment in New DOE Projects</u>	<u>Total DOE Employment</u>
1985	12,485	1,560	14,045
1986	12,636	1,685	14,321
1987	12,788	1,820	14,608
1988	12,943	1,965	14,908
1989	13,099	2,122	15,221
1990	13,387	2,292	15,679
1991	13,682	2,476	16,158
1992	13,983	2,674	16,657
1993	14,290	2,887	17,177
1994	14,605	3,118	17,723
1995	14,926	3,368	18,294
1996	15,254	3,637	18,891
1997	15,590	3,923	19,518
1998	15,933	4,243	20,176
1999	16,283	4,582	20,865
2000	16,624	4,949	21,591
2001	17,008	5,344	22,352
2002	17,382	5,772	23,154
2003	17,764	6,234	23,998
2004	18,155	6,732	24,887
2005	18,555	7,271	25,826
2006	18,963	7,853	26,816
2007	19,380	8,481	27,861
2008	19,806	9,169	28,965
2009	20,242	9,892	30,134
2010	20,687	10,684	31,371

Source: Pacific Northwest Laboratory

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9.0 EFFLUENT AND ENVIRONMENTAL MEASUREMENTS AND MONITORING PROGRAMS

This chapter describes the methods used to obtain baseline environmental data for the Skagit/Hanford Nuclear Plant (S/HNP) and describes programs that were proposed for monitoring the environmental impacts of site preparation and S/HNP construction and operation. The material in this chapter is taken directly from the environmental report on the S/HNP (PSP&L 1981a). It is believed that information on measurement and monitoring programs for the S/HNP is applicable to the NPR, because the reference location for the NPR is the same area PSP&L had proposed for locating the S/HNP.

As a result, the term "site" used in this chapter refers not only to that area on the Hanford Reservation proposed for the S/HNP, but also to the Skagit/Hanford Site for the NPR. In addition, although the term "facility" (in the context of PSP&L's environmental report) refers strictly to the S/HNP, it also refers to the NPR in this chapter.

Section 9.1 of this chapter discusses the proposed preoperational environmental programs, Section 9.2 discusses the proposed operational environmental monitoring programs, and Section 9.3 discusses related environmental measurement and monitoring programs. Appendix E provides a generic description of exposure pathways for reference.

9.1 PREOPERATIONAL ENVIRONMENTAL PROGRAMS

Preoperational environmental monitoring programs have been developed to assess the characteristics of the site and the surrounding region prior to facility operation. Portions of these programs will continue through facility operation. However, as data are collected and evaluated, the scope of these programs may change. The purpose of these programs is to establish a reference framework for assessing subsequent effects attributable to site preparation, facility construction, and station operation. Reports that present data and appropriate conclusions of monitoring efforts will be made available to federal and state agencies at the conclusion of each program. Technical descriptions of procedures, techniques, and instrumentation used in the preoperational studies are discussed in this subsection.

9.1.1 Surface Water

No surface water exists in the vicinity of the site. The Columbia River, 11 km (7 mi) to the northeast, will serve as the source for cooling water make-up, as well as the receiving body for wastewater discharges. The Yakima River, approximately 11 km (7 mi) south of the site, will not be affected by facility construction or operation. Sampling programs to determine preconstruction and preoperational baseline water conditions and the related ecology of the Columbia River are described in the subsequent sections.

9.1.1.1 Physical and Chemical Parameters

This section describes the monitoring programs developed to determine physical and chemical characteristics of the Columbia River in the vicinity of the facility intake and discharge structures (River Mile [RM] 361.5).

9.1.1.1.1 Preapplication Monitoring. The purpose of the preapplication monitoring program is to assess site acceptability with regard to thermal and chemical impacts that could result from operation of the facility. The following factors were considered in developing the preapplication monitoring programs for physical and chemical characteristics:

- existing environmental baseline data
- location and number of monitoring stations as required to consider the following factors
 - bathymetric characteristics in the vicinity of the intake and discharge structures
 - type of cooling system employed and its probable operating modes
 - transient hydrological parameters in the vicinity of the intake and discharge structures
 - vertical and horizontal temperature and salinity structure in the vicinity of the intake and discharge structures
- sampling frequency and times to ensure that important temporal variations were adequately monitored
- duration of monitoring programs
- data analysis procedures.

The Columbia River in the vicinity of the site has been studied for the last 36 years. These studies have included both general observations and detailed analyses of the impacts upon the river from plutonium reactor effluents. Study reports have been reviewed and summarized by Becker and Waddel (1972), and by Neitzel (1979), and they provide a comprehensive historical picture of water quality conditions in the river. Major information sources include publications by the U.S. Geological Survey (1981); the Washington Public Power Supply System (Supply System)^(a); Puget Sound Power & Light Company (1981a, Tables 2.14-2.17); U.S. Environmental Protection Agency (U.S. EPA 1979); and the Washington State Department of Ecology (1980). A summary of these data is included in Section 2.4 of Puget Sound Power & Light Company (1981a).

Two ongoing water quality monitoring programs in the Hanford Reach (see Section 9.3) are of particular interest. The U.S. Geological Survey (USGS 1981) has collected monthly water quality data since 1974 at a monitoring station located upstream of the facility at Vernita Bridge (RM 388.1). Parameters analyzed include an extensive list of general chemical, thermal, inorganic and organic constituents, as well as a full complement of nutrients, trace metals, and solid residues. Prior to 1974, samples were collected at Vernita Ferry (RM 394.5); however, this record is incomplete. Downstream of the site, the Supply System is conducting a one-year water chemistry study at RM 352.1. Their objective is to collect site-specific data and expand the preoperational data base for WNP 1, 2, and 4. Samples are collected weekly or monthly and analyzed for a full complement of parameters.

Because a comprehensive history of surface water data exists and because water quality sampling programs that bracket the area in the vicinity of the intake and discharge structures are in progress, a specific preapplication water quality monitoring program was unnecessary.

An instream data collection program for bathymetric survey and current velocity measurements was conducted from May 8 through May 11, 1981, along a 4-km (2.5-mi) portion (66 cross-sections) of the Columbia RM 361.5 where the

(a) Letter from R. A. Chitwood to J. Mecca, Washington Public Power Supply System, Columbia River Water Chemistry, February 26, 1981.

facility intake and discharge structures will be located (PSP&L 1981a, Appendix B). This program provides field-surveyed input data to various environmental analyses presented in this report, including the thermal plume modeling, the radionuclide dispersion calculations, the intake and discharge structures location, and the aquatic ecology studies.

The river discharge as measured below Priest Rapids Dam (RM 394.5) during the instream data collection program was 144,500 cfs. The discharge at RM 361.5, computed from the cross section area and depth profiles, was about 143,000 cfs. The maximum recorded velocity at RM 361.5 was about 2 m/sec (7.0 ft/sec) and was found in midstream. The intake and discharge structures will be located in a channel crossing where the transverse-channel profile is uniform. The main flow channel upstream of RM 361.5 is located along the east bank of the river and crosses to the west bank downstream of RM 361.5. The minimum bed elevation (maximum depth) in the vicinity of the intake and discharge structures is about 101 m (335 ft) above National Geodetic Vertical Datum (NGVD).

A continuous recording fathometer was used to obtain the hydrographic data. Horizontal positioning was accomplished with a navigation system and data processor. A 7-m (23-ft) survey vessel was used to collect the instream data. The vertical velocity profiles at RM 361.5 were obtained using a current meter. A complete description of the field work, station locations, equipment and procedures used, and results and discussion are presented in the instream data collection program report (PSP&L 1981a, Appendix B).

The stage-discharge relationship for the Columbia River at RM 361.5 was developed using the U.S. Corps of Engineers HEC-2 water surface profiles computer program (1981) with input data obtained from the instream data collection program. The general procedures for applying HEC-2 to the Columbia River, as described in Appendix B of Puget Sound Power & Light Company (1981a), include Columbia River model development, model calibrations, and computation of water surface profiles. The results of the calculations are presented in Section 2.4 of that document.

The thermal plume (dilution) analysis was conducted using a state-of-the-art mathematical model implemented on a high speed digital computer. The computer code, designated HOTSUB3, was adapted from the work of Koh and Fan (1970) and the U.S. Nuclear Regulatory Commission's (NRC's) Regulatory Guide 1.113 (1977). With an input of discharge design, discharge flow parameters, and receiving water characteristics, the code generates excess temperature (concentration) profiles in the ambient receiving water. The format of the output is such that isotherms (isopleths) may be plotted for horizontal planes at selected depths. In addition, by using the data from the isotherm (isopleth) contours, the program calculates corresponding surface areas and volumes. A complete description of the thermal plume modeling is presented in Appendix C of Puget Sound Power & Light Company (1981a).

9.1.1.1.2 Site Preparation and Construction Monitoring Program. A water quality monitoring program will be established to detect possible direct or indirect effects of site preparation and facility construction on surface waters, and to evaluate potential impacts on the Columbia River ecology. This program will also serve as part of the construction impact control program to ensure that construction activities will be performed in a manner to minimize scouring, erosion, runoff, turbidity, and toxicity.

A monitoring program will be initiated during excavation and backfilling activities for the intake and discharge structures. The basic program of water quality monitoring during construction will include measurements of total suspended solids (TSS), turbidity, light penetration, pH, oil and grease, temperature, and dissolved oxygen at stations located both upstream and downstream from the excavation site. Duplicate water samples will be collected at five locations (Table 9.1 and Figure 9.1).

Water samples will consist of a 1-liter (0.3 gal) aliquot taken from a composite of three subsurface grab samples per station. Samples will be returned to the laboratory for determination of total suspended solids (non-filterable residue) and for various calibration purposes. Water quality measurement from temperature, dissolved oxygen, pH, and turbidity will be conducted. The proposed analytical methods and levels of detection are presented in Table 9.2.

TABLE 9.1. Water Quality Sampling Stations for Site Preparation and Construction Monitoring Program

<u>Station</u>	<u>Location</u>	<u>Description</u>
WQ-1	RM 361.5 + 91 m (300 ft)	Control Station; 0.10 km (0.06 mi) upstream of the NPR intake
WQ-2	RM 361.4	D.16 km (0.1 mi) downstream of the NPR discharge
WQ-3	RM 361.3	0.32 km (0.2 mi) downstream of the NPR discharge
WQ-4	RM 359.5	3.2 km (2.0 mi) downstream of the NPR discharge
WQ-5	RM 351.9	WNP 1 and 4 intake; 15 km (9.6 mi) downstream of the NPR discharge.

Note: See Figure 9.1 for station locations.

In addition, samples of material to be dredged shall be collected and standard bulk sediment and elutriate testing performed (U.S. EPA 1979). Such tests delineate the type and amount of trace substances and the organic content of the material in question. Should results indicate high levels of contaminating substances, the basic monitoring program can be expanded to incorporate these parameters.

9.1.1.1.3 Preoperational Monitoring Program. The objective of the preoperational water quality monitoring program is to provide the data base necessary for identifying and assessing any changes in water quality resulting from plant operation. The monitoring program, to be initiated one year prior to fuel load, is designed to be compatible with the operational monitoring program (see Section 9.2).

0 1 2 MILES

MIXING ZONE

NO WATER QUALITY
STATION RECORD

Station (62567 10815)
Observations: water quality
sampling stations in the
estuary

FIGURE 3-1
Location of water quality

0 1 2 MILES

0 1 2 MILES

MO-1
MO-2
MO-3
MO-4
MO-5
BILLE POINT STATION
COLUMBIA RIVER
ESTUARY

0 1 2 MILES

0 1 2 MILES

COLUMBIA RIVER
ESTUARY

TABLE 9.2. Analytical Methods and Levels of Detection for Water Characteristics to be Measured During the Construction Monitoring Program (PSP&L 1981a)

Characteristic	Method	Detection Limit
1. Temperature	In situ Probe ^(a) W/ERTCD, ASTM mercury thermometers for calibration and verification	1.0°C
2. Dissolved oxygen	In situ Probe ^(a) W/Azide modification of Winkler Iodometric ^(d) for calibration and verification	0.10 mg/liter
3. pH	In situ Probe ^(a,b) W/Potentiometric (Corning 610A) for calibration and verification	0.1 pH units
4. Turbidity	In situ Turbidimeter ^(c) W/Nephelometric ^(d) formazin standards for calibration	0.01 NTU
5. Suspended Solids	Glass Fiber filtration ^(b) and gravimetric at 105°C (mettler balance) Preservation: cool to 4°C; 2 days maximum	1.0 mg/liter
6. Light Penetration	20 cm black and white Secchi Disk	
7. Oil and Grease	Solvent extraction, partition	1.0 mg/liter

(a) Hydrolab Corporation (1978)

(b) American Public Health Association, American Water Works Association, Water Pollution Control Federation (1980)

(c) Research Technology, Inc. (1979)

(d) U.S. EPA (1979)

The following factors were considered in developing the preoperational monitoring program for physical and chemical characteristics:

- the average and extreme extent and enclosed surface area of the limiting excess temperature isotherms as established by the state, by comparison with background and baseline data
- temperatures at positions appropriate to define the extent of the mixing zones.
- time-temperature relationships at biological monitoring stations.

Water quality characteristics, frequency of sampling, and the methods to be used in sample preservation and analysis are provided in Table 9.3. The study includes all of the physical and chemical parameters considered essential to characterize the water quality in the vicinity of the intake and discharge structures. Seven sampling locations, described in Table 9.4 and shown in Figure 9.1, have been established.

Three stations unique to the site will be sampled on a weekly or monthly basis depending on the parameter (Table 9.3). The stations include the facility intake (WQ-1), the downstream boundary of a legally defined mixing zone (WQ-2), and a station approximately 3.2 km (2 mi) downstream of the facility discharge in the major axis of the discharge plume (WQ-4). The remaining four stations (WQ-0, 5, 6, and 7) correspond to sampling locations for related monitoring programs (Section 9.3). These stations will be sampled quarterly to ensure that preoperational results can be correlated with other studies in progress. This objective will be accomplished by performing side-by-side sample collection and sample splitting with the various agencies or analytical laboratories involved.

The water quality parameters to be monitored were chosen to detect any possible direct effects of facility operation on the thermal regime or water quality characteristics of the Columbia River, and to detect possible synergistic effects that may affect the ecology of the Columbia River. General sampling and analytical procedures are discussed below.

Duplicate grab samples will be collected in the main river current approximately 30 cm (1 ft) below the water surface at each station. Samples collected

TABLE 9.3. Analytical Methods, Detection Limits and Preservation Techniques Proposed for the Water Quality Parameters to be Surveyed in the Preoperational Monitoring Program (PSP&L 1981a)

Parameter	Detection Units	Limit	Analytical Method	Calibration Method	Preservation Technique	Reference
WEEKLY SAMPLES						
Temperature	°C	-0.5	In situ Electrode	SSTCO ASTM Bq Thermometer	---	29
Dissolved Oxygen	mgO ₂ /l	0.1	In situ Electrode	(Iodometric Osterberg Modification)	Fix 2ml each HgSO ₄ , NaOH-KI, H ₂ SO ₄	29
pH	pH units	0.1	In situ Electrode	Potentiometric	Cool to 4°C; (6 hours) maximum	29, 33
Specific Conductivity	umhos/cm	0.00	In situ Electrode	0.01 M Potassium Chloride STD Solution	25°C	29
Turbidity	NTU	0.01	In situ Electrode	Nephelometric Turbidity Standards	Cool to 4°C; (2 days)	11, 30
Total Alkalinity	mg CaCO ₃ /l	1.0	Potentiometric; Titrimetric	---	Cool to 4°C; (24 hrs)	11
Total Hardness	mg CaCO ₃ /l	1.0	EDTA Titrimetric	---	Cool to 4°C; (7 days)	11
Cadmium (Total + Dissolved)	ug Cd/l	0.1	Graphite Furnace	---	14 HNO ₃	11
Chromium (Total + Dissolved)	ug Cr/l	0.5	Graphite Furnace	---	14 HNO ₃	11
Copper (Total + Dissolved)	ug Cu/l	1.0	Graphite Furnace	---	14 HNO ₃	11
Iron (Total + Dissolved)	ug Fe/l	1.0	Graphite Furnace	---	14 HNO ₃	11
Lead (Total + Dissolved)	ug Pb/l	1.0	Graphite Furnace	---	14 HNO ₃	11
Mercury (Total + Dissolved)	ug Hg/l	0.2	Cold Vapor (flameless)	---	14 HNO ₃	11
Zinc (Total + Dissolved)	ug Zn/l	5.0	AA Direct	---	14 HNO ₃	11
MONTHLY SAMPLES						
Total Suspended Solids (Non-filterable Residue)	mg TSS/l	1.0	Gravimetric @ 105°C	---	Cool (to 4°C; (2 days)	11
Total Dissolved Solids (Filterable Residue)	mg TDS/l	1.0	Gravimetric @ 180°C	---	Cool to 4°C; (2 days)	11
Ammonia-Nitrogen	mg NH ₄ -N/l	0.005	Phenate	---	Cool to 4°C; (24 hrs) 2ml H ₂ SO ₄ /l	11
Nitrate-Nitrogen	mg NO ₃ -N/l	0.01	Cadmium Reduction	---	Cool to 4°C; (7 days) 2ml H ₂ SO ₄ /l	12
Nitrite-Nitrogen	mg NO ₂ -N/l	0.01	Diazotization	---	Cool to 4°C; (24 hrs)	12
Organic-Nitrogen	mg N/l	0.50	Titrimetric	---	Cool to 4°C; (24 hrs)	11
Orthophosphorus	mg OPO ₄ -P/l	0.005	Colorimetric (Vanadomolybdophosphoric)	---	Cool to 4°C; filter (24 hrs)	11
Total Phosphorus	mg TPO ₄ -P/l	0.005	Colorimetric (Vanadomolybdophosphoric)	---	Cool to 4°C; (7 days)	11
Calcium	mg Ca/l	0.02	AA, Direct	---	14 HNO ₃	11
Magnesium	mg Mg/l	0.01	AA, Direct	---	14 HNO ₃	11
Sodium	mg Na/l	0.002	AA, Direct	---	Polybottle	12
Potassium	mg K/l	0.01	AA, Direct	---	Polybottle	12
Bicarbonate	mg H ₂ CO ₃ /l	1.0	Potentiometric + Titrimetric	---	Cool to 4°C; (24 hrs)	11
Sulfate	mg SO ₄ /l	1.0	Turbidimetric	---	Cool to 4°C; (7 days)	11
Chloride	mg Cl/l	1.0	Titrimetric	---	Cool (7 days)	11
Fluoride	mg F/l	0.10	Specific Ion Electrode	Colorimetric-Spano Method	Cool to 4°C; (7 days)	11, 12
Silica	mg Si/l	0.10	Colorimetric (Molybdosulfate)	---	Cool to 4°C; (7 days)	11
Arsenic (Total + Dissolved)	ug As/l	0.1	Graphite Furnace	---	14 HNO ₃	11
Barium (Total + Dissolved)	ug Ba/l	0.10	AA, Direct	---	14 HNO ₃	11
Boron (Total + Dissolved)	ug Bo/l	10.0	Plasma Emission Spectroscopy	---	14 HNO ₃ ; (6 mos)	11
Cobalt (Total + Dissolved)	ug Co/l	1.0	Graphite Furnace	---	14 HNO ₃	11
Manganese (Total + Dissolved)	ug Mn/l	1.0	AA, Direct	---	14 HNO ₃	11
Selenium (Total + Dissolved)	ug Se/l	1.0	Graphite Furnace	---	14 HNO ₃	11
Total residual Chlorine	mg/l	1.0	In situ Electrode	Colorimetric	None-conduct at streamside	12, 13
Oil and Grease	mg/l	1.0	Solvent Extraction; Partition	Gravimetric	9ml Conc. H ₂ SO ₄ ; Cool to 4°C	12
Color, Apparent	Color Units	0.0	Colorimetric (Platinum-Cobalt)	---	Cool to 4°C; 24 hrs max	11
Fecal Coliform	organisms/100ml	1	Multiple Tube Fermentation	---	Sealed; insulated; cool to 4°C	12
QUARTERLY SAMPLES						
PCBs	pg/l	1.0	Mass Spectroscopy/Gas Chromatography	---	Cool to 4°C	12
Chlorinated Hydrocarbons	pg/l	1.0	Mass Spectroscopy/Gas Chromatography	---	Cool to 4°C	12
Hydrogen Sulphide	mg H ₂ S/l	0.02	Colorimetric (Methylene Blue)	---	2ml in-Acetic; 24 hrs	12

TABLE 9.4. Water Quality Sampling Stations for the Preoperational Monitoring Program (PSP&L 1981a)

<u>Station</u>	<u>Location</u>	<u>Description</u>
WQ-0	RM 388.1	Control station. Vernita Bridge (Hwy #24) (42.5 km or 26.5 mi upstream of NPR intake)
WQ-1	RM 361.5	NPR intake
WQ-2	RM 361.4	Downstream boundary of mixing zone. (0.16 km or 0.1 mi downstream of NPR discharge)
WQ-4	RM 359.5	3.2 km (2.0 mi) downstream of facility discharge
WQ-5	RM 351.9	WNP 1 and 4 intake (15.4 km or 9.6 mi down- stream of NPR intake)
WQ-6	RM 345.0	300 area intake. (26.4 km or 16.5 mi down- stream of NPR discharge)
WQ-7	RM 338.0	City of Richland municipal intake (37.6 km or 23.5 mi downstream of NPR discharge)

Note: See Figure 9.1 for station locations.

will be filtered onsite where necessary and stored in ice-filled coolers prior to shipment. Samples will be shipped promptly to a certified analytical laboratory.

In situ instrumentation will be calibrated per manufacturer's instruction immediately prior to and following field sampling. Dual calibration will provide information regarding drift in calibration due to sensor fouling. In addition, a small number of discrete water samples will be returned to the laboratory for analysis and further verification of in situ instrumentation.

Sampling and analytical methodology will be performed in accordance with the latest guidelines set forth by the U.S. EPA (1979), the American Public Health Association (APHA 1980), and/or the American Society for Testing and Materials (ASTM 1980). In the event of a conflict, the U.S. EPA (1979) will be used as the principal reference document.

For quality control purposes, standard solutions will be run prior to each sampling effort to ensure accuracy of results. Blind duplicates will be submitted to ensure reproducibility and accuracy. Satisfactory completion of the U.S. EPA's sample audit program (1972) will also be accomplished. All work related to this program will be stringently recorded in bound field notebooks, bound laboratory notebooks, including worksheets and copies of standard curves, and final data reports.

9.1.1.2 Ecological Parameters

This section describes the monitoring programs to determine aquatic ecological characteristics of the Columbia River in the vicinity of the facility intake and discharge structures (RM 361.5).

9.1.1.2.1 Preapplication Program. Studies at the Hanford Site over a 36-year period have provided substantial qualitative and quantitative information useful for impact assessment. In addition, the Supply System has conducted literature reviews (Neitzel 1979; Becker 1973) and field studies on the Columbia River since 1973 (Battelle 1976a,b; 1977; 1978; 1979a,b; Beak Consultants 1980). These studies provide comprehensive baseline information on the composition, structure and function of the aquatic ecosystem of the Hanford Reach of the Columbia River. The information was used to describe the existing ecological conditions (PSP&L 1981a, Section 2.2.2) in the vicinity of the facility intake and discharge locations at RM 361.5.

Predictions of nonlethal physiological and behavioral responses as described in Sections 4.1.2, 5.1.3 and 5.3.1 of Puget Sound Power & Light Company (1981a) are based upon:

- knowledge of local aquatic ecosystems
- a thorough review of literature on tolerance levels and nonlethal physiological and behavioral responses of local aquatic organisms to thermal, physical, and chemical stresses
- predicted stresses of construction and operation activities.

9.1.1.2.2 Site Preparation and Construction Program. A potential ecological concern may arise during facility construction as a result of the excavation and backfilling activities associated with construction of river intake and discharge structures. Increases in suspended and settleable

materials may affect aquatic biota in several ways. An increase in suspended particles may decrease light penetration and reduce photosynthetic activities of macrophytes, phytoplankton, and periphyton. A reduction of plant growth may be reflected in all food-web levels. Additions of suspended and settleable materials may mechanically abrade and clog gills of fish and sessile organisms, as well as interfere with the feeding processes of filter feeding organisms (Shark 1973; Warren 1971). Settling and shifting of solid materials on the river bottom may fill substrate interstices, eliminating micro- and macro-invertebrate habitats and thus altering the benthic community structure (Hynes 1966).

The Supply System evaluated these possibilities during installation of WNP-2 makeup and circulating water blowdown lines (Page 1976). Results indicated that, after backfilling was completed, settled material covered approximately 2.8 ha (6.9 acres) (or 13 percent of the river cross section), to a point approximately 300 m (1000 ft) downstream from the WNP construction activities. Periphyton growth and macro-invertebrate numbers were markedly reduced in the affected area. The river, however, continued to wash the area, dissipating the deposits within a few weeks. Other researchers have noted that the recolorization of bottom substrates is usually rapid and can occur in as little as a few days (Rosenberg and Snow 1975). It was concluded that the impacts from the installation of the intake and discharge structures are inconsequential to the aquatic community (Page 1976).

The Supply System study provided sufficient data to address the biological impacts to the river from facility construction activities. Therefore, no aquatic monitoring is proposed during the site preparation and construction program.

9.1.1.2.3 Preoperational Program. The objective of the preoperational aquatic ecology monitoring program will be to augment the historical and confirmatory data used for identifying and assessing potential ecological changes resulting from facility operation. Accordingly, preoperational monitoring will be concentrated on that portion of the river immediately adjacent to the plant intake/discharge facilities, and will emphasize organisms most likely to be affected by facility operation (i.e., benthic biota and fish).

The following factors were considered in developing the preoperational monitoring program for aquatic ecology:

- alteration of habitat - The composition of bottom substrates, movement of material, and the size of affected areas in relation to intake and discharge velocities and ambient environmental conditions were considered.
- entrainment, impingement, entrapment - The distribution and abundance of important species and their various life stages susceptible to entrainment, impingement, and entrapment were considered so that estimates of potential losses and predictions of the effects of these losses could be made.
- thermal and chemical stress - The distribution and abundance by life stage of important species in the cooling water body to be influenced by thermal and chemical discharges were considered so that estimates of potential losses and predictions of the effects of these discharges could be made. Water quality monitoring pertinent to determining the impact of NPR operation was considered.

The seasonal cycles found in ecosystems may require long-term studies to detect perturbations. Therefore, the preoperational program will collect field data for two years prior to fuel load to provide additional information on natural variations in the seasonal occurrences and abundance of important aquatic species near the facility intake and discharge location. A knowledge of the extent of natural variations will permit evaluation of changes in the abundance of important aquatic species in the intake and discharge vicinity before and during operation. A comparison of changes in species abundance in the vicinity of the intake and discharge, and in control areas outside the influence of the facility will also be made before and during operation. The following monitoring program was designed to be consistent and compatible with data collected in the preapplication program as well as with data from other locations in the Hanford Reach.

Benthic Organisms: Alterations of Columbia River aquatic biota due to the influence of plant effluent should be most readily indicated by changes in the structure of the benthic community in the immediate vicinity of the discharge. The preoperational benthic program will focus on characterizing the benthic flora and fauna in the area of expected impact.

Sampling locations for preoperational benthic studies are shown in Figure 9.2 and described in Table 9.5. Stations will be sampled four times per year (in March, June, September, and December) to establish baseline information on community composition and abundance. To sample benthic fauna, rock-filled baskets will be incubated on the bottom for a three-month period. Upon recovery, species composition, biomass and community dominance will be determined. Benthic flora will be sampled using glass microscope slides incubated at the same sites as the rock-filled baskets and samples at the same frequency. Qualitative species analysis, chlorophyll-a and biomass measurements will be made. Replicate benthic flora and fauna samples will be taken to allow for statistical analysis of community changes. Representatives of all taxa present will be preserved in a species reference collection, complete with voucher specimens.

Special benthic programs may occur on an intermittent basis in response to regional concerns. A survey of asiatic clam (Corbicula sp.) distribution in the vicinity of the plant intake and the upriver shoreline and back-water slough areas will be initiated in accordance with guidance provided in U.S. NRC (1981).

Fish: Identification of fish species in the Hanford Reach is essentially complete. The Supply System's preliminary Program (Battelle 1976a,b; 1977; 1978; 1979a,b; Beak Consultants 1980) has examined the spatial and temporal distribution, relative species abundance, age structure and feeding habits of fish found near the WNP-1/4 and 2 intake and discharge locations. In the preoperational program, emphasis will be placed on fish found in the immediate vicinity of the facility intake and discharge structures.

Species and numbers of fish residing seasonally near the structures will be examined with particular attention given to anadromous outmigrants and juvenile smallmouth bass. Samples will be obtained using one or more of the following sampling methods: hoop-nets, electroshocking, or beach seining. Sampling locations for each of these methods are shown in Figure 9.2. A tag and release program will be used in an attempt to determine population size and residence time within the study area.

TABLE 9.5. Benthic Invertebrate Sampling Stations for the Preoperational Monitoring Program (PSP&L 1981a)

<u>Station</u>	<u>Location</u>	<u>Description</u>
BI-1	RM 361.5 + 300 ft	Control station 0.10 km or 0.06 mi upstream of facility intake)
BI-2	RM 361.4	Downstream boundary of mixing zone (0.16 km or 0.1 mi downstream of facility discharge)
BI-3	RM 359.5	3.2 km or 2.0 mi downstream of facility discharge

Fish sampling will be conducted at least monthly. The planned sampling frequency by method is provided in Table 9.6. The program will be statistically designed to estimate the standard error of all calculations.

Special fish sampling programs may occur intermittently in response to regional concerns. The Columbia River upstream of the intake and discharge location is currently receiving considerable attention from federal and state fisheries agencies and the mid-Columbia PUDs to determine the impacts of hydroelectric development on fisheries resources. Studies regarding fish passage and migrations, spawning and rearing success, and turbine and system mortality either are in progress or have been planned (see Section 9.3). Periodic studies in the vicinity of the facility intake are planned to capture marked fish released at upstream locations. Such studies will provide improved information on distribution and residence time of anadromous species near the intake and discharge location. Other short-term studies may be initiated as the need arises.

Plankton: Some fraction of the river's plankton will be drawn into the plant with cooling water and another fraction will be exposed to the effects of entrainment in the discharge plume. The numbers affected represent an extremely small fraction of the population passing the plant. Studies conducted by the Supply System on the Columbia River indicate that

TABLE 9.6. Proposed Fish Sampling Frequency, by Station and Method, for the Preoperational Monitoring Program (PSP&L 1981a)

<u>Month</u>	<u>Beach Seine (six stations)</u>	<u>Hoop Net (four stations)</u>	<u>Electro- Fishing (five stations)</u>
January	1	0	0
February	1	0	0
March	2	1	2
April	4	2	4
May	4	2	4
June	4	2	4
July	2	1	2
August	2	1	2
September	2	1	2
October	1	0	0
November	1	0	0
December	1	0	0

Note: See Figure 9.2 for station locations.

planktonic algae and microcrustaceans in the aquatic system near WNP-1/4 and 2 do not have a major role in energy transfer pathways (Battelle 1976a,b; 1977; 1978; 1979a,b; Beak Consultants 1980). The small volume of water to be withdrawn by the facility and the small volume to be discharged is inconsequential in comparison to the total river flow. No significant impact on the plankton community is expected. Therefore, no plankton sampling is proposed during the preoperational monitoring program.

9.1.2 Groundwater

McGhan and Damschen (1979) provides the most complete catalog of monitoring wells located on the Hanford Site. There are over 2,200 wells on the Hanford Site, more than 45 of which are located within 8 km (5 mi) of the site (see Section 2.4.1 of PSP&L 1981a). Extensive environmental monitoring programs concerning the physical, chemical and radiological characteristics of

groundwater on the Hanford Reservation have been conducted for DOE (Myers, Fix and Raymond 1977). These programs and investigations continue to accumulate comprehensive information on groundwater characteristics and are expected to be continued routinely as part of the DOE program. Eight additional monitoring wells were recently installed in the immediate vicinity of the site. There are no plans to monitor nonradiological groundwater quality parameters during the preoperational phase.

There will be no release of radioactive liquid to the ground during normal operations. There are no realistic accidental releases of radioactive liquids to the ground. Puget Sound Power & Light Company (1981b) describes the models used for transport of radionuclides to groundwater.

9.1.3 Air

9.1.3.1 Meteorology

Meteorological data were collected at the WNP-2 site from April 1, 1974 through March 30, 1976. The data collection system is shown in Appendix D of Puget Sound Power & Light Company (1981a).

Two options exist for the preoperational and operational meteorological monitoring programs. The first option is to initiate an onsite monitoring program after issuance of the construction permit. This program will satisfy requirements of regulatory guidelines regarding operational meteorological monitoring programs. The second option recognizes the unique characteristics of the Hanford Site in terms of existing meteorological monitoring programs and that there may be some form of joint monitoring program in the future. Under this option, onsite meteorological measurements and routine and accidental dose assessments would be performed for the entire Hanford Site through a common headquarters. The selection of the specific option will depend on regulatory requirements in effect following issuance of the construction permit (CP) and on the administrative feasibility of conducting cooperative meteorological monitoring programs for the Hanford Site and vicinity (see Section 9.3.3).

9.1.3.2 Models

9.1.3.2.1 Short-Term Atmospheric Dispersion Model. The dispersion factors (x/Q) for ground-level releases were determined using the methodology presented in Regulatory Guide 1.145 (U.S. NRC 1979).

The x/Q values applicable for releases of less than or equal to 2 hours duration were calculated at the distances of interest, using the joint frequency distributions of wind speed and wind direction by atmospheric stability class.

During neutral (D) or stable (E, F, or G) atmospheric stability conditions when the 10-m (33-ft) wind speed is less than 6 m/s, (20 ft/s) the 2-hour x/Q value was calculated from the following set of equations:

$$x/Q = \frac{1}{\bar{u}(\pi\sigma_y \sigma_z + A/2)} \quad (9.1)$$

$$x/Q = \frac{1}{\bar{u}(3\pi\sigma_y \sigma_z)} \quad (9.2)$$

$$x/Q = \frac{1}{\bar{u} \Sigma_y \sigma_z} \quad (9.3)$$

where x/Q = the relative concentration at ground level (sec/m^3)

$\pi = 3.14159$

$\bar{u}$ = the mean wind speed at 10 m (33 ft) (m/s)

σ_y = the Pasquill-Gifford lateral plume spread, a function of atmospheric stability and distance (m)

σ_z = the Pasquill-Gifford vertical plume spread, a function of atmospheric stability and distance (m)

$A = 2,200 \text{ m}^2$, (1.4 mi^2) the smallest vertical plane cross-sectional area of the building from which the effluent is released

Σ_y = the lateral plume spread with meander and building wake effects (m). Σ_y is a function of atmospheric stability, windspeed, and

distance. For distances of 800 m (2,600 ft) or less, $\Sigma_y = M \sigma_y$ where M is based on Figure 3 of Becker and Waddel (1972). For distances greater than 800 m, $\Sigma_y = (M-1) \sigma_y 800 \text{ m} + \sigma_y$.

x/Q values were calculated using Equations (9.1), (9.2), and (9.3). The higher value calculated from Equations (9.1) and (9.2) was compared to the value computed from Equation (9.3) and the lower was chosen as the appropriate x/Q value.

For all other meteorological conditions (i.e., unstable - A, B, or C atmospheric stability and/or 10-m (33-ft) wind speeds of 6 m/s (20 ft/s) or greater), plume meander was not considered. The appropriate x/Q value was chosen as the higher value calculated from Equation (9.1) or (9.2).

The realistic x/Q values from the standard population distances were calculated using a direction-dependent (sector-dependent) methodology. Cumulative probability distributions of x/Q values were determined for each of the 16 wind direction sectors relative to the total hours in all sectors. For realistic estimates at the population distances, x/Q values at the 3.125 percentile (relative to all sectors, or approximately 50 percent for a given sector) were selected from these probability distributions. These selected values represented periods of 2 hours or less. The annual-average value was calculated in accordance with the methodology described in Regulatory Guide 1.111, Rev. 1 (U.S. NRC 1977). Values for periods of 8, 16, 72, and 624 hours were obtained by logarithmic interpolation between the 2-hour value and the annual-average value in the same sector.

To select representative atmospheric dispersion value at the Exclusion Area Boundary and Low Population Zone (LPZ) Boundary, x/Q values were determined using direction-independent methodology per Regulatory Guide 1.111 (U.S. NRC 1977). This methodology, although sector-independent, gives realistic estimates for the site as a whole. The 2-hour x/Q values were ranked without regard to sector and an overall cumulative probability distribution determined. From this distribution, the value that was exceeded no more than 50 percent of the total time was selected for the realistic estimate. Values for longer time periods (i.e., 8 and 16 hours, and 3 and 26 days) were determined by a logarithmic interpolation between the overall 50th percentile two-hour value and the maximum annual average x/Q value over the 16 sectors.

Input meteorological data consisted of joint frequency distributions (JFDs) of hourly averages of wind speed and wind direction by stability class. For computer modeling purposes, 12 wind speed groups were used to give good resolution at lower wind speeds (NUS 1981). The annual JFD with the standard seven wind speed groups is shown in Table 9.7. The JFDs were based on two years of data collected at WNP-2 as described in Section 9.1.3. Occurrences of calms and variable wind directions were distributed by direction and stability class to the lowest wind speed group of the JFDs. Calms were assigned a speed one-half of the threshold speed of the wind vane. Winds were based on observations at 10 m (33 ft) and stability class on observations of delta T 74 - 10 m (245-33 ft) in accordance with Regulatory Guide 1.23 (U.S. NRC 1972).

9.1.3.2.2 Short-Term Dispersion Estimates. The realistic χ/Q estimates at the Exclusion Area Boundary and LPZ Boundary for a hypothetical accident are presented in Table 9.8. The maximum zero to two-hour value at the Exclusion Area Boundary is $2.8 \times 10^{-5} \text{ sec/m}^3$, and at the LPZ is $4.7 \times 10^{-6} \text{ sec/m}^3$.

The realistic χ/Q estimates as a function of distance are presented in Table 9.9. These are sector-dependent values. The higher values are to the south/southeast (SSE) of the facility and the lower values are to the west (W).

9.1.3.2.3 Long-Term Atmospheric Dispersion Model. This section describes the model for atmospheric dispersion estimates applicable for long-term dose assessment. Dispersion factors (χ/Q) were determined using the methodology presented in Regulatory Guide 1.111, Rev. 1 (U.S. NRC 1977) and the NRC computer code X0QD0Q (Sagendorf and Goll 1977).

The calculations were made for the site boundary and at the standard distances out to 80 km (50 mi). All releases were assumed to be at ground level.

χ/Q values were determined by:

$$(\chi/Q)_0 = \frac{2.032}{x} \sum_{ij} \frac{n_{ij}}{N \sum_{zj} \bar{u}_{ij}} \quad (9.4)$$

where $(\chi/Q)_0$ = the average effluent concentration, χ , normalized by source strength, Q , at a downwind distance, x , for a given direction, D (sec/m^3)

TABLE 9.7. Annual Distribution of Variable Winds (PSP&L 1981a)

Stability Class A																	
Speed (mph)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
Calm																	0
0.75- 3.49	2	1	0	0	0	0	1	0	0	0	0	0	0	1	1	2	8
3.50- 7.49	22	17	8	7	7	3	16	15	9	11	12	4	12	9	15	26	193
7.50-12.49	20	20	12	8	1	3	7	13	52	8	6	5	10	9	20	19	213
12.50-18.49	7	5	1	0	0	0	2	4	21	21	8	9	9	7	13	6	113
18.50-23.99	0	0	0	0	0	0	0	0	6	0	6	6	12	8	20	1	59
>23.99	1	0	0	0	0	0	0	0	0	0	1	5	6	5	9	1	28
Total	52	43	21	15	8	6	26	32	88	40	33	29	49	39	78	55	614
Stability Class B																	
Speed (mph)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
Calm																	0
0.75- 3.49	2	3	0	2	1	0	1	0	2	3	1	1	3	0	2	0	21
3.50- 7.49	41	25	17	7	6	21	20	30	21	22	25	15	29	21	21	38	359
7.50-12.49	17	15	6	2	4	11	9	12	68	19	12	13	10	3	8	14	223
12.50-18.49	11	4	0	0	0	0	0	1	14	17	12	11	11	12	9	6	108
18.50-23.99	0	0	0	0	0	0	0	0	1	4	8	7	6	3	10	2	41
>23.99	0	0	0	0	0	0	0	0	0	0	2	1	2	2	6	0	13
Total	71	47	23	11	11	32	30	43	106	65	60	48	61	41	56	60	765
Stability Class C																	
Speed (mph)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
Calm																	0
0.75- 3.49	5	5	3	1	2	3	1	1	5	1	3	4	1	5	10	10	60
3.50- 7.49	58	36	15	13	6	12	31	53	49	31	22	22	21	18	29	43	459
7.50-12.49	36	27	12	14	6	6	11	26	68	49	16	14	22	12	12	16	347
12.50-18.49	13	7	2	0	0	0	1	2	8	25	26	16	14	6	13	9	142
18.50-23.99	1	0	0	0	0	0	0	0	3	5	7	8	7	3	7	1	42
>23.99	0	0	0	0	0	0	0	0	0	1	5	3	4	2	6	0	21
Total	113	75	32	28	14	21	44	82	113	112	79	67	69	46	77	79	1071

TABLE 9.7. (contd)

Stability Class D

Speed (mph)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
Calm																	4
0.75- 3.49	62	37	32	29	32	52	53	58	39	55	58	41	43	66	68	78	803
3.50- 7.49	99	97	46	65	50	59	122	169	148	119	71	58	62	91	161	159	1576
7.50-12.49	74	48	19	22	15	8	27	75	165	183	74	56	53	78	106	82	1085
12.50-18.49	23	12	4	0	0	0	8	15	70	154	103	50	48	75	81	24	667
18.50-23.99	0	1	2	0	0	0	1	0	6	39	47	25	13	50	47	4	235
>23.99	0	8	0	0	0	0	0	0	0	18	30	9	8	11	25	0	109
Total	258	203	103	116	97	119	211	317	428	568	383	239	227	371	488	347	4479

Stability Class E

Speed (mph)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
Calm																	12
0.75- 3.49	67	45	35	28	37	48	56	53	66	50	50	55	47	90	88	78	893
3.50- 7.49	68	32	53	52	37	36	83	156	141	108	100	98	100	169	238	156	1627
7.50-12.49	25	13	9	10	4	8	45	147	140	102	66	69	77	216	220	86	1237
12.50-18.49	1	4	1	1	0	0	11	33	71	127	82	26	26	126	86	13	608
18.50-23.99	0	7	0	0	0	0	1	3	7	52	28	11	8	25	12	0	154
>23.99	0	13	0	0	0	0	0	0	1	26	14	6	2	2	0	0	64
Total	161	114	98	91	78	92	196	392	426	465	340	265	260	628	644	333	4595

Stability Class F

Speed (mph)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
Calm																	5
0.75- 3.49	68	56	35	37	32	31	32	30	41	54	39	53	34	66	62	72	742
3.50- 7.49	65	64	55	31	14	24	71	157	144	113	64	54	54	86	136	127	1259
7.50-12.49	7	8	3	10	1	0	17	98	96	64	20	16	43	80	66	16	545
12.50-18.49	0	0	3	0	0	0	0	7	14	19	6	0	2	1	2	0	54
18.50-23.99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>23.99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	140	128	96	78	47	55	120	292	295	250	129	123	133	233	266	215	2605

TABLE 9.7. (contd)

Stability Class G																	
Speed (mph)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
Calm																	11
0.75- 3.49	108	97	100	67	71	54	41	42	44	35	44	37	36	52	81	108	1017
3.50- 7.49	87	65	67	37	8	13	47	122	125	56	31	22	25	44	119	119	987
7.50-12.49	2	1	3	3	0	0	2	42	71	16	4	8	4	9	27	9	201
12.50-18.49	0	0	0	0	0	0	0	0	8	3	0	0	0	0	0	0	11
18.50-23.99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>23.99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	197	163	170	107	79	67	90	206	248	110	79	67	65	105	227	236	2227

Stability Class All																	
Speed (mph)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
Calm																	32
0.75- 3.49	314	244	205	164	175	188	185	184	197	198	195	191	164	280	312	348	3544
3.50- 7.49	440	336	261	212	128	168	390	702	637	460	325	273	303	438	719	668	6460
7.50-12.49	181	132	64	69	31	36	118	413	660	441	198	181	219	407	459	242	3851
12.50-18.49	55	32	11	1	0	0	22	62	206	366	237	112	110	227	204	58	1703
18.50-23.99	1	8	2	0	0	0	2	3	23	100	96	57	46	89	96	8	531
>23.99	1	21	0	0	0	0	0	0	1	45	52	24	22	22	46	1	235
Total	992	773	543	446	334	392	717	1364	1724	1610	1103	838	864	1463	1836	1325	16356

Annual
Percentage Occurrence by Stability Classes

A	B	C	D	E	F	G
3.75	4.68	6.55	27.38	28.09	15.93	13.62

Annual
Distribution of Wind Direction Vs Stability

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM
A	52	43	21	15	8	6	26	32	88	40	33	29	49	39	78	55	0
B	71	47	23	11	11	32	30	43	106	65	60	48	61	41	56	60	0
C	113	75	32	28	14	21	44	82	133	112	79	67	69	46	77	79	0
D	258	203	103	116	97	119	211	317	428	568	383	239	227	371	488	347	4
E	161	114	98	91	78	92	196	392	426	465	340	265	260	628	644	333	12
F	140	128	96	78	47	55	120	292	295	250	129	123	133	233	266	215	5
G	197	163	170	107	79	67	90	206	248	110	79	67	65	105	227	236	11
Total	992	773	543	446	334	392	717	1364	1724	1610	1103	838	864	1463	1836	1325	32

TABLE 9.7. (contd)

Speed (mph)	A	B	C	D	E	F	G	TOTAL
Calm	0	0	0	0	0	0	0	0
0.75-3.49	1	5	15	48	30	41	43	183
3.50- 7.49	22	31	32	42	19	11	8	165
7.50-12.49	3	1	3	3	3	0	0	13
12.50-18.49	0	0	0	0	1	0	0	1
18.50-23.99	0	0	0	0	0	0	0	0
>23.99	0	0	0	0	0	0	0	0
Total	26	37	50	93	53	52	51	362

*Based on WNP-2 data with the 33-ft wind and delta T (245-33 ft) stability.

Total Number of Observations: 17544

Total Number of Valid Observations: 16356

Total Number of Missing Observations: 1188

Percent Data Recovery for this Period: 93.2 %

Mean Wind Speed for this Period: 7.5 mph

Total Number of Observations with Backup Data: 0

Wind Measured At: 33.0 Feet

Wind Threshold at: 0.75 mph

TABLE 9.8. Realistic Short-Term Chi/Qs by Sector for the Facility at the Exclusion Area Boundary and the Low Population Zone Boundary (PSP&L 1981a)

Accident Period (hr)	Location	
	Exclusion Area Boundary	Low Population Zone Boundary (4 mi)
2	2.8E-5	4.7E-6
8	2.0E-5	3.0E-6
16	1.7E-5	2.4E-6
72 (3 days)	1.2E-5	1.5E-6
624 (26 days)	7.2E-6	7.8E-7

Note:

1. These realistic chi/Q values (sec/m^3) are applicable for a ground-level release to a ground-level receptor, based on delta T stability class category and include plume meander and building wake effects. The values are sector-independent 50th percentile chi/Q values.
2. Based on WNP-2 meteorological data for the period April 1, 1974, to March 31, 1976: (33-ft) wind and delta T 74-10 m (245-33 ft). (a)

(a) Unpublished data transmitted to Burns and Roe, Woodbury, Long Island, New York, by PNL, Richland, Washington 1974-1977.

x = downwind distance (m)

n_{ij} = length of time in hours of valid data for a given wind direction, D, wind speed class, i, and atmospheric stability, j

N = total number of hours of valid data

Σ_{zj} = effective vertical dispersion parameter (m) for stability class j

$\bar{u}_{ij}$ = average wind speed (m/s) for wind speed class, i, and stability class, j, for sector D.

An effective vertical stability parameter, Σ_{zj} , is calculated to account for building wake effects as follows (U.S. NRC 1977):

$$\Sigma_{zj} = \sigma_{zj}^2 + \frac{H^2}{2\pi}^{1/2} \quad (9.5)$$

TABLE 9.9. Realistic Short-Term Accident Chi/Qs by Sector for Facility at Standard Distances (PSP&L 1981a)

Receptor ^(a) Director	Accident Period (hr)			
	8	16	72	624
	Distance: 805 m (2,650 ft)			
N	7.4E-5 ^(b)	6.5E-5	4.8E-5	3.1E-5
NNE	5.3E-5	4.7E-5	3.6E-5	2.5E-5
NE	4.0E-5	3.5E-5	2.7E-5	1.9E-5
ENE	3.8E-5	3.4E-5	2.6E-5	1.8E-5
E	3.5E-5	3.1E-5	2.4E-5	1.7E-5
ESE	6.2E-5	5.5E-5	4.2E-5	2.9E-5
SE	7.8E-5	6.9E-5	5.3E-5	3.7E-5
SSE	7.8E-5	6.9E-5	5.2E-5	3.6E-5
S	5.8E-5	5.1E-5	4.0E-5	2.8E-5
SSW	3.7E-5	3.4E-5	2.7E-5	2.0E-5
SW	1.2E-5	1.2E-5	1.2E-5	1.2E-5
WSW	9.4E-6	9.4E-6	9.4E-6	9.4E-6
W	7.6E-6	7.6E-6	7.6E-6	7.6E-6
WNW	8.7E-6	8.7E-6	8.7E-6	8.7E-6
NW	3.6E-5	3.2E-5	2.5E-5	1.8E-5
NNW	7.1E-5	6.2E-5	4.5E-5	2.9E-5

(a) N-north, E-east, S-south, W-west

(b) Can also be written 7.4×10^{-5}

Notes:

1. These realistic chi/Q values (sec/m^3) are for a ground-level release to a ground-level receptor, based on delta T stability class category and include plume meander and building wake effects. The values are sector-dependent 50th percentile values.
2. Based on WNP-2 meteorological data for the period April 1, 1974 to March 31, 1976: 33-ft wind and delta T (245-33 ft).
3. Standard distances based on Regulatory Guide 1.111 (U.S. NRC 1977).

TABLE 9.9. (contd)

Receptor Director	Accident Period (hr)			
	8	16	72	624
	Distance: 2,414 m (734 ft)			
N	1.8E-5	1.5E-5	9.1E-6	4.6E-6
NNE	1.3E-5	1.0E-5	6.7E-6	3.6E-6
NE	8.3E-6	6.9E-6	4.6E-6	2.6E-6
ENE	7.7E-6	6.5E-6	4.4E-6	2.5E-6
E	7.0E-6	5.8E-6	3.9E-6	2.2E-6
ESE	1.4E-5	1.2E-5	7.7E-6	4.2E-6
SE	2.0E-5	1.7E-5	1.1E-5	5.5E-6
SSE	2.0E-5	1.6E-5	1.0E-5	5.4E-6
S	1.3E-5	1.1E-5	7.1E-6	4.0E-6
SSW	7.2E-6	6.2E-6	4.5E-6	2.8E-6
SW	1.4E-6	1.4E-6	1.4E-6	1.4E-6
WSW	1.1E-6	1.1E-6	1.1E-6	1.1E-6
W	8.7E-7	8.7E-7	8.7E-7	8.6E-7
WNW	9.9E-7	9.9E-7	9.8E-7	9.6E-7
NW	7.7E-6	6.4E-6	4.3E-6	2.5E-6
NNW	1.7E-5	1.4E-5	8.6E-6	4.3E-6

TABLE 9.9. (contd)

Receptor Director	Accident Period (hr)			
	8	16	72	624
	Distance: 4,023 m (2.5 mi)			
N	9.5E-6	7.3E-6	4.2E-6	1.9E-6
NNE	6.2E-6	4.9E-6	2.9E-6	1.4E-6
NE	3.8E-6	3.1E-6	2.0E-6	1.0E-6
ENE	3.8E-6	3.1E-6	2.0E-6	1.0E-6
E	3.4E-6	2.8E-6	1.7E-6	8.9E-7
ESE	7.5E-6	5.9E-6	3.5E-6	1.7E-6
SE	1.0E-5	8.1E-6	4.8E-6	2.2E-6
SSE	1.0E-5	8.1E-6	4.7E-6	2.2E-6
S	6.3E-6	5.0E-6	3.1E-6	1.6E-6
SSW	3.4E-6	2.8E-6	1.9E-6	1.1E-6
SW	5.0E-7	4.9E-7	4.9E-7	4.8E-7
WSW	3.9E-7	3.8E-7	3.8E-7	3.7E-7
W	3.2E-7	3.1E-7	3.1E-7	3.0E-7
WNW	3.5E-7	3.5E-7	3.5E-7	3.4E-7
NW	3.7E-6	3.0E-6	1.9E-6	9.6E-7
NNW	8.9E-6	6.8E-6	3.9E-6	1.7E-6

TABLE 9.9. (contd)

Receptor Director	Accident Period (hr)			
	8	16	72	624
	Distance: 5,633 m (3.5 mi)			
N	6.3E-6	4.7E-6	2.6E-6	1.1E-6
NNE	3.9E-6	3.0E-6	1.7E-6	7.8E-7
NE	2.4E-6	1.9E-6	1.1E-6	5.6E-7
ENE	2.4E-6	1.9E-6	1.1E-6	5.6E-7
E	2.1E-6	1.7E-6	1.0E-6	4.9E-7
ESE	4.6E-6	3.6E-6	2.1E-6	9.4E-7
SE	7.0E-6	5.3E-6	3.0E-6	1.3E-6
SSE	7.0E-6	5.3E-6	2.9E-6	1.3E-6
S	4.0E-6	3.1E-6	1.9E-6	8.8E-7
SSW	2.0E-6	1.6E-6	1.1E-6	6.0E-7
SW	2.5E-7	2.5E-7	2.5E-7	2.5E-7
WSW	2.0E-7	2.0E-7	2.0E-7	2.0E-7
W	1.6E-7	1.6E-7	1.6E-7	1.6E-7
WNW	1.8E-7	1.8E-7	1.8E-7	1.7E-7
NW	1.3E-6	1.8E-6	1.1E-6	5.3E-7
NNW	5.7E-6	4.3E-6	2.3E-6	9.7E-7

TABLE 9.9. (contd)

Receptor Director	Accident Period (hr)			
	8	16	72	624
	Distance: 7,242 m (4.5 mi)			
N	4.4E-6	3.3E-6	1.8E-6	7.0E-7
NNE	2.8E-6	2.1E-6	1.2E-6	5.2E-7
NE	1.7E-6	1.3E-6	7.8E-7	3.7E-7
ENE	1.7E-6	1.3E-6	7.8E-7	3.7E-7
E	1.5E-6	1.2E-6	6.9E-7	3.2E-7
ESE	3.4E-6	2.6E-6	1.4E-6	6.3E-7
SE	5.2E-6	3.9E-6	2.1E-6	8.5E-7
SSE	5.1E-6	3.8E-6	2.1E-6	8.4E-7
S	2.8E-6	2.2E-6	1.3E-6	5.9E-7
SSW	1.4E-6	1.1E-6	7.4E-7	4.0E-7
SW	1.6E-7	1.6E-7	1.6E-7	1.6E-7
WSW	1.2E-7	1.2E-7	1.2E-7	1.2E-7
W	1.0E-7	1.0E-7	1.0E-7	1.0E-7
WNW	1.1E-7	1.1E-7	1.1E-7	1.1E-7
NW	1.7E-6	1.3E-6	7.6E-7	3.6E-7
NNW	4.1E-6	3.1E-6	1.6E-6	6.5E-7

TABLE 9.9. (contd)

Receptor Director	Accident Period (hr)			
	8	16	72	624
	Distance: 12,070 m (7.5 mi)			
N	2.6E-6	1.9E-6	9.4E-7	3.4E-7
NNE	1.6E-6	1.2E-6	6.4E-7	2.5E-7
NE	9.9E-7	7.5E-7	4.2E-7	1.8E-7
ENE	9.9E-7	7.5E-7	4.2E-7	1.8E-7
E	9.2E-7	7.0E-7	3.8E-7	1.6E-7
ESE	2.0E-6	1.5E-6	7.8E-7	3.1E-7
SE	3.0E-6	2.2E-6	1.1E-6	4.1E-7
SSE	3.0E-6	2.2E-6	1.1E-6	4.1E-7
S	1.8E-6	1.3E-6	7.1E-7	3.0E-7
SSW	8.8E-7	6.9E-7	4.2E-7	2.0E-7
SW	1.2E-7	1.1E-7	1.0E-7	8.7E-8
WSW	5.9E-8	5.9E-8	5.8E-8	5.7E-8
W	4.8E-8	4.8E-8	4.7E-8	4.6E-8
WNW	5.4E-8	5.3E-8	5.2E-8	5.0E-8
NW	9.8E-7	7.4E-7	4.2E-7	1.7E-7
NNW	2.4E-6	1.7E-6	8.5E-7	3.1E-7

TABLE 9.9. (contd)

Receptor Director	Accident Period (hr)			
	8	16	72	624
	Distance: 24,140 m (15 mi)			
N	1.3E-6	9.2E-7	4.3E-7	1.5E-7
NNE	8.3E-7	6.0E-7	2.9E-7	1.1E-7
NE	5.0E-7	3.7E-7	1.9E-7	7.6E-8
ENE	4.8E-7	3.6E-7	1.9E-7	7.5E-8
E	4.9E-7	3.6E-7	1.8E-7	7.0E-8
ESE	1.1E-6	7.7E-7	3.8E-7	1.3E-7
SE	1.5E-6	1.1E-6	5.1E-7	1.8E-7
SSE	1.5E-6	1.1E-6	5.2E-7	1.8E-7
S	9.1E-7	6.7E-7	3.4E-7	1.3E-7
SSW	5.1E-7	3.9E-7	1.2E-7	9.2E-8
SW	8.0E-8	7.2E-8	5.8E-8	4.2E-8
WSW	2.4E-8	2.3E-8	2.3E-8	2.2E-8
W	1.9E-8	1.9E-8	1.8E-8	1.8E-8
WNW	2.1E-8	2.0E-8	2.0E-8	1.9E-8
NW	5.1E-7	3.7E-7	1.9E-7	7.5E-8
NNW	1.2E-6	8.4E-7	4.0E-7	1.3E-7

TABLE 9.9. (contd)

Receptor Director	Accident Period (hr)			
	8	16	72	624
	Distance: 40,234 m (25 mi)			
N	8.1E-7	5.6E-7	2.5E-7	8.1E-8
NNE	5.0E-7	3.6E-7	1.7E-7	5.8E-8
NE	3.1E-7	2.2E-7	1.1E-7	4.2E-8
ENE	2.9E-7	2.1E-7	1.1E-7	4.1E-8
E	3.1E-7	2.2E-7	1.1E-7	3.9E-8
ESE	6.5E-7	4.6E-7	2.1E-7	7.2E-8
SE	9.3E-7	6.5E-7	3.0E-7	9.7E-8
SSE	9.3E-7	6.5E-7	3.0E-7	9.9E-8
S	6.1E-7	4.4E-7	2.1E-7	7.4E-8
SSW	3.3E-7	2.5E-7	1.3E-7	5.3E-8
SW	6.1E-8	5.3E-8	3.9E-8	2.6E-8
WSW	1.2E-8	1.2E-8	1.2E-8	1.2E-8
W	9.5E-9	9.5E-9	9.4E-9	9.4E-9
WNW	9.9E-9	9.9E-9	9.9E-9	9.8E-9
NW	3.1E-7	2.3E-7	1.1E-7	4.1E-8
NNW	7.2E-7	5.0E-7	2.3E-7	7.3E-8

TABLE 9.9. (contd)

Receptor Director	Accident Period (hr)			
	8	16	72	624
	Distance: 56,327 m (35 mi)			
N	5.7E-7	3.9E-7	1.7E-7	5.4E-8
NNE	3.8E-7	2.6E-7	1.2E-7	3.9E-8
NE	2.2E-7	1.6E-7	7.9E-8	2.8E-8
ENE	2.1E-7	1.5E-7	7.4E-8	2.7E-8
E	2.3E-7	1.6E-7	7.6E-8	2.6E-8
ESE	4.8E-7	3.4E-7	1.5E-7	4.9E-8
SE	6.7E-7	4.6E-7	2.1E-7	6.6E-8
SSE	6.7E-7	4.7E-7	2.1E-7	6.7E-8
S	4.4E-7	3.1E-7	1.5E-7	5.0E-8
SSW	2.6E-7	1.9E-7	9.6E-8	3.7E-8
SW	5.1E-8	4.3E-8	3.0E-8	1.8E-8
WSW	7.6E-9	7.6E-9	7.6E-9	7.5E-9
W	6.1E-9	6.1E-9	6.1E-9	6.1E-9
WNW	6.6E-9	6.5E-9	6.5E-9	6.4E-9
NW	2.3E-7	1.6E-7	7.9E-8	2.8E-8
NNW	5.2E-7	3.6E-7	1.6E-7	4.9E-8

TABLE 9.9. (contd)

Receptor Director	Accident Period (hr)			
	8	16	72	624
	Distance: 72,420 m (45 mi)			
N	4.6E-7	3.1E-7	1.4E-7	4.1E-8
NNE	3.0E-7	2.1E-7	9.3E-8	3.0E-8
NE	1.7E-7	1.2E-7	6.0E-8	2.1E-8
ENE	1.7E-7	1.2E-7	5.8E-8	2.1E-8
E	1.8E-7	1.3E-7	5.9E-8	2.0E-8
ESE	3.9E-7	2.7E-7	1.2E-7	3.7E-8
SE	5.2E-7	3.6E-7	1.6E-7	4.9E-8
SSE	5.2E-7	3.6E-7	1.6E-7	5.0E-8
S	3.6E-7	2.5E-7	1.2E-7	3.8E-8
SSW	2.1E-7	1.5E-7	7.6E-8	2.8E-8
SW	4.5E-8	3.7E-8	2.5E-8	1.4E-8
WSW	5.5E-9	5.5E-9	5.5E-9	5.5E-9
W	4.4E-9	4.4E-9	4.4E-9	4.4E-9
WNW	4.6E-9	4.6E-9	4.6E-9	4.6E-9
NW	1.8E-7	1.3E-7	6.0E-8	2.1E-8
NNW	4.0E-7	2.7E-7	1.2E-7	3.7E-8

with the constraint

$$z_{zj} \leq \sigma_{zj} \sqrt{3} \quad (9.6)$$

where σ_{zj} = Pasquill-Gifford vertical plume spread (m), a function of atmospheric stability, j, and distance, x

H = maximum adjacent building height (m).

The value used for the term H was 34 m (112 ft). This approximates the average height of the buildings adjacent to which routine releases are expected: Containment, Turbine, Auxiliary, Fuel, and Radwaste Buildings. Open terrain correction factors were used as described in Regulatory Guide 1.111, Rev. 1 (U.S. NRC 1977).

9.1.3.2.4 Long-Term Dispersion Estimates. The annual average relative concentrations (χ/Q_s) at the site boundary are presented in Figure 9.3 for S/HNP Units 1 and 2 separately. The same information is listed in Table 9.10. The highest estimate for releases from Unit 1 is 1.5×10^{-5} sec/m³ in the east/southeast (ESE) sector and from Unit 2 is 2.6×10^{-5} sec/m³, in the ESE sector.

The annual average relative concentrations at the Hanford Site and at selected locations are given in Tables 9.11 and 9.12. The annual average relative concentrations as a function of distance are presented in Table 9.13. From this table, the relative concentrations at a distance of 3.2 km (2 mi) are plotted in Figure 9.4. The higher values at each distance are to the SSE. Values of 2.26 day decay and undepleted χ/Q , eight-day depleted and decayed relative concentration (χ/Q) and for deposition (D/Q) are also presented in Table 9.13 as provided by Computer Code XOQDOQ (Sagendorf and Goll 1977).

9.1.3.3 Cooling Tower Effects Models

The environmental impacts of the operation of an evaporation cooling system include the formation of fog, ice, and elevated visible plumes, as well as the airborne concentration and ground deposition of dissolved solids contained in drift droplets released from the cooling system.

The occurrence of icing, ground-level fog, elevated visible plumes, and the airborne concentration and ground deposition rates of dissolved solids in

FIGURE 9.3. Annual Chi/Q at Site Boundary

drift, were calculated using the computer model FOG (Fisher 1974; 1981). The FOG model provides predictions of these environmental impacts over the area surrounding the site. This model uses the entire set of hourly meteorological measurements collected at the meteorological tower at WNP-2.

A second limited dispersion modeling analysis was conducted with the Lagrangian Vapor Plume Model (LVPM) (Lee 1974). This model was used to represent expected plume rise and plume moisture content during typical summer morning and winter morning periods. Input to the LVPM model are average morning meteorological conditions as obtained from the WNP-2 meteorological data base.

9.1.3.3.1 FOG Model. The FOG model simulates the dispersion of the plume from evaporative cooling systems using sequential hourly meteorological data.

TABLE 9.10. Annual Average Atmospheric Dispersion and Deposition Parameters for NPR

Site Boundary: Unit 1

Direction ^(a)	Distance (m)	Chi/Q (sec/m ³)	Chi/Q Decayed (sec/m ³)	Chi/Q Decayed, Depleted (sec/m ³)	D/Q (m ⁻²)
N	1150.	1.043E-05 ^(b)	1.040E-05	9.308E-06	4.571E-08
NNE	1175.	8.661E-06	8.632E-06	7.722E-06	4.112E-08
NE	1095.	7.276E-06	7.252E-06	6.513E-06	3.177E-08
ENE	930.	9.820E-06	9.780E-06	8.876E-06	3.185E-08
E	910.	8.727E-06	8.699E-06	7.900E-06	3.383E-08
ESE	930.	1.504E-05	1.499E-05	1.360E-05	5.545E-08
SE	1095.	1.400E-05	1.396E-05	1.253E-05	5.311E-08
SSE	1290.	1.012E-05	1.007E-05	8.970E-06	2.780E-08
S	1265.	8.321E-06	8.281E-06	7.385E-06	2.202E-08
SSW	1290.	6.341E-06	6.310E-06	5.621E-06	1.626E-08
SW	1325.	4.941E-06	4.918E-06	4.373E-06	1.061E-08
WSW	1125.	5.499E-06	5.474E-06	4.913E-06	1.242E-08
W	1100.	4.439E-06	4.423E-06	3.972E-06	9.598E-09
WNW	1120.	5.175E-06	5.148E-06	4.624E-06	1.106E-08
NW	1325.	4.921E-06	4.896E-06	4.355E-06	1.397E-08
NNW	1175.	9.362E-06	9.334E-06	8.348E-06	3.502E-08

(a) N-north, E-east, S-south, W-west.
 (b) Can also be written 1.043×10^{-05} .

Notes:

1. Relative concentrations are for a ground-level release are undepleted and undecayed, and incorporate Pasquill-Gifford dispersion coefficients, building height wake, and open terrain correction factors.
2. Based on WNP-2 meteorological data for the period April 1, 1974 to March 31, 1976: 33-ft wind and delta T (245-33 ft).
3. Distances are from the center of each containment.

TABLE 9.10. (contd)

Site Boundary: Unit 2

Direction ^(a)	Distance (m)	Chi/Q (sec/m ³)	Chi/Q Decayed (sec/m ³)	Chi/Q Decayed, Depleted (sec/m ³)	D/Q (m ⁻²)
N	1150.	1.043E-05	1.040E-05	9.308E-06	4.571E-08
NNE	1145.	9.001E-06	8.972E-06	8.037E-06	4.295E-08
NE	765.	1.288E-05	1.286E-05	1.179E-05	5.699E-08
ENE	650.	1.707E-05	1.702E-05	1.577E-05	5.677E-08
E	635.	1.528E-05	1.524E-05	1.413E-05	6.037E-08
ESE	650.	2.616E-05	2.610E-05	2.417E-05	9.884E-08
SE	765.	2.473E-05	2.468E-05	2.264E-05	9.528E-08
SSE	1145.	1.270E-05	1.264E-05	1.134E-05	3.594E-08
S	1265.	8.321E-06	8.281E-06	7.385E-06	2.202E-08
SSW	1290.	6.341E-06	6.310E-06	5.621E-06	1.626E-08
SW	1520.	3.601E-06	3.582E-06	3.160E-06	7.416E-09
WSW	1400.	3.542E-06	3.522E-06	3.123E-06	7.525E-09
W	1375.	2.887E-06	2.873E-06	2.550E-06	5.871E-09
WSW	1400.	3.282E-06	3.261E-06	2.894E-06	6.653E-09
NW	1385.	4.428E-06	4.404E-06	3.908E-06	1.244E-08
NNW	1175.	9.362E-06	9.334E-06	8.348E-06	3.501E-08

A bent-over plume treatment is used by incorporating Briggs plume rise equations (Briggs 1969) to the downwind distance where the plume rise stops. Gaussian dispersion equations are then used for calculations beyond this distance. The plume buoyancy employed in the plume rise calculations is computed from the effluent temperature and air flow rate at the exit of the cooling tower and from the ambient dry bulb temperature and relative humidity. For the round mechanical-draft multifan cooling towers, plume merging is considered using equations developed by Briggs (1974) for a "cluster" of cells. No enhanced plume rise due to the merging of plumes from neighboring towers is considered; this conservative assumption leads to lower plume rises and greater ground-level effects.

TABLE 9.11. Annual Average Atmospheric Dispersion and Deposition Parameters for the Facility (PSP&L 1981a)

Hanford Site Boundary

Direction ^(a)	Distance (m)	Chi/Q (sec/m ³)	Chi/Q Decayed (sec/m ³)	Chi/Q Decayed, Depleted (sec/m ³)	D/Q (m ⁻²)
N	30000.	2.899E-08 ^(b)	2.687E-08	1.683E-08	4.094E-11
NNE	15100.	5.747E-08	5.501E-08	3.855E-08	1.233E-10
NE	13000.	5.610E-08	5.379E-08	3.861E-08	1.099E-10
ENE	12600.	6.184E-08	5.831E-08	4.257E-08	8.905E-11
E	12600.	5.243E-08	5.009E-08	3.623E-08	9.127E-11
ESE	13100.	8.867E-08	8.434E-08	6.080E-08	1.450E-10
SE	15000.	8.996E-08	8.609E-08	6.041E-08	1.431E-10
SSE	13200.	1.100E-07	1.047E-07	7.536E-08	1.305E-10
S	11800.	1.026E-07	9.808E-08	7.163E-08	1.191E-10
SSW	13700	6.822E-08	6.471E-08	4.640E-08	7.155E-11
SW	15600.	4.899E-08	4.639E-08	3.258E-08	3.990E-11
WSW	1699).	3.463E-08	3.230E-08	2.261E-08	2.854E-11
W	26600.	1.508E-08	1.369E-08	8.936E-09	9.842E-12
WNW	27800.	1.554E-08	1.375E-08	9.052E-09	1.083E-11
NW	30700.	1.758E-08	1.557E-08	1.001E-08	1.654E-11
NNW	31200.	2.515E-08	2.332E-08	1.447E-08	3.035E-11

(a) N-north, E-east, S-south, W-west.

(b) Can also be written 2.899×10^{-8} .

The FOG model makes calculations over a polar grid centered on the cooling system. This grid consists of up to 20 downwind distances. After all calculations have been made, the results are further processed and summarized on a Cartesian grid. The plume is assumed to propagate rectilinearly, and any meandering effects due to wind shifts are neglected. Required Pasquill stability classes are determined from the measured difference between the dry bulb temperatures at the two levels of the onsite meteorological tower. The dispersion parameters used (σ_y and σ_z) were those of Pasquill-Gifford

TABLE 9.12. Annual Average Atmospheric Dispersion Parameters and Deposition Estimates at Selected Locations (PSP&L 1981a)

Item	Direction ^(a)	Distance (m)	Chi/Q (sec/m ³)	Chi/Q Decayed (sec/m ³)	Chi/Q Decayed Depleted (sec/m ³)	D/Q (m ⁻²)
Residence	S	12125	9.862E-08 ^(b)	9.420E-08	6.856E-08	1.137E-10
Residence	NE	13485	5.317E-08	5.089E-08	3.636E-08	1.031E-10
Residence	ENE	13765	5.433E-08	5.095E-08	3.680E-08	7.640E-11
Residence	E	13750	4.612E-08	4.388E-08	3.138E-08	7.845E-11
Residence	ESE	14840	7.385E-08	6.978E-08	4.949E-08	1.166E-10
Residence	SSE	15640	8.621E-08	8.128E-08	5.723E-08	9.701E-11
WYE Barricade	E	3500	5.180E-07	5.116E-07	4.240E-07	1.471E-09

(a) S-south, N-north, E-east.

(b) Can also be written 9.862×10^{-08} .

TABLE 9.13. Annual Average Dispersion Parameters and Deposition Estimates at Standard Distances for the Facility (PSP&L 1981a)

No Decay, Undepleted
Corrected for Open Terrain Recirculation

Annual Average X/Q (sec/m³)

	Distance in Miles										
Sector	0.250	0.500	0.750	1.000	1.500	2.000	2.500	3.000	3.500	4.000	4.500
S	5.521E-05	1.756E-05	9.238E-06	4.739E-06	1.921E-06	1.049E-06	6.705E-07	4.715E-07	3.534E-07	2.773E-07	2.252E-07
SSW	4.458E-05	1.401E-05	7.367E-06	3.797E-06	1.549E-06	8.496E-07	5.446E-07	3.838E-07	2.883E-07	2.266E-07	1.843E-07
SW	3.727E-05	1.163E-05	6.101E-06	3.165E-06	1.301E-06	7.176E-07	4.617E-07	3.264E-07	2.457E-07	1.935E-07	1.576E-07
WSW	2.988E-05	9.452E-06	4.981E-06	2.571E-06	1.050E-06	5.767E-07	3.699E-07	2.608E-07	1.960E-07	1.541E-07	1.253E-07
W	2.336E-05	7.409E-06	3.895E-06	2.009E-06	8.201E-07	4.501E-07	2.886E-07	2.034E-07	1.528E-07	1.201E-07	9.766E-08
WNW	2.707E-05	8.799E-06	4.644E-06	2.370E-06	9.543E-07	5.190E-07	3.305E-07	2.318E-07	1.733E-07	1.357E-07	1.100E-07
NW	3.525E-05	1.155E-05	6.115E-06	3.113E-06	1.249E-06	6.779E-07	4.310E-07	3.018E-07	2.255E-07	1.764E-07	1.429E-07
NNW	5.136E-05	1.693E-05	9.003E-06	4.580E-06	1.836E-06	9.957E-07	6.327E-07	4.429E-07	3.308E-07	2.588E-07	2.095E-07
N	5.611E-05	1.833E-05	9.716E-06	4.946E-06	1.986E-06	1.078E-06	6.855E-07	4.802E-07	3.589E-07	2.809E-07	2.275E-07
NNE	4.662E-05	1.558E-05	8.324E-06	4.205E-06	1.670E-06	8.996E-07	5.688E-07	3.966E-07	2.952E-07	2.302E-07	1.859E-07
NE	3.608E-05	1.190E-05	6.304E-06	3.197E-06	1.276E-06	6.904E-07	4.378E-07	3.060E-07	2.283E-07	1.783E-07	1.442E-07
ENE	3.702E-05	1.231E-05	6.581E-06	3.342E-06	1.337E-06	7.238E-07	4.594E-07	3.211E-07	2.398E-07	1.874E-07	1.517E-07
E	3.192E-05	1.059E-05	5.635E-06	2.856E-06	1.140E-06	6.163E-07	3.908E-07	2.731E-07	2.037E-07	1.592E-07	1.287E-07
ESE	5.612E-05	1.886E-05	1.008E-05	5.111E-06	2.041E-06	1.104E-06	7.005E-07	4.897E-07	3.653E-07	2.854E-07	2.308E-07
SE	6.918E-05	2.285E-05	1.215E-05	6.181E-06	2.480E-06	1.346E-06	8.556E-07	5.991E-07	4.476E-07	3.502E-07	2.836E-07
SSE	6.912E-05	2.226E-05	1.177E-05	6.031E-06	2.441E-06	1.332E-06	8.502E-07	5.974E-07	4.475E-07	3.510E-07	2.848E-07
	5.000	7.500	10.000	15.000	20.000	25.000	30.000	35.000	40.000	45.000	50.000
S	1.877E-07	9.930E-08	6.574E-08	3.891E-08	2.696E-08	2.033E-08	1.617E-08	1.333E-08	1.129E-08	9.751E-09	8.559E-09
SSW	1.538E-07	8.175E-08	5.430E-08	3.228E-08	2.243E-08	1.695E-08	1.350E-08	1.115E-08	9.449E-09	8.172E-09	7.179E-09
SW	1.318E-07	7.038E-08	4.691E-08	2.800E-08	1.950E-08	1.477E-08	1.178E-08	9.736E-09	8.262E-09	7.151E-09	6.287E-09
WSW	1.046E-07	5.557E-08	3.690E-08	2.192E-08	1.522E-08	1.149E-08	9.147E-09	7.549E-09	6.397E-09	5.530E-09	4.856E-09
W	8.151E-08	4.329E-08	2.874E-08	1.707E-08	1.184E-08	8.941E-09	7.116E-09	5.872E-09	4.975E-09	4.301E-09	3.777E-09
WNW	9.157E-08	4.814E-08	3.174E-08	1.867E-08	1.287E-08	9.669E-09	7.665E-09	6.304E-09	5.326E-09	4.593E-09	4.024E-09
NW	1.188E-07	6.230E-08	4.098E-08	2.404E-08	1.654E-08	1.241E-08	9.827E-09	8.075E-09	6.816E-09	5.873E-09	5.143E-09
NNW	1.742E-07	9.122E-08	5.997E-08	3.514E-08	2.417E-08	1.812E-08	1.434E-08	1.178E-08	9.939E-09	8.561E-09	7.494E-09
N	1.893E-07	9.934E-08	6.541E-08	3.842E-08	2.648E-08	1.988E-08	1.576E-08	1.296E-08	1.094E-08	9.434E-09	8.264E-09
NNE	1.542E-07	8.009E-08	5.234E-08	3.041E-08	2.080E-08	1.553E-08	1.224E-08	1.003E-08	8.439E-09	7.252E-09	6.336E-09
NE	1.198E-07	6.259E-08	4.107E-08	2.401E-08	1.649E-08	1.235E-08	9.764E-09	8.014E-09	6.758E-09	5.819E-09	5.091E-09
ENE	1.261E-07	6.589E-08	4.326E-08	2.530E-08	1.738E-08	1.301E-08	1.029E-08	8.444E-09	7.120E-09	6.129E-09	5.361E-09
E	1.070E-07	5.586E-08	3.666E-08	2.142E-08	1.471E-08	1.101E-08	8.707E-09	7.145E-09	6.024E-09	5.185E-09	4.536E-09
ESE	1.918E-07	1.001E-07	6.561E-08	3.829E-08	2.625E-08	1.963E-08	1.550E-08	1.271E-08	1.071E-08	9.211E-09	8.053E-09
SE	2.358E-07	1.236E-07	8.126E-08	4.762E-08	3.276E-08	2.456E-08	1.944E-08	1.597E-08	1.347E-08	1.160E-08	1.016E-08
SSE	2.373E-07	1.252E-07	8.278E-08	4.887E-08	3.379E-08	2.543E-08	2.020E-08	1.663E-08	1.407E-08	1.214E-08	1.065E-08

TABLE 9.13. (contd)

2,260 Day Decay, Undepleted
Corrected for Open Terrain Recirculation

Sector	Distance in Miles										
	0.250	0.500	0.750	1.000	1.500	2.000	2.500	3.000	3.500	4.000	4.500
S	5.513E-05	1.750E-05	9.196E-06	4.710E-06	1.903E-06	1.037E-06	6.603E-07	4.629E-07	3.459E-07	2.706E-07	2.191E-07
SSW	4.451E-05	1.397E-05	7.334E-06	3.774E-06	1.535E-06	8.392E-07	5.362E-07	3.768E-07	2.821E-07	2.211E-07	1.792E-07
SW	3.722E-05	1.160E-05	6.075E-06	3.147E-06	1.290E-06	7.095E-07	4.552E-07	3.209E-07	2.409E-07	1.892E-07	1.537E-07
WSW	2.983E-05	9.421E-06	4.957E-06	2.554E-06	1.040E-06	5.691E-07	3.637E-07	2.556E-07	1.914E-07	1.500E-07	1.216E-07
W	2.333E-05	7.388E-06	3.879E-06	1.998E-06	8.131E-07	4.450E-07	2.844E-07	1.999E-07	1.497E-07	1.174E-07	9.514E-08
WNW	2.702E-05	8.767E-06	4.618E-06	2.353E-06	9.438E-07	5.114E-07	3.245E-07	2.267E-07	1.689E-07	1.318E-07	1.064E-07
NW	3.519E-05	1.152E-05	6.087E-06	3.093E-06	1.237E-06	6.694E-07	4.242E-07	2.961E-07	2.205E-07	1.720E-07	1.388E-07
NNW	5.131E-05	1.689E-05	8.976E-06	4.561E-06	1.825E-06	9.876E-07	6.263E-07	4.375E-07	3.261E-07	2.546E-07	2.057E-07
N	5.606E-05	1.829E-05	9.687E-06	4.926E-06	1.973E-06	1.069E-06	6.785E-07	4.743E-07	3.537E-07	2.762E-07	2.233E-07
NNE	4.657E-05	1.554E-05	8.296E-06	4.186E-06	1.658E-06	8.914E-07	5.623E-07	3.911E-07	2.904E-07	2.260E-07	1.821E-07
NE	3.603E-05	1.187E-05	6.281E-06	3.181E-06	1.267E-06	6.835E-07	4.324E-07	3.014E-07	2.242E-07	1.747E-07	1.410E-07
ENE	3.695E-05	1.226E-05	6.546E-06	3.318E-06	1.322E-06	7.131E-07	4.509E-07	3.142E-07	2.336E-07	1.819E-07	1.466E-07
E	3.187E-05	1.056E-05	5.612E-06	2.840E-06	1.130E-06	6.093E-07	3.852E-07	2.684E-07	1.996E-07	1.555E-07	1.254E-07
ESE	5.604E-05	1.880E-05	1.003E-05	5.080E-06	2.023E-06	1.091E-06	6.899E-07	4.807E-07	3.575E-07	2.785E-07	2.245E-07
SE	6.910E-05	2.280E-05	1.210E-05	6.153E-06	2.463E-06	1.313E-06	8.456E-07	5.907E-07	4.403E-07	3.436E-07	2.776E-07
SSE	6.901E-05	2.219E-05	1.172E-05	5.995E-06	2.419E-06	1.316E-06	8.374E-07	5.866E-07	4.381E-07	3.425E-07	2.771E-07
Sector	Distance in Miles										
	5.000	7.500	10.000	15.000	20.000	25.000	30.000	35.000	40.000	45.000	50.000
S	1.821E-07	9.486E-08	6.188E-08	3.556E-08	2.395E-08	1.755E-08	1.358E-08	1.089E-08	8.979E-09	7.554E-09	6.459E-09
SSW	1.491E-07	7.803E-08	5.104E-08	2.944E-08	1.986E-08	1.457E-08	1.128E-08	9.056E-09	7.466E-09	6.282E-09	5.372E-09
SW	1.281E-07	6.747E-08	4.435E-08	2.576E-08	1.746E-08	1.287E-08	9.998E-09	8.053E-09	6.660E-09	5.619E-09	4.817E-09
WSW	1.011E-07	5.286E-08	3.453E-08	1.986E-08	1.336E-08	9.783E-09	7.555E-09	6.053E-09	4.982E-09	4.185E-09	3.572E-09
W	7.918E-08	4.144E-08	2.711E-08	1.564E-08	1.054E-08	7.734E-09	5.983E-09	4.800E-09	3.955E-09	3.325E-09	2.841E-09
WNW	8.828E-08	4.559E-08	2.953E-08	1.678E-08	1.118E-08	8.127E-09	6.236E-09	4.968E-09	4.067E-09	3.400E-09	2.890E-09
NW	1.151E-07	5.935E-08	3.842E-08	2.183E-08	1.457E-08	1.061E-08	8.159E-09	6.516E-09	5.350E-09	4.486E-09	3.825E-09
NNW	1.707E-07	8.850E-08	5.762E-08	3.311E-08	2.235E-08	1.645E-08	1.278E-08	1.031E-08	8.550E-09	7.236E-09	6.226E-09
N	1.854E-07	9.630E-08	6.277E-08	3.613E-08	2.441E-08	1.798E-08	1.397E-08	1.128E-08	9.347E-09	7.911E-09	6.805E-09
NNE	1.507E-07	7.734E-08	4.996E-08	2.837E-08	1.898E-08	1.386E-08	1.069E-08	8.574E-09	7.067E-09	5.950E-09	5.094E-09
NE	1.168E-07	6.020E-08	3.898E-08	2.219E-08	1.484E-08	1.083E-08	8.349E-09	6.681E-09	5.495E-09	4.615E-09	3.940E-09
ENE	1.214E-07	6.228E-08	4.014E-08	2.263E-08	1.500E-08	1.086E-08	8.302E-09	6.595E-09	5.388E-09	4.496E-09	3.816E-09
E	1.039E-07	5.348E-08	3.459E-08	1.965E-08	1.312E-08	9.558E-09	7.357E-09	5.881E-09	4.832E-09	4.055E-09	3.461E-09
ESE	1.860E-07	9.555E-08	6.171E-08	3.495E-08	2.328E-08	1.692E-08	1.300E-08	1.038E-08	8.514E-09	7.137E-09	6.085E-09
SE	2.303E-07	1.193E-07	7.751E-08	4.438E-08	2.984E-08	2.187E-08	1.693E-08	1.361E-08	1.124E-08	9.476E-09	8.123E-09
SSE	2.302E-07	1.197E-07	7.792E-08	4.467E-08	3.001E-08	2.197E-08	1.697E-08	1.361E-08	1.121E-08	9.427E-09	8.060E-09

TABLE 9.13. (contd)

8.000 Day Decay, Depleted
Corrected for Open Terrain Recirculation

	Distance in Miles										
Sector	0.250	0.500	0.750	1.000	1.500	2.000	2.500	3.000	3.500	4.000	4.500
S	5.223E-05	1.602E-05	8.222E-06	4.141E-06	1.627E-06	8.658E-07	5.408E-07	3.725E-07	2.741E-07	2.114E-07	1.689E-07
SSW	4.217E-05	1.278E-05	6.557E-06	3.318E-06	1.312E-06	7.011E-07	4.392E-07	3.033E-07	2.236E-07	1.727E-07	1.382E-07
SW	3.526E-05	1.062E-05	5.430E-06	2.766E-06	1.103E-06	5.923E-07	3.725E-07	2.580E-07	1.907E-07	1.476E-07	1.183E-07
WSW	2.826E-05	8.623E-06	4.433E-06	2.247E-06	8.895E-07	4.758E-07	2.982E-07	2.060E-07	1.519E-07	1.174E-07	9.391E-08
W	2.210E-05	6.760E-06	3.467E-06	1.756E-06	6.948E-07	3.715E-07	2.328E-07	1.608E-07	1.186E-07	9.160E-08	7.329E-08
WNW	2.561E-05	8.027E-06	4.132E-06	2.070E-06	8.079E-07	4.280E-07	2.663E-07	1.829E-07	1.343E-07	1.033E-07	8.240E-08
NW	3.335E-05	1.054E-05	5.442E-06	2.720E-06	1.058E-06	5.593E-07	3.476E-07	2.385E-07	1.748E-07	1.345E-07	1.071E-07
NNW	4.859E-05	1.545E-05	8.016E-06	4.004E-06	1.557E-06	8.226E-07	5.111E-07	3.506E-07	2.571E-07	1.977E-07	1.576E-07
N	5.309E-05	1.673E-05	8.651E-06	4.325E-06	1.681E-06	8.904E-07	5.537E-07	3.801E-07	2.789E-07	2.146E-07	1.711E-07
NNE	4.411E-05	1.422E-05	7.410E-06	3.676E-06	1.415E-06	7.430E-07	4.593E-07	3.138E-07	2.293E-07	1.758E-07	1.397E-07
NE	3.413E-05	1.086E-05	5.612E-06	2.794E-06	1.082E-06	5.701E-07	3.534E-07	2.420E-07	1.772E-07	1.361E-07	1.083E-07
ENE	3.562E-05	1.123E-05	5.856E-06	2.919E-06	1.132E-06	5.968E-07	3.702E-07	2.536E-07	1.857E-07	1.427E-07	1.136E-07
E	3.020E-05	9.664E-06	5.016E-06	2.496E-06	9.656E-07	5.087E-07	3.153E-07	2.159E-07	1.580E-07	1.214E-07	9.660E-08
ESE	5.309E-05	1.721E-05	8.968E-06	4.466E-06	1.729E-06	9.113E-07	5.650E-07	3.869E-07	2.833E-07	2.175E-07	1.731E-07
SE	6.545E-05	2.086E-05	1.081E-05	5.404E-06	2.102E-06	1.111E-06	6.907E-07	4.740E-07	3.476E-07	2.674E-07	2.131E-07
SSE	6.539E-05	2.031E-05	1.048E-05	5.271E-06	2.067E-06	1.099E-06	6.857E-07	4.720E-07	3.471E-07	2.675E-07	2.136E-07
	5.000	7.500	10.000	15.000	20.000	25.000	30.000	35.000	40.000	45.000	50.000
S	1.387E-07	6.909E-08	4.341E-08	2.357E-08	1.521E-08	1.078E-08	8.098E-09	6.339E-09	5.112E-09	4.218E-09	3.543E-09
SSW	1.136E-07	5.687E-08	3.584E-08	1.954E-08	1.264E-08	8.972E-09	6.752E-09	5.291E-09	4.271E-09	3.526E-09	2.964E-09
SW	9.743E-08	4.902E-08	3.101E-08	1.700E-08	1.103E-08	7.850E-09	5.921E-09	4.649E-09	3.760E-09	3.109E-09	2.618E-09
WSW	7.721E-08	3.862E-08	2.432E-08	1.325E-08	8.555E-09	6.063E-09	4.557E-09	3.567E-09	2.876E-09	2.372E-09	1.992E-09
W	6.026E-08	3.014E-08	1.899E-08	1.035E-08	6.689E-09	4.744E-09	3.569E-09	2.796E-09	2.256E-09	1.862E-09	1.565E-09
WNW	6.755E-08	3.341E-08	2.088E-08	1.125E-08	7.214E-09	5.083E-09	3.803E-09	2.965E-09	2.382E-09	1.959E-09	1.640E-09
NW	8.777E-08	4.331E-08	2.702E-08	1.453E-08	9.304E-09	6.551E-09	4.898E-09	3.817E-09	3.066E-09	2.521E-09	2.111E-09
NNW	1.291E-07	6.375E-08	3.983E-08	2.148E-08	1.380E-08	9.747E-09	7.312E-09	5.718E-09	4.609E-09	3.802E-09	3.195E-09
N	1.403E-07	6.941E-08	4.343E-08	2.347E-08	1.510E-08	1.068E-08	8.022E-09	6.278E-09	5.063E-09	4.179E-09	3.513E-09
NNE	1.142E-07	5.590E-08	3.469E-08	1.853E-08	1.183E-08	8.308E-09	6.203E-09	4.831E-09	3.879E-09	3.189E-09	2.671E-09
NE	8.868E-08	4.363E-08	2.718E-08	1.459E-08	9.339E-09	6.576E-09	4.918E-09	3.834E-09	3.082E-09	2.535E-09	2.124E-09
ENE	9.296E-08	4.570E-08	2.844E-08	1.522E-08	9.714E-09	6.818E-09	5.083E-09	3.951E-09	3.166E-09	2.597E-09	2.169E-09
E	7.906E-08	3.889E-08	2.422E-08	1.299E-08	8.306E-09	5.843E-09	4.366E-09	3.401E-09	2.732E-09	2.246E-09	1.880E-09
ESE	1.417E-07	6.961E-08	4.330E-08	2.318E-08	1.479E-08	1.039E-08	7.750E-09	6.029E-09	4.836E-09	3.971E-09	3.322E-09
SE	1.746E-07	8.623E-08	5.385E-08	2.902E-08	1.862E-08	1.314E-08	9.843E-09	7.687E-09	6.189E-09	5.099E-09	4.279E-09
SSE	1.753E-07	8.714E-08	5.465E-08	2.960E-08	1.906E-08	1.347E-08	1.011E-08	7.904E-09	6.367E-09	5.248E-09	4.405E-09

TABLE 9.13. (contd)

Corrected for Open Terrain Recirculation

Sector	Distance in Miles										
	0.250	0.500	0.750	1.000	1.500	2.000	2.500	3.000	3.500	4.000	4.500
S	1.425E-07	4.819E-08	2.474E-08	1.176E-08	4.226E-09	2.096E-09	1.234E-09	8.079E-10	5.685E-10	4.213E-10	3.247E-10
SSW	1.108E-07	3.747E-08	1.924E-08	9.146E-09	3.285E-09	1.629E-09	9.594E-10	6.282E-10	4.420E-10	3.276E-10	2.524E-10
SW	7.756E-08	2.627E-08	1.347E-08	6.403E-09	2.100E-09	1.141E-09	6.716E-10	4.397E-10	3.094E-10	2.293E-10	1.767E-10
WSW	6.354E-08	2.149E-08	1.107E-08	5.245E-09	1.884E-09	9.343E-10	5.502E-10	3.602E-10	2.535E-10	1.879E-10	1.448E-10
W	4.730E-08	1.599E-08	8.212E-09	3.904E-09	1.402E-09	6.955E-10	4.095E-10	2.681E-10	1.887E-10	1.398E-10	1.078E-10
WNW	5.618E-08	1.900E-08	9.754E-09	4.637E-09	1.666E-09	8.260E-10	4.864E-10	3.185E-10	2.241E-10	1.661E-10	1.280E-10
NW	1.021E-07	3.453E-08	1.771E-08	8.430E-09	3.028E-09	1.507E-09	8.842E-10	5.790E-10	4.074E-10	3.019E-10	2.327E-10
NNW	1.928E-07	6.520E-08	3.348E-08	1.592E-08	5.717E-09	2.835E-09	1.669E-09	1.093E-09	7.692E-10	5.700E-10	4.393E-10
N	2.428E-07	8.209E-08	4.215E-08	2.004E-08	7.198E-09	3.570E-09	2.102E-09	1.376E-09	9.684E-10	7.177E-10	5.531E-10
NNE	2.264E-07	7.657E-08	3.931E-08	1.869E-08	6.714E-09	3.329E-09	1.960E-09	1.284E-09	9.033E-10	6.694E-10	5.159E-10
NE	1.554E-07	5.254E-08	2.698E-08	1.282E-08	4.607E-09	2.285E-09	1.345E-09	8.808E-10	6.198E-10	4.593E-10	3.540E-10
ENE	1.193E-07	4.034E-08	2.071E-08	9.848E-09	3.537E-09	1.754E-09	1.033E-09	6.764E-10	4.759E-10	3.527E-10	2.718E-10
E	1.223E-07	4.135E-08	2.123E-08	1.009E-08	3.625E-09	1.798E-09	1.059E-09	6.932E-10	4.877E-10	3.615E-10	2.786E-10
ESE	2.077E-07	7.023E-08	3.606E-08	1.714E-08	6.158E-09	3.054E-09	1.798E-09	1.177E-09	8.285E-10	6.140E-10	4.732E-10
SE	2.597E-07	8.784E-08	4.510E-08	2.144E-08	7.702E-09	3.819E-09	2.249E-09	1.473E-09	1.036E-09	7.679E-10	5.918E-10
SSE	1.895E-07	6.407E-08	3.289E-08	1.564E-08	5.617E-09	2.786E-09	1.640E-09	1.074E-09	7.558E-10	5.601E-10	4.316E-10
Sector	Distance in Miles										
	5.000	7.500	10.000	15.000	20.000	25.000	30.000	35.000	40.000	45.000	50.000
S	2.579E-10	1.146E-10	6.941E-11	3.508E-11	2.123E-11	1.424E-11	1.020E-11	7.660E-12	5.956E-12	4.758E-12	3.883E-12
SSW	2.005E-10	8.909E-11	5.397E-11	2.728E-11	1.651E-11	1.107E-11	7.932E-12	5.956E-12	4.631E-12	3.699E-12	3.019E-12
SW	1.404E-10	6.236E-11	3.778E-11	1.909E-11	1.156E-11	7.749E-12	5.552E-12	4.169E-12	3.242E-12	2.589E-12	2.114E-12
WSW	1.150E-10	5.109E-11	3.095E-11	1.564E-11	9.468E-12	6.348E-12	4.549E-12	3.415E-12	2.656E-12	2.121E-12	1.731E-12
W	8.560E-11	3.803E-11	2.304E-11	1.164E-11	7.047E-12	4.725E-12	3.386E-12	2.542E-12	1.977E-12	1.579E-12	1.289E-12
WNW	1.017E-10	4.517E-11	2.736E-11	1.383E-11	8.370E-12	5.612E-12	4.021E-12	3.020E-12	2.348E-12	1.875E-12	1.531E-12
NW	1.848E-10	8.211E-11	4.974E-11	2.514E-11	1.522E-11	1.020E-11	7.310E-12	5.489E-12	4.268E-12	3.409E-12	2.783E-12
NNW	3.490E-10	1.550E-10	9.391E-11	4.747E-11	2.873E-11	1.926E-11	1.380E-11	1.036E-11	8.059E-12	6.437E-12	5.254E-12
N	4.394E-10	1.952E-10	1.182E-10	5.976E-11	3.617E-11	2.425E-11	1.738E-11	1.305E-11	1.015E-11	8.105E-12	6.615E-12
NNE	4.098E-10	1.821E-10	1.103E-10	5.574E-11	3.374E-11	2.262E-11	1.621E-11	1.217E-11	9.461E-12	7.559E-12	6.170E-12
NE	2.812E-10	1.249E-10	7.567E-11	3.825E-11	2.315E-11	1.552E-11	1.112E-11	8.351E-12	6.493E-12	5.187E-12	4.234E-12
ENE	2.159E-10	9.592E-11	5.811E-11	2.937E-11	1.778E-11	1.192E-11	8.540E-12	6.413E-12	4.986E-12	3.983E-12	3.251E-12
E	2.213E-10	9.831E-11	5.955E-11	3.010E-11	1.822E-11	1.221E-11	8.752E-12	6.572E-12	5.110E-12	4.082E-12	3.332E-12
ESE	3.759E-10	1.670E-10	1.012E-10	5.113E-11	3.095E-11	2.075E-11	1.487E-11	1.116E-11	8.680E-12	6.934E-12	5.660E-12
SE	4.701E-10	2.088E-10	1.265E-10	6.394E-11	3.870E-11	2.595E-11	1.859E-11	1.396E-11	1.086E-11	8.672E-12	7.078E-12
SSE	3.429E-10	1.523E-10	9.227E-11	4.664E-11	2.823E-11	1.893E-11	1.356E-11	1.018E-11	7.918E-12	6.325E-12	5.162E-12

*33 ft winds, delta T (254°-33°). Data Period 4/74-3/76.

FIGURE 9.4. Site Annual Chi/Q at 3.2 km (2 mi)

(U.S. NRC 1979). Formulations for critical wind speed relative to the aerodynamic downwash of the exhaust plumes are also included in the FOG model.

Induced ground level fogging. Induced ground-level fog is defined as a reduction in ground-level visibility to 1,000 m (5/8 mi) or less as a result of the operation of the cooling systems. According to the international definition, 1,000 m (5/8 mi) is the limit on visibility above which fog is not considered to occur (Huschke 1959). The fogging calculations were based on a criterion that 2.1×10^{-5} lbs of liquid water per lb of dry air ($0.015 \text{ g of water/m}^3$) would result in a visibility of 1,000 m (5/8 mi) or less (Pettersen 1956). The water content of the plumes at ground level is calculated by means of the dispersion analysis. All moisture in excess of that required to saturate the ambient air is assumed to form condensed water droplets. An empirical equation presented by Pettersen (1956) is then used to relate the atmospheric water content to horizontal visibility.

Induced ground level icing. The frequencies of occurrence of various ice thicknesses resulting from the operation of the cooling towers were calculated by the FOG model, which includes subroutines to simulate the formation and accumulation of ice and to calculate the frequencies of ice occurrence.

The ice-formation routines predict accumulations of ice around a cooling system from the impingement of condensed water and drift droplets. Calculations of ice buildup are made for both vertical and horizontal flat surfaces. The rate of ice buildup can be limited either by the liquid water delivery rate to the collecting surface or by the heat balance necessary to sustain freezing conditions.

In the case of ice formation on elevated flat vertical surfaces, ice buildup can result from the impingement of both condensed water and drift droplets. The liquid water delivery rate is computed as the liquid mass flux times the intercepted surface area. This value is then multiplied by a collection efficiency of 0.8 for the condensed water droplets. The dispersion of the relatively small condensed water droplets is treated the same as that of the vapor plume, while the transport of the drift droplets is the same as that employed for the salt deposition calculations. The FOG model performs an energy balance on the surface or volume of interest. Ice formation is assumed to occur only when the ambient temperature is less than 0°C . Under certain conditions, the ice buildup rate can be limited by heat transfer considerations. This occurs when the latent heat of fusion released during freezing results in a surface temperature equal to 0°C . Since any additional ice buildup would increase the surface temperature above 0°C , such ice formation would not be possible.

In the case of ice formation on horizontal ground-level surfaces, ice buildup is assumed to result only from the fallout of the drift droplets. Since the much smaller condensed water droplets have negligibly small settling velocities, the condensed water droplets are assumed not to impinge on flat horizontal surfaces. The heat transfer limitations on ice formation on flat horizontal surfaces are basically the same as those discussed above for flat vertical surfaces, with the exception of melting due to solar radiation, which

is not included because unshielded flat horizontal surfaces are always exposed to solar radiation, whereas vertical surfaces are not.

Elevated visible plumes. The FOG model was used to calculate the frequencies of occurrence of elevated visible plumes over each grid point. The total flux of air through a cross-section of the plume normal to the plume axis is calculated at successive downwind distances. This calculation is made whether the plume is in the rising stage or has reached its maximum height and leveled off. The amount of entrained air is computed as the difference between the total air flow and the air flow leaving the cooling system. The entrained air and the effluent air from the cooling system are assumed to be thoroughly mixed isobarically, and the thermodynamic properties of the resulting mixture are calculated. A visible plume is predicted to occur if calculations show that the mixed plume is supersaturated.

Drift analysis. The FOG model was used to calculate the transport and ground deposition rate of dissolved solids contained in the entrained drift droplets released from the cooling systems.

Drift deposition analysis by the FOG model involves the following three calculations: the sequential release of the entrained drift droplets from the effluent plume, the subsequent horizontal transport of the drift droplets, and the airborne concentrations and deposition rates at prespecified downwind distances for each wind direction.

It is assumed in the FOG model that the excess water vapor, the temperature excess, the vertical velocity, and the initial concentration of drift droplets follow a Gaussian distribution normal to the plume axis. The plume is assumed to extend two standard deviations (i.e., two sigma y and two sigma z) away from the plume axis. The release of the entrained droplets at any point within the plume depends on the relative magnitudes of the terminal fall velocity of the droplets and the vertical velocity of the air in the plume. At each downwind distance under consideration, these two velocities are compared for the various size categories of plume droplets, and a fraction of the droplets is released. This process is repeated until all droplets are released from the plume. When the plume

reaches its maximum height, the vertical velocity throughout the plume is zero. Droplets released from the plume fall first through the plume air, and then through the ambient air beneath the plume. This drift is carried downstream by the ambient wind until it is deposited on the ground. The rate of fall of the drift droplets is proportional to their terminal velocity, which in turn is dependent on the droplet size. The droplet size can change by evaporative processes, which depend on the physical and transport properties of both the liquid droplets and the surrounding air. For relative humidities below 50 percent, complete evaporation of the drift droplets to dry particles is possible. A stepwise procedure is employed in the FOG model to compute the trajectory of the droplets by considering the above effects.

Drift deposition rates and airborne concentrations of dry drift particles are calculated for each of the sequential meteorological records included in the two-year meteorological data set. These are then summarized to obtain the deposition (lb/acre-yr) and airborne concentrations of dry particles (micrograms/m³) over the entire grid. The calculation of airborne concentration is made at a height of 2 m (6.5 ft) above the ground surface.

9.1.3.3.2 LVPM Model. Cooling tower plume rise and moisture content were calculated with the LVPM (USGS 1981), a one-dimensional numerical model capable of predicting the detailed behavior of plumes for a given meteorological condition. The numerical technique utilized in the LVPM model is described by equations for the motion of a quasi-incompressible fluid. Based on the assumption of steady-state plume, the model simulates a continuous efflux into a horizontally homogeneous atmosphere. This assumption simplifies the numerical computation and leads to practical and economical application.

The LVPM model was used to calculate plume rise and plume moisture content, i.e., vertical profiles of temperature, vertical velocity, and moisture through the plume at selected downwind distances for average summer and winter conditions. In addition, variations of plume rise as a function of ambient atmospheric stability are calculated.

9.1.3.4 Air Quality

Nonradiological air quality measurements in Benton County, where the site is located, are the responsibility of the Tri-County Air Pollution Control Authority (TCAPCA). As a result of the small quantities of nonradiological air pollutants to be released to the atmosphere, the Applicant will not conduct a preoperational air quality monitoring program.

The primary air quality nuisance at the Hanford Site area is fugitive dust. Thus, only total suspended particulates (TSP) are monitored by the TCAPCA at the Hanford Site. During the 1980's, the annual mean average of TSP at the Hanford Site was below the federal standard of 60 micrograms/m³. The highest 24-hour measurement at the Hanford Site was 279 micrograms/m³ on July 9, 1980 (TCAPCA 1981). The sample mainly consisted of volcanic ash from the Mt. St. Helen's eruption that was being resuspended as windblown dust into the atmosphere. During the day of the eruption (May 18, 1980), however, Sehmel (1981) reported an average concentration for respirable particles (less than 5.5 micrograms diameter) of 1430 micrograms/m³.

9.1.4 Land

9.1.4.1 Geology and Soils

No geological or soil studies have been made specifically to determine the environmental impact on these factors of construction and operation of the facility. Detailed analyses of soil engineering properties at the site have been carried out for the purpose of determining safety-related design parameters. These analyses and the results are reported in Section 2.5.4 of Puget Sound Power and Light Company (1981b). Detailed geological studies have also been carried out in the Site Area and are reported in Section 2.5.1 of the same document. There are no indications from any of the geological or soils studies that construction or operation of the plant would have an adverse environmental impact on these factors.

9.1.4.2 Land Use and Demographic Surveys

Land use information and data presented in Section 2.1 of Puget Sound Power & Light Company (1981a) were obtained by such means as onsite visits, personal communications with cognizant persons and organizations (e.g., agricultural extension agents and relevant county and state agencies), publications,

maps, and aerial photographs. The list of numbered references in Section 2.1 of the same document indicates the specific sources of information and data contained in the text, tables, and figures.

Demographic analyses were conducted using traditional scientific demographic methods. The list of numbered references for Section 2.1 of Puget Sound Power & Light Company (1981a) indicates specific sources of demographic information and data.

Population estimates are based on the latest available data. All population estimates and projections were calculated with the approximate centroid of the facility reference site as the geographic reference. For the analysis of the population within 16 km (10 mi), a house count was conducted in October, 1981. For the estimate of the population between 16 and 80 km (10 and 50 mi), data from the 1980 U.S. Census were analyzed for blocks, tracts and enumeration districts.

Population projections from 1990 through 2030 were based on county forecasts for the states of Washington and Oregon. For the census years 1990 and 2000, existing projections were directly employed. For the years 2010, 2020 and 2030, projections were made following a logic similar to that of the U.S. Census projections through 2030 for the nation as a whole. It was assumed that after the year 2000, stabilization of population growth will gradually occur within a 80 km (50-mi) radius of the site. For each of the census years, from 2010 through 2030, it was estimated that the rate of population increase in each county would decline by one-half of the rate prevalent in the previous decade. For each county within 80 km (50 mi), this procedure results in a stabilized population by the year 2030.

Distribution of population growth was assumed to be equal throughout each county, with the major exceptions of the Benton and Franklin metropolitan counties, which are nearest to the site. Based on interviews with local planners and city officials, and review of land use and annexation plans, a number of areas within the Tri-Cities were identified as having high growth potential. Those areas include the Horn Rapids Triangle in Richland, the Horn-Willamette area in West Richland and northwest Pasco near the new I-182 bridge. Accordingly, for the period 1980-2000, appropriate enumeration

districts and census blocks were projected to grow at approximately twice the rate of the remainder of the metropolitan area. Several of these areas were projected to sustain growth from 2000-2010, but after 2010 all areas were projected to stabilize and generally parallel the overall metropolitan area growth rates.

9.1.4.3 Preoperational Ecological Programs

This section describes the preoperational program designed to assess the terrestrial ecological characteristics of the site, with primary reference to important terrestrial species. A species was considered important as defined in Regulatory Guide 4.2, Rev. 2 (U.S. NRC 1978). Species listed as endangered, threatened, or sensitive, and species of special interest as defined by the Washington Natural Heritage Program were considered important species.

The monitoring program was designed to identify preoperational ecological conditions so that specific environmental changes induced by the facility could be recognized and assessed. The program was divided into three stages: pre-application, site preparation and construction, and preoperational.

Preapplication studies were designed with these specific objectives:

- describe the terrestrial biota from a regional and site-specific perspective
- determine which important species might occur within the study area, and verify occurrence whenever possible
- identify important species or areas of special concern that may be affected by the facility.

Site preparation and construction monitoring will expand upon the important conclusions of preapplication monitoring, and will continue until plant construction is completed. The objectives of this monitoring effort are:

- determine the actual distribution of important species within the site and associated areas
- monitor abundance and/or habitat usage of species indicated above
- estimate the impact of site preparation and construction upon plant or wildlife species and/or habitats

- describe potential mitigation measures, if necessary, to ameliorate and/or compensate for adverse terrestrial impacts.

Preoperational monitoring is the final stage before operation and is designed to provide the data necessary for evaluating any changes to the terrestrial environment arising from facility operation. In many instances, the previous monitoring programs will provide the necessary data base.

9.1.4.3.1 Preapplication Monitoring. The vegetation and wildlife of the Hanford Site has been thoroughly studied in connection with the activities of the DOE (and its predecessor agencies), the Supply System and the U.S. Army Corps of Engineers (riparian zone only). The preapplication monitoring program was designed to confirm that the area likely to be affected by the facility is similar to areas already described in the literature, and therefore, impacts will be predictable based primarily on data from previous studies. Field surveys also were conducted to check for the occurrence of important species, as defined in NRC Regulatory Guide 4.2 (U.S. NRC 1978).

Relevant literature is listed in Section 2.2 Puget Sound Power & Light Company (1981a). The area studied was the site and associated areas, which encompassed the site and the railroad, transmission line, pipeline, and access road corridors. To assure proper coverage, the corridor width was assumed to be 300 m (1,000 ft).

Qualitative field surveys of vegetation were conducted in April-October, 1981. Each area was searched on foot by a plant taxonomist/ecologist to identify any threatened, endangered, or other sensitive plant species or habitats and to document their presence, local and regional abundance, sensitivity, and relationships to the site.

A qualitative field investigation of wildlife was conducted to: assure applicability of existing information to the site and associated areas, locate specific areas used by important wildlife species, and search for unique wildlife features within the area to be directly impacted by site preparation and station construction. This field investigation was conducted in May, June, and July 1981. The site and associated areas were traversed in a systematic manner to record all signs of wildlife and observations.

The facility intake/discharge location and the old Hanford townsite were studied in detail. The townsite is unique within the Hanford Site because of the trees planted decades ago by early settlers for shade and fruit production. Since the pipeline corridor transects the townsite, a reconnaissance of the entire area was conducted.

Most of the trees within the townsite were checked for signs of wildlife use. Trees with significant signs of wildlife use (e.g., raptor nests) were mapped for future identification. An attempt was made to ascertain if nests were active and which species were using them. If possible, nest success was determined. In addition to trees, all other remaining features of the townsite (i.e., the old schoolhouse, pumphouse, and miscellaneous remnants from the town) were checked for signs of wildlife use.

The remaining important feature of the townsite was the riparian habitat along the Columbia River. This area was also checked for signs of wildlife use, especially breeding and feeding activity of hydrophilic species. The extent and quality of riparian habitat available to wildlife was noted on aerial photographs.

Sections 4.1, 4.2, and 4.5 of Puget Sound Power & Light Company (1981a) describe mitigation measures to be utilized to minimize environmental impact. The construction impact control program described in Section 4.5 of the same document is divided into three categories: construction control, environmental monitoring, and restoration. As indicated in Section 4.5, a detailed description of the elements of the construction impact control program will be submitted to EFSEC for its review and approval prior to commencement of site construction activities.

9.1.4.3.2 Site Preparation and Construction Monitoring. As previously mentioned, the site preparation and construction monitoring effort will determine the distribution of important species within the site and associated areas and monitor the abundance of these important species or areas of special concern: bald eagles, long-billed curlews, and the old Hanford townsite. This monitoring effort will begin sufficiently in advance of the start of construction activities to provide the preconstruction data base necessary for assessing the extent of construction impacts. Studies will continue until construction effects have subsided or the extent of impact has been satisfactorily

appraised. The following describes the methodologies for each facet of the monitoring program.

Important plant species. The listing status of persistent sepal yellow cress, Rorippa calycina, var. Columbiae, will be monitored in case of a change from its present status as a candidate for listing as threatened or endangered on the federal list, and threatened on the Washington State list. The area occupied by the population along the riparian zone will be determined during the time of low water levels in the spring. The percentage of the population which will be disturbed by construction will be estimated. An additional check of the population during the low water period in late summer or fall will be conducted to help determine the ability of the species to resist disturbance.

Important Wildlife Species. A reconnaissance of the site and associated areas will occur twice each spring and winter to map the distribution of important species. Occurrence data will be recorded and no effort will be made to estimate population levels. The objective of this investigation is to determine if the distribution of important species changes during construction activities.

Bald eagles. Bald eagles primarily are found during the winter at the old Hanford townsite. This area will be surveyed monthly during the winter to determine the number of eagles present. An attempt will be made to determine habitat usage within the site and associated areas. Observation regarding prey selection, preferred roosting sites and sensitivity to disturbance will be recorded.

Long-billed curlews. Curlews are found during the breeding period (March-June) and at least two pairs have been found within the site and associated areas. Potential nesting habitat within or adjacent to the site and associated areas will be surveyed monthly (during the breeding period) for signs of breeding activity. Territories actively defended will be mapped and nesting success will be determined whenever possible. In addition, the breeding chronology will be monitored to assist in scheduling construction activities.

Old Hanford townsite. The townsite is an area of special concern for wildlife. The objective of this portion of the monitoring program is to develop a data base on wildlife occurrence and monitor the impacts of construction activities upon wildlife at the townsite. Raptors, landbirds, and deer will be monitored.

Wildlife abundance will be monitored in the spring and fall/winter to sample breeding adults and winter residents, respectively. Spring sampling will occur in April and May; fall/winter sampling will occur from November through January. The procedures for this monitoring effort are outlined in Table 9.14.

TABLE 9.14. Summary of Procedures for Monitoring Wildlife Occurrence at the Old Hanford Townsite (PSP&L 1981a)

<u>Species/Group</u>	<u>Sampling Period</u>	
	<u>Spring</u>	<u>Fall/Winter</u>
Raptors	Method: Biweekly counts of nesting raptors. Data: Breeding population, breeding chronology, nest location, clutch size and number fledged.	Method: Monthly direct counts of winter residents Data: Occurrence.
Landbirds	Method: Biweekly direct counts along predetermined strip transects. Data: Relative abundance and species diversity	Method: Monthly reconnaissance. Data: Species diversity of winter population.
Deer	Method: Biweekly spotlight surveys and dawn counts. Data: Number of deer using townsite for breeding and fawn production (if possible).	No surveys planned, but deer observations incidental to other surveys will be recorded.

9.1.4.3.3 Preoperational Monitoring. Site preparation and construction monitoring will supply an adequate data base for monitoring the effects of plant operation on Rorippa calycina, var. Columbiae, bald eagles, long-billed curlews, and wildlife at the old Hanford townsite. Monitoring other wildlife species or wildlife use areas is not deemed necessary at this time.

Data regarding the land area altered or rendered unsuitable for biological productivity will be measured near the end of construction. A map showing all areas of disturbance will be developed.

The Supply System is studying the effects of drift on vegetation and wildlife. The drift effects associated with the facility do not require monitoring and will be less than those found at the Supply System units because of a much reduced particulate ratio. Therefore, the Supply System study will serve as a conservative estimate of the drift effects which might result from the facility.

9.1.5 Radiological Monitoring

The NPR preoperational radiological environmental monitoring program (REMP) is designed to provide measurements of radiation and radioactive materials in those exposure pathways and for those radionuclides that are expected to lead to the highest radiation exposures to individuals from the operation of the NPR. The preoperational program objectives are to measure background levels and their variations in exposure pathways surrounding the site, to train personnel, and to evaluate procedures, equipment, and techniques.

The facility preoperation REMP is based on a combination of airborne, terrestrial, and aquatic monitoring stations. Airborne sample stations have been chosen based on the projected population distribution around the site, adjacent land use, and meteorological data presented in Chapter 2 of Puget Sound Power & Light Company (1981a). The area within a 16-km (10-mi) radius of the site is of primary interest in the terrestrial monitoring part of the program. Attention is given to the area of Franklin County that uses Columbia River water for irrigation and is in the prevailing downwind direction. Aquatic sampling locations have been chosen based on the need to determine the facility's impact on the aquatic environs separately from other facilities on the Hanford Site.

Table 9.15 describes the sample type, approximate location, sample collection, and analyses to be performed on each sample. Analytical techniques will be used such that the detection capabilities in Table 9.16 are achieved. Figure 9.5 and 9.6 show the approximate location of the stations.

TABLE 9.15. Radiological Environmental Monitoring Program
(PSP&L 1981a)

Sample Media	Location	Sampling Frequency ⁽¹⁾	Analysis	
			Type	Frequency
Airborne Radioiodine ⁽²⁾ Particulates ⁽³⁾	3 locations at Site Boundary (in different sectors) with highest calculated annual average groundlevel concentra- tions	Continuous sampling, weekly collection	Radioiodine I-131	Weekly
	1 location at Site Boundary in an upwind direction		Particulates Gross Beta ⁽⁴⁾	Weekly
	Supply System Station 8 (residence having highest X/O)		Gamma Isotopic ⁽⁵⁾	Composite, by location quarterly
	Supply System Station Number 6 (community)			
	Supply System Station Number 9 (control) approximately 30 miles from the Site Boundary			
Direct Radiation ⁽⁶⁾	A station will be located in each sector of: (1) an inner ring in the general area of the Site Boundary (inclusive of airborne locations), and (2) an outer ring in the four to five mile range	Quarterly set (2 TLDs)	Gamma Dose	Quarterly
		Annual set (2 TLDs)	Gamma Dose	Annually
	Supply System Station Number 6 (Community)			
	Supply System Station Number 9 (Control)			
Waterborne Drinking Water ⁽³⁾	Supply System Station Numbers 29 and 30 (Richland Water Treatment Plant and DOE 300 Area)	Composite ⁽⁷⁾ for month	H-3 Radioiodine Gamma Isotopic	Quarterly composite Semi-monthly Monthly
River Water ⁽³⁾	S/HNP Intake S/HNP Discharge	Composite ⁽⁷⁾ for month	H-3 Gamma Isotopic	Quarterly composite Monthly

TABLE 9.15. (contd)

Sample Media	Location	Sampling Frequency (1)	Analysis	
			Type	Frequency
Aquatic Indicator Organisms (6) Sediment (6)	Above and below S/HMP discharge Supply System Station Number 35 and above S/HMP discharge	Semi-annually Semi-annually	Gamma Isotopic Gamma Isotopic	Semi-annually Semi-annually
Ingestion				
Milk (7,8)	Closest milk animal Supply System Station 8 Supply System Station Number 9 (Control) Supply System Station Number 17 Supply System Station Number 18 S/HMP discharge	Semi-monthly during grazing season; monthly at other times	Gamma Isotopic 1-131	Semi-monthly; monthly Semi-monthly when animals are in pasture
Fish (6)	Supply System Station 27 (in vicinity of WNP-2 discharge) Snake River (1 control)	Semi-annually	Gamma Isotopic (Edible portion)	Semi-annually
Fruit and Vegetables (9)	Supply System Station Number 8 Supply System Station Number 9 (Control)	Monthly during growing season	Gamma Isotopic	Monthly

- (1) Deviation may be required if samples are unobtainable due to hazardous conditions, seasonal availability, malfunction of automatic sampling equipment, or other legitimate reasons. All deviations will be documented in the annual report.
- (2) Minimum six month preoperational sampling.
- (3) Minimum one year preoperational sampling.
- (4) Particulate sample filters will be analyzed for gross Beta after at least 24 hours decay. If gross Beta activity is greater than 10 times the mean of the control sample, gamma isotopic analysis should be performed on the individual sample.
- (5) Gamma isotopic means identification and quantification of gamma emitting radionuclides that may be attributable to the effluents of the facility.
- (6) Minimum two years preoperational monitoring.
- (7) Composite samples will be collected with equipment which is capable of collecting an aliquot at time intervals which are short relative to the compositing period.
- (8) Milk samples will be obtained from farms or individual milk animals which are located in sectors with the higher calculated annual average ground-level D/Q's. If Cesium-134 or Cesium-137 is measured in an individual milk sample in excess of 10 pCi/l, then Strontium 90 analysis should be performed.
- (9) Fruit and vegetables will be obtained from farms or gardens which use Columbia River water, if possible, for irrigation, and different varieties will be obtained as they are in season. One sample each of root food, leafy vegetables, and fruit should be collected each period.

TABLE 9.16. Maximum Value for the Lower Limit of Detection (LLD)^(a)
(PSP&L 1981a)

Analysis	Water (pCi/l)	Airborne Particulate or Gas (pCi/m)	Fish (pCi/kg, wet)	Milk ^b (pCi/l)	Vegetation (pCi/kg, wet)	Sediment (pCi/kg, dry)
gross beta	4	1 x 10 ⁻²				
3H	2,000					
54Mn	15		130			
59Fe	30		260			
58,60Co	15		130			
65Zn	30		260			
95Zr	30					
95Nb	15					
131I	15	7 x 10 ⁻²		1	60	
134Cs	15	5 x 10 ⁻²	130	15	60	150
137Cs	18	6 x 10 ⁻²	150	18	80	180
140Ba	60			60		
140La	15			15		

Note: This list does not mean that these nuclides are to be detected and reported. Other peaks which are measurable and identifiable, together with the above nuclides, shall also be identified and reported.

^aThese detection capabilities are tabulated in terms of the lower limits of detection (LLDs). The LLD is defined, for purposes of this guide, as the smallest concentration of radioactive material in a sample that will yield a net count (above system background) that will be detected with 95% probability with only 5% probability of falsely concluding that a blank observation represents a "real" signal.

For a particular measurement system (which may include radiochemical separation):

$$LLD = \frac{4.66 s_b}{E \cdot V \cdot 2.22 \cdot Y \cdot \exp(-\lambda \Delta t)}$$

where

LLD is the lower limit of detection as defined above (as pCi per unit mass or volume)

s_b is the standard deviation of the background counting rate or of the counting rate of a blank sample as appropriate (as counts per minute).

E is the counting efficiency (as counts per disintegration).

V is the sample size (in units of mass or volume)

2.22 is the number of disintegrations per minute per picocurie.

Y is the fractional radiochemical yield (when applicable).

λ is the radioactive decay constant for the particular radionuclide.

Δt is the elapsed time between sample collection and counting.

The value of s_b used in the calculation of the LLD for a particular measurement system should be based on the actual observed variance of the background counting rate or of the counting rate of the blank samples (as appropriate) rather than on an unverified theoretically predicted variance. In calculating the LLD for a radionuclide determined by gamma-ray spectrometry, the background should include the typical contributions of other radionuclides normally present in the samples (e.g. potassium-40 milk samples).

^bLLD for drinking water.

STATION NO.	MEDIA
1 THROUGH 3	PARTICULATES RADIOIODINE DIRECT RADIATION
4.5.7 10 THROUGH 15	DIRECT RADIATION
16	PARTICULATES RADIOIODINE DIRECT RADIATION
17 THROUGH 19	DIRECT RADIATION

FIGURE 9.6. Monitoring Locations Beyond the Site Boundary (PSP&L 1981a)

LEGEND:

STATION NO.	MEDIA
6 (WPPSS-5)	PARTICULATES RADIOIODINE DIRECT RADIATION
8 (WPPSS-5)	PARTICULATES RADIOIODINE MILK FRUITS AND/OR VEGETABLES
9 (WPPSS-5)	PARTICULATES RADIOIODINE DIRECT RADIATION MILK FRUITS AND/OR VEGETABLES
20	SEDIMENT AND INDICATOR ORGANISMS
21 THROUGH 26	DIRECT RADIATION
27 (WPPSS-27)	FISH
28	DIRECT RADIATION
29 and 30 (WPPSS 29 and 39)	DRINKING WATER
31 THROUGH 34	DIRECT RADIATION
35 (WPPSS-35)	SEDIMENT AND INDICATOR ORGANISMS
36	DIRECT RADIATION
37 and 38 (WPPSS 37 and 38)	MILK
39 THROUGH 42	DIRECT RADIATION
43 and 44	RIVER WATER
45	FISH

A more detailed discussion of the facility REMP is discussed below:

Radioiodine and particulates. The air sampling network will consist of seven stations. Three of the stations will be located in the vicinity of the site boundary in three different downwind directions. One additional site boundary station will be situated in an upwind direction to monitor potential impact from the Hanford Site 200 Area. Three stations from the Supply System program will be used to complete the air monitoring network. The Supply System Station 6, located approximately 14 km (9 mi) SSE from the facility, is situated in the vicinity of a proposed residential community. Supply System Station 8 is in the general vicinity of the nearest farm approximately 18 km (11 mi) ESE from the facility. The control station for this monitoring program will be Supply System Station 9 located about 40 km (25 mi) west/southwest (WSW) from the facility.

Airborne iodine and particulates will be sampled by continuous low volume air samplers with a flow rate of approximately 1 ft³/min. Radioiodine will be collected via charcoal canisters fitted in-line with the glass fiber filter for particulate collection.

The particulate filters will be changed weekly and analyzed for gross beta (beta analysis will occur no sooner than 24 hours from the time of collection to allow for radon and thoron daughter decay). Quarterly composited filters, by location, will be analyzed for gamma-emitting nuclides. Individual weekly filters will have gamma isotopic analysis performed only if gross beta results are ten times the mean of the control location. Charcoal canisters will be analyzed weekly for iodine-131.

Direct radiation. Direct radiation levels will be measured by a thermoluminescent dosimeter (TLD) system consisting tentatively of 34 stations. The exact number and location of stations will depend upon data on prevailing wind directions, station accessibility and the existing TLD stations maintained by the Supply System and PNL for DOE.

A TLD station will be located in each sector on an inner ring in the general area of the site boundary (inclusive of airborne locations) and an outer emergency assessment ring in the 6 to 8 km (4 to 5 mi) range. Data from the Supply System Stations 6 (community) and 9 (control) will be used to complete the sampling network.

Duplicate TLD sets will be placed at each location. One set will be exchanged on a quarterly basis, the other set of dosimeters will be collected annually.

Groundwater. Groundwater will not be used for drinking or construction activities at the facility. Groundwater on the Hanford Site is extensively monitored by PNL; during 1982, 324 wells were sampled at various times for radionuclide and chemical contaminants (Eddy, Prater and Rieger 1983). As a result of continual groundwater monitoring in the Hanford Site, and the fact that the facility will not utilize groundwater, the facility preoperational REMP will not include this medium as part of its program.

Columbia River water. River water will be sampled at the facility intake and discharge facilities. The intake water will be sampled to identify the isotopes and concentrations present prior to use by the facility. The water from the discharge line will be sampled prior to dilution by the Columbia River, and analysis will identify the isotopes and their concentrations which may be due to the facility operation. Similar samples will be taken immediately downstream from the facility discharge. The Columbia River will be sampled at the first downstream user. The water will be sampled, prior to any treatment or mixing, in the vicinity of the river water intake.

Drinking water. Drinking water will be monitored utilizing the data from the Supply System's stations at the DOE 300-Area and at the Municipal Water Treatment Plant for the City of Richland.

Sediment. Sediment samples will be collected above and below the facility discharge structure. Due to the velocity of the Columbia River in the vicinity of the discharge, sedimentary deposits are minimal. Data from the Supply System Sediment Station 35 will be used to evaluate potential radionuclide adsorption to sediments below the facility discharge.

Indicator organisms. Periphyton, moss, or rooted macrophytes will be sampled where available near the sediment station location. These indicator organisms will be analyzed to determine if radioactive effluents released from upstream users and potentially from the facility discharge are accumulated by the biota.

Fish. Fish will be collected from locations near the facility discharge utilizing, in part, available data from the Supply System. The species selected will include resident fish and/or those fish which are seasonally available. A station at the lower Granite Dam on the Snake River, utilized by the Supply System REMP, will be used as a control station.

Milk. Milk samples will be obtained from farms or individual milk animals which are located in sectors with the higher calculated annual average atmospheric dilution factors. The facility REMP will utilize data from the Supply System Stations 8, 9, 37, and 38. Milk Station 9 is the control location.

Food products. Data from the Supply System food product sampling network (Supply System Stations 8 and 9) will be used by the facility REMP.

The type of analysis to be performed for the various media was chosen to provide measurements of radionuclides from which the population doses may be estimated or verified to be below that specified in Appendix I of 10 CFR 50. In some cases, the analysis provides a trend indicator and will signal the need to perform additional specific analyses of individual samples. The frequencies selected are those expected to minimize the effect of day-to-day variations and provide an adequate quantity of samples to meet minimum sensitivity requirements of Table 9.16. The samples will provide statistically valid data which will be compared to subsequent results in order to detect variation from expected values.

The facility REMP will employ quality control procedures to ensure that samples are collected and prepared for measurement in a thorough, concise manner. Instrumentation to measure radioactivity will be state-of-the-art technology at the time the program begins. The analytical laboratory will be required to meet internal quality control standards and to participate in an inter-laboratory quality control program. The internal quality control analyses will include spikes (samples to which known activity is added), duplicate samples and blanks (samples free of activity). The results of all quality control analyses will be included in each progress and/or semi-annual report.

The facility preoperational REMP will be instituted two years prior to plant operation. The duration of the facility preoperational REMP for specific media will be as follows:

<u>Two Years</u>	<u>One Year</u>	<u>Six Months</u>
Direct radiation	Airborne particulate	Airborne iodine
Fish	Milk (except iodine)	Milk (iodine)
Vegetation	River water	
Sediment	Drinking water	

9.2 OPERATIONAL MONITORING PROGRAMS

9.2.1 Radiological Monitoring

The REMP is designed to meet federal and state requirements.

The facility's operational REMP will be an extension of the preoperational REMP described in Section 9.1.5. A comprehensive radiological monitoring program will be conducted for the first 3 years of facility operation (or the period corresponding to the maximum fuel burnup in the initial core cycle). The scope of monitoring in subsequent years will be determined based upon the results of the 2-year preoperational program and the initial 3 years of facility operation. If it can be demonstrated that the concentrations of radionuclides and doses to organisms associated with a particular pathway are sufficiently small, the number of samples and sample types may be reduced. An adequate program for measuring radiation levels and radioactivity in the facility environs will be maintained on a continuing basis to assist in verifying anticipated radioactivity concentrations and related public exposure.

To the extent possible, the facility's REMP will be interfaced with the monitoring program established for the Supply System nuclear projects 1, 2, and 4. The operational monitoring program will also utilize data from the DOE and Washington State radiological surveillance programs. The PNL has conducted a comprehensive annual radiological monitoring program of the Hanford Generating Plant and surrounding environs for more than 20 years. The Washington State Division of Social and Health Services collects and analyzes samples of Columbia River water, air, milk, and shellfish at a number of locations

relevant to the facility (Section 9.3.4). Together with the facility monitoring program, this extensive data base will be used to monitor:

- important pathways for the anticipated types and quantities of radionuclides released from the plant
- potential buildup of long-lived radionuclides in the environment, and the physical and biological sites of accumulation that may contribute to human exposure
- potential radiation exposure to important plants and animals
- correlations between levels of radiation and radioactivity releases from plant operation.

9.2.2 Chemical Effluent Monitoring

The water quality monitoring program will ensure that the quality of the receiving waters, the Columbia River, is maintained at the level specified by state and federal standards during construction and operation. Sampling will be done on effluents from the various waste streams entering the facility's discharge line. The effluent plume will also be sampled. The operational monitoring program frequency and methods of analysis will be basically those of the preoperational monitoring program described in Section 9.1. Detailed descriptions of sampling locations, frequencies and analytical techniques are included in that section.

Additional sampling locations in the facility discharge and in the major axis of the discharge plume will be established as part of the operational sampling program as necessary. Effluent in the discharge pipeline will be sampled weekly during the first few months of operation until a satisfactory balance of chemical additions is established. It is expected that during the initial year of operation, sufficient data will be gathered to characterize the effluent so that the sampling frequency may be adjusted appropriately. The sampling frequency then will be reduced to biweekly or monthly for a period of one year. Each sample taken for analysis will consist of a 24-hour composite to ensure a representative sample. Expected chemical waste characteristics of the discharge are given in Table 3.6-5 of Puget Sound Power & Light Company (1981a). Analysis will be for parameters which:

- the preoperational program has shown to exist in the intake water
- are expected to be part of the discharge (see Section 3.6 of Puget Sound Power & Light Company 1981a);
- are required by current state or federal regulations.

A detailed chemical study to define the extent and nature of the effluent plume will be performed during the first few months of operation. The sampling scheme will be a three-dimensional grid blanketing the region of the plume, with control locations sampled directly upstream from the facility's discharge point. The samples collected will be analyzed for the parameters identified above. This study will monitor changes in plume structure and water quality. From the results, positions for monthly and biweekly sampling locations in the major axis of the plume will be determined as part of the overall operational water quality monitoring program. Knowledge and experience gained during the first year's sampling program will be the basis for the ongoing water quality and chemical discharge monitoring studies.

The operational program will be coordinated with the existing water quality monitoring conducted upstream at Vernita Bridge (RM 388.1) by the USGS, and similar discharge monitoring conducted for WNP 1, 2, and 4 downstream of the facility, as well as with the USGS program at Richland (RM 338.9).

9.2.3 Thermal Effluent Monitoring

The operational program for thermal effluent monitoring is part of an integrated chemical and hydrological study of the discharge and receiving waters. Many of the sampling locations are the same as have been identified in the preoperational program in Section 9.1 and the additional three-dimensional plume monitoring stations required for water quality monitoring in Section 9.2.2. The thermal monitoring program consists of instantaneous and continuous monitoring studies. The instantaneous temperature monitoring program functions in conjunction with the operational water quality program to provide biweekly to monthly measurements. Seasonal studies of the temperature profiles in the Columbia River near the facility's discharge point will monitor the extent of the thermal plume.

9.2.3.1 Continuous Thermal Monitoring

Continuous thermographs will be placed in the facility's intake and discharge points. Temperature measurements will be made at seven locations. This monitoring grid will tie into two existing continuous thermographs maintained by USGS at Vernita Bridge and the City of Richland water supply intake as well as with proposed continuous thermograph at the intake of WNP 1/4.

9.2.3.2 Instantaneous Thermal Monitoring

The thermal and water quality monitoring programs undertaken during facility operations will be integrated. Instantaneous temperature measurements will be routinely made at all water quality sampling locations. During initial facility operation, thermal plume definition will be made in conjunction with the chemical water quality studies outlined in Section 9.2.2 over a three-dimensional grid.

9.2.4 Meteorological Monitoring

The operational meteorological monitoring program will be a continuation of the preoperational program discussed in Section 9.1.3.1.

9.2.5 Ecological Monitoring

The ecology of the Hanford Site has been under continuous study since 1943 by state and federal agencies (Section 9.3). The operational and preoperational program will supplement the accumulation of scientific data by acquiring additional biological information.

The operational monitoring program for the facility will be a continuation of the preoperational program (discussed in Section 9.1.1). The operational program will be conducted for one year, after which an evaluation will determine the necessity of continuation or alteration.

Additional monitoring programs will be conducted during the first year of operation to evaluate the incidence of impingement and entrainment in the plant intake and cooling water supply system.

9.3 RELATED ENVIRONMENTAL MEASUREMENT AND MONITORING PROGRAMS

A number of environmental measurement and monitoring programs may be related to programs that would be conducted if the facility were sited at Hanford. These are listed in the following subsections.

9.3.1 Hydrological and Water Quality Studies in Progress

<u>Agency</u>	<u>Program</u>
U.S. Geological Survey, Tacoma District Office	Continuous water stage and discharge measurements of the Columbia River below Priest Rapids Dam (RM 394.5) (USGS 1974).
U.S. Geological Survey, Tacoma District Office	Continuous water temperature measurements of the Columbia River at the City of Richland water supply treatment plant (RM 338) and at Vernita Bridge (RM 388.1) ^(a,b) .
U.S. Geological Survey, Tacoma District Office	Monthly to quarterly monitoring of National Stream Quality Accounting Network Stations at Vernita Bridge and City of Richland pumping plant intake. Parameters measured are: conductance, pH, turbidity, dissolved oxygen, fecal coliform, hardness, major cations and anions, alkalinity, dissolved and suspended solids, dissolved silica, total and dissolved nutrients, metals (total recoverable, suspended recoverable, and dissolved). In addition, at the Vernita Bridge Station, periphyton biomass, chlorophyll <u>a</u> and <u>b</u> and phytoplankton cell counts are conducted.
U.S. Department of Energy, Richland Operations Office	Weekly pH, turbidity, dissolved oxygen, biochemical oxygen demand, and coliform sampling of the Columbia River at the City of Richland water supply treatment plant (RM 338), 300 Area (RM 345), and Vernita Bridge (RM 388.1), by PNL (Bramson and Corley 1973).
U.S. Department of Energy, Richland Operations Office	Weekly coliform, fluoride and nitrate sampling of Columbia River at the City of Richland water supply treatment plant (RM 338), 300 Area (RM 345), and 100 Areas (to RM 384), by Hanford Environmental Health Foundation (Schultz 1972).

- (a) E. L. Hilty and J. P. Corley, personal communication, Pacific Northwest Laboratory, Richland, Washington, 1975.
- (b) Letter from Y. Onishi, Pacific Northwest Laboratory to P. G. Holsted, U.S. Atomic Energy Commission, Columbia River Quality Radionuclide and Sediment Transport, December 11, 1974.

Agency	Program
U.S. Department of Energy, Richland Operations Office	Monthly to annual groundwater depth and water quality measurements for observation wells on Hanford Site, by PNL and Rockwell Hanford Operations (Bramson and Corley 1973; Kipp 1973).
U.S. Department of Energy, Division of Biomedical and Environmental Research	Studies by PNL on sediment and radionuclide transport in the Columbia River below Priest Rapids.
U.S. Department of Energy, Richland Operations Office	Environmental surveillance of the levels of radionuclide concentrations in Columbia River water, foodstuffs, wildlife, soils and vegetation, and direct radiation on the Hanford Site, by PNL (Sula et al. 1983).
U.S. Army Corps of Engineers North Pacific Division	Review of Columbia River and tributaries water resources (U.S. Army Corps of Engineers 1972).
Washington State Department of Ecology	Water temperature, dissolved oxygen, conductivity, color, pH, turbidity, total coliform bacteria and fecal coliform bacteria sampling in the Columbia River at Highway 24 Bridge near Vernita (RM 388.1) (semi-monthly during water year 1972, quarterly during water year 1975), and at the Port of Pasco public dock (RM 328.4 (semimonthly December 1971 - September 1972), and occasional biochemical oxygen demand and stream-flow determinations at both sites. Sampling of additional 21 parameters at Vernita Bridge during water year 1972 ^(a) . Data also available through STORET (U.S. EPA 1976).
U.S. Environmental Protection Agency	Miscellaneous water quality measurements in STORET data system for period 1957 to present at following Columbia River locations between McNary and Priest Rapids Dams: RM 292.0 (McNary Dam), 292.4, 292.5, 293.0, 324.9 (above mouth of Snake River), 326.3, 328.0 (Kennewick-Pasco State Highway 12 bridge), 328.0, 329.0, 330.0, 334.7 (below mouth of Yakima River), 388.1 (Vernita Bridge, State Highway 24), 388.5, 395.6, 397.1 (Priest Rapids Dam) (U.S. EPA 1976).

- (a) Letter from R. Cunningham, Water Quality Monitoring Section, Washington State Department of Ecology, Olympia, Washington to A. Brandstetter, Pacific Northwest Laboratory, Richland, Washington, May 26, 1976.

9.3.2 Ecological Parameters

9.3.2.1 Aquatic Studies in Progress

<u>Agency</u>	<u>Program</u>
U.S. Department of Energy, Division of Biomedical and Environmental Research	Annual (since 1947) census of the fall chinook salmon spawning population in the Columbia River between Richland and Priest Rapids Dam, by PNL. Weekly aerial observations have provided data to evaluate the fluctuations in spawning populations in this section of the river and examine the relationships between numbers of fish and perturbations in the river (Watson 1970)
U.S. Department of Energy, Division of Biomedical and Environmental Research	Studies on fish behavior in waters whose quality has been altered by various perturbations. Emphasis in this work is on the effects of water level fluctuation on the use of shoreline and shallow water habitats by resident and anadromous fish (PNL 1976).
U.S. Department of Energy, Division of Biomedical and Environmental Research	Studies by PNL on the impact of flow manipulation due to hydroelectric power generation on important fish species.
U.S. Army Corps of Engineers, Grant County PUD, Chelan County PUD	Studies of upstream adult migrant fish passage over Columbia River dams. These fish counts are generally made from April to October each year.
Mid-Columbia Studies Committee	Studies on Priest Rapids Dam and the Hanford Reach to increase salmon production by assessing mortalities accurately, assessing fish condition and improving survivability past Priest Rapids Dam (Whitney 1981).
Grant County PUD Ephrata, Washington	Ongoing survey of fall chinook salmon spawning areas on Vernita Bar, downstream of Priest Rapids Dam, from 1978 to 1980 (Weitcamp, Chapman and Welsh 1979, 1981).
Grant County PUD Ephrata, Washington	Studies of the contribution of Priest Rapids Hatchery fall chinook to the artificial and natural spawning populations near Priest Rapids Dam during 1979 (Young and Arthur 1980).
Grant County PUD Ephrata, Washington	Studies at Priest Rapids Dam in 1981 to assess fry movements downstream through the forebay and dam (Mid-Columbia Studies Committee).

<u>Agency</u>	<u>Program</u>
Grant, Douglas and Chelan Counties PUD's	An assessment of the down-stream migration of juvenile salmonids in the mid-Columbia River (CH2M-Hill 1980).
Grant, Douglas and Chelan Counties PUD's	Evaluation of the effectiveness of water spilling at Wanapum Dam for the passage of juvenile salmon (CH2M-Hill and Washington Department of Fisheries 1980).
Washington State Department of Fisheries	Aerial spawning surveys in the Hanford Reach and vicinity. Surveys to determine chinook spawning are conducted from October through November. Carcass recovery of spawning fall chinook salmon occurs on an irregular basis.
Washington State Department of Game	Year-round creel census of anglers in the Ringold area, and in the upper Hanford Reach from July to October. Periodic fish sampling and slough surveys are conducted to determine relative abundance of fish species and production of resident fish spawning area.
U.S. Fish and Wildlife	Studies to determine impact of resident fish populations on salmonid smolt rearing in McNary pool.
National Marine Fisheries Service	Research on timing and abundance of juvenile downstream migrant salmonids at Priest Rapids Dam.
National Marine Fisheries Service	Research on the enhancement of downstream passage of juvenile salmonids at Priest Rapids Dam and other PUD dams on the Columbia River.

9.3.2.2 Related Terrestrial Ecology Monitoring Programs

<u>Agency</u>	<u>Program</u>
Grant County PUD	Grant County PUD is conducting a short-term study of the effects of fluctuating water levels on island habitats in the Hanford Reach of the Columbia River. This study will supply little relevant information for the facility; nonetheless, the final report will be reviewed. ^(a)

(a) Personal communication of A.D. Every, NUS Corporation, August 1981.

Agency	Program
Washington Public Power Supply System	<p><u>Vegetation.</u> Studies in the vicinity of WNP 1, 2, and 4 have been conducted under contract to PNL and Beak Consultants, Inc. These studies are continuing and include vegetation transects and soil and plant chemistry. These studies will provide base-line data for monitoring the effects of drift on the soil and vegetation. These data will be used to determine if drift impacts might potentially occur at the facility (Rickard and Gano 1979 a,b; Glad 1981).</p> <p><u>Wildlife.</u> Studies in the vicinity of WNP 1, 2, and 4 have been conducted by Supply System personnel and PNL. These studies documented relative abundance of pocket mice, deer, rabbits, and landbirds. These data will assess the impact of drift on resident wildlife. Studies of deer, rabbits, and landbirds are continuing. These data also will be used to determine if drift impacts might potentially occur at the facility (Rickard and Gano 1979a,b; Nudge 1981).</p>
U.S. Army Corps of Engineers	<p>Studies of the riparian biota were conducted in 1980 under contract to PNL. The issued report is titled "Wildlife Usage, Threatened and Endangered Species and Habitat Studies of the Hanford Reach, Columbia River, Washington." This study evaluated potential impacts of the potential Ben Franklin Dam. Data presented in this report is directly related to the facility and is cited frequently in Section 2.2.1 of Puget Sound Power and Light Company (1981a) (Fickeisen et al. 1980).</p>
U.S. Department of Energy	<p><u>ALE Reserve.</u> The objective of the Arid Lands Ecology (ALE) Reserve is to quantitatively assess the role of environmental stresses on the structure and function of shrub steppe ecosystems in the northwestern United States. Natural and man-induced stresses have been evaluated for a 10-year period on the ALE Reserve. Widespread stresses studied include drought, fire, cattle grazing, and plowing. Data regarding habitat stress is relevant to the facility (see Section 2.2.1.6 of Puget Sound Power and Light Company, 1981a). Data regarding vegetation and wildlife provides valuable regional data on the shrub steppe</p>

that is summarized in Section 2.2.1 of the same document. (a)

Vegetation. PNL has conducted vegetation studies on the Hanford Site for several years, including ecological characterization and studies of productivity, succession, fire effects, revegetation, drought response, and uptake of transuranic elements by plants. Some of these were close enough to the facility to provide valuable background information (Section 2.2.1 and footnotes of Puget Sound Power and Light Company, 1981a).

Rockwell Hanford Operations is conducting radionuclide accumulation studies of plant samples, but not ecological vegetation studies. These data are not particularly relevant to the facility. (b)

Wildlife. PNL has conducted many studies on the wildlife of the Hanford Site including habitat requirements, food habits, population ecology, breeding ecology, and radionuclide transport. In general, these studies provide relevant data on the area and often will help monitor wildlife impacts which may result from the facility. (c)

In addition to the continuing studies at the ALE Reserve, long-term monitoring of certain wildlife populations are being conducted throughout the Hanford Site.

a. Canada Goose Nesting Surveys

Since 1953, routine yearly surveys of goose nesting on islands in the Columbia River directly across from the Hanford Site have been conducted. Productivity of individual nests on each of 20 islands has been documented and related to natural and man-caused environmental changes. (c)

(a) Personal Communication of R. E. Fitzner, PNL, May 1981.

(b) Personal communication of A. D. Every, NUS Corporation, August 1981.

(c) Personal communication of R. E. Fitzner, PNL, May 1981.

Agency	Program
	b. Great Blue Heron Studies
	Radionuclide and heavy metal analyses of excreta collected under a colony at the islands across from the Hanford Site have been compared to several other colonies in the Northwest. This study enables researchers to examine the trends in chemical composition of excreta as they relate to known ^(b) contamination in the environment.
	c. Bald Eagle Wintering Surveys
	Yearly wintering surveys of bald eagles are conducted on the Hanford Reach of the Columbia River. A careful watch is being made to determine if Hanford operations are having any impact on ^(a) this threatened species activities.
	d. Gulls and Terns
	Two colonies of ring-billed and California gulls, and three colonies of Forster's terns nest on islands in the Hanford Reach. Periodic nesting surveys relate nesting success to various environmental perturbations ^(a) .
	e. Deer
	Over 20 mule deer have been radio-tracked to determine movement patterns in ^(a) relation to Hanford operations.

(a) Personal communication of R. E. Fitzner, PNL, May 1981.

9.3.3 Meteorological Monitoring Programs in Progress

Washington Public Power Supply System	The meteorological data collection program at the WNP-2 site (about 8 km (5 mi) from the site) was operational from April 1974 to June 1976 and was resumed in the fall of 1979. System measurements include wind speed and wind direction at the 10- and 74-m (33- and
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<u>Agency</u>	<u>Program</u>
	245-ft) levels. Temperature difference measurements are made between the two levels. Dewpoint temperature is measured at the 10 m (33-ft) level; precipitation is measured at ground level.
U.S. Department of Energy	The Hanford Meteorological Station 18 km (11 mi) west/northwest of the site) is operated for DOE by PNL. This station is manned by an observer-forecaster 24 hr/day. Complete surface weather observations are made hourly. Wind and temperature profiles from the surface to 122 m (400 ft) are monitored continuously (Stone 1964). In addition, a network of eighteen telemetered wind and temperature stations, including those near the WNP-2 site and the facility site, is operated on the Hanford Site to assist in defining airflow patterns. Micrometeorological and climatological records dating

(a) Personal communication of A. D. Every, NUS Corporation, August 1981.

9.3.4 Radiological Studies in Progress

<u>Agency</u>	<u>Program</u>
	from 1944 to 1980 are available from the Hanford Meteorological Station (Stone, Thorp, Gifford, and Hoitink 1983).
U.S. Department of Energy Richland Operations Office	Climatological measurements of maximum and minimum temperature, humidity, and temperature, humidity, and precipitation are currently being made on DOE's ALE Reserve by PNL (Thorp 1973). The ALE Reserve lies to the west of the site.
U.S. Department of Energy	A comprehensive radiological monitoring program for the Hanford Plant and surrounding environs is carried out by PNL to evaluate the disposition and translocation of Hanford plant-released radionuclides (continuous since before 1960). Table 9.19 provides a summary of the program, taken from (Blumer et al. 1982) and Figures 9.7 and 9.8 show sampling locations. Annual reports provide surveillance program details (Blumer, et al 1982) and results (Sula et al. 1983; Eddy et al. 1983).

Agency	Program
Washington State, Division of Social and Health Services	A state-wide radiological program is carried out by the Radiological Control Units (Mooney 1975). Samples of Columbia River water, air, milk, and shellfish are obtained at a number of locations relevant to WNP-2 and WNP-1/4 which are shown in Table 9.20 and Figure 9.9. Results are reported to the EPA and published annually.
Washington Public Power Supply System	<p>Preoperational radiological environmental program prior to the start-up of WNP-2. Table 9.21 provides a summary of the program taken from (WPPSS). Figure 9.10 and its key, Table 9.22, show the sampling locations. Table 9.23 lists representation results of samples collected between March 1978 through June 1980.</p> <p>The results of the U.S. DOE and Washington State programs are published annually and are available publicly. Their procedures and methodologies are discussed in their annual reports (Blumer et al. 1982; Sula et al. 1983; Eddy et al. 1983; Mooney 1983, and later reports).</p> <p>The Supply System program is discussed in WPPSS.</p> <p>The results of all three programs are readily available to the facility.</p>

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APPENDIX A

DETAILED ECOLOGICAL DATA

TABLE A.1. Terrestrial Plants Expected in the Environs of the Primary Site
(U.S. NRC 1982)

PLANTS

Shrubs

Big sagebrush	Artemesia tridentata
Bitterbrush	Purshia tridentata
Green rabbitbrush	Chrysothamnus viscidiflorus
Gray rabbitbrush	C. nauseosus
Spiny hopsage	Grayia spinosa
Snow eriogonum	Eriogonum niveum

Forbs

Longleaf phlox	Phlox longifolia
Balsamorhiza	Balsamorhiza careyana
Sand dock	Rumex venosus
Scurf-pea	Psoralea lanceolata
Lupine	Lupinus laxiflorus
Pale evening primrose	Oenothera pallida
Desert mallow	Sphaeralcea munroana
Cluster lily	Brodiaea douglasii
Sego lily	Calochortus macrocarpus
Tansy mustard	Descurainia pinnata
Tumble mustard	Sisymbrium altissimum
Cryptantha	Cryptantha circumscissa
Russian thistle (tumbleweed)	Salsola kali
Fleabane	Erigeron filifolius
Wild parsley	Cymopterus terebinthum
Spring draba	Draba verna
Bur sage	Franeria acanthicarpa
Littlebells polemonium	Polemonium micranthum
Longhorn plectritis	Plectritis macrocera

Grasses

Sandberg bluegrass	Poa sandbergii
Cheatgrass	Bromus tectorum
Indian ricegrass	Oryzopsis hymenoides
Squirrel tail	Sitanion hystrix
Six-week fescue	Festuca octoflora
Thickspike wheatgrass	Agropyron dasystachyum
Sand dropseed	Sporobolus cryptandrus

Riparian Vegetation

Willow	Salix exigua and others
Cottonwood	Populus trichocarpa
Sedges	Carex spp.
Rushes	Juncus sp.
Horsetail	Equisetum sp.
Cocklebur	Xanthium sp.
Wild onion	Allium sp.

TABLE A.2. A Description of Soil Types Within Primary Site and Associated Areas with Cross-References to Other Classification Schemes

Rugers Sand (Rp)	The surface is a brown to grayish brown (10YR ⁵ /2) coarse sand, which grades to a dark grayish brown (10YR ⁴ /2) sand at about 90 cm. Rupert soils developed under grass, sagebrush, and hopsage in coarse sandy alluvial deposits which were mantled by wind-blown sand. Relief characteristically consists of hummocky terraces and dune-like ridges. Active sand dunes are present. Some dune areas are separated; however, many small dunes, blow-outs, and associated small areas of Ephrata and Burbanks soils are included.	Regosol (a) Typic Torripsamment (b)
Burbank Loam Sand (Ba)	This is a dark-colored [surface is very dark grayish brown (10YR ³ /2 ₄); subsoil is dark grayish brown (10YR ⁴ /s)], coarse-textured soil which is underlain by gravel. The surface soil is usually about 40 cm thick but can be 76 cm thick. The gravel content of the subsoil may range from 20 to 80 volume percent. Areas of Ephrata and Rupert are included.	Regosol (a) Typic Torripsamment (b)
Ephrata Sandy Loam (E1)	This is a dark colored [surface is very dark grayish brown (10YR ³ /s); subsoil is dark grayish brown (10YR ⁴ /2)] medium-textured soil which is underlain by gravelly material which may continue for several meters. This soil is associated with the Burbank soil and many small areas were included in delineations of this soil type. The topography is generally level.	Sierozem (a) Andic Mollic Camborthid (b)
Dune Sand (D)	This unit represents a miscellaneous land type which consists of hills or ridges of sand-sized particles drifted and piled up by wind and are either actively shifting or so recently fixed or stabilized that no soil horizons have developed. In places, recently blown-out land and areas of Rupert, sand are included. Many small active dunes and accompanying blown-out areas are included with other soils, mostly Rupert, Hezel and less frequently Burbank.	

(a) Baldwin, B., C.E. Kellogg, and J. Thorpe, 1938.

Soil Classification in Soils and Man, U.S. Dept. Agric., Yearbook pp. 979-1001.

(b) Soil Survey Staff. 1960. Soils Classifications, A comprehensive System, 7th Approximation, Soil Cons. Serv., U.S. Dept. Agric. Source: Hajek, 1966.

TABLE A.3. Average Chemical and Physical Properties of Soil from Sagebrush/Cheatgrass Plant Communities on the Hanford Reservation

	Soil Depth (dm)						
	0-1	1-2	2-3	3-4	4-5	5-6	Avg
Texture							
% Sand	59	62	67	63	57	57	61
% Silt	40	37	32	36	42	42	38
% Clay	1	1	1	1	1	1	1
Organic Matter							
%	0.68	0.45	0.35	0.43	0.43	0.50	0.47
Elec. Cond.							
mmhos/cm	0.25	0.20	0.24	0.29	0.21	0.30	0.25
pH	7.5	7.6	7.7	7.9	7.9	8.1	7.8

Source: Cline, J. F., O. W. Uresk, and W. H. Rickard. 1977. "Plants and Soil of a Sagebrush Community of the Hanford Reservation." Northwest Sci. 51(1):60-70.

TABLE A.4. Summary of Soil Chemistry Data from Nine Sites Near WNP 1, 2 and 4^(a) Located Within 5-8 km of the Primary Site (Soil Type was Predominantly Rupert Sand)

<u>Parameter</u>	<u>Mean</u> ^(b)	<u>Standard Deviation</u>
pH (1:2 soil to water)	7.19	.304
Bicarbonate (mea. of HCO ₃ /gm)	2.67	1.715
Conductivity (umhos/cm @ 25°C) (1:2 soil to water)	23.10	7.123
Sulfate (ug/g)	63.67	50.022
Chloride (ug/g)	13.14	3.265
Copper (ug/g)	12.22	1.302
Lead (ug/g)	4.41	0.701
Cadmium (ug/g)	0.67	0.701
Nickel (ug/g)	17.11	1.324
Zinc (ug/g)	60.61	12.503
Sodium (%)	0.12	0.043
Potassium (%)	0.28	0.044
Calcium (%)	0.64	0.075
Mercury (ug/g)	.04	-
Fluoride (ug/g)	267.44	40.570

(a) Source: (Glad 1981)

(b) Calculated from raw data presented by Glad (PSP&L 1981).

TABLE A.5. A Comparison of Beetle Abundance on the 200 Area Plateau With a Control Area on the Arid Lands Ecology (ALE) Reserve (Rogers and Rickard 1977)

Species ^(a)	REDOX Pond Area	B-C Cribs Area	Control Area
	-----1974-----		
ANCA	1	2	7
CONE	29	0	318
COSE	3	0	1
ELHI	20	16	48
ELHU	1	1	5
ELNI	0	0	15
ELNO	1	0	2
ELOB	3	1	0
EUMU	8	89	0
PHDE	4	70	9
Total	70	179	405
	-----1975-----		
ANCA	0	0	1
CONE	1	2	2
COSE	5	0	1
ELHI	3	7	9
ELHU	0	1	0
ELNI	0	0	1
ELNO	0	0	0
ELOB	0	0	0
EUMU	19	4	1
PHDE	11	3	8
Total	39	17	23
SCIENTIFIC NAME	ABBREVIATION ^(a)		
<u>Anemia californica</u>	ANCA		
<u>Blapstinus spp.</u>	BLSP		
<u>Coniontis lanei</u>	COLA		
<u>Coniontis ovalis</u>	COOV		
<u>Coniontis setosa</u>	COSE		
<u>Conisattus nelsoni</u>	CONE		
<u>Eleodes granulata</u>	ELGR		
<u>Eleodes hispidulabris</u>	ELHI		
<u>Eleodes humeralis</u>	ELHU		
<u>Eleodes nigrina</u>	ELNI		
<u>Eleodes novoverrucula</u>	ELNO		
<u>Eleodes obscura</u>	ELOB		
<u>Eusattus muricatus</u>	EUMU		
<u>Oxygonodera hispidula</u>	OXHI		
<u>Philolithus densicollis</u>	PHDE		
<u>Stenomorpha puncticollis</u>	STPU		

(a) Abbreviations derived from first two letters of genus & species names, respectively.

TABLE A.6. Darkling Beetle Abundance on the 200 Area Plateau, Hanford Reservation (Rogers et al. 1978)

	Control		B-C Crib		Bitterbrush		Sagebrush- Bitter- brush	
	1976	1977	1976	1977	1976	1977	1976	1977
<u>Eleodes hispilabris</u> Say	404	278	344	219	193	280	358	429
<u>Eleodes novoverucula</u> Bod.	153	40	90	38	191	166	198	178
<u>Eleodes humeralis</u> LeC	56	93	81	83	56	62	10	29
<u>Eleodes nigrina</u> LeC	55	47	5	6	5	11	5	29
<u>Eleodes granulata</u> LeC	18	4	12	10	10	2	14	1
<u>Eleodes obscura</u> Say	0	1	0	0	24	24	0	5
<u>Eusatus muricatus</u> LeC	20	38	310	3	5	54	0	18
<u>Coniontis setosa</u> Csy.	55	35	131	16	17	959	41	1323
<u>Conisattus nelsoni</u> Bod.	0	0	0	0	0	3	0	0
<u>Oxygonodera hispidula</u> Horn	0	0	0	0	0	1	0	0
<u>Philolitus densicollis</u> (Horn)	37	21	180	39	1	0	135	72
Total	798	557	1153	414	502	1562	761	2084

TABLE A.7. Grasshopper Species Collected at B-C Crib and REDOX Pond Areas
(Sheldon and Rogers 1976)

B-C Crib	REDOX Pond
Species:	
<u>Agoneotettix deorum</u> (Scudder)	<u>Agoneotettix deorum</u> (Scudder)
-----	<u>*Amphitornus coloradus</u> (Thomas)
<u>Apote notabilis</u> (Scudder)	<u>Apote notabilis</u> Scudder
-----	<u>Arphia pseudonietana</u> (Thomas)
<u>Aulocara elliotti</u> (Thomas)	<u>Aulocara elliotti</u> (Thomas)
<u>Conozoa wallula</u> (Scudder)	<u>Conozoa wallula</u> (Scudder)
<u>Hesperotettix viridis</u> (Thomas)	<u>Hesperotettix viridis</u> (Thomas)
<u>Melanoplus cinereus</u> (Scudder)	<u>Melanoplus cinereus</u> Scudder
<u>Melanoplus sanguinipes</u> (F.)	<u>Melanoplus sanguinipes</u> (F.)
<u>Mealanoplus yarrowii</u> (Thomas)	<u>Mealanoplus yarrowii</u> (Thomas)
<u>Oedaleonotus enigma</u> (Scudder)	<u>Oedaleonotus enigma</u> (Scudder)
-----	<u>Paropomala pallida</u> Brumer
<u>Steiroxys</u> sp.	<u>Steiroxys</u> sp.
<u>Trimerotropis bilobata</u> (Rehn and Bebard)	-----
<u>Trimerotropis caeruleipennis</u> (Brunner)	<u>Trimerotropis caeruleipennis</u> (Brunner)
<u>Trimerotropis pallidipennis</u> (Burmeister)	<u>Trimerotropis pallidipennis</u> (Burmeister)
<u>Zanthippus lateritus</u> (Saussure)	<u>Zanthippus lateritus</u> (Saussure)
TOTAL: 14	TOTAL: 16

* Collected during the summer of 1975.

TABLE A.8. Species List of Birds Associated Either Directly or Peripherally with the Pacific Northwest Steppe. Habitat Preferences Are Shown, Along with Crude Estimates of Abundance (Rogers and Rickard 1977)

<u>Status</u>	<u>Species</u>	<u>Steppe</u>	<u>Shrub-Steppe</u>
Permanent Residents	Marsh Hawk	+	+
	Red-tailed Hawk	+	+
	Sharp-tailed Grouse	-	-
	Sage Grouse	-	-
	Chukar	+	+
	Ring-necked Pheasant	-	-
	Gray Partridge	-	-
	Short-eared Owl	-	-
	Horned Lark	++	+
	Black-billed Magpie	+	++
	Common Raven	+	+
	Common Crow	-	+
	Western Meadowlark	+	++
	California Quail	+	+
Summer Residents	Prairie Falcon	-	-
	Long-billed Curlew	+	
	Mourning Dove	+	+
	Burrowing Owl	+	+
	Swainson's Hawk	+	+
	Common Nighthawk	+	+
	Barn Swallow	-	+
	Sage Thrasher		+
	Loggerhead Shrike	-	
	Grasshopper Sparrow	-	
	Vesper Sparrow	+	
	Lark Sparrow	-	-
	Black-throated Sparrow		-
	Sage Sparrow		++
Winter Residents	Brewer's Sparrow		+
	Rough-legged Hawk	+	+
	Northern Shrike	-	-
	Bald Eagle	-	-

TABLE A.9. Vascular Plants of Waste Storage Sites in the 200 Areas of the Hanford Reservation (Price and Rickard 1973)

<u>Common Name</u>	<u>Scientific Name</u>	<u>General Occurrence</u>
Annual fescue	<u>Festuca pacifica</u>	Dry areas
Asparagus	<u>Asparagus officinalis</u>	Ditch banks and moist areas
Aster	<u>Aster canescens</u>	Disturbed dry areas
Barnyard grass	<u>Echinochloa crusgalli</u>	Ditch banks and moist areas
Bassia	<u>Bassia hyssopifolia</u>	Disturbed dry areas
Bastard toad-flax	<u>Comandra pallida</u>	Dry areas
Beggar-tick	<u>Bidens faronosa</u>	Ditch banks and moist areas
Big bluegrass	<u>Poa ampla</u>	Dry areas
Big sagebrush	<u>Artemisia tridentata</u>	Undisturbed dry areas
Blazing Star	<u>Mentzelia albicaulis</u>	Dry areas
Bluebunch Wheatgrass	<u>Agropyron spicatum</u>	Dry areas
Bluegrass	<u>Poa canbyi</u>	Dry areas
Bracken fern	<u>Pteridum aquilinum</u>	Dry areas
Bristlegrass	<u>Setaria viridis</u>	Ditch banks and moist areas
Brodiaea	<u>Brodiaea douglasii</u>	Dry areas
Brodiaea	<u>Brodiaea howellii</u>	Dry areas
Buckwheat	<u>Eriogonum sp.</u>	Dry areas
Bulrush	<u>Scirpus maritimus</u>	Ditches and ponds aquatic emergent
Bulrush	<u>Scirpus validus</u>	Ditches and ponds aquatic emergent
Bur Sage	<u>Franseria acanthicarpa</u>	
Cattail	<u>Typha latifolia</u>	Ditches and ponds aquatic emergent
Chaenactis	<u>Chaenactis douglasii</u>	Dry areas

TABLE A.9. (contd)

<u>Common Name</u>	<u>Scientific Name</u>	<u>General Occurrence</u>
Cheatgrass	<u>Bromus tectorum</u>	Solid waste burial grounds Disturbed dry areas
Comandra	<u>Comandra pallida</u>	
Common mullen	<u>Verbascum thapsus</u>	Ditch banks and moist areas
Cottonwood	<u>Populus deltoides</u>	Ditch banks and moist areas around ponds
Cryptantha	<u>Cryptantha circumscissa</u>	Dry areas
Cryptantha	<u>Cryptantha pterocarya</u>	Dry areas
Cudweed	<u>Gnaphalium chilensis</u>	Disturbed moist areas
Daisy	<u>Townsendia florifer</u>	Dry areas
Dandelion	<u>Taraxacum officinale</u>	Ditch banks and moist areas
Desert mallow	<u>Spharalcea munroana</u>	Dry areas
Desert parsley	<u>Lomatium grayi</u>	Dry areas
Desert parsley	<u>Lomatium spp.</u>	Dry areas
Dock	<u>Rumex spp.</u>	Old pond bottom, disturbed moist areas
Dogbane	<u>Apocynum sibiricum</u>	Ditch banks and moist areas
Dogbane	<u>Apocynum androsoemifolium</u>	Old pond bottom, moist areas
Douglas Brodiaea	<u>Brodiaea douglasii</u>	
Draba	<u>Draba verna</u>	Dry areas
Erigeron species	<u>Erigeron spp.</u>	Dry areas
Evening primrose	<u>Oenothera andina</u>	Dry areas
Evening primrose	<u>Oenothera pallida</u>	Dry areas
Fiddleneck	<u>Amsinckia tessellata</u>	Disturbed dry areas
Fleabane	<u>Erigeron filifolius</u>	Dry areas

TABLE A.9. (contd)

<u>Common Name</u>	<u>Scientific Name</u>	<u>General Occurrence</u>
Fleabane	<u>Erigeron pumilus</u>	Dry areas
Gilia	<u>Gilia leptomeria</u>	Dry areas
Goldenrod	<u>Salidago spp.</u>	Old pond bottom and moist areas
Green rabbitbrush	<u>Chrysothamnus nauseosus</u>	Solid waste burial grounds, disturbed dry areas
Grey rabbitbrush	<u>Chrysothamnus viscidiflorus</u>	Solid waste burial grounds, disturbed dry areas
Hardstem bulrush	<u>Scirpus acutus</u>	Ditches and ponds, aquatic emergent
Hawksbeard	<u>Crepis atrabarba</u>	Dry areas
Hopsage	<u>Grayia spinosa</u>	
Horsetail	<u>Equisetum laevigatum</u>	Shoreline, wet areas
Horsetail	<u>Equisetum hyemale</u>	Ditch banks and moist areas
Horseweed	<u>Conyze canadensis</u>	Disturbed dry areas
Indian ricegrass	<u>Oryzopsis hymenoides</u>	Dry, sandy areas
Jim Hill mustard	<u>Sisymbrium altissimum</u>	Solid waste burial grounds, disturbed dry areas
Larkspur	<u>Delphinium nelsonii</u>	Dry areas
Layia	<u>Layia glandulosa</u>	Dry areas
Locoweed	<u>Astragalus purshii</u>	Dry areas
Locoweed	<u>Astragalus spp.</u>	Dry areas
Matted Cryptantha	<u>Cryptantha circumscissa</u>	
Microsteris	<u>Microsteris gracillis</u>	Dry areas
Muhlenbergia	<u>Muhlenbergia asperifolia</u>	Ditch banks and moist areas
Mustard	<u>Thelypodium laciniatum</u>	Dry areas
Needle and thread	<u>Stipa comata</u>	Sandy, dry areas

TABLE A.9. (contd)

<u>Common Name</u>	<u>Scientific Name</u>	<u>General Occurrence</u>
Nettle	<u>Urtica dioica</u>	Ditch banks and moist areas
Panic grass	<u>Panicum capillare</u>	Ditch banks
Peachleaf willow	<u>Salix amygdaloides</u>	Ditch banks, pond shoreline
Penstemon	<u>Penstemon acuminatus</u>	Dry areas
Phacelia	<u>Phacelia linearis</u>	Solid waste burial grounds, dry areas
Phlox	<u>Phlox longifolia</u>	Dry areas
Pigweed	<u>Chenopodium</u> <u>tephophyllum</u>	Dry areas
Plantain	<u>Plantago patagonica</u>	Moist areas
Plectritis	<u>Plectritis macrocera</u>	Moist areas
Reed Canary grass	<u>Phalaris arundinacea</u>	Moist areas
Rabbit brush	<u>Chrysothamnus nauseosus</u>	
Rabbit brush	<u>Chrysothamnus</u> <u>viscidiflorus</u>	
Russian Napweed	<u>Centaurea repens</u>	Disturbed moist areas
Russian thistle	<u>Salsola kali</u>	Solid waste burial grounds, tank farms, dry areas
Sand dropseed	<u>Sporobolus cryptandrus</u>	Ditch banks and disturbed areas
Sandbar willow	<u>Salix exigua</u>	Ditch banks, pond shoreline
Sandbur	<u>Franseria acanthicarpa</u>	Solid waste burial grounds, disturbed dry areas
Sandberg bluegrass	<u>Poa sandbergii</u>	Undisturbed dry areas
Sand verbena	<u>Abronia mellifera</u>	Dry areas
Scurf-pea	<u>Psoralea lanceolata</u>	
Sharp-leaved Penstemon	<u>Penstemon acuminatus</u>	

TABLE A.9. (contd)

<u>Common Name</u>	<u>Scientific Name</u>	<u>General Occurrence</u>
Sixweek Fescue	<u>Festuca octoflora</u>	
Smartweed	<u>Polygonum persicaria</u>	Ditch banks and pond shoreline
Speedwell	<u>Veronica anagallis-aquatica</u>	Ditch banks, pond shoreline,
Spiny hopsage	<u>Grayia spinosa</u>	Solid waste burial sites, dry areas
Spiny hopsage	<u>Grayia spinosa</u>	Solid waste burial sites, dry areas
Spurred lupine	<u>Lupinus sp.</u>	
Squirrel tail	<u>Sitanion hystrix</u>	Dry areas
Star tulip	<u>Calochortus macrocarpus</u>	
Stickseed	<u>Lappula redowskii</u>	Disturbed dry areas
Storks-bill	<u>Erodium cicutarium</u>	
Sunflower	<u>Balsamorhiza careyana</u>	Dry areas
Swainsona	<u>Swainsona salsula</u>	Ditch banks, moist areas
Sweet bullclover	<u>Melilotus alba</u>	Ditch banks, disturbed moist areas
Tansy mustard	<u>Descurainia pinnata</u>	Solid waste burial grounds, disturbed dry areas
Thick-spike wheatgrass	<u>Agropyron dasytachyum</u>	
Thistle	<u>Cirsium brevifolium</u>	Moist areas
Three-square bulrush	<u>Scirpus americanus</u>	Ditches and ponds, aquatic emergent
Tumbleweed	(see Russian thistle)	
Turpentine cymopterus	<u>Cymopterus terebinthinus</u>	
Wallflower	<u>Erysimum asperum</u>	Dry areas

TABLE A.9. (contd)

<u>Common Name</u>	<u>Scientific Name</u>	<u>General Occurrence</u>
Watercress	<u>Rorippa nasturtium-</u> <u>aquaticum</u>	Ditches, running water
White-stem mentzelia	<u>Mentzelia albicaulis</u>	
Willow herb	<u>Epilobium</u> <u>suffruticosum</u>	Disturbed dry areas
Wing-nut Cryptantha	<u>Cryptantha pterocarya</u>	
Wild lettuce	<u>Lactuca serriola</u>	Ditch bank, disturbed moist areas
Yarrow	<u>Achillea millifolium</u>	Disturbed dry areas
Yarrow	<u>Achillea lanulosa</u>	

TABLE A.10. Algae in the Phytoplankton and Periphyton Communities of the Hanford Reach of the Columbia River (PSP&L 1982; Neitzel et al. 1982)

Chrysophyta - Diatoms
(Bacillariophyceae)

Asterionella formosa
Achnanthes lewisiana
A. lanceolata
A. minutissima
A. trinodis
A. exigua
A. linearis
A. clevei
A. flexella
A. lanceolata v. omisa
Amphora persusilla
A. ovalis
Amphipleura sp.
Amphiprora sp.
A. pergalli
Amphipleura pellucida
Cymatopleura solea
Campylodiscus sp.
Caloneis sp.
Caloneis ventricosa v.
(? subundulata)
C. amphisbaena
C. lewisii
C. hyalina
Cymbella tumida
C. naviculiformis
Cymbella sp.
C. turgid
C. sinuata
C. cistula
C. minuta
C. mexicana
C. affinis
C. prostrata
C. muelleri
C. microcephala
Cymbellonitzschia
diluviana
Cyclotella spp.
C. pseudostelligera
C. kutzingiana
C. meneghiniana

C. glomerata
C. comta
C. comensis
C. bodanica
C. stelligera
C. atomas
C. ocellata
Dinobryon divergens
Denticula sp.
Diatoma sp.
D. vulgare
D. tenue v. tenue
D. hiemale v. (? mesodon)
Diploneis elliptica
D. puella
D. smithii v. dilatata
D. oculata
Epithemia spp.
E. turgida
E. sorex
Eunotia sp.
E. pectinalis
Frugilaria leptostauron
v. dubia
F. vaucheriae
v. vaucheriae
F. leptostauron
v. leptostauron
F. construens v. venter
F. crotonensis
F. construens
F. capucina
F. leptostauron
F. virescens
Frustulia sp.
F. thomboides
F. vulgaris
Gomphonema sp.
G. parvulum
G. subclavum
G. olivacedides
G. truncatum
G. ventricosum
G. olivaceum
G. olivaceum v. calcurea

TABLE A.10. (contd)

Chrysophyta
(Bacillariophyceae)
 (continued)

<u>G. geminatum</u>	<u>N. circumtexta</u>
<u>Gyrosigma sp.</u>	<u>N. bacillum Ehr. v.</u>
<u>Gyrosigma spencerii</u>	<u> bacillum</u>
<u>Hannaca arcus</u>	<u>N. cincta</u>
<u>H. arcus v. amphioxys</u>	<u>N. latens</u>
<u>Hantzschia amphioxys</u>	<u>N. mutica v. cohnii</u>
<u>Melosira spp.</u>	<u>N. mutica v. tropica</u>
<u>M. ambigua</u>	<u>Nedium dubium</u>
<u>M. granulata</u>	<u>N. spp.</u>
<u>M. granulata v. angust</u>	<u>N. affine v. humerus</u>
<u>M. italica</u>	<u>Nitzschia latens</u>
<u>M. varians</u>	<u>N. paleacea</u>
<u>M. distans v. alpigena</u>	<u>N. silica</u>
<u>M. americana</u>	<u>N. palea</u>
<u>Meridion sp.</u>	<u>N. dissipata</u>
<u>M. circulare</u>	<u>N. innominata</u>
<u>Navicula spp.</u>	<u>N. perminuta</u>
<u>N. seminuloides</u>	<u>N. allansoni</u>
<u>N. minima</u>	<u>N. frustulum</u>
<u>N. tripunctata</u>	<u>N. osmophila</u>
<u>N. cryptocephala</u>	<u>N. obsoleta</u>
<u>N. cryptocephala v.</u>	<u>N. linearis</u>
<u> veneta</u>	<u>N. intermissa</u>
<u>N. mutica</u>	<u>N. acicularis</u>
<u>N. arvensis</u>	<u>N. amphibia</u>
<u>N. pupula</u>	<u>N. oregona</u>
<u>N. reinhardtii</u>	<u>N. fonticola</u>
<u>N. pseudoreinhardtii</u>	<u>N. bacota f. lin.</u>
<u>N. radiosa</u>	<u>N. recta</u>
<u>N. viridula</u>	<u>N. angustata</u>
<u>N. peregrina</u>	<u>N. holsatica</u>
<u>N. decussis</u>	<u>N. gracilis</u>
<u>N. menisculus v. up.</u>	<u>N. stagnorum</u>
<u>N. capitata</u>	<u>N. lauenbergiana</u>
<u>N. cascadiensis</u>	<u>N. amphioxides</u>
<u>N. bacillum</u>	<u>N. sigmoidea</u>
<u>N. vitabunda</u>	<u>N. subacicularis</u>
<u>N. minuscula</u>	<u>N. accomodata</u>
<u>N. infirmata</u>	<u>N. demota</u>
	<u>N. hungarica</u>
	<u>N. subpunctata</u>
	<u>N. vermicularis</u>
	<u>N. serpenticula</u>

TABLE A.10. (contd)

Chrysophyta(Bacillariophyceae)
(continued)

N. sigma v. diminuta
N. martyi sp.
Opephora sp.
Pinnularia sp.
Pinnularia subcapitata
v. paucistriata
P. borealis
Rhoicosphenia curvata
Rhopalodia gibba
Rhizosolenia eriensis
Surirella spp.
S. linearis
S. angustata
Synedra spp.
S. capitata
S. ulna
S. ulna v. chaseana
S. acus
S. delicatissima
S. rumpens
S. vaucheriae
S. parasitica
S. mazamaensis
S. cyclopum
S. pulchella
S. radians
S. socia
Stephanodiscus sp.
S. astraia
S. astraia v. min.
S. hantzschii
S. dubius
Stauroneis kriegeri
Tabellaria fenestrata
T. flocculosa

Chrysophyta - Golden or Yellow-Brown Algae
(Chrysophyceae)

Chrysococcus refescens
Codosiga
Kephyrion spirale
K. asper
K. ovale
K. gracilis
Mallomonas alpina
Mallomonas tonsurata
Ochromonas-like
Rhizochrysis

Chlorophyta - Green Algae

Ankistrodesmus falcatus
Actinastrum sp.
Asterococcus sp.
Botryococcus sp.
Crucigenia quadrata
Cosmarium sp.
Cladophora sp.
Characlum ambiguum
C. sp.
Closterium acutum
C. sp.
C. gracile
Dictyosphaerium
ehrenbergianum
Eudorina sp.
E. elegans
Golenkinia sp.
Kirchneriella obesa
Lagerheimia sp.
Mougeotia
Odcystis pusilla
O. lacustria
Pandorina morum
Pediastrum boryanum
P. tetras
P. duplex

TABLE A.10. (contd)

Chlorophyta
(continued)

Spirogyra sp.
Stigeoclonium spp.
Staurostrum paradoxum
S. sp.
Scenedesmus quadricauda
S. abundans
S. acuminatus
S. longus
S. sp.
S. denticulatus
S. dimorphus
S. acutiformis
S. opoliensis
Schroederia judayi
S. setigera
Sphaerocystis schroeteri
Selenastrum minutum
S. sp.
Tetradismus sp.
Tetraspora lacustris,
lemm.
Treubaria
triappendiculata
T. sp.
Ulothrix zonata
Zygnema sp.

Cyanophyta - Blue-Green Algae

Anacystis cyanea
A. montana
Anabaena sp.
Arthrospira jenneri
A. brevis
Chroococcus sp.
Calothrix parietina
Dactylococcopsis sp.
Entophysalis rivularis
Lyngbya sp.

L. limnetica
Marssoniiella sp.
Oscillatoria spp.
O. planctonica
O. limnetica
O. lutea
Oedogonium sp.
Spirulina sp.
Schizothrix calcicola
S. sp.
S. fragilis
S. friesli
Tolypothrix distorta
Plectonema sp.

Rhodophyta - Red Algae

Audouinella violacea

Pyrrophyta - Dinoflagellates

Ceratium hirundinella
Cryptomonas erosa
Glenodinium sp.
Rhodomonas minuta
R. lacustris

TABLE A.11. Total Number of Phytoplankton Species (S) Within Major Algal Division and the Percent of Mean Monthly Phytoplankton Density Comprised by Algal Division (%) at RM352 (RKM566), September 1978 - March 1980 (Beak Consultants Inc. 1980)

Algal Division	1978				1979												1980		
	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
S	49	44	46	52	28	25	22	21	31	37	42	33	35	47	48	53	31	14	20
CHRYSTOPHYTA																			
%	90.2	70.8	85.0	84.2	96.2	99.9	99.8	98.8	90.9	97.4	83.7	87.2	89.2	83.3	74.2	76.4	82.2	94.4	96.5
S	4	8	2	7	2	1	1	1	1	3	7	5	12	5	4	5	2	2	1
CHLOROPHYTA																			
%	2.2	8.7	2.2	14.0	1.8	0.1	0.2	0.5	2.8	1.6	10.6	4.8	5.5	10.1	15.4	8.6	2.5	2.3	0.8
S	3	2	3		3			1	1	1	2	3	3	1	3	2	2	1	1
PYRROPHYTA																			
%	7.4	18.1	12.8		2.0			0.7	0.5	0.3	3.9	7.5	5.0	5.9	9.9	15.0	12.5	1.3	2.5
S	1	2		2					1	2	3	2	1	1	1		1	1	1
CYANOPHYTA																			
%	0.2	2.4		1.8					5.8	0.7	1.8	0.5	0.3	0.7	0.5		2.8	2.0	0.2
Total Taxa	57	56	51	61	33	26	23	23	34	43	54	43	51	54	56	60	36	18	23

TABLE A.12. Zooplankton Taxa Collected in the Hanford Reach, Columbia River (PSP&L 1982; Neitzel et al, 1982b)

Coelenterata

Hydra. spp.

Ectoprocta

Bryozoa

Paludicellidae

Paludicella articulata

Nematoda

Rotifera

Brachionidae

Kellicottia longispina

Keratella cochlearis

Kerratella (? quadrata)

Brachionus spp.

Euchlanis spp.

Kellicottia spp.

Lecanidae

Lecane spp.

Synchaetidae

Synchaeta spp.

Polyarthra sp.

Testudinellidae

Testudinella spp.

Tardigrada

Annelida

Oligochaeta

Hirudinea

Arthropoda

Cladocera

Leptodoridae

Leptodora kindtii

Sididae

Sida crystallina

Latona spp.

Diaphanosoma spp.

Daphnidae

Daphnia spp.

Daphnia pulex

Daphnia middendorffiana

Ceriodaphnia spp.

Bosminidae

Bosmina longirostris

Macrothricidae

Macrothrix spp.

Dyocryptus spp.

Chydoridae

Pleuroxus spp.

Pleuroxus denticulatus

Alona costata

Alona quadrangularis

Alona guttata

Alona rectangula

TABLE A.12. (contd)

Arthropoda (con't)

Chydorus spp.
 Eurycercinae
 Eurycercus lamellatus
 Ostracoda
 Copepoda
 Calanoida
 Temoridae
 Epischura spp.
 Temoridae copepodid
 Diaptomidae
 Diaptomus spp.
 Diaptomus ashlandi
 Cyclopoida
 Cyclopidae
 Copepoda nauplii
 Cyclops spp.
 Cyclopoid copepodid
 Cyclops bicuspidatus thomasi
 Harpacticoida

Amphipoda

 Acari

Insecta

 Collembola
 Ephemeroptera
 Trichoptera
 Rhyacophilidae
 Hydropsychidae
 Diptera
 Chironomidae
 Simuliidae
 Simulium sp.

Platyhelminthes

 Turbellaria
 Dugesia sp.

Protozoa

Vorticella sp.

TABLE A.13. Benthic Macrofauna of the Hanford Reach, Columbia River (PSP&L 1982)

Annelida

Oligochaeta
Hirudinea

Arthropoda

Hydracarina
Hygrobatidae
Hydrachnidae
Insecta
Trichoptera
Hydropsychidae
Hydropsyche cocherelli
Cheumatopsyche campyla
C. enonis
Brachycentridae
Brachycentrus sp.
Leptoceridae
Oecetis sp.
Glossomatidae
Hydroptilidae
Psychomyiidae
Rhyacophilidae
Lepidoptera
Pyralidae
Hemiptera
Corixidae

Odonata

Collembola

Coleoptera

Elmidae

Ephemeroptera

Baetidae

Diptera

Chironomidae

Simuliidae

Simulium sp.

Plecoptera

Crustacea

Amphipoda

Gammarus sp.

Decapoda

Pacifastacus (leniusculus) trowbridgii

Ostracoda

Bryozoa

Paludicella sp.

TABLE A.13. (contd)

Mollusca

Gastropoda

Physa sp.

Fisherola nuttallii

Lymnaea sp.

Parapholyx sp.

Lithoglyphus sp.

Platyhelminthes

Turbellaria

Dugesia sp.

Cura sp.

Nematoda

Tardigrada

Coelenterata

Hydra sp.

Porifera

Spongilla lacustris

Chordata

Agnatha

Lampetra tridentatus

TABLE A.14. Appearance of Algae in Ponds and Streams on the Hanford Site

Division (Common Name)	Family	Gable Pond	B- Pond	U- Pond	West Pond	A-29 Ditch	B-3 Ditch	Z-19 Ditch	100-N Trench
Cyanophyta (Blue-green Algae)	Oscillatoriaceae	+	+	+	+	+	+	+	+
	Chroococcaceae	+	+	+	+	+	+		
	Nostocaceae	+	+	+	+	+	+	+	+
Chlorophyta (Green Algae)	Desmidiaceae	+	+	+	+	+	+	+	+
	Palmellaceae		+	+		+			
	Volvocaceae		+						
	Characiaceae	+	+	+					
	Phacotaceae	+	+		+	+	+		
	Oocystaceae	+	+	+	+	+	+	+	+
	Scenedesmaceae	+		+	+	+	+	+	
	Tetrasporaceae			++					
	Micractiniaceae						+		
	Coccomyxaceae						+		
	Zygnemataceae	+		+		++		++	++
	Cladophoraceae	+	+	++	+	+	+	+	+
	Hydrodictyaceae	+		+				+	++
	Characeae	+							
Euglenophyta (Euglenoid Algae)	Euglenaceae			+	+				
Chrysophyta (Golden-brown Algae & Diatoms)	Mallomonadaceae					+			
	Ochromonadaceae						+		
	Coscinodiscaceae	++	+	+	+	+	++	+	+
	Rhizosoleniaceae				+				
	Tabellariaceae	+					+		
	Diatomaceae	+			+		+		
	Acnannanthaceae	+	+	+	+	+	+		
	Naviculaceae	+	+	+	++	+	+	+	+
	Gomphonemataceae	+	+	+	+	+	+		
	Cymbellaceae	+	++	+	+	++	+	+	+
	Nitzschaceae	+	+	+		+	+		
	Surirellaceae	+	+	+	+		+		
	Fragilariaceae	+	+	+	+	++	++	+	+
	Synuraceae				+				
Pyrrophyta (Dinoflagellates)	Gymnodiniaceae				+				
	Glenodiniaceae			+	+				
Cryptophyceae (Cryptomonads)	Cryptomonadaceae		+	+	+	+	+		

Note: The presence of a taxon is indicated by a "+", notably large abundance by a "++", and no symbol indicates an absence

Source: Emery and McShane (1980).

TABLE A.15. Dominant Macrophytes Observed in Ponds and Streams on the Hanford Site

Common Name	Genus	Gable Pond	B- Pond	U- Pond	West Pond	A-29 Ditch	B-3 Ditch	Z-19 Ditch	100-ft Trench
Horsetail	<u>Equisetum</u>	+		+					
Pondweed	<u>Potamogeton</u>	++	+	++				++	
Hornwort	<u>Ceratophyllum</u>	++							
Water Milfoil	<u>Myriophyllum</u>	++							
Duckweed	<u>Lemna</u>			+					
Cattail	<u>Typha</u>	-	+	++	+	+	+	++	
Bulrush	<u>Scirpus</u>	-	-	+	+	+	++	+	-
Smartweed	<u>Polygonum</u>			+					
Speedwell	<u>Veronica</u>					+	+	-	-
Watercress	<u>Rorippa</u>			+				-	
Wild Lettuce	<u>Lactuca</u>			+				-	
Willow	<u>Salix</u>	+		+					
Cottonwood	<u>Populus</u>	+		-		+		+	

Note: The presence of a taxon is indicated by a "+", notably large abundance by a "++", and no symbol indicates an absence.

Source: Emery and McShane (1980).

TABLE A.16. Appearance of Aquatic Fauna in Ponds and Streams on the Hanford Site

Common	Taxon	Gable Pond	B- Pond	U- Pond	West Pond	A-29 Ditch	B-3 Ditch	Z-19 Ditch	100-N Trench
Flatworm	<u>Dugesia</u>	+	+	+		+	+		
Leech	<u>Hirundinea</u>		+	+					
Segmented worm	<u>Oligochaeta</u>	+	+	+	++	+	+	+	+
Waterflea	<u>Daphnia</u>	++	+	++					
Seed Shrimp	<u>Ostracoda</u>			+					
Scud	<u>Hyalella</u>	++	++	+			+		
Watermite	<u>Hydrocarina</u>			+					
Mayfly	<u>Baetidae</u>	+	+	+					
Dragonfly	<u>Aeschna</u>	++	+	++			+		+
Dragon	<u>Libellula</u>	+	+	++					
Dragonfly	<u>Tramea</u>			+					
Dragonfly	<u>Erythemis</u>			+					
Dragonfly	<u>Anax</u>	+	+						
Damselfly	<u>Ischnura</u>	+	+	++	+		+	+	+
Waterstrider	<u>Gerridae</u>	+	+	+		+	+	+	
Backswimmer	<u>Notonectidae</u>	+	+	++	+			+	+
Creeping Water Bug	<u>Naucoridae</u>			+					
Water Scorpion	<u>Nepidae</u>	+		+					
Giant Water Bug	<u>Belostomatidae</u>	+		+					
Water Boatman	<u>Corixidae</u>	+	++	++	+			+	
Caddisfly	<u>Tricoptera</u>	+	+	+	+		+		
Predaceous Diving Beetle	<u>Dytiscidae</u>	+	+	+			+	+	
Water Scavenger Beetle	<u>Hydrophilidae</u>	+	+						
Crawling Water Beetle	<u>Halipidae</u>	+							
Beetle	<u>Amphizoidae</u>			+					
Beetle	<u>Noteridae</u>			+					
Beetle	<u>Helodidae</u>			+					
Midge	<u>Chironomidae</u>	+	+	+	+	++	++	+	++
Black Fly	<u>Simuliidae</u>					+			
Shore Fly	<u>Ephydriidae</u>				+				
Aquatic Caterpillar	<u>Nymphulidae</u>		+				+		
Snail	<u>Physa</u>	+	+	+					
Snail	<u>Lymnaea</u>	++		++					++
Snail	<u>Planorbidae</u>	+	+						
Goldfish	<u>Carassius</u>	+	+	++			+		

Note: Presence of a taxon is indicated by a "+", notably large abundance of a taxon by a "++", and no symbol indicates an absence.

Source: Emery and McShane (1980).

TABLE A.17. Fish Observed in the Hanford Reach, Columbia River (Gray and Dauble 1977, p. 211-212; U.S. DOE 1982, p. 4.6)

Acipenseridae (sturgeons)	<u>Acipenser transmontanus</u>	white sturgeon
Catostomidae (sucker)	<u>Catostomus columbianus</u> <u>C. macrocheilus</u> <u>C. platyrhynchus</u>	bridgelip sucker largescale sucker mountain sucker
Centrarchidae (bass and sunfish)	<u>Lepomis gibbosus</u> <u>L. macrochirus</u> <u>Micropterus dolomieu</u> <u>M. salmoides</u> <u>Pomoxis annularis</u> <u>P. nigromaculatus</u>	pumpkinseed* bluegill* smallmouth bass* largemouth bass* white crappie* black crappie*
Clupeidae (herrings)	<u>Alosa sapidissima</u>	American shad*
Cottidae (sculpins)	<u>Cottus asper</u> <u>C. bairdi</u> <u>C. beldingi</u> <u>C. perplexus</u> <u>C. rhotheus</u>	prickly sculpin mottled sculpin piute sculpin reticulate sculpin torrent sculpin
Cyprinidae (minnows and carp)	<u>Acrocheilus alutaceus</u> <u>Cyprinus carpio</u> <u>Mylocheilus caurinus</u> <u>Ptychocheilus oregonensis</u> <u>Rhinichthys cataractae</u> <u>R. falcatus</u> <u>R. osculus</u> <u>Richardsonius balteatus</u> <u>Tinca tinca</u>	chiselmouth carp* peamouth northern squawfish longnose dace leopard dace speckled dace redside shiner tench*
Gadidae (codfishes)	<u>Lota lota</u>	burbot
Gasterosteidae (sticklebacks)	<u>Gasterosteus aculeatus</u>	threespine stickleback
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*

TABLE A.17. (contd)

Percidae (perches)	<u>Perca flavescens</u>	yellow perch*
	<u>Stizostedion vitreum</u> <u>vitreum</u>	walleye*
Percopsidae (troutperches)	<u>Percopsis transmontanus</u>	sand roller
Petromyzontidae (lampreys)	<u>Entosphenus tridentatus</u>	Pacific lamprey
	<u>Lampetra ayresi</u>	river lamprey
Salmonidae (salmon, trout, and whitefish)	<u>Oncorhynchus kisutch</u>	coho salmon
	<u>O. nerka</u>	sockeye salmon
	<u>O. tshawytscha</u>	chinook salmon
	<u>Salmo clarki</u>	cutthroat trout
	<u>S. gairdneri</u>	rainbow (steelhead trout
	<u>Salvelinus malma</u>	Dolly Varden
	<u>Coregonus clupeaformis</u>	lake whitefish
	<u>Prosopium williamsoni</u>	mountain whitefish

* Introduced species

TABLE A.18. Summary of Fall Chinook Salmon Production at the Priest Rapids Spawning Channel and Rearing Facility, 1963 Through 1978 (from Meekin and Allen, 1973, and Washington State Department of Fisheries, unpublished annual reports)

Brood Year	Spawning Channel			Rearing Facility			
	Adults Spawned	Egg Deposition	Juvenile Release	Adults Spawned	Eggs Taken	Juvenile Release	Total Release
		(x 10 ⁶)	(x 10 ⁶)		(x 10 ⁶)	(x 10 ⁶)	(x 10 ⁶)
1963	1237	2.95	1.10	-	-	-	1.10
1964	4440	7.07	0.35	-	-	-	0.35
1965	5589	10.91	1.22	-	-	-	1.22
1966	5410	11.29	1.96	-	-	-	1.96
1967	3355	9.20	7.19	-	-	-	7.19
1968	1820	4.99	3.02	-	-	-	3.02
1969	3130	7.02	3.61	-	-	-	3.61
1970	2814	5.97	1.83	-	-	-	1.83
1971	2973	7.13	2.80	-	-	-	2.80
1972	716	1.57	0.41	927	1.95	0.25	0.66
1973	1973	4.56	0.54	857	3.20	2.37	2.91
1974	1063	2.50	0.72	223	0.85	0.57	1.29
1975	608	1.41	0.54	813	2.99	1.34	1.88
1976	593	ND	ND	451	1.19	ND	ND
1977	529	0.75	ND	816	1.98	ND	ND
1978	ND	ND	ND	ND	ND	ND	ND

ND - No data available at time of preparation

FIGURE A.1. Fall Chinook Salmon Released From Priest Rapids Spawning Channel and Rearing Facility, 1963 Through 1978 (from Meekin and Allen, 1973, and Washington State Department of Fisheries, 1973, 1974, 1975, 1976, 1977, 1978)

RELEASE
YEAR

FIGURE A.2. Chinook Salmon Released from Ringold Rearing Ponds 1962 Through 1976 (from K. Bauersfeld, Washington State Department of Fisheries, personal communication)

FIGURE A12: Chinook salmon released from Pacific Northwest
1962-1978 (Source: Washington State Dept. of
Fisheries, personal communication)

APPENDIX B

WIND DATA SUMMARIES FOR THE SKAGIT/HANFORD SITE

APPENDIX B

WIND DATA SUMMARIES FOR THE SKAGIT/HANFORD SITE

Wind data summaries for the Skagit/Hanford Site are presented in Tables B.1 and B.2. The summaries are based on data collected at the Wye Barricade from late March 1982 through the end of January 1984, a period of approximately 22 months. Monthly and annual summaries are provided for use with ground-level and elevated (89 m) release points.

In the summaries, the frequencies of occurrence of wind speeds and directions are given as functions of atmospheric stability class. Stability Class 1 corresponds to extremely stable (Pasquill A) conditions and Class 7 corresponds to extremely unstable (Pasquill G) conditions. Prior to March 1983 atmospheric stabilities were determined at the Hanford Meteorology Station using the Pasquill-Gifford-Turner approach based on sky cover/wind speed (see Gifford 1968, p. 101, or Turner 1969, p. 6). Since then they have been determined using the NRC temperature gradient (Regulatory Guide 1.23) method.

The wind speed classes used are: W1 = 0 to 4 mph; W2 = 4 to 8 mph; W3 = 8 to 13 mph; W4 = 13 to 19 mph; W5 = 19 to 25 mph; W6 = 25 to 32 mph; W7 = 32 to 39 mph, and W8 = 39 mph or greater. Class W9 includes all winds less than 4 mph. This class differs from Class W1 because calm and variable winds have been distributed according to the frequency of occurrence of wind directions in Class W1.

The joint frequency distributions for elevated release points were developed using the HMS atmospheric stability, the Wye Barricade wind direction, and a wind speed estimated from the Wye Barricade wind speed and a correction factor determined from the vertical profile of the winds on the tower at the HMS. The wind speed correction is based on the assumption that the wind speed shears at the HMS and the Wye Barricade are the same. In a climatological sense this assumption may be reasonably good. However, for individual hours the assumption may be seriously in error.

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- Turner, D. B. 1969. Workbook of Atmospheric Dispersion Estimate. 999-AP-26, U.S. Department of Health, Education and Welfare, Washington, D.C.
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TABLE B.1. Wind Data Summary for Ground Level Release Point

RELEASE HEIGHT: 7 M

STARTING DATE: 3 25 82 END DATE: 1 31 84

TOTAL # OF HOURS: 15674 # OF LOW SPEED CLASSONE WINDS: 1938

WIND SPEED CLASS	1	2	3	4	5	6	7	8
# OF OCCURANCES	1938	6071	5067	1928	519	146	5	0

WIND DIRECTION (16 SECTORS + CALM + VARIABLE)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CM	VR
WIND DIR OCCURANCE	324	150	89	51	98	82	99	225	898	1819	2302	1862	3324	2910	990	452	0	0
WIND ROSE	0.021	0.010	0.006	0.003	0.006	0.005	0.006	0.014	0.057	0.116	0.147	0.119	0.212	0.186	0.063	0.029	0.000	0.000
LOW SPD WIND ROSE	0.034	0.022	0.016	0.014	0.027	0.022	0.027	0.046	0.092	0.090	0.112	0.140	0.203	0.078	0.043	0.033	0.000	0.000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED AND WIND DIRECTION

W1	0.0042	0.0027	0.0020	0.0015	0.0033	0.0027	0.0034	0.0057	0.0114	0.0112	0.0138	0.0173	0.0251	0.0097	0.0054	0.0040	0.0000	0.0000
W2	0.0084	0.0035	0.0017	0.0010	0.0025	0.0022	0.0025	0.0068	0.0262	0.0406	0.0582	0.0538	0.0891	0.0514	0.0261	0.0131	0.0000	0.0000
W3	0.0059	0.0020	0.0009	0.0003	0.0004	0.0003	0.0004	0.0017	0.0159	0.0436	0.0423	0.0296	0.0683	0.0797	0.0218	0.0103	0.0000	0.0000
W4	0.0021	0.0011	0.0007	0.0002	0.0000	0.0000	0.0000	0.0003	0.0034	0.0169	0.0189	0.0115	0.0253	0.0360	0.0054	0.0012	0.0000	0.0000
W5	0.0001	0.0003	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0029	0.0093	0.0052	0.0033	0.0080	0.0031	0.0002	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0008	0.0039	0.0013	0.0009	0.0008	0.0015	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED, WIND DIRECTION AND STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	VAR
STABILITY CLASS 1																		
W1	0.0005	0.0002	0.0001	0.0001	0.0003	0.0001	0.0001	0.0002	0.0003	0.0005	0.0006	0.0006	0.0011	0.0008	0.0007	0.0006	0.0000	0.0000
W2	0.0021	0.0005	0.0003	0.0001	0.0002	0.0001	0.0004	0.0004	0.0016	0.0026	0.0036	0.0022	0.0033	0.0024	0.0027	0.0022	0.0000	0.0000
W3	0.0015	0.0004	0.0001	0.0001	0.0000	0.0001	0.0001	0.0001	0.0004	0.0036	0.0045	0.0037	0.0033	0.0023	0.0012	0.0019	0.0000	0.0000
W4	0.0004	0.0002	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0005	0.0027	0.0027	0.0017	0.0027	0.0020	0.0003	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0006	0.0015	0.0004	0.0000	0.0002	0.0001	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0005	0.0002	0.0001	0.0001	0.0003	0.0001	0.0001	0.0002	0.0003	0.0005	0.0006	0.0006	0.0011	0.0008	0.0007	0.0006	0.0000	0.0000
STABILITY CLASS 2																		
W1	0.0007	0.0006	0.0004	0.0004	0.0006	0.0003	0.0002	0.0007	0.0015	0.0010	0.0017	0.0019	0.0024	0.0011	0.0016	0.0004	0.0000	0.0000
W2	0.0018	0.0010	0.0004	0.0001	0.0009	0.0004	0.0003	0.0009	0.0028	0.0050	0.0070	0.0045	0.0054	0.0040	0.0034	0.0027	0.0000	0.0000
W3	0.0013	0.0004	0.0001	0.0000	0.0002	0.0001	0.0001	0.0003	0.0013	0.0071	0.0041	0.0031	0.0027	0.0012	0.0009	0.0024	0.0000	0.0000
W4	0.0000	0.0001	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0002	0.0026	0.0026	0.0010	0.0010	0.0006	0.0003	0.0001	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0002	0.0002	0.0003	0.0001	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0007	0.0006	0.0004	0.0004	0.0006	0.0003	0.0002	0.0007	0.0015	0.0010	0.0017	0.0019	0.0024	0.0011	0.0016	0.0004	0.0000	0.0000
STABILITY CLASS 3																		

(Annual)

W1	0.0006	0.0004	0.0003	0.0003	0.0004	0.0003	0.0003	0.0006	0.0014	0.0013	0.0017	0.0023	0.0033	0.0013	0.0003	0.0004	0.0000	0.0000
W2	0.0015	0.0005	0.0001	0.0002	0.0003	0.0003	0.0004	0.0008	0.0020	0.0033	0.0042	0.0053	0.0075	0.0040	0.0041	0.0020	0.0000	0.0000
W3	0.0011	0.0002	0.0002	0.0000	0.0001	0.0001	0.0001	0.0003	0.0019	0.0035	0.0038	0.0024	0.0027	0.0034	0.0030	0.0022	0.0000	0.0000
W4	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0002	0.0013	0.0013	0.0010	0.0014	0.0007	0.0003	0.0003	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0005	0.0004	0.0002	0.0003	0.0002	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0001	0.0000	0.0001	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0006	0.0004	0.0003	0.0003	0.0004	0.0003	0.0003	0.0006	0.0014	0.0013	0.0017	0.0023	0.0033	0.0013	0.0003	0.0004	0.0000	0.0000

STABILITY CLASS 4

W1	0.0010	0.0003	0.0005	0.0003	0.0009	0.0011	0.0010	0.0015	0.0031	0.0030	0.0044	0.0059	0.0097	0.0036	0.0014	0.0008	0.0000	0.0000
W2	0.0018	0.0008	0.0006	0.0004	0.0002	0.0003	0.0008	0.0018	0.0084	0.0135	0.0198	0.0202	0.0365	0.0213	0.0068	0.0030	0.0000	0.0000
W3	0.0015	0.0007	0.0005	0.0001	0.0002	0.0000	0.0003	0.0007	0.0064	0.0144	0.0139	0.0095	0.0294	0.0394	0.0077	0.0029	0.0000	0.0000
W4	0.0011	0.0004	0.0005	0.0001	0.0000	0.0000	0.0000	0.0002	0.0019	0.0073	0.0101	0.0064	0.0141	0.0229	0.0036	0.0008	0.0000	0.0000
W5	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0014	0.0059	0.0037	0.0027	0.0064	0.0025	0.0002	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0008	0.0026	0.0013	0.0006	0.0007	0.0015	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0010	0.0003	0.0005	0.0003	0.0009	0.0011	0.0010	0.0015	0.0031	0.0030	0.0044	0.0059	0.0097	0.0036	0.0014	0.0008	0.0000	0.0000

STABILITY CLASS 5

W1	0.0008	0.0005	0.0003	0.0003	0.0006	0.0005	0.0010	0.0010	0.0020	0.0024	0.0021	0.0029	0.0042	0.0011	0.0008	0.0010	0.0000	0.0000
W2	0.0008	0.0004	0.0003	0.0001	0.0005	0.0006	0.0000	0.0019	0.0053	0.0081	0.0118	0.0108	0.0175	0.0107	0.0038	0.0016	0.0000	0.0000
W3	0.0003	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0003	0.0033	0.0087	0.0085	0.0063	0.0195	0.0200	0.0056	0.0006	0.0000	0.0000
W4	0.0004	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0019	0.0021	0.0011	0.0047	0.0080	0.0006	0.0000	0.0000	0.0000
W5	0.0000	0.0002	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0004	0.0012	0.0005	0.0002	0.0009	0.0002	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0010	0.0001	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0008	0.0005	0.0003	0.0003	0.0006	0.0005	0.0010	0.0010	0.0020	0.0024	0.0021	0.0029	0.0042	0.0011	0.0008	0.0010	0.0000	0.0000

STABILITY CLASS 6

W1	0.0003	0.0004	0.0004	0.0003	0.0004	0.0003	0.0006	0.0012	0.0021	0.0024	0.0023	0.0030	0.0034	0.0011	0.0006	0.0006	0.0000	0.0000
W2	0.0004	0.0002	0.0001	0.0000	0.0003	0.0004	0.0003	0.0007	0.0045	0.0058	0.0089	0.0080	0.0144	0.0070	0.0043	0.0013	0.0000	0.0000
W3	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0013	0.0040	0.0050	0.0030	0.0084	0.0098	0.0033	0.0002	0.0000	0.0000
W4	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0010	0.0001	0.0003	0.0011	0.0013	0.0002	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0003	0.0004	0.0004	0.0003	0.0004	0.0003	0.0006	0.0012	0.0021	0.0024	0.0023	0.0030	0.0034	0.0011	0.0006	0.0006	0.0000	0.0000

STABILITY CLASS 7

W1	0.0003	0.0003	0.0001	0.0001	0.0001	0.0001	0.0003	0.0005	0.0010	0.0006	0.0010	0.0008	0.0010	0.0004	0.0001	0.0002	0.0000	0.0000
W2	0.0001	0.0001	0.0000	0.0000	0.0001	0.0002	0.0003	0.0003	0.0016	0.0023	0.0029	0.0029	0.0046	0.0022	0.0010	0.0004	0.0000	0.0000
W3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0022	0.0026	0.0017	0.0024	0.0033	0.0007	0.0001	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0000	0.0002	0.0004	0.0001	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0003	0.0003	0.0001	0.0001	0.0001	0.0001	0.0003	0.0005	0.0010	0.0006	0.0010	0.0008	0.0010	0.0004	0.0001	0.0002	0.0000	0.0000

(January)

RELEASE HEIGHT: 0 M TOTAL # OF HOURS: 1338

OF LOW SPEED CLASS ONE WINDS: 232

WIND SPEED CLASS

OF OCCURRENCES

1	2	3	4	5	6	7	8
232	612	295	106	60	33	0	0

WIND DIRECTION (16 SECTORS + CALM + VARIABLE)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CM	VR
WIND DIR OCCURRENCE	40.	23.	11.	7.	21.	22.	16.	25.	87.	133.	204.	133.	268.	253.	64.	31.	0.	0.
WIND ROSE	0.030	0.017	0.008	0.005	0.016	0.016	0.012	0.019	0.065	0.099	0.152	0.099	0.200	0.189	0.048	0.023	0.000	0.000
LOW SPD WIND ROSE	0.056	0.022	0.013	0.017	0.039	0.039	0.043	0.052	0.069	0.091	0.121	0.103	0.177	0.091	0.030	0.039	0.000	0.000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED AND WIND DIRECTION

W1	0.0097	0.0037	0.0022	0.0030	0.0067	0.0067	0.0075	0.0090	0.0120	0.0157	0.0209	0.0179	0.0306	0.0157	0.0052	0.0067	0.0000	0.0000
W2	0.0090	0.0037	0.0022	0.0022	0.0090	0.0097	0.0045	0.0075	0.0366	0.0269	0.0568	0.0531	0.1161	0.0755	0.0299	0.0127	0.0000	0.0000
W3	0.0060	0.0030	0.0000	0.0000	0.0000	0.0000	0.0015	0.0149	0.0239	0.0262	0.0120	0.0396	0.0777	0.0120	0.0037	0.0000	0.0000	0.0000
W4	0.0045	0.0037	0.0007	0.0000	0.0000	0.0000	0.0007	0.0015	0.0187	0.0172	0.0060	0.0052	0.0202	0.0007	0.0000	0.0000	0.0000	0.0000
W5	0.0007	0.0030	0.0030	0.0000	0.0000	0.0000	0.0000	0.0000	0.0112	0.0157	0.0067	0.0045	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0030	0.0157	0.0037	0.0022	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED, WIND DIRECTION AND STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	VAR
STABILITY CLASS 1																		
W1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W3	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STABILITY CLASS 2																		
W1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000
W2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0030	0.0000	0.0000	0.0000	0.0000	0.0000
W3	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000
STABILITY CLASS 3																		
W1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0015	0.0015	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000
W2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0022	0.0052	0.0067	0.0022	0.0015	0.0007	0.0000	0.0000

(January)

RELEASE HEIGHT: 0 M TOTAL # OF HOURS: 1338

OF LOW SPEED CLASS ONE WINDS: 232

WIND SPEED CLASS	1	2	3	4	5	6	7	8
# OF OCCURRENCES	232	612	295	106	60	33	0	0

WIND DIRECTION (16 SECTORS + CALM + VARIABLE)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CM	VR
WIND DIR OCCURRENCE	40.	23.	11.	7.	21.	22.	16.	25.	87.	133.	204.	133.	268.	253.	64.	31.	0.	0.
WIND ROSE	0.030	0.017	0.008	0.005	0.016	0.016	0.012	0.019	0.065	0.099	0.152	0.099	0.200	0.189	0.048	0.023	0.000	0.000
LOW SPD WIND ROSE	0.056	0.022	0.013	0.017	0.039	0.039	0.043	0.052	0.069	0.091	0.121	0.103	0.177	0.091	0.030	0.039	0.000	0.000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED AND WIND DIRECTION

W1	0.0097	0.0037	0.0022	0.0030	0.0067	0.0067	0.0075	0.0090	0.0120	0.0157	0.0209	0.0179	0.0306	0.0157	0.0052	0.0067	0.0000	0.0000
W2	0.0090	0.0037	0.0022	0.0022	0.0090	0.0097	0.0045	0.0075	0.0366	0.0269	0.0568	0.0531	0.1181	0.0755	0.0299	0.0127	0.0000	0.0000
W3	0.0060	0.0030	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0149	0.0239	0.0262	0.0120	0.0396	0.0777	0.0120	0.0037	0.0000	0.0000
W4	0.0045	0.0037	0.0007	0.0000	0.0000	0.0000	0.0000	0.0007	0.0015	0.0187	0.0172	0.0060	0.0052	0.0202	0.0007	0.0000	0.0000	0.0000
W5	0.0007	0.0030	0.0030	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0112	0.0137	0.0067	0.0045	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0030	0.0157	0.0037	0.0022	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED, WIND DIRECTION AND STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	VAR
STABILITY CLASS 1																		
W1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W3	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STABILITY CLASS 2																		
W1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000
W2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0030	0.0000	0.0000	0.0000	0.0000	0.0000
W3	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000
STABILITY CLASS 3																		
W1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0015	0.0015	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000
W2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0022	0.0052	0.0067	0.0022	0.0015	0.0007	0.0000	0.0000

(February)

RELEASE HEIGHT: 0 M TOTAL # OF HOURS: 670

OF LOW SPEED CLASS ONE WINDS: 54
WIND SPEED CLASS 1 2 3 4 5 6 7 8
OF OCCURRENCES 54 313 232 61 10 0 0 0

WIND DIRECTION (16 SECTORS + CALM + VARIABLE)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CM	VR
WIND DIR OCCURRENCE	2.	1.	1.	0.	2.	1.	3.	5.	28.	66.	99.	81.	163.	162.	49.	7.	0.	0.
WIND ROSE	0.003	0.001	0.001	0.000	0.003	0.001	0.004	0.007	0.042	0.099	0.148	0.121	0.243	0.242	0.073	0.010	0.000	0.000
LOW SPD WIND ROSE	0.019	0.000	0.019	0.000	0.037	0.019	0.019	0.037	0.037	0.111	0.130	0.093	0.296	0.111	0.019	0.056	0.000	0.000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED AND WIND DIRECTION

W1	0.0015	0.0000	0.0015	0.0000	0.0030	0.0015	0.0015	0.0030	0.0030	0.0090	0.0104	0.0075	0.0239	0.0090	0.0015	0.0045	0.0000	0.0000
W2	0.0015	0.0015	0.0000	0.0000	0.0000	0.0015	0.0030	0.0134	0.0388	0.0642	0.0731	0.1358	0.0940	0.0358	0.0045	0.0000	0.0000	0.0000
W3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0015	0.0239	0.0388	0.0358	0.0284	0.0687	0.1119	0.0343	0.0015	0.0000	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0119	0.0224	0.0119	0.0149	0.0269	0.0015	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0149	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED, WIND DIRECTION AND STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	VAR
STABILITY CLASS 1																		
W1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STABILITY CLASS 2																		
W1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W2	0.0015	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0090	0.0104	0.0015	0.0030	0.0000	0.0000	0.0000
W3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0030	0.0015	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STABILITY CLASS 3																		
W1	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0030	0.0000	0.0000	0.0000	0.0000	0.0000
W2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0030	0.0015	0.0045	0.0104	0.0104	0.0090	0.0030	0.0000	0.0000

(March)

RELEASE HEIGHT: 0 M TOTAL # OF HOURS: 868

OF LOW SPEED CLASS ONE WINDS: 73

WIND SPEED CLASS

OF OCCURRENCES

1

2

3

4

5

6

7

8

73

291

328

138

27

11

0

0

WIND DIRECTION (16 SECTORS + CALM + VARIABLE)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CM	VR
WIND DIR OCCURANCE	16.	4.	3.	2.	3.	0.	5.	16.	60.	87.	155.	122.	178.	147.	55.	15.	0.	0.
WIND ROSE	0.018	0.005	0.003	0.002	0.003	0.000	0.006	0.018	0.069	0.100	0.179	0.141	0.205	0.169	0.063	0.017	0.000	0.000
LOW SPD WIND ROSE	0.055	0.041	0.027	0.014	0.027	0.000	0.055	0.027	0.123	0.082	0.096	0.164	0.137	0.110	0.041	0.000	0.000	0.000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED AND WIND DIRECTION

W1	0.0046	0.0035	0.0023	0.0012	0.0023	0.0000	0.0046	0.0023	0.0104	0.0069	0.0081	0.0138	0.0115	0.0092	0.0035	0.0000	0.0000	0.0000
W2	0.0035	0.0012	0.0000	0.0012	0.0012	0.0000	0.0012	0.0092	0.0300	0.0357	0.0553	0.0369	0.0680	0.0541	0.0253	0.0127	0.0000	0.0000
W3	0.0046	0.0000	0.0012	0.0000	0.0000	0.0000	0.0000	0.0069	0.0242	0.0484	0.0530	0.0426	0.0783	0.0876	0.0265	0.0046	0.0000	0.0000
W4	0.0058	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0035	0.0081	0.0449	0.0288	0.0426	0.0173	0.0081	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012	0.0000	0.0127	0.0115	0.0046	0.0012	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012	0.0046	0.0069	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED, WIND DIRECTION AND STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	VAR
STABILITY CLASS 1																		
W1	0.0012	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012	0.0000	0.0012	0.0012	0.0012	0.0000	0.0012	0.0000	0.0000	0.0000
W2	0.0012	0.0012	0.0000	0.0000	0.0012	0.0000	0.0012	0.0000	0.0023	0.0046	0.0023	0.0000	0.0035	0.0046	0.0058	0.0035	0.0000	0.0000
W3	0.0035	0.0000	0.0012	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0023	0.0012	0.0012	0.0035	0.0012	0.0069	0.0012	0.0000	0.0000
W4	0.0058	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0081	0.0035	0.0150	0.0012	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0069	0.0023	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0012	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012	0.0000	0.0012	0.0012	0.0012	0.0000	0.0012	0.0000	0.0000	0.0000
STABILITY CLASS 2																		
W1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012	0.0012	0.0000	0.0023	0.0000	0.0000	0.0000	0.0000
W2	0.0000	0.0000	0.0000	0.0012	0.0000	0.0000	0.0000	0.0000	0.0023	0.0035	0.0035	0.0012	0.0046	0.0069	0.0023	0.0000	0.0000	0.0000
W3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012	0.0023	0.0012	0.0012	0.0012	0.0000	0.0000	0.0000	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012	0.0023	0.0104	0.0058	0.0046	0.0012	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012	0.0012	0.0000	0.0023	0.0000	0.0000	0.0000	0.0000
STABILITY CLASS 3																		
W1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012	0.0000	0.0000	0.0000	0.0012	0.0012	0.0000	0.0000	0.0000	0.0000	0.0000
W2	0.0012	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012	0.0035	0.0000	0.0035	0.0012	0.0081	0.0046	0.0035	0.0000	0.0000	0.0000

(April)

RELEASE HEIGHT: 0 M TOTAL # OF HOURS: 1438

OF LOW SPEED CLASS ONE WINDS: 174

WIND SPEED CLASS

OF OCCURRENCES

1 2 3 4 5 6 7 8

174 512 435 209 86 22 0 0

WIND DIRECTION (16 SECTIONS + CALM + VARIABLE)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CM	VR
WIND DIR OCCURRENCE	30.	20.	7.	4.	4.	6.	7.	17.	63.	176.	256.	213.	298.	195.	90.	50.	0.	0.
WIND ROSE	0.021	0.014	0.005	0.003	0.003	0.004	0.005	0.012	0.044	0.124	0.176	0.148	0.207	0.136	0.063	0.035	0.000	0.000
LOW SPD WIND ROSE	0.029	0.023	0.011	0.011	0.023	0.029	0.023	0.040	0.096	0.121	0.115	0.167	0.121	0.092	0.052	0.046	0.000	0.000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED AND WIND DIRECTION

W1	0.0035	0.0028	0.0014	0.0014	0.0028	0.0035	0.0028	0.0049	0.0118	0.0146	0.0139	0.0202	0.0146	0.0111	0.0063	0.0056	0.0000	0.0000
W2	0.0104	0.0056	0.0035	0.0007	0.0000	0.0007	0.0014	0.0063	0.0181	0.0376	0.0556	0.0529	0.0779	0.0389	0.0271	0.0195	0.0000	0.0000
W3	0.0070	0.0049	0.0000	0.0047	0.0000	0.0000	0.0007	0.0007	0.0118	0.0431	0.0584	0.0417	0.0556	0.0443	0.0243	0.0090	0.0000	0.0000
W4	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0223	0.0285	0.0174	0.0487	0.0243	0.0014	0.0007	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0056	0.0174	0.0111	0.0083	0.0139	0.0028	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0042	0.0049	0.0021	0.0028	0.0007	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED, WIND DIRECTION AND STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	VAR
STABILITY CLASS 1																		
W1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0014	0.0014	0.0028	0.0007	0.0000	0.0000	0.0000
W2	0.0042	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0035	0.0021	0.0111	0.0042	0.0083	0.0076	0.0000	0.0000
W3	0.0028	0.0035	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0035	0.0070	0.0028	0.0042	0.0042	0.0028	0.0056	0.0000	0.0000
W4	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0028	0.0021	0.0035	0.0028	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0042	0.0000	0.0000	0.0007	0.0007	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0014	0.0014	0.0028	0.0007	0.0000	0.0000	0.0000
STABILITY CLASS 2																		
W1	0.0007	0.0000	0.0000	0.0000	0.0014	0.0007	0.0000	0.0007	0.0035	0.0035	0.0021	0.0049	0.0035	0.0014	0.0028	0.0014	0.0000	0.0000
W2	0.0000	0.0007	0.0007	0.0000	0.0000	0.0007	0.0000	0.0007	0.0014	0.0042	0.0104	0.0070	0.0035	0.0063	0.0014	0.0014	0.0000	0.0000
W3	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0035	0.0070	0.0063	0.0063	0.0007	0.0007	0.0000	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0035	0.0042	0.0007	0.0028	0.0021	0.0000	0.0007	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0007	0.0014	0.0007	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0007	0.0000	0.0000	0.0000	0.0014	0.0007	0.0000	0.0007	0.0035	0.0035	0.0021	0.0049	0.0035	0.0014	0.0028	0.0014	0.0000	0.0000
STABILITY CLASS 3																		
W1	0.0014	0.0021	0.0007	0.0014	0.0000	0.0007	0.0007	0.0014	0.0014	0.0007	0.0021	0.0000	0.0021	0.0007	0.0000	0.0007	0.0000	0.0000
W2	0.0021	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0014	0.0028	0.0035	0.0063	0.0056	0.0014	0.0021	0.0035	0.0000	0.0000

(April)

M3	0.0021	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0049	0.0042	0.0007	0.0021	0.0028	0.0007	0.0000	0.0000	0.0000
M4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0021	0.0007	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000
M5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M9	0.0014	0.0021	0.0007	0.0014	0.0000	0.0007	0.0007	0.0014	0.0014	0.0007	0.0021	0.0000	0.0021	0.0007	0.0000	0.0007	0.0000	0.0000	0.0000

STABILITY CLASS 4

M1	0.0000	0.0000	0.0007	0.0000	0.0014	0.0014	0.0007	0.0007	0.0021	0.0021	0.0028	0.0042	0.0035	0.0014	0.0007	0.0000	0.0000	0.0000
M2	0.0021	0.0021	0.0021	0.0007	0.0000	0.0000	0.0007	0.0014	0.0070	0.0097	0.0153	0.0174	0.0167	0.0076	0.0063	0.0035	0.0000	0.0000
M3	0.0014	0.0000	0.0000	0.0007	0.0000	0.0000	0.0007	0.0007	0.0028	0.0118	0.0146	0.0160	0.0188	0.0104	0.0118	0.0021	0.0000	0.0000
M4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0132	0.0195	0.0104	0.0292	0.0132	0.0014	0.0000	0.0000	0.0000
M5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0028	0.0118	0.0111	0.0076	0.0104	0.0014	0.0000	0.0000	0.0000
M6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0042	0.0049	0.0021	0.0028	0.0007	0.0000	0.0000	0.0000
M7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M9	0.0000	0.0000	0.0007	0.0000	0.0014	0.0014	0.0007	0.0007	0.0021	0.0021	0.0028	0.0042	0.0035	0.0014	0.0007	0.0000	0.0000	0.0000

STABILITY CLASS 5

M1	0.0007	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0014	0.0007	0.0014	0.0007	0.0049	0.0028	0.0000	0.0014	0.0007	0.0000	0.0000
M2	0.0014	0.0014	0.0007	0.0000	0.0000	0.0000	0.0000	0.0028	0.0042	0.0063	0.0090	0.0097	0.0146	0.0076	0.0042	0.0028	0.0000	0.0000
M3	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0028	0.0125	0.0118	0.0076	0.0153	0.0104	0.0056	0.0007	0.0000	0.0000
M4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0000	0.0021	0.0076	0.0049	0.0000	0.0000	0.0000	0.0000
M5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0000	0.0000	0.0000
M6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M9	0.0007	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0014	0.0007	0.0014	0.0007	0.0049	0.0028	0.0000	0.0014	0.0007	0.0000	0.0000

STABILITY CLASS 6

W1	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0014	0.0007	0.0028	0.0063	0.0042	0.0049	0.0014	0.0028	0.0007	0.0021	0.0000	0.0000
W2	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0028	0.0083	0.0111	0.0049	0.0174	0.0090	0.0035	0.0007	0.0000	0.0000
W3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0035	0.0042	0.0118	0.0042	0.0056	0.0111	0.0014	0.0007	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0014	0.0035	0.0014	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0014	0.0007	0.0028	0.0063	0.0042	0.0049	0.0014	0.0028	0.0007	0.0021	0.0000	0.0000

STABILITY CLASS 7

W1	0.00007	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.0014	0.00000	0.0014	0.00000	0.00000	0.0021	0.00000	0.00007	0.00000	0.00000
W2	0.00010	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.0014	0.0028	0.0028	0.0056	0.0090	0.0028	0.0014	0.00000	0.00000	0.00000
W3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.0021	0.0028	0.0021	0.0042	0.0035	0.0049	0.0014	0.00000	0.00000	0.00000
W4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.0007	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
W5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
W6	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
W7	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
W8	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
W9	0.00007	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.0014	0.00000	0.0014	0.00000	0.00000	0.0021	0.00000	0.00007	0.00000	0.00000

(May)

RELEASE HEIGHT: 0 M TOTAL # OF HOURS: 1445

OF LOW SPEED CLASS ONE WINDS: 166
 WIND SPEED CLASS 1 2 3 4 5 6 7 8
 # OF OCCURRENCES 166 529 438 230 64 18 0 0

WIND DIRECTION (16 SECTORS + CALM + VARIABLE)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CH	VR
WIND DIR OCCURRENCE	56.	30.	11.	6.	10.	4.	6.	21.	61.	160.	161.	174.	313.	284.	104.	44.	0.	0.
WIND ROSE	0.039	0.021	0.008	0.004	0.007	0.003	0.004	0.015	0.042	0.111	0.111	0.120	0.217	0.197	0.072	0.030	0.000	0.000
LOW SPD WIND ROSE	0.048	0.042	0.024	0.012	0.024	0.012	0.012	0.030	0.078	0.133	0.078	0.114	0.217	0.066	0.048	0.060	0.000	0.000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED AND WIND DIRECTION

W1	0.0055	0.0048	0.0028	0.0014	0.0028	0.0014	0.0014	0.0035	0.0040	0.0152	0.0090	0.0131	0.0249	0.0076	0.0055	0.0069	0.0000	0.0000
W2	0.0208	0.0076	0.0021	0.0007	0.0028	0.0014	0.0028	0.0097	0.0242	0.0457	0.0505	0.0561	0.0630	0.0360	0.0263	0.0166	0.0000	0.0000
W3	0.0111	0.0055	0.0014	0.0014	0.0014	0.0000	0.0000	0.0014	0.0083	0.0339	0.0429	0.0381	0.0782	0.0595	0.0131	0.0069	0.0000	0.0000
W4	0.0014	0.0028	0.0014	0.0007	0.0000	0.0000	0.0000	0.0000	0.0007	0.0152	0.0083	0.0097	0.0478	0.0657	0.0055	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0035	0.0021	0.0242	0.0131	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0035	0.0083	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED, WIND DIRECTION AND STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	VAR
STABILITY CLASS 1																		
W1	0.0021	0.0014	0.0000	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0014	0.0014	0.0000	0.0021	0.0021	0.0000	0.0000
W2	0.0104	0.0007	0.0007	0.0000	0.0000	0.0000	0.0021	0.0007	0.0042	0.0069	0.0083	0.0028	0.0042	0.0021	0.0042	0.0028	0.0000	0.0000
W3	0.0048	0.0014	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0007	0.0042	0.0090	0.0125	0.0083	0.0021	0.0014	0.0028	0.0000	0.0000
W4	0.0014	0.0014	0.0014	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0076	0.0055	0.0035	0.0021	0.0069	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0021	0.0014	0.0000	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0014	0.0014	0.0000	0.0021	0.0021	0.0000	0.0000
STABILITY CLASS 2																		
W1	0.0007	0.0021	0.0007	0.0007	0.0000	0.0007	0.0000	0.0007	0.0021	0.0014	0.0021	0.0035	0.0055	0.0014	0.0021	0.0007	0.0000	0.0000
W2	0.0042	0.0035	0.0007	0.0000	0.0014	0.0000	0.0007	0.0007	0.0035	0.0097	0.0097	0.0083	0.0090	0.0028	0.0076	0.0042	0.0000	0.0000
W3	0.0028	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0083	0.0055	0.0035	0.0090	0.0014	0.0035	0.0021	0.0000	0.0000
W4	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0007	0.0000	0.0000	0.0007	0.0007	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0007	0.0021	0.0007	0.0007	0.0000	0.0007	0.0000	0.0007	0.0021	0.0014	0.0021	0.0035	0.0055	0.0014	0.0021	0.0007	0.0000	0.0000
STABILITY CLASS 3																		
W1	0.0000	0.0007	0.0000	0.0000	0.0007	0.0000	0.0007	0.0014	0.0021	0.0035	0.0014	0.0021	0.0028	0.0028	0.0014	0.0007	0.0000	0.0000
W2	0.0007	0.0007	0.0000	0.0000	0.0007	0.0014	0.0000	0.0014	0.0021	0.0028	0.0035	0.0069	0.0125	0.0042	0.0028	0.0035	0.0000	0.0000

(June)

RELEASE HEIGHT: 0 M TOTAL # OF HOURS: 1399

OF LOW SPEED CLASS ONE WINDS: 155

WIND SPEED CLASS

OF OCCURRENCES

1

2

3

4

5

6

7

8

155

491

472

221

48

12

0

0

WIND DIRECTION (16 SECTORS + CALM + VARIABLE)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CM	VR
WIND DIR OCCURRENCE	28.	16.	11.	10.	12.	12.	14.	33.	112.	249.	219.	160.	251.	181.	53.	38.	0.	0.
WIND ROSE	0.020	0.011	0.008	0.007	0.009	0.009	0.010	0.024	0.080	0.178	0.157	0.114	0.179	0.129	0.038	0.027	0.000	0.000
LOW SPD WIND ROSE	0.032	0.026	0.013	0.032	0.039	0.052	0.032	0.065	0.123	0.103	0.142	0.155	0.077	0.019	0.058	0.032	0.000	0.000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED AND WIND DIRECTION

W1	0.0036	0.0029	0.0014	0.0036	0.0043	0.0057	0.0036	0.0071	0.0136	0.0114	0.0157	0.0172	0.0086	0.0021	0.0064	0.0036	0.0000	0.0000
W2	0.0100	0.0050	0.0050	0.0029	0.0036	0.0021	0.0043	0.0100	0.0307	0.0600	0.0543	0.0450	0.0565	0.0250	0.0186	0.0179	0.0000	0.0000
W3	0.0057	0.0014	0.0014	0.0007	0.0007	0.0007	0.0021	0.0050	0.0293	0.0686	0.0593	0.0350	0.0736	0.0422	0.0057	0.0057	0.0000	0.0000
W4	0.0007	0.0014	0.0000	0.0000	0.0000	0.0000	0.0014	0.0050	0.0329	0.0214	0.0122	0.0329	0.0465	0.0036	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0043	0.0043	0.0050	0.0036	0.0122	0.0029	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0014	0.0000	0.0043	0.0014	0.0007	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED, WIND DIRECTION AND STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	VAR
STABILITY CLASS 1																		
W1	0.0007	0.0000	0.0000	0.0007	0.0000	0.0007	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0007	0.0007	0.0007	0.0007	0.0000	0.0000
W2	0.0007	0.0007	0.0014	0.0007	0.0000	0.0007	0.0007	0.0007	0.0057	0.0050	0.0057	0.0050	0.0057	0.0014	0.0007	0.0057	0.0000	0.0000
W3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0014	0.0129	0.0100	0.0107	0.0021	0.0043	0.0007	0.0007	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0029	0.0093	0.0086	0.0036	0.0021	0.0029	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0036	0.0029	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0029	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0007	0.0000	0.0000	0.0007	0.0000	0.0007	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0007	0.0007	0.0007	0.0007	0.0000	0.0000
STABILITY CLASS 2																		
W1	0.0007	0.0014	0.0014	0.0014	0.0021	0.0000	0.0007	0.0014	0.0043	0.0014	0.0014	0.0007	0.0021	0.0000	0.0029	0.0007	0.0000	0.0000
W2	0.0057	0.0021	0.0021	0.0007	0.0007	0.0007	0.0014	0.0036	0.0093	0.0100	0.0086	0.0064	0.0100	0.0114	0.0050	0.0050	0.0000	0.0000
W3	0.0036	0.0007	0.0000	0.0000	0.0007	0.0007	0.0007	0.0014	0.0057	0.0179	0.0079	0.0057	0.0029	0.0029	0.0000	0.0021	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0071	0.0036	0.0007	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0007	0.0000	0.0007	0.0007	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0007	0.0014	0.0014	0.0014	0.0021	0.0000	0.0007	0.0014	0.0043	0.0014	0.0014	0.0007	0.0021	0.0000	0.0029	0.0007	0.0000	0.0000
STABILITY CLASS 3																		
W1	0.0007	0.0000	0.0000	0.0000	0.0000	0.0007	0.0014	0.0007	0.0029	0.0043	0.0029	0.0043	0.0021	0.0000	0.0000	0.0000	0.0000	0.0000
W2	0.0014	0.0014	0.0000	0.0000	0.0029	0.0000	0.0014	0.0021	0.0029	0.0036	0.0079	0.0036	0.0043	0.0000	0.0021	0.0000	0.0000	0.0000

(July)

RELEASE HEIGHT: 0 M TOTAL # OF HOURS: 1450

OF LOW SPEED CLASS ONE WINDS: 159

WIND SPEED CLASS

OF OCCURRENCES

1	2	3	4	5	6	7	8
159	491	505	236	54	5	0	0

WIND DIRECTION (16 SECTORS + CALM + VARIABLE)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CM	VR
WIND DIR OCCURRENCE	37.	17.	17.	11.	24.	11.	10.	20.	64.	165.	193.	166.	260.	266.	113.	76.	0.	0.
WIND ROSE	0.026	0.012	0.012	0.008	0.017	0.008	0.007	0.014	0.044	0.114	0.133	0.114	0.179	0.183	0.078	0.052	0.000	0.000
LOW SPD WIND ROSE	0.050	0.013	0.044	0.050	0.063	0.025	0.025	0.031	0.057	0.063	0.075	0.126	0.170	0.069	0.088	0.050	0.000	0.000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED AND WIND DIRECTION

W1	0.0055	0.0014	0.0048	0.0055	0.0069	0.0028	0.0028	0.0034	0.0062	0.0069	0.0083	0.0138	0.0186	0.0076	0.0097	0.0055	0.0000	0.0000
W2	0.0097	0.0083	0.0014	0.0014	0.0076	0.0034	0.0041	0.0076	0.0276	0.0414	0.0572	0.0386	0.0503	0.0366	0.0255	0.0179	0.0000	0.0000
W3	0.0103	0.0021	0.0028	0.0000	0.0021	0.0014	0.0000	0.0028	0.0083	0.0448	0.0428	0.0400	0.0703	0.0752	0.0193	0.0262	0.0000	0.0000
W4	0.0000	0.0000	0.0028	0.0007	0.0000	0.0000	0.0000	0.0000	0.0021	0.0200	0.0193	0.0186	0.0338	0.0476	0.0152	0.0028	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0055	0.0034	0.0062	0.0159	0.0055	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0028	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED, WIND DIRECTION AND STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	VAR
STABILITY CLASS 1																		
W1	0.0097	0.0007	0.0014	0.0007	0.0014	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0000	0.0007	0.0014	0.0021	0.0021	0.0000	0.0000
W2	0.0048	0.0028	0.0007	0.0000	0.0007	0.0000	0.0000	0.0000	0.0014	0.0007	0.0048	0.0034	0.0048	0.0028	0.0028	0.0021	0.0000	0.0000
W3	0.0041	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0076	0.0076	0.0090	0.0076	0.0007	0.0076	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0055	0.0021	0.0034	0.0083	0.0014	0.0014	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0034	0.0021	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0007	0.0007	0.0014	0.0007	0.0014	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0000	0.0007	0.0014	0.0021	0.0021	0.0000	0.0000
STABILITY CLASS 2																		
W1	0.0021	0.0000	0.0007	0.0014	0.0014	0.0007	0.0014	0.0007	0.0014	0.0014	0.0028	0.0028	0.0062	0.0014	0.0034	0.0007	0.0000	0.0000
W2	0.0014	0.0021	0.0007	0.0000	0.0055	0.0021	0.0014	0.0028	0.0062	0.0076	0.0131	0.0055	0.0097	0.0034	0.0048	0.0048	0.0000	0.0000
W3	0.0028	0.0014	0.0007	0.0000	0.0014	0.0007	0.0000	0.0014	0.0014	0.0172	0.0069	0.0062	0.0034	0.0034	0.0014	0.0062	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0034	0.0062	0.0048	0.0021	0.0007	0.0014	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0021	0.0000	0.0007	0.0014	0.0014	0.0007	0.0014	0.0007	0.0014	0.0014	0.0028	0.0028	0.0062	0.0014	0.0034	0.0007	0.0000	0.0000
STABILITY CLASS 3																		
W1	0.0007	0.0000	0.0000	0.0007	0.0014	0.0007	0.0007	0.0014	0.0014	0.0021	0.0014	0.0034	0.0034	0.0028	0.0000	0.0014	0.0000	0.0000
W2	0.0014	0.0021	0.0000	0.0007	0.0000	0.0007	0.0007	0.0000	0.0034	0.0090	0.0034	0.0055	0.0055	0.0041	0.0034	0.0007	0.0000	0.0000

(August)

RELEASE HEIGHT: 0 M TOTAL # OF HOURS: 1448

OF LOW SPEED CLASS ONE WINDS: 180

WIND SPEED CLASS

OF OCCURANCES

1

2

3

4

5

6

7

8

180

607

472

162

22

5

0

0

WIND DIRECTION (16 SECTORS + CALM + VARIABLE)

N

NNE

NE

ENE

E

ESE

SE

SSE

S

SSW

SW

WSW

W

WNW

NW

NNW

CH

VR

WIND DIR OCCURANCE

16.

11.

5.

4.

11.

15.

12.

32.

112.

253.

229.

170.

249.

211.

83.

35.

0.

0.

WIND ROSE

0.011

0.008

0.003

0.003

0.008

0.010

0.008

0.022

0.077

0.175

0.158

0.117

0.172

0.146

0.057

0.024

0.000

0.000

LOW SPD WIND ROSE

0.022

0.044

0.022

0.017

0.033

0.033

0.028

0.100

0.111

0.089

0.094

0.111

0.183

0.044

0.044

0.022

0.000

0.000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED AND WIND DIRECTION

	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18
W1	0.0028	0.0055	0.0028	0.0021	0.0041	0.0041	0.0035	0.0124	0.0138	0.0110	0.0117	0.0138	0.0228	0.0055	0.0055	0.0028	0.0000	0.0000
W2	0.0048	0.0014	0.0007	0.0007	0.0035	0.0055	0.0041	0.0090	0.0338	0.0773	0.0787	0.0670	0.0615	0.0387	0.0235	0.0090	0.0000	0.0000
W3	0.0035	0.0007	0.0000	0.0000	0.0000	0.0007	0.0007	0.0007	0.0207	0.0642	0.0483	0.0297	0.0691	0.0580	0.0180	0.0117	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0090	0.0193	0.0166	0.0069	0.0186	0.0373	0.0035	0.0007	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0028	0.0014	0.0000	0.0000	0.0055	0.0055	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0000	0.0000	0.0007	0.0014	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED, WIND DIRECTION AND STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	VAR
STABILITY CLASS 1																		
W1	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0014	0.0007	0.0021	0.0014	0.0021	0.0048	0.0021	0.0007	0.0014	0.0000	0.0000
W2	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0014	0.0014	0.0048	0.0076	0.0055	0.0062	0.0035	0.0035	0.0035	0.0000	0.0000	0.0000
W3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0007	0.0021	0.0062	0.0055	0.0028	0.0014	0.0035	0.0007	0.0000	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0028	0.0028	0.0041	0.0021	0.0028	0.0014	0.0007	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0014	0.0007	0.0021	0.0014	0.0021	0.0048	0.0021	0.0007	0.0014	0.0000	0.0000
STABILITY CLASS 2																		
W1	0.0007	0.0021	0.0007	0.0000	0.0014	0.0007	0.0000	0.0035	0.0021	0.0014	0.0028	0.0028	0.0035	0.0014	0.0014	0.0007	0.0000	0.0000
W2	0.0035	0.0007	0.0000	0.0000	0.0021	0.0007	0.0000	0.0014	0.0035	0.0124	0.0152	0.0076	0.0076	0.0090	0.0076	0.0035	0.0000	0.0000
W3	0.0035	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0028	0.0180	0.0117	0.0062	0.0021	0.0014	0.0021	0.0076	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0076	0.0055	0.0007	0.0021	0.0014	0.0000	0.0007	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0007	0.0021	0.0007	0.0000	0.0014	0.0007	0.0000	0.0035	0.0021	0.0014	0.0028	0.0028	0.0035	0.0014	0.0014	0.0007	0.0000	0.0000
STABILITY CLASS 3																		
W1	0.0000	0.0007	0.0007	0.0007	0.0014	0.0000	0.0000	0.0000	0.0028	0.0007	0.0035	0.0014	0.0035	0.0000	0.0014	0.0000	0.0000	0.0000
W2	0.0007	0.0000	0.0000	0.0007	0.0000	0.0014	0.0007	0.0007	0.0041	0.0053	0.0062	0.0097	0.0041	0.0014	0.0007	0.0000	0.0000	0.0000

(September)

RELEASE HEIGHT: 0 M TOTAL # OF HOURS: 1400

OF LOW SPEED CLASS ONE WINDS: 160

WIND SPEED CLASS

OF OCCURRENCES

1	2	3	4	5	6	7	8
160	499	540	159	17	5	0	0

WIND DIRECTION (16 SECTORS + CALM + VARIABLE)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CM	VR
WIND DIR OCCURRENCE	59.	19.	19.	5.	5.	5.	13.	14.	77.	161.	178.	113.	240.	271.	139.	86.	0.	0.
WIND ROSE	0.042	0.014	0.014	0.004	0.004	0.004	0.009	0.010	0.055	0.115	0.127	0.081	0.171	0.194	0.096	0.061	0.000	0.000
LOW SPD WIND ROSE	0.081	0.019	0.025	0.006	0.025	0.019	0.069	0.044	0.131	0.044	0.075	0.119	0.138	0.087	0.075	0.044	0.000	0.000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED AND WIND DIRECTION

W1	0.0093	0.0021	0.0029	0.0007	0.0029	0.0021	0.0079	0.0050	0.0150	0.0050	0.0086	0.0136	0.0157	0.0100	0.0086	0.0050	0.0000	0.0000
W2	0.0157	0.0050	0.0036	0.0014	0.0000	0.0014	0.0007	0.0043	0.0221	0.0371	0.0636	0.0379	0.0543	0.0414	0.0407	0.0271	0.0000	0.0000
W3	0.0164	0.0043	0.0036	0.0007	0.0007	0.0000	0.0007	0.0007	0.0143	0.0593	0.0429	0.0221	0.0786	0.0836	0.0336	0.0243	0.0000	0.0000
W4	0.0007	0.0021	0.0029	0.0007	0.0000	0.0000	0.0000	0.0000	0.0036	0.0121	0.0107	0.0057	0.0186	0.0450	0.0086	0.0029	0.0000	0.0000
W5	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0014	0.0014	0.0036	0.0136	0.0021	0.0021	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0029	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED, WIND DIRECTION AND STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	VAR
STABILITY CLASS 1																		
W1	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0007	0.0007	0.0000	0.0000	0.0007	0.0014	0.0007	0.0000	0.0000	0.0000
W2	0.0021	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0014	0.0000	0.0021	0.0057	0.0021	0.0007	0.0029	0.0036	0.0029	0.0000	0.0000
W3	0.0021	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0093	0.0043	0.0014	0.0071	0.0036	0.0029	0.0036	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0014	0.0014	0.0007	0.0043	0.0007	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0007	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0007	0.0007	0.0000	0.0000	0.0007	0.0014	0.0007	0.0000	0.0000	0.0000
STABILITY CLASS 2																		
W1	0.0021	0.0000	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0014	0.0014	0.0007	0.0036	0.0043	0.0007	0.0000	0.0000
W2	0.0029	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0021	0.0043	0.0071	0.0050	0.0036	0.0021	0.0079	0.0093	0.0000	0.0000
W3	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0029	0.0100	0.0029	0.0029	0.0014	0.0014	0.0014	0.0079	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0029	0.0014	0.0000	0.0007	0.0007	0.0007	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0021	0.0000	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0014	0.0014	0.0007	0.0036	0.0043	0.0007	0.0000	0.0000
STABILITY CLASS 3																		
W1	0.0014	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0000	0.0007	0.0014	0.0007	0.0021	0.0000	0.0007	0.0000	0.0000
W2	0.0050	0.0000	0.0007	0.0007	0.0000	0.0000	0.0000	0.0007	0.0021	0.0036	0.0057	0.0014	0.0050	0.0021	0.0086	0.0071	0.0000	0.0000

(October)

RELEASE HEIGHT: 0 M TOTAL # OF HOURS: 1428

OF LOW SPEED CLASS ONE WINDS: 274

WIND SPEED CLASS

OF OCCURRENCES

1 2 3 4 5 6 7 8
274 649 388 91 22 3 1 0

WIND DIRECTION (16 SECTORS + CALM + VARIABLE)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	VAR
WIND DIR OCCURRENCE	7.	2.	2.	2.	4.	6.	6.	22.	105.	151.	258.	238.	346.	215.	53.	11.	0.	0.
WIND ROSE	0.005	0.001	0.001	0.001	0.003	0.004	0.004	0.015	0.074	0.106	0.181	0.167	0.242	0.151	0.037	0.008	0.000	0.000
LOW SPD WIND ROSE	0.007	0.007	0.004	0.007	0.015	0.018	0.018	0.040	0.113	0.088	0.161	0.201	0.226	0.069	0.015	0.011	0.000	0.000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED AND WIND DIRECTION

W1	0.0014	0.0014	0.0007	0.0014	0.0028	0.0035	0.0035	0.0077	0.0217	0.0168	0.0308	0.0385	0.0434	0.0133	0.0028	0.0021	0.0000	0.0000
W2	0.0028	0.0000	0.0007	0.0000	0.0000	0.0007	0.0007	0.0077	0.0336	0.0357	0.0847	0.0819	0.1176	0.0651	0.0196	0.0035	0.0000	0.0000
W3	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0161	0.0413	0.0518	0.0315	0.0623	0.0539	0.0119	0.0021	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0119	0.0077	0.0070	0.0161	0.0175	0.0014	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0028	0.0077	0.0028	0.0007	0.0014	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED, WIND DIRECTION AND STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	VAR
STABILITY CLASS 1																		
W1	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0007	0.0021	0.0007	0.0000	0.0000	0.0000	0.0000
W2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0042	0.0021	0.0035	0.0063	0.0028	0.0007	0.0000	0.0000
W3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0049	0.0021	0.0014	0.0007	0.0000	0.0000	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0000	0.0000	0.0007	0.0021	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0007	0.0021	0.0007	0.0000	0.0000	0.0000	0.0000
STABILITY CLASS 2																		
W1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0000	0.0035	0.0028	0.0028	0.0007	0.0007	0.0000	0.0000	0.0000
W2	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0035	0.0070	0.0035	0.0049	0.0021	0.0007	0.0000	0.0000	0.0000
W3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0007	0.0014	0.0021	0.0021	0.0000	0.0000	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0000	0.0035	0.0028	0.0028	0.0007	0.0007	0.0000	0.0000	0.0000
STABILITY CLASS 3																		
W1	0.0000	0.0000	0.0007	0.0000	0.0007	0.0007	0.0000	0.0000	0.0021	0.0035	0.0049	0.0098	0.0105	0.0042	0.0000	0.0000	0.0000	0.0000
W2	0.0007	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0014	0.0028	0.0014	0.0084	0.0112	0.0161	0.0112	0.0056	0.0021	0.0000	0.0000

(November)

RELEASE HEIGHT: 0 M TOTAL # OF HOURS: 1416

OF LOW SPEED CLASS ONE WINDS: 145

WIND SPEED CLASS

OF OCCURRENCES

1

2

3

4

5

6

7

8

145

531

497

163

60

19

1

0

WIND DIRECTION (16 SECTIONS + CALM + VARIABLE)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	VR
WIND DIR OCCURANCE	7.	2.	1.	0.	2.	0.	6.	10.	91.	143.	216.	183.	319.	312.	94.	28.	0.	0.
WIND ROSE	0.005	0.001	0.001	0.000	0.001	0.000	0.004	0.007	0.064	0.101	0.154	0.129	0.225	0.220	0.066	0.020	0.000	0.000
LOW SPD WIND ROSE	0.014	0.014	0.007	0.000	0.007	0.000	0.014	0.021	0.090	0.110	0.110	0.138	0.317	0.117	0.028	0.014	0.000	0.000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED AND WIND DIRECTION

W1	0.0014	0.0014	0.0007	0.0000	0.0007	0.0000	0.0014	0.0021	0.0092	0.0113	0.0113	0.0141	0.0325	0.0120	0.0028	0.0014	0.0000	0.0000
W2	0.0014	0.0000	0.0000	0.0000	0.0007	0.0000	0.0028	0.0049	0.0339	0.0311	0.0473	0.0565	0.1194	0.0508	0.0205	0.0056	0.0000	0.0000
W3	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0184	0.0403	0.0268	0.0282	0.0593	0.1285	0.0381	0.0106	0.0000	0.0000
W4	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0028	0.0155	0.0297	0.0169	0.0127	0.0290	0.0049	0.0021	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0028	0.0028	0.0268	0.0113	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0113	0.0021	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED, WIND DIRECTION AND STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	VAR
STABILITY CLASS 1																		
W1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STABILITY CLASS 2																		
W1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STABILITY CLASS 3																		
W1	0.0014	0.0007	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0056	0.0014	0.0000	0.0000	0.0000	0.0000
W2	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0014	0.0014	0.0021	0.0042	0.0085	0.0071	0.0071	0.0021	0.0000	0.0000

(December)

RELEASE HEIGHT: 0 M TOTAL # OF HOURS: 1374

OF LOW SPEED CLASS ONE WINDS: 166
 WIND SPEED CLASS 1 2 3 4 5 6 7 8
 # OF OCCURANCES 166 546 465 152 29 13 3 0

WIND DIRECTION (16 SECTIONS + CALM + VARIABLE)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CM	VR
WIND DIR OCCURANCE	26.	5.	0.	0.	0.	0.	1.	10.	38.	73.	132.	109.	439.	413.	97.	31.	0.	0.
WIND ROSE	0.019	0.004	0.000	0.000	0.000	0.000	0.001	0.007	0.028	0.053	0.096	0.079	0.320	0.301	0.071	0.023	0.000	0.000
LOW SPD WIND ROSE	0.006	0.012	0.000	0.000	0.000	0.000	0.000	0.042	0.048	0.060	0.114	0.145	0.410	0.108	0.030	0.024	0.000	0.000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED AND WIND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CM	VR
W1	0.0007	0.0015	0.0000	0.0000	0.0000	0.0000	0.0051	0.0058	0.0073	0.0138	0.0175	0.0495	0.0131	0.0036	0.0029	0.0000	0.0000	
W2	0.0058	0.0007	0.0000	0.0000	0.0000	0.0007	0.0007	0.0051	0.0153	0.0313	0.0502	0.1689	0.0873	0.0255	0.0058	0.0000	0.0000	
W3	0.0007	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0138	0.0182	0.0080	0.0895	0.1572	0.0328	0.0095	0.0000	0.0000	
W4	0.0116	0.0015	0.0000	0.0000	0.0000	0.0007	0.0073	0.0087	0.0124	0.0036	0.0102	0.0415	0.0087	0.0044	0.0000	0.0000	0.0000	
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0036	0.0131	0.0000	0.0015	0.0015	0.0000	0.0000	0.0000	0.0000	
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0044	0.0051	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0022	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED, WIND DIRECTION AND STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	VAR
STABILITY CLASS 1																		
W1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STABILITY CLASS 2																		
W1	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0007	0.0022	0.0000	0.0007	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000
W2	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0029	0.0007	0.0007	0.0015	0.0000	0.0015	0.0000	0.0000
W3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0007	0.0000	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0007	0.0022	0.0000	0.0007	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000
STABILITY CLASS 3																		
W1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0022	0.0000	0.0000	0.0007	0.0000	0.0000
W2	0.0029	0.0007	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0015	0.0007	0.0015	0.0044	0.0022	0.0051	0.0007	0.0000	0.0000

TABLE B.2. Wind Data Summary for Elevated (89-m) Release Point

RELEASE HEIGHT: 89 M

STARTING DATE : 3 25 82 END DATE: 1 31 84

TOTAL # OF HOURS: 15674 # OF LOW SPEED CLASSONE WINDS: 2304

WIND SPEED CLASS	1	2	3	4	5	6	7	8
# OF OCCURANCES	2304	3685	3700	2916	1619	903	369	178

WIND DIRECTION (16 SECTORS + CALM + VARIABLE)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CM	VR
WIND DIR OCCURANCE	324.	150.	88.	51.	98.	82.	99.	225.	898.	1819.	2302.	1862.	3324.	2910.	990.	452.	0.	0.
WIND ROSE	0.021	0.010	0.006	0.003	0.006	0.005	0.006	0.014	0.057	0.116	0.147	0.119	0.212	0.186	0.063	0.029	0.000	0.000
LOW SPD WIND ROSE	0.024	0.015	0.010	0.010	0.019	0.015	0.016	0.032	0.065	0.107	0.125	0.149	0.237	0.092	0.039	0.024	0.000	0.000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED AND WIND DIRECTION

W1	0.0036	0.0022	0.0015	0.0015	0.0028	0.0022	0.0024	0.0047	0.0125	0.0158	0.0184	0.0219	0.0349	0.0135	0.0057	0.0035	0.0000	0.0000
W2	0.0069	0.0030	0.0014	0.0008	0.0020	0.0020	0.0026	0.0062	0.0195	0.0265	0.0340	0.0283	0.0471	0.0300	0.0154	0.0093	0.0000	0.0000
W3	0.0060	0.0017	0.0008	0.0006	0.0012	0.0008	0.0012	0.0021	0.0137	0.0333	0.0349	0.0269	0.0461	0.0386	0.0175	0.0106	0.0000	0.0000
W4	0.0022	0.0015	0.0011	0.0002	0.0003	0.0001	0.0001	0.0010	0.0073	0.0230	0.0279	0.0218	0.0413	0.0428	0.0120	0.0036	0.0000	0.0000
W5	0.0011	0.0004	0.0004	0.0001	0.0000	0.0001	0.0000	0.0002	0.0024	0.0096	0.0118	0.0103	0.0263	0.0339	0.0052	0.0015	0.0000	0.0000
W6	0.0008	0.0004	0.0000	0.0001	0.0000	0.0001	0.0000	0.0001	0.0011	0.0041	0.0093	0.0055	0.0122	0.0192	0.0043	0.0003	0.0000	0.0000
W7	0.0001	0.0003	0.0003	0.0000	0.0000	0.0001	0.0000	0.0004	0.0019	0.0054	0.0026	0.0038	0.0064	0.0023	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0003	0.0019	0.0051	0.0015	0.0004	0.0013	0.0006	0.0000	0.0000	0.0000	0.0000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED, WIND DIRECTION AND STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	VAR
STABILITY CLASS 1																		
W1	0.0006	0.0002	0.0002	0.0003	0.0003	0.0001	0.0001	0.0003	0.0008	0.0013	0.0013	0.0010	0.0022	0.0010	0.0012	0.0008	0.0000	0.0000
W2	0.0019	0.0005	0.0002	0.0000	0.0002	0.0001	0.0005	0.0003	0.0013	0.0023	0.0041	0.0024	0.0023	0.0024	0.0019	0.0020	0.0000	0.0000
W3	0.0014	0.0004	0.0001	0.0001	0.0000	0.0001	0.0000	0.0000	0.0003	0.0031	0.0033	0.0025	0.0027	0.0016	0.0013	0.0019	0.0000	0.0000
W4	0.0006	0.0001	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0004	0.0024	0.0020	0.0019	0.0025	0.0022	0.0003	0.0000	0.0000	0.0000
W5	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0008	0.0015	0.0005	0.0006	0.0008	0.0002	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0007	0.0002	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0006	0.0002	0.0002	0.0003	0.0003	0.0001	0.0001	0.0003	0.0008	0.0013	0.0013	0.0010	0.0022	0.0010	0.0012	0.0008	0.0000	0.0000
STABILITY CLASS 2																		
W1	0.0008	0.0004	0.0003	0.0003	0.0004	0.0003	0.0001	0.0007	0.0017	0.0015	0.0026	0.0028	0.0031	0.0012	0.0015	0.0004	0.0000	0.0000
W2	0.0015	0.0011	0.0004	0.0002	0.0008	0.0003	0.0004	0.0009	0.0027	0.0047	0.0054	0.0033	0.0044	0.0031	0.0027	0.0021	0.0000	0.0000
W3	0.0013	0.0003	0.0001	0.0001	0.0004	0.0002	0.0001	0.0003	0.0011	0.0051	0.0036	0.0022	0.0022	0.0018	0.0013	0.0024	0.0000	0.0000
W4	0.0003	0.0003	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0002	0.0036	0.0030	0.0015	0.0013	0.0006	0.0005	0.0007	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0002	0.0008	0.0008	0.0005	0.0006	0.0004	0.0002	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0006	0.0004	0.0003	0.0003	0.0004	0.0003	0.0001	0.0007	0.0017	0.0015	0.0026	0.0028	0.0031	0.0012	0.0015	0.0004	0.0000	0.0000

STABILITY CLASS 3

W1	0.0006	0.0005	0.0003	0.0002	0.0003	0.0002	0.0002	0.0004	0.0012	0.0015	0.0018	0.0025	0.0037	0.0015	0.0004	0.0004	0.0000	0.0000
W2	0.0011	0.0004	0.0001	0.0003	0.0003	0.0004	0.0003	0.0010	0.0023	0.0026	0.0034	0.0031	0.0050	0.0031	0.0030	0.0017	0.0000	0.0000
W3	0.0012	0.0003	0.0001	0.0000	0.0002	0.0001	0.0003	0.0002	0.0013	0.0023	0.0031	0.0027	0.0033	0.0030	0.0032	0.0019	0.0000	0.0000
W4	0.0002	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0006	0.0026	0.0024	0.0022	0.0019	0.0011	0.0008	0.0007	0.0000	0.0000
W5	0.0001	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0004	0.0005	0.0005	0.0007	0.0006	0.0001	0.0002	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0003	0.0002	0.0003	0.0004	0.0003	0.0001	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0000	0.0001	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0006	0.0005	0.0003	0.0002	0.0003	0.0002	0.0002	0.0004	0.0012	0.0015	0.0018	0.0025	0.0037	0.0015	0.0004	0.0004	0.0000	0.0000

STABILITY CLASS 4

W1	0.0009	0.0003	0.0003	0.0001	0.0008	0.0008	0.0006	0.0013	0.0039	0.0046	0.0069	0.0084	0.0129	0.0056	0.0014	0.0007	0.0000	0.0000
W2	0.0012	0.0004	0.0003	0.0003	0.0001	0.0004	0.0006	0.0015	0.0059	0.0042	0.0100	0.0098	0.0184	0.0120	0.0038	0.0019	0.0000	0.0000
W3	0.0014	0.0004	0.0004	0.0003	0.0001	0.0001	0.0006	0.0005	0.0050	0.0108	0.0114	0.0083	0.0187	0.0184	0.0059	0.0024	0.0000	0.0000
W4	0.0007	0.0006	0.0008	0.0001	0.0002	0.0000	0.0000	0.0005	0.0033	0.0080	0.0105	0.0087	0.0189	0.0221	0.0045	0.0018	0.0000	0.0000
W5	0.0009	0.0003	0.0002	0.0000	0.0000	0.0000	0.0000	0.0002	0.0011	0.0044	0.0057	0.0056	0.0138	0.0184	0.0029	0.0007	0.0000	0.0000
W6	0.0004	0.0001	0.0000	0.0001	0.0000	0.0001	0.0000	0.0001	0.0004	0.0022	0.0052	0.0031	0.0072	0.0122	0.0025	0.0002	0.0000	0.0000
W7	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0001	0.0000	0.0003	0.0011	0.0039	0.0020	0.0027	0.0047	0.0019	0.0000	0.0000	0.0000
W8	0.0000	0.0001	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0010	0.0033	0.0011	0.0003	0.0010	0.0006	0.0000	0.0000	0.0000
W9	0.0009	0.0003	0.0003	0.0001	0.0008	0.0008	0.0006	0.0013	0.0039	0.0046	0.0069	0.0084	0.0129	0.0056	0.0014	0.0007	0.0000	0.0000

STABILITY CLASS 5

W1	0.0004	0.0003	0.0003	0.0003	0.0004	0.0004	0.0006	0.0010	0.0017	0.0033	0.0021	0.0028	0.0057	0.0017	0.0005	0.0005	0.0000	0.0000
W2	0.0007	0.0004	0.0002	0.0001	0.0003	0.0004	0.0004	0.0013	0.0038	0.0037	0.0051	0.0040	0.0070	0.0043	0.0017	0.0008	0.0000	0.0000
W3	0.0004	0.0003	0.0000	0.0001	0.0004	0.0003	0.0000	0.0007	0.0029	0.0061	0.0077	0.0059	0.0101	0.0067	0.0027	0.0012	0.0000	0.0000
W4	0.0002	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0003	0.0015	0.0043	0.0056	0.0052	0.0117	0.0099	0.0033	0.0002	0.0000	0.0000
W5	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0022	0.0020	0.0021	0.0077	0.0108	0.0011	0.0004	0.0000	0.0000
W6	0.0004	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0008	0.0019	0.0012	0.0032	0.0057	0.0010	0.0001	0.0000	0.0000
W7	0.0001	0.0003	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0006	0.0011	0.0003	0.0007	0.0015	0.0002	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0004	0.0013	0.0002	0.0000	0.0003	0.0001	0.0000	0.0000	0.0000
W9	0.0004	0.0003	0.0003	0.0003	0.0004	0.0004	0.0006	0.0010	0.0017	0.0033	0.0021	0.0028	0.0057	0.0017	0.0005	0.0005	0.0000	0.0000

STABILITY CLASS 6

W1	0.0001	0.0003	0.0002	0.0003	0.0003	0.0002	0.0006	0.0008	0.0015	0.0025	0.0027	0.0033	0.0052	0.0020	0.0006	0.0005	0.0000	0.0000
W2	0.0005	0.0002	0.0002	0.0001	0.0002	0.0004	0.0002	0.0007	0.0028	0.0036	0.0041	0.0042	0.0070	0.0036	0.0020	0.0006	0.0000	0.0000
W3	0.0001	0.0004	0.0001	0.0000	0.0001	0.0001	0.0001	0.0004	0.0024	0.0040	0.0045	0.0035	0.0073	0.0054	0.0024	0.0005	0.0000	0.0000
W4	0.0001	0.0001	0.0000	0.0000	0.0001	0.0000	0.0001	0.0001	0.0011	0.0016	0.0031	0.0019	0.0043	0.0052	0.0024	0.0002	0.0000	0.0000
W5	0.0000	0.0001	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0003	0.0007	0.0008	0.0009	0.0023	0.0020	0.0006	0.0003	0.0000	0.0000
W6	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0003	0.0008	0.0004	0.0012	0.0008	0.0003	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0003	0.0001	0.0001	0.0003	0.0001	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0004	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000
W9	0.0001	0.0003	0.0002	0.0003	0.0003	0.0002	0.0006	0.0008	0.0015	0.0025	0.0027	0.0033	0.0052	0.0020	0.0006	0.0005	0.0000	0.0000

STABILITY CLASS 7

W1	0.0003	0.0002	0.0001	0.0001	0.0001	0.0001	0.0002	0.0003	0.0017	0.0010	0.0011	0.0012	0.0022	0.0005	0.0001	0.0002	0.0000	0.0000
W2	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0002	0.0004	0.0008	0.0013	0.0019	0.0015	0.0030	0.0015	0.0004	0.0001	0.0000	0.0000
W3	0.0002	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0009	0.0018	0.0014	0.0019	0.0017	0.0017	0.0008	0.0004	0.0000	0.0000
W4	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0006	0.0013	0.0005	0.0006	0.0017	0.0003	0.0001	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0003	0.0004	0.0001	0.0005	0.0008	0.0001	0.0000	0.0000	0.0000
W6	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0003	0.0002	0.0001	0.0001	0.0001	0.0001	0.0002	0.0003	0.0017	0.0010	0.0011	0.0012	0.0022	0.0005	0.0001	0.0002	0.0000	0.0000

(January)

RELEASE HEIGHT: 89 M TOTAL # OF HOURS: 1338

OF LOW SPEED CLASS ONE WINDS: 288

WIND SPEED CLASS	1	2	3	4	5	6	7	8
# OF OCCURRENCES	288	325	280	203	83	60	47	52

WIND DIRECTION (16 SECTORS + CALM + VARIABLE)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CM	VR
WIND DIR OCCURRENCE	40.	23.	11.	7.	21.	22.	16.	25.	87.	133.	204.	133.	268.	253.	64.	31.	0.	0.
WIND ROSE	0.030	0.017	0.008	0.005	0.016	0.016	0.012	0.019	0.065	0.099	0.152	0.099	0.200	0.189	0.048	0.023	0.000	0.000
LOW SPD WIND ROSE	0.031	0.010	0.007	0.010	0.028	0.024	0.017	0.038	0.069	0.069	0.142	0.132	0.236	0.135	0.024	0.024	0.000	0.000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED AND WIND DIRECTION

W1	0.0067	0.0022	0.0015	0.0022	0.0060	0.0052	0.0037	0.0082	0.0149	0.0149	0.0306	0.0284	0.0508	0.0291	0.0052	0.0052	0.0000	0.0000
W2	0.0090	0.0022	0.0022	0.0015	0.0045	0.0060	0.0060	0.0052	0.0194	0.0149	0.0321	0.0247	0.0590	0.0344	0.0164	0.0052	0.0000	0.0000
W3	0.0045	0.0030	0.0007	0.0015	0.0045	0.0045	0.0022	0.0030	0.0194	0.0209	0.0187	0.0179	0.0389	0.0486	0.0182	0.0067	0.0000	0.0000
W4	0.0037	0.0022	0.0000	0.0000	0.0007	0.0000	0.0000	0.0007	0.0060	0.0157	0.0172	0.0109	0.0291	0.0523	0.0112	0.0022	0.0000	0.0000
W5	0.0022	0.0007	0.0000	0.0000	0.0000	0.0007	0.0000	0.0015	0.0022	0.0060	0.0067	0.0052	0.0112	0.0209	0.0007	0.0037	0.0000	0.0000
W6	0.0037	0.0037	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0022	0.0090	0.0149	0.0045	0.0030	0.0037	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0030	0.0030	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0067	0.0127	0.0037	0.0060	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0112	0.0194	0.0045	0.0022	0.0000	0.0000	0.0000	0.0000	0.0000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED, WIND DIRECTION AND STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	VAR
STABILITY CLASS 1																		
W1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W5	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STABILITY CLASS 2																		
W1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0030	0.0000	0.0000	0.0000	0.0000	0.0000
W2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000
W3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W4	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0030	0.0000	0.0000	0.0000	0.0000	0.0000
STABILITY CLASS 3																		
W1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0015	0.0015	0.0007	0.0007	0.0007	0.0000	0.0000	0.0000
W2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0030	0.0037	0.0060	0.0015	0.0007	0.0007	0.0000	0.0000

(January)

M3	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0022	0.0015	0.0022	0.0015	0.0000	0.0007	0.0000	0.0000
M4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0030	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000
M5	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0015	0.0015	0.0007	0.0007	0.0007	0.0000	0.0000

STABILITY CLASS 4

M1	0.0052	0.0000	0.0000	0.0000	0.0030	0.0037	0.0022	0.0030	0.0060	0.0090	0.0172	0.0194	0.0262	0.0224	0.0030	0.0030	0.0000	0.0000
M2	0.0045	0.0015	0.0007	0.0007	0.0015	0.0015	0.0022	0.0007	0.0075	0.0045	0.0127	0.0127	0.0336	0.0239	0.0075	0.0030	0.0000	0.0000
M3	0.0022	0.0007	0.0000	0.0007	0.0000	0.0007	0.0007	0.0007	0.0052	0.0082	0.0067	0.0075	0.0254	0.0344	0.0067	0.0000	0.0000	0.0000
M4	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0052	0.0045	0.0045	0.0247	0.0433	0.0045	0.0007	0.0000	0.0000
M5	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0015	0.0030	0.0037	0.0015	0.0052	0.0179	0.0000	0.0000	0.0000
M6	0.0015	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0030	0.0097	0.0037	0.0030	0.0015	0.0000	0.0000	0.0000
M7	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0030	0.0105	0.0037	0.0052	0.0000	0.0000	0.0000	0.0000
M8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0067	0.0157	0.0037	0.0015	0.0000	0.0000	0.0000	0.0000
M9	0.0052	0.0000	0.0000	0.0000	0.0030	0.0037	0.0022	0.0030	0.0060	0.0090	0.0172	0.0194	0.0262	0.0224	0.0030	0.0030	0.0000	0.0000

STABILITY CLASS 5

M1	0.0007	0.0015	0.0007	0.0015	0.0022	0.0015	0.0007	0.0015	0.0037	0.0022	0.0052	0.0015	0.0142	0.0030	0.0015	0.0015	0.0000	0.0000
M2	0.0030	0.0007	0.0007	0.0007	0.0015	0.0022	0.0037	0.0030	0.0060	0.0060	0.0082	0.0045	0.0082	0.0045	0.0030	0.0015	0.0000	0.0000
M3	0.0000	0.0015	0.0000	0.0007	0.0030	0.0030	0.0000	0.0007	0.0060	0.0067	0.0075	0.0052	0.0060	0.0090	0.0030	0.0022	0.0000	0.0000
M4	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0022	0.0060	0.0075	0.0022	0.0030	0.0067	0.0022	0.0007	0.0000	0.0000
M5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0022	0.0022	0.0037	0.0030	0.0000	0.0030	0.0000	0.0000
M6	0.0015	0.0022	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0030	0.0037	0.0007	0.0000	0.0022	0.0000	0.0000	0.0000	0.0000
M7	0.0000	0.0030	0.0022	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0037	0.0022	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M8	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0022	0.0022	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M9	0.0007	0.0015	0.0007	0.0015	0.0022	0.0015	0.0007	0.0015	0.0037	0.0022	0.0052	0.0015	0.0142	0.0030	0.0015	0.0015	0.0000	0.0000

STABILITY CLASS 6

M1	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0000	0.0015	0.0007	0.0015	0.0037	0.0030	0.0052	0.0007	0.0000	0.0007	0.0000	0.0000
M2	0.0015	0.0000	0.0007	0.0000	0.0007	0.0022	0.0000	0.0015	0.0045	0.0007	0.0052	0.0037	0.0060	0.0030	0.0045	0.0000	0.0000	0.0000
M3	0.0000	0.0000	0.0007	0.0000	0.0007	0.0000	0.0007	0.0015	0.0045	0.0030	0.0015	0.0030	0.0030	0.0030	0.0037	0.0022	0.0000	0.0000
M4	0.0007	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0022	0.0037	0.0022	0.0000	0.0000	0.0015	0.0045	0.0000	0.0000	0.0000
M5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0007	0.0007	0.0000	0.0007	0.0022	0.0000	0.0007	0.0007	0.0000	0.0000
M6	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0015	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0022	0.0007	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000
M9	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0000	0.0015	0.0007	0.0015	0.0037	0.0030	0.0052	0.0007	0.0000	0.0007	0.0000	0.0000

STABILITY CLASS 7

M1	0.0007	0.0007	0.0007	0.0000	0.0000	0.0000	0.0007	0.0007	0.0030	0.0022	0.0015	0.0030	0.0015	0.0022	0.0000	0.0000	0.0000	0.0000
M2	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0015	0.0022	0.0030	0.0000	0.0037	0.0015	0.0007	0.0000	0.0000	0.0000
M3	0.0015	0.0000	0.0000	0.0000	0.0007	0.0007	0.0007	0.0000	0.0037	0.0022	0.0007	0.0007	0.0022	0.0007	0.0007	0.0015	0.0000	0.0000
M4	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0015	0.0007	0.0007	0.0007	0.0000	0.0007	0.0000	0.0000
M5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000
M6	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000
M8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M9	0.0007	0.0007	0.0007	0.0000	0.0000	0.0000	0.0007	0.0007	0.0030	0.0022	0.0015	0.0030	0.0015	0.0022	0.0000	0.0000	0.0000	0.0000

(February)

RELEASE HEIGHT: 89 M TOTAL # OF HOURS: 670

OF LOW SPEED CLASS ONE WINDS: 166

WIND SPEED CLASS

OF OCCURRENCES

1 2 3 4 5 6 7 8
166 165 164 117 44 11 3 0

WIND DIRECTION (16 SECTORS + CALM + VARIABLE)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CM	VR
WIND DIR OCCURRENCE	2.	1.	1.	0.	2.	1.	3.	5.	28.	66.	99.	81.	163.	162.	49.	7.	0.	0.
WIND ROSE	0.003	0.001	0.001	0.000	0.003	0.001	0.004	0.007	0.042	0.099	0.148	0.121	0.243	0.242	0.073	0.010	0.000	0.000
LOW SPD WIND ROSE	0.012	0.000	0.006	0.000	0.012	0.006	0.006	0.012	0.012	0.133	0.120	0.151	0.325	0.163	0.024	0.018	0.000	0.000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED AND WIND DIRECTION

W1	0.0030	0.0000	0.0015	0.0000	0.0030	0.0015	0.0015	0.0030	0.0030	0.0328	0.0299	0.0373	0.0806	0.0403	0.0060	0.0045	0.0000	0.0000
W2	0.0000	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0030	0.0134	0.0194	0.0328	0.0328	0.0582	0.0507	0.0284	0.0060	0.0000	0.0000
W3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0030	0.0000	0.0134	0.0254	0.0284	0.0224	0.0493	0.0731	0.0299	0.0000	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0075	0.0134	0.0373	0.0179	0.0433	0.0478	0.0060	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0075	0.0104	0.0090	0.0104	0.0239	0.0030	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0075	0.0015	0.0015	0.0060	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0030	0.0000	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED, WIND DIRECTION AND STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	VAR
STABILITY CLASS 1																		
W1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STABILITY CLASS 2																		
W1	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0075	0.0075	0.0015	0.0015	0.0000	0.0000	0.0000
W2	0.0000	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0030	0.0030	0.0000	0.0015	0.0000	0.0000	0.0000
W3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0000	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0075	0.0075	0.0015	0.0015	0.0000	0.0000	0.0000
STABILITY CLASS 3																		
W1	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0015	0.0030	0.0075	0.0030	0.0000	0.0000	0.0000	0.0000
W2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0015	0.0030	0.0060	0.0090	0.0090	0.0045	0.0000	0.0000

(March)

RELEASE HEIGHT: 89 M TOTAL # OF HOURS: 868

OF LOW SPEED CLASS ONE WINDS: 132

WIND SPEED CLASS

OF OCCURRENCES

1	2	3	4	5	6	7	8
132	171	188	199	108	40	23	7

WIND DIRECTION (16 SECTORS + CALM + VARIABLE)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CM	VR
WIND DIR OCCURRENCE	16.	4.	3.	2.	3.	0.	5.	16.	60.	87.	155.	122.	178.	147.	55.	15.	0.	0.
WIND ROSE	0.018	0.005	0.003	0.002	0.003	0.000	0.006	0.018	0.069	0.100	0.179	0.141	0.203	0.169	0.063	0.017	0.000	0.000
LOW SPD WIND ROSE	0.023	0.023	0.015	0.008	0.015	0.000	0.030	0.008	0.053	0.152	0.083	0.098	0.235	0.144	0.068	0.015	0.000	0.000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED AND WIND DIRECTION

W1	0.0035	0.0035	0.0023	0.0012	0.0023	0.0000	0.0046	0.0012	0.0127	0.0230	0.0127	0.0150	0.0357	0.0219	0.0104	0.0023	0.0000	0.0000
W2	0.0035	0.0012	0.0000	0.0000	0.0012	0.0000	0.0012	0.0069	0.0184	0.0219	0.0300	0.0230	0.0323	0.0369	0.0115	0.0092	0.0000	0.0000
W3	0.0023	0.0000	0.0012	0.0012	0.0000	0.0000	0.0000	0.0023	0.0230	0.0300	0.0311	0.0230	0.0369	0.0438	0.0196	0.0023	0.0000	0.0000
W4	0.0081	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0069	0.0104	0.0161	0.0634	0.0380	0.0392	0.0300	0.0173	0.0000	0.0000	0.0000
W5	0.0012	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0023	0.0058	0.0173	0.0207	0.0415	0.0311	0.0023	0.0023	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012	0.0012	0.0012	0.0127	0.0069	0.0150	0.0046	0.0023	0.0012	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012	0.0023	0.0104	0.0081	0.0035	0.0012	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012	0.0058	0.0012	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED, WIND DIRECTION AND STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	VAR
STABILITY CLASS 1																		
W1	0.0012	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012	0.0012	0.0012	0.0012	0.0023	0.0035	0.0035	0.0012	0.0000	0.0000
W2	0.0012	0.0012	0.0000	0.0000	0.0012	0.0000	0.0012	0.0000	0.0023	0.0035	0.0023	0.0000	0.0023	0.0012	0.0035	0.0023	0.0000	0.0000
W3	0.0012	0.0000	0.0012	0.0000	0.0000	0.0000	0.0000	0.0000	0.0023	0.0012	0.0000	0.0012	0.0000	0.0058	0.0012	0.0000	0.0000	0.0000
W4	0.0081	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0058	0.0023	0.0115	0.0023	0.0012	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0035	0.0023	0.0058	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0058	0.0023	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0012	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012	0.0012	0.0012	0.0012	0.0023	0.0035	0.0035	0.0012	0.0000	0.0000
STABILITY CLASS 2																		
W1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0023	0.0023	0.0035	0.0000	0.0023	0.0000	0.0000	0.0000	0.0000
W2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012	0.0035	0.0023	0.0012	0.0035	0.0035	0.0000	0.0000	0.0000	0.0000
W3	0.0000	0.0000	0.0000	0.0012	0.0000	0.0000	0.0000	0.0000	0.0023	0.0023	0.0023	0.0012	0.0023	0.0035	0.0023	0.0000	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0092	0.0023	0.0035	0.0000	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012	0.0000	0.0000	0.0012	0.0012	0.0012	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0023	0.0023	0.0035	0.0000	0.0023	0.0000	0.0000	0.0000	0.0000
STABILITY CLASS 3																		
W1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012	0.0023	0.0000	0.0012	0.0000	0.0000	0.0000
W2	0.0012	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0023	0.0023	0.0000	0.0035	0.0012	0.0035	0.0035	0.0023	0.0000	0.0000	0.0000

(April)

RELEASE HEIGHT: 89 M TOTAL # OF HOURS: 1438

OF LOW SPEED CLASS ONE WINDS: 230

WIND SPEED CLASS	1	2	3	4	5	6	7	8
# OF OCCURRENCES	230	315	303	227	184	95	58	26

WIND DIRECTION (16 SECTORS + CALM + VARIABLE)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CM	VR
WIND DIR OCCURRENCE	30.	20.	7.	4.	4.	6.	7.	17.	63.	178.	256.	213.	298.	195.	90.	50.	0.	0.
WIND ROSE	0.021	0.014	0.005	0.003	0.003	0.004	0.005	0.012	0.044	0.124	0.178	0.148	0.207	0.136	0.063	0.035	0.000	0.000
LOW SPD WIND ROSE	0.017	0.017	0.009	0.004	0.009	0.009	0.013	0.030	0.096	0.104	0.148	0.200	0.191	0.083	0.039	0.030	0.000	0.000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED AND WIND DIRECTION

M1	0.0028	0.0028	0.0014	0.0007	0.0014	0.0014	0.0021	0.0049	0.0153	0.0167	0.0236	0.0320	0.0306	0.0132	0.0063	0.0049	0.0000	0.0000
M2	0.0083	0.0042	0.0007	0.0007	0.0014	0.0028	0.0007	0.0049	0.0076	0.0264	0.0362	0.0223	0.0382	0.0285	0.0209	0.0153	0.0000	0.0000
M3	0.0083	0.0063	0.0021	0.0007	0.0000	0.0000	0.0014	0.0007	0.0111	0.0313	0.0320	0.0285	0.0341	0.0236	0.0188	0.0118	0.0000	0.0000
M4	0.0014	0.0007	0.0007	0.0007	0.0000	0.0000	0.0007	0.0007	0.0063	0.0209	0.0313	0.0285	0.0327	0.0223	0.0090	0.0021	0.0000	0.0000
M5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0014	0.0174	0.0271	0.0167	0.0410	0.0188	0.0042	0.0007	0.0000	0.0000
M6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0049	0.0132	0.0097	0.0223	0.0139	0.0021	0.0000	0.0000	0.0000
M7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0028	0.0063	0.0076	0.0083	0.0132	0.0007	0.0000	0.0000	0.0000
M8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0035	0.0083	0.0028	0.0000	0.0021	0.0007	0.0000	0.0000	0.0000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED, WIND DIRECTION AND STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	VAR
STABILITY CLASS 1																		
M1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0014	0.0021	0.0070	0.0028	0.0007	0.0000	0.0000	0.0000
M2	0.0035	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0063	0.0021	0.0063	0.0049	0.0083	0.0076	0.0000	0.0000
M3	0.0035	0.0035	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0035	0.0035	0.0021	0.0021	0.0021	0.0028	0.0056	0.0000	0.0000
M4	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0021	0.0021	0.0021	0.0028	0.0000	0.0000	0.0000	0.0000
M5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0035	0.0000	0.0028	0.0021	0.0007	0.0000	0.0000	0.0000
M6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0014	0.0021	0.0070	0.0028	0.0007	0.0000	0.0000	0.0000
STABILITY CLASS 2																		
M1	0.0007	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0007	0.0042	0.0035	0.0063	0.0070	0.0035	0.0007	0.0021	0.0021	0.0000	0.0000
M2	0.0000	0.0007	0.0007	0.0000	0.0014	0.0007	0.0000	0.0007	0.0014	0.0042	0.0070	0.0042	0.0049	0.0070	0.0021	0.0007	0.0000	0.0000
M3	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0028	0.0028	0.0021	0.0028	0.0007	0.0000	0.0000	0.0000	0.0000
M4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0035	0.0049	0.0028	0.0007	0.0007	0.0007	0.0000	0.0000
M5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0042	0.0007	0.0028	0.0021	0.0000	0.0000	0.0000	0.0000
M6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0000	0.0007	0.0007	0.0007	0.0000	0.0000
M7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M9	0.0007	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0007	0.0042	0.0035	0.0063	0.0070	0.0035	0.0007	0.0021	0.0021	0.0000	0.0000
STABILITY CLASS 3																		
M1	0.0007	0.0021	0.0007	0.0007	0.0000	0.0000	0.0007	0.0014	0.0014	0.0021	0.0028	0.0021	0.0028	0.0014	0.0000	0.0007	0.0000	0.0000
M2	0.0021	0.0007	0.0000	0.0007	0.0000	0.0007	0.0000	0.0014	0.0014	0.0035	0.0028	0.0021	0.0042	0.0000	0.0021	0.0035	0.0000	0.0000

(April)

M3	0.0028	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0021	0.0021	0.0021	0.0028	0.0007	0.0000	0.0000	0.0000
M4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0042	0.0014	0.0021	0.0007	0.0000	0.0000	0.0000	0.0000
M5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M9	0.0007	0.0021	0.0007	0.0007	0.0000	0.0000	0.0007	0.0014	0.0014	0.0021	0.0028	0.0021	0.0028	0.0014	0.0000	0.0007	0.0000	0.0000

STABILITY CLASS 4

M1	0.0000	0.0000	0.0007	0.0000	0.0014	0.0000	0.0007	0.0000	0.0042	0.0028	0.0049	0.0063	0.0049	0.0028	0.0021	0.0000	0.0000	0.0000
M2	0.0021	0.0014	0.0000	0.0000	0.0000	0.0014	0.0000	0.0007	0.0014	0.0070	0.0063	0.0070	0.0070	0.0042	0.0049	0.0028	0.0000	0.0000
M3	0.0014	0.0007	0.0021	0.0007	0.0000	0.0000	0.0014	0.0007	0.0035	0.0076	0.0083	0.0097	0.0104	0.0056	0.0070	0.0021	0.0000	0.0000
M4	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0007	0.0021	0.0090	0.0118	0.0118	0.0104	0.0035	0.0042	0.0007	0.0000	0.0000
M5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0014	0.0070	0.0160	0.0118	0.0216	0.0097	0.0021	0.0000	0.0000	0.0000
M6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0035	0.0076	0.0083	0.0160	0.0076	0.0007	0.0000	0.0000	0.0000
M7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0063	0.0063	0.0076	0.0111	0.0007	0.0000	0.0000	0.0000
M8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0014	0.0070	0.0028	0.0000	0.0014	0.0007	0.0000	0.0000	0.0000
M9	0.0000	0.0000	0.0007	0.0000	0.0014	0.0000	0.0007	0.0000	0.0042	0.0028	0.0049	0.0063	0.0049	0.0028	0.0021	0.0000	0.0000	0.0000

STABILITY CLASS 5

M1	0.0007	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0021	0.0014	0.0014	0.0014	0.0063	0.0042	0.0014	0.0007	0.0007	0.0000	0.0000
M2	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0014	0.0042	0.0042	0.0021	0.0063	0.0035	0.0021	0.0000	0.0000	0.0000
M3	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0042	0.0063	0.0083	0.0056	0.0042	0.0035	0.0035	0.0028	0.0000	0.0000
M4	0.0007	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0049	0.0049	0.0063	0.0104	0.0056	0.0028	0.0007	0.0000	0.0000
M5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0049	0.0021	0.0021	0.0104	0.0035	0.0014	0.0000	0.0000	0.0000
M6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0042	0.0049	0.0007	0.0000	0.0000	0.0000
M7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0007	0.0007	0.0014	0.0000	0.0000	0.0000	0.0000
M8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0007	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000
M9	0.0007	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0021	0.0014	0.0014	0.0014	0.0063	0.0042	0.0014	0.0007	0.0007	0.0000	0.0000

STABILITY CLASS 6

M1	0.0000	0.0007	0.0000	0.0000	0.0000	0.0007	0.0007	0.0014	0.0049	0.0049	0.0056	0.0049	0.0028	0.0007	0.0014	0.0000	0.0000	0.0000
M2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0021	0.0049	0.0076	0.0035	0.0049	0.0070	0.0014	0.0007	0.0000	0.0000	0.0000
M3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0076	0.0063	0.0028	0.0097	0.0063	0.0035	0.0007	0.0000	0.0000	0.0000
M4	0.0007	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0042	0.0014	0.0035	0.0007	0.0049	0.0056	0.0000	0.0000	0.0000	0.0000	0.0000
M5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0014	0.0021	0.0021	0.0014	0.0000	0.0007	0.0000	0.0000	0.0000
M6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0028	0.0000	0.0014	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000
M7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000
M8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M9	0.0000	0.0007	0.0000	0.0000	0.0000	0.0007	0.0007	0.0014	0.0049	0.0049	0.0056	0.0049	0.0028	0.0007	0.0014	0.0000	0.0000	0.0000

STABILITY CLASS 7

M1	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0028	0.0007	0.0021	0.0028	0.0035	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000
M2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0021	0.0014	0.0049	0.0021	0.0000	0.0000	0.0000	0.0000	0.0000
M3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0021	0.0007	0.0042	0.0028	0.0028	0.0014	0.0007	0.0000	0.0000	0.0000
M4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0014	0.0014	0.0000	0.0035	0.0014	0.0000	0.0000	0.0000	0.0000
M5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0000	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M9	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0028	0.0007	0.0021	0.0028	0.0035	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000

(May)

RELEASE HEIGHT: 89 M TOTAL # OF HOURS: 1445

OF LOW SPEED CLASS ONE WINDS: 182

WIND SPEED CLASS

OF OCCURRENCES

1	2	3	4	5	6	7	8
182	362	324	262	159	103	43	10

WIND DIRECTION (16 SECTORS + CALM + VARIABLE)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CM	VR
WIND DIR OCCURRENCE	56.	30.	11.	6.	10.	4.	6.	21.	61.	160.	161.	174.	313.	284.	104.	44.	0.	0.
WIND ROSE	0.039	0.021	0.008	0.004	0.007	0.003	0.004	0.015	0.042	0.111	0.111	0.120	0.217	0.197	0.072	0.030	0.000	0.000
LOW SPD WIND ROSE	0.049	0.038	0.005	0.005	0.016	0.016	0.005	0.016	0.082	0.165	0.066	0.181	0.198	0.060	0.055	0.038	0.000	0.000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED AND WIND DIRECTION

W1	0.0062	0.0048	0.0007	0.0007	0.0021	0.0021	0.0007	0.0021	0.0104	0.0208	0.0083	0.0228	0.0249	0.0076	0.0069	0.0048	0.0000	0.0000
W2	0.0187	0.0069	0.0028	0.0007	0.0021	0.0007	0.0035	0.0097	0.0201	0.0318	0.0346	0.0284	0.0394	0.0221	0.0145	0.0145	0.0000	0.0000
W3	0.0111	0.0028	0.0014	0.0021	0.0014	0.0000	0.0000	0.0028	0.0062	0.0298	0.0394	0.0367	0.0450	0.0228	0.0145	0.0083	0.0000	0.0000
W4	0.0021	0.0048	0.0007	0.0007	0.0014	0.0000	0.0000	0.0000	0.0035	0.0221	0.0221	0.0228	0.0457	0.0457	0.0069	0.0028	0.0000	0.0000
W5	0.0007	0.0014	0.0021	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0055	0.0055	0.0062	0.0374	0.0422	0.0076	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0014	0.0035	0.0194	0.0346	0.0111	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0048	0.0159	0.0090	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0055	0.0014	0.0000	0.0000	0.0000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED, WIND DIRECTION AND STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	VAR
STABILITY CLASS 1																		
W1	0.0021	0.0014	0.0000	0.0000	0.0014	0.0000	0.0000	0.0007	0.0014	0.0028	0.0014	0.0021	0.0021	0.0007	0.0048	0.0021	0.0000	0.0000
W2	0.0104	0.0007	0.0007	0.0000	0.0000	0.0000	0.0021	0.0000	0.0028	0.0055	0.0104	0.0042	0.0048	0.0021	0.0014	0.0028	0.0000	0.0000
W3	0.0048	0.0014	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0007	0.0042	0.0069	0.0083	0.0069	0.0000	0.0014	0.0028	0.0000	0.0000
W4	0.0014	0.0007	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0055	0.0021	0.0055	0.0014	0.0069	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0007	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0028	0.0000	0.0007	0.0014	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0021	0.0014	0.0000	0.0000	0.0014	0.0000	0.0000	0.0007	0.0014	0.0028	0.0014	0.0021	0.0021	0.0007	0.0048	0.0021	0.0000	0.0000
STABILITY CLASS 2																		
W1	0.0014	0.0014	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0042	0.0035	0.0035	0.0055	0.0062	0.0028	0.0014	0.0000	0.0000	0.0000
W2	0.0035	0.0042	0.0007	0.0007	0.0014	0.0000	0.0007	0.0014	0.0035	0.0062	0.0055	0.0055	0.0076	0.0014	0.0069	0.0048	0.0000	0.0000
W3	0.0028	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0062	0.0062	0.0035	0.0069	0.0000	0.0028	0.0014	0.0000	0.0000
W4	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0042	0.0028	0.0007	0.0028	0.0014	0.0028	0.0007	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0014	0.0014	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0042	0.0035	0.0035	0.0055	0.0062	0.0028	0.0014	0.0000	0.0000	0.0000
STABILITY CLASS 3																		
W1	0.0000	0.0014	0.0000	0.0000	0.0007	0.0007	0.0007	0.0007	0.0014	0.0028	0.0021	0.0028	0.0035	0.0007	0.0007	0.0007	0.0000	0.0000
W2	0.0007	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0028	0.0028	0.0028	0.0035	0.0021	0.0062	0.0048	0.0021	0.0021	0.0000	0.0000

(May)

H3	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0007	0.0000	0.0014	0.0048	0.0076	0.0042	0.0021	0.0021	0.0014	0.0000	0.0000
H4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0028	0.0007	0.0014	0.0053	0.0014	0.0000	0.0014	0.0000	0.0000
H5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0007	0.0000	0.0021	0.0021	0.0000	0.0000	0.0000	0.0000
H6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0014	0.0000	0.0000	0.0000
H7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H9	0.0000	0.0014	0.0000	0.0000	0.0007	0.0007	0.0007	0.0007	0.0014	0.0028	0.0021	0.0028	0.0035	0.0007	0.0007	0.0007	0.0000	0.0000

STABILITY CLASS 4

W1	0.0028	0.0000	0.0007	0.0000	0.0000	0.0007	0.0000	0.0000	0.0007	0.0048	0.0007	0.0042	0.0055	0.0028	0.0000	0.0000	0.0000	0.0000
W2	0.0021	0.0007	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0042	0.0083	0.0042	0.0083	0.0069	0.0021	0.0021	0.0014	0.0000	0.0000
W3	0.0014	0.0000	0.0007	0.0007	0.0007	0.0000	0.0000	0.0007	0.0007	0.0028	0.0083	0.0083	0.0118	0.0131	0.0014	0.0014	0.0000	0.0000
W4	0.0007	0.0021	0.0007	0.0000	0.0014	0.0000	0.0000	0.0000	0.0014	0.0055	0.0062	0.0069	0.0187	0.0201	0.0000	0.0000	0.0000	0.0000
W5	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0000	0.0035	0.0256	0.0284	0.0055	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0035	0.0111	0.0215	0.0083	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0028	0.0131	0.0076	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0048	0.0014	0.0000	0.0000	0.0000
W9	0.0028	0.0000	0.0007	0.0000	0.0000	0.0007	0.0000	0.0000	0.0007	0.0048	0.0007	0.0042	0.0055	0.0028	0.0000	0.0000	0.0000	0.0000

STABILITY CLASS 5

M1	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0014	0.0035	0.0000	0.0048	0.0014	0.0000	0.0000	0.0014	0.0000	0.0000
M2	0.0007	0.0007	0.0000	0.0000	0.0007	0.0000	0.0000	0.0028	0.0042	0.0028	0.0035	0.0007	0.0035	0.0042	0.0000	0.0021	0.0000	0.0000
M3	0.0014	0.0007	0.0000	0.0007	0.0000	0.0000	0.0000	0.0014	0.0014	0.0055	0.0069	0.0048	0.0062	0.0028	0.0035	0.0000	0.0000	0.0000
M4	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0028	0.0055	0.0062	0.0138	0.0069	0.0021	0.0000	0.0000	0.0000
M5	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0007	0.0014	0.0076	0.0069	0.0021	0.0000	0.0000	0.0000
M6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0000	0.0062	0.0125	0.0014	0.0000	0.0000	0.0000
M7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0028	0.0014	0.0000	0.0000	0.0000
M8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000
M9	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0014	0.0035	0.0000	0.0048	0.0014	0.0000	0.0000	0.0014	0.0000	0.0000

STABILITY CLASS 6

W1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0014	0.0014	0.0000	0.0028	0.0048	0.0007	0.0000	0.0007	0.0000	0.0000
W2	0.0014	0.0007	0.0014	0.0000	0.0000	0.0000	0.0000	0.0007	0.0021	0.0042	0.0048	0.0076	0.0083	0.0042	0.0014	0.0014	0.0000	0.0000
W3	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0069	0.0048	0.0028	0.0055	0.0042	0.0014	0.0000	0.0000	0.0000
W4	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0042	0.0014	0.0035	0.0042	0.0021	0.0007	0.0000	0.0000
W5	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0007	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0014	0.0014	0.0000	0.0028	0.0048	0.0007	0.0000	0.0007	0.0000	0.0000

STABILITY CLASS 7

W1	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0007	0.0007	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000
W2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0007	0.0021	0.0028	0.0000	0.0021	0.0035	0.0007	0.0000	0.0000	0.0000	0.0000
W3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0028	0.0014	0.0014	0.0035	0.0007	0.0021	0.0014	0.0000	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0048	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0007	0.0007	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000

(June)

RELEASE HEIGHT: 89 M TOTAL # OF HOURS: 1399

OF LOW SPEED CLASS ONE WINDS: 149
 WIND SPEED CLASS 1
 # OF OCCURRENCES 149 345 337 301 149 83 28 7

WIND DIRECTION (16 SECTORS + CALM + VARIABLE)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSH	SW	WSW	W	WNW	NW	NNW	CH	VM
WIND DIR OCCURRENCE	28.	16.	11.	10.	12.	12.	14.	33.	112.	249.	219.	160.	251.	181.	53.	38.	0.	0.
WIND ROSE	0.020	0.011	0.008	0.007	0.009	0.009	0.010	0.024	0.080	0.178	0.157	0.114	0.179	0.129	0.038	0.027	0.000	0.000
LOW SPD WIND ROSE	0.020	0.000	0.020	0.040	0.034	0.040	0.013	0.060	0.121	0.121	0.121	0.168	0.121	0.020	0.060	0.040	0.000	0.000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED AND WIND DIRECTION

W1	0.0021	0.0000	0.0021	0.0043	0.0036	0.0043	0.0014	0.0064	0.0129	0.0129	0.0129	0.0179	0.0129	0.0021	0.0064	0.0043	0.0000	0.0000
W2	0.0057	0.0057	0.0036	0.0014	0.0029	0.0021	0.0043	0.0100	0.0336	0.0400	0.0336	0.0329	0.0293	0.0193	0.0100	0.0122	0.0000	0.0000
W3	0.0100	0.0029	0.0000	0.0007	0.0021	0.0007	0.0043	0.0036	0.0136	0.0543	0.0500	0.0257	0.0407	0.0143	0.0086	0.0093	0.0000	0.0000
W4	0.0014	0.0014	0.0014	0.0000	0.0000	0.0007	0.0000	0.0036	0.0164	0.0443	0.0400	0.0229	0.0479	0.0279	0.0057	0.0014	0.0000	0.0000
W5	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0157	0.0143	0.0107	0.0279	0.0322	0.0021	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0014	0.0086	0.0029	0.0036	0.0157	0.0229	0.0036	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0029	0.0000	0.0043	0.0093	0.0014	0.0000	0.0000	0.0000
W8	0.0000	0.0007	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0007	0.0007	0.0014	0.0000	0.0000	0.0000	0.0000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED, WIND DIRECTION AND STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSH	SW	WSW	W	WNW	NW	NNW	CALM	VAR
STABILITY CLASS 1																		
W1	0.0014	0.0000	0.0007	0.0014	0.0000	0.0007	0.0000	0.0000	0.0014	0.0014	0.0021	0.0000	0.0014	0.0007	0.0007	0.0029	0.0000	0.0000
W2	0.0000	0.0007	0.0007	0.0000	0.0000	0.0000	0.0014	0.0007	0.0057	0.0064	0.0071	0.0093	0.0050	0.0021	0.0007	0.0036	0.0000	0.0000
W3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0100	0.0071	0.0043	0.0021	0.0029	0.0007	0.0007	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0029	0.0093	0.0079	0.0050	0.0021	0.0036	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0029	0.0029	0.0007	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0007	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0014	0.0000	0.0007	0.0014	0.0000	0.0007	0.0000	0.0000	0.0014	0.0014	0.0021	0.0000	0.0014	0.0007	0.0007	0.0029	0.0000	0.0000
STABILITY CLASS 2																		
W1	0.0000	0.0000	0.0014	0.0014	0.0021	0.0000	0.0000	0.0014	0.0021	0.0029	0.0014	0.0014	0.0029	0.0000	0.0029	0.0000	0.0000	0.0000
W2	0.0043	0.0036	0.0021	0.0007	0.0007	0.0000	0.0021	0.0036	0.0136	0.0093	0.0064	0.0057	0.0079	0.0086	0.0036	0.0057	0.0000	0.0000
W3	0.0057	0.0007	0.0000	0.0000	0.0007	0.0007	0.0007	0.0014	0.0021	0.0114	0.0071	0.0036	0.0043	0.0043	0.0014	0.0014	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0014	0.0093	0.0057	0.0014	0.0007	0.0021	0.0000	0.0007	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0036	0.0007	0.0021	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0000	0.0000	0.0014	0.0014	0.0021	0.0000	0.0000	0.0014	0.0021	0.0029	0.0014	0.0014	0.0029	0.0000	0.0029	0.0000	0.0000	0.0000
STABILITY CLASS 3																		
W1	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0021	0.0029	0.0007	0.0036	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W2	0.0000	0.0007	0.0000	0.0000	0.0021	0.0007	0.0007	0.0021	0.0043	0.0029	0.0057	0.0029	0.0021	0.0000	0.0021	0.0000	0.0000	0.0000

(June)

H3	0.0021	0.0014	0.0000	0.0000	0.0007	0.0000	0.0021	0.0007	0.0021	0.0043	0.0050	0.0014	0.0043	0.0007	0.0014	0.0014	0.0000	0.0000
H4	0.0007	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0036	0.0057	0.0036	0.0014	0.0021	0.0029	0.0000	0.0000	0.0000	0.0000
H5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0029	0.0014	0.0014	0.0000	0.0007	0.0007	0.0000	0.0000	0.0000
H6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0014	0.0007	0.0000	0.0000	0.0000
H7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H9	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0021	0.0029	0.0007	0.0036	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000

STABILITY CLASS 4

M1	0.0000	0.0000	0.0000	0.0000	0.0007	0.0014	0.0000	0.0021	0.0043	0.0029	0.0064	0.0064	0.0036	0.0000	0.0007	0.0014	0.0000	0.0000
M2	0.0014	0.0000	0.0007	0.0007	0.0000	0.0000	0.0000	0.0029	0.0057	0.0122	0.0086	0.0057	0.0100	0.0043	0.0021	0.0021	0.0000	0.0000
M3	0.0014	0.0007	0.0000	0.0007	0.0000	0.0000	0.0014	0.0007	0.0043	0.0157	0.0186	0.0086	0.0129	0.0021	0.0021	0.0029	0.0000	0.0000
M4	0.0007	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0014	0.0079	0.0143	0.0157	0.0107	0.0236	0.0107	0.0036	0.0007	0.0000	0.0000
M5	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0057	0.0093	0.0057	0.0172	0.0193	0.0014	0.0000	0.0000	0.0000
M6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0007	0.0064	0.0014	0.0021	0.0100	0.0164	0.0021	0.0000	0.0000	0.0000
M7	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0029	0.0000	0.0029	0.0079	0.0014	0.0000	0.0000	0.0000
M8	0.0000	0.0007	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000
M9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0014	0.0000	0.0021	0.0043	0.0029	0.0064	0.0036	0.0000	0.0007	0.0014	0.0000	0.0000

STABILITY CLASS 5

H1	0.0000	0.0000	0.0000	0.0007	0.0007	0.0014	0.0007	0.0007	0.0014	0.0021	0.0007	0.0050	0.0014	0.0007	0.0000	0.0000	0.0000	0.0000
H2	0.0000	0.0007	0.0000	0.0000	0.0000	0.0014	0.0000	0.0007	0.0036	0.0036	0.0014	0.0043	0.0021	0.0021	0.0014	0.0007	0.0000	0.0000
H3	0.0007	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0007	0.0029	0.0064	0.0064	0.0036	0.0086	0.0021	0.0014	0.0029	0.0000	0.0000
H4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0029	0.0050	0.0036	0.0172	0.0071	0.0021	0.0000	0.0000	0.0000
H5	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0093	0.0107	0.0000	0.0000	0.0000	0.0000
H6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0014	0.0029	0.0043	0.0000	0.0000	0.0000	0.0000
H7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000
H8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000
H9	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0014	0.0007	0.0007	0.0014	0.0021	0.0007	0.0050	0.0014	0.0007	0.0000	0.0000	0.0000

STABILITY CLASS 6

M1	0.0000	0.0000	0.0000	0.0007	0.0000	0.0007	0.0000	0.0007	0.0000	0.0007	0.0014	0.0000	0.0007	0.0007	0.0014	0.0000	0.0000	0.0000
M2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0029	0.0029	0.0043	0.0014	0.0007	0.0000	0.0000	0.0000	0.0000
M3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0029	0.0050	0.0021	0.0079	0.0014	0.0007	0.0000	0.0000	0.0000
M4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0021	0.0014	0.0007	0.0014	0.0007	0.0000	0.0000	0.0000	0.0000
M5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000
M6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000
M7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M9	0.0000	0.0000	0.0000	0.0007	0.0000	0.0007	0.0000	0.0007	0.0000	0.0007	0.0014	0.0000	0.0007	0.0007	0.0014	0.0000	0.0000	0.0000

STABILITY CLASS 7

M1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0014	0.0000	0.0000	0.0014	0.0014	0.0000	0.0007	0.0000	0.0000	0.0000
M2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0029	0.0014	0.0007	0.0007	0.0014	0.0000	0.0000	0.0000	0.0000
M3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0036	0.0007	0.0021	0.0007	0.0007	0.0007	0.0000	0.0000	0.0000
M4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0007	0.0000	0.0007	0.0007	0.0007	0.0000	0.0000	0.0000
M5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000
M6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0014	0.0000	0.0000	0.0014	0.0014	0.0000	0.0007	0.0000	0.0000	0.0000

(July)

RELEASE HEIGHT: 89 M TOTAL # OF HOURS: 1450

OF LOW SPEED CLASS ONE WINDS: 160
 WIND SPEED CLASS 1 2 3 4 5 6 7 8
 # OF OCCURRENCES 160 330 391 273 170 93 24 9

WIND DIRECTION (16 SECTORS + CALM + VARIABLE)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CM	VR
WIND DIR OCCURRENCE	37.	17.	17.	11.	24.	11.	10.	20.	64.	165.	193.	166.	260.	266.	113.	76.	0.	0.
WIND ROSE	0.026	0.012	0.012	0.008	0.017	0.008	0.007	0.014	0.044	0.114	0.133	0.114	0.179	0.183	0.078	0.052	0.000	0.000
LOW SPD WIND ROSE	0.031	0.006	0.025	0.031	0.050	0.025	0.025	0.019	0.081	0.106	0.106	0.106	0.181	0.075	0.087	0.044	0.000	0.000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED AND WIND DIRECTION

W1	0.0034	0.0007	0.0028	0.0034	0.0055	0.0028	0.0028	0.0021	0.0090	0.0117	0.0117	0.0117	0.0200	0.0083	0.0097	0.0048	0.0000	0.0000
W2	0.0103	0.0069	0.0021	0.0028	0.0069	0.0021	0.0034	0.0083	0.0179	0.0290	0.0345	0.0234	0.0352	0.0214	0.0110	0.0124	0.0000	0.0000
W3	0.0090	0.0021	0.0021	0.0000	0.0034	0.0028	0.0007	0.0034	0.0076	0.0393	0.0462	0.0324	0.0317	0.0386	0.0262	0.0241	0.0000	0.0000
W4	0.0028	0.0021	0.0041	0.0000	0.0007	0.0000	0.0000	0.0000	0.0035	0.0234	0.0214	0.0269	0.0517	0.0324	0.0097	0.0076	0.0000	0.0000
W5	0.0000	0.0000	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0028	0.0083	0.0131	0.0159	0.0276	0.0366	0.0083	0.0034	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0014	0.0014	0.0034	0.0028	0.0103	0.0366	0.0076	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0014	0.0000	0.0028	0.0083	0.0034	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0014	0.0000	0.0014	0.0021	0.0000	0.0000	0.0000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED, WIND DIRECTION AND STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	VAR
STABILITY CLASS 1																		
W1	0.0007	0.0007	0.0014	0.0007	0.0014	0.0000	0.0000	0.0000	0.0021	0.0007	0.0007	0.0007	0.0021	0.0014	0.0028	0.0021	0.0000	0.0000
W2	0.0048	0.0028	0.0007	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0021	0.0062	0.0028	0.0034	0.0034	0.0021	0.0028	0.0000	0.0000
W3	0.0034	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0062	0.0076	0.0083	0.0062	0.0007	0.0069	0.0000	0.0000
W4	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0034	0.0007	0.0028	0.0090	0.0014	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0041	0.0028	0.0000	0.0007	0.0014	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0007	0.0007	0.0014	0.0007	0.0014	0.0000	0.0000	0.0000	0.0021	0.0007	0.0007	0.0007	0.0021	0.0014	0.0028	0.0021	0.0000	0.0000
STABILITY CLASS 2																		
W1	0.0021	0.0000	0.0000	0.0007	0.0014	0.0007	0.0014	0.0007	0.0014	0.0021	0.0021	0.0021	0.0069	0.0028	0.0034	0.0007	0.0000	0.0000
W2	0.0007	0.0014	0.0007	0.0007	0.0041	0.0014	0.0014	0.0028	0.0055	0.0076	0.0117	0.0062	0.0083	0.0021	0.0034	0.0028	0.0000	0.0000
W3	0.0021	0.0007	0.0007	0.0000	0.0028	0.0014	0.0000	0.0014	0.0021	0.0131	0.0083	0.0041	0.0021	0.0034	0.0028	0.0062	0.0000	0.0000
W4	0.0014	0.0014	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0069	0.0055	0.0048	0.0034	0.0007	0.0007	0.0021	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0021	0.0007	0.0007	0.0007	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0021	0.0000	0.0000	0.0007	0.0014	0.0007	0.0014	0.0007	0.0014	0.0021	0.0021	0.0021	0.0069	0.0028	0.0034	0.0007	0.0000	0.0000
STABILITY CLASS 3																		
W1	0.0007	0.0000	0.0000	0.0007	0.0000	0.0007	0.0007	0.0000	0.0014	0.0028	0.0021	0.0014	0.0021	0.0014	0.0007	0.0014	0.0000	0.0000
W2	0.0014	0.0021	0.0000	0.0007	0.0014	0.0007	0.0007	0.0014	0.0034	0.0041	0.0021	0.0021	0.0055	0.0048	0.0021	0.0014	0.0000	0.0000

(July)

M3	0.0007	0.0000	0.0007	0.0000	0.0007	0.0007	0.0000	0.0007	0.0014	0.0062	0.0034	0.0062	0.0041	0.0034	0.0028	0.0034	0.0000	0.0000
M4	0.0000	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0034	0.0021	0.0034	0.0028	0.0014	0.0014	0.0014	0.0000	0.0000
M5	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0014	0.0007	0.0014	0.0000	0.0000
M6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000
M7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0000	0.0000
M8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M9	0.0007	0.0000	0.0000	0.0007	0.0000	0.0007	0.0007	0.0000	0.0014	0.0028	0.0021	0.0014	0.0021	0.0014	0.0007	0.0014	0.0000	0.0000

STABILITY CLASS 4

W1	0.0000	0.0000	0.0014	0.0000	0.0014	0.0007	0.0000	0.0000	0.0028	0.0028	0.0034	0.0048	0.0055	0.0014	0.0021	0.0007	0.0000	0.0000
W2	0.0014	0.0000	0.0007	0.0014	0.0000	0.0000	0.0007	0.0014	0.0034	0.0117	0.0055	0.0041	0.0083	0.0034	0.0014	0.0028	0.0000	0.0000
W3	0.0028	0.0014	0.0007	0.0000	0.0000	0.0000	0.0007	0.0000	0.0007	0.0090	0.0179	0.0055	0.0097	0.0076	0.0048	0.0041	0.0000	0.0000
W4	0.0007	0.0007	0.0021	0.0000	0.0007	0.0000	0.0000	0.0000	0.0034	0.0069	0.0097	0.0097	0.0193	0.0124	0.0034	0.0028	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0034	0.0048	0.0076	0.0152	0.0145	0.0055	0.0014	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0021	0.0014	0.0076	0.0297	0.0076	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0000	0.0028	0.0062	0.0021	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0014	0.0000	0.0014	0.0021	0.0000	0.0000	0.0000
W9	0.0000	0.0000	0.0014	0.0000	0.0014	0.0007	0.0000	0.0000	0.0028	0.0028	0.0034	0.0048	0.0055	0.0014	0.0021	0.0007	0.0000	0.0000

STABILITY CLASS 5

M1	0.00000	0.00000	0.00000	0.00000	0.0014	0.00000	0.00000	0.0007	0.00000	0.0028	0.0007	0.0007	0.0014	0.0007	0.0007	0.00000	0.00000	0.00000
M2	0.0014	0.0007	0.00000	0.00000	0.00000	0.00000	0.00000	0.0014	0.0048	0.0014	0.0062	0.0055	0.0034	0.0034	0.0007	0.0014	0.00000	0.00000
M3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.0014	0.0021	0.0090	0.0076	0.0062	0.0062	0.0048	0.0069	0.0021	0.00000	0.00000
M4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.0007	0.0021	0.0007	0.0055	0.0124	0.0076	0.0034	0.0007	0.00000	0.00000
M5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.0014	0.0028	0.0007	0.0028	0.0090	0.0159	0.00000	0.00000	0.00000	0.00000
M6	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.0014	0.00000	0.0007	0.0007	0.0021	0.0062	0.00000	0.00000	0.00000	0.00000
M7	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.0021	0.00000	0.00000	0.00000	0.00000
M8	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
M9	0.00000	0.00000	0.00000	0.00000	0.0014	0.00000	0.00000	0.0007	0.00000	0.0028	0.0007	0.0007	0.0014	0.0007	0.0007	0.00000	0.00000	0.00000

STABILITY CLASS 6

M1	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0007	0.0007	0.0014	0.0007	0.0021	0.0021	0.0021	0.0007	0.0000	0.0000	0.0000	0.0000
M2	0.0007	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0014	0.0007	0.0021	0.0007	0.0021	0.0033	0.0034	0.0014	0.0014	0.0000	0.0000
M3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0014	0.0007	0.0028	0.0028	0.0007	0.0076	0.0062	0.0007	0.0000	0.0000
M4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0007	0.0007	0.0007	0.0034	0.0055	0.0007	0.0007	0.0000	0.0000
M5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0007	0.0028	0.0000	0.0007	0.0000	0.0000
M6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000
M7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M9	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0007	0.0007	0.0014	0.0007	0.0021	0.0021	0.0021	0.0007	0.0000	0.0000	0.0000	0.0000

STABILITY CLASS 7

H1	0.0000	0.0000	0.0000	0.0007	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0021	0.0007	0.0007	0.0007	0.0000	0.0000	0.0000
H3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0055	0.0021	0.0007	0.0000
H4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0014	0.0034	0.0000	0.0000	0.0000
H5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0000	0.0014	0.0007	0.0000	0.0000	0.0000
H6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H9	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0007	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

(August)

RELEASE HEIGHT: 89 M TOTAL # OF HOURS: 1448

OF LOW SPEED CLASS ONE WINDS: 221
 WIND SPEED CLASS 1 2 3 4 5 6 7 8
 # OF OCCURRENCES 221 379 393 289 113 42 10 1

WIND DIRECTION (16 SECTORS + CALM + VARIABLE)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CM	VR
WIND DIR OCCUPANCE	16.	11.	5.	4.	11.	15.	12.	32.	112.	253.	229.	170.	249.	211.	83.	35.	0.	0.
WIND ROSE	0.011	0.008	0.003	0.003	0.008	0.010	0.008	0.022	0.077	0.175	0.158	0.117	0.172	0.146	0.057	0.024	0.000	0.000
LOW SPD WIND ROSE	0.018	0.036	0.014	0.009	0.032	0.032	0.014	0.068	0.104	0.140	0.149	0.127	0.176	0.032	0.032	0.018	0.000	0.000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED AND WIND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CM	VR
W1 0.0028 0.0055 0.0021 0.0014 0.0048 0.0048 0.0021 0.0104 0.0159 0.0214 0.0228 0.0193 0.0269 0.0048 0.0048 0.0028 0.0000 0.0000																		
W2 0.0041 0.0014 0.0014 0.0014 0.0021 0.0048 0.0048 0.0097 0.0269 0.0511 0.0380 0.0359 0.0331 0.0221 0.0193 0.0055 0.0000 0.0000																		
W3 0.0028 0.0000 0.0000 0.0000 0.0007 0.0007 0.0014 0.0021 0.0221 0.0573 0.0587 0.0256 0.0407 0.0331 0.0152 0.0110 0.0000 0.0000																		
W4 0.0014 0.0007 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0083 0.0394 0.0304 0.0318 0.0428 0.0311 0.0090 0.0048 0.0000 0.0000																		
W5 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0041 0.0041 0.0062 0.0041 0.0242 0.0345 0.0007 0.0000 0.0000 0.0000																		
W6 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0014 0.0021 0.0007 0.0041 0.0159 0.0048 0.0000 0.0000 0.0000																		
W7 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0035 0.0035 0.0000 0.0000 0.0000																		
W8 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0007 0.0000 0.0000 0.0000 0.0000																		

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED, WIND DIRECTION AND STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	VAR
STABILITY CLASS 1																		
W1 0.0000 0.0000 0.0000 0.0000 0.0007 0.0007 0.0000 0.0014 0.0021 0.0055 0.0041 0.0041 0.0069 0.0021 0.0014 0.0014 0.0000 0.0000																		
W2 0.0000 0.0000 0.0000 0.0000 0.0007 0.0007 0.0014 0.0021 0.0041 0.0055 0.0041 0.0048 0.0014 0.0041 0.0028 0.0000 0.0000 0.0000																		
W3 0.0000 0.0000 0.0000 0.0000 0.0000 0.0007 0.0000 0.0000 0.0021 0.0048 0.0041 0.0014 0.0014 0.0028 0.0007 0.0000 0.0000 0.0000																		
W4 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0014 0.0028 0.0041 0.0028 0.0014 0.0007 0.0000 0.0000 0.0000 0.0000																		
W5 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0007 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000																		
W6 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0014 0.0014 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000																		
W7 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000																		
W8 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000																		
W9 0.0000 0.0000 0.0000 0.0000 0.0007 0.0007 0.0000 0.0014 0.0021 0.0055 0.0041 0.0041 0.0069 0.0021 0.0014 0.0014 0.0000 0.0000																		
STABILITY CLASS 2																		
W1 0.0007 0.0021 0.0007 0.0000 0.0014 0.0007 0.0000 0.0035 0.0035 0.0021 0.0048 0.0048 0.0041 0.0014 0.0014 0.0007 0.0000 0.0000																		
W2 0.0035 0.0007 0.0000 0.0000 0.0014 0.0007 0.0000 0.0014 0.0021 0.0131 0.0117 0.0055 0.0076 0.0069 0.0069 0.0021 0.0000 0.0000																		
W3 0.0021 0.0000 0.0000 0.0000 0.0007 0.0000 0.0000 0.0000 0.0023 0.0110 0.0090 0.0048 0.0014 0.0035 0.0021 0.0076 0.0000 0.0000																		
W4 0.0014 0.0007 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0124 0.0076 0.0021 0.0007 0.0014 0.0007 0.0021 0.0000 0.0000																		
W5 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0007 0.0014 0.0021 0.0000 0.0014 0.0000 0.0000 0.0000 0.0000 0.0000																		
W6 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000																		
W7 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000																		
W8 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000																		
W9 0.0007 0.0021 0.0007 0.0000 0.0014 0.0007 0.0000 0.0035 0.0035 0.0021 0.0048 0.0048 0.0041 0.0014 0.0014 0.0007 0.0000 0.0000																		
STABILITY CLASS 3																		
W1 0.0000 0.0007 0.0007 0.0007 0.0014 0.0000 0.0000 0.0000 0.0021 0.0014 0.0035 0.0028 0.0028 0.0000 0.0014 0.0000 0.0000 0.0000																		
W2 0.0007 0.0000 0.0000 0.0007 0.0000 0.0014 0.0007 0.0007 0.0035 0.0069 0.0041 0.0048 0.0035 0.0007 0.0007 0.0000 0.0000 0.0000																		

(September)

RELEASE HEIGHT: 89 M TOTAL # OF HOURS: 1400

OF LOW SPEED CLASS ONE WINDS: 132
WIND SPEED CLASS 1 2 3 4 5 6 7 8
OF OCCURRENCES 132 319 407 295 134 86 23 4

WIND DIRECTION (16 SECTIONS + CALM + VARIABLE)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	VAR
WIND DIR OCCURRENCE	59.	19.	19.	5.	5.	5.	13.	14.	77.	161.	178.	113.	240.	271.	135.	86.	0.	0.
WIND ROSE	0.042	0.014	0.014	0.004	0.004	0.004	0.009	0.010	0.055	0.115	0.127	0.081	0.171	0.194	0.096	0.061	0.000	0.000
LOW SPD WIND ROSE	0.083	0.023	0.030	0.015	0.023	0.008	0.061	0.030	0.136	0.068	0.098	0.098	0.129	0.091	0.061	0.045	0.000	0.000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED AND WIND DIRECTION

W1	0.0079	0.0021	0.0029	0.0014	0.0021	0.0007	0.0057	0.0029	0.0129	0.0064	0.0093	0.0093	0.0121	0.0086	0.0057	0.0043	0.0000	0.0000
W2	0.0121	0.0029	0.0021	0.0007	0.0007	0.0021	0.0014	0.0064	0.0179	0.0221	0.0400	0.0200	0.0357	0.0250	0.0229	0.0157	0.0000	0.0000
W3	0.0150	0.0021	0.0014	0.0007	0.0007	0.0007	0.0014	0.0000	0.0171	0.0464	0.0357	0.0293	0.0471	0.0379	0.0264	0.0286	0.0000	0.0000
W4	0.0050	0.0043	0.0050	0.0007	0.0000	0.0000	0.0000	0.0007	0.0050	0.0271	0.0271	0.0129	0.0421	0.0507	0.0214	0.0086	0.0000	0.0000
W5	0.0021	0.0021	0.0021	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0079	0.0086	0.0057	0.0221	0.0321	0.0086	0.0021	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0036	0.0057	0.0029	0.0100	0.0300	0.0071	0.0021	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0014	0.0007	0.0007	0.0021	0.0079	0.0029	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0014	0.0000	0.0000	0.0000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED, WIND DIRECTION AND STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	VAR
STABILITY CLASS 1																		
W1	0.0014	0.0000	0.0000	0.0007	0.0000	0.0000	0.0007	0.0007	0.0007	0.0014	0.0014	0.0000	0.0007	0.0007	0.0007	0.0000	0.0000	0.0000
W2	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0014	0.0050	0.0021	0.0007	0.0036	0.0014	0.0029	0.0000	0.0000
W3	0.0029	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0086	0.0036	0.0014	0.0064	0.0021	0.0043	0.0036	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0007	0.0007	0.0014	0.0043	0.0014	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0021	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0014	0.0000	0.0000	0.0007	0.0000	0.0000	0.0007	0.0007	0.0007	0.0014	0.0014	0.0000	0.0007	0.0007	0.0007	0.0000	0.0000	0.0000

STABILITY CLASS 2

W1	0.0021	0.0000	0.0007	0.0007	0.0000	0.0000	0.0000	0.0007	0.0014	0.0007	0.0014	0.0014	0.0007	0.0021	0.0043	0.0007	0.0000	0.0000
W2	0.0029	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0057	0.0071	0.0043	0.0029	0.0029	0.0057	0.0064	0.0000	0.0000
W3	0.0014	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0036	0.0064	0.0021	0.0029	0.0021	0.0021	0.0029	0.0093	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0043	0.0021	0.0007	0.0007	0.0007	0.0007	0.0014	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0007	0.0000	0.0007	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0021	0.0000	0.0007	0.0007	0.0000	0.0000	0.0000	0.0007	0.0014	0.0007	0.0014	0.0014	0.0007	0.0021	0.0043	0.0007	0.0000	0.0000

STABILITY CLASS 3

W1	0.0014	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0000	0.0007	0.0007	0.0007	0.0014	0.0000	0.0007	0.0000	0.0000
W2	0.0036	0.0000	0.0007	0.0007	0.0000	0.0000	0.0000	0.0007	0.0043	0.0021	0.0036	0.0014	0.0029	0.0021	0.0050	0.0043	0.0000	0.0000

(October)

RELEASE HEIGHT: 89 M TOTAL # OF HOURS: 1428

OF LOW SPEED CLASS ONE WINDS: 264

WIND SPEED CLASS

OF OCCURRENCES

1	2	3	4	5	6	7	8
264	415	298	225	129	6A	22	7

WIND DIRECTION (16 SECTORS + CALM + VARIABLE)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	VR
WIND DIR OCCURRENCE	7.	2.	2.	2.	4.	6.	6.	22.	105.	151.	258.	238.	346.	215.	53.	11.	0.	0.
WIND ROSE	0.005	0.001	0.001	0.001	0.003	0.004	0.004	0.015	0.074	0.106	0.181	0.167	0.242	0.151	0.037	0.008	0.000	0.000
LOW SPD WIND ROSE	0.004	0.004	0.004	0.008	0.011	0.011	0.011	0.042	0.114	0.083	0.178	0.208	0.223	0.080	0.011	0.008	0.000	0.000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED AND WIND DIRECTION

W1	0.0007	0.0007	0.0007	0.0014	0.0021	0.0021	0.0021	0.0077	0.0210	0.0154	0.0329	0.0385	0.0413	0.0147	0.0021	0.0014	0.0000	0.0000
W2	0.0021	0.0007	0.0007	0.0000	0.0007	0.0021	0.0021	0.0049	0.0287	0.0245	0.0490	0.0476	0.0721	0.0406	0.0105	0.0042	0.0000	0.0000
W3	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0105	0.0301	0.0406	0.0273	0.0525	0.0350	0.0070	0.0021	0.0000	0.0000
W4	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0056	0.0196	0.0343	0.0238	0.0378	0.0273	0.0077	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0028	0.0126	0.0091	0.0140	0.0252	0.0210	0.0056	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0042	0.0035	0.0084	0.0105	0.0084	0.0098	0.0028	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0035	0.0042	0.0042	0.0021	0.0014	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0028	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED, WIND DIRECTION AND STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	VAR
STABILITY CLASS 1																		
W1	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0021	0.0007	0.0000	0.0000	0.0000	0.0000
W2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0049	0.0014	0.0021	0.0049	0.0021	0.0007	0.0000	0.0000
W3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0035	0.0021	0.0021	0.0014	0.0007	0.0000	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0014	0.0007	0.0014	0.0014	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0021	0.0007	0.0000	0.0000	0.0000	0.0000
STABILITY CLASS 2																		
W1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0000	0.0035	0.0028	0.0021	0.0000	0.0007	0.0000	0.0000	0.0000
W2	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0028	0.0063	0.0028	0.0042	0.0021	0.0007	0.0000	0.0000	0.0000
W3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0025	0.0014	0.0021	0.0028	0.0000	0.0000	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0000	0.0035	0.0028	0.0021	0.0000	0.0007	0.0000	0.0000	0.0000
STABILITY CLASS 3																		
W1	0.0000	0.0000	0.0007	0.0000	0.0007	0.0007	0.0000	0.0007	0.0021	0.0042	0.0049	0.0091	0.0119	0.0063	0.0000	0.0000	0.0000	0.0000
W2	0.0007	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0007	0.0035	0.0021	0.0070	0.0105	0.0133	0.0077	0.0042	0.0021	0.0000	0.0000

(October)

M3	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0014	0.0049	0.0035	0.0028	0.0035	0.0028	0.0021	0.0000	0.0000
M4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0028	0.0035	0.0014	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000
M5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0007	0.0007	0.0021	0.0000	0.0000	0.0000	0.0000	0.0000
M6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000
M7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M9	0.0000	0.0000	0.0007	0.0000	0.0007	0.0007	0.0000	0.0007	0.0021	0.0042	0.0049	0.0091	0.0119	0.0063	0.0000	0.0000	0.0000	0.0000

STABILITY CLASS 4

M1	0.0000	0.0007	0.0000	0.0000	0.0007	0.0000	0.0014	0.0028	0.0070	0.0042	0.0119	0.0105	0.0091	0.0014	0.0007	0.0000	0.0000	0.0000
M2	0.0007	0.0000	0.0000	0.0000	0.0000	0.0007	0.0014	0.0014	0.0070	0.0098	0.0147	0.0175	0.0182	0.0112	0.0021	0.0014	0.0000	0.0000
M3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0028	0.0091	0.0133	0.0063	0.0154	0.0105	0.0007	0.0000	0.0000	0.0000
M4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0063	0.0140	0.0084	0.0175	0.0119	0.0014	0.0000	0.0000	0.0000
M5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0084	0.0042	0.0063	0.0105	0.0091	0.0021	0.0000	0.0000	0.0000
M6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0028	0.0007	0.0063	0.0049	0.0021	0.0049	0.0000	0.0000	0.0000	0.0000
M7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0028	0.0028	0.0007	0.0014	0.0000	0.0000	0.0000
M8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000
M9	0.0000	0.0007	0.0000	0.0000	0.0007	0.0000	0.0014	0.0028	0.0070	0.0042	0.0119	0.0105	0.0091	0.0014	0.0007	0.0000	0.0000	0.0000

STABILITY CLASS 5

M1	0.0000	0.0000	0.0000	0.0007	0.0000	0.0007	0.0000	0.0007	0.0028	0.0014	0.0028	0.0049	0.0049	0.0014	0.0000	0.0007	0.0000	0.0000
M2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0042	0.0035	0.0042	0.0035	0.0091	0.0042	0.0000	0.0000	0.0000	0.0000
M3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0014	0.0105	0.0077	0.0049	0.0105	0.0049	0.0021	0.0000	0.0000	0.0000
M4	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0042	0.0077	0.0063	0.0105	0.0063	0.0028	0.0000	0.0000	0.0000
M5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0035	0.0007	0.0035	0.0098	0.0056	0.0021	0.0000	0.0000	0.0000
M6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0014	0.0014	0.0028	0.0021	0.0014	0.0000	0.0000	0.0000
M7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000
M8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M9	0.0000	0.0000	0.0000	0.0007	0.0000	0.0007	0.0000	0.0007	0.0028	0.0014	0.0028	0.0049	0.0049	0.0014	0.0000	0.0007	0.0000	0.0000

STABILITY CLASS 6

M1	0.0000	0.0000	0.0000	0.0007	0.0007	0.0007	0.0007	0.0007	0.0028	0.0035	0.0049	0.0077	0.0091	0.0105	0.0049	0.0007	0.0007	0.0000
M2	0.0000	0.0007	0.0000	0.0000	0.0007	0.0014	0.0000	0.0014	0.0112	0.0049	0.0077	0.0091	0.0189	0.0084	0.0014	0.0000	0.0000	0.0000
M3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0042	0.0035	0.0077	0.0056	0.0189	0.0098	0.0007	0.0000	0.0000	0.0000
M4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0028	0.0042	0.0063	0.0063	0.0063	0.0014	0.0000	0.0000	0.0000
M5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0014	0.0035	0.0028	0.0028	0.0007	0.0000	0.0000
M6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0021	0.0007	0.0035	0.0028	0.0021	0.0007	0.0000	0.0000	0.0000
M7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0000	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000
M8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M9	0.0000	0.0000	0.0000	0.0007	0.0007	0.0007	0.0007	0.0007	0.0028	0.0035	0.0049	0.0077	0.0091	0.0105	0.0049	0.0007	0.0007	0.0000

STABILITY CLASS 7

M1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0042	0.0007	0.0014	0.0014	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000
M2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0014	0.0007	0.0042	0.0028	0.0063	0.0021	0.0000	0.0000	0.0000	0.0000
M3	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0021	0.0021	0.0028	0.0000	0.0021	0.0000	0.0000	0.0000	0.0000
M4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0014	0.0035	0.0007	0.0014	0.0014	0.0014	0.0000	0.0000	0.0000
M5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0021	0.0000	0.0000	0.0021	0.0000	0.0000	0.0000	0.0000
M6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0007	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000
M7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0042	0.0007	0.0014	0.0014	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000

(November)

RELEASE HEIGHT: 89 M TOTAL # OF HOURS: 1416

OF LOW SPEED CLASS ONE WINDS: 189
WIND SPEED CLASS 1
OF OCCURRENCES 189 292 305 259 175 117 50 29

WIND DIRECTION (16 SECTORS + CALM + VARIABLE)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CM	VR
WIND DIR OCCURANCE	7.	2.	1.	0.	2.	0.	6.	10.	91.	143.	218.	183.	319.	312.	94.	28.	0.	0.
WIND ROSE	0.005	0.001	0.001	0.000	0.001	0.000	0.004	0.007	0.064	0.101	0.154	0.129	0.225	0.220	0.066	0.020	0.000	0.000
LOW SPD WIND ROSE	0.016	0.011	0.005	0.000	0.005	0.000	0.016	0.016	0.085	0.111	0.132	0.153	0.323	0.095	0.021	0.011	0.000	0.000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED AND WIND DIRECTION

W1	0.0021	0.0014	0.0007	0.0000	0.0007	0.0000	0.0021	0.0021	0.0113	0.0148	0.0177	0.0205	0.0431	0.0127	0.0028	0.0014	0.0000	0.0000
W2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0021	0.0198	0.0169	0.0261	0.0261	0.0607	0.0325	0.0162	0.0042	0.0000	0.0000
W3	0.0007	0.0000	0.0000	0.0000	0.0007	0.0000	0.0007	0.0028	0.0198	0.0212	0.0177	0.0282	0.0558	0.0417	0.0194	0.0078	0.0000	0.0000
W4	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0092	0.0169	0.0162	0.0177	0.0360	0.0643	0.0184	0.0035	0.0000	0.0000
W5	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0028	0.0141	0.0155	0.0113	0.0177	0.0516	0.0064	0.0028	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0092	0.0290	0.0162	0.0106	0.0134	0.0064	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0035	0.0184	0.0064	0.0014	0.0042	0.0014	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0042	0.0134	0.0028	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED, WIND DIRECTION AND STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	VAR
STABILITY CLASS 1																		
W1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STABILITY CLASS 2																		
W1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STABILITY CLASS 3																		
W1	0.0021	0.0007	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0007	0.0000	0.0007	0.0014	0.0071	0.0028	0.0000	0.0000	0.0000	0.0000
W2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0007	0.0007	0.0021	0.0021	0.0056	0.0064	0.0071	0.0021	0.0000	0.0000

(November)

M3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0007	0.0014	0.0021	0.0021	0.0005	0.0042	0.0000	0.0000
M4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0000	0.0035	0.0014	0.0014	0.0028	0.0014	0.0000	0.0000
M5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000
M6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M9	0.0021	0.0007	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0007	0.0014	0.0071	0.0028	0.0000	0.0000	0.0000

STABILITY CLASS 4

M1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0021	0.0078	0.0042	0.0056	0.0113	0.0219	0.0078	0.0014	0.0007	0.0000	0.0000
M2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0113	0.0085	0.0134	0.0113	0.0339	0.0184	0.0056	0.0021	0.0000	0.0000
M3	0.0047	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0085	0.0106	0.0078	0.0078	0.0339	0.0261	0.0042	0.0035	0.0000	0.0000
M4	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0035	0.0035	0.0071	0.0064	0.0162	0.0360	0.0049	0.0021	0.0000	0.0000
M5	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0035	0.0071	0.0071	0.0064	0.0247	0.0042	0.0021	0.0000	0.0000
M6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0049	0.0169	0.0071	0.0056	0.0028	0.0000	0.0000	0.0000	0.0000
M7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0099	0.0042	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000
M8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0028	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0021	0.0078	0.0042	0.0056	0.0113	0.0219	0.0078	0.0014	0.0007	0.0000	0.0000

STABILITY CLASS 5

M1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0056	0.0056	0.0021	0.0092	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000
M2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0042	0.0021	0.0064	0.0078	0.0120	0.0035	0.0007	0.0000	0.0000	0.0000
M3	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0014	0.0056	0.0049	0.0042	0.0106	0.0127	0.0078	0.0021	0.0000	0.0000	0.0000
M4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0035	0.0078	0.0028	0.0064	0.0106	0.0177	0.0056	0.0000	0.0000	0.0000
M5	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0056	0.0071	0.0021	0.0071	0.0226	0.0021	0.0000	0.0000	0.0000
M6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0042	0.0092	0.0049	0.0028	0.0099	0.0021	0.0000	0.0000	0.0000
M7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0071	0.0021	0.0014	0.0028	0.0000	0.0000	0.0000	0.0000
M8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0106	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0056	0.0056	0.0021	0.0092	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000

STABILITY CLASS 6

M1	0.0000	0.0007	0.0007	0.0000	0.0000	0.0000	0.0014	0.0000	0.0014	0.0042	0.0035	0.0042	0.0049	0.0014	0.0007	0.0007	0.0000	0.0000
M2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0021	0.0042	0.0035	0.0042	0.0071	0.0028	0.0028	0.0000	0.0000	0.0000
M3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0056	0.0042	0.0028	0.0064	0.0071	0.0056	0.0028	0.0000	0.0000	0.0000
M4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0028	0.0049	0.0007	0.0078	0.0092	0.0049	0.0000	0.0000	0.0000
M5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0028	0.0014	0.0007	0.0042	0.0028	0.0000	0.0007	0.0000	0.0000
M6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0007	0.0021	0.0007	0.0007	0.0000	0.0000	0.0000
M7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0000	0.0007	0.0014	0.0000	0.0000	0.0000
M8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M9	0.0000	0.0007	0.0007	0.0000	0.0000	0.0000	0.0014	0.0000	0.0014	0.0042	0.0035	0.0042	0.0049	0.0014	0.0007	0.0007	0.0000	0.0000

STABILITY CLASS 7

M1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0021	0.0014	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000
M2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0014	0.0007	0.0007	0.0021	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000
M3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0021	0.0021	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000
M4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0014	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000
M6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0021	0.0014	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000

(December)

RELEASE HEIGHT: 89 M TOTAL # OF HOURS: 1374

OF LOW SPEED CLASS ONE WINDS: 191

WIND SPEED CLASS

OF OCCURRENCES

1

2

3

4

5

6

7

8

191

267

310

266

171

105

38

26

WIND DIRECTION (16 SECTORS + CALM + VARIABLE)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CM	VR
WIND DIR OCCURRENCE	26.	5.	0.	0.	0.	0.	1.	10.	38.	73.	132.	109.	439.	413.	97.	31.	0.	0.
WIND ROSE	0.019	0.004	0.000	0.000	0.000	0.000	0.001	0.007	0.028	0.053	0.096	0.079	0.320	0.301	0.071	0.023	0.000	0.000
LOW SPD WIND ROSE	0.010	0.010	0.000	0.000	0.000	0.000	0.000	0.026	0.042	0.068	0.089	0.115	0.476	0.120	0.031	0.010	0.000	0.000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED AND WIND DIRECTION

W1	0.0015	0.0015	0.0000	0.0000	0.0000	0.0000	0.0036	0.0058	0.0095	0.0124	0.0160	0.0662	0.0167	0.0044	0.0015	0.0000	0.0000	0.0000
W2	0.0036	0.0007	0.0000	0.0000	0.0000	0.0007	0.0015	0.0056	0.0124	0.0182	0.0226	0.0742	0.0408	0.0087	0.0044	0.0000	0.0000	0.0000
W3	0.0022	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0044	0.0066	0.0131	0.0211	0.0793	0.0728	0.0189	0.0058	0.0000	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0058	0.0080	0.0124	0.0102	0.0466	0.0822	0.0211	0.0073	0.0000	0.0000	0.0000
W5	0.0051	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0022	0.0073	0.0087	0.0066	0.0255	0.0553	0.0109	0.0029	0.0000	0.0000	0.0000
W6	0.0058	0.0007	0.0000	0.0000	0.0000	0.0007	0.0007	0.0036	0.0116	0.0116	0.0015	0.0218	0.0255	0.0036	0.0007	0.0000	0.0000	0.0000
W7	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0036	0.0080	0.0015	0.0058	0.0051	0.0015	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0022	0.0116	0.0000	0.0000	0.0022	0.0015	0.0000	0.0000	0.0000	0.0000

FREQUENCY DISTRIBUTION OF THE WIND AS A FUNCTION OF WIND SPEED, WIND DIRECTION AND STABILITY

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	VAR
STABILITY CLASS 1																		
W1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STABILITY CLASS 2																		
W1	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0007	0.0029	0.0000	0.0015	0.0015	0.0000	0.0000	0.0000	0.0000
W2	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0015	0.0000	0.0000	0.0007	0.0000	0.0007	0.0000	0.0000
W3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0007	0.0000	0.0007	0.0007	0.0007	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W9	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0007	0.0029	0.0000	0.0015	0.0015	0.0000	0.0000	0.0000	0.0000
STABILITY CLASS 3																		
W1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0029	0.0000	0.0000	0.0007	0.0000	0.0000
W2	0.0029	0.0007	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0015	0.0007	0.0007	0.0015	0.0000	0.0015	0.0007	0.0000	0.0000

(December)

N3	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0029	0.0036	0.0022	0.0000	0.0000	0.0000
N4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0015	0.0000	0.0000	0.0000
N5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0000	0.0000	0.0000	0.0000
N6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000
N7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000
N8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0022	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
N9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0029	0.0000	0.0000	0.0007	0.0000	0.0000

STABILITY CLASS 4

M1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0022	0.0015	0.0073	0.0102	0.0306	0.0073	0.0015	0.0000	0.0000	0.0000
M2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0036	0.0038	0.0080	0.0109	0.0378	0.0277	0.0022	0.0000	0.0000	0.0000
M3	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0036	0.0051	0.0029	0.0109	0.0400	0.0495	0.0124	0.0036	0.0000	0.0000
M4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0036	0.0066	0.0073	0.0044	0.0277	0.0473	0.0095	0.0073	0.0000	0.0000
M5	0.0051	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0066	0.0066	0.0022	0.0146	0.0291	0.0051	0.0029	0.0000	0.0000
M6	0.0029	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0036	0.0073	0.0007	0.0131	0.0138	0.0007	0.0000	0.0000	0.0000
M7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0036	0.0073	0.0015	0.0036	0.0022	0.0007	0.0000	0.0000	0.0000
M8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0022	0.0095	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000
M9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0022	0.0015	0.0073	0.0102	0.0306	0.0073	0.0015	0.0000	0.0000	0.0000

STABILITY CLASS 5

M1	0.00007	0.00007	0.00000	0.00000	0.00000	0.00000	0.00000	0.00007	0.00007	0.00022	0.00000	0.00022	0.0189	0.0036	0.0015	0.00000	0.00000	0.00000
M2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00015	0.00022	0.00029	0.0058	0.0182	0.0073	0.00007	0.00022	0.00000	0.00000
M3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00007	0.00007	0.00036	0.00066	0.0226	0.0138	0.0015	0.00015	0.00000	0.00000
M4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00007	0.00007	0.00036	0.00029	0.0138	0.0255	0.0058	0.00000	0.00000	0.00000
M5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00007	0.00015	0.00036	0.00007	0.0211	0.00029	0.00000	0.00000	0.00000
M6	0.00029	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00022	0.00007	0.0051	0.0109	0.00029	0.00000	0.00000	0.00000
M7	0.00007	0.00007	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00015	0.00029	0.00007	0.00000	0.00000	0.00000
M8	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00015	0.00007	0.00000	0.00000	0.00000
M9	0.00007	0.00007	0.00000	0.00000	0.00000	0.00000	0.00000	0.00007	0.00007	0.00022	0.00000	0.00022	0.0189	0.0036	0.0015	0.00000	0.00000	0.00000

STABILITY CLASS b

W1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0036	0.0022	0.0022	0.0058	0.0044	0.0015	0.0000	0.0000	0.0000
W2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0022	0.0044	0.0029	0.0116	0.0036	0.0044	0.0007	0.0000	0.0000
W3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0044	0.0022	0.0124	0.0036	0.0022	0.0000	0.0000	0.0000
W4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0007	0.0007	0.0029	0.0036	0.0073	0.0036	0.0000	0.0000	0.0000
W5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0022	0.0029	0.0029	0.0000	0.0000	0.0000
W6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0029	0.0007	0.0000	0.0000	0.0000	0.0000
W7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
W8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000
W9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0036	0.0022	0.0022	0.0058	0.0044	0.0015	0.0000	0.0000	0.0000

STABILITY CLASS 7

N1	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0007	0,0022	0,0015	0,0000	0,0015	0,0066	0,0000	0,0000	0,0007	0,0000	0,0000
N2	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0007	0,0022	0,0051	0,0015	0,0000	0,0000	0,0000	0,0000
N3	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0015	0,0000	0,0015	0,0015	0,0000	0,0000	0,0000	0,0000
N4	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0007	0,0000	0,0007	0,0007	0,0007	0,0000	0,0000	0,0000
N5	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0007	0,0000	0,0000	0,0000	0,0000	0,0007	0,0000	0,0000	0,0000	0,0000
N6	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0007	0,0000	0,0000	0,0000	0,0000	0,0000
N7	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
N8	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
N9	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0007	0,0022	0,0015	0,0000	0,0015	0,0066	0,0000	0,0000	0,0007	0,0000	0,0000

APPENDIX C

MIXING LAYER THICKNESS CLIMATOLOGY FOR THE HANFORD SITE

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MIXING LAYER THICKNESS CLIMATOLOGY FOR THE HANFORD SITE

Climatological summaries of the mixing layer thickness at Hanford for the 22-month period from March 25, 1982, through January 31, 1984, are shown in Table C.1. The mixing layer thickness is a measure of the vertical extent to which material released near the earth's surface will mix as a result of turbulence in the wind. The first four summaries give frequencies of occurrence of mixing layer thicknesses as a function of season and time-of-day. The fifth summary gives the frequencies by time-of-day, and the last summary gives seasonal and annual frequencies. These summaries should be appropriate for use in dispersion estimates for the Skagit/Hanford Site.

The mixing layer thicknesses are estimated using: 1) temperature profiles on the 125-m Hanford Meteorological Station tower, 2) a Doppler acoustic sounder, and 3) the temperature at the top of Rattlesnake Ridge. The acoustic sounder is the primary method of determining the thickness. However, it is not reliable during heavy precipitation or high winds. During heavy precipitation, the mixing layer thickness is assumed to be small (<100 m), and during high winds it is assumed to be large (>1,000 m). The assumption of a small thickness during precipitation is conservative because material is not allowed to mix upward, which tends to increase estimates of ground-level X/Q. The assumption of a large mixing layer thickness under high wind conditions is not conservative, but it has little effect on the overall X/Q estimates because high winds are associated with good dispersion. The effects of the assumptions are also minimal because of infrequency of heavy precipitation and high winds.

TABLE C.1. Hanford Mixing Layer Thickness Climatology^(a)

<u>Winter (Dec., Jan., Feb.)</u>						
	Time-of-day (PST)					
	<u>00-04</u>	<u>04-08</u>	<u>08-12</u>	<u>12-16</u>	<u>16-20</u>	<u>20-24</u>
0-100m	0.1737	0.1737	0.1018	0.1093	0.1737	0.1976
100-250m	0.4835	0.4775	0.3653	0.2410	0.4641	0.4805
250-500m	0.2470	0.2485	0.3877	0.3982	0.2814	0.2620
500-1000m	0.0240	0.0195	0.0464	0.1317	0.0359	0.0150
> 1000m	0.0719	0.0808	0.0988	0.1198	0.0449	0.0449
<u>Spring (Mar., Apr., May)</u>						
	Time-of-day (PST)					
	<u>00-04</u>	<u>04-08</u>	<u>08-12</u>	<u>12-16</u>	<u>16-20</u>	<u>20-24</u>
0-100m	0.1711	0.0978	0.0109	0.0124	0.1056	0.1662
100-250m	0.3904	0.3929	0.0994	0.0544	0.1677	0.3168
250-500m	0.2846	0.3432	0.2655	0.1537	0.2189	0.2407
500-1000m	0.0327	0.0699	0.3090	0.3075	0.1599	0.0497
> 1000m	0.1213	0.0963	0.3152	0.4721	0.3478	0.2267
<u>Summer (June, July, Aug.)</u>						
	Time-of-day (PST)					
	<u>00-04</u>	<u>04-08</u>	<u>08-12</u>	<u>12-16</u>	<u>16-20</u>	<u>20-24</u>
0-100m	0.0927	0.0565	0.0134	0.0054	0.0430	0.0766
100-250m	0.3925	0.3186	0.0255	0.0067	0.1075	0.3226
250-500m	0.3710	0.4772	0.1949	0.0901	0.1586	0.2245
500-1000m	0.0981	0.1048	0.5202	0.4489	0.2675	0.1237
> 1000m	0.0457	0.0430	0.2460	0.4489	0.4234	0.2527

(a) Based on temperature records and acoustic sounder data 3/25/82 through 1/31/84.

TABLE C.1. (contd)

Fall (Sept., Oct., Nov.)

	Time-of-day (PST)					
	<u>00-04</u>	<u>04-08</u>	<u>08-12</u>	<u>12-16</u>	<u>16-20</u>	<u>20-24</u>
0-100m	0.1544	0.1148	0.0506	0.0342	0.1639	0.1557
100-250m	0.4126	0.4071	0.1475	0.0738	0.3142	0.3934
250-500m	0.3292	0.3921	0.4208	0.2965	0.2719	0.3142
500-1000m	0.0506	0.0451	0.2691	0.4358	0.1434	0.0656
> 1000m	0.0533	0.0410	0.1120	0.1598	0.1066	0.0710

Annual Summary

	Time-of-day (PST)					
	<u>00-04</u>	<u>04-08</u>	<u>08-12</u>	<u>12-16</u>	<u>16-20</u>	<u>20-24</u>
0-100m	0.1464	0.1094	0.0438	0.0394	0.1205	0.1471
100-250m	0.4191	0.3971	0.1560	0.0915	0.2611	0.3777
250-500m	0.3104	0.3691	0.3167	0.2328	0.2317	0.2608
500-1000m	0.0527	0.0606	0.2920	0.3368	0.1546	0.0653
> 1000m	0.0714	0.0639	0.1915	0.2995	0.2321	0.1492

	<u>Winter</u>	<u>Spring</u>	<u>Summer</u>	<u>Fall</u>	<u>Annual</u>
0-100m	0.1549	0.0940	0.0479	0.1123	0.1011
100-250m	0.4187	0.2369	0.1956	0.2914	0.2837
250-500m	0.3041	0.2511	0.2527	0.3374	0.2869
500-1000m	0.0454	0.1548	0.2605	0.1683	0.1603
> 1000m	0.0769	0.2633	0.2433	0.0906	0.1679

APPENDIX D

GEOTECHNICAL PROPERTIES: PARTIALLY SATURATED ZONE CHARACTERISTICS OF THE SKAGIT/HANFORD SITE

APPENDIX D

GEOTECHNICAL PROPERTIES: PARTIALLY SATURATED ZONE CHARACTERISTICS OF THE SKAGIT/HANFORD

INTRODUCTION

The hydrology of the partially saturated (vadose) zone^(a) at the Department of Energy Hanford Site has been of considerable interest for the past 15 to 20 years (Reisenauer 1963; Brownell et al. 1975; Isaacson and Brown 1978; Jones 1978; Jones and Gee 1984). Hydrologic interest has centered on the use of the vadose zone at Hanford as a long-term radioactive waste storage area. The vadose zone can also be considered a buffer or delay zone that can extend the travel time of contaminants that might potentially seep to groundwater from waste processing operations or power-production facilities. The safety of buried radioactive wastes depends in part upon the hydrologic isolation of the radionuclides from the relatively deep ground-water table at Hanford (Galley 1966; National Academy of Sciences 1957, 1976, 1978).

Past work at the Hanford site indicated that the vadose zone sediments remain fairly dry under the existing arid climate conditions (Enfield, Hsieh and Warrick 1973; Jones 1978; Jones and Gee 1984). However, the soils and sediments at the Hanford site, although highly variable, are generally coarse in texture and drain readily (Newcomb, Strand and Frank 1972; Routson and Fecht 1979). When excess water (from irrigation, liquid waste disposal, or increased precipitation) is applied at the surface, these soils and sediments can readily transmit water downward below the root zone such that further additions of water can be a source for deep drainage to the water table. Recent studies indicate that, when above-normal precipitation occurs,

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- (a) The partially saturated (vadose) zone can be defined as the zone of geologic material (e.g., soils, sediments, and rocks) that lies between the land surface and the deepest water table. Generally, water in this zone is under pressure that is less than atmospheric (sometimes called negative pressure). At least some of the soil voids contain air or other gases at or near atmospheric pressure. At the Hanford site, this zone ranges from 15 m (45 ft) to over 100 m (300 ft).

significant amounts of water can be transmitted below the root zone on coarse-textured soils at the Hanford site (Jones and Gee 1984; Kirkham and Gee 1984). Unfortunately, only limited hydrologic characterization has been completed on the Hanford site sediments; hence, the analysis of vadose zone water flow remains incomplete.

This report documents a recent effort to hydrologically characterize vadose zone sediments at the Hanford site. The report details measurements of field water contents for samples collected from five boreholes drilled in the vicinity of the Skagit Hanford site Nuclear Project, a few kilometers west of the Wye barricade and about 15 km north of Richland, Washington. Capillary pressure (matric water potential) laboratory analysis data were taken on samples from three of the five holes. Laboratory analyses were performed to determine field moisture content, water potential, water retention characteristics, hydraulic conductivity, particle size analysis, calcium carbonate content, pH, and electrical conductivity. Results are tabulated by hole and depth, and a general discussion concerning the use of this information for hydrologic modeling is provided.

METHOD

SAMPLING

Samples from four of the five boreholes were taken in approximately 1.5-m segments. From each core segment, a 0.5-m section was saved for laboratory analysis in sealed airtight plastic buckets. From borehole #5, each core segment was saved in 0.75-m sections for a complete field water content analysis over the entire profile. All other analyses for borehole #5 were performed on only the odd-numbered samples, to be consistent with the other boreholes; that is, a 0.5-m section of every odd-numbered 1.5-m segment was used for analysis.

Samples were collected from the depth of the water table or from the depth where further drilling became impossible, whichever was deeper. For boreholes #2 through #5, water was added to a drilling lubricant at about 25 to 28 m; therefore, no water contents were obtained for the samples taken at this level.

Forty samples, eight from each borehole, were chosen for detailed analysis, based on visual texture changes down through the profile. One sample was selected to represent each of the visually distinct layers in the profile.

SOIL PROPERTIES PROCEDURES

Field Moisture Content

Field moisture content was determined on all samples. Samples were taken at the depths indicated in the previous section, by core borehole techniques and placed immediately in vapor-tight containers in the field. The samples were first logged into the laboratory using the field log information recorded on the buckets. Before the seal was broken on the lid, the samples were mixed by rolling the bucket to evenly distribute the water and to readsorb the condensation on the lid. Subsamples for moisture content were taken quickly to ensure minimum water loss caused by evaporation. These subsamples were weighed and oven-dried (16 h or more at 110°C) to determine moisture content according to ASTM procedure D 2216 (ASTM 1980).

Water Potential

When subsamples were taken from boreholes #3 through #5 for the field moisture content analysis, a second set of subsamples was collected to determine the water potential at the field moisture content. A commercial psychrometer sample changer(a) was used to determine the water potential. The samples were packed into small cups 1.4 cm x 1.2 cm (diameter x height). The cups were put into vapor-tight chambers in the psychrometer sample changer. After approximately 1 h, the relative humidity was measured with a miniature thermocouple psychrometer. The psychrometer measures the wet bulb depression (humidity) in a closed chamber directly above the sample using a miniature thermocouple connected to a microvolt sensing unit. The equilibrium vapor pressure, or relative humidity, can be related directly to the water potential of the water in the sample (Campbell 1977). The relationship between the water potential and the relative humidity can be written as:

$$\psi = -RT/M \ln (RH/100)$$

where

ψ = total water potential

R = universal gas constant

T = Kelvin temperature M = molecular weight of water

RH = relative humidity.

Particle Size

Particle size was determined on two separate bases. The particles larger than 2 mm were determined by dry sieve analysis using sieve sizes of 3 in., 2 in., 1 in., 3/4 in., 1/2 in., No. 4 and No. 10 mesh (Tyler numbers). Size distribution was done in accordance with ASTM procedure D 422 (ASTM 1972). For all samples, sand, silt and clay distribution was determined based on only the less than 2-mm sized particles from each large sample. The 40 predetermined samples were analyzed for a complete distribution curve, except for dispersion of the sample, of the particle sizes by ASTM procedure D 422. Sample dispersion was done using an ultrasonic homogenizer for more complete dispersion of the particles.

Water Retention

Water retention characteristics were measured at 0.1, 1.0, and 15.0 bars applied pressure for each sample using a pressure plate extractor obtained from Soilsmoisture Equipment Corp., Santa Barbara, California. Equilibrium water contents were obtained by packing samples in containing rings on a porous ceramic plate where they were saturated and pressure-drained in the extractor.

Both the samples and porous plate were brought to saturation by allowing an excess of water to stand on the surface of the plate for 24 h. On complete saturation, the plate was placed in the extractor vessel and the internal air pressure raised to the desired test level. Equilibrium was reached when the drainage ceased. At the end of the run, the samples were weighed and oven-dried to determine the moisture contents. Water content data are tabulated in terms of the associated matric water potential expressed in -bars. At equilibrium, the applied pressure is equal to the matric water potential (Richards 1965).

Hydraulic Conductivity

Hydraulic conductivity of each of the 40 predetermined samples was determined using a falling water head method of analysis (Klute 1965). In this method, the sample is placed in a container and enclosed with lids having an inflow valve at one end and an outflow valve at the other end. The inflow valve is connected to a standpipe of a known cross-sectional area and height. The sample is saturated before any test runs are done. An initial head in the standpipe is recorded, and water is allowed to flow from the standpipe through the sample for a given length of time. The ending head level in the standpipe is recorded. The hydraulic conductivity is determined using the following equation:

$$K = (aL/At) \ln(H_1/H_2)$$

where

a = cross-sectional area of the standpipe

L = length of the sample

A = cross-sectional area of the sample

t = time for the hydraulic head difference
to decrease from H₁ to H₂.

The hydraulic conductivity values were determined on an average of five falling head runs over a period of several minutes or several hours, depending on the flow rate, and at room temperature (22 ± 2°C).

Chemistry

The cation exchange capacity (CEC) for each of the 40 samples tested was done by sodium saturation and sodium determination by atomic adsorption (Chapman 1965). The CaCO₃ content was determined using a volumetric calcimeter method (Allison and Moodie 1965). The pH and electrical conductivity were determined on a 1:1 soil extract (Bower and Wilcox 1965).

RESULTS AND DISCUSSION

SOILS AND WELL DESCRIPTION

Field Operations

Collection of field samples for testing of the unsaturated zone at the in this was initiated in November 1983 and completed in late December of the same year. Five sites were selected for collection of samples. These sites were located at the approximate corners of the primary site and near the center of the proposed reactor location. The four corner holes were drilled and then backfilled with clean materials. The centrally located test hole was cased to its entire depth and preserved as a site for repeatable soil moisture analyses using radioactive logging techniques. Samples were collected using a percussion drilling machine and drive-barrel tools. The drive barrel inside diameter was 12.7 cm (5 in.); its length changed over the course of operations because of reforming and refurbishing. The operating procedure was as follows:

1. Set up drilling machine over selected hole location.
2. Drive sampler tube to maximum capacity.
3. Measure depth of hole and record.
4. Empty sample tube into sample container.
5. Lower drive sampler back into hole; remeasure depth and record.
6. Repeat steps 2 through 5.

The onsite geologist then marked the sample container and its lid according to well location and sample number. Sample containers were filled to as near capacity as feasible and then sealed to prevent moisture gain or loss during handling. Samples were transported to the laboratory at the end of each drilling day, or as soon as possible. The containers were covered during each intervening sample run to minimize soil moisture changes caused by atmospheric contact. At the four corner locations, a 0.5 m sample was collected from each 1.5-m (5-ft) intervals. Continuous sampling was carried out at the central location. Sample volume was a nominal 19 L (5 gal). The target depth for each 6 of the holes was to the regional water table. The method selected was such that, except under extremely adverse conditions, no

drilling fluid would be needed. This assured that the samples obtained were representative of the actual conditions at depth. Heavy gravels were encountered in each of the holes near the water table. It became necessary to change over from drive-barrel methods to hard tools in four of the five holes. This changeover resulted in the lowermost samples being inappropriate for water-content analysis and biased the particle-size analysis toward the smaller size range.

PHYSICAL CHARACTERIZATION

Heterogeneity

Tables D.1 and D.2 list the results of the physical characterization completed for all samples from the five boreholes. Sieve analysis results confirm that, at this site, the soils are typically coarse-textured, with clay contents of all samples generally $\leq 5\%$ and sand contents ranging from 60 to 90% or more. Silt contents varied considerably, ranging from ≤ 10 to $\approx 60\%$. The gravel and stone content of the material was also highly variable, ranging from 0 to over 60% by weight. The particle-size distributions for these materials reflect an extremely heterogeneous profile indicative of the glacial-fluvial processes that were responsible for the formation of the sediment layers (Routson and Fecht 1979).

Moisture

Previous reports (McHenry 1957; Benson, Nelson and Alkine 1963; Routson and Fecht 1979) have documented soil properties. However, none clearly documents the field moisture status of the sediment profiles sampled. The Routson and Fecht (1979) study of 12 wells located south of the 200 East Area reported moisture contents, but indicated that the values (ranging from 0.2 to 3.2 wt%) represented a "minimum moisture;" the authors suggested that most samples had dried during storage, prior to analysis.

As indicated in the description of sampling and methods, we designed the study primarily to assess the moisture content of the sediment profile. The field moisture content values reported in Table D.1 are generally higher than those reported by Routson and Fecht (1979). The values that we measured

TABLE D.1. Moisture Analysis

SAMPLE	DEPTH (m)	FIELD WATER %	WATER RETENTION		
			-1 bars	-1.0 bars	-15.0 bars
1-26	0.0	4.43	7.37	5.05	3.26
1-1	1.5	3.10	4.81	3.81	3.23
1-2	3.0	3.00	5.14	3.99	3.35
1-3	4.6	7.06	7.48	4.49	3.55
1-4	6.1	14.63	17.65	10.63	8.45
1-5	7.6	9.17	9.16	5.95	4.77
1-6	9.1	8.91	10.49	6.13	4.93
1-7	10.7	8.11	11.79	6.56	5.15
1-8	12.2	9.84	8.46	7.30	6.36
1-9	13.7	2.71	7.29	5.24	3.58
1-10	15.2	2.48	7.55	6.08	3.74
1-11	16.8	2.38	7.86	5.28	3.48
1-12	18.3	2.44	8.21	5.33	3.52
1-13	19.8	2.70	9.48	4.62	3.65
1-14	21.3	4.97	5.75	3.82	2.77
1-15	22.9	3.44	9.11	4.62	2.56
1-16	24.4	2.92	10.00	3.85	2.32
1-17	25.9	3.02	5.89	3.27	1.92
1-18	27.4	3.45	8.93	4.05	2.12
1-19	29.0	3.72	6.86	3.36	1.71
1-20	30.5	3.09	12.00	3.78	0.98
1-21	32.0	2.71	5.87	3.08	1.72
1-22	33.5	2.49	5.38	3.20	0.92
1-23	35.1	2.05	9.82	4.92	2.24
1-24	36.6	1.97	7.63	4.78	2.75
1-25	38.1	1.85	8.72	5.59	2.38
2-1	0.0	5.35	7.70	6.38	5.55
2-2	1.5	3.42	8.74	5.77	4.65
2-3	3.0	5.27	7.08	4.12	3.17
2-4	4.6	4.81	6.01	4.02	3.22
2-5	6.1	3.55	7.36	3.35	2.46
2-6	7.6	12.13	10.29	5.33	4.01
2-7	9.1	5.44	12.88	5.37	3.70
2-8	10.7	4.02	8.40	4.20	2.85
2-9	12.2	3.75	8.05	3.99	2.80
2-10	13.7	3.55	6.98	3.21	2.27
2-11	15.2	3.18	6.35	3.26	2.36
2-12	16.8	3.12	5.93	2.74	1.83
2-13	18.3	2.96	5.38	2.69	2.35
2-14	19.8	2.99	4.65	2.63	2.01
2-15	21.3	2.69	5.05	2.49	2.13
2-16	22.9	2.57	4.73	2.49	1.99
2-17	24.4	2.69	4.38	2.89	2.01
2-18	25.9	3.09	5.22	2.66	2.14
2-19	27.4	2.40	13.38	7.11	4.51
2-20	29.0	2.67	16.48	7.69	5.36
2-21	30.5		12.72	7.42	3.34
2-22	32.0		14.17	8.66	4.13
2-23	33.5		13.93	7.66	3.94
2-24	35.1		12.97	7.49	3.70
2-25	36.6		13.81	7.56	3.57
2-26	38.1		15.64	8.78	5.24
2-27	39.6		4.08	2.56	1.63

TABLE D.1. (contd)

SAMPLE	DEPTH (m)	FIELD WATER %	WATER RETENTION		
			-1 bars	-1.0 bars	-15.0 bars
3-1	0.0	5.87	4.57	2.55	2.35
3-2	3.0	6.67	7.72	3.74	3.38
3-3	4.6	8.74	8.14	4.50	3.43
3-4	6.1	4.80	5.59	3.53	2.77
3-5	7.6	4.23	5.60	3.91	2.68
3-6	9.1	4.55	5.78	4.62	3.35
3-7	10.7	4.89	4.89	3.87	3.19
3-8	12.2	5.53	5.77	4.07	3.21
3-9	13.7	6.16	5.65	4.48	2.95
3-10	15.2	5.32	5.92	3.91	2.68
3-11	16.8	6.78	5.59	4.00	2.89
3-12	18.3	5.50	5.67	3.92	2.90
3-13	19.8	6.47	7.69	2.22	2.70
3-14	21.3	5.02	5.05	2.62	1.64
3-15	22.9	4.07	4.59	3.11	2.54
3-16	24.4	4.00	2.52	2.30	2.12
3-17	25.9	3.54	4.08	3.71	3.10
3-18	27.4		13.83	7.00	3.51
3-19	29.0		12.56	8.46	4.52
3-20	30.5		14.18	8.64	4.14
3-21	32.0		12.88	7.37	3.96
3-22	33.5		14.30	7.79	3.79
3-23	35.1		12.12	6.50	3.46
3-24	36.6		12.77	7.47	3.81
3-25	38.1		13.26	7.83	4.03
3-26	39.6		11.84	6.86	3.41
4-1	0.0	5.63	3.09	2.93	2.79
4-2	3.0	4.36	4.75	4.30	3.77
4-3	4.6	4.68	6.03	5.82	5.32
4-4	6.1	10.86	9.51	8.81	6.50
4-5	7.6	3.68	4.60	4.43	3.70
4-6	9.1	3.17	4.09	3.95	3.19
4-7	10.7	3.52	4.78	3.70	3.62
4-8	12.2	3.82	4.41	3.66	3.61
4-9	13.7	3.97	4.28	3.78	3.69
4-10	15.2	4.14	5.58	4.24	3.51
4-11	16.8	2.79	6.31	3.79	3.19
4-12	18.3	2.27	10.00	5.55	3.40
4-13	19.8	2.35	8.43	4.62	3.11
4-14	21.3	2.46	5.78	3.42	2.50
4-15	22.9	2.49	7.41	4.17	2.38
4-16	24.4	2.25	6.47	3.70	2.86
4-17	25.9		15.71	8.82	4.42
4-18	27.4		14.09	8.05	4.20
4-19	29.0		12.00	8.54	3.56
4-20	30.5		14.29	8.21	3.80
4-21	32.0		16.28	7.88	3.60
4-22	33.5		19.32	8.20	3.81
4-23	35.1		18.49	9.68	3.99
4-24	36.6		11.17	4.34	2.06
4-25	38.1		17.67	8.85	3.31

TABLE D.1. (contd)

SAMPLE	DEPTH (m)	FIELD WATER %	WATER RETENTION		
			-1 bars	-1.0 bars	-15.0 bars
5-1	0.0	5.41	6.89	5.01	3.56
5-2	1.5	5.47			
5-3	2.1	3.24	7.38	3.93	2.99
5-4	3.0	3.98			
5-5	3.7	4.01	7.48	4.26	3.22
5-6	4.0	4.51			
5-7	4.6	4.93	6.26	3.92	3.04
5-8	5.2	4.51			
5-9	6.1	4.68	8.45	3.56	3.02
5-10	6.7	4.53			
5-11	7.6	4.82	4.92	3.21	2.93
5-12	7.9	4.24			
5-13	8.8	4.42	4.51	3.75	3.20
5-14	9.4	5.48			
5-15	10.1	5.59	4.06	3.23	2.95
5-16	10.2	4.79			
5-17	11.3	7.00	5.12	4.17	3.19
5-18	11.9	8.02			
5-19	12.8	9.64	7.33	6.33	4.87
5-20	13.4	5.57			
5-21	14.3	4.41	5.00	4.02	3.07
5-22	14.9	3.66			
5-23	15.2	4.08	3.92	3.20	2.48
5-24	16.2	3.86			
5-25	16.8	3.70	3.62	2.94	2.28
5-26	17.4	3.54			
5-27	17.7	3.29	3.08	2.56	2.04
5-28	18.6	3.37			
5-29	19.2	3.86	3.29	2.27	1.91
5-30	19.8	3.42			
5-31	20.1	3.96	3.00	2.26	2.23
5-32	20.7	3.86			
5-33	21.3	4.11	3.26	2.12	1.91
5-34	22.3	3.76			
5-35	22.9	3.72	2.90	1.75	1.70
5-36	23.5	3.38			
5-37	23.8	3.08	3.42	2.28	1.85
5-38	24.4	3.15			
5-39	25.0	2.87	3.40	2.12	1.48
5-40	25.3	2.97			
5-41	25.9	2.93	3.37	1.98	1.49
5-42	26.5	2.59			
5-43	27.1	2.71	4.31	2.21	1.61
5-44	27.4	2.54			
5-45	28.0	2.30	6.89	3.21	2.13
5-46	28.3	3.48			
5-47	29.0	3.93	8.91	4.63	2.85
5-48	30.2				
5-49	31.1		12.46	7.08	4.17
5-50	31.7				
5-51	32.9		9.55	5.75	4.00
5-52	33.8				
5-53	34.4		10.72	5.97	4.99
5-54	35.4				
5-55	36.0		9.62	4.95	3.94
5-56	36.9				

TABLE D.2. Mechanical Analysis

SAMPLE	DEPTH (m)	% >2MM	% SAND	% SILT	% CLAY
1-26	0.0	22.00	63.77	31.69	4.54
1-1	1.5	13.38	80.03	17.94	2.03
1-2	3.0	19.77	70.77	26.33	2.90
1-3	4.6	4.62	82.26	15.07	2.67
1-4	6.1	0.00	72.19	22.72	5.06
1-5	7.6	0.00	84.93	12.36	2.71
1-6	9.1	0.00	80.62	16.23	3.15
1-7	10.7	0.00	79.01	17.81	3.18
1-8	12.2	0.00	80.48	15.40	4.12
1-9	13.7	62.89	30.08	65.47	3.45
1-10	15.2	47.80	35.93	58.47	5.60
1-11	16.8	55.70	32.31	63.64	4.15
1-12	18.3	53.30	29.10	63.93	6.97
1-13	19.8	48.06	32.68	62.75	4.57
1-14	21.3	31.96	56.62	39.37	4.01
1-15	22.9	20.38	65.88	30.72	3.40
1-16	24.4	30.01	60.89	36.50	2.61
1-17	25.9	23.81	67.23	30.50	2.27
1-18	27.4	2.20	86.99	10.78	2.23
1-19	29.0	8.21	83.14	14.41	2.45
1-20	30.5	16.21	73.13	24.34	2.53
1-21	32.0	1.34	88.53	9.16	2.31
1-22	33.5	11.71	78.90	18.51	2.59
1-23	35.1	54.87	36.49	59.25	4.26
1-24	36.6	47.54	42.83	53.43	3.74
1-25	38.1	40.35	46.46	49.21	4.33
2-1	0.0	37.21	83.12	12.96	3.92
2-2	1.5	40.11	81.40	13.83	4.77
2-3	3.0	14.74	88.66	9.35	1.99
2-4	4.6	27.41	86.90	11.82	1.28
2-5	6.1	27.06	88.67	8.67	2.66
2-6	7.6	2.67	78.47	17.00	4.53
2-7	9.1	0.50	81.94	14.30	3.76
2-8	10.7	0.86	85.66	11.64	2.70
2-9	12.2	1.58	91.15	6.92	1.53
2-10	13.7	12.30	90.45	9.22	0.33
2-11	15.2	11.57	92.41	6.11	1.48
2-12	16.8	4.69	89.89	8.54	1.57
2-13	18.3	5.08	93.11	5.97	0.92
2-14	19.8	3.26	90.28	7.55	2.17
2-15	21.3	2.56	91.76	6.15	2.09
2-16	22.9	3.37	91.33	7.05	1.62
2-17	24.4	1.73	94.44	3.64	1.92
2-18	25.9	1.36	93.76	4.83	1.41
2-19	27.4	55.81	68.01	27.95	4.04
2-20	29.0	45.59	66.23	28.69	5.08
2-21	30.5	36.68	69.65	23.03	7.32
2-22	32.0	24.76	60.55	28.97	10.48
2-23	33.5	15.19	69.75	22.30	7.95
2-24	35.1	26.55	66.49	24.64	8.87
2-25	36.6	13.53	66.78	24.71	8.51
2-26	38.1	0.45	32.42	50.06	17.52
2-27	39.6	14.45	90.69	5.53	3.78

TABLE D.2. (contd)

SAMPLE	DEPTH (m)	% >2MM	% SAND	% SILT	% CLAY
3-1	0.0	0.10	88.58	9.54	1.88
3-2	3.0	0.00	84.81	12.70	2.49
3-3	4.6	0.00	86.98	10.44	2.58
3-4	6.1	4.00	86.94	10.84	2.23
3-5	7.6	9.11	88.44	8.48	3.08
3-6	9.1	14.37	88.21	8.26	3.53
3-7	10.7	8.36	89.04	7.88	3.08
3-8	12.2	1.98	88.29	9.66	2.05
3-9	13.7	6.96	90.61	7.07	2.32
3-10	15.2	13.41	91.62	6.06	2.32
3-11	16.8	4.09	89.81	7.74	2.45
3-12	18.3	11.22	91.36	6.39	2.25
3-13	19.8	0.07	86.66	10.48	2.86
3-14	21.3	0.39	88.57	8.14	3.29
3-15	22.9	4.89	90.62	6.59	2.79
3-16	24.4	5.50	89.59	7.83	2.58
3-17	25.9	39.53	88.16	8.73	3.11
3-18	27.4	30.11	69.15	24.47	6.38
3-19	29.0	21.59	69.58	22.49	7.93
3-20	30.5	25.51	66.93	26.68	6.39
3-21	32.0	30.11	88.38	6.29	5.33
3-22	33.5	27.76	74.22	19.26	6.52
3-23	35.1	40.14	52.36	41.23	6.41
3-24	36.6	33.81	62.87	30.91	6.22
3-25	38.1	37.25	67.68	24.89	7.43
3-26	39.6	18.66	70.63	23.49	5.88
4-1	0.0	0.61	95.37	2.34	2.29
4-2	3.0	9.73	90.01	7.34	2.65
4-3	4.6	39.27	85.10	11.63	3.27
4-4	6.1	0.00	81.02	14.18	4.80
4-5	7.6	1.36	92.78	5.14	2.08
4-6	9.1	5.90	89.13	10.14	0.73
4-7	10.7	1.67	88.79	8.99	2.22
4-8	12.2	6.41	90.84	7.09	2.07
4-9	13.7	9.54	90.63	7.21	2.16
4-10	15.2	1.11	90.19	7.72	2.09
4-11	16.8	39.24	77.63	19.19	3.18
4-12	18.3	45.71	67.54	27.17	5.29
4-13	19.8	58.76	70.97	24.64	4.39
4-14	21.3	46.78	80.07	17.17	2.78
4-15	22.9	41.52	73.26	22.08	4.66
4-16	24.4	27.51	78.39	18.16	3.45
4-17	25.9	27.72	62.03	34.88	3.09
4-18	27.4	26.29	64.83	29.21	5.96
4-19	29.0	23.09	65.19	28.77	6.04
4-20	30.5	22.34	66.28	27.56	6.16
4-21	32.0	32.91	67.76	26.48	5.76
4-22	33.5	18.46	62.83	31.80	5.37
4-23	35.1	1.38	64.82	30.08	5.10
4-24	36.6	16.73	82.23	14.88	2.89
4-25	38.1	2.93	63.01	28.67	8.32

TABLE D.2. (contd)

SAMPLE	DEPTH (m)	% >2MM	% SAND	% SILT	% CLAY
5-1	0.0	24.50	90.01	7.52	2.47
5-2	1.5				
5-3	2.1	16.74	90.41	8.58	1.28
5-4	3.0				
5-5	3.7	19.33	94.48	4.26	1.26
5-6	4.0				
5-7	4.6	6.06	92.50	6.15	1.35
5-8	5.2				
5-9	6.1	6.71	93.08	4.95	1.97
5-10	6.7				
5-11	7.6	5.24	93.52	4.79	1.69
5-12	7.9				
5-13	8.8	16.41	92.14	5.25	2.61
5-14	9.4				
5-15	10.1	3.29	84.89	11.86	3.29
5-16	10.2				
5-17	11.3	13.35	83.16	13.36	3.48
5-18	11.9				
5-19	12.8	0.95	74.71	21.63	3.66
5-20	13.4				
5-21	14.3	8.46	86.66	10.11	3.23
5-22	14.9				
5-23	15.2	7.53	88.23	9.38	2.39
5-24	16.2				
5-25	16.8	8.15	86.58	10.18	3.24
5-26	17.4				
5-27	17.7	9.96	90.38	7.24	2.38
5-28	18.6				
5-29	19.2	11.06	92.12	5.81	2.07
5-30	19.8				
5-31	20.1	6.22	91.77	5.53	2.70
5-32	20.7				
5-33	21.3	0.62	89.89	6.90	3.21
5-34	22.3				
5-35	22.9	5.02	92.02	5.25	2.73
5-36	23.5				
5-37	23.8	18.00	90.62	6.43	2.95
5-38	24.4				
5-39	25.0	22.21	91.69	5.85	2.46
5-40	25.3				
5-41	25.9	4.98	91.01	6.60	2.39
5-42	26.5				
5-43	27.1	6.81	89.57	7.97	2.46
5-44	27.4				
5-45	28.0	32.72	83.20	13.84	2.96
5-46	28.3				
5-47	29.0	35.78	87.03	9.94	3.23
5-48	30.2				
5-49	31.1	23.50	65.12	27.80	7.08
5-50	31.7				
5-51	32.9	20.72	66.35	26.97	6.68
5-52	33.8				
5-53	34.4	19.43	64.25	27.86	7.89
5-54	35.4				
5-55	36.0	25.91	69.42	23.71	6.77
5-56	36.9				

ranged from 2 to 15 wt%. The higher field moisture contents (those above 10%) appear to be associated with fine-textured sediments containing fairly high water- retention values at metric potential at -0.1 bar. Based on the measured water- retention values, the bulk of the data indicate wetness values that are consistent with moisture contents associated with a draining profile (0- to -1-bar capillary pressure), particularly in the region from 5 to 20 m deep. The moisture data at depths below 25 to 30 m are unavailable in all but hole #1 because of difficulties in obtaining core material from the very coarse gravel/soil layers at this site. The data from hole #1 indicate some desiccation at depth, but this is very difficult to interpret. In general, the lowest water contents were found at the lowest depths, but the lower depths (i.e., below 20 m) also tended to be associated with the coarsest soils (i.e., 2-mm fragments exceeding 60%). Hole #3 yielded the most uniformly wet profile, indicating that moisture redistribution and drainage had extended to depths below 25 m. All field moistures at this hole were consistently wetter than the measured -1-bar capillary pressure, suggesting that drainage was occurring and that evaporation was likely not occurring at depth.

Water Potential

The measured total water potential was reported to be wetter than -1 bar for all but samples measured in hole #4. These data confirm that, in general, the soil remained wet at depth at this site. The data measured from hole #4 remain to be explained. A water potential at -5 bars (Sample 4-14) adjacent to a sample at -1 bars (Sample 4-15) is not consistent with the concepts of equilibrium (e.g., the samples at depth should indicated equal to slowly varying water potential. Silt content of the soil solution, sample desiccation, or measurement error are possible explanations for the observed water potential. Careful and detailed measurement of 17 samples from hole #3 and 47 samples from hole #5 indicated that no samples to depths of 29 m had water potentials drier than -1 bars. The resolution of the water potential sensing unit is 1 bar. However, we also determined from pressure plate tests that, in general, all samples with total water potential was ≥ 1 bar also had metric potential wetter than -1 bar. These data support the concept of a draining profile at this site.

Hydraulic Conductivity

All measurements were made on disturbed samples. The coarse sediments made it impossible to sample without noticeable segregation of material. Tables D.3 and D.4 give detailed characterization for the sand (<2-mm size) fraction for eight samples from each of the five boreholes tested. Included in Table D.3 are measured hydraulic conductivity values. The measured conductivities vary from 10^{-3} to 10^{-5} cm/s and under the compaction conditions, reflect moderately high permeabilities indicative of samples with a wide range of particle sizes. Because of large fragments present in many of the samples, an attempt was made to estimate the effect of coarse fragments on the packing. The conductivity was calculated using a method described by Bouwer and Rice (1984) for stony soils. The relationship is:

$$k = k_s (e_t/e_s)$$

where

- k = the overall hydraulic conductivity
- k_s = the conductivity of the sand fraction (<2 mm)
- e_t = the void ratio of the total sample
- e_s = the sand fraction.

The data indicate that the overall conductivity is not significantly affected by the presence of the larger fragments. Thus, for general calculations, the sand fraction permeability could be used. The reported values are considered representative of vertical permeabilities of the sediments. Because of the disturbed nature of the samples no attempt was made to measure differences between vertical and horizontal permeabilities for these materials.

Chemical Properties

No unusual chemical properties were noted in these sediments. They are alkaline with low cation exchange capacities and generally low carbonates. These findings are very similar to those reported by Routson and Fecht (1979) for 200 East Area sediments.

TABLE D.3. Detailed Moisture Analysis

SAMPLE DEPTH	HYDRAULIC CONDUCTIVITY (cm/sec)	FIELD WATER (%)	Water Retention		
			-1 BAR	-1 BAR	-15 BAR
HOLE #1					
SURFACE	4.65e-04	4.43	7.37	5.05	3.26
3.0 m	7.48e-04	3.70	5.14	3.99	3.35
12.2 m	3.71e-04	9.84	8.46	7.30	6.36
18.3 m	3.30e-04	2.44	8.21	5.33	3.52
24.4 m	2.41e-03	2.92	10.00	3.85	2.32
29.0 m	1.46e-03	3.72	6.86	3.36	1.71
33.5 m	4.64e-04	2.49	5.38	3.20	0.92
36.6 m	8.36e-05	1.97	7.63	4.78	2.75
HOLE #2					
SURFACE	2.25e-03	5.35	7.70	6.38	5.55
4.6 m	2.38e-03	4.81	6.01	4.02	3.22
7.6 m	4.37e-05	12.13	10.29	5.33	4.01
13.7 m	1.43e-03	3.55	6.98	3.21	2.27
22.9 m	6.11e-04	2.57	4.73	2.49	1.99
27.4 m	2.84e-03	2.40	13.38	7.11	4.51
32.0 m	6.19e-05		8.66	7.66	4.13
36.6 m	4.10e-05		7.56	7.56	3.57
HOLE #3					
SURFACE	1.63e-03	5.87	4.57	2.55	2.35
4.6 m	7.78e-04	8.74	8.14	4.50	3.43
9.1 m	5.00e-03	4.55	5.78	4.62	3.35
18.3 m	2.28e-03	5.50	5.67	3.92	2.90
21.3 m	2.08e-03	5.02	5.05	2.62	1.64
25.9 m	1.84e-03	3.54	4.08	3.71	3.10
32.2 m	1.47e-04		12.88	7.37	3.96
38.1 m	2.61e-04		13.26	7.83	4.03
HOLE #4					
SURFACE	1.33e-03	5.63	3.09	2.93	2.79
4.6 m	4.25e-04	4.68	6.03	5.82	5.32
6.1 m	2.81e-04	10.86	9.51	8.81	6.50
12.2 m	1.84e-03	3.82	4.41	3.66	3.61
19.8 m	2.35e-03	2.35	8.43	4.62	3.11
27.4 m	2.42e-04		12.00	8.54	3.56
35.1 m	2.37e-03		18.49	9.68	3.99
38.1 m	2.71e-03		17.67	8.85	3.31
HOLE #5					
SURFACE	2.24e-03	5.41	6.89	5.01	3.56
10.1 m	2.63e-03	5.59	4.06	3.23	2.95
11.3 m	7.95e-04	7.00	5.12	4.17	3.19
15.2 m	2.43e-03	4.08	3.92	3.20	2.48
21.3 m	2.72e-03	4.11	3.26	2.12	1.91
28.0 m	3.67e-03	2.30	6.89	3.21	2.13
32.9 m	2.65e-03		9.55	5.75	4.00
36.0 m	2.68e-03		9.62	4.95	3.94

TABLE D.4. Chemistry

SAMPLE DEPTH	CEC meq/l	CaCO ₃ %	pH	EC (mmhos)
HOLE #1				
SURFACE	8.0	0.20	8.2	0.10
3.0 m	9.7	1.37	8.2	0.19
12.2 m	13.9	1.04	8.2	0.16
18.3 m	8.0	1.30	8.2	0.18
24.4 m	6.0	0.86	8.3	0.16
29.0 m	4.1	0.91	8.2	0.15
33.5 m	4.2	0.96	8.3	0.15
36.6 m	5.3	0.98	8.2	0.17
HOLE #2				
SURFACE	11.7	0.84	8.3	0.17
4.6 m	9.5	1.09	8.4	0.14
7.6 m	12.0	1.26	8.2	0.16
13.7 m	6.2	1.27	8.3	0.13
22.9 m	3.4	1.17	8.3	0.15
27.4 m	6.4	0.67	8.3	0.19
32.0 m	5.0	0.29	8.2	0.22
36.6 m	3.1	1.38	8.2	0.22
HOLE #3				
SURFACE	4.4	0.38	8.0	0.16
4.6 m	8.7	1.54	8.3	0.15
9.1 m	8.2	0.76	8.2	0.15
18.3 m	7.1	0.71	8.2	0.14
21.3 m	3.7	1.15	8.3	0.15
25.9 m	4.9	1.21	8.2	0.14
32.2 m	4.8	0.46	8.1	0.23
38.1 m	4.6	0.58	8.3	0.22
HOLE #4				
SURFACE	4.1	1.30	8.4	0.14
4.6 m	21.0	1.35	8.2	0.15
6.1 m	15.0	1.54	8.3	0.17
12.2 m	7.2	0.69	8.2	0.17
19.8 m	7.1	0.60	8.2	0.15
27.4 m	5.4	0.45	8.4	0.15
35.1 m	4.1	0.57	8.3	0.22
38.1 m	10.0	0.26	8.1	0.21
HOLE #5				
SURFACE	7.2	1.28	8.2	0.16
10.1 m	7.5	0.54	8.2	0.18
11.3 m	7.9	0.68	8.1	0.15
15.2 m	7.0	1.38	8.1	0.12
21.3 m	3.5	1.29	8.4	0.15
28.0 m	3.4	1.07	8.2	0.15
32.9 m	4.1	0.29	8.3	0.21
36.0 m	3.1	0.41	8.3	0.22

Travel Time Estimates

Travel time in the vadose zone can be defined as the time necessary for water to move from the soil surface to the water table. Travel time is a key parameter needed to estimate consequences for siting facilities where radioactive waste can be potentially leached to ground water. For radioactive species (e.g., tritium, ruthenium, iodine, or organically complexed species that are sorbed little on soil or sediments), the major mode of concentration reduction is through decay; hence, long travel times are desirable. Travel times can be estimated using the hydrologic properties that have been measured at the test site. For unsaturated flow considerations, the major uncertainty is the annual seepage (recharge) rate that occurs at depth, below the zone of evaporation (top 2 to 3 m). From recent lysimeter studies at the Hanford site (Jones and Gee 1984), we estimate that the annual recharge rate can range from 0.5 to 5.0 cm/yr. Much uncertainty still exists as to the actual recharge rate but, for our calculations, we made travel time estimates assuming 0.5 and 5.0 cm/yr as steady-state recharge values.

Travel times were analyzed in two ways. The first method assumed that the soil properties could be averaged over the entire depth [37.6 m (ft)]. The second method separated the sediments into two zones, based on textural differences, and computed the travel times by summing the travel time in the individual zones. Table D.5 tabulates the estimated travel times based on the properties reported for hole #3, using annual recharge rates of 0.5 and 5.0 cm/yr.

TABLE D.5. Estimated Times for Hole #3 Soil Characteristics

Method	Recharge Rate	
	0.5 cm/yr	5.0 cm/yr
Method 1 - Averaged Soil Values	677 yr	86 yr
Method 2 - Two Layer System	677 yr	88 yr

The results presented in Table D.5 show that travel times depend on both the estimated recharge rates and the method of calculation. Essentially no difference occurred in calculating travel times assuming average soil

characteristics (method 1) and computing travel times in individual layers (method 2). However, more detailed analysis may show added importance for including the individual layer characteristics of the soil in the calculation. In addition to the uncertainty in the recharge rate, the nonuniformity (spatial variability) present at this site makes it impossible to estimate a single travel time for water flow to the water table. A complete analysis of travel times in the vadose zone awaits more definite measurements of recharge rates and a detailed uncertainty analysis of the hydrologic properties of the layered unsaturated sediments. It is anticipated that over the next few years, ongoing research at the Hanford site will provide detailed measurements and analysis that will complement this initial characterization study.

SUMMARY

The following key observations can be made:

1. The sediment profiles at this site are extremely heterogeneous but, in general, the soils are coarse-textured and drain relatively quickly.
2. The sediment profiles were wet to extended depth (25 m), suggesting that drainage is occurring at this site. Rates of drainage were estimated, but can be determined using the measured soil hydraulic properties and more detailed measurements of climatic variables (rainfall, radiation, wind speed, temperature) and plant cover (evapotranspiration).
3. Estimated travel times for water to move through the unsaturated zone to the water table at this site range from less than 100 yr to over 600 yr for annual water influx rates ranging from 0.5 to 5 cm/yr.
4. The soil properties determined here will be useful in modeling the transport of water and chemicals (e.g., radionuclides) to the ground water at this site.

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APPENDIX E

EXPOSURE PATHWAYS

APPENDIX E

EXPOSURE PATHWAYS^(a)

The potential environmental pathways through which persons may be exposed to radiation originating in a nuclear reactor or related fuel cycle facilities are shown in Figure E.1. When an individual is exposed through one of these pathways, the dose is determined in part by the amount of time he/she is in the vicinity of the source, or the amount of time the radioactivity inhaled or ingested is retained in his/her body. The actual effect of the radiation or radioactivity is determined by calculating the dose commitment. The annual dose commitment is calculated to be the total dose that would be received over a 50-year period following the intake of radioactivity for 1 year under the conditions expected to exist at the midpoint of facility operation. This would represent an average exposure over the life of the facility. However, with few exceptions, most of the internal dose commitment for each nuclide is given during the first few years after exposure because of the turnover of the nuclide by physiological processes and radioactive decay.

There are a number of possible exposure pathways to man that are appropriate for study to determine the impact of routine releases from the NPR or other fuel cycle facilities on members of the general public living and working outside of the site boundaries, and whether the releases projected at this point in the licensing process will in fact meet regulatory requirements. A detailed listing of these exposure pathways would include external radiation exposure from the gaseous effluents, inhalation of iodines and particulate contaminants in the air, drinking milk from a cow or eating meat from an animal that feeds on open pasture near the site on which iodines or particulates may have been deposited, eating vegetables from a garden near the site that may be contaminated by similar deposits, and drinking water or eating fish caught near the point of discharge of liquid effluents.

(a) This information is taken from U.S. NRC and Washington State Energy Facility Site Evaluation Council (1982). It is recognized that site-specific identification of exposure pathways requires definition of those facilities generating emissions. As a result, the presentation of exposure pathways will be modified and updated as more information becomes available on the NPR and other fuel cycle facilities.

FIGURE E.1. Potentially Meaningful Exposure Pathways to Individuals

Other less important pathways include: external irradiation from radionuclides deposited on the ground surface; eating animals and food crops raised near the site using irrigation water that may contain liquid effluents; shoreline, boating, and swimming activities near lakes or streams that may be contaminated by effluents; drinking potentially contaminated water; and direct radiation from within the facility itself.

Calculations of the effects for most pathways are limited to a radius of 80 km (50 mi). This limitation is based on several facts. Experience, as demonstrated by calculations, has shown that all individual dose commitments do not exceed 0.1 mrem/yr beyond a radius of 80 km from the plant. Beyond 80 km, the doses to individuals are smaller than 0.1 mrem/yr, which is far below natural-background doses, and the doses are subject to substantial uncertainty because of limitations of predictive mathematical models.

REFERENCE

U.S. NRC and Washington State Energy Facility Site Evaluation Council. 1982. Draft Environmental Statement Related to the Construction of Skagit/Hanford Nuclear Project, Units 1 and 2. NUREG-0894, Washington, D.C.

APPENDIX F

ENVIRONMENTAL PERMITS

ENVIRONMENTAL PERMITS

A preliminary list of environmental permits which will likely have to be obtained assuming construction and operation of an NPR are shown in Table F.1.

The responsible federal, state, or local agency is shown in Column 2 of the table. To date no application has been made for any of the permits listed in Table F.1.

TABLE F.1. Preliminary List of Environmental Permits

	<u>Permit</u>	<u>Agency</u>	<u>Comments</u>
Federal	Section 10 or 404 of the Clean Water Act	Army Corps of Engineers, Seattle District Office	Required for any activity in navigable waters.
	Prevention of Significant Deterioration (PSD)	EPA (Environmental Protection Agency), Region X	Required to determine compliance with federal air quality standards.
State	Permit to Appropriate Public Waters (water right)	Department of Ecology	For use or diversion of surface or ground water or change of use.
	Water Quality Certification	Department of Ecology	Required by federal law for discharges to water.
	National Pollutant Discharge Elimination System (NPDES) or State Waste Discharge	Department of Ecology	Needed if pollutants will be discharged into state's waters (surface or ground).
	Sewage and Industrial Waste Treatment Facilities Approval	Department of Ecology	Required if improvements or extensions are needed to a new sewage treatment or disposal system.
	Public Water Supply Approval	Department of Social and Health Services	If a public drinking water supply is needed or altered.
Local	New Source Construction Approval	Local or State Air Pollution Control Authority	Regulation insures proper controls are included in plant design. Authorizing agency depends upon project location.
	Shoreline Substantial Development	County or City Planning Department	Required if project is located within local shoreline jurisdiction.

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