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**Environmental Surveillance  
at Hanford for CY-1981**

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

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Pacific Northwest Laboratory  
Operated for the U.S. Department of Energy  
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## **Environmental Surveillance at Hanford for CY-1981**

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May 1982

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the U.S. Department of Energy  
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Mary Ann McKinney edited this report and arranged for its production.

## PREFACE

The Environmental Surveillance Program at the Hanford Site in Washington State is conducted by the Pacific Northwest Laboratory (PNL) under contract to the Department of Energy (DOE). The data collected by the Environmental Surveillance Program provide an historical record of the levels of radionuclides and radiation attributable to natural causes, worldwide fallout, and Hanford operations. The findings of the present program demonstrate the relatively small impact attributable to either current or past Hanford operations. Where appropriate, the data are compared with applicable standards for air and water quality set forth by the Department of Energy, the Environmental Protection Agency (EPA), and the state of Washington. Summaries and interpretations of the data are published annually; this document is for calendar year 1981. Previous reports in this series for the past ten years are:

1980	PNL-3728	M. J. Sula and P. J. Blumer	(April 1981)
1979	PNL-3283	J. R. Houston and P. J. Blumer	(April 1980)
1978	PNL-2932	J. R. Houston and P. J. Blumer	(April 1979)
1977	PNL-2614	J. R. Houston and P. J. Blumer	(April 1978)
1976	BNWL-2142	J. J. Fix, P. J. Blumer, G. R. Hoenes, P E Bramson	(April 1977)
1975	BNWL-1979	D. R. Speer, J. J. Fix, P. J. Blumer	(June 1976)
1974	BNWL-1910	J. J. Fix	(April 1975)
1973	BNWL-1811	W. L. Nees and J. P. Corley	(April 1974)
1972	BNWL-1727	P. E. Bramson and J. P. Corley	(April 1973)
1971	BNWL-1683	P. E. Bramson and J. P. Corley	(August 1972)

Two other summary reports are issued by the Hanford Environmental Surveillance Program annually. These are:

- *Environmental Status of the Hanford Site* (to be issued as PNL-4212 for 1981), and
- *Radiological Status of the Groundwater Beneath the Hanford Site* (to be issued as PNL-4237 for 1981).

These reports provide summaries of environmental and groundwater monitoring programs conducted on the Hanford Site.





## SUMMARY

Environmental surveillance activities performed by the Pacific Northwest Laboratory for the Department of Energy's Hanford Site for 1981 are discussed in this report. Data were collected in support of the Hanford Environmental Surveillance Program for radioactivity in most environmental media including air, river water, foodstuffs, wildlife, soil, vegetation, and penetrating radiation and for nonradioactive pollutants in the Columbia River. The results are summarized in the following highlights.

- Observed radionuclide concentrations and radiation dose measurements were in every case far below all applicable concentration guides and radiation dose standards.
- There was no distinguishable difference detected between airborne radionuclide concentrations in samples collected near to and far from the Hanford Site.
- A difference in  $^{129}\text{I}$  concentration in Columbia River water downstream of the Hanford Site compared to samples collected upstream of the site was observed. A slight difference in  $^{90}\text{Sr}$  concentrations was also observed in 1981 as a result of relocating the upstream sample point. Strontium-90 concentrations downstream of the Site remained similar to past years while reduced concentrations were observed in the upstream samples. In addition, during 1981,  $^{60}\text{Co}$  and  $^{131}\text{I}$  were observed more frequently in the downstream river water samples than in the upstream samples, but at concentrations too low for differences between upstream and downstream samples to be quantified. In all of the above cases, the downstream radionuclide concentrations were small in comparison to DOE radionuclide concentration guides and state and EPA drinking water standards and were similar to previous years values.
- Low concentrations of radionuclides attributed to operations at Hanford were observed in several samples of wildlife collected onsite near operating areas. However, it was calculated that if an individual were to consume the entire edible portions of the specific game animal at the maximum observed concentration, the resulting radiation dose would be well below the applicable dose standard.
- Low concentrations of fallout radionuclides from worldwide atmospheric nuclear testing were observed in samples of foodstuffs and in soil and vegetation samples. There was no indication of a Hanford contribution to radionuclide levels in these media.
- The highest penetrating dose rates observed in the Hanford environs were in the immediate vicinities of the 100N and 300 Areas. The maximum dose rate observed during 1981 along the 100N shoreline was 0.04 mrem/hr, and the maximum observed near the 300 Area perimeter fence was 0.08 mrem/hr. Dose rates at both locations resulted from the presence, within the operating areas, of contained radioactive materials. Dose rates at all normally occupied locations in the offsite environment were at normal background levels.
- Nonradiological water quality parameters were all within State Water Quality Standards for the Hanford Reach of the Columbia River with the exception of a single pH determination which was slightly below the standard but the same at both the upstream and downstream measurement locations.
- The maximum 50-year whole body dose commitment to an individual from effluents released in 1981 was calculated to be 0.4 mrem. This included contributions from airborne effluents, drinking water, irrigated foodstuffs, and aquatic recreation pathways. The maximum 50-year dose to a single organ, considering all pathways was approximately 1.3 mrem to the bone, primarily due to  $^{90}\text{Sr}$  in the Columbia River observed during 1981. These doses can be compared with the DOE dose standards of 500 mrem/yr for the whole body and 1500 mrem/yr for the bone.
- Operations at Hanford during 1981 resulted in a 50-year whole body dose commitment to the population residing within an 80-km radius of the site of about 4 man-rem. (A dose expressed in "man-rem" is the summation of all individual doses received within 80-km of the site.) This dose, primarily due to immersion in short-lived noble gases released at 100N Area, may be compared to the approximately 34,000 man-rem whole body dose received each year by the same population from natural background radiation.



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## INTRODUCTION

For the past 39 years, an environmental surveillance program has been conducted for the Hanford Site. The results of this program have been publicly recorded since January of 1948 in quarterly reports. Since 1959, the results have been available in annual reports. This report summarizes the data collected for calendar year 1981. The Hanford Environmental Surveillance Program is conducted by PNL, which is operated for the DOE by Battelle Memorial Institute.

The objectives of the program include:

- assessing dose impacts to the uncontrolled public from site operations
- verifying in-plant controls for the containment of radioactive materials within controlled areas
- monitoring to determine buildup of long-lived radionuclides in uncontrolled areas
- providing reassurance to the public that the program is capable of adequately assessing impacts and identifying noteworthy changes in the radiological status of the environment.

Environmental surveillance at the Hanford Site involves numerous measurements of a variety of

environmental media for potential contaminants. Samples are collected in accordance with a master schedule published each year (Blumer, Sula, and Eddy 1981). Unless stated otherwise, radionuclide analyses of samples were performed by United States Testing Company, Inc., Richland, Washington. Individual sample results or summaries of the individual results are presented in the following sections of this report. Since all of the radioactive and nonradioactive pollutants considered in this report are present in the environment, either naturally or as a result of non-Hanford activities such as atmospheric nuclear weapons testing (fallout radionuclides) and agricultural activities (nitrates, coliforms, etc.), measurements made in the vicinity of the site are compared to background or control measurements. Any contribution to air or waterborne radionuclide concentrations or environmental dose rate levels considered to be attributable to Hanford operations is compared with applicable guides and standards in DOE Order 5480.1 Chapter XI. Concentrations of nonradioactive pollutants are compared with applicable standards of the Washington State Department of Ecology or the Environmental Protection Agency.

## DESCRIPTION OF THE HANFORD SITE

The U. S. Department of Energy's Hanford Site is located in a rural region of southeastern Washington and occupies an area of 1500 km<sup>2</sup>. The site, shown in Figure 1, lies about 320 km east of Portland, Oregon, 270 km southeast of Seattle, Washington, and 200 km southwest of Spokane, Washington. The Columbia River flows through the northern edge of the Hanford Site and forms part of its eastern boundary.

### SITE CHARACTERISTICS

The desert plain on which Hanford is located has a sparse covering of vegetation primarily suited for grazing. The most broadly distributed type of vegetation on the site is the sagebrush/cheat-grass/bluegrass community. The mule deer is the most abundant big game mammal on the site and the most abundant small game animal is the cottontail rabbit. The raccoon is the most

abundant furbearing animal. The osprey, golden eagle, and bald eagle are all occasional visitors to the relatively large areas of uninhabited land comprising the Hanford Site.

Hanford's climate is mild and dry; the area receives approximately 16 cm of precipitation annually. About 40% of the total precipitation occurs during November, December, and January with only 10% falling in July, August, and Sep-

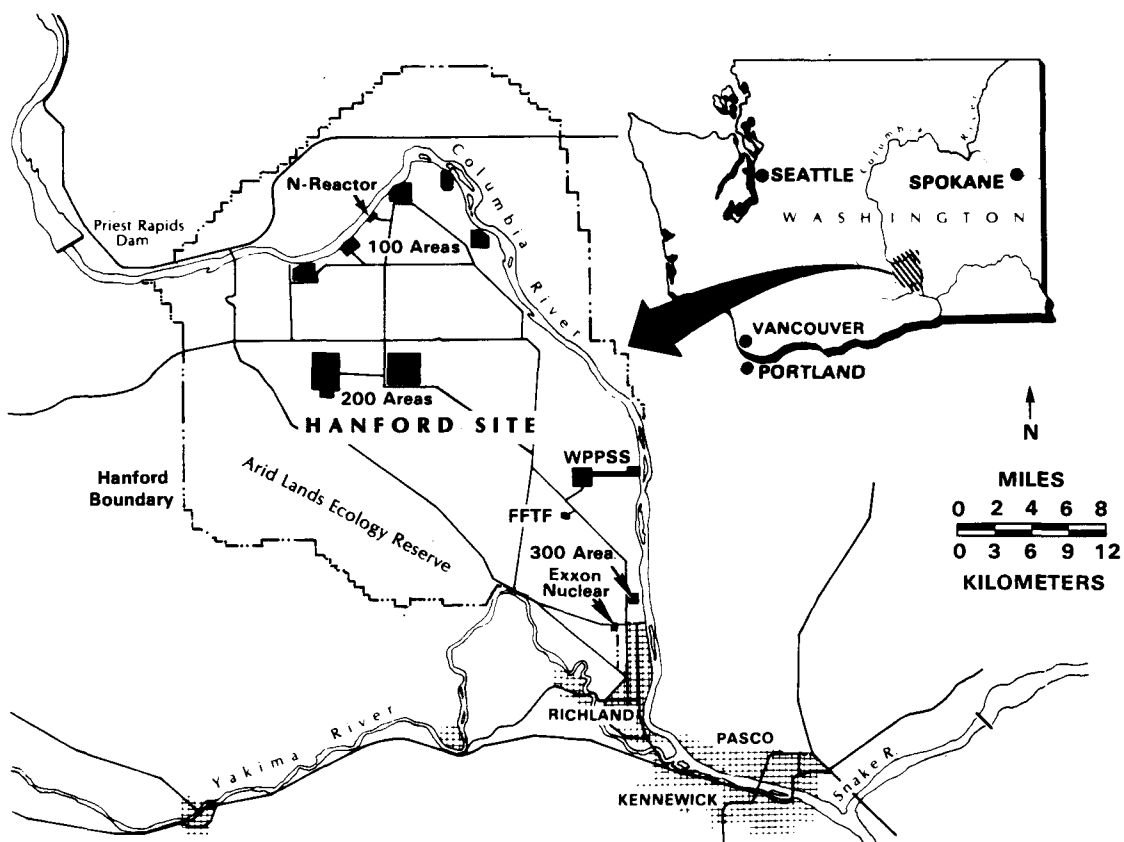


FIGURE 1. DOE's Hanford Site in Washington State

tember. The average maximum and minimum temperatures in July are 32°C (92°F) and 16°C (61°F). For January, the respective averages are 3°C (37°F) and -6°C (22°F). Approximately 45% of all precipitation from December through February is snow.

Mean monthly wind speeds range from about 14 km/hr in the summer to 10 km/hr in the winter. The prevailing regional winds are from the northwest with strong drainage and crosswinds causing complicated surface flow patterns. The region is a typical desert area with frequent strong inversions that occur at night and break during the day, causing unstable and turbulent conditions.

With the exception of Hanford Site-related industries, the economy of the region is primarily agricultural. Major crops include apples, alfalfa, wheat, corn, and potatoes. The Columbia River is used extensively for recreational purposes including fishing and waterfowl hunting.

The population center nearest to the Hanford site is the Tri-Cities area (Richland, Pasco, and Kennewick), situated on the Columbia River downstream from the site with a combined population of approximately 90,000. Approximately 340,000 people live within an 80-km radius of the Hanford Site in the Yakima area, the Tri-Cities, several small communities, and the surrounding agricultural area. Considerably more detail on site characteristics and activities is available in the *Final Environmental Statement for Waste Management Operations at Hanford* (ERDA 1975).

## MAJOR ACTIVITIES

Established in 1943, the Hanford plant was originally designed, built, and operated to produce plutonium for nuclear weapons. At one time, nine production reactors were in operation, including eight with once-through cooling by treated river water. Between December 1964 and January 1971, all eight reactors with once-through cooling were deactivated. N Reactor, the remaining production reactor in operation, has a closed primary cooling loop.

Four major operating areas exist at the Hanford Site. The "100 Areas" include facilities for the N-Production Reactor and the eight deactivated production reactors along the Columbia River.

The reactor fuel-processing and waste-management facilities are on a plateau about 11.3 km from the river in the "200 Areas." The "300 Area," just north of the city of Richland, contains the reactor fuel manufacturing facilities and research and development laboratories. The Fast Flux Test Facility (FFTF) is located in the "400 Area" approximately 8.8 km northwest of the 300 Area.

Privately owned facilities located within the Hanford Site boundaries include the Washington Public Power Supply System generating station adjacent to N Reactor, the Washington Public Power Supply System power reactor site and office buildings (under construction), a hazardous waste disposal site, and a radioactive waste burial site. The Exxon fuel fabrication facility is located immediately adjacent to the southern boundary of the Hanford Site.

Principal DOE Contractors operating at Hanford are:

Rockwell Hanford Operations—responsible for fuel processing, waste management, and all site support services such as plant security, fire protection, central stores, electrical power distribution, etc.

Battelle Memorial Institute—responsible for operating the Department of Energy's Pacific Northwest Laboratory (PNL). This includes research in the physical, life and environmental sciences, environmental surveillance, and advanced methods of nuclear waste management.

UNC Nuclear Industries (UNC)—responsible for fabricating fuel and operating N Reactor.

Westinghouse Hanford Company (WHC)—responsible for operating the Hanford Engineering Development Laboratory (HEDL), including advanced reactor developments, principally the Liquid Metal Fast Breeder Reactor Program and FFTF.

Highlights of operational activities at Hanford during 1981 were:

- N Reactor operated for 103 days during which time it supplied steam used by the Washington Public Power System to generate 870 MW of electrical power. Since its start-up, N Reactor has supplied steam for the production of nearly 50 billion kilowatt-hours of electric power, which has been

supplied to the Bonneville Power Administration grid covering the Pacific Northwest.

- The FFTF underwent an eight-day full-power run in late November during which a series of radiation tests were successfully performed in preparation for regular operation to begin in April 1982.
- A steam generator, removed from the Surry Nuclear Generating Station transported onsite during 1980, was moved to a permanent housing facility in the 300 Area in late December. The generator will be the subject of a five-year research effort.

- Baghouses were installed on the coal-fired steam plants in the 200 Areas and initial performance testing was begun.
- A solid cover was installed over the N Reactor trench to deter wildlife entry.

Work at Hanford during 1981 also included Hanford National Environmental Research Park (NERP) studies, Arid Land Ecology (ALE) Studies, and Basalt Waste Isolation Program (BWIP) activities, as well as continued operation of a variety of national research and laboratory facilities.



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## ATMOSPHERIC MONITORING

Radioactivity in air is sampled continuously by a network of 19 perimeter and five distant air samplers located as shown in Figure 2. The site perimeter sample locations provide a general 360° coverage for the Site with emphasis in the primary downwind directions to the south and east. Other locations include the nearby communities of Benton City, Richland, Pasco, Connell, and Othello. Background air concentration data are provided by samplers located in the more distant communities of Sunnyside, Moses Lake, Washtucna, Walla Walla, and McNary.

Airborne radionuclide concentrations during early 1981 continued an increasing trend that began during late 1980 following a foreign atmospheric nuclear test (Sula and Blumer 1981). Maximum air concentrations were observed at all locations in May and June, after which a downward trend began. By the end of 1981, airborne radionuclide concentrations at all sampling locations were similar to pre-test levels. During 1981, airborne radionuclide concentrations remained similar between the perimeter samples and the distant locations, verifying that the observed radionuclides were not of Site origin.

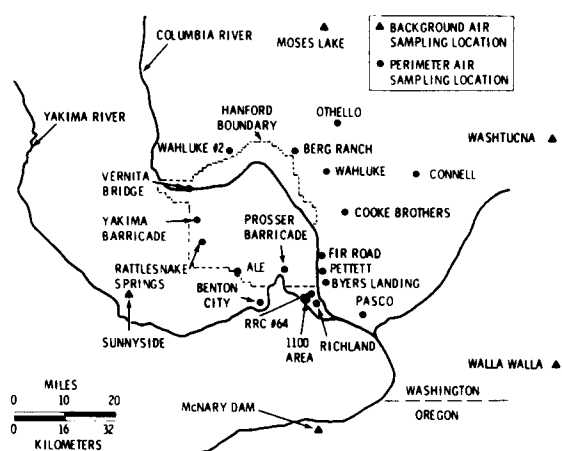


FIGURE 2. Air Sampling Locations

### SAMPLE COLLECTION AND ANALYSIS

Air is sampled at various locations for particulate radioactivity, radioiodine, and tritium. Particulate airborne radionuclides are sampled by drawing air at a flow rate of 2.6 m<sup>3</sup>/hr through a 5-cm diameter high-efficiency particulate filter. (a) Radioiodines are collected on a 4.4-cm diameter by 5.5-cm deep bed of KI and TEDA impregnated charcoal. (b) Samplers located at

(a) Model LB 5211, manufactured by Hollingsworth and Vose. Measured efficiencies exceed 99% for DOP (dioctyl-phthalate) particles.

(b) Manufactured by Nuclear Consulting Services, Inc. Retention efficiencies are 99% for both elemental and methyl-iodide.

the Fir Road, Richland, and Benton City locations also contain a tritium collection unit.

The particulate filters are collected biweekly and analyzed for gross beta and, in some cases, for gross alpha radioactivity after a seven-day holding period during which the naturally occurring radon and thoron daughters collected by the filter decay. The filters are combined monthly by geographical location and analyzed as a composite for gamma-emitting radionuclides, primarily <sup>137</sup>Cs. On a quarterly basis, the filters in each geographical group are combined and analyzed for <sup>90</sup>Sr and plutonium. All analyses are performed by U.S. Testing Company Inc. (UST), using methods summarized in Appendix C.

Charcoal cartridges from several of the sampling locations are exchanged on a biweekly frequency and analyzed for <sup>131</sup>I. The remaining cartridges are exchanged monthly to maintain fresh adsorption media, but are analyzed only if <sup>131</sup>I is identified in one of the routinely analyzed samples.

The tritium collection unit consists of two cartridges containing silica gel through which a stream of air is passed at a flow rate of 0.03 m<sup>3</sup>/hr. The first silica gel cartridge removes tritium in the form of water vapor (HTO). A catalytic oxidizer located downstream of the first silica gel cartridge then converts gaseous hydrogen and hydrocarbons in the air to water vapor that is collected by the second silica gel cartridge. Airborne tritium results are thus reported as <sup>3</sup>H (HTO) and <sup>3</sup>H (HT).

The silica gel cartridges are replaced every two weeks. Moisture is removed from the silica gel by heating and then condensing the trapped water. The water is collected and analyzed for tritium by UST, using liquid-scintillation counting methods.

## DISCUSSION OF RESULTS

Results of particulate gross-beta and gross-alpha emitter concentrations are shown in Table 1. Gross-beta emitter concentrations were similar at all sampling locations, averaging  $0.14 \pm 0.01$  pCi/m<sup>3</sup> for perimeter stations and  $0.13 \pm 0.02$  pCi/m<sup>3</sup> for distant locations. Thus, any contribution to general airborne particulate radioactivity as a result of Hanford operations could not be distinguished from worldwide fallout and naturally occurring radioactivity.

General airborne particulate radioactivity levels in the Hanford environs were greater in 1981 than in recent years as the result of a foreign atmospheric nuclear test conducted during the latter part of 1980 (Sula and Blumer 1981). Figure 3 shows the monthly averaged gross-beta particulate air concentrations for both perimeter and distant locations during the past five years. An increase in general background levels was observed almost immediately following the October 1980 detonation, with maximum concentrations observed in samples collected during the spring and summer of 1981. By the end of 1981, airborne concentrations had returned to pretest levels. As will be discussed in subsequent chapters of this report, increased radionuclide concentrations were observed in river water, vegetation, and several foodstuffs as a result of fallout from the nuclear test.

Shown in Table 2 are the results of specific analysis for radionuclides of potential Hanford origin. All of the radionuclides were observed at similar concentrations in downwind, distant, and perim-

eter locations indicating that observed concentrations were attributable to a nonlocal source, i.e., worldwide fallout. Maximum concentrations were observed in the summer months during the height of observed fallout activity. By the end of 1981, the shorter-lived radionuclides (<sup>95</sup>ZrNb, <sup>144</sup>CePr) were no longer detectable in the samples, and concentrations of the long-lived radionuclides had returned to levels observed just before the foreign nuclear test. Iodine-131 was not observed in any air samples collected during 1981.

## NONRADIOLOGICAL AIR MONITORING

Nonradiological pollutants in routine gaseous emissions from chemical processes and fossil-fueled power plants at Hanford consist primarily of particulates, sulfur dioxide (SO<sub>2</sub>), and oxides of nitrogen (NO<sub>x</sub>). The particulate emissions from two coal-fired power plants in the 200 Areas are the only emissions exceeding the applicable national or state standards (Appendix A) in recent years. During 1981, baghouses were installed at the two coal-fired power plants to reduce particulate emissions, and initial limited testing has indicated that current emissions are in compliance with the applicable standards. Emissions testing, which is being performed by the Hanford Environmental Health Foundation (HEHF), will be completed during 1982.

Operation of the ambient nitrogen dioxide (NO<sub>2</sub>) sampling network, maintained by HEHF, was suspended during 1981 following the accumulation of sufficient data prior to the restart of PUREX programs at Hanford. Data collected by the network during 1980 indicated a maximum observed annual average NO<sub>2</sub> concentration of less than 0.007 parts per million (ppm) as compared to the 0.05 ppm national ambient air standard (40 CFR 50, 1973). Operation of the network will resume again prior to the resumption of PUREX operations.

**TABLE 1.** Airborne Radioactivity in the Hanford Environs

Concentration Guide <sup>(b)</sup>	Gross Beta Concentrations <sup>(a)</sup> pCi/m <sup>3</sup> (10 <sup>-12</sup> µCi/ml)				Gross Alpha Concentrations <sup>(a)</sup> pCi/m <sup>3</sup> (10 <sup>-12</sup> µCi/ml)			
	100				0.03			
Locations	No. of Samples	Maximum	Minimum	Average	No. of Samples	Maximum	Minimum	Average
<b>Perimeter Stations</b>								
Prosser Barricade	25	0.34 ± 0.009	0.02 ± 0.004	0.16 ± 0.04	25	0.004 ± 0.0009	0.005 ± 0.0003	0.001 ± 0.0004
Benton City	25	0.34 ± 0.009	0.02 ± 0.004	0.14 ± 0.04	25	0.0004 ± 0.0009	0.0006 ± 0.0004	0.001 ± 0.0003
ALE	26	0.38 ± 0.011	0.02 ± 0.004	0.16 ± 0.05				
Rattlesnake Springs	24	0.36 ± 0.009	0.02 ± 0.004	0.15 ± 0.04				
Yakima Barricade	24	0.38 ± 0.010	0.03 ± 0.004	0.15 ± 0.04				
Vernita Bridge	26	0.29 ± 0.009	0.03 ± 0.005	0.14 ± 0.04				
Wahluke #2	26	0.34 ± 0.009	0.02 ± 0.004	0.14 ± 0.04				
Berg Ranch	26	0.28 ± 0.009	0.02 ± 0.005	0.13 ± 0.04	26	0.003 ± 0.0008	0.0005 ± 0.0003	0.001 ± 0.0003
Othello	25	0.28 ± 0.009	0.02 ± 0.004	0.13 ± 0.04				
Wahluke Watermaster	24	0.29 ± 0.009	0.02 ± 0.004	0.13 ± 0.04				
Connell	25	0.37 ± 0.010	0.02 ± 0.004	0.15 ± 0.04				
Cooke Bros.	26	0.32 ± 0.009	0.02 ± 0.004	0.14 ± 0.04				
Fir Road	25	0.40 ± 0.010	0.01 ± 0.004	0.13 ± 0.04				
Pettett	26	0.31 ± 0.009	0.02 ± 0.004	0.13 ± 0.04				
Byers Landing	23	0.27 ± 0.008	0.02 ± 0.004	0.14 ± 0.04	22	0.003 ± 0.0007	0.0006 ± 0.0004	0.001 ± 0.0004
Pasco	26	0.27 ± 0.004	0.02 ± 0.005	0.12 ± 0.03				
Richland	25	0.28 ± 0.009	0.03 ± 0.004	0.12 ± 0.04	25	0.003 ± 0.0007	0.0006 ± 0.0004	0.001 ± 0.0004
1100 Area	26	0.39 ± 0.010	0.02 ± 0.004	0.15 ± 0.04				
RRC #64	24	0.35 ± 0.009	0.02 ± 0.004	0.14 ± 0.04	24	0.004 ± 0.0009	0.0006 ± 0.0004	0.001 ± 0.0004
Overall Perimeter Station Average				0.14 ± 0.01				0.001 ± 0.0001
<b>Distant Stations</b>								
McNary	23	0.33 ± 0.009	0.01 ± 0.004	0.14 ± 0.04				
Walla Walla	25	0.41 ± 0.010	0.01 ± 0.006	0.15 ± 0.05				
Washtucna	26	0.34 ± 0.009	0.02 ± 0.003	0.14 ± 0.04				
Moses Lake	25	0.29 ± 0.009	0.02 ± 0.003	0.12 ± 0.04				
Sunnyside	26	0.25 ± 0.008	0.01 ± 0.004	0.11 ± 0.03				
Overall Distant Station Average				0.13 ± 0.02				

(a)Maximum and minimum concentrations include the ± two-sigma counting error. Averages include the two-standard error term (95% confidence interval).

(b)As stated in DOE ORDER 5480.1 (Appendix A).

No entry indicates no analysis was performed.



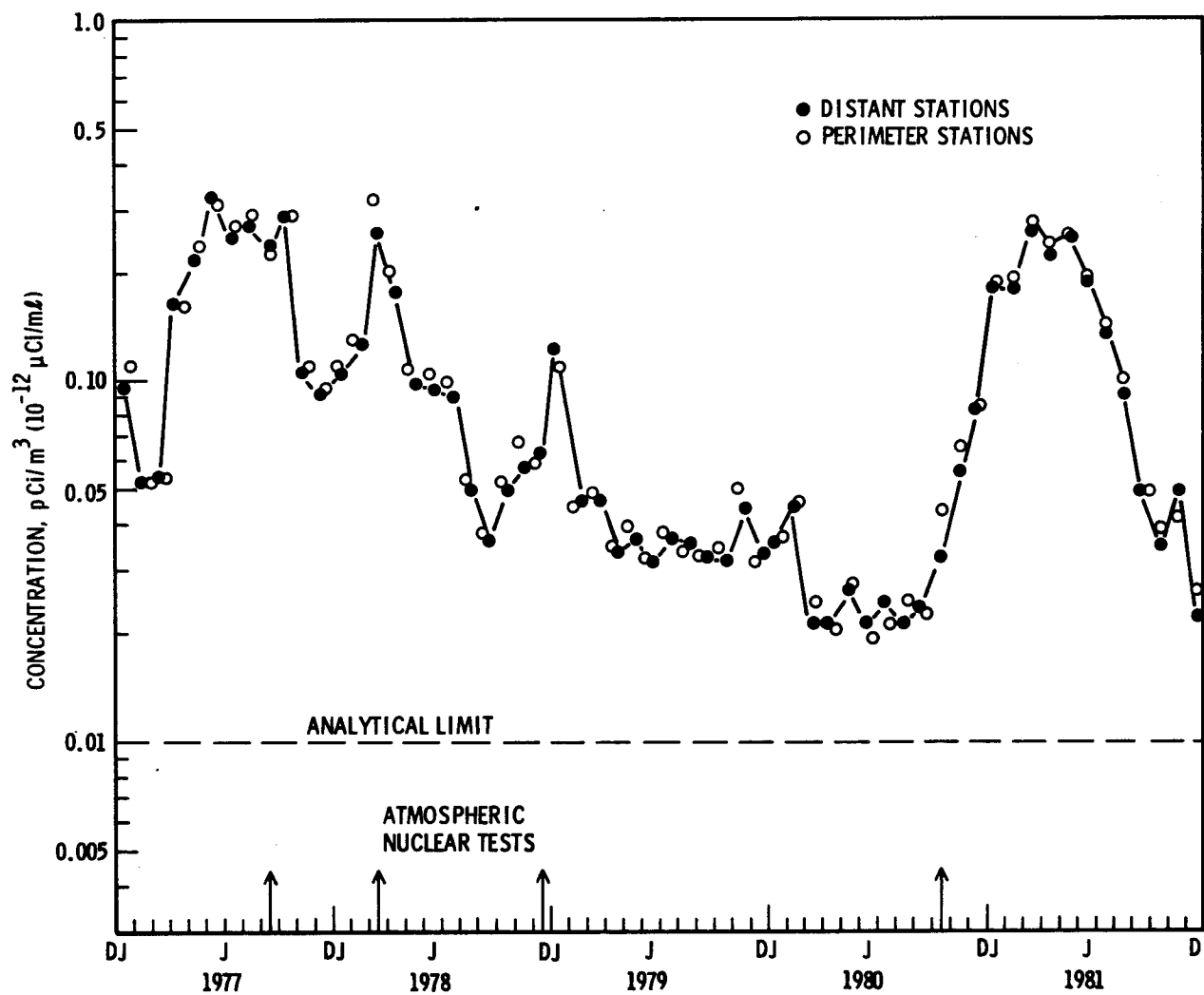


FIGURE 3. Monthly Averaged Gross-Beta Particulate Air Concentrations

**TABLE 2. Selected Airborne Radionuclide Concentrations in the Hanford Environs**

Radionuclide	Concentration Guide (pCi/m <sup>3</sup> )	Composite Group <sup>(b)</sup>	No. of Analyses	No Results >DL	Concentration, pCi/m <sup>3</sup> (10 <sup>-12</sup> µCi/ml) <sup>(a)</sup>		
					Maximum	Minimum	Average
<sup>3</sup> H (HTO)	200,000	Distant	—	—	—	—	—
		Perimeter	76	67	2.5 ± 0.6	<DL	0.74 ± 0.27
		Downwind Perimeter	51	46	2.5 ± 0.6	<DL	0.74 ± 0.27
<sup>3</sup> H (HT)	200,000	Distant	—	—	—	—	—
		Perimeter	53	44	2.1 ± 0.8	<DL	0.68 ± 0.25
		Downwind Perimeter	27	23	2.1 ± 0.8	<DL	0.68 ± 0.25
<sup>90</sup> Sr	30	Distant	12	11	0.002 ± 0.0006	<DL	0.0009 ± 0.0005
		Perimeter	16	16	0.002 ± 0.0002	0.002 ± 0.00004	0.0009 ± 0.0004
		Downwind Perimeter	4	4	0.002 ± 0.0002	0.002 ± 0.00004	0.0008 ± 0.0009
<sup>95</sup> ZrNb	1,000	Distant	35	27	0.15 ± 0.004	<DL	0.057 ± 0.019
		Perimeter	48	36	0.16 ± 0.003	<DL	0.056 ± 0.016
		Downwind Perimeter	12	9	0.13 ± 0.002	<DL	0.052 ± 0.026
<sup>131</sup> I	100	Distant	27	0	<DL	<DL	0.002 ± 0.002
		Perimeter	128	0	<DL	<DL	0.002 ± 0.003
		Downwind Perimeter	103	0	<DL	<DL	0.002 ± 0.002
<sup>137</sup> Cs	500	Distant	36	22	0.03 ± 0.003	<DL	0.004 ± 0.002
		Perimeter	48	30	0.02 ± 0.0008	<DL	0.004 ± 0.004
		Downwind Perimeter	12	8	0.02 ± 0.0008	<DL	0.004 ± 0.003
<sup>144</sup> CePr	200	Distant	36	23	0.51 ± 0.04	<DL	0.053 ± 0.028
		Perimeter	48	30	0.13 ± 0.01	<DL	0.045 ± 0.013
		Downwind Perimeter	12	8	0.11 ± 0.009	<DL	0.041 ± 0.018
<sup>239+240</sup> Pu	0.06	Distant	12	8	0.0001 ± 0.00007	<DL	0.00005 ± 0.00003
		Perimeter	16	12	0.00006 ± 0.00001	<DL	0.00002 ± 0.000009
		Downwind Perimeter	4	3	0.00003 ± 0.000007	<DL	0.00002 ± 0.00001

>DL = Greater than the detection level, i.e., analysis of the sample yielded a positive identification.

<DL = Less than the detection level; radionuclide not identified in sample.

(a) Maximum and minimum concentrations include the ± two-sigma counting error. Averages include the two-standard error term (95% confidence interval).

(b) Distant stations include Moses Lake, Washtucna, Walla Walla, McNary, and Sunnyside.

Downwind Perimeter Stations include Fir Road, Byers Landing, Pasco, Richland, Pettett, 1100 Area, and RRC #64.

Perimeter Stations include the downwind perimeter locations above, plus Wahluke #2, Berg Ranch, Othello, Vernita, Wahluke Water-master, Connell, Cooke, Yakima Barricade, Rattlesnake Springs, ALE, Benton City, and Prosser Barricade.

No result indicates no analysis performed.



## COLUMBIA RIVER MONITORING—RADIOLOGICAL

The Columbia River, which runs through the northern part of the Hanford Site and forms the Site's east boundary, provides a means for the offsite transport of Site-generated radionuclides discharged via liquid effluents. In the early years of Hanford operations, substantial quantities of radioactivity—thousands of curies per day, largely short-lived radionuclides—were released to the river from the production reactors located along the shoreline. However, following the shutdown of the old production reactors by 1972, and with the current effluent control systems at the only remaining production reactor, N Reactor, radionuclide concentrations in the river water have decreased to extremely low levels.

Since the Columbia River is used for drinking water and crop irrigation, as well as fishing, hunting, and other recreational activities, it continues to be closely monitored for radionuclides of potential Site origin. The levels of radionuclides in the river water attributable to Hanford activities, past or present, are determined by comparing radionuclide concentrations in samples collected both upstream and downstream of the Site.

Samples collected during 1981 show that the impact of Hanford on radionuclide levels in the Columbia River is very small. Although higher concentrations were observed at the downstream sampling location for two Hanford-produced radionuclides, the concentrations themselves were slight and well below applicable DOE Concentration Guides.

### SAMPLE COLLECTION AND ANALYSIS

Samples of Columbia River water were collected throughout 1981 at locations upstream and downstream of Site discharge points. Two types of samplers were used: a conventional cumulative-type sampler that intermittently collected a measured volume of river water in a large container, and a specially designed large-volume sampler that continuously collected waterborne radionuclides from the river on a series of filtration and ion exchange media. The sampling locations are shown in Figure 4.

The cumulative sampler consists of a timer-activated solenoid valve that intermittently diverts a continuous sample stream of Columbia River water into a large container. Approximately 30 ml of water are diverted into the container every 30 minutes so that by the end of the monthly sampling period about 45 liters have been accumulated. The cumulative sampler is used to collect river water samples for tritium,  $^{89}\text{Sr}$ ,  $^{90}\text{Sr}$ , and uranium determination. Analyses are performed using procedures described in Appendix C.

The large-volume sampler has been described by Fix and Robertson (1976). River water is continuously pumped through the sampler at a rate

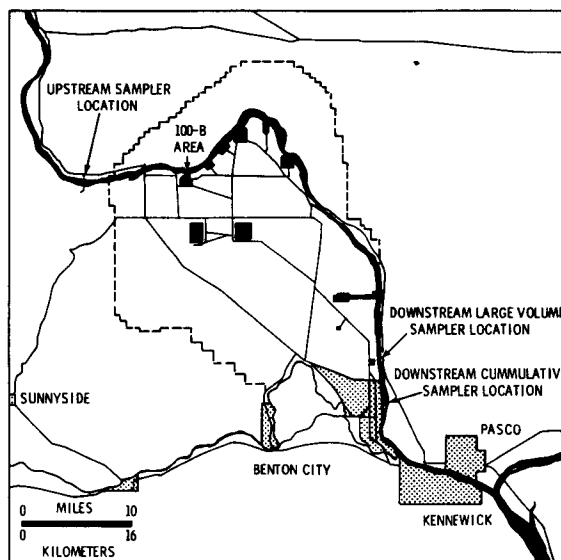


FIGURE 4. Columbia River Sampling Locations

of 50 ml/min. Particulates greater than  $0.45\ \mu\text{m}$  in diameter are removed from the sample stream by a series of filters and dissolved radionuclides are accumulated in an ion exchange resin column. The filtration media are exchanged at two-week intervals during which time approxi-

mately 1000 liters of river water have been pumped through the sampler. Samples are analyzed for gamma-emitting radionuclides,  $^{129}\text{I}$ , and plutonium. Analyses are performed by PNL as described in Appendix C.

## DISCUSSION OF RESULTS

Results of the analysis of Columbia River water samples for 1981 are summarized in Tables 3 and 4. For samples collected using the large-volume sampler, results are provided for both the particulate and dissolved components. The data show that in every case downstream radionuclide concentrations were well below the applicable DOE Concentration Guide.

Radionuclides consistently observed (i.e., in greater than 75% of the samples) both upstream and downstream of the Site were  $^3\text{H}$ ,  $^{90}\text{Sr}$ ,  $^{95}\text{Zr}$ ,  $^{95}\text{Nb}$ ,  $^{129}\text{I}$ ,  $^{137}\text{Cs}$ , U, and  $^{239,240}\text{Pu}$ . These radionuclides are either naturally occurring ( $^3\text{H}$ , U) or are present in worldwide fallout resulting from atmospheric nuclear tests and all are potentially associated with nuclear operations at Hanford. Of these radionuclides, concentrations were perceptibly higher only for  $^{90}\text{Sr}$  and  $^{129}\text{I}$  at the downstream location.

The Hanford contribution to  $^{129}\text{I}$  in the river is attributed to seepage of ground water from the unconfined aquifer underlying the Site into which process cooling water and low-level liquid wastes have been discharged at the 200 Areas. Figure 5 provides a comparison of  $^{129}\text{I}$  upstream and downstream of the Site during the past five years and shows the effect of river flow rate on the observed downstream levels. As shown in the figure, the differences in concentration between the upstream and downstream locations during 1981 were similar to previous years. The dose impact due to the net increase in  $^{129}\text{I}$  in the river water ( $3.9 \times 10^{-5}$  pCi/l) is negligible as discussed in the "Radiological Impact of Hanford Operations" section. Since tritium is also present in the Hanford aquifer, there is also some seepage of tritium into the river; however, even though the tritium detection capabilities were improved during 1981, any contribution to the river was too small to be accurately measured in the presence of the relatively high background concentration of tritium in the Columbia River.

There appeared to be a slight difference (0.09 pCi/l) in  $^{90}\text{Sr}$  concentrations downstream as compared to upstream samples during 1981. In fact, the downstream concentrations remained similar to previous years and the difference was the result of lower concentrations observed upstream. The upstream sample location was moved from the 100-B Area water intake to the Priest Rapids Dam at the beginning of 1981 (Figure 4) to avoid the possibility of residual radionuclides from past activities at B-Area affecting the upstream sample results. Whether the observed reduction in upstream concentration was the result of the sample location change, or was the result of biases introduced during sample handling and analysis, has not been positively determined. An investigation into the possible causes for the lower upstream concentrations and the potential implications of the apparent difference with respect to historical data is underway and will be reported in the next annual report. For the purposes of assessing the dose impact from Hanford operations (see "Radiological Impact of Hanford Operations" section) dose commitments were calculated using the observed  $^{90}\text{Sr}$  difference. Hanford sources for  $^{90}\text{Sr}$  are the liquid effluents from N Reactor (1.8 Ci during 1981) and possibly the relatively stagnant ground-water plumes in the retired production areas along the river.

Other radionuclides included in the tables were observed only occasionally in river water samples, and as a result, averaged annual concentrations could not be determined with any degree of certainty. Where it was possible, mean values are reported but are enclosed within brackets to denote the high degree of uncertainty associated with the result. Of these radionuclides,  $^{60}\text{Co}$  and  $^{131}\text{I}$  were observed more frequently in the downstream than in the upstream samples suggesting a possible contribution from Hanford. Hanford sources of  $^{60}\text{Co}$  are current effluents from N Reactor (0.6 Ci during 1981) and resuspension of  $^{60}\text{Co}$  deposited in the riverbed during past operations of the single-pass production reactors. Neither source is significant in consideration of the dispersion provided by the river. Downstream  $^{60}\text{Co}$  concentrations were similar to those observed in previous years and were well below the applicable DOE Concentration Guide.

Iodine-131 was observed at very low concentrations in a few downstream samples. Concentrations were similar to that observed in previous years, and were in every case only a small fraction of the applicable DOE Concentration Guide.<sup>(a)</sup>

N Reactor is the only likely source of  $^{131}\text{I}$  and the positive identifications coincided with extended periods of N Reactor operation. (N Reactor reported 2.4 Ci of  $^{131}\text{I}$  discharged to the river during 1981).

Because of the infrequent observation of  $^{131}\text{I}$  and  $^{60}\text{Co}$  in the river water, dose impacts in the "Radiological Impact of Hanford Operations" section were calculated based on 1981 releases from N Reactor.

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(a) Data collected using the large-volume sampler has been summarized in previous reports by combining the particulate and dissolved fractions. In this report (Tables 3 and 4), the particulate and dissolved fractions are reported separately. Although correct in a statistical sense, the former method is less sensitive in distinguishing small differences between sampling locations. A review of historical data showed current  $^{131}\text{I}$  concentrations to be similar to particulate and dissolved concentrations observed in previous years.

In addition to the radionuclides presented in Tables 3 and 4, river water samples were analyzed for a number of additional radionuclides of potential Hanford origin; however, none of the other radionuclides were positively identified in any sample.

To determine compliance with the Washington State Public Water Supply Standards (1977), cumulative water samples collected at the Richland Sanitary Water treatment plant were analyzed for gross alpha and gross beta radioactivity.

Washington state water quality standards require that radionuclide concentrations in drinking water not exceed 15 pCi/l of gross alpha activity and that the average annual concentration of beta particle and photon radioactivity from man-made radionuclides not produce an annual dose equivalent to the total body or to any internal organ greater than 4 mrem/yr.

Compliance with the 4 mrem/yr dose limitation is assured if the average annual concentration for gross beta activity, tritium, and strontium-90 is less than 50 pCi/l, 20,000 pCi/l and 8 pCi/l, respectively. Compliance with the state standard is demonstrated by comparing the above concentration limits with the applicable 1981 sampling data in Tables 4 and 5.

**TABLE 3.** Radionuclide Concentrations in Columbia River Water Upstream from Hanford Operations

Radionuclide <sup>(b)</sup>	No. of Analyses	No. Results >DL	Concentration, pCi/l ( $10^{-9}$ $\mu$ Ci/ml) <sup>(a)</sup>		
			Minimum Result <sup>(c)</sup>	Maximum Result	Average <sup>(d)</sup>
<sup>3</sup> H (Tritium)	12	12	77 $\pm$ 22	240 $\pm$ 20	170 $\pm$ 30
<sup>60</sup> Co	Particulate	26	(0.005)	0.013 $\pm$ 0.005	—
	Dissolved	26	(.011)	0.11 $\pm$ 0.02	—
<sup>89</sup> Sr		5	(0.09)	0.17 $\pm$ 0.06	—
<sup>90</sup> Sr		5	0.11 $\pm$ 0.05	0.18 $\pm$ 0.14	0.14 $\pm$ 0.04
<sup>95</sup> Zr	Particulate	26	(0.003)	0.056 $\pm$ 0.014	(<0.020 $\pm$ 0.007)
	Dissolved	26	(0.001)	0.088 $\pm$ 0.040	(<0.030 $\pm$ 0.010)
<sup>95</sup> Nb	Particulate	26	(0.001)	0.13 $\pm$ 0.01	0.037 $\pm$ 0.014
	Dissolved	25	(0.003)	0.11 $\pm$ 0.04	0.035 $\pm$ 0.011
<sup>106</sup> Ru	Particulate	26	(0.033)	0.057 $\pm$ 0.030	—
	Dissolved	26	(0.075)	0.23 $\pm$ 0.16	(<0.079)
<sup>129</sup> I	Dissolved	12	3.4 $\times 10^{-6}$ $\pm 6.8 \times 10^{-7}$	1.1 $\times 10^{-5}$ $\pm 2.2 \times 10^{-6}$	6.5 $\times 10^{-6}$ $\pm 1.1 \times 10^{-6}$
<sup>131</sup> I	Particulate	21	(0.007)	<DL	—
	Dissolved	17	(0.017)	<DL	—
<sup>137</sup> Cs	Particulate	26	(0.004)	0.042 $\pm$ 0.005	(<0.012 $\pm$ 0.005)
	Dissolved	26	(0.004)	0.10 $\pm$ 0.01	(<0.024 $\pm$ 0.011)
<sup>144</sup> CePr	Particulate	26	(0.007)	0.024 $\pm$ 0.012	—
	Dissolved	26	(0.026)	0.021 $\pm$ 0.015	—
Uranium		10	0.19 $\pm$ 0.07	0.54 $\pm$ 0.19	0.41 $\pm$ 0.08
<sup>238</sup> Pu	Particulate	4	(3 $\times 10^{-6}$ )	<DL	—
	Dissolved	4	(4 $\times 10^{-5}$ )	<DL	—
<sup>239,240</sup> Pu	Particulate	4	2.0 $\times 10^{-5}$ $\pm 6.2 \times 10^{-6}$	6.6 $\times 10^{-5}$ $\pm 6.0 \times 10^{-6}$	3.5 $\times 10^{-5}$ $\pm 2.1 \times 10^{-5}$
	Dissolved	4	9.0 $\times 10^{-5}$ $\pm 6.0 \times 10^{-5}$	3.4 $\times 10^{-4}$ $\pm 1.0 \times 10^{-4}$	1.8 $\times 10^{-4}$ $\pm 1.1 \times 10^{-4}$

>DL = Greater than the detection level, i.e., analysis of the sample yielded a positive identification.

<DL = Less than the detection level; radionuclide not identified in sample.

(a)Maximum and minimum results include  $\pm$  two sigma counting error. Averages include the two-standard error term (95% confidence interval).

(b)Radionuclides measured using the large-volume sampler show the particulate and dissolved fractions separately. Other radionuclides are based on samples collected by the cumulative sampler (see text).

(c)If minimum result was <DL, the average minimum detectable concentration is shown within parenthesis.

(d)If fewer than 75% of the results were >DL, the average was enclosed in parenthesis except that if fewer than 25% of the results were >DL, no average was calculated.

**TABLE 4. Radionuclide Concentrations in Columbia River Water Downstream from Hanford Operations**

Radionuclide <sup>(b)</sup>		No. of Analyses	No. Results >DL	Concentration, pCi/l (10 <sup>-9</sup> µCi/ml) <sup>(a)</sup>			Concentration Guide <sup>(e)</sup>
				Minimum Result <sup>(c)</sup>	Maximum Result	Average <sup>(d)</sup>	
<sup>3</sup> H	(Tritium)	12	12	120 ± 20	280 ± 10	200 ± 30	3,000,000
<sup>60</sup> Co	Particulate	26	17	(0.004)	0.020 ± 0.006	(<0.008)	30,000
	Dissolved	26	14	(0.011)	0.040 ± 0.013	(<0.018)	50,000
<sup>89</sup> Sr		5	1	(0.09)	0.13 ± 0.09	(0.09 ± 0.10)	
<sup>90</sup> Sr		5	5	0.16 ± 0.14	0.28 ± 0.06	0.23 ± 0.05	300
<sup>95</sup> Zr	Particulate	26	20	(0.004)	0.068 ± 0.013	(<0.020 ± 0.0004)	60,000
	Dissolved	26	19	(0.001)	0.043 ± 0.020	(<0.021 ± 0.005)	60,000
<sup>95</sup> Nb	Particulate	25	25	0.002 ± 0.002	0.11 ± 0.01	0.031 ± 0.010	100,000
	Dissolved	26	25	(0.003)	0.07 ± 0.02	0.029 ± 0.008	100,000
<sup>106</sup> Ru	Particulate	26	2	(0.028)	0.025 ± 0.024	—	10,000
	Dissolved	26	7	(0.066)	0.010 ± 0.06	(<0.066)	10,000
<sup>129</sup> I	Dissolved	12	12	8.8 x 10 <sup>-6</sup> ±2.6 x 10 <sup>-6</sup>	1.3 x 10 <sup>-4</sup> ±1.8 x 10 <sup>-5</sup>	4.5 x 10 <sup>-5</sup> ±2.2 x 10 <sup>-5</sup>	60
<sup>131</sup> I	Particulate	22	2	(0.006)	0.011 ± 0.006	—	60,000
	Dissolved	16	5	(0.015)	0.064 ± 0.010	(<0.023)	300
<sup>137</sup> Cs	Particulate	26	20	(0.004)	0.042 ± 0.006	(<0.011 ± 0.004)	40,000
	Dissolved	26	13	(0.004)	0.12 ± 0.01	(<0.027 ± 0.014)	20,000
<sup>144</sup> CePr	Particulate	26	5	(0.009)	0.016 ± 0.010	—	10,000
	Dissolved	26	1	(0.021)	0.016 ± 0.015	—	10,000
Uranium		12	12	0.26 ± 0.09	0.54 ± 0.19	0.42 ± 0.07	20,000
<sup>238</sup> Pu	Particulate	4	0	(4 x 10 <sup>-6</sup> )	<DL	—	30,000
	Dissolved	4	0	(2 x 10 <sup>-5</sup> )	<DL	—	5,000
<sup>239, 240</sup> Pu	Particulate	4	4	2.5 x 10 <sup>-5</sup> ±4.0 x 10 <sup>-6</sup>	8.0 x 10 <sup>-5</sup> ±8.0 x 10 <sup>-6</sup>	5.4 x 10 <sup>-5</sup> ±2.3 x 10 <sup>-5</sup>	30,000
	Dissolved	4	4	6.4 x 10 <sup>-5</sup> ±4.0 x 10 <sup>-5</sup>	1.5 x 10 <sup>-4</sup> ±8.0 x 10 <sup>-5</sup>	1.1 x 10 <sup>-4</sup> ±4.7 x 10 <sup>-5</sup>	5,000

>DL = Greater than the detection level, i.e., analysis of the sample yielded a positive identification.

<DL = Less than the detection level; radionuclide not identified in sample.

(a) Maximum and minimum results include ± two sigma counting error. Averages include the two-standard error term (95% confidence interval).

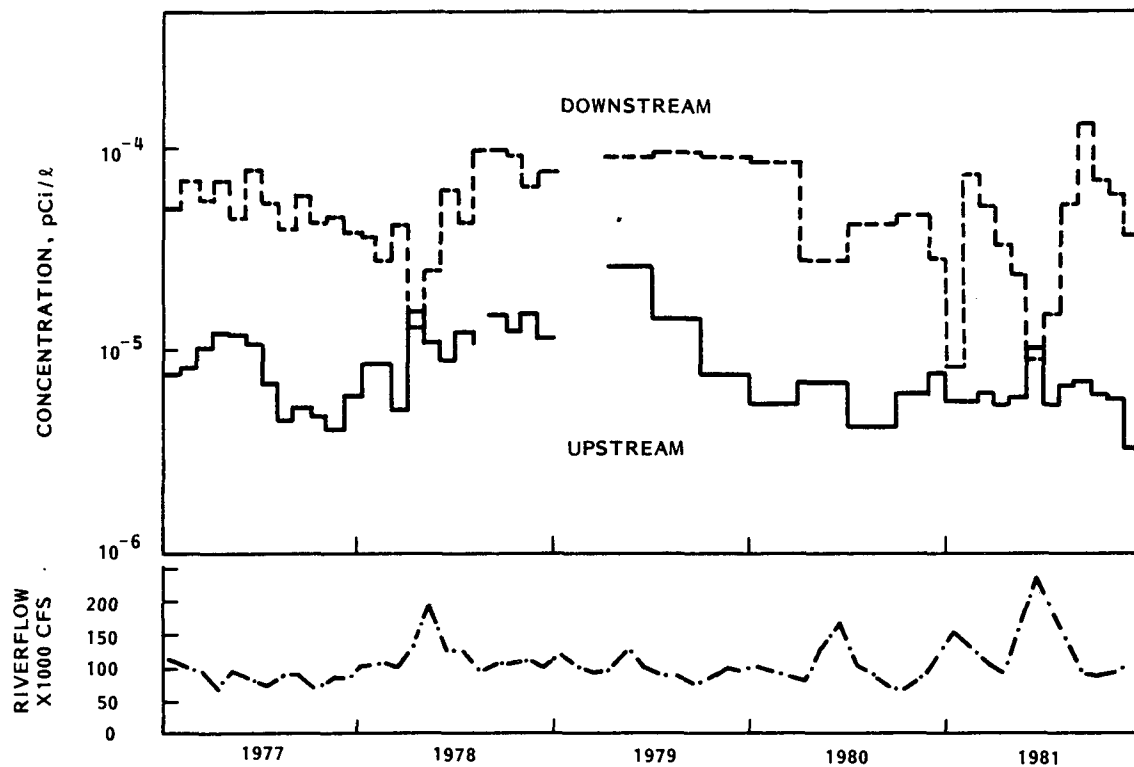
(b) Radionuclides measured using the large-volume sampler show the particulate and dissolved fractions separately. Other radionuclides are based on samples collected by the cumulative sampler (see text).

(c) If minimum result was <DL, the average minimum detectable concentration is shown within parenthesis.

(d) If fewer than 75% of the results were >DL, the average was enclosed in parenthesis except that if fewer than 25% of the results were >DL, no average was calculated.

(e) From DOE Order 5480.1 (see Appendix A).





**FIGURE 5.** Iodine-129 in Columbia River Water, 1977-1981

**TABLE 5.** Radiological Analyses of Richland Drinking Water

Measurement	No. of Samples	No. of Result >DL	Concentration, pCi/l ( $10^{-9}$ $\mu$ Ci/ml)			
			Maximum	Minimum	Average(a)	State Standard
Gross Alpha	46	19	$5.1 \pm 1.2$	<DL	$(0.67 \pm 0.30)$	15
Gross Beta	46	8	$13 \pm 5$	<DL	(5.2)	50

(a) Fewer than 75% of the Gross Alpha results were above detection level. Fewer than 25% of the Gross Beta results were above detection level.

## COLUMBIA RIVER MONITORING—NONRADIOLOGICAL

The Columbia River from Grand Coulee Dam to the Washington-Oregon border, a stretch that includes the Hanford reach, has been designated Class A, or Excellent, by the Washington State Department of Ecology. This designation requires that industrial uses of the river be compatible with all other uses of the water, including drinking water, recreation, and wildlife, as indicated in Appendix A.

Wastewater from Hanford activities is discharged at eight points along the Hanford reach of the Columbia River. These discharges consist of backwash water from water intake screens, cooling water, water storage tank overflow, and fish laboratory wastewater and each discharge point is identified in an existing National Pollutant Discharge Elimination System (NPDES) permit issued by the EPA. Effluents from each of these outfalls are routinely monitored as required by their NPDES permit and reported to the EPA.

Measurements of several Columbia River water quality parameters were conducted routinely during 1981 both upstream and downstream of the Hanford Site to monitor any effects on the river that may be attributable to Hanford discharges and to determine compliance with the Class A designation requirements. The measurements indicated that Hanford operations had a minimal, if any, impact on the quality of the Columbia River water.

### SAMPLE COLLECTION AND ANALYSIS

Grab samples of Columbia River water were collected weekly at the Vernita Bridge (upstream of Hanford) and at Richland (downstream). Turbidity and pH determinations were made in the field and the samples then delivered to the Hanford Environmental Health Foundation (HEHF) laboratory for additional water quality parameter analyses.

Columbia River water quality measurements were also performed by the United States Geological Survey (USGS) as part of their national river water quality monitoring program. The USGS samples were collected every other month at the same upstream and downstream locations. Analyses were performed at the USGS laboratory in Denver, Colorado for numerous physical, biological, and chemical constituents. The USGS was also contracted to provide continuous temperature and flow-rate monitoring of the river upstream and downstream of the Site.

### DISCUSSION OF RESULTS

One of the most likely parameters of the Columbia River to be affected by Hanford operations is water temperature. Figure 6 illustrates the average monthly temperatures upstream and downstream of the Hanford Site during 1981. Figure 7 shows the average monthly flow

rate of the Columbia River. N Reactor, the only Hanford facility capable of affecting the river temperature, operated only intermittently during 1981. No definite relationship between

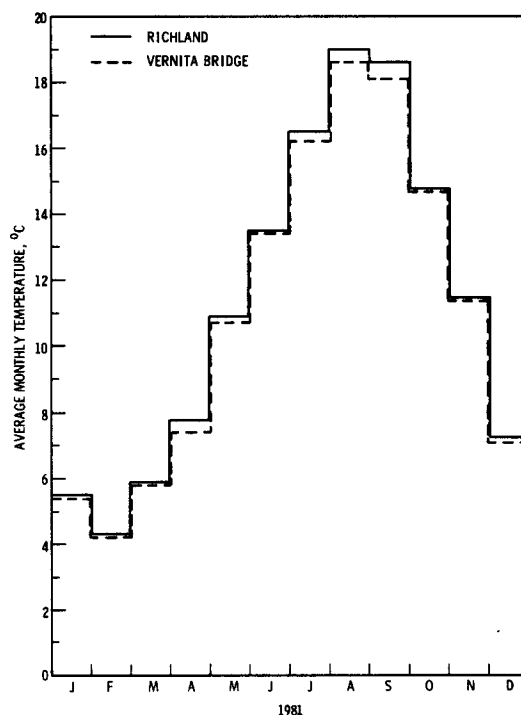
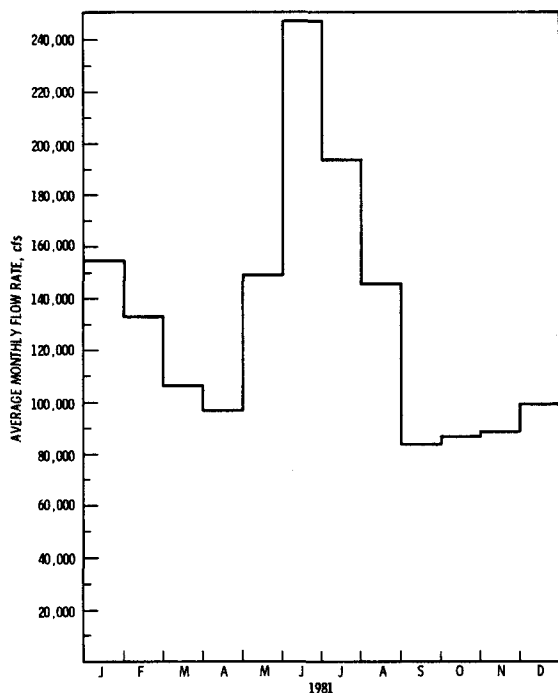


FIGURE 6. Average Monthly Water Temperature at Richland and Vernita



**FIGURE 7.** Average Monthly Columbia River Flow Rate at Priest Rapids

upstream and downstream temperatures, flow rate, and the time when N Reactor was operating is apparent, indicating that any contribution of heat from N Reactor effluents is, at best, a small fraction of the minor heat increases observed. Insolation, therefore, appears to be the major cause of water temperature increase along the Hanford reach.

Table 6 summarizes the results of analyses conducted on water samples collected at Vernita and Richland during 1981. All pH measurements were within the 6.5 to 8.5 standard with the exception of a single determination in which both the upstream and downstream pH was 6.0. All dissolved oxygen results were above the 8-mg/l minimum specified by the state. Nitrate concentrations at both locations were far below the 45-mg/l standard throughout 1981. No significant difference was noted in the upstream versus downstream turbidity measurements; hence, the values observed during 1981 are assumed to represent normal background and do not exceed the state standard. While the total and fecal coliform levels were below applicable levels, the results observed during 1981 indicate an increase in the downstream samples. This increase has been noted consistently in past years and is attributed to agricultural drainage and wildlife. Several outfalls of return irrigation water enter the Columbia River along the Hanford reach. The Hanford stretch also serves as a refuge for large populations of waterfowl, especially in the fall and winter.

Results of the USGS analyses also indicate no discernible impact on the quality of Columbia River water as a result of Hanford activities. Where analyses duplicate those performed onsite, the results are generally comparable and provide additional verification of Hanford compliance with the State's Class A water quality standards.

**TABLE 6.** Columbia River Water Quality Data

Analysis	Units	Vernita Bridge (Upstream)				Richland (Downstream)				
		No. of Samples	Maximum	Minimum	Annual Average <sup>(a)</sup>	No. of Samples	Maximum	Minimum	Annual Average <sup>(a)</sup>	State Standard <sup>(b)</sup>
Environmental Surveillance Sampling Program										
NO <sub>3</sub> <sup>-</sup>	mg/l	51	0.53	<0.1	0.19 ± 0.03	51	0.60	<0.1	0.19 ± 0.04	45
pH	units	40	7.7	6.0		40	7.8	6.0		8.5 - 6.5
Turbidity	NTU <sup>(c)</sup>	42	4.5	1.1	2.1 ± 0.3	45	7.5	1.1	2.6 ± 0.4	5+background
Dissolved O <sub>2</sub>	mg/l	49	16	8.0	11.4 ± 0.5	48	15.8	8.0	11.8 ± 0.5	8 (minimum)
Total Coliforms	#/100 ml	12	>2400	14.	79 <sup>(d)</sup>	12	350	33	180 <sup>(d)</sup>	
Fecal Coliforms	#/100 ml	12	49	<2.0	2.0 <sup>(d)</sup>	12	130	<2.0	8 <sup>(d)</sup>	100
BOD <sup>(e)</sup>	mg/l	12	15	1.1	3.2 ± 2.2	12	11	<.5	2.4 ± 1.7	
USGS Sampling Program										
Turbidity	NTU <sup>(c)</sup>	6	3.3	0.7	1.7 ± 0.7	5	4.0	0.9	2.0 ± 1.0	5+background
Dissolved Oxygen	mg/l	5	12	9.8	11 ± 1	4	12.4	9.6	11 ± 1	8 (minimum)
pH (lab)	units	6	8.1	7.5		5	8.2	7.5		8.5 - 6.5
Hardness,as CaCO <sub>3</sub>	mg/l	6	74	60	66 ± 4	5	68	61	64 ± 3	
Coliform, fecal	#/100 ml	5	3	<1	<1.4 ± 0.8	4	3	<1	<2.5 ± 1.0	100
Nitrogen, total as N	mg/l	5	0.63	0.40	0.55 ± 0.08	5	0.69	0.36	0.48 ± 0.12	
Phosphorus, total	mg/l	6	0.07	0.03	0.05 ± 0.02	5	0.10	0.03	0.05 ± 0.03	

(a) Average ± two standard error term (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 methods

TABLE 6. Columbia River Water Quality Data (contd)

Analysis	Units	Vernita Bridge (Upstream)				Richland (Downstream)			
		No. of Samples	Maximum	Minimum	Annual Average <sup>(a)</sup>	No. of Samples	Maximum	Minimum	Annual Average <sup>(a)</sup>
Calcium, dissolved	mg/l	6	21	18	19 ± 1	5	20	18	19 ± 1
Magnesium, dissolved	mg/l	6	5.2	3.6	4.3 ± 0.5	5	4.5	3.9	4.2 ± 0.3
Sodium, dissolved	mg/l	5	2.4	1.2	1.7 ± 0.5	5	2.6	2.0	2.3 ± 0.3
Potassium, dissolved	mg/l	6	4.0	0.7	1.3 ± 1.0	5	0.9	0.8	0.84 ± 0.05
Chloride, dissolved	mg/l	6	1.5	0.8	1.1 ± 0.3	5	1.8	1.0	1.3 ± 0.3
Sulfate, dissolved	mg/l	6	17	<5	11 ± 4	5	15	6.0	11 ± 3
Fluoride, dissolved	mg/l	6	0.5	0.1	0.17 ± 0.13	5	0.2	0.1	0.84 ± 0.04
Silica, dissolved	mg/l	6	5.4	3.5	4.7 ± 0.7	5	5.6	3.5	4.7 ± 0.8
Arsenic, dissolved	µg/l	5	2	1	1.4 ± 0.5	5	3	0	1.6 ± 1.0
Cadmium, total <sup>(f)</sup>	µg/l	5	1	0	0.6 ± 0.5	5	2	0	0.8 ± 0.7
Chromium, total	µg/l	5	20	0	8.0 ± 7.5	5	20	0	8.0 ± 7.5
Cobalt, total	µg/l	5	8	0	2.4 ± 3.0	5	2	0	0.6 ± 0.8
Copper, total	µg/l	6	180	6	43 ± 55	5	110	8	47 ± 47
Iron, total	µg/l	6	210	70	125 ± 40	5	460	90	230 ± 150
Lead, total	µg/l	6	61	1	20 ± 19	5	60	2	21 ± 21
Zinc, total	µg/l	6	70	30	43 ± 12	5	50	20	42 ± 12
Nitrogen as NO <sub>3</sub>	mg/l	5	2.8	1.8	2.5 ± 0.4	5	3.1	1.6	2.1 ± 0.5
Mercury, total	µg/l	5	0.8	0.1	0.5 ± 0.3	5	0.7	0.1	0.3 ± 0.3
Manganese, total	µg/l	6	20	10	15 ± 4	5	20	10	14 ± 5

(a)Average ± two standard error term (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 methods

## GROUND WATER

Since 1943, large volumes of process cooling water and low-level radioactive liquid wastes have been released to the ground via cribs, trenches, and ponds. Liquid wastes discharged to the ground percolate downward and laterally and eventually enter the unconfined aquifer underlying the Hanford Site. As the radionuclides and other contaminants move in the ground water their concentrations are reduced by ion exchange, diffusion, radioactive decay, and hydrodynamic dispersion.

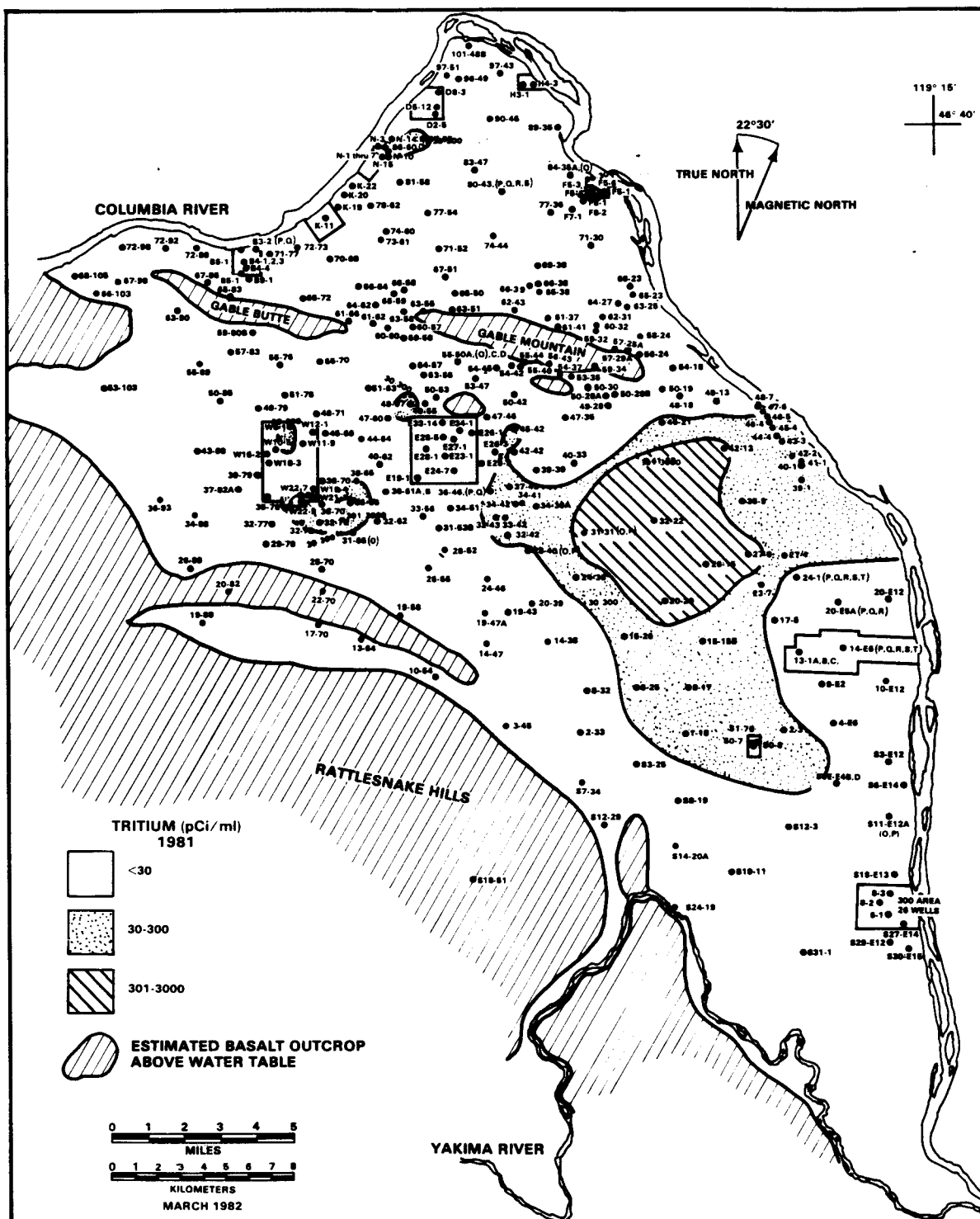
The contaminants in the Hanford ground water are monitored at a large number of locations on the site, and the results of the monitoring program are provided in an annual report *Radiological Status of the Ground Water Beneath the Hanford Site*. Results of ground-water monitoring for 1981 (Eddy, Cline, and Prater, 1982) show that water discharged to the ground in the 200 Areas has gradually migrated to the Columbia River and that trace quantities of tritium and  $^{129}\text{I}$  from past releases in the 200 Areas are entering the river. The overall effect of the ground-water contribution to radioactivity in the Columbia River is small as discussed in the Columbia River sections of this report.

Contaminants in the ground water are sampled from wells, and analytical results of the samples provide information concerning the distribution and movement of radionuclides and other contaminants in the ground water. Figure 8 shows the locations of the ground-water sampling wells and provides tritium concentration isopleths calculated based on results of samples collected during 1981 (Eddy, Cline, and Prater, 1982). In addition to tritium, data are also collected for  $^{106}\text{Ru}$ ,  $^{90}\text{Sr}$ ,  $^{129}\text{I}$ , U,  $\text{NO}_3$ , F, and  $\text{Cr}^{+6}$ . Samples are analyzed by the USGS, UST and PNL.

As shown in Figure 8 the contaminated Hanford ground water has migrated slowly in an east to

southeast direction from the 200 Areas. Although the ground water has reached the Columbia River, except for trace quantities of  $^{129}\text{I}$ , any changes in radionuclide concentrations in the Columbia River attributable to this source have been undetectable.

The figure also shows several small ground-water mounds associated with past operational activities at the old production reactor sites and past and current activities at N Reactor. Radionuclides observed in the Columbia River potentially attributable to these sources are  $^{131}\text{I}$  and  $^{90}\text{Sr}$  as discussed in the "Columbia River Monitoring—Radiological" section of this report.



**FIGURE 8.** Tritium Distribution in Unconfined Ground Water

## FOODSTUFFS

Several types of foodstuffs, including milk, beef, fruit, and leafy vegetables were collected from strategic locations in the Hanford Site's environs during 1981. The samples were analyzed for  $^{90}\text{Sr}$ ,  $^{137}\text{Cs}$ , and  $^{131}\text{I}$  (milk only). These radionuclides are used for assessing dose impact from Hanford operations and also serve as sensitive indicators of the presence of any Hanford-generated radioactive material in the environment. Samples of foodstuffs were collected primarily from locations in a generally downwind direction from the Site, i.e., to the south and east. Control (background) samples were also collected from a generally upwind location to provide an indication of the radionuclide concentrations attributable to worldwide fallout.

Samples collected during 1981 indicated there was no apparent contribution to radioactivity in locally produced foodstuffs as a result of Hanford Site operations. Strontium-90 and Cesium-137 were found to be present in most of the samples; however, the observed concentrations were at worldwide fallout levels and thus were not attributed to Hanford operations. Iodine-131, which had been observed in local milk samples collected during 1980 shortly after a foreign atmospheric nuclear test, was not detected in any of the 150 milk samples collected during 1981.

### MILK

Although radionuclides of Hanford origin have not been identified in samples of locally produced milk in recent years, dose-impact assessment models based on reported effluents from site operations and assumed environmental dispersion/concentration parameters have indicated that the irrigation/deposition-grass-cow-milk pathway represents a primary potential offsite dose pathway (Sula and Blumer 1981). Even though the calculated doses are extremely low by applicable standards, sampling of this pathway is nevertheless routinely performed to monitor the current radionuclide levels in local milk and to detect any contributions attributable to Site operations.

Samples of raw, whole milk were collected on a two-week frequency at several farms in a generally downwind direction of the Site (Locations 1 through 5, Figure 9) as well as from a farm somewhat distant and upwind of the Site (Location 6). All samples were analyzed for  $^{131}\text{I}$  and  $^{137}\text{Cs}$ . Strontium-89 and Strontium-90 analyses were also performed on either a monthly or quarterly basis as indicated in Table 7. Analysis of all samples was performed using methods described in Appendix C.

As shown in Table 7, there was no indication of the presence of  $^{131}\text{I}$  in milk samples collected during 1981. Strontium-89 and strontium-90 were

observed in several of the samples collected from locations both upwind and downwind of the Site at concentrations normally expected as a result of worldwide fallout. Cesium-137 was undetectable in all but two of the samples analyzed. The two positive identifications were at extremely low concentrations, near the detection level, and were attributed to the statistical nature of the analytical process.

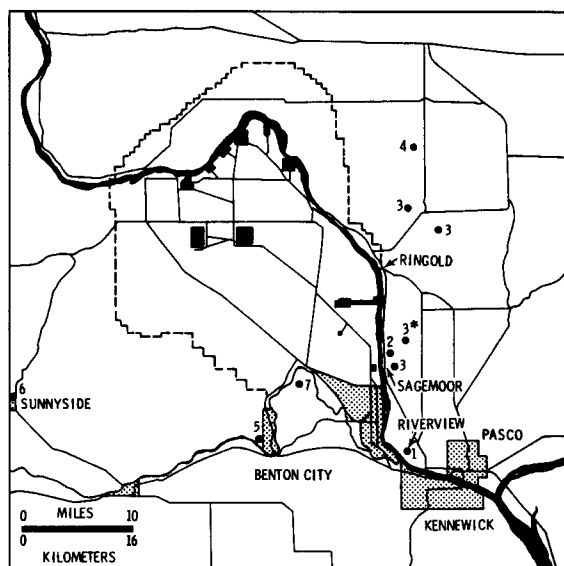


FIGURE 9. Foodstuffs Sampling Locations (Referenced in Tables 7 and 8)



**TABLE 7. Radionuclides in Milk Samples**

Location	Map Number	Concentration, pCi/l <sup>(a)</sup>					
		<sup>131</sup> I			<sup>137</sup> Cs		
		Fraction of Results >DL	Maximum	Average <sup>(b)</sup>	Fraction of Results >DL	Maximum	Average
Riverview	1	0/26	<DL	(-0.11 ± 0.08)	1/26	14 ± 7.9	(-0.56 ± 2.3)
Sagemoor	2	0/24	<DL	(-0.06 ± 0.08)	0/24	<DL	(-0.72 ± 2.7)
Columbia Basin Composite	3	0/26	<DL	(-0.04 ± 0.07)	0/26	<DL	(-0.60 ± 2.5)
Wahluke	4	0/25	<DL	(-0.10 ± 0.07)	0/25	<DL	(-1.2 ± 2.0)
Benton City	5	0/26	<DL	(-0.07 ± 0.07)	1/26	8.1 ± 7.5	(-0.80 ± 2.6)
Sunnyside	6	0/26	<DL	(-0.05 ± 0.08)	0/26	<DL	(1.8 ± 2.3)

Location	Map Number	<sup>89</sup> Sr			<sup>90</sup> Sr		
		Fraction of Results >DL	Maximum	Average	Fraction of Results >DL	Maximum	Average
Riverview	1	1/4	2.1 ± 1.3	(0.73 ± 1.22)	3/4	2.0 ± 0.6	1.5 ± 0.6
Sagemoor	2	4/11	2.4 ± 2.3	0.91 ± 0.65	8/11	2.0 ± 1.4	1.1 ± 0.5
Columbia Basin Composite	3				2/4	1.7 ± 0.63	1.2 ± 0.6
Wahluke	4				2/4	1.5 ± 0.6	1.3 ± 0.5
Benton City	5				3/4	2.0 ± 0.6	1.3 ± 0.7
Sunnyside	6	1/12	1.4 ± 1.3	0.59 ± 0.57	7/12	1.9 ± 0.6	0.96 ± 0.4

>DL = Greater than the detection level, i.e. analysis of the sample yielded a positive identification.

<DL = Less than the detection level; radionuclide not identified in sample.

(a) Individual results shown with the ± two sigma counting error term. Averages shown with the ± two standard error term (95% confidence interval)

(b) Average was enclosed within parenthesis if the ± two standard error term shown was greater than the indicated concentration.

No entry in table indicates no analysis was performed.

## BEEF

Samples of locally produced beef were collected from three locations and analyzed for <sup>90</sup>Sr and <sup>137</sup>Cs. Samples were obtained from a farm in the Riverview area (Location 1, Figure 9), and one sample each was obtained from farms located east of the Fast Flux Test Facility (FFTF) Site (Location 3\*), and in the Horn Rapids area (Location 7). The samples were analyzed by UST using methods described in Appendix C. Neither <sup>90</sup>Sr nor <sup>137</sup>Cs was identified in any of the samples.

## LEAFY VEGETABLES

Leafy vegetables provide a rather large surface area for the foliar deposition and retention of airborne materials and thus are sampled to provide an indication of radionuclide concentra-

tions in locally grown food crops as a result of the airborne transport of Site-generated radionuclides. Samples of leafy vegetables (spinach, leaf lettuce, turnip greens, and mustard greens) were obtained during the growing season from several gardens both near to and distant from the Site. These samples were composed of random mixtures of the edible portions of the various leafy vegetables grown at the designated sampling locations. Several samples were collected at different times during the season at the Riverview and Benton City locations; whereas, single samples were collected at the other locations.

Samples were analyzed for <sup>90</sup>Sr and <sup>137</sup>Cs using methods described in Appendix C and results of the analyses are shown in Table 8. As anticipated, <sup>90</sup>Sr was observed in most of the samples but with no difference between downwind and back-

**Table 8. Radionuclides in Leafy Vegetables**

Location(b)	No. of Samples	Concentration, pCi/g, wet weight(a)			
		<sup>90</sup> Sr		<sup>137</sup> Cs	
		Maximum	Average(c)	Maximum	Average(c)
Riverview	4	0.05 ± 0.01	0.02 ± 0.03	0.06 ± 0.03	(0.008 ± 0.037)
Sagemoor Vicinity	1		N.A.		(-0.006 ± 0.02)
Ringold	1		0.006 ± 0.003		(-0.007 ± 0.02)
Benton City	3	0.013 ± 0.001	0.01 ± 0.001	<DL	(-0.002 ± 0.016)
Othello	1		0.005 ± 0.001		(-0.007 ± 0.02)
Moses Lake	1		0.007 ± 0.0009		(-0.01 ± 0.02)
Umatilla	1		0.01 ± 0.001		(-0.005 ± 0.01)
Walla Walla	1		0.02 ± 0.001		(-0.009 ± 0.02)
Sunnyside	1		(0.001 ± 0.001)		(-0.004 ± 0.02)

<DL = less than detection level, radionuclide not identified in samples.

N.A. = No analysis performed.

(a) Individual results shown with the ± two sigma counting error. Averages include the two-standard error term (95% confidence interval).

(b) Locations shown in Figure 2 or 9.

(c) Individual results and averages were enclosed in parenthesis if the associated uncertainty was equal to or greater than the indicated concentration.

ground locations. Cesium-137 was identified at near background detection levels in one of the 14 samples. The relatively high coefficient of error associated with the results at these low levels (50%) and the failure to detect <sup>137</sup>Cs in any of the other three samples collected from the same location indicates the single positive identification was within the statistical variation of the analytical process.

#### FRUIT

Fruit does not accumulate airborne radionuclides as efficiently as do leafy vegetables.

Nevertheless, samples of several varieties of fruit were collected from a downwind location near the Site boundary and at a distant upwind location to detect any possible Hanford contribution to radionuclide concentrations in this important commercial crop.

Separate samples were obtained of cherries, plums, peaches, pears, grapes, and apples at their respective picking times. Each sample was analyzed for <sup>137</sup>Cs. There were no positive identifications of <sup>137</sup>Cs in any of the samples analyzed.



## WILDLIFE

The Hanford Site serves as a refuge for migratory waterfowl, upland gamebirds, and a variety of mammals. These wildlife have unrestricted access to areas near Site facilities (primarily wastewater ponds) that contain low levels of radionuclides attributable to Site operations. The number of animals that visit these areas is small compared to the total population in the area, and, as a result, human consumption of an animal from one of the sampling locations is unlikely. Sampling is performed routinely in the vicinity of operating areas where the highest potential exists for uptake of radionuclides by wildlife. These samples help provide an estimate of the maximum potential dose impact in the event of the incidental human consumption of onsite game.

Fish sampling is also performed routinely along the Hanford Reach of the Columbia River. Results provide an indication of the average radionuclide concentrations attributable to Hanford in local fish so that the potential dose impact to humans for this pathway can be evaluated.

Analytical results of terrestrial wildlife samples collected during 1981 were very similar to those observed in recent previous years, and samples of fish collected from the Columbia River along the Hanford Site showed no discernible difference in radionuclide concentration compared to samples collected upstream of the site. The dose that would be received by a person following consumption of one of the sampled species with the maximum radionuclide concentration observed in 1981 would be well within the applicable Department of Energy (DOE) dose standard in Appendix A.

### DEER

The routine method for sampling deer at Hanford consists of analyzing deer that have been accidentally killed by vehicles on Hanford-Site roads. Although deer tend to have definable home ranges, long-distance movements within or off the Site are common; therefore, the specific foraging locations for the sampled deer are unknown.

Table 9 shows results of samples of deer muscle from road kills analyzed for  $^{137}\text{Cs}$ . Analysis of the

samples was performed using methods described in Appendix C. For comparison, results are also included for five deer that were collected intentionally during 1981 as part of a special study to estimate the maximum concentrations of  $^{137}\text{Cs}$  that could be present in deer foraging at specific locations on the Hanford Site. The five deer were sampled after they had been observed (using radiotelemetry techniques) to forage for an extended period of time in the vicinity of Gable Pond or B Pond—the onsite areas with the highest probability for radio-

**TABLE 9. Cesium-137 in Deer Muscle**

Sample	No. of Samples	Number of >DL	Concentration pCi/g, wet weight <sup>(a)</sup>		
			Maximum	Minimum	Average
Random (road kills)	6	1	0.44 ± 0.03	<DL	[0.08 ± 0.15]
Specially Selected Locations <sup>(b)</sup>	5	3	1.4 ± 0.2	<DL	0.6 ± 0.5

[ ] = Average significantly biased by single high result.

>DL = Greater than the detection level, i.e., analysis of the sample yielded a positive identification.

<DL = Less than detection level, radionuclide not identified in sample.

(a) Individual results shown with the ± two sigma analytical uncertainty term. Average shown with the ± two standard error term (95% confidence interval).

(b) Deer were collected as part of a special study currently underway. Sampled deer were known (through radiotelemetry monitoring) to have resided in the immediate vicinity of the Gable Mountain Pond or B-Pond Area for three months prior to sampling.

nuclide uptake by foraging animals.(a)

Results in Table 9 generally show that the road-killed deer had lower  $^{137}\text{Cs}$  concentrations than the specially selected deer. Except for a single sample,  $^{137}\text{Cs}$  was not identified in the road kills. The single, positive result (0.44 pCi/g) was similar to that observed in the special deer samples.

An individual who consumed the entire edible portion of a deer (estimated to be 45 kg of meat) with a  $^{137}\text{Cs}$  concentration equal to the highest concentration observed during 1981 (1.4 pCi/g) would be expected to receive a calculated dose commitment of about 4 millirems to the total body, i.e., less than 1% of the applicable DOE dose standard in Appendix A.(b)

## WATERFOWL

Waterfowl samples (ducks and geese) were collected along the Columbia River in the vicinity of the 100-N and 300 Areas as well as from each of

(a) The study of specially selected deer is continuing and results reported here are preliminary in nature. Additional discussion of the special samples will be provided in a final report on the study expected to be issued in September 1982.

(b) Dose calculation methods are described in Appendix E.

the six onsite ponds shown in Figure 10. Approximately 0.5-kg samples of breast meat from each bird were analyzed for  $^{137}\text{Cs}$  using methods described in Appendix C. Results are shown in Table 10.

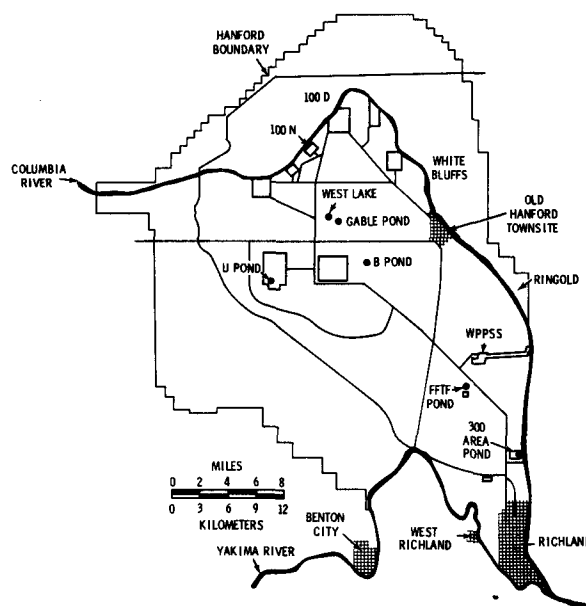


FIGURE 10. Onsite Waste Water Ponds

TABLE 10. Cesium-137 in Muscle Tissue of Waterfowl

Location	Type	Number Sampled	Number of Results >DL	Concentration pCi/g, wet weight <sup>(a)</sup>		
				Maximum	Minimum	Average <sup>(b)</sup>
100-Area	Columbia River	2	0	<DL	<DL	(0.006 ± 0.037)
	Columbia River	3	1	45 ± 1	<DL	[15 ± 30]
200 Area	B-Pond	5	1	130 ± 2	<DL	[29 ± 48]
	U-Pond	7	6	280 ± 3	<DL	110 ± 80
	Gable Pond	5	3	71 ± 1	<DL	29 ± 27
	West Lake	4	3	50 ± 1	<DL	23 ± 26
300 Area	Columbia River	6	1	0.03 ± 0.02	<DL	(0.011 ± 0.015)
	Pond	3	0	<DL	<DL	(0.016 ± 0.056)

[ ] = Average significantly biased by single high result.

>DL = Greater than detection level, i.e., analysis of the sample yielded a positive identification.

<DL = less than detection level, radionuclide not identified in samples.

(a) Individual results shown with the ± two sigma counting error term. Averages include the two-standard error term (95% confidence interval).

(b) Average was enclosed in parenthesis if the associated two standard error was greater than the indicated concentration.

With the exception of one duck collected near the 100-N Area, samples taken from the Columbia River did not contain detectable levels of  $^{137}\text{Cs}$ . The duck sample collected near 100-N Area contained  $^{137}\text{Cs}$  at a concentration typical of those birds collected from waste-water ponds in the 200 Areas.

Samples collected from waste-water ponds near the 200 Areas showed an accumulation of  $^{137}\text{Cs}$  in tissues at levels similar to that observed in recent years. The maximum concentration of  $^{137}\text{Cs}$  (280 pCi/g) was observed in a duck collected from U-Pond.

Because the number of waterfowl frequenting the sampling locations is an extremely small fraction of the total local population available for offsite hunting, it is unlikely that a person would consume a bird immediately after the bird had spent an extended time at an onsite pond.<sup>(a)</sup> Nevertheless, if an individual were to consume 0.5 kg of meat at the highest observed concentration (280 pCi/g), a dose commitment of about 10 mrem total body or 2% of the applicable DOE dose standard in Appendix A would be received.<sup>(b)</sup>

## UPLAND GAME BIRDS

Upland gamebirds including chuckar, dove, pheasant, and quail were collected on the Hanford Site during 1981. Samples were collected in the vicinity of the 100, 200, and 300 Areas as well as in the White Bluffs area across the river from 100-F (see Figure 10). A minimum of three samples was scheduled for collection at each location (the 100 Areas were subdivided into six locations for a total of 18 birds and the 200 Areas were subdivided into west and east areas for a total of six birds). In several cases, fewer than the scheduled numbers of samples were obtained because enough birds were not available.

Samples of breast meat from each bird were analyzed for  $^{137}\text{Cs}$  and  $^{60}\text{Co}$ , using methods described in Appendix C. Results are shown in Table 11.

(a) The effective half-life of  $^{137}\text{C}$  in waterfowl tissue (i.e., the time it takes for  $^{137}\text{Cs}$  in waterfowl meat to decrease by a factor of two) is about 14 days (Halford 1978).

(b) Dose calculation methods are described in Appendix E.

**TABLE 11.** Cobalt-60 and Cesium-137 in Upland Gamebirds

		Concentration pCi/g, wet weight <sup>(a)</sup>					
Location/ Type	No. of Samples	<sup>60</sup> Co			<sup>137</sup> Cs		
		No. of Results >DL	Maximum	Average	No. of Results >DL	Maximum	Average
<b>100 Areas</b>							
Quail	6	2	4.3 ± 0.6	[1.5 ± 1.5]	4	120 ± 8	[22 ± 39]
Dove	1	1	—	4.0 ± 0.2	1	—	0.30 ± 0.09
Pheasant	12	0	<DL	(0.003 ± 0.009)	4	0.05 ± 0.04	0.02 ± 0.01
<b>200 Areas</b>							
Chuckar	3	0	<DL	(0.00 ± 0.04)	1	0.14 ± 0.06	(0.07 ± 0.17)
Pheasant	1	0	<DL	(0.01 ± 0.03)	0	—	(0.01 ± 0.02)
<b>300 Area</b>							
Quail	1	0	—	(0.04 ± 0.04)	0	—	(0.01 ± 0.03)
<b>White Bluffs</b>							
Pheasant	1	0	—	(0.00 ± 0.03)	0	—	(0.01 ± 0.02)

[ ] = Average significantly biased by single high result.

>DL = Greater than the detection level; i.e., analysis of the sample yielded a positive identification.

<DL = Less than the detection level; radionuclide not identified in sample.

(a) Individual results shown with the ± two sigma analytical uncertainty term. Averages shown with the ± two standard error term (95% confidence interval).

(b) Average enclosed in parenthesis if the ± two standard error term was greater than the indicated concentration.

All results, except for two quail and one dove collected from the 100-N Area, were either below the detection level or were in the range attributable to worldwide fallout. The highest radionuclide concentrations (120 pCi  $^{137}\text{Cs}$ /g and 4.3 pCi  $^{60}\text{Co}$ /g) were observed in a quail collected near the 100-N Trench. The potential dose commitment resulting from consumption of 0.1 kg of meat at these concentrations is calculated to be less than 1 mrem to the total body.<sup>(a)</sup> Subsequent to the collection of the samples, a permanent solid cover has been installed over the 100-N Trench. The cover is expected to restrict the future access of wildlife to radionuclides contained in the trench.

## FISH

Fish were caught at various locations along the Columbia River during 1981. Boneless fillets were removed from each fish and analyzed individually for gamma-emitting radionuclides (primarily  $^{60}\text{Co}$  and  $^{137}\text{Cs}$ ), using methods described in Appendix C. Results of these analyses are shown in Table 12.

(a) Dose calculation methods are described in Appendix E.

Nineteen whitefish were collected along the Hanford Reach of the Columbia River, and three additional fish were collected upstream of the Site. Radionuclide concentrations in the fish were either undetectable or very low. The highest  $^{137}\text{Cs}$  result (0.13 pCi/g) at Ringold was similar to the maximum concentration observed in 1980 (0.12 pCi/g, also at Ringold). Although it is possible that some or all of the  $^{137}\text{Cs}$  observed in the whitefish was of Hanford origin, samples in which  $^{137}\text{Cs}$  was observed were at very low levels, near the analytical limit and could have been of fallout origin.

The presence of  $^{60}\text{Co}$  in the whitefish is most probably a result of the residual radioactivity in the Columbia River sediments from past Hanford operations or current releases from N Reactor (0.6 Ci during 1981). An individual consuming a 0.5 kg fish fillet at the maximum observed  $^{60}\text{Co}$  concentration (0.09 pCi/g) would receive a GI-tract (critical-organ) dose of 0.002 mrem.<sup>(a)</sup> No other gamma-emitting radionuclides were identified in the samples.

Bass were collected near the old Hanford Townsite, a popular bass-fishing area. Cesium-137 was observed in all of the samples at an average concentration of 0.08 pCi/g. Part of this concentra-

**TABLE 12.** Cobalt-60 and Cesium-137 in Columbia River Fish

Type	Location	No. of Samples Collected	Concentration pCi/g, wet weight					
			$^{60}\text{Co}$			$^{137}\text{Cs}$		
			No. of Results >DL	Maximum	Average <sup>(b)</sup>	No. of Results >DL	Maximum	Average <sup>(b)</sup>
Whitefish	Upstream of site boundary	3	0	<DL	(0.00 ± 0.03)	0	<DL	(0.01 ± 0.03)
	100-D Vicinity	11	2	0.09 ± 0.03	(0.02 ± 0.02)	2	0.05 ± 0.03	(0.02 ± 0.02)
	Hanford Townsite	3	0	<DL	(0.02 ± 0.04)	0	<DL	(0.00 ± 0.05)
	Ringold	6	1	0.09 ± 0.06	(0.02 ± 0.04)	3	0.13 ± 0.06	0.04 ± 0.05
Bass	Hanford Townsite	5	0	<DL	(0.01 ± 0.02)	5	0.10 ± 0.03	0.08 ± 0.02
Catfish	Finley Area	4	0	<DL	(0.00 ± 0.02)	0	<DL	(0.01 ± 0.03)

>DL = Greater than the detection level, i.e., analysis of the sample yielded a positive identification.

<DL = Less than the detection level; radionuclide not identified in sample.

(a) Individual results shown with the ± two sigma counting error term. Average shown with the ± two standard error term (95% confidence interval).

(b) Average enclosed within parenthesis if the ± two standard error term was equal to or greater than the indicated concentration.

tion, possibly all, is attributable to worldwide fallout. A conservative estimate of the maximum possible dose commitment received by a member of the population via this pathway would be 0.003 mrem per 0.5 kg of fish consumed.<sup>(a)</sup>

Catfish are not normally sampled as part of the routine Hanford Environmental Surveillance program. However, during 1981 several were collected from the Columbia River near Finley and analyzed for gamma-emitting radionuclides. As shown in Table 12, there was no positive identification of radionuclides in the sampled catfish.

### PIGEONS

The collection of pigeons for radionuclide analysis is not a routine activity of the Hanford Environmental Surveillance program. Wild pigeons are generally not hunted for food in this area and, thus, do not represent a direct dose-impact pathway. However, during 1981 it was discovered that pigeons roosting in the 200 Areas were

frequenting contaminated areas, ingesting radionuclides, and redepositing the contamination in droppings. Investigation by Rockwell Hanford Operations personnel indicated the contamination to be largely confined within the 200 Areas. Measures have been taken to restrict access of pigeons to contaminated areas.<sup>(b)</sup>

Environmental Surveillance personnel have surveyed numerous locations both onsite and offsite to determine if any pigeon droppings were deposited outside the 200 Areas. No instances of fecal contamination were observed offsite, and only one spot was identified in 27 onsite buildings, outside of the 200 Areas. Analysis of the single, contaminated, fecal deposit indicated the presence of <sup>90</sup>Sr and <sup>137</sup>Cs at concentrations greater than that attributable to worldwide fallout, but insignificant with respect to potential offsite impact.

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(a) Dose calculation methods are described in Appendix E.

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(b) These measures are discussed in Rockwell Hanford Operations Occurrence Report 81-72, available in the Public Reading Room of the Hanford Science Center in Richland, Washington.





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## SOIL AND VEGETATION

Surface soil and vegetation samples are collected from a number of locations for the purpose of monitoring the atmospheric deposition of radionuclides. Samples are collected in undisturbed, unirrigated locations so that the primary pathway for radionuclides in the media is through atmospheric deposition on surface soils and foliage. Because the radionuclides of interest with respect to Hanford operations are also present in the environment as a result of several decades of worldwide fallout or are naturally occurring (uranium), the presence of radionuclides to some extent in all samples of soil and vegetation is expected.

Contributions from Hanford operations to background levels of radionuclides are determined by comparing the results of samples collected in generally downwind locations from the Site, primarily to the south and east, with samples collected from distant or generally upwind directions. Based on samples collected during 1981, no contribution from Hanford operations to radionuclide concentrations in soil and vegetation in the offsite environment could be discerned.

### SAMPLE COLLECTION AND ANALYSIS

Soil and vegetation samples were collected during the summer months at 14 locations in the offsite environs as shown on the map in Figure 11. The majority of the samples were collected in a generally downwind direction of the Site where any Hanford contribution to radionuclide levels in offsite soil would be expected to be most easily detected. Samples were also collected in a generally upwind direction for comparison.

Each soil sample consisted of a composite of five "plugs" of soil approximately 2.5 cm deep and

10 cm in diameter collected at random within a 100-m<sup>2</sup> area at the sampling location. The composites were mixed and dried before aliquots were taken for analysis.

Samples of perennial vegetation were collected in the immediate vicinity of the soil sampling locations at the same time soil sampling was performed. Vegetation samples included a mixture of rabbitbrush, sagebrush, and bitterbrush in rough proportions according to the natural relative abundance of the three plants at the particular sampling location. No single species of perennial vegetation exists at all of the sampling locations. The vegetation samples were collected by cutting a small amount of the new growth from a sufficient number of plants in the area to make up an approximately 1-kg sample. The sample was then dried and ground before aliquots were taken for analysis.

Soil and vegetation samples were analyzed for <sup>137</sup>Cs and other gamma-emitting radionuclides, <sup>90</sup>Sr, plutoniums, and uranium. The analytical methods are described in Appendix C.

### SOIL

Results of soil sample analyses for samples collected during 1981 are shown in Table 13. Although some variability exists between sampling locations, concentrations of the long-lived radionuclides, <sup>90</sup>Sr, <sup>137</sup>Cs, and <sup>239/240</sup>Pu are similar to those observed in previous years. No geographical distribution pattern indicative of a Hanford source could be discerned. The relatively

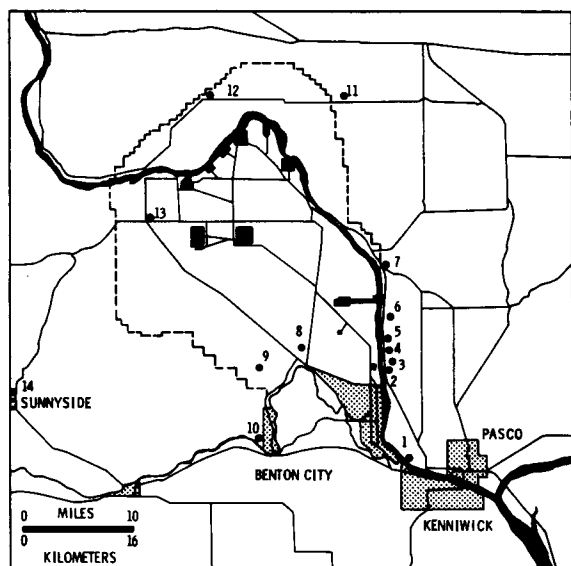


FIGURE 11. Soil and Vegetation Sampling Locations

TABLE 13. Radionuclides in Soil

Sample Location	Map No.	Concentration, pCi/g dry weight <sup>(a)</sup>								
		<sup>90</sup> Sr	<sup>95</sup> ZrNb	<sup>106</sup> Ru	<sup>134</sup> Cs	<sup>137</sup> Cs	<sup>144</sup> Ce	<sup>238</sup> Pu	<sup>239,240</sup> Pu	Total U
Riverview	1	0.21 ± 0.009	(0.02 ± 0.02)	(0.00 ± 0.07)	0.03 ± 0.01	0.46 ± 0.03	0.28 ± 0.06	(-0.0004 ± 0.0003)	0.01 ± 0.001	0.64 ± 0.23
Byers Landing	2	0.06 ± 0.003	(0.02 ± 0.02)	0.13 ± 0.08	0.03 ± 0.01	0.23 ± 0.02	0.27 ± 0.07	(-0.0005 ± 0.0004)	0.005 ± 0.001	0.47 ± 0.17
Sagemoor	3	0.006 ± 0.003	0.07 ± 0.03	(0.05 ± 0.09)	0.02 ± 0.01	0.04 ± 0.02	0.34 ± 0.07	(-0.0004 ± 0.0004)	0.001 ± 0.0006	0.59 ± 0.21
Taylor Flats #1	4	0.11 ± 0.01	0.11 ± 0.02	(0.08 ± 0.08)	0.02 ± 0.01	0.79 ± 0.04	0.50 ± 0.07	0.002 ± 0.0007	0.02 ± 0.002	1.1 ± 0.40
Taylor Flats #2	5	0.25 ± 0.001	0.04 ± 0.02	(0.05 ± 0.08)	0.04 ± 0.02	1.1 ± 0.05	0.18 ± 0.07	0.002 ± 0.0006	0.04 ± 0.002	0.92 ± 0.32
W. End Fir Road	6	0.05 ± 0.003	0.05 ± 0.02	(0.05 ± 0.07)	0.03 ± 0.01	0.15 ± 0.02	0.35 ± 0.07	0.0009 ± 0.0007	0.004 ± 0.001	0.58 ± 0.31
Ringold	7	0.20 ± 0.002	(0.02 ± 0.02)	(0.03 ± 0.08)	0.03 ± 0.01	0.94 ± 0.05	0.23 ± 0.07	(0.0005 ± 0.0006)	0.02 ± 0.002	0.82 ± 0.29
Prosser Barricade	8	0.13 ± 0.007	0.08 ± 0.02	0.10 ± 0.08	0.03 ± 0.01	0.21 ± 0.02	0.44 ± 0.07	(-0.0004 ± 0.0005)	0.006 ± 0.001	0.05 ± 0.12
ALE	9	0.27 ± 0.03	(0.00 ± 0.02)	(0.05 ± 0.07)	0.04 ± 0.01	0.37 ± 0.03	0.29 ± 0.07	0.001 ± 0.0006	0.01 ± 0.001	0.35 ± 0.12
Benton City	10	0.30 ± 0.003	0.13 ± 0.03	0.16 ± 0.08	0.04 ± 0.01	0.89 ± 0.04	0.50 ± 0.07	(-0.0004 ± 0.0004)	0.02 ± 0.002	0.63 ± 0.22
Berg Ranch	11	0.11 ± 0.005	(0.00 ± 0.02)	(-0.03 ± 0.09)	0.02 ± 0.01	0.49 ± 0.04	0.45 ± 0.08	(0.0004 ± 0.0006)	0.009 ± 0.002	0.32 ± 0.11
Wahluke #2	12	0.09 ± 0.002	0.07 ± 0.02	0.11 ± 0.08	0.04 ± 0.02	0.10 ± 0.02	0.32 ± 0.06	(-0.0006 ± 0.0003)	0.004 ± 0.0008	0.46 ± 0.16
Yakima Barricade	13	0.22 ± 0.02	0.04 ± 0.02	(0.02 ± 0.07)	0.02 ± 0.01	0.31 ± 0.03	0.31 ± 0.06	0.009 ± 0.002	0.02 ± 0.002	0.50 ± 0.17
Sunnyside	14	0.16 ± 0.02	0.08 ± 0.02	0.11 ± 0.08	0.03 ± 0.01	0.63 ± 0.04	0.44 ± 0.07	(-0.001 ± 0.0004)	0.01 ± 0.001	0.34 ± 0.12
Mean ± 2 standard errors of mean		0.16 ± 0.048	0.052 ± 0.022	0.065 ± 0.035	0.03 ± 0.005	0.48 ± 0.18	0.35 ± 0.057	(0.0007 ± 0.0015)	0.02 ± 0.009	0.52 ± 0.15

(a) Individual results shown with ± 2 sigma counting error.

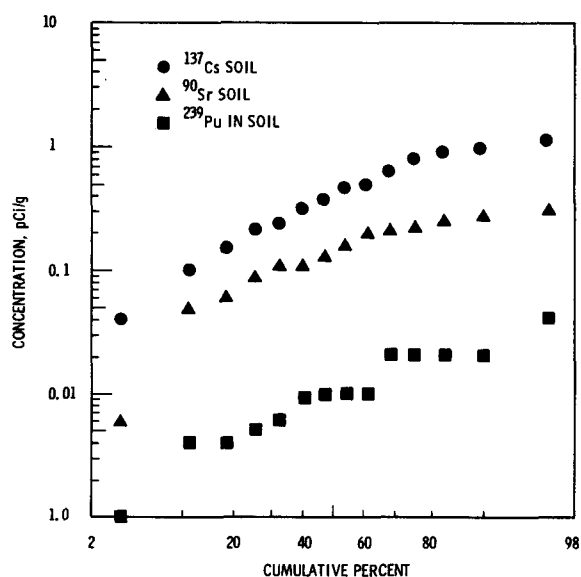
(b) Results enclosed in parenthesis if the associated uncertainty was greater than the indicated concentration.

linear log-probability plots shown in Figure 12 illustrate the homogeneity of the results of 1981 samples and provide evidence that observed concentrations were due to the accumulation in the soil of fallout from several decades of worldwide atmospheric nuclear weapons testing.

Worldwide fallout resulting from an atmospheric nuclear test by a foreign nation during the latter part of 1980 is believed to be the source of the low levels of several short-lived radionuclides observed in the soil samples. Concentrations of these radionuclides ( $^{95}\text{ZrNb}$ ,  $^{106}\text{Ru}$ , and  $^{144}\text{Ce}$ ) with half-lives ranging from approximately two

months to a year also showed no significant difference between upwind and downwind locations. As indicated in other sections of this report, short-lived fallout radionuclides were identifiable in many environmental samples collected both near to and distant from the Hanford Site during 1981.

Uranium, a feed material for plutonium production operations at Hanford, is also a naturally occurring radioactive element that is present in all soils. As with the other radionuclides, there was no distinguishable difference in uranium concentrations between upwind and downwind soil sampling locations.



**FIGURE 12.** Log Normal Probability Plot of Radionuclides in Soil Samples Collected in 1981

## VEGETATION

Results of analyses for radionuclides in samples of mature vegetation collected during 1981 are shown in Table 14. Traces of radionuclides associated with worldwide fallout were observed in all samples collected both upwind and downwind from the Site. Also, as expected, short-lived radionuclides ( $^{95}\text{ZrNb}$ ,  $^{106}\text{Ru}$ ,  $^{144}\text{Ce}$ ) attributed to the late-1980 foreign atmospheric nuclear test were present. None of these short-lived radionuclides were identified in the vegetation samples that were collected prior to the test.

Radionuclide concentrations in the vegetation samples, except for the short-lived fallout radionuclides, were similar to those observed in previous years and no geographical patterns were apparent. The Hanford contribution, if any, to the radionuclide concentrations in the vegetation samples was negligible compared to the contributions made by fallout or natural (in the case of uranium) sources.

TABLE 14. Radionuclides in Vegetation

Sample Location	Map No.	Concentration, pCi/g dry weight <sup>(a)</sup>							
		<sup>90</sup> Sr	<sup>95</sup> ZrNb	<sup>106</sup> Ru	<sup>137</sup> Cs	<sup>144</sup> Ce	<sup>238</sup> Pu	<sup>239/240</sup> Pu	Total U
Riverview	1	0.05 ± 0.003	0.48 ± 0.06	(0.07 ± 0.13)	(0.02 ± 0.02)	0.56 ± 0.11	(-0.0006 ± 0.0005)	0.002 ± 0.0009	0.02 ± 0.008
Byers Landing	2	0.03 ± 0.004	0.52 ± 0.08	0.34 ± 0.18	(-0.006 ± 0.02)	0.61 ± 0.14	(-0.0005 ± 0.0004)	0.0006 ± 0.0004	0.02 ± 0.008
Sagemoor	3	0.03 ± 0.004	0.41 ± 0.07	(0.16 ± 0.16)	(0.02 ± 0.02)	0.52 ± 0.13	(-0.0009 ± 0.0004)	0.002 ± 0.0009	0.02 ± 0.008
Taylor Flats #1	4	0.03 ± 0.003	0.59 ± 0.07	0.29 ± 0.17	(0.02 ± 0.02)	0.71 ± 0.14	(-0.00007 ± 0.0005)	0.002 ± 0.0006	0.20 ± 0.07
Taylor Flats #2	5	0.03 ± 0.003	0.66 ± 0.06	0.30 ± 0.11	0.05 ± 0.02	0.80 ± 0.10	(-0.0005 ± 0.0004)	0.002 ± 0.0006	0.03 ± 0.01
W. End Fir Road	6	0.06 ± 0.007	0.84 ± 0.07	0.22 ± 0.13	0.03 ± 0.02	1.2 ± 0.12	0.0007 ± 0.0006	0.002 ± 0.0007	0.02 ± 0.007
Ringold	7	0.10 ± 0.01	0.72 ± 0.07	0.20 ± 0.16	(-0.010 ± 0.02)	0.97 ± 0.13	(-0.001 ± 0.0007)	0.001 ± 0.0009	0.04 ± 0.01
Prosser Barricade	8	0.06 ± 0.005	0.84 ± 0.09	0.20 ± 0.18	0.08 ± 0.03	0.97 ± 0.16	(0.0001 ± 0.001)	0.004 ± 0.001	0.006 ± 0.003
ALE	9	0.05 ± 0.005	0.77 ± 0.08	0.49 ± 0.18	0.04 ± 0.03	0.96 ± 0.14	(-0.00008 ± 0.0008)	0.001 ± 0.0008	0.007 ± 0.002
Benton City	10	0.04 ± 0.005	0.63 ± 0.07	0.45 ± 0.17	0.03 ± 0.02	0.63 ± 0.13	(-0.0002 ± 0.0005)	0.002 ± 0.0007	0.009 ± 0.003
Berg Ranch	11	0.03 ± 0.003	0.50 ± 0.07	(0.11 ± 0.16)	(-0.04 ± 0.02)	0.56 ± 0.13	(-0.0006 ± 0.0004)	0.003 ± 0.0008	0.01 ± 0.005
Wahluke #2	12	0.05 ± 0.005	0.39 ± 0.06	(0.04 ± 0.14)	(-0.005 ± 0.02)	0.24 ± 0.11	(-0.0004 ± 0.0004)	0.001 ± 0.0005	0.02 ± 0.006
Yakima Barricade	13	0.06 ± 0.005	0.54 ± 0.06	0.22 ± 0.13	(0.02 ± 0.02)	0.62 ± 0.11	(0.0006 ± 0.0006)	0.002 ± 0.0008	0.12 ± 0.04
Sunnyside	14	0.19 ± 0.02	0.37 ± 0.06	0.14 ± 0.13	0.03 ± 0.02	0.47 ± 0.11	(-0.0007 ± 0.0004)	0.003 ± 0.0008	0.01 ± 0.005
Mean ± 2 standard errors of the mean		0.058 ± 0.023	0.59 ± 0.09	0.23 ± 0.08	0.02 ± 0.017	0.70 ± 0.14	(-0.0004 ± 0.0003)	(0.003 ± 0.003)	0.038 ± 0.030

(a) Individual results shown with ± 2 sigma analytical uncertainty term.

(b) Result was enclosed in parenthesis if the associated uncertainty was greater than or equal to the indicated concentration.

## PENETRATING RADIATION

Dose rates from penetrating radiations (primarily gamma-rays) were measured at a number of locations in the Hanford environs during 1981. The measurements were made using thermoluminescent dosimeters (TLDs) to provide estimates of the dose rates from external radiation sources. Naturally occurring sources, including radiations of cosmic origin and natural radioactive materials in the air and ground, as well as fallout from the atmospheric testing of nuclear weapons result in the measurement of a certain amount of penetrating radiation at all dosimeter locations (NCRP 1975). Increases in the measured dose rates above these "background levels" could be the result of exposure of the dosimeter to radioactive materials associated with activities at Hanford.

Dose rate measurements at all locations in the vicinity of residential areas during 1981 were at background levels. Measurements made near operating areas and along the Columbia River indicated several locations where dose rates were somewhat higher than background levels. In one location near the 300 area, the dose rate increased after a radioactive steam generator was brought onsite for research purposes. However, the dose rates at all other locations were similar to previous years.

### DOSE MEASUREMENTS

Dosimeters consist of three  $\text{CaF}_2\text{:Mn}$  chips (TLD-400) encased in an opaque plastic capsule lined with 0.025-cm of tantalum and 0.005-cm of lead to flatten the low-energy response (Fix and Miller 1978). The dosimeters were mounted one meter above ground level and exchanged every four weeks. The TLD's were prepared and read by PNL.

### HANFORD VICINITY

Dosimeters were located at each of the air sampling locations shown in Figure 2. The measured dose rates are shown in Table 15 and are expressed in units of mrem/yr to enable comparison with the radiation protection standards in Appendix A.

The dose rates measured at all locations during 1981 were similar to those observed in previous years. The variability in dose rates observed at locations near the site was similar to that observed in measurements made at the distant locations. Background dose rates averaged 62 to 83 mrem/yr at the perimeter locations and 64 to 72 mrem/yr at the distant locations. The overall averages of the two groups were not significantly different from a statistical standpoint (at the 95% confidence level).

### COLUMBIA RIVER IMMERSION DOSE RATE

Dosimeters were submerged in the Columbia River at Coyote Rapids and at the Richland pumphouse (Figure 13) to provide a comparison of penetrating dose rates which would be received by a person in the water before and after it passes through the Hanford Site. Results of the measurements, shown in Table 16, were similar at both locations and were about half the background dose rate of 0.008 mrem/hr measured on land.

### OPERATIONS AREA BOUNDARIES

Dosimeters were placed near publicly accessible locations at operating areas on the Hanford Site as shown in Figure 14. Results for 1981 are shown in Table 17.

Dose rates near the river shoreline in the 100-N Area were similar to those observed in previous years with a maximum of 0.04 mrem/hr measured. Dose rates in this area are attributed to direct radiations from onsite waste storage facilities.

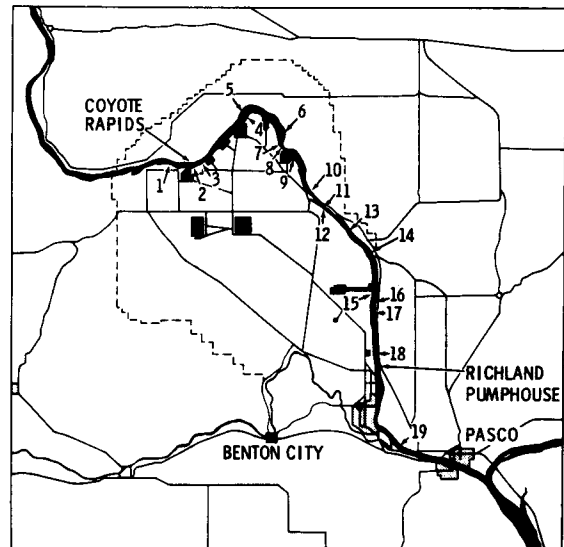
Dose rates in the 300 Area were at normal background levels with the exception of the 300 Pond dosimeter location where a maximum monthly dose rate of 0.083 mrem/hr was measured. The increased dose rate at this location is attributed

**TABLE 15.** External Radiation Dose Measurements in The Hanford Vicinity

Location	No. of Samples	Dose Rate (mrem/yr) <sup>(a)</sup>		
		Maximum	Minimum	Average <sup>(b)</sup>
<b>Perimeter Stations</b>				
Rattlesnake Springs	13	88	69	78 ± 3
ALE	13	91	69	83 ± 3
Benton City	13	66	51	58 ± 2
Yakima Barricade	13	88	69	79 ± 3
Vernita Bridge	14	80	66	74 ± 2
Wahluke #2	14	88	69	78 ± 3
Othello	14	69	55	62 ± 2
Connell	14	77	62	68 ± 2
Berg Ranch	13	88	77	82 ± 2
Wahluke Watermaster	13	80	73	77 ± 1
Cooke Bros.	13	73	66	69 ± 1
Richland	14	77	62	68 ± 3
Pasco	14	69	58	67 ± 2
Byers Landing	14	77	69	72 ± 1
Sagemoor	14	77	69	73 ± 2
Pettett Farm	14	73	55	64 ± 3
Fir Road	14	77	66	73 ± 2
RRC CP #64	14	80	62	70 ± 3
1100 Area	14	69	55	61 ± 3
Prosser Barricade	13	84	69	76 ± 3
				71 ± 3
<b>Distant Stations</b>				
Walla Walla	14	84	58	66 ± 3
McNary	14	80	69	72 ± 2
Moses Lake	13	69	58	64 ± 2
Washtucna	12	73	58	68 ± 3
Sunnyside	13	77	58	65 ± 3
				66 ± 3

(a) Monthly integrated readings in mR were converted to annual dose equivalent rates.

(b) Average shown includes ± two-standard error term (95% confidence level).



**FIGURE 13.** Dosimeter Locations Along the Hanford Reach of the Columbia River.

**TABLE 16.** Immersion Dose Rates in the Columbia River

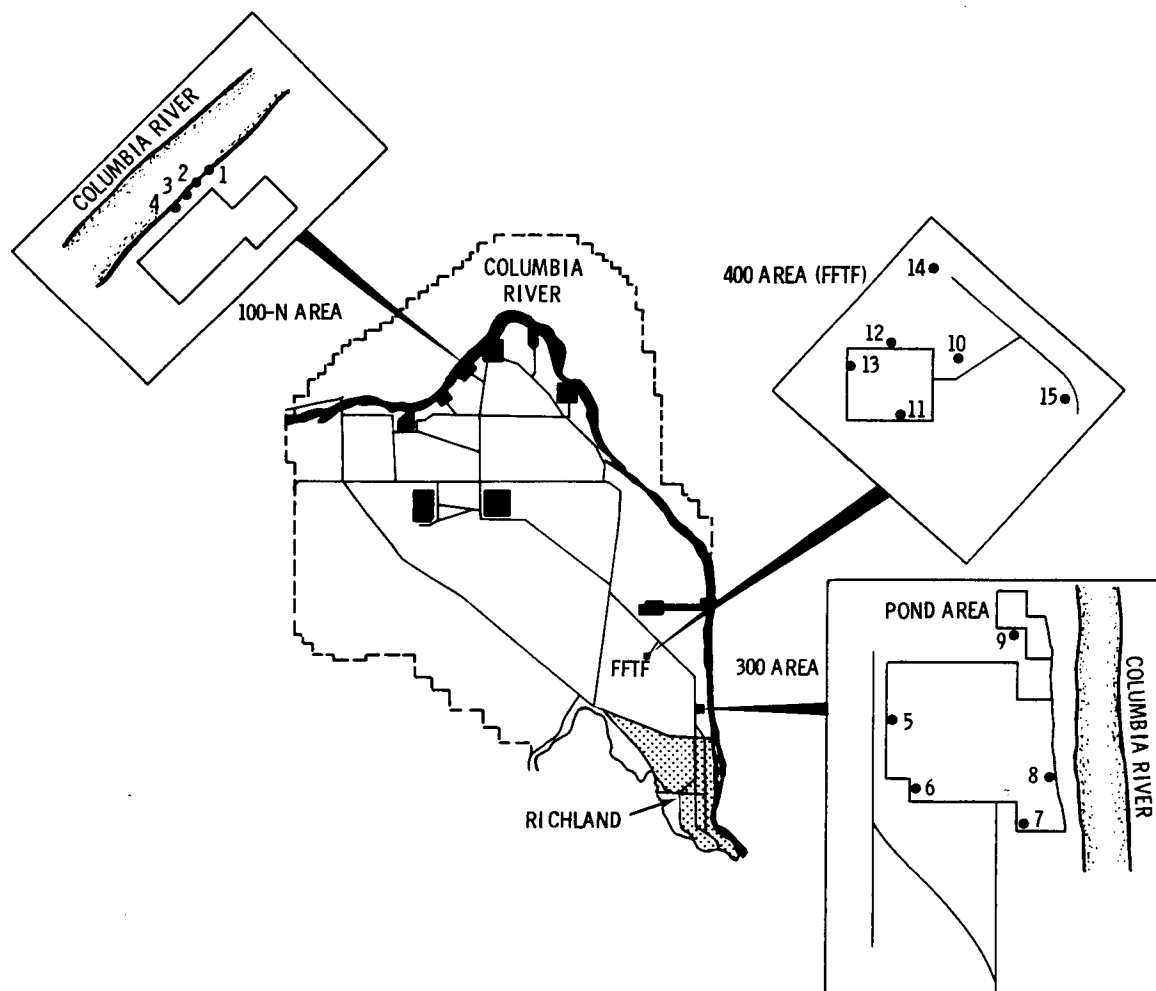
Location	No. of Measurements	Dose Rate (mrem/hr) <sup>(a)</sup>		
		Maximum	Minimum	Average <sup>(b)</sup>
Coyote Rapids	10	0.009	0.004	0.005 ± 0.0008
Richland Pumphouse	12	0.006	0.003	0.004 ± 0.0004

(a) Monthly integrated readings in mR were converted to hourly dose equivalent rates.

(b) Average includes ± two standard error term (95% confidence level).

to the nearby storage of a radioactive nuclear power plant steam generator, which is the subject of a five-year research program in the 300 Area.

Dose rates at the 400 Area locations were at background levels indicating no measureable penetrating dose rate contribution from FFTF activities during 1981.



**FIGURE 14.** Dosimeter Locations Near Publicly Accessible Locations at Operating Areas

### COLUMBIA RIVER SHORELINES

During reactor operations at Hanford from 1944 to 1972, radionuclides were discharged to the Columbia River along with the reactor cooling water. These radionuclides were diluted and dispersed in the river by an average 120,000 cubic feet per second flowing volume of water. Nevertheless, low levels of residual radioactivity (primarily  $^{60}\text{Co}$  and  $^{154}\text{Eu}$ ) can still be measured at several locations along the shorelines and on islands in the Hanford reach of the river. Radiation dose rates from these radionuclides were the subject of an extensive radiological survey of the Hanford reach of the river performed in 1979 (Sula 1980). In 1980, based upon findings of the survey, dosimeters were placed in areas along the river, shown in Figure 13, where dose rates

due to the residual radioactivity deposits were determined to be highest.<sup>(a)</sup>

Table 18 provides results of measurements at these locations during 1981. In general, dose rates measured during 1981 were similar to those observed in 1980. The consistency of the dose rate measurements during the past two years indicates the radionuclides in the ground to be relatively immobile and resistant to resuspension and redistribution by the mechanical forces of wind and water. Dose rates along the river thus are expected to gradually decrease at a rate commensurate with the radioactive half-lives of the radionuclides present.

(a) The 1979 survey is summarized in the 1979 Environmental Surveillance Report (Houston and Blumer 1980).



**TABLE 17.** External Radiation Dose Rate Measurements Near Publicly Accessible Locations At Hanford Operating Areas

Location	Map No.	No. of Measurements	Dose Rate (mrem/hr) <sup>(a)</sup>		
			Maximum	Minimum	Average <sup>(b)</sup>
<b>100-N Area Shoreline</b>					
100-N Trench Springs	1	13	0.027	0.017	0.021 ± 0.002
Below 100 N Main Stack <sup>(c)</sup>	2	4	0.039	0.022	0.029 ± 0.007
Upstream Tip 100 N Berm <sup>(c)</sup>	3	4	0.033	0.025	0.028 ± 0.004
Downstream 100 N Outfall <sup>(c)</sup>	4	4	0.040	0.026	0.030 ± 0.006
<b>300 Area Perimeter Fence</b>					
3705 West Fence	5	14	0.010	0.008	0.008 ± 0.0003
300 Area SW Gate	6	14	0.008	0.007	0.008 ± 0.0002
300 South Gate	7	14	0.009	0.008	0.008 ± 0.0002
ACRMS	8	14	0.008	0.008	0.008 ± 0.0002
300 Pond	9	14	0.083	0.020	0.041 ± 0.014
<b>400 Area (FFTF) Perimeter Fence</b>					
400 East	10	15	0.009	0.008	0.008 ± 0.0002
400 South	11	15	0.008	0.007	0.008 ± 0.0001
400 North	12	15	0.009	0.007	0.008 ± 0.0002
400 West	13	15	0.008	0.007	0.007 ± 0.0002
FFTF North	14	14	0.009	0.008	0.008 ± 0.0002
FFTF SE	15	14	0.009	0.008	0.008 ± 0.0002

(a) Monthly integrated readings in mR were converted to hourly dose equivalent rates.

(b) Average include ± two standard error term (95% confidence level).

(c) Dose rate measurements were initiated in September 1981.

**TABLE 18.** External Radiation Dose Rate Measurements Along the Columbia River Shoreline and Islands

Location	Map No.	No. of Measurements	Dose Rate (mrem/hr) <sup>(a)</sup>		
			Maximum	Minimum	Average <sup>(b)</sup>
Upriver 100-B Area	1	14	0.010	0.003	0.008 ± 0.001
Below 100-B Retention Basin	2	13	0.024	0.011	0.020 ± 0.002
Above 100-K Boat Ramp	3	14	0.011	0.008	0.009 ± 0.001
Downriver 100-D	4	14	0.015	0.008	0.012 ± 0.001
Downriver Opposite 100-D	5	14	0.009	0.007	0.008 ± 0.0003
Lower End Locke Island	6	14	0.010	0.008	0.009 ± 0.0004
White Bluffs Slough	7	13	0.019	0.012	0.016 ± 0.001
White Bluffs Ferry Landing	8	14	0.010	0.008	0.009 ± 0.0004
Below 100-F	9	13	0.010	0.006	0.008 ± 0.001
Hanford Powerline Crossing	10	14	0.011	0.008	0.009 ± 0.001
Hanford Ferry Landing	11	10	0.010	0.007	0.008 ± 0.001
Hanford Railroad Track	12	13	0.015	0.007	0.013 ± 0.001
Savage Island Slough	13	12	0.014	0.010	0.011 ± 0.001
Ringold Island	14	14	0.010	0.008	0.009 ± 0.0003
Powerline Crossing	15	14	0.011	0.008	0.010 ± 0.001
North End Wooded Island	16	11	0.011	0.005	0.008 ± 0.001
South End Wooded Island	17	14	0.012	0.008	0.010 ± 0.001
Island RM 344	18	11	0.018	0.005	0.014 ± 0.002
Island RM 333	19	13	0.012	0.007	0.010 ± 0.001

(a) Monthly, integrated readings in mR were converted to hourly dose equivalent rates.

(b) Averages include ± two standard error term (95% confidence level).

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## RADIOLOGICAL IMPACT OF HANFORD OPERATIONS

The radiological impact from operations at the Hanford Site was measured directly or was calculated based on measured environmental radionuclide concentrations or contractor supplied environmental release source terms. The resulting dose impacts, expressed in units of millirem and man-rem (see Appendix E), were summarized for several potential public exposure scenarios of interest including an assumed maximum exposed individual and the entire population residing within an 80-km radius of the Site.

The assessments of dose impact showed that radiation dose equivalents to the public attributable to 1981 operations at Hanford were well below all applicable regulatory limits and were significantly less than doses potentially received from other common sources or radiation. For example, the fifty-year whole body dose commitment potentially received by the assumed maximum exposed individual was calculated to be 0.4 mrem, less than 0.1% of the applicable DOE Radiation Protection Standard. The fifty-year population dose commitment was calculated to be 4 man-rem. These doses can be compared to the approximately 100 millirem and 34,000 man-rem received annually by an average individual and the surrounding population, respectively, as a result of naturally occurring radiations in our environment.

### RADIOLOGICAL IMPACT FROM 1981 OPERATIONS

Hanford operations during 1981 resulted in the release of small quantities of radioactive materials to the environment. In addition, certain Hanford facilities were potential sources of direct radiation exposure to members of the public. The radiological impacts of 1981 operations were assessed to determine compliance with pertinent regulations as required by DOE Order 5484.1.

The radiological impact of 1981 Hanford operations was assessed in terms of the following:

- the maximum dose rate in a publicly accessible location on or within the site boundary (the "fence-post" dose rate),
- the dose to an assumed maximum exposed individual in an uncontrolled location,
- the whole body dose to the population residing within an 80-km radius of one or more of the onsite operating areas.

When possible, the determination of radiation dose impacts was based on the direct measurement of dose rates or radionuclide concentrations in the environment. However, in all but one case, the quantities of radionuclide releases associated with 1981 operations were too small to be measured once dispersed in the offsite

environment. As a result, doses were calculated principally using environmental dose pathway models (described in Appendix E) and source terms based on measurements of radioactive materials released to the environment at Hanford in 1981 as shown in Table 19.

The exception to the use of reported effluents for calculation of dose impacts due to Hanford operations during 1981 was the use of measured <sup>90</sup>Sr concentrations in the Columbia River. As described in the "Columbia River Monitoring -Radiological" section, <sup>90</sup>Sr concentrations measured in the Columbia River downstream of the Hanford Site during 1981 were slightly higher than those measured upstream during the same period.

#### Maximum "Fence-Post" Dose Rate

The "fence-post" dose rate provides a measure of the maximum external radiation dose rate that existed in publicly accessible locations on or near the Site during 1981. The "fence-post" dose rate is based on measurements made at fixed environmental dosimeter locations and does not represent a dose actually received by any member of the public. Fence-post dose rates were measured in the vicinity of the 100N, 300 and 400 (FFTF) operating areas as described in the "Penetrating Radiation" section of this report.

**TABLE 19. Radionuclide Composition of Hanford Effluents for Calendar Year 1981**

Radionuclide	Half-Life	Effluent (Ci)				
		Liquid to River	Airborne			
			100 Area	200 Area	300 Area	400 Area
<sup>3</sup> H (HTO)	12.3 yr	82	18			
<sup>14</sup> C	5700 yr		3.2		4.5 x 10 <sup>-7</sup>	
<sup>24</sup> Na	15.0 hr		0.12			
<sup>32</sup> P	14.3 d	0.68				
<sup>41</sup> Ar	1.8 hr		65,000			
<sup>54</sup> Mn	303 d	0.036	0.003			
<sup>56</sup> Mn	2.6 hr	3.8	0.46			
<sup>59</sup> Fe	46.0 d		0.003			
<sup>58</sup> Co	71.0 d	0.023	0.008			
<sup>60</sup> Co	5.3 yr	0.60	0.018		3.3 x 10 <sup>-7</sup> (a)	
<sup>65</sup> Zn	245 d		0.001			
<sup>76</sup> As	26.4 hr		0.68			
<sup>85 m</sup> Kr	4.4 hr		250			
<sup>87</sup> Kr	76.0 min		280			
<sup>88</sup> KrRb	2.8 hr		530			450
<sup>89</sup> Sr	52.7 d	1.2	0.002			
<sup>90</sup> Sr	27.7 yr	1.8	0.006	0.02 (b)	4.6 x 10 <sup>-5</sup> (c)	4.1 x 10 <sup>-5</sup> (c)
<sup>91</sup> Sr	9.7 hr		0.18			
<sup>95</sup> ZrNb	65.5 d	0.1				
<sup>95</sup> Nb	35.0 d		0.001			
<sup>99 m</sup> MoTc	66.7 hr	0.83	0.26			
<sup>103</sup> Ru	39.5 d	0.038	0.003			
<sup>106</sup> Ru	368 d	0.34	0.004			
<sup>124</sup> Sb	60.4 d	0.077	0.037			
<sup>125</sup> Sb	2.7 yr	0.12				
<sup>132</sup> Te	77.7 hr		0.006			
<sup>129</sup> I	1.7 x 10 <sup>7</sup> yr	8.0 x 10 <sup>-6</sup>	1.9 x 10 <sup>-8</sup>			
<sup>131</sup> I	8.1 d	2.4	0.097		2.9 x 10 <sup>-4</sup>	1.3 x 10 <sup>-5</sup>
<sup>132</sup> I	2.3 hr		4.7			
<sup>133</sup> I	20.3 hr	0.62	0.82			
<sup>135</sup> I	6.7 hr		3.0			
<sup>133</sup> Xe	5.3 d	1.5				
<sup>135</sup> Xe	9.1 hr		490			
<sup>134</sup> Cs	2.1 yr		7.5 x 10 <sup>-5</sup>			
<sup>137</sup> Cs	30.0 yr	0.053	0.01	0.06		
<sup>138</sup> Cs	32.2 min		11,000			
<sup>140</sup> BaLa	12.8 d	0.5	0.11			
<sup>144</sup> CePr	284 d	0.02	0.11			
<sup>147</sup> Nd	11.1 d		0.011			
<sup>154</sup> Eu	16.0 yr		0.15			
<sup>155</sup> Eu	1.8 yr		0.026			
<sup>187</sup> W	23.9 hr		0.10			
U-nat	4.4 x 10 <sup>9</sup>				7.5 x 10 <sup>-5</sup>	
<sup>238</sup> Pu	86.4 yr	2.9 x 10 <sup>-4</sup>	1.0 x 10 <sup>-5</sup>			
<sup>239</sup> Pu	2.4 x 10 <sup>4</sup> yr	7.3 x 10 <sup>-5</sup>	6.4 x 10 <sup>-5</sup>	7.3 x 10 <sup>-4</sup> (d)	4.2 x 10 <sup>-5</sup> (e)	6.3 x 10 <sup>-6</sup> (e)

(a) Reported as mixed activation products. Cobalt-60 was assumed for dose calculations.

(b) Reported as total beta activity composed principally of <sup>90</sup>Sr.

(c) Reported as mixed fission products and unidentified beta-gamma activity. Strontium-90 was assumed for dose calculations.

(d) Reported as total alpha activity composed principally of <sup>239</sup>Pu.

(e) Reported as <sup>239</sup>Pu and unidentified alpha activity. Plutonium-239 was assumed for dose calculations.

NOTE: As reported by the operating contractor.

Near the 100N Area, the Columbia River provides access to within a few hundred meters of the N Reactor and its associated facilities. Measurements made at the 100N Area shoreline (Table 17) were consistently above background due to the proximity of N Reactor radioactive liquid waste handling facilities. The maximum observed dose rate along the shoreline during 1981 was 0.04 mrem/hr, or about five times the dose rate normally observed at offsite locations (0.008 mrem/hr).

Public access to the vicinity of the 300 Area is available on the Columbia River to the east and at parking lots and roads located to the north, south, and west. Dose rate measurements near the 300 Area were at background levels (Table 17) except at the 300 Area Pond dosimeter location where a maximum reading of 0.08 mrem/hr was observed, a result of the nearby temporary storage of a radioactive steam generator.

Public access to the 400 Area was possible at the Visitors Information Center located southeast of the FFTF reactor building and at several parking lots and access roads around the perimeter fence. Penetrating dose rate measurements in the vicinity of these accessible areas during 1981 (Table 17) did not indicate any identifiable dose rate above normal background levels.

### Maximum Exposed Individual Dose

The maximum exposed individual dose is that calculated to be potentially received by an imaginary individual whose living and dietary habits are chosen so as to maximize the combined dose from all realistically available exposure pathways.

The particular characteristics of the assumed maximum exposed individual are defined annually upon evaluation of numerous influencing factors such as the magnitude and composition of radioactive effluents from the various potential release points at Hanford; atmospheric dispersion of airborne releases; river dispersion of liquid releases; and assumptions concerning the living, dietary, and recreational habits of individuals in the population surrounding the site.

The following exposure pathways were included in the calculation of the maximum individual dose: inhalation and submersion in airborne effluents, consumption of foodstuffs contami-

nated via dry deposition from airborne releases, use of drinking water obtained from the Columbia River, ingestion of foodstuffs for which Columbia River water was used for irrigation, consumption of fish taken from the Columbia River, and direct exposure to radionuclides in the river water during recreational activities on the river. Thyroid doses were calculated for both an adult and a one-year old infant. Other organ doses were calculated for adults only. With the exception of  $^{90}\text{Sr}$  in the Columbia River, doses were calculated using the source terms shown in Table 19. Dose impacts from  $^{90}\text{Sr}$  via liquid pathways were based on a net 0.09 pCi/l contribution to Columbia River radioactivity during 1981 (see "Columbia River Monitoring - Radiological" section).

For 1981, the maximum exposed individual was determined to be a person who:

- resided in the southeastern part of the River-view district in Pasco, approximately 13 km south-southeast of the 300 Area,
- consumed foodstuffs grown in the northwestern part of the Riverview district using Columbia River water for irrigation,
- consumed Pasco city drinking water obtained from the Columbia River, and
- used the Columbia River extensively for recreational activities including boating, swimming, and fishing (including consumption of the fish).

The first-year dose (i.e., the dose received during 1981) and the 50-year dose commitment for the maximum exposed individual are summarized in Table 20. The difference between the first-year and 50-year commitments is caused by radionuclides with long physical and biological half-lives.

All the doses resulting from effluents discharged to the environment during operations at Hanford in 1981 were well below the applicable Radiation Protection Standards in DOE Order 5480.1. The organ receiving the largest fraction of the standard was the bone for which a maximum individual 50-year dose commitment of 1 mrem (or about 0.07% of the dose standard) was calculated. All other organ doses were less than 0.07% of their respective standard. The bone dose was primarily the result of the  $^{90}\text{Sr}$  measured in the river during 1981.

**TABLE 20.** Dose to the Maximum Exposed Individual from 1981 Hanford Operations

Pathway	First-Year Dose (mrem)					Thyroid	
	Whole Body	GI(a)	Bone	Lung		Adult	Infant
Direct Airborne(b)	.01	.01	.01	.01		.01	.01
Foodstuffs(c)	.01	.03	.07	<.01		.08	.5
Drinking Water	<.01	<.01	<.01	<.01		.02	.07
River Recreation(d)	<.01	.01	.03	<.01		.02	—
Total	.03	.05	.1	.01		.1	.6
Pathway	50-Year Dose Commitment (mrem)					Thyroid	
	Whole Body	GI(a)	Bone	Lung		Adult	Infant
Direct Airborne(b)	.01	.01	.01	.01		.01	.01
Foodstuffs(c)	.3	.03	.9	<.01		.08	.5
Drinking Water	.02	<.01	.04	<.01		.02	.07
River Recreation(d)	.10	.01	.4	<.01		.02	—
Total	.4	.05	1.3	.02		.1	.6

(a)Gastrointestinal tract (lower large intestine).

(b)Includes inhalation, submersion, and direct exposure to ground deposition.

(c)Includes consumption of all foodstuffs contaminated via irrigation water and dry deposition as well as direct exposure to soils contaminated via irrigation water.

(d)Includes consumption of fish taken from the Columbia River.

Comparison of maximum individual doses due to 1981 Hanford operations with those estimated for 1980 (Sula and Blumer 1981) revealed differences for several organs and pathways. Higher doses to the whole body and bone for foodstuff and river recreation pathways were calculated for 1981. These changes were primarily due to the different  $^{90}\text{Sr}$  source term used in the calculations. The 1981 source term was based on measured concentrations of  $^{90}\text{Sr}$  in the Columbia River during 1981 as described in the "Columbia River Monitoring - Radiological" section. The 1980 source term, by comparison, was based on calculated river concentrations using reported N Reactor releases. An apparent decrease in drinking water doses resulted from application of water treatment plant cleanup factors in the 1981 dose pathway model. The small decrease in thyroid doses in 1981 compared to 1980 was primarily due to the greater dilution of N Reactor

liquid effluents afforded by a higher than average Columbia River flow during 1981. Air submersion doses to all organs were slightly higher in 1981 compared to 1980 as a result of increased short-lived noble gas releases at N Reactor and noble gas releases from the FFTF facility (Table 19).

### Population Dose

The overall regional dose impact from 1981 Hanford operations was evaluated by calculating the collective dose equivalent to the population residing within an 80-km radius of any of the onsite operating areas. Collective population doses are expressed in units of man-rem and are the sum, for all possible pathways, of the product of the average individual dose and the number of persons potentially exposed. Both airborne and river-related pathways were considered in

the calculation for which results are shown in Table 21. Site specific population distributions and other dose calculation parameters are detailed in Appendix E.

The primary airborne pathway contribution to the population dose was immersion in short-lived noble gases from N Reactor. The consumption of drinking water obtained from the Columbia River downstream of Hanford was the principal dose pathway for liquid effluents, the primary radionuclide being  $^{90}\text{Sr}$ . A "per capita" dose may be derived from the collective population dose commitments in Table 21 by dividing by the 80-km population of 340,000 persons. The per capita whole body dose commitment from 1981 Hanford operations is thus calculated to be 0.01 mrem/person.

These dose estimates can be compared with doses from other routinely encountered sources of radiation such as natural background radiation (Oakley 1972), medical diagnostic procedures (USEPA 1972), and a 5-hr commercial jet flight (NCRP 1975). Compared graphically in Figure 15 are the average doses from these sources and the average per capita whole body dose commitment from Hanford operations for 1981. The estimated population dose (in man-rem) may also be compared with the approximately 34,000 man-rem received annually by the same population from background radiation.

Comparison of population dose commitments due to Hanford operations during 1981 with those calculated for 1980 (Sula and Blumer 1981) indicated that population doses were higher during 1981 for most pathways and organs. As with the maximum individual, population whole body and bone doses for foodstuffs and river recreation pathways were higher in 1981 due to the larger  $^{90}\text{Sr}$  source term used in the calculations. Drinking water pathway doses also increased as a result of an increase in the size of the population affected by this pathway. During 1981, the city of Kennewick began supplying approximately 40% of its domestic water from the Columbia River.

Population air submersion doses to all organs were higher during 1981 as a result of the short-

lived noble gas releases from N Reactor and the FFTF facility and the use of a larger 80-km population in the air submersion dose calculations. The population residing within an 80-km radius of the Hanford Site during 1981 was estimated to be 340,000 people based on 1980 Bureau of Census data that became available in late 1981. The estimated population used in the 1980 population dose calculations was 250,000 people as projected from 1970 Bureau of Census data. An additional increase in the 1981 air submersion doses resulted from improved calculational techniques.

### **RADIOLOGICAL IMPACT FROM PAST HANFORD OPERATIONS**

In the preceding chapters of this report, measured levels of radioactivity in the environment were sometimes attributed to past operations at Hanford. The primary sources of current environmental impacts resulting from past operations are residual radionuclides deposited along the Columbia River shoreline and in the river sediments and the seepage of water containing tritium and  $^{129}\text{I}$  from the unconfined Hanford aquifer into the river.

Environmental radiation dose rates along the Columbia River shorelines and islands due to residual radionuclides were discussed by Sula (1980). Dose rates along the river were found to be slightly above normal background levels except at a few locations where dose rates were observed to be several times background. (See the "Penetrating Radiation" section.)

As discussed in previous sections, tritium and  $^{129}\text{I}$  at low concentrations, associated with the unconfined aquifer underlying the Hanford Site, are seeping into the river. Increased concentrations of tritium in the river cannot be measured but are apparent for  $^{129}\text{I}$  by using extremely sensitive sampling and analytical techniques. However, the dose impact from  $^{129}\text{I}$  entering the river is calculated to be only 0.001 mrem to the thyroid of an assumed maximum exposed individual, less than  $10^{-6}\%$  of the DOE thyroid dose standard and less than 0.03% of the State and EPA Drinking Water Standard (Appendix A).



**TABLE 21.** 50-Year Population Dose Commitment from Effluents Released During 1981

Pathway	80-km Population Dose Commitment (man-rem)				
	Whole Body	Gt(a)	Bone	Lung	Thyroid
Direct Airborne(b)	2	3	3	3	3
Foodstuffs(c)	<1	*	1	*	<1
Drinking Water	<1	*	2	*	<1
River Recreation(d)	*	*	<1	*	*
Total	4	3	6	3	4

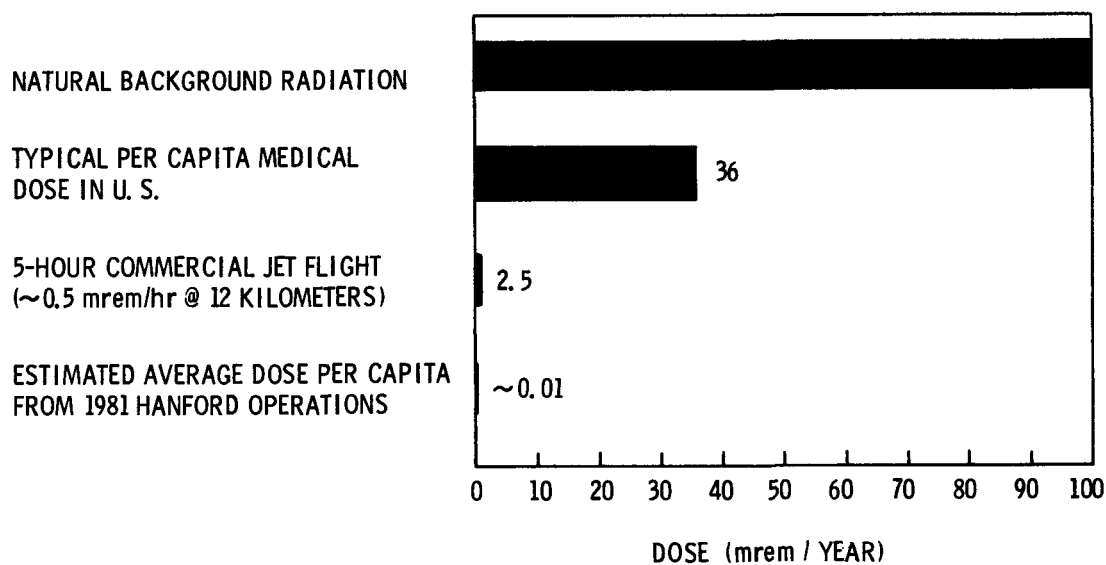
\*Doses were calculated to be less than .1 man-rem and are not reported in the summary table but are included in the dose total.

(a)Gastrointestinal tract (lower large intestine).

(b)Includes inhalation, submersion, and direct exposure to ground deposition.

(c)Includes consumption of all foodstuffs contaminated via irrigation water and dry deposition as well as direct exposure to soils contaminated via irrigation water.

(d)Includes consumption of fish taken from the Columbia River.



**FIGURE 15.** Whole Body Doses Received From Various Radiation Sources

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**APPENDIX A**  
**APPLICABLE STANDARDS**

## APPENDIX A

### APPLICABLE STANDARDS

Operations at the Hanford Site must conform to a variety of federal and state standards designed to ensure the radiological, chemical, biological, and physical quality of the environment for either aesthetic or public health considerations. The state of Washington has promulgated water quality standards for the Columbia River (Washington State Department of Ecology 1977). Of interest to Hanford operations is the designation of the Hanford reach of the Columbia River as Class A excellent. This designation requires that the water be usable for substantially all needs including drinking water, recreation, and wildlife. Class A water standards are summarized in Table A.1. Air quality standards have been promulgated by the Environmental Protection Agency (EPA 1973) and are summarized in Table A.2.

Environmental radiation protection standards are published in DOE ORDER 5480.1 *Environmental Protection, Safety, and Health Protection Program for DOE Operations*. These standards (shown in Table A.3) are based on guidelines

originally recommended by the Federal Radiation Council (FRC) and other scientific groups such as the International Commission on Radiological Protection (ICRP) and the National Commission on Radiation Protection and Measurements (NCRP). The standards govern exposures to ionizing radiation from DOE operations. DOE ORDER 5480.1 also lists radionuclide concentration guides for air and water. Several of the concentration guides for air and water are listed in Table A.4

Copies of these regulations may be obtained from the following organizations:

State of Washington,  
Department of Ecology  
Olympia, WA 98504

U.S. Environmental Protection Agency  
Region 10  
1200 Sixth Avenue  
Seattle, WA 98101

U.S. Department of Energy  
Richland Operations Office  
Richland, WA 99352

**TABLE A.1.** Washington State Water Quality Standards for the Hanford Reach of the Columbia River

Parameter	Permissible Levels
Fecal Coliform Organism	1) $\leq 100$ organisms/100 ml (median) 2) $\leq 10\%$ of samples may exceed 200 organisms/100 ml
Dissolved Oxygen	$> 8$ mg/l
Temperature	1) $\leq 18^{\circ}\text{C}$ ( $64^{\circ}\text{F}$ ) due to human activities 2) Increases not to exceed $(28/T + 27)$ , 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	$\leq 5$ NTU <sup>(a)</sup> 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 A.2. Water Quality Standards**

Parameter	Maximum Permissible Level	Period
SO <sub>2</sub> <sup>(a)</sup>	0.10 ppm 0.02 ppm	24-hr Average Annual Average
NO <sub>2</sub> <sup>(b)</sup>	100 µg/m <sup>3</sup> 250 µg/m <sup>3</sup> <sup>(c)</sup>	Annual Arithmetic Mean 24-hr Average
Suspended Particulates <sup>(a)</sup>	60 µg/m <sup>3</sup> <sup>(d)</sup>	Annual Mean

(a)Ref: Washington State Department of Ecology.

(b)Ref: U.S. EPA.

(c)Not to be exceeded more than once per year.

(d)Less background east of the Cascades.

**TABLE A.3. Radiation Protection Standards for External and Internal Exposure**

Type of Exposure	Annual Dose Equivalent or Dose Commitment (millirem) <sup>(a)</sup>	
	Based on Dose to Individuals at Points of Maximum Probable Exposure	Based on an Average Dose to a Suitable Sample of the Exposed Population <sup>(b)</sup>
Whole Body, Gonads, or Bone Marrow	500	170
Other Organs	1500	500

(a)In keeping with DOE policy on lowest practicable exposure, exposures to the public shall be limited to as small a fraction of the respective annual dose limits as is reasonably achievable.

(b)See paragraph 5.4 Federal Radiation Council Report No. 1, for discussion on concept of suitable sample of exposed population.

**TABLE A.4.** Radionuclide Concentration Guides

Radionuclide	Water ( $10^{-9}$ $\mu$ Ci/ml)	Air ( $10^{-12}$ $\mu$ Ci/ml)
Gross Alpha	30	0.02
Gross Beta	3,000	100
$^3\text{H}$	3,000,000	200,000
$^{54}\text{Mn}$	100,000	1,000
$^{51}\text{Cr}$	2,000,000	80,000
$^{60}\text{Co}$	30,000	300
$^{65}\text{Zn}$	100,000	2,000
$^{90}\text{Sr}$	300	30
$^{95}\text{ZrNb}$	60,000	1,000
$^{106}\text{Ru}$	10,000	200
$^{131}\text{I}$	300	100
$^{137}\text{Cs}$	20,000	500
$^{140}\text{BaLa}$	20,000	500
$^{144}\text{Ce}$	10,000	200
$^{239}\text{Pu}$	5,000	0.06

**APPENDIX B**  
**DATA ANALYSIS**

## APPENDIX B

### DATA ANALYSIS

The measurement of any physical quantity, whether it be temperature, distance, time, or radioactivity has some degree of inherent uncertainty associated with the final result. The uncertainty results from the combination of all possible inaccuracies in the measurement process including, for example, the reading of the result, the calibration of the measurement device, numerical rounding errors, etc. In this report, most radioactivity measurements are accompanied by a plus or minus ( $\pm$ ) analytical uncertainty term. This term represents the statistical counting error (two-standard deviations) associated with the measurement of the radioactivity in the sample. Many of the concentrations of radioactivity in samples of environmental media are very low, near zero, such that the counting error associated with the measurement may be larger than the indicated concentration. In these situations, the radioactivity in the sample was too low to be detected using the particular measurement technique. As an aid to the reader, individual measurements in this report, if less than their associated analytical uncertainty, are enclosed within parenthesis. If the number within the parenthesis includes a " $\pm$ " term, the actual observed result is given along with its statistical counting error. This result will always be smaller than its counting error and may even be zero or a negative number. If the number within the parenthesis is preceded by a "<" sign, the number signifies the

statistical counting error with the implied assumption that the observed result was lower.

Although values that are less than their associated uncertainty term do not represent a physically real quantity in themselves, it is appropriate to include them when computing the overall averages of a group of samples. For samples whose results were reported as less than (<) the statistical counting error, the concentration in the sample was assumed to be equal to the reported counting error when calculating group averages. This procedure results in a high biased average, which is reported with an accompanying less than (<) sign.

In this report, averages also include an uncertainty term that represents the distribution of the calculated mean. The term used to express the uncertainty associated with the mean is the two-standard error of the mean and includes consideration of the uncertainty of the individual results as well as their variability with respect to each other.

Maximum and minimum values are also included in most data tables. These are shown numerically only if the result was greater than the associated uncertainty level. To report maximum or minimum results in which the radionuclide was not identified in the sample would not be appropriate.

Footnotes to the tables further explain the data presented.



**APPENDIX C**  
**ANALYTICAL PROCEDURE**

## APPENDIX C

### ANALYTICAL PROCEDURES

#### RADIOLOGICAL SAMPLES

All routine environmental surveillance samples are analyzed according to detailed, written analytical procedures that are described in general terms below. Minimum detectable concentrations for the various medium/analysis combinations are shown in Table C.1.

#### Air Samples

**Alpha-, Beta-, and Gamma-Emitting Radionuclides** are measured by a direct count of the glass fiber filter; alpha on a low-background gas flow proportional counter, beta on a gas flow proportional counter, and gamma on a 23-cm x 23-cm (9-in. x 9-in.) NaI (Tl) well detector with a multichannel gamma-ray spectrometer.

**Strontium-89, 90** are determined by leaching the glass fiber filters with nitric acid, scavenging with barium chromate, precipitating as a carbonate, transferring to a stainless steel planchet, and

counting with a low-background gas flow proportional counter.

**Plutonium** is leached from the glass fiber filters with fuming nitric acid and passed through an anion exchange resin. The plutonium on the resin column is eluted with nitric and hydrofluoric acids and electrodeposited on a stainless steel disk, exposed to nuclear track film, and then counted.

**Tritium** in air as HTO is determined by collecting the water vapor with silica gel. The water vapor is removed by heat and vacuum and collected in a freeze trap. The tritium content of the water vapor is determined with a liquid scintillation spectrometer.

**Iodine-131** is collected on activated charcoal which is then counted in a 23-cm x 23-cm (9-in. x 9-in.) NaI (Tl) well detector with a multichannel gamma-ray spectrometer.

**TABLE C.1.** Minimum Detectable Concentrations (MDC)<sup>(a)</sup>

Radionuclide	Air		Water		Water (Resin Sampler)		Foodstuff & Wildlife		Soil & Vegetation	
	Minimum Sample Size (m <sup>3</sup> )	MDC (pCi/m <sup>3</sup> )	Minimum Sample Size (liters)	MDC (pCi/l)	Minimum Sample Size (liters)	MDC (pCi/l)	Minimum Sample Size (kg)	MDC (pCi/kg)	Minimum Sample Size (kg)	MDC (pCi/kg)
<sup>3</sup> H	5 m <sup>3</sup>	300 pCi/l	1	50						
<sup>89</sup> Sr	1500	0.06	10	0.6			0.5	5		
<sup>90</sup> Sr	1500	0.006	10	0.06			0.5	2	0.5	5
<sup>129</sup> I					1000	0.00001				
<sup>131</sup> I	1500	0.01	1	4	1000	0.1	4 <sup>l</sup> (milk)	0.5 (pCi/l)		
U-nat			0.01	0.5					0.5	10
<sup>238</sup> Pu					1000	0.01			0.5	0.6
<sup>239/240</sup> Pu	1500	0.0001			1000	0.01			0.5	0.6
Gamma-Emitters	1500	0.1 <sup>(b)</sup>	5	8 <sup>(b)</sup>	1000	0.1 <sup>(b)</sup>	0.5	15 <sup>(b)</sup>	0.5	20 soil, 30 vegetation
Gross Alpha	800	0.001	1	5						
Gross Beta	800	0.01	1	10						

(a) Contractually established MDC based on the minimum sample size shown. Lower MDCs are usually obtained in actual practices.

(b) Based on <sup>137</sup>Cs minimum detectable concentration. When present individually, other gamma emitting radionuclides will have a MDC commensurate with their photon yield and energy as related to <sup>137</sup>Cs.

## Water Samples

**Beta-Emitting Radionuclides** are measured by a direct count of dried residue with a gas flow proportional counter.

**Alpha-Emitting Radionuclides (Uranium and Plutonium)** are extracted into ether from strong nitric acid. The ether phase is evaporated. The residue is plated on a stainless steel planchet and counted with a low-background gas flow proportional counter.

**Gamma-Emitting Radionuclides** are determined by a direct count of 500 ml of sample in a 23-cm x 23-cm (9-in. x 9-in.) NaI (TI) well detector with a multichannel gamma-ray spectrometer.

**Strontium-90** in large-volume water samples is precipitated with fuming nitric acid, scavenged with barium chromate, precipitated as a carbonate, transferred to stainless steel planchet, and counted with a low-background gas flow proportional counter. After a 15-day period the yttrium-90 daughter is separated and then counted with a proportional counter.

**Tritium** samples are either counted directly with a liquid scintillation spectrometer or the sample is enriched by electrolysis and then counted with a spectrometer.

**Filter-Resin Samples** are analyzed for gamma-emitting radionuclides using a Ge(Li) detector with a multichannel gamma-ray spectrometer. Aliquots of the samples are analyzed by neutron activation analysis for  $^{129}\text{I}$  and by chemical separation and alpha spectrometry for plutonium.

## Milk

**Gamma-Emitting Radionuclides** are measured by a direct count of the sample in a 23-cm x 23-cm (9-in. x 9-in.) NaI (TI) well detector with a multichannel gamma-ray spectrometer.

**Iodine-131** is removed from milk with an anion exchange resin. The iodine is eluted with sodium hypochlorite, precipitated as palladium iodide and beta-counted with a low-background gas flow proportional counter.

**Strontium-90** is removed by drying, wet ashing, precipitating with fuming nitric acid, scavenging with barium chromate, precipitating as a carbonate, and transferring to a stainless steel planchet for counting with a low-background gas flow proportional counter.

## Farm Produce

**Gamma-Emitting Radionuclides** are determined by a direct count of the sample in the well of a 23-cm x 23-cm (9-in. x 9-in.) NaI (TI) well detector with a multichannel gamma-ray spectrometer.

**Plutonium** analyses are made like those for air filter samples after drying, ashing in a furnace, and treating with nitric acid prior to the anion exchange step.

**Uranium** analyses are made like those for water samples after drying, ashing in a furnace, and treating with nitric acid prior to the ether extraction step.

**Strontium-90** analyses are made like those for air samples after drying, ashing in a furnace, and treating with nitric acid prior to the fuming nitric acid step.

## Vegetation

**Uranium, Plutonium, Strontium, and Gamma-Emitting Radionuclides** are determined using the procedures described for farm produce.

## Soil

**Gamma-Emitting Radionuclides** are analyzed by placing the sample into a marinelli beaker and counting on a Ge(Li) detector, with a multichannel pulse height analyzer.

**Plutonium and Strontium-90** are determined after the soil is dried, mixed thoroughly, leached with a mixture of nitric and hydrochloric acids, and then passed through an ion exchange resin in nitric acid.

The nitric acid retains strontium and other metal ions. Strontium-90 is separated and counted in a manner similar to the fuming nitric acid procedure described for air filter samples.

The plutonium is eluted from the resin column with nitric and hydrofluoric acids and analyzed by a method similar to the procedure described for air filter samples.

**Uranium** analysis is conducted after the sample is dried, ashed in a furnace, and leached with hot nitric acid. Uranium is extracted from the acid leachate as tetrapropyl ammonium uranyl trinitrate and then extracted back into water. A portion of the water extract is fused with sodium and lithium fluoride and analyzed with a fluorometer.

### **NONRADIOLOGICAL SAMPLES**

Water samples collected to monitor water quality of the Columbia River are analyzed according to standard methods. The most applicable

methods recommended by the American Public Health Association in their publication *Standard Methods for the Examination of Water and Wastewater* are used for a wide range of analyses.

**APPENDIX D**

**QUALITY ASSURANCE**

## APPENDIX D

### QUALITY ASSURANCE

A number of steps are taken to ensure that the data collected are representative of actual concentrations in the environment. First, extensive environmental data are obtained to eliminate an unrealistic reliance on only a few results. Second, newly collected data are continually compared with both recent results and historical data for each location and each environmental medium to ensure that deviations from previous conditions are identified and promptly evaluated. Third, samples are collected using well-established and documented procedures to ensure consistency in sample collection. Fourth, identical sampling methods are used at all locations to minimize the effects of bias inherent in the sample collection process. These procedures, in conjunction with a program to demonstrate the accuracy and precision of radiochemical analyses, ensure that the sampling program provides data that can be used to accurately evaluate environmental impacts resulting from Hanford operations.

#### ANALYTICAL LABORATORY QUALITY ASSURANCE

The majority of the routine radioanalyses for the Hanford Environmental Surveillance Program are performed under subcontract by the United States Testing Company, Inc., (UST) Richland, Washington. This laboratory maintains an internal quality assurance program that involves routine calibration of counting instruments, daily source and background counts, routine yield determinations of radiochemical procedures, replicate analyses to check precision, and analyses of reagents to ensure purity of chemicals. The accuracy of radionuclide determination is ensured through the use of standards traceable to the National Bureau of Standards, when available. The laboratory also participates in laboratory intercomparison programs conducted by the Environmental Measurements Laboratory (EML) and the Environmental Protection Agency (EPA). In these programs, a number of different environmental media (water, milk, air filters, soil, and foodstuffs) containing one or more radionuclides in known amounts are prepared

and distributed to participating laboratories. Replicate analyses are performed on each sample, and the results are forwarded to the sponsoring laboratory for comparison with known values and with the results from other laboratories. These programs enable the laboratory to demonstrate that it is capable of performing accurate analyses.

Summarized in Tables D.1 and D.2 are comparisons of UST, EPA and EML results. The EML and EPA results, while not necessarily the true values, are the mean of replicate analyses by the participating laboratories and are used as the reference values in the programs.

In addition to these programs, the laboratory is provided, without their knowledge, quantitatively spiked samples. During 1981, spiked samples of milk, meat, produce, soil, and water were submitted routinely for analysis. Some results clearly indicated the need for a review of analytical methods and procedures, and as a result, the methods used for analyzing  $^{90}\text{Sr}$ , plutonium, and gamma-emitting radionuclides will be improved.

#### SAMPLE COLLECTION QUALITY ASSURANCE

Of primary importance in the operation of an environmental surveillance program is the collection of representative samples. To check on the precision of samples, duplicate air particulate filters were collected at several locations. Tables D.3 and D.4 show the average biases and the range of individual biases for gross beta and gross alpha analyses of the duplicate air filters. Due to the very small amounts of radioactive particulate material in the Hanford environs, results of individual duplicate pairs of air filter samples may vary by 100%. However, the average biases, representing 12 monthly sampling periods, show good agreement between duplicates. Table D.5 shows the results obtained from duplicate air samples composited for the analysis of  $^{137}\text{Cs}$ ,  $^{90}\text{Sr}$ , and  $^{239/240}\text{Pu}$ . The observed degree of bias is acceptable. Table D.6 shows the individual and average percent biases for the results of duplicate TLDs. Each month three pairs of duplicate TLDs were exposed at one of three

**TABLE D.1.** Summary of Environmental Measurements Laboratory Intercomparison Results for 1981

Sample Media	Radionuclide	No. of Analyses	Average Ratio UST to EML	Sample Media	Radionuclide	No. of Analyses	Average Ratio UST to EML
Air	<sup>7</sup> Be	4	1.26 ± .10	Vegetation	<sup>40</sup> K	2	0.90 ± .03
	<sup>57</sup> Co	2	1.48 ± .06		<sup>90</sup> Sr	2	0.70 ± .05
	<sup>58</sup> Co	2	1.31 ± .13		<sup>137</sup> Cs	2	0.95 ± .18
	<sup>60</sup> Co	2	1.18 ± .04		<sup>226</sup> Ra	1	1.45 ± .60
	<sup>89</sup> Sr	2	1.01 ± .04		<sup>239</sup> Pu	1	2.38 ± .63
	<sup>90</sup> Sr	4	0.89 ± .10		U-nat	2	0.23 ± .11
	<sup>95</sup> Zr	2	2.85 ± .45	Tissue	<sup>40</sup> K	1	1.66 ± .45
	<sup>125</sup> Sb	4	0.93 ± .45		<sup>90</sup> Sr	1	0.76 ± .05
	<sup>134</sup> Cs	2	1.10 ± .04		<sup>226</sup> Ra	1	0.78 ± .06
	<sup>137</sup> Cs	2	1.35 ± .05		U-nat	1	1.27 ± .63
	<sup>238</sup> Pu	2	0.91 ± .18	Water	<sup>3</sup> H	2	0.85 ± .03
	<sup>239</sup> Pu	4	1.02 ± .14		<sup>51</sup> Cr	1	0.99 ± .09
	U-nat	4	0.41 ± .14		<sup>54</sup> Mn	1	0.90 ± .53
Soil	<sup>40</sup> K	2	0.92 ± .05		<sup>57</sup> Co	1	0.83 ± .04
	<sup>90</sup> Sr	2	1.02 ± .20		<sup>59</sup> Fe	1	0.93 ± .55
	<sup>137</sup> Cs	2	0.94 ± .08		<sup>60</sup> Co	1	0.63 ± .04
	<sup>226</sup> Ra	1	0.83 ± .14		<sup>90</sup> Sr	2	1.13 ± .17
	<sup>238</sup> Pu	2	6.85 ± 2.83		<sup>137</sup> Cs	1	0.73 ± .06
	<sup>239</sup> Pu	2	1.02 ± .18		<sup>144</sup> Ce	1	1.03 ± .09
	U-nat	2	0.38 ± .04		<sup>239</sup> Pu	2	1.01 ± .29
					U-nat	2	0.70 ± .23

**TABLE D.2** Environmental Protection Agency Laboratory Intercomparison Results for 1981

Sample Media	Radionuclide	Month	Concentrations (a)		
			UST(b)	Expected (b)	Other Lab (c)
Air Filters	Gross Alpha	Mar	30.8 ± 1.5	30 ± 22.5	32 ± 15
	Gross Beta		69.1 ± 2.3	50 ± 15.0	56 ± 33
	<sup>90</sup> Sr		16.7 ± 0.5	18 ± 4.5	17 ± 9
	<sup>137</sup> Cs		11.9 ± 4.5	14 ± 15.0	16 ± 12
	Gross Alpha	June	29.9 ± 0.9	28 ± 12.0	32 ± 18
	Gross Beta		70.8 ± 1.8	54 ± 8.7	64 ± 30
	<sup>90</sup> Sr		18.3 ± 0.5	19 ± 2.6	19 ± 9
	<sup>137</sup> Cs		20.0 ± 5.1	16 ± 8.7	20 ± 15
	Gross Alpha	June	20.9 ± 3.5	25 ± 11.0	26 ± 18
	Gross Beta		60.8 ± 4.8	52 ± 8.7	61 ± 30
	<sup>90</sup> Sr		15.7 ± 1.8	16 ± 2.6	17 ± 9
	<sup>137</sup> Cs		4.5 ± 9.8	19 ± 8.7	24 ± 18
Water	Gross Alpha	Jan	8.6 ± 3.4	9 ± 15.0	9 ± 9
	Gross Beta		38.2 ± 6.3	44 ± 15.0	44 ± 18
	<sup>89</sup> Sr		46.2 ± 3.5	16 ± 15.0	15 ± 15
	<sup>90</sup> Sr		22.6 ± 2.1	34 ± 5.4	32 ± 15
	<sup>239</sup> Pu		3.6 ± 0.7	7.4 ± 2.1	3.9 ± 1.8

**TABLE D.2** Environmental Protection Agency Laboratory Intercomparison Results for 1981 (Contd)

Sample Media	Radionuclide	Month	Concentrations <sup>(a)</sup>		
			UST <sup>(b)</sup>	Expected <sup>(b)</sup>	Other Lab <sup>(c)</sup>
Water	<sup>3</sup> H	Feb	1419 ± 200	1760 ± 1023	1778 ± 690
	<sup>51</sup> Cr		10.7 ± 14.0*	(d)	49 ± 33
	<sup>60</sup> Co		20.7 ± 3.2	25 ± 15.0	25 ± 12
	<sup>65</sup> Zn		79.6 ± 8.4	85 ± 15.0	89 ± 33
	<sup>106</sup> Ru		6.3 ± 83.0*	(d)	50 ± 129
	<sup>134</sup> Cs		29.0 ± 2.7	36 ± 15.0	33 ± 15
	<sup>137</sup> Cs		3.9 ± 1.5	4 ± 15.0	5 ± 6
	Gross Alpha	Mar	26.1 ± 5.4	25 ± 18.0	24 ± 18
	Gross Beta		28.2 ± 4.4	25 ± 15.0	28 ± 15
	<sup>226</sup> Ra		2.9 ± 0.4	3.4 ± 1.5	3.4 ± 2.1
	<sup>228</sup> Ra		6.9 ± 0.6	7.3 ± 3.3	7.0 ± 4.8
	<sup>3</sup> H	Apr	2038 ± 335.0	2710 ± 615	2717 ± 1119
	<sup>131</sup> I		34.6 ± 2.9	30 ± 10.0	29 ± 15
	<sup>131</sup> I		94.3 ± 2.0	73 ± 13.0	72 ± 21
	Gross Alpha	May	23.0 ± 1.8	21 ± 15.8	19 ± 15
	Gross Beta		12.2 ± 2.8	14 ± 15.0	16 ± 12
	<sup>89</sup> Sr		41.4 ± 0.6	36 ± 15.0	32 ± 30
	<sup>90</sup> Sr		18.5 ± 0.4	22 ± 4.5	22 ± 18
	<sup>3</sup> H	June	1191 ± 149.0	1950 ± 1032	1948 ± 726
	<sup>51</sup> Cr		-2.0 ± 7.4*	(d)	15 ± 69
	<sup>60</sup> Co		14.1 ± 2.1	17 ± 15.0	17 ± 9
	<sup>65</sup> Zn		-1.0 ± 1.7*	(d)	(d)
	<sup>106</sup> Ru		20.8 ± 6.3	15 ± 15.0	12 ± 27
	<sup>134</sup> Cs		16.1 ± 1.7	21 ± 15.0	20 ± 9
	<sup>137</sup> Cs		30.1 ± 2.4	31 ± 15.0	31 ± 15
	<sup>226</sup> Ra		16.8 ± 0.9	6.7 ± 1.7	6.5 ± 3.9
	<sup>228</sup> Ra		11.1 ± 0.4	8.0 ± 2.1	7.7 ± 8.3
	Gross Alpha		20.7 ± 2.0	22 ± 16.5	18 ± 15
	Gross Beta	July	14.3 ± 1.8	15 ± 15.0	17 ± 12
	<sup>239</sup> Pu		5.8 ± 0.6	5.8 ± 1.8	6.2 ± 4.5
	<sup>3</sup> H	Aug	3055 ± 259.0	2630 ± 613	2613 ± 1083
	U (total)		21.0 ± 1.5	23 ± 18.0	23 ± 12
	Gross Alpha	Sept	29.2 ± 2.3	33 ± 24.9	28 ± 24
	Gross Beta		20.6 ± 2.0	28 ± 15.0	25 ± 18
	<sup>89</sup> Sr		22.9 ± 0.5	23 ± 15.0	22 ± 9
	<sup>90</sup> Sr		10.9 ± 0.2	11 ± 4.5	11 ± 6
	<sup>226</sup> Ra		30.3 ± 0.7	8.3 ± 3.9	8.2 ± 4.8
	<sup>228</sup> Ra		3.9 ± 0.3	11.7 ± 5.4	10.9 ± 9.3
	<sup>3</sup> H	Oct	2106 ± 387	2210 ± 1074	2133 ± 642
	<sup>51</sup> Cr		28.1 ± 5.7	34 ± 15.0	36 ± 27
	<sup>60</sup> Co		19.6 ± 1.7	22 ± 15.0	23 ± 9
	<sup>65</sup> Zn		18.8 ± 2.4	24 ± 15.0	24 ± 12
	<sup>106</sup> Ru		2.0 ± 4.2*	(d)	(d)
	<sup>134</sup> Cs		16.8 ± 1.4	21 ± 15.0	20 ± 12
	<sup>137</sup> Cs		30.9 ± 1.8	32 ± 15.0	33 ± 12
	Gross Alpha	Nov	11.9 ± 1.8	21 ± 15.8	20 ± 15
	Gross Beta		19.2 ± 2.1	23 ± 15.0	23 ± 15
	<sup>3</sup> H	Dec	2253 ± 297.0	2700 ± 615	2676 ± 672



**TABLE D.2** Environmental Protection Agency Laboratory Intercomparison Results for 1981 (Contd)

Sample Media	Radionuclide	Month	Concentrations <sup>(a)</sup>		
			UST <sup>(b)</sup>	Expected <sup>(b)</sup>	Other Lab <sup>(c)</sup>
Milk	<sup>89</sup> Sr	Jan	5.2 ± 6.8	(d)	29 ± 111
	<sup>90</sup> Sr		14.9 ± 4.1	20 ± 9.0	19 ± 9
	<sup>131</sup> I		32.3 ± 22.5	26 ± 30.0	26 ± 18
	<sup>137</sup> Cs		31.6 ± 15.8	43 ± 27.0	42 ± 21
	<sup>140</sup> Ba		21.6 ± 40.8*	(d)	4 ± 15
	<sup>89</sup> Sr	May	26.9 ± 31.	25 ± 15.0	22 ± 18
	<sup>90</sup> Sr		9.2 ± 1.9	11 ± 4.5	10 ± 9
	<sup>131</sup> I		50.9 ± 44.8	26 ± 18.0	27 ± 21
	<sup>137</sup> Cs		13.6 ± 15.8	22 ± 15.0	23 ± 9
	<sup>140</sup> Ba		19.7 ± 27.5*	(d)	(d)
	<sup>89</sup> Sr	July	26.5 ± 1.4	25 ± 15.0	28 ± 18
	<sup>90</sup> Sr		14.8 ± 0.8	17 ± 4.5	16 ± 6
	<sup>131</sup> I		18.9 ± 6.1	(d)	7.2 ± 21.3
	<sup>137</sup> Cs		13.4 ± 6.6	31 ± 15	32 ± 12
	<sup>140</sup> Ba		13.0 ± 11.7	(d)	(d)
	<sup>89</sup> Sr	Oct	19.4 ± 2.2	23 ± 8.7	22 ± 15
	<sup>90</sup> Sr		17.5 ± 0.8	18 ± 2.6	18 ± 9
	<sup>131</sup> I		86.7 ± 23.7	52 ± 10.0	53 ± 21
	<sup>137</sup> Cs		9.1 ± 4.3	25 ± 8.7	27 ± 9
	<sup>140</sup> Ba		9.5 ± 18.1*	(d)	(d)
Food	<sup>89</sup> Sr	Mar	76.9 ± 6.8	47 ± 15	43 ± 54
	<sup>90</sup> Sr		21.1 ± 4.1	29 ± 4.5	27 ± 24
	<sup>131</sup> I		146.6 ± 41.4	119 ± 36.0	123 ± 39
	<sup>137</sup> Cs		56.7 ± 20.0	53 ± 15.0	53 ± 18
	<sup>140</sup> Ba		21.7 ± 56.4*	(d)	(d)
	<sup>89</sup> Sr	July	51.8 ± 1.0	44 ± 15.0	44 ± 27
	<sup>90</sup> Sr		30.0 ± 0.5	31 ± 4.8	29 ± 9
	<sup>131</sup> I		110.7 ± 19.0	82 ± 24.0	87 ± 45
	<sup>137</sup> Cs		34.5 ± 4.9	45 ± 15.0	46 ± 18
	<sup>140</sup> Ba		16 ± 55*	(d)	(d)
	<sup>60</sup> Co	Nov	25.0 ± 7.9	30 ± 8.7	30 ± 12
	<sup>89</sup> Sr		41.7 ± 2.2	38 ± 8.7	35 ± 4.5
	<sup>90</sup> Sr		24.4 ± 1.1	23 ± 2.6	23 ± 12
	<sup>137</sup> Cs		14.0 ± 6.6	33 ± 8.7	35 ± 12
	<sup>140</sup> Ba		3.7 ± 23.1*	(d)	(d)

(a) Picocuries per liter for water and milk; Picocuries per sample for air; Picocuries per gram for food.

(b) Concentration plus or minus three sigma based on counting statistics.

(c) Average concentration plus or minus three sigma based upon range of values encountered.

(d) Sample did not contain the radionuclide.

\*—Not identified in sample.

**TABLE D.3.** Evaluation of Duplicate Air Samples—Gross Beta Analyses. (Expressed as results of duplicate sample minus result of record sample.)

Location <sup>(a)</sup>	Average Bias (pCi/m <sup>3</sup> )	Average Bias (%)	Range of Individual Biases (%)
A (25)	.009	10	-25 to 110
B (25)	-.002	-3.3	-91 to 80
C (24)	-.009	-4.0	-24 to 16
D (22)	.003	4.4	-22 to 41

(a) Value in parenthesis is the number of duplicate pairs of air samples analyzed.

**TABLE D.4.** Evaluation of Duplicate Air Samples—Gross Alpha Analyses. (Expressed as results of duplicate sample minus result of record sample.)

Location <sup>(a)</sup>	Average Bias (pCi/m <sup>3</sup> )	Average Bias (%)	Range of Individual Biases (%)
A (24)	-.0001	4.2	-75 to 100
B (25)	-.0001	-11	-100 to 122
C (25)	-.0002	-1.7	-50 to 185

(a) Value in parenthesis is the number of duplicate pairs of air samples analyzed.

**TABLE D.5.** Duplicate Air Sample Results for Composited Samples

Constituent	Date	Record Concentration (pCi/m <sup>3</sup> )	Duplicate Concentration (pCi/m <sup>3</sup> )	Bias (pCi/m <sup>3</sup> )	Bias (%)
<sup>137</sup> Cs	1-26-81	.006 ± .001	.004 ± .001	-.002	-33
	2-23-81	.005 ± .001	.006 ± .002	.001	20
	3-30-81	.006 ± .0009	.007 ± .0009	.001	17
	4-27-81	.007 ± .001	.004 ± .001	-.003	-43
	5-26-81	.008 ± .001	.007 ± .001	-.001	-13
	6-29-81	.006 ± .0009	.008 ± .0009	.002	33
	7-27-81	.003 ± .001	.000 ± .001	-.003	—
	8-31-81	.000 ± .001	.000 ± .0006	0	0
	9-28-81	.000 ± .001	.000 ± .001	0	0
	10-26-81	.000 ± .001	.000 ± .001	0	0
	11-30-81	.000 ± .001	.000 ± .0009	0	0
	12-21-81	.000 ± .001	.000 ± .001	0	0
<sup>90</sup> Sr	2-23-81	.0004 ± .00007	.0003 ± .00007	-.0001	-25
	5-26-81	.001 ± .0001	.001 ± .0001	0	0
	8-31-81	.002 ± .0003	.002 ± .0002	0	0
	12-21-81	.0003 ± .0002	.0005 ± .0002	.0002	67
<sup>239</sup> / <sup>240</sup> Pu	2-31-81	.00000 ± .000003	.00003 ± .000007	.00003	—
	5-26-81	.00003 ± .00002	.00003 ± .00002	0	0
	8-31-81	.00002 ± .000008	.00002 ± .000008	0	0

**TABLE D.6.** Individual and Average Percent Bias for the Analysis of Duplicate TLDs

Month	Individual Bias (%) <sup>(a)</sup>			Average Bias (%)
January	4.0	3.1	3.1	3.6
February	-5.7	-0.8	-4.8	-3.8
March	0.0	-4.4	-2.3	-2.2
April	-3.2	-3.7	-4.1	-3.7
May	2.1	3.8	-0.8	1.7
June	-1.7	0.7	0.5	-0.2
July	5.2	3.7	2.7	3.9
August	-1.5	-0.9	0.2	-0.7
September	-0.7	0.5	0.0	-0.1
October	6.9	1.2	4.1	4.1
November	8.3	8.2	6.3	7.6
December	4.6	7.4	1.1	4.4

(a) Each pair of TLDs was exposed at one of three different levels between 8 and 23 mR

levels of radiation representing environmental levels. These results also show an acceptable degree of bias.

#### DOSE CALCULATIONS QUALITY ASSURANCE

Assurance of the quality of dose calculations is provided in several ways. First, comparisons are made against past calculated doses and significant differences are verified. Second, all computed doses are double checked by the originator and by an independent third party who also checks all input data and assumptions used in the calculation. Third, information necessary to perform all of the calculations is fully documented (see Appendix E, Dose Calculations).

**APPENDIX E**

**DOSE CALCULATIONS**

## APPENDIX E

### DOSE CALCULATIONS

The impact on the public from operations involving radioactive materials at Hanford are assessed in terms of the radiation “dose equivalent.” The radiation dose equivalent is expressed in units of millirem and provides a means for expressing radiation impact regardless of the type or source of radiation and the means by which exposure is incurred. The reported millirem dose equivalent can be compared to the dose standards in Appendix A, which have been established by the DOE.

For certain types of exposure pathways, the dose equivalent results from the inhalation or ingestion of radionuclides in the air, water, foods, etc., such that the radionuclides may be metabolically absorbed by the body and retained for some time. To fully account for the dose equivalent received in these cases, the dose impact is expressed as the “dose equivalent commitment” (or, dose commitment), also reported in units of millirem. The dose commitment includes the total dose equivalent received for a period of 50 years following the intake of the radionuclide.

Where possible, radiation dose commitments provided in this report are based on measured radionuclide concentrations in environmental media, and conversion factors are applied to relate the environmental concentrations in terms of dose. The preferred method of assessing environmental doses is to perform the radionuclide measurements as close to the point of exposure as possible (i.e., in drinking water, air, foods, etc.). However, the quantities of radionuclides actually released from Hanford are usually too low to be measured in the offsite environment, and, in most cases, doses are calculated based on measurements at the release point to which are applied environmental dispersion or reconcentration factors as appropriate for the various possible exposure pathways. Exposure pathways that are considered in dose calculations are illustrated in Figure E.1.

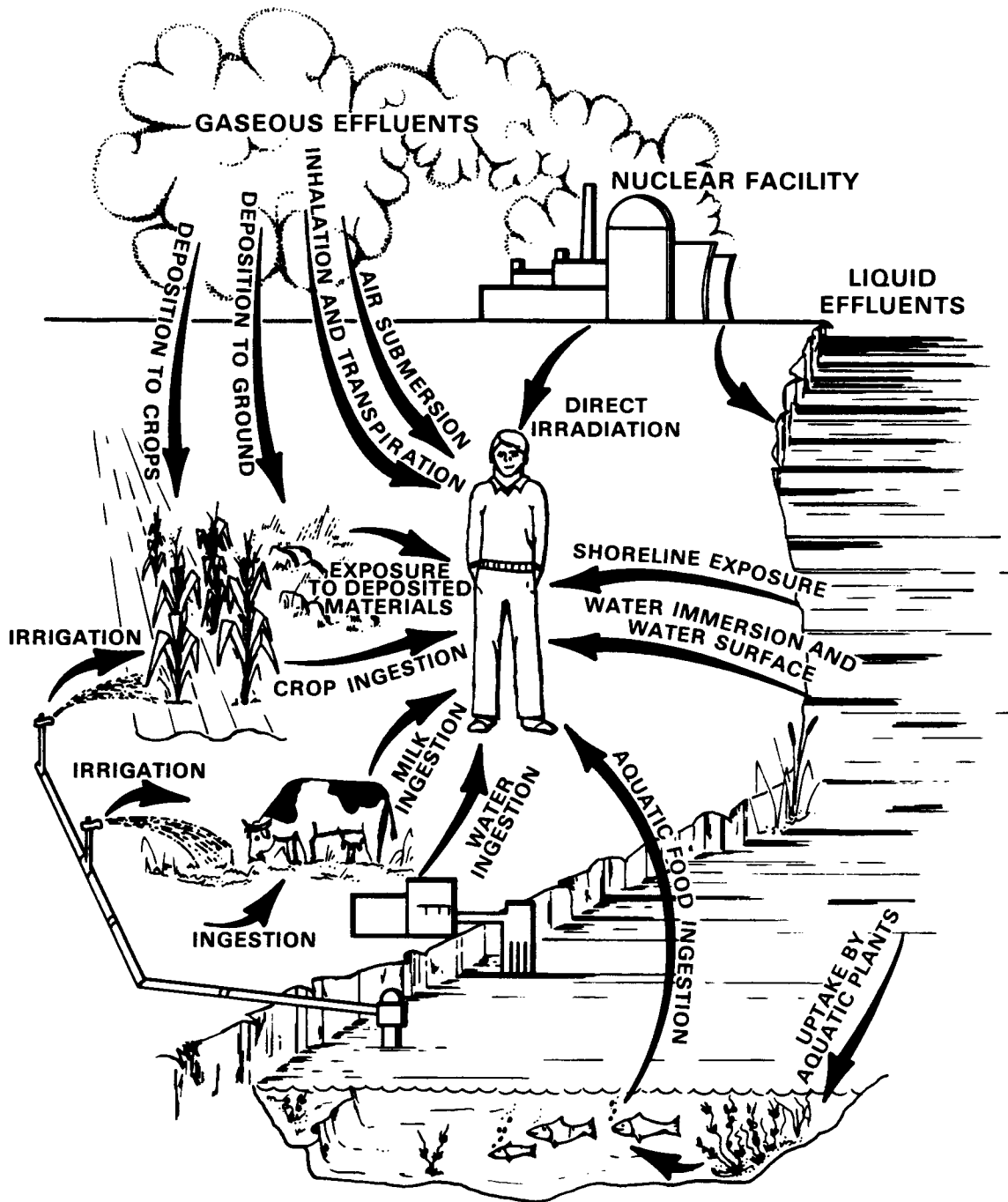
Regardless of the location or type of measurements upon which the environmental radiation

doses are based, a set of standardized computer programs are used to perform the calculations (Houston and Strenge 1974; Napier et al. 1980; Strenge et al. 1975; Strenge and Watson 1973). These programs contain internally consistent models that use site specific dispersion and uptake parameters when available. Because the calculated results are highly dependent on the specific inputs and assumptions used, a general description of the calculations and input data is provided here.

#### TYPES OF DOSE CALCULATIONS PERFORMED

The impact of Hanford operations is estimated in order to provide assurance that the health and safety of the public is not being jeopardized and that applicable regulations are being complied with. To those ends, various specific dose impacts are evaluated. These are:

1. **Fence-Post Whole Body Dose Rate.** This is an evaluation of the maximum external radiation dose rate at any time during the year in areas accessible by the public. This rate is normally based on measurements taken at locations of potential public access in close proximity to operating facilities.
2. **Maximum Individual Organ Dose.** The maximum individual (MI) is a member of the offsite population who, by virtue of his location and living habits, would receive the highest radiation dose. The MI is hypothetical in that an actual offsite individual is not identified. However, the MI is realistic to the extent that all exposure pathways are credible. The assessment of MI organ doses provides an evaluation of the maximum radiation doses that a member of the public could receive from a continuous year of exposure to Hanford operations. Exposure pathways that are considered are:
  - inhalation of radioactive airborne effluents
  - submersion in radioactive airborne effluents



**FIGURE E.1.** Environmental Dose Pathways

- ingestion of foodstuffs contaminated by airborne deposition and by irrigation with contaminated Columbia River water
- drinking sanitary water obtained from the Columbia River
- exposure to ground contaminated by airborne deposition and by irrigation with Columbia River water
- ingestion of fish taken from the Columbia River
- recreation along the Columbia River—boating, swimming and shoreline activities.

3. **80-km Population Doses.** While there are no regulatory limits for collective population doses, such an evaluation provides an indication of the overall impact of Hanford operations. The 80-km population dose represents the summation of the average 50-year dose commitment received by each member of the public residing within an 80-km radius of any of the four major operating areas on the Hanford Site. The units used are man-rem.

Pathways considered in calculating the doses to residents within the 80-km radii are the same as listed for the MI.

4. **Maximum Hypothetical Dose.** This is an evaluation of the maximum dose that could possibly be received by a member of the public regardless of the actual probability of the dose ever being incurred. Maximum hypothetical doses are calculated based on **observed maximum radionuclide concentrations** in onsite wildlife that could potentially move offsite and be hunted. Doses reported are based on the assumption that a single individual consumes the entire edible portion of a single animal with the stated radionuclide concentrations. The calculation of the dose enables comparison of such hypothetical scenarios with DOE dose standards but are not considered to be credible exposure pathways and are thus not included in the overall assessment of “realistic” dose impacts discussed in the “Radiological Impact of Hanford Operations” section.

## DATA

Input data necessary to perform dose calculations can be extensive. Calculations based on measured effluent release will require data describing initial transport through the atmosphere or river, transfer or accumulation in terrestrial and aquatic pathways, public exposure, and dosimetry. By comparison, calculations based on measurement of radioactive material concentrations in foodstuffs will only require the data describing exposure and dosimetry. These data are discussed in more detail in the sections that follow.

## POPULATION DISTRIBUTION

Geographic distributions of population residing within an 80-km radius of the four operating areas are listed in Tables E.1 through E.4. These distributions are based on 1980 Bureau of Census data (Sommer 1981). Population exposure to airborne effluents is determined through the use of population weighted X/Qs for each compass sector and annular ring.

**TABLE E.1.** Distribution of Population in 80-km Radius of the 100-N Reactor by Population Grid Sector for 1980

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

**TABLE E.2.** Distribution of Population in 80-km Radius of 200 Area Hanford Meteorological Tower by Population Grid Sector for the Year 1980

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

**TABLE E.3.** Distribution of Population in 80-km Radius of the FFTF by Population Grid Sector for the Year 1980

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

**TABLE E.4.** Distribution of Population in 80-km Radius of 300 Area by Population Grid Sector for the Year 1980

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

## ATMOSPHERIC DISPERSION

Radioactive material released to the atmosphere becomes diluted as it is carried away from the release point by the wind. The degree of dilution and magnitude of resultant air concentrations are predicted by atmospheric dispersion models that employ site specific measurements of the occurrence frequency for wind speed, wind direction, and atmospheric stability. The products of the dispersion model are annual average dispersion factors ( $X/Q$ , units  $\text{Ci}/\text{m}^3/\text{Ci}/\text{sec} = \text{sec}/\text{m}^3$ ) that, when combined with annual average release rates, will predict average radio-nuclide air concentrations for the year. Annual average dispersion factors for the 100, 200, and 300/400 Areas are listed in Tables E.5 through E.7.

## TERRESTRIAL AND AQUATIC PATHWAYS

Following release and initial transport through the environment, radioactive materials may enter terrestrial or aquatic pathways that lead to



**TABLE E.5** Annual Average Atmospheric Dispersion Around the 100-N Area for an 82-m Release Height (units are sec/m<sup>3</sup>)(a)

Direction	Range in Miles (km)									
	0.5 (0.8)	1.5 (2.4)	2.5 (4.0)	3.5 (5.6)	4.5 (7.2)	7.5 (12)	15 (24)	25 (40)	35 (56)	45 (72)
N	3.68E-08	1.60E-08	9.02E-09	5.69E-09	4.05E-09	2.49E-09	1.91E-09	1.44E-09	1.10E-09	8.69E-10
NNE	5.24E-08	2.05E-08	1.08E-08	6.64E-09	4.62E-09	1.94E-09	1.94E-09	1.46E-09	1.12E-09	8.90E-10
NE	1.44E-07	4.84E-08	2.35E-08	1.39E-08	9.39E-09	5.02E-09	3.30E-09	2.44E-09	1.87E-09	1.48E-09
ENE	1.21E-07	5.50E-08	2.81E-08	1.70E-08	1.17E-08	6.65E-09	4.72E-09	3.56E-09	2.73E-09	2.17E-09
E	1.14E-07	6.79E-08	3.60E-08	2.20E-08	1.54E-08	9.31E-09	7.43E-09	5.95E-09	4.70E-09	3.79E-09
ESE	1.20E-07	7.12E-08	3.76E-08	2.29E-08	1.59E-08	9.18E-09	6.87E-09	5.41E-09	4.27E-09	3.45E-09
SE	7.91E-08	4.84E-08	2.60E-08	2.60E-08	1.10E-08	5.95E-09	3.81E-09	2.74E-09	2.07E-09	1.63E-09
SSE	7.94E-08	4.40E-08	2.27E-08	1.37E-08	9.28E-09	4.73E-09	2.72E-09	1.85E-09	1.36E-09	1.05E-09
S	9.41E-08	4.26E-08	2.14E-08	1.27E-08	8.58E-09	4.25E-09	2.32E-09	1.55E-09	1.13E-09	8.70E-10
SSW	1.61E-07	5.84E-08	2.82E-08	1.65E-08	1.10E-08	5.38E-09	2.89E-09	1.93E-09	1.41E-09	1.09E-09
SW	7.78E-08	3.33E-08	1.77E-08	1.08E-08	7.49E-09	4.13E-09	2.67E-09	1.89E-09	1.41E-09	1.10E-09
WSW	5.39E-08	2.74E-08	1.62E-08	1.04E-08	7.39E-09	4.34E-09	2.99E-09	2.14E-09	1.59E-09	1.24E-09
W	7.20E-08	3.48E-08	1.97E-08	1.25E-08	8.81E-09	5.20E-09	3.64E-09	2.62E-09	1.95E-09	1.52E-09
WNW	8.53E-08	3.75E-08	2.07E-08	1.29E-08	9.02E-09	5.09E-09	3.39E-09	2.41E-09	1.80E-09	1.40E-09
NW	8.32E-08	3.48E-08	1.90E-08	1.18E-08	8.24E-09	4.62E-09	3.60E-09	2.19E-09	1.64E-09	1.28E-09
NNW	4.68E-08	2.07E-08	1.18E-08	7.43E-09	5.22E-09	2.99E-09	2.04E-09	1.48E-09	1.11E-09	8.69E-10

(a) Calculated from meteorological data collected at 100-N Area for the period 2-70 through 1-71.

**TABLE E.6** Annual Average Atmospheric Dispersion Around the 200 Areas for an 89-m Release Height (units are sec/m<sup>3</sup>)(a)

Direction	Range in Miles (km)									
	0.5 (0.8)	1.5 (2.4)	2.5 (4.0)	3.5 (5.6)	4.5 (7.2)	7.5 (12)	15 (24)	25 (40)	35 (56)	45 (72)
N	3.29E-08	1.76E-08	1.04E-08	6.91E-09	4.87E-09	2.29E-09	1.08E-09	7.81E-10	6.23E-10	5.10E-10
NNE	4.70E-08	1.90E-08	1.05E-08	6.82E-09	4.76E-09	2.22E-09	1.08E-09	8.11E-10	6.60E-10	5.47E-10
NE	8.05E-08	3.02E-08	1.54E-08	9.44E-09	6.40E-09	2.92E-09	1.50E-09	1.19E-09	9.86E-10	8.26E-10
ENE	7.61E-87	2.84E-08	1.45E-08	3.94E-09	6.07E-09	2.85E-09	1.64E-09	1.37E-09	1.15E-09	9.64E-10
E	4.61E-08	2.28E-08	1.32E-08	8.72E-09	6.17E-09	3.18E-09	2.22E-09	1.95E-09	1.65E-09	1.39E-09
ESE	7.97E-08	4.00E-08	2.17E-08	1.36E-08	9.38E-09	4.77E-09	3.60E-09	3.37E-09	2.93E-09	2.50E-09
SE	1.67E-07	7.60E-08	4.02E-08	2.49E-08	1.70E-08	7.97E-09	4.54E-09	3.73E-09	3.12E-09	2.62E-09
SSE	8.34E-08	4.19E-08	2.47E-08	1.64E-08	1.16E-08	5.42E-09	2.40E-09	1.60E-09	1.22E-09	9.76E-10
S	8.65E-08	4.38E-08	2.55E-08	1.68E-08	1.18E-09	5.40E-09	2.14E-09	1.33E-09	9.81E-10	7.71E-10
SSW	7.93E-08	3.88E-08	2.19E-08	1.42E-08	9.89E-09	4.43E-09	1.65E-09	9.59E-10	6.90E-10	5.35E-10
SW	6.89E-08	4.06E-08	2.36E-08	1.54E-08	1.08E-08	4.82E-09	1.73E-09	9.64E-10	6.79E-10	5.19E-10
WSW	3.74E-08	2.39E-08	1.49E-08	1.01E-08	7.20E-09	3.30E-09	1.24E-09	7.20E-10	5.18E-10	4.02E-10
W	3.72E-08	2.57E-08	1.64E-08	1.13E-08	8.13E-09	3.76E-09	1.44E-09	8.57E-10	6.24E-10	4.87E-10
WNW	3.42E-08	2.37E-08	1.58E-08	1.12E-08	8.09E-09	3.84E-09	1.63E-09	1.07E-09	8.20E-10	6.56E-10
NW	4.17E-08	2.69E-08	1.82E-08	1.29E-08	9.41E-09	4.55E-09	2.08E-09	1.45E-09	1.13E-09	9.10E-10
NNW	2.68E-08	1.57E-08	1.03E-08	7.27E-09	5.27E-09	2.56E-09	1.22E-09	8.79E-10	6.94E-10	5.64E-10

(a) Calculated from meteorological data collected at the Hanford Meteorological Station from 1955 through 1970.

**TABLE E.7.** Annual Average Atmospheric Dispersion Around the 300 and 400 Areas for a Ground-Level Release Height (units are sec/m<sup>3</sup>)(a)

Direction	Range in Miles (km)									
	0.5 (0.8)	1.5 (2.4)	2.5 (4.0)	3.5 (5.6)	4.5 (7.2)	7.5 (12)	15 (24)	25 (40)	35 (56)	45 (72)
N	5.7E-06	8.7E-07	3.9E-07	2.4E-07	1.6E-07	7.9E-08	3.1E-08	1.6E-08	1.0E-08	7.4E-09
NNE	5.0E-06	7.6E-07	3.4E-07	2.1E-07	1.4E-07	6.9E-08	2.7E-08	1.3E-08	8.7E-09	6.3E-09
NE	3.9E-06	5.9E-07	2.6E-07	1.6E-07	1.1E-07	5.3E-08	2.1E-08	1.0E-08	6.7E-09	4.9E-09
ENE	3.6E-06	5.5E-07	2.5E-07	1.5E-07	1.0E-07	5.0E-08	1.9E-08	9.8E-09	6.4E-09	4.6E-09
E	3.4E-06	5.1E-07	2.3E-07	1.4E-07	9.4E-08	4.6E-08	1.8E-08	9.0E-09	5.9E-09	4.3E-09
ESE	5.8E-06	8.8E-07	4.0E-07	2.4E-07	1.7E-07	8.0E-08	3.1E-08	1.6E-08	1.0E-08	7.5E-09
SE	7.2E-06	1.1E-06	4.9E-07	3.0E-07	2.1E-07	1.0E-07	3.9E-08	2.0E-08	1.3E-08	9.3E-09
SSE	7.2E-06	1.1E-06	4.7E-07	2.9E-07	2.0E-07	9.6E-08	3.8E-08	1.9E-08	1.2E-08	9.0E-09
S	5.5E-06	8.4E-07	3.8E-07	2.4E-07	1.6E-07	7.8E-08	3.0E-08	1.5E-08	1.0E-08	7.3E-09
SSW	4.4E-06	6.8E-07	3.1E-07	1.9E-07	1.3E-07	6.3E-08	2.5E-08	1.3E-08	8.2E-09	6.0E-09
SW	3.8E-06	5.9E-07	2.7E-07	1.7E-07	1.1E-07	5.5E-08	2.2E-08	1.1E-08	7.2E-09	5.2E-09
WSW	3.0E-06	4.6E-07	2.1E-07	1.3E-07	8.8E-08	4.3E-08	1.7E-08	8.5E-09	5.6E-09	4.0E-09
W	2.6E-06	4.1E-07	1.8E-07	1.2E-07	7.8E-08	3.8E-08	1.5E-08	7.5E-09	4.9E-09	3.6E-09
WNW	2.9E-06	4.4E-07	2.0E-07	1.2E-07	8.2E-08	4.0E-08	1.5E-08	7.8E-09	5.1E-09	3.7E-09
NW	3.6E-06	5.4E-07	2.4E-07	1.5E-07	1.0E-07	4.9E-08	1.9E-08	9.5E-09	6.2E-09	4.5E-09
NNW	5.4E-06	8.2E-07	3.7E-07	2.2E-07	1.5E-07	7.4E-08	2.9E-08	1.5E-08	9.5E-09	6.9E-09

(a) Calculated from meteorological data collected at the Washington Public Power Supply System WNP-2 reactor during the period 4-74 through 3-76.

public exposure. These potential pathways include fish consumption, drinking water, and consumption of foodstuffs and are generally comprised of compartments between which the radionuclides move. For example, radioactive material released to the river is diluted (compartment 1), after which it may be withdrawn at a certain rate for irrigation (compartment 2), deposited on the plants and soil (compartments 3 and 4), and taken into the plant via the roots and leaves (compartment 5). The compartment transfer factors used for dose calculation in this report are described by Houston, Streng and Watson (1974) and Napier et al. (1980).

Other parameters affecting the movement of radionuclides within potential exposure pathways include irrigation rates, growing period, hold up, etc. These parameters are listed in Table E.8. Note that certain parameters are specific to maximum and average individuals.

## PUBLIC EXPOSURE

Offsite radiation dose impact is related to the extent of public exposure to or consumption of radionuclides associated with Hanford operations. Parameters describing assumed diet, residency and river recreation for maximum and average individuals are provided in Tables E.9 through E.11, respectively.

## DOSE CALCULATION DOCUMENTATION

Assurance of quality in dose calculations are provided in several ways. First, comparisons are made against doses calculated for previous annual reports and differences are validated. Second, all computed doses are reviewed through the Hanford Dose Overview Program. Third, computer codes and inputs to the codes are documented. Summaries of this information are provided in Tables E.12 - E.16.

**TABLE E.8. Pathway Parameters**

	Holdup (days, except as noted)(a)		Growing Period (days)	Yield (Kg/m <sup>2</sup> )	Irrigation Rate (l/m <sup>2</sup> /month)
	Maximum Individual	Average Individual			
Leafy Veg.	1	14	90	1.5	150
Other above ground veg.	1	14	60	0.7	160
Potatoes	10	14	90	4	180
Other root veg.	1	14	90	5	150
Berries	1	14	60	2.7	150
Melons	1	14	90	0.8	150
Orch. Fruit	10	14	90	1.7	150
Wheat	10	14	90	0.72	0
Other Grains	1	14	90	1.4	150
Eggs	1	18	90	0.84	150
Milk	1	4	30	1.3	200
Beef	15	34	90	0.84	140
Pork	15	34	90	0.84	140
Poultry	1	34	90	0.84	140
Fish	24 hours	24	—	—	—
Drinking Water	24	24	—	—	—

(a) Holdup is the time between harvest and consumption.

**TABLE E.9. Dietary Parameters**

	Consumption (Kg/yr)	
	Maximum Individual	Average Individual
Leafy Veg.	30	15
Other above- ground veg.	30	15
Potatoes	110	100
Other root veg.	72	17
Berries	30	6
Melons	40	8
Orch. Fruit	265	50
Wheat	80	72
Other grains	8.3	7.5
Eggs	30	20
Milk	274(a)	230(a)
Beef	40	40
Pork	40	30
Poultry	18	8.5
Fish	40	(c)
Drinking Water	730(b)	438(b)

(a) Units l/yr.

(b) 330 l/yr for infant.

(c) Radiation doses are calculated based on estimated total annual catch of 15,000 kg.

**TABLE E.10. Residency Parameters**

Parameter	Exposure (hr/yr)	
	Maximum Individual	Average Individual
Ground Contamination	4383	2920
Air Submersion	8766	8766
Inhalation(a)	8766	8766

(a) Inhalation Rates:

Adult—250 cm<sup>3</sup>/sec routine — Infant—44 cm<sup>3</sup>/sec

**TABLE E.11. Recreational Activities**

Activity	Exposure (hr/yr)(a)	
	Maximum Individual	Average Individual
Shoreline	500	17
Boating	100	5
Swimming	100	10

(a) Assumes 8 hour holdup for maximum individual and 13 hours for average.

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**TABLE E.12.** Documentation of 100 Area Airborne Release Dose Calculation

Facility name:	100 Area
Releases:	See Table 19
Meteorological conditions:	100-N meteorological tower 1-year data (2-70 through 1-71), annual average, see Table E.5
Dispersion model:	Gaussian, Hanford parameters (ERDA 1975)
X/Q:	Maximum individual $1.5 \times 10^{-9}$ sec/m <sup>3</sup> at 53 km SSE 80-km population $5.7 \times 10^{-4}$ person-sec/m <sup>3</sup>
Release height:	82.3 meters effective (60.96 meters actual stack height)
Population distribution:	340,000, see Table E.1
Computer code:	DACRIN, Rev. 1.2, 1980
Calculated dose:	Chronic inhalation, maximum individual and 80-km population, first year dose and 50-yr dose commitment
Files addressed:	Organ data library, Rev. 2-5-81 Radionuclide library, Rev. 1-15-81
Computer code:	FOOD, Rev. 1.0, 1978
Calculated dose:	Chronic ingestion and ground contamination exposure, maximum individual and 80-km population, first-year dose and 50-year dose commitment
Files addressed:	Radionuclide Library, Rev. 1-15-81 Food Transfer Library, Rev. 2-27-78 Organ Data Library, Rev. 2-5-81 Ground Dose Factor Library, Rev. 3-15-78
Computer code:	SUBDOS, Rev. 3-16-82
Calculated dose:	Chronic air submersion, maximum individual, first-year dose.
Files addressed:	Radionuclide Library, Rev. 1-15-81 Beta Energy Library Gamma Energy Library Gamma Dose Rate Factor Library
Computer code:	KRONIC, Rev. 4-6-82
Calculated dose:	Chronic air submersion, 80-km population, first year dose
Files addressed:	RNDBET GISLIB

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**TABLE E.13.** Documentation of 100 Area Liquid Release Dose Calculation

Facility name:	100 Area
Releases:	See Table 19
River flow:	132,000 cfs
Mixing ratio:	1
Reconcentration formula:	3
Shore-width factor:	0.2
Population	70,000—drinking water pathway 125,000—fish and direct exposure 2,000—irrigated foodstuff
Computer code:	ARRRG, Rev. 1.1, 3-15-82
Calculated dose:	Chronic ingestion, direct exposure to water and shoreline, maximum individual and 80-km population, first-year dose and 50-year dose commitment
Files addressed:	Radionuclide Library, Rev. 1-15-81 Organ Data Library, Rev. 2-5-81 Hanford Specific Bio. Accum. Library External Dose Factor Library, Rev. 3-15-78
Computer code:	FOOD, Rev. 1.1, 3-15-82
Calculated dose:	Chronic ingestion and ground contamination, maximum individual and 80 km population first-year dose and 50-year dose commitment
Files addressed:	Radionuclide Library, Rev. 1-15-81 Food Transfer Library, Rev. 2-27-78 Organ Data Library, Rev. 2-5-81 Ground Dose Factor Library, Rev. 3-15-78

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**TABLE E.14. Documentation of 200 Areas Airborne Release Dose Calculation**

Facility name:	200 Area
Releases:	See Table 19
Meteorological conditions:	HMS historical 15-year data (1955-1970), annual average, see Table E.6
Dispersion model:	Gaussian, Hanford parameters (ERDA 1975)
X/Q:	Maximum individual $3.6 \times 10^{-9}$ sec/m <sup>3</sup> at 43 km SE 80-km population $5 \times 10^{-4}$ person sec/m <sup>3</sup>
Release height:	89.2 meters effective (60.96 meters actual stack height)
Population distribution:	341,000, See Table E.2
Computer code:	DACRIN, Rev. 1.2, 1980
Calculated dose:	Chronic inhalation, maximum individual and 80-km population, first-year dose and 50-year dose commitment
Files addressed:	Organ Data Library, Rev. 2-5-81 Radionuclide Library, Rev. 1-15-81
Computer code:	FOOD, Rev. 1.1, 3-15-82
Calculated dose:	Chronic ingestion and ground contamination exposure, maximum individual and 80-km population, first-year dose and 50-year dose commitment
Files addressed:	Radionuclide Library, Rev. 1-15-81 Food Transfer Library, Rev. 2-27-78 Organ Data Library, Rev. 2-5-81 Ground Dose Factor Library, Rev. 3-15-78
Computer code:	SUBDOS, Rev. 3-16-82
Calculated dose:	Chronic air submersion, maximum individual, first-year dose
Files addressed:	Radionuclide Library, Rev. 1-15-81 Beta Energy Library Gamma Energy Library Gamma Dose Rate Factor Library

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**TABLE E.15.** Documentation of 300 Area Airborne Release Dose Calculation

Facility name:	300 Area
Releases:	See Table 19
Meteorological conditions:	Washington Public Power Supply System 2-year data (4-74 through 3-76), annual average, see Table E.7
Dispersion model:	Gaussian, Pasquill parameters
X/Q:	Maximum individual $9.2 \times 10^{-8}$ sec/m <sup>3</sup> at 1.3 km SSE 80-km population $1.5 \times 10^{-2}$ person sec/m <sup>3</sup>
Release height:	Ground level
Population distribution:	265,000, see Table E.4
Computer code:	DACRIN, Rev. 1.2, 1980
Calculated dose:	Chronic inhalation, maximum individual and 80-km population, first-year dose and 50-year dose commitment
Files addressed:	Organ Data Library, Rev. 2-5-81 Radionuclide Library, Rev. 1-8-81
Computer code:	FOOD, Rev. 1.1, 3-15-82
Calculated dose:	Chronic ingestion and ground contamination exposure, maximum individual and 80-km population, first-year dose and 50-year dose commitment
Files addressed:	Radionuclide Library, Rev. 1-15-81 Food Transfer Library, Rev. 2-27-78 Organ Data Library, Rev. 2-5-81 Ground Dose Factor Library, Rev. 3-15-78
Computer code:	SUBDOS, Rev. 3-15-82
Calculated dose:	Chronic air submersion, maximum individual, first-year dose
Files addressed:	Radionuclide Library, Rev. 1-15-81 Beta Energy Library Gamma Energy Library Gamma Dose Rate Factor Library

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**TABLE E.16.** Documentation of 400 Area Airborne Release Dose Calculations

Facility name:	400 Area
Releases:	See Table 19
Meteorological conditions:	Washington Public Power Supply System 2-year data (4-74 through 3-76, annual average, see Table E.3)
Dispersion model:	Gaussian, Pasquill parameters
X/Q:	Maximum individual $3.2 \times 10^{-8}$ sec/m <sup>3</sup> at 29 km SSE 80-km population $1.1 \times 10^{-2}$ person-sec/m <sup>3</sup>
Release height:	Ground level
Population distribution:	264,000, see Table E.3
Computer code:	DACRIN, Rev. 1.2, 1980
Calculated dose:	Chronic inhalation, maximum individual and 80-km population, first-year dose and 50-year dose commitment
Files addressed:	Organ Data Library, Rev. 2-5-81 Radionuclide Library, Rev. 1-8-81
Computer code:	FOOD, Rev. 1.1, 3-15-82
Calculated dose:	Chronic ingestion and ground contamination exposure, maximum individual and 80-km population, first-year dose and 50-year dose commitment
Files addressed:	Radionuclide Library, Rev. 1-15-81 Food Transfer Library, Rev. 2-27-78 Organ Data Library, Rev. 2-5-81 Ground Dose Factor Library, Rev. 3-15-78
Computer code:	SUBDOS, Rev. 3-15-82
Calculated dose:	Chronic air submersion, maximum individual, first-year dose
Files addressed:	Radionuclide Library, Rev. 1-15-81 Beta Energy Library Gamma Energy Library Gamma Dose Rate Factor Library
Computer code:	KRONIC, Rev. 4-6-82
Calculated dose:	Chronic air submersion, 80-km population, first-year dose
Files addressed:	RNDBET GISLIB

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