

Environmental Surveillance at Hanford for CY-1977



April 1978

Pacific Northwest Laboratory
Richland, Washington 99352
Operated for the
U.S. Department of Energy
by



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ENVIRONMENTAL SURVEILLANCE AT
HANFORD FOR CY-1977

by
J.R. Houston
P.J. Blumer

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BATTELLE
Pacific Northwest Laboratories
Richland, Washington 99352

FOREWORD

The Environmental Surveillance Program at Hanford is conducted by the Pacific Northwest Laboratory (PNL) under contract to the Department of Energy (DOE). U.S. Government operations at Hanford have always included support for environmental surveillance, and the data collected provide a 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 negligible impact attributable to either current Hanford operations or cumulative environmental effects from 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; the present document is for calendar year 1977.



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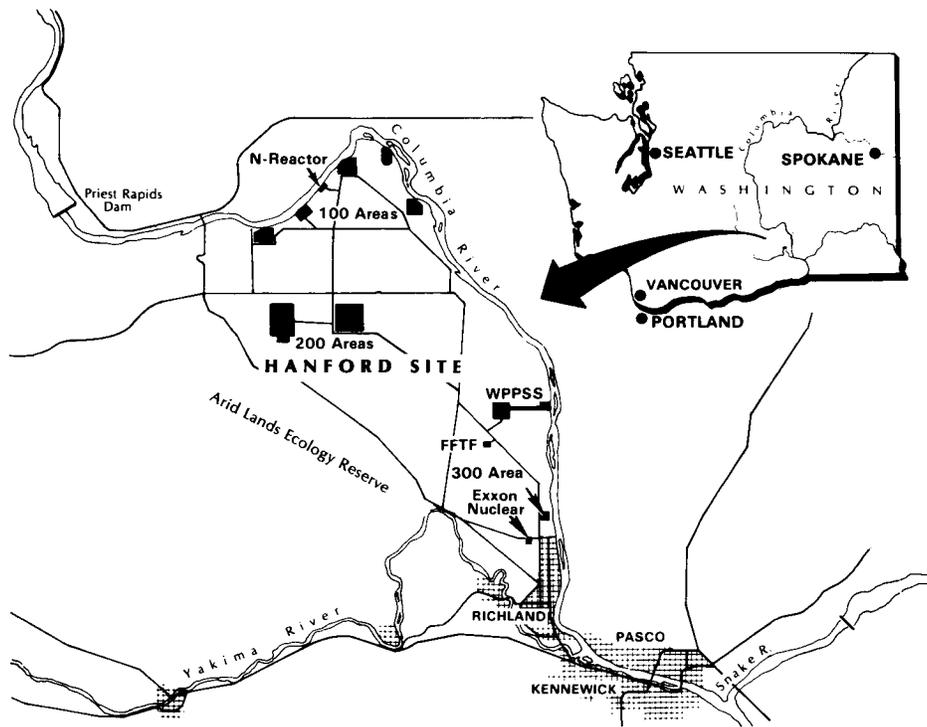


FIGURE 1. DOE's Hanford Site in Washington State

INTRODUCTION

The U.S. Department of Energy's Hanford Site is located in a rural region of south-eastern Washington State and occupies an area of 1500 km² (560 square miles). The site, shown in Figure 1, lies about 320 km (200 miles) east of Portland, Oregon, 270 km (170 miles) southeast of Seattle, Washington, and 200 km (125 miles) southwest of Spokane, Washington. The Columbia River flows through the northern edge of the Hanford Site and forms part of its eastern boundary.

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. 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. Steam from N Reactor operation is used to drive turbine generators that produce up to 860 million watts of electrical power in the Washington Public Power Supply System's (WPPSS) Hanford Generating Plant. By the end of 1977, N Reactor had supplied enough steam to produce nearly 40 billion kilowatt-hours of electrical energy, which was fed to the Bonneville Power Administration grid covering the Pacific Northwest.

Facilities on the Hanford Site include the historic reactor facilities for plutonium production along the Columbia River, in what are known as the 100 Areas. The reactor fuel-processing and waste-management facilities are on a plateau about 11.3 km (7 miles) 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 3.4 km (2.1 miles) northwest of the 300 Area.

Privately owned facilities located within the Hanford Site boundaries include the WPPSS generating station adjacent to N Reactor, the WPPSS power reactor site and office buildings, 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 (RHO)--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's Pacific Northwest Laboratories--responsible for operating the Pacific Northwest Laboratory (PNL), including research in the physical, life, and environmental sciences, environmental surveillance, and advanced methods of nuclear waste management.
- United Nuclear Industries (UNI)--responsible for operating and fabricating fuel for 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 Program and the Fast Flux Test Facility.

During 1977, work at Hanford included N Reactor operation, nuclear fuel fabrication, liquid waste solidification, continued construction of the Fast Flux Test Facility, Hanford National Environmental Research Park (NERP) studies, and Arid Lands Ecology (ALE) studies, as well as continued use of a variety of research and laboratory facilities.

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/cheatgrass/bluegrass community. The mule deer is the most abundant big game mammal on the site while 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 (6.3 in.) of precipitation annually. About 40% of the total precipitation occurs during November, December, and January, with only 10% falling in July, August, and September. The average maximum and minimum temperatures in July are 33°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 (9 mph) in the summer to 10 km/hr (6 mph) 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-related industries, the economy of the region is primarily agricultural. Crops include alfalfa, wheat, sugar beets, and potatoes. Several fruit orchards are located within a short distance of the Hanford Site. The Columbia River is used extensively for recreational purposes including fishing.

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. The three communities, with a combined population of approximately 80,000, use the Columbia River as a source of drinking water. Approximately 250,000 people live within an 80-km (50-mile) radius of the Hanford Site, in the Yakima area, the Tri-Cities, several small communities, and the surrounding agricultural areas.

The Hanford Environmental Surveillance Program is conducted by PNL under contract to DOE. The program is designed to measure the levels of radionuclides and radiation in the Hanford environs and to determine what portions are attributable to natural causes, worldwide fallout, and Hanford operations. The comprehensive ground-water monitoring program, also conducted by PNL for DOE, complements the surface portion of the total program by determining the concentration, distribution, and impact of radionuclide and chemical constituents and is documented separately.⁽¹⁾ Other environmental data collected deal with the chemical and biological quality of the Columbia River and sanitary water.

All data collected are presented and evaluated in a series of annual reports;⁽²⁾ included in this report are data collected during 1977. Any contribution to air- or waterborne radionuclide concentrations that is attributable to Hanford operations is compared with the regulations in Manual Chapter 0524.⁽³⁾ Concentrations of nonradioactive pollutants are compared with applicable standards of the State of Washington⁽⁴⁾ or the Environmental Protection Agency.⁽⁵⁾

SUMMARY

Environmental data collected during 1977 show continued compliance by Hanford with all applicable state and federal regulations.

Data were collected for most environmental media including air, Columbia River water, external radiation, foodstuffs (milk, beef, eggs, poultry, and produce) and wildlife (deer, fish, game birds, and oysters from Willapa Bay), as well as soil and vegetation samples.

In general, offsite levels of radionuclides attributable to Hanford operations during 1977 were indistinguishable from background levels. The data are summarized in the following highlights.

- Hanford's 1977 operations caused no distinguishable impact on concentrations of airborne radionuclides and on external radiation dose as measured near to and far from the Hanford Site. (See pages 4-6 and 20-22.)
- Maximum concentrations of airborne radionuclides during 1977 were observed in the summer months and are attributed to past atmospheric nuclear detonations. (See page 4.)
- Following the September 17, 1977 atmospheric test by the People's Republic of China, ^{131}I was observed in milk. The maximum concentration observed was 66 pCi/l. The maximum hypothetical dose to an infant thyroid from milk consumption was about 8 mrem. (See pages 12-13.)
- All radionuclides that were observed in foodstuffs, wildlife, and soil samples were attributed to either worldwide fallout or natural sources. (See pages 12-19.)
- External dosimeter measurements along the Columbia River islands and shoreline near the Hanford Site showed elevated doses attributed to the continued presence of a few long-lived radionuclides, principally ^{60}Co , from past operation of once-through-cooled production reactors. (See pages 20-22.)
- Low-level concentrations of a few radionuclides released to the Columbia River from N Reactor during 1977 were observed at the downstream sampling location. All of the observed river concentrations were far less than 1% of the most restrictive Manual Chapter guides for unrestricted areas. (See pages 7-8.)
- The maximum "fence-post" exposure rate for 1977, 0.01 mR/hr, occurred at selected locations on the Columbia River islands and shorelines. Residual long-lived radionuclides, principally ^{60}Co in sediments deposited on the islands and shoreline during periods of high water flow, were responsible for the majority of the "fence-post" exposure rates. These radionuclides are due to past operation of once-through-cooled production reactors, the last of which were shut down in January 1971. (See pages 23-28.)
- The maximum annual total-body dose to an individual from 1977 effluents was estimated to be less than 0.1 mrem. This includes contributions from airborne, drinking-water, irrigated foodstuff, and aquatic recreation pathways. The annual organ dose potentially received from any pathway was less than 0.5 mrem. These doses can be compared with the standards in Manual Chapter 0524 of 500 mrem/yr for the total body and 1500 mrem/yr for other organs (See pages 23-28.)
- Airborne effluents from the Hanford Site's three operating areas resulted in an annual total-body dose to the population within an 80-km (50-mile) radius of Hanford of about 2 person-rem. Contributions from liquid effluents during 1977 add very little (about 0.02 person-rem) to the total population dose. This dose estimate may be compared with the approximately 25,000 person-rem received annually from natural background radiation. (See pages 27-28.)

ATMOSPHERIC MONITORING

Many radionuclides are present in the atmosphere from both natural sources and worldwide fallout. Potential contributions to radionuclide levels from Hanford operations are similar to those already present from worldwide fallout. Air is routinely sampled at numerous locations close to and distant from the Hanford Site to determine the existence and makeup of any Hanford contribution to the airborne radionuclide concentration. During 1977, no statistically significant difference was observed between radionuclide concentrations at sampling locations near to and distant from the Hanford Site. This finding indicates that Hanford contributions were indistinguishable from existing regional levels. The maximum levels of airborne radionuclides were measured during the summer months and are attributed to a period of relatively high regional fallout from previous nuclear weapons testing.

AIR SAMPLING

Radionuclides in the atmosphere were sampled during 1977 by a network of 18 perimeter and 5 distant continuous air samplers at locations shown in Figure 2. Each air sampler draws a flow of 2.5 m³/hr through a particle filter (Hollingsworth and Vose Company, HV-70) and a 5.5-cm-long, 4.4-cm-diameter charcoal cartridge (Nuclear Consulting Services, NUSORB KITEG 1016). The particulate sampling system has been tested at a collection efficiency of essentially 100% for 0.3- μ particles. Both the elemental and organic forms of radioiodine are collected and held on the charcoal sampling system at an efficiency of greater than 99%. Noble gases are not sampled.

The filters were collected biweekly and analyzed for gross beta and alpha activity after a wait of 7 days to allow the naturally-occurring short-lived radon and thoron daughters to decay. Once a month the filters were grouped according to geographical location and analyzed by gamma spectrometry. On a quarterly basis the filters from each geographical location were dissolved and analyzed for ⁹⁰Sr and plutonium.

ANALYSIS

Results for the gross beta, gross alpha and ¹³¹I analyses for perimeter and distant sampling locations are shown in Table 1. The distant stations are sufficiently remote from the Hanford Site to insure that the observed levels of radionuclide concentrations in air are due to natural sources or worldwide fallout.

The annual patterns of gross beta activity for the years 1973 through 1977 are shown in Figure 3. Data shown are the average monthly beta-emitting radionuclide concentrations at eastern quadrant stations (usually downwind from Hanford) as compared with the concentrations at distant stations. The airborne radionuclide concentration rises each spring because of an increase in the rate at which natural and nuclear weapons test radioactivity is transferred from the lower stratosphere to the troposphere.

During 1977, the maximum airborne concentrations of beta emitters were observed during the summer months. This increase was probably due to residual activity entering the troposphere from previous atmospheric nuclear tests conducted by the People's Republic of China.

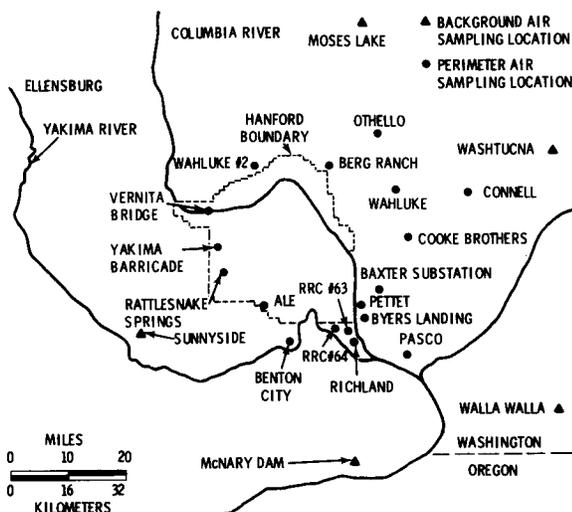


FIGURE 2. Air Sampling Locations

TABLE 1. Radioactivity in Air

Detection Limit Concentration Guide ^(b)	Concentration (10^{-12} μ Ci/ml)											
	Gross Beta				Gross Alpha ^(a)				Iodine-131			
	No. of Samples	Maximum	Minimum	Average ^(c)	No. of Samples	Maximum	Minimum	Average ^(c)	No. of Samples	Maximum	Minimum	Average ^(c)
		0.005				0.0003				0.02		
		100				0.03				100		
Location	No. of Samples	Maximum	Minimum	Average ^(c)	No. of Samples	Maximum	Minimum	Average ^(c)	No. of Samples	Maximum	Minimum	Average ^(c)
Perimeter Stations												
Rattlesnake Springs	21	0.42	0.03	0.19 \pm 0.23								
ALE	26	0.57	0.03	0.21 \pm 0.29								
Benton City	23	0.59	0.03	0.14 \pm 0.24	25	0.004	*	<0.001	22	*	*	*
Yakima Barricade	24	0.61	0.03	0.21 \pm 0.27								
Vernita	26	0.54	0.02	0.21 \pm 0.27								
Wahluke #2	25	0.42	0.03	0.21 \pm 0.25								
Othello	23	0.35	0.02	0.13 \pm 0.16								
Connell	26	0.49	0.04	0.22 \pm 0.27								
Berg Ranch	26	0.51	0.03	0.22 \pm 0.26	26	0.005	0.0007	0.002 \pm 0.002				
Wahluke Watermaster	26	0.40	0.03	0.19 \pm 0.23								
Cook Bros.	24	0.31	0.03	0.15 \pm 0.19								
Richland	25	0.42	0.03	0.19 \pm 0.24	25	0.002	0.0007	0.001 \pm 0.001	24	*	*	*
Pasco	24	0.37	0.03	0.18 \pm 0.19								
Byers Landing	25	0.41	0.04	0.19 \pm 0.23	25	0.004	0.0006	0.002 \pm 0.001	24	*	*	*
Baxter Substation	24	0.47	0.02	0.18 \pm 0.25					25	*	*	*
Pettett Farm	18	0.37	0.08	0.21 \pm 0.17					17	*	*	*
RRC CP #63	24	0.37	0.03	0.17 \pm 0.20	24	0.004	0.0005	0.001 \pm 0.002				
RRC CP #64 ^(d)	22	0.43	0.03	0.18 \pm 0.22								
				0.19 \pm 0.24				<0.002				
Distant Stations												
Walla Walla	24	0.47	0.03	0.21 \pm 0.25								
McNary	26	0.50	0.01	0.19 \pm 0.25								
Moses Lake	24	0.35	0.03	0.16 \pm 0.20								
Wash Tucna	26	0.47	0.02	0.18 \pm 0.25								
Sunnyside	22	0.36	0.05	0.17 \pm 0.19					14	*	*	*
				0.18 \pm 0.23								

- (a) Gross alpha activity does not include any significant contribution due to naturally-occurring radon and short-lived daughters in the air. Filters are held 7 days before analysis to allow radioactive decay of these radionuclides.
- (b) Manual Chapter 0524 standards apply only to radionuclide concentrations above those from worldwide fallout or naturally-occurring radiation.
- (c) Average \pm two standard deviations is shown if all analyses were positive. Otherwise, a less-than-detectable value was calculated from all results, assuming that all less-than-detectable results were equal to the detection limit for the analysis.
- (d) Richland Research Complex control plot.
No entry indicates no analysis.
*Less than detectable.

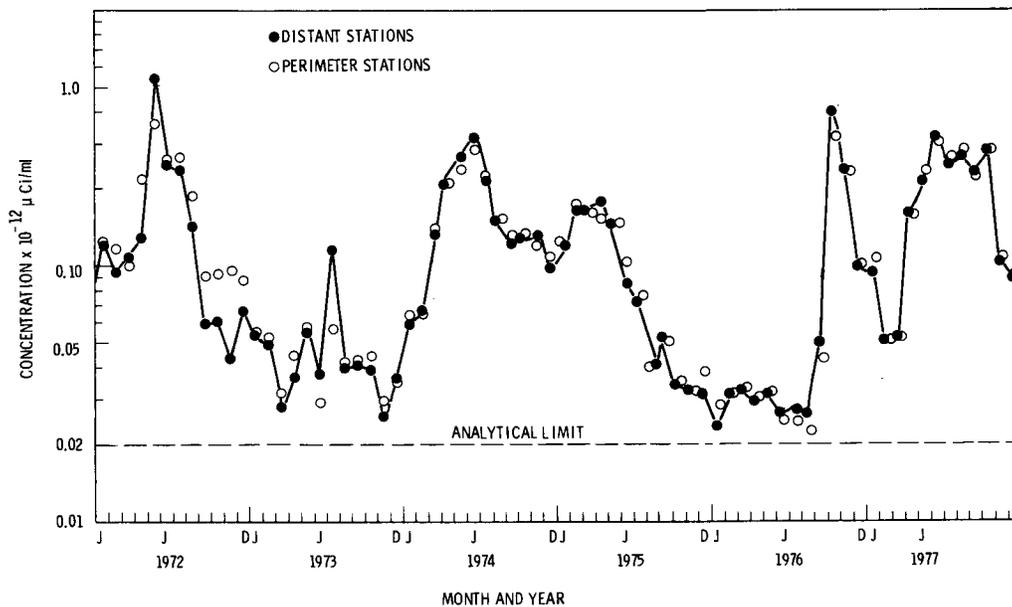


FIGURE 3. Average Monthly Gross Beta Activity in the Atmosphere

The maximum concentration observed was 0.61×10^{-12} $\mu\text{Ci/ml}$ on a sample taken at the Yakima Barricade during the July 20 to August 3 sampling period, a time during which both near and distant samples were significantly above the annual average. The annual average concentration of beta emitters for all perimeter stations during 1977, 0.19×10^{-12} $\mu\text{Ci/ml}$, was statistically indistinguishable from the average concentration at the distant stations. None of the 126 airborne radioiodine analyses performed during 1977 exceed the analytical limit.

Shown in Table 2 are the results of specific radionuclide analyses. Beryllium-7 is a naturally-occurring radionuclide formed by the interaction of cosmic rays and nitrogen in the upper atmosphere. The other radionuclides,

except plutonium, are fission products that result from the atmospheric testing of nuclear weapons and, potentially, from Hanford operations.

The data show that all the radionuclides were observed at similar concentrations at distant and perimeter locations. This finding also holds at downwind and distant locations. All of the maximum observed concentrations occurred during the summer months and are attributed to a period of increased worldwide fallout. Only a slight increase in airborne fission product concentrations was recorded following the Chinese nuclear test on September 17, 1977.

A maximum ^{90}Sr concentration of 0.02×10^{-12} $\mu\text{Ci/ml}$ was observed during the period May 26 to August 30 for the northeast quadrant. This reading is believed to be erroneous since it is uncorroborated by any other sample results.

TABLE 2. Selected Radionuclide Concentrations in Air

Radionuclide	Manual Chapter 0524, Table II(a)	Composite Group(b)	Concentration (10^{-12} $\mu\text{Ci/ml}$)		
			Maximum Observed	Minimum Observed	Annual Average(c)
^7Be	40,000	Distant	0.30	*	<0.06
		Perimeter	0.37	*	<0.05
		Downwind	0.07	*	<0.04
^{90}Sr	30	Distant	0.003	0.0002	0.001
		Perimeter	0.02	0.0002 ₅	0.002 ₄
		Downwind	7×10^{-4}	7×10^{-5}	4×10^{-4}
^{106}Ru	200	Distant	0.61	*	<0.3
		Perimeter	0.53	*	<0.2
		Downwind	0.40	*	<0.2
^{137}Cs	500	Distant	0.006	*	<0.002
		Perimeter	0.007	*	<0.003
		Downwind	0.006	*	<0.003
$^{144}\text{CePr}$	200	Distant	0.15	*	<0.04
		Perimeter	0.14	*	<0.06
		Downwind	0.13	*	<0.06
Pu	0.06	Distant	7×10^{-5}	*	$<4 \times 10^{-5}$
		Perimeter	3×10^{-4}	1×10^{-6}	3×10^{-5}
		Downwind	1×10^{-5}	3×10^{-6}	7×10^{-6}

(a) Manual Chapter 0524 standards apply only to radionuclide concentrations above those from worldwide fallout or naturally-occurring radiation.

(b) Distant stations include Moses Lake, Washtucna, Walla Walla, McNary Dam, and Sunnyside. Perimeter stations are Wahluke #2, Berg Ranch, Othello, Vernita, Wahluke Watermaster, Connell, Cooke Bros., Yakima Barricade, Rattlesnake Springs, ALE, Benton City, Baxter Substation, Byers Landing, Pettett, Richland, Pasco, and RRC CP #63 and 64. Downwind stations are Baxter Substation, Byers Landing, Pasco, Richland, Pettett, and RRC CP #63 and 64.

(c) Annual average \pm two standard deviations is shown if all analyses were positive. Otherwise, a less-than-detectable value was calculated from all results, assuming that all less-than-detectable results were equal to the detection limit for the analysis.

* Less than the detection limit. This limit varies for each analysis because of different air flow volumes, counting times and radionuclide concentrations. Approximate detection limits in units of 10^{-12} $\mu\text{Ci/ml}$ were ^7Be , 0.05; ^{90}Sr , 0.00002; ^{106}Ru , 0.02; ^{137}Cs , 0.002; $^{144}\text{CePr}$, 0.02; Pu, 0.000001.

COLUMBIA RIVER MONITORING

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.⁽⁴⁾ This designation requires that industrial uses of the river be compatible with substantially all water needs including sanitary water, recreation, and wildlife, as indicated in Appendix A. Many measurements of radionuclide concentration, temperature, nitrate ion, pH, turbidity, dissolved oxygen, fecal and total coliform, and biological oxygen demand are routinely conducted upstream and downstream from Hanford to monitor any effects that may be attributable to Hanford operations. The 1977 measurements show that Hanford operations had a minimal impact on the quality of Columbia River water. All parameters monitored were well within state or federal limits both upstream and downstream from the Hanford Site.

RADIONUCLIDE ANALYSES

Samples of Columbia River water were routinely collected at upstream and downstream locations. Upstream sampling consisted of a continuous filter-resin sampler at Priest Rapids Dam and a cumulative sampling apparatus at the 100-B Area water intake. Downstream sampling consisted of a continuous filter-resin sampler at the 300 Area forebay and a cumulative sampling apparatus at the Richland sanitary water treatment plant. Analyses for gamma-emitting radionuclides, tritium, strontium-90, iodine-129, total plutonium and natural uranium were routinely performed on the samples.

Since shutdown of the last once-through-cooled production reactor in January 1971, radionuclide concentrations attributable to Hanford operations have been generally undetectable in Columbia River water. Table 3 summarizes the 1977 concentrations of natural and worldwide fallout radionuclides measured in a stretch of the Columbia River before it reaches the Hanford site. Table 4 presents analogous data obtained downstream from Hanford. The tables show that trace amounts of two radionuclides (⁵⁴Mn and ⁶⁰Co) detected at the downstream sampling location were not observed upstream from Hanford.

Graphically compared in Figure 4 are the upstream and downstream data for all radionuclides observed consistently at concentrations greater than 0.001 pCi/l. Only ⁶⁰Co shows a marked difference between upstream and downstream concentrations. The other radionuclide concentrations are similar at both locations and are due to worldwide fallout (³H, ⁹⁰Sr, ¹⁰⁶Ru) or natural causes (⁴⁰K, U-Nat). The ⁶⁰Co activity observed downstream is attributed to routine N reactor releases.

TABLE 3. Radionuclide Concentrations Upstream from Hanford Operations^(a)

Radionuclide	No. of Samples	Concentration (10 ⁻⁹ μCi/ml)		
		Maximum Observed	Minimum Observed	Annual Average ^(b)
<u>Naturally-Occurring</u>				
⁴⁰ K	24	1.3	0.1	0.6 ± 0.6
²²⁶ Ra	4	0.04	0.04	0.04
²²⁸ Ra	4	0.23	0.11	0.17 ± 0.10
²²⁸ Th	24	0.01	*	<0.002
U-Nat	12	2.6	0.1	0.6 ± 1.3
<u>Worldwide Fallout</u>				
³ H	12	670	*	<420
⁵⁴ Mn	24	0.04	*	<0.006
⁶⁰ Co	24	0.05	*	<0.003
⁶⁵ Zn	24	0.09	*	<0.009
⁹⁰ Sr	4	0.59	0.24	0.3 ± 0.3
⁹⁵ ZrNb	24	0.09	0.008	0.03 ± 0.05
¹⁰⁶ Ru	24	0.3	0.02	0.07 ± 0.12
¹²⁹ I	6	1.2 x 10 ⁻⁵	7.6 x 10 ⁻⁶	1 x 10 ⁻⁵
¹³⁷ Cs	24	0.09	*	<0.02
¹⁵² Eu	24	0.03	*	<0.01
Pu Total	4	3.3 x 10 ⁻⁴	*	<1.9 x 10 ⁻⁴

(a) Samples collected at Priest Rapids Dam and 100B Area forebay.

(b) Annual average ± two standard deviations is shown if all analyses were positive. Otherwise, a less-than-detectable value was calculated from all results, assuming that all less-than-detectable results were equal to the detection limit for the analysis.

* Less than detectable.

All of the radionuclides detected downstream from the Hanford Site and attributed to Hanford operations are included in Table 17 (p. 24), which lists all radionuclides released to the environs during 1977. Figure 4 can be used to compare the relative concentrations of these radionuclides with radionuclides routinely observed in the Columbia River. The missing data point for ³H in Figure 4 is due to the analytical laboratory's loss of the tritium analytical result for the August cumulative sample. Table 4 also compares the detected radionuclide concentrations

TABLE 4. Radionuclide Concentrations Downstream from Hanford Operations(a)

Radionuclide	No. of Samples	Concentrations (10^{-9} μ Ci/ml)			Concentration Guide(c)
		Maximum Observed	Minimum Observed	Annual Average(b)	
<u>Naturally-Occurring</u>					
^{40}K	26	0.9	0.4	0.6 ± 0.3	--
^{226}Ra	4	0.08	0.01	0.05 ± 0.06	30
^{228}Ra	4	0.24	0.08	0.2 ± 0.1	30
^{228}Th	26	0.007	*	<0.001	7,000
U-Nat	12	1.0	0.3	0.7 ± 0.6	20,000
<u>Artificially-Produced</u>					
^3H	11	2000	*	<670	3,000,000
^{54}Mn	26	0.01	*	<0.005	100,000
^{60}Co	26	0.02	0.005	0.01 ± 0.005	30,000
^{65}Zn	26	*	*	*	100,000
^{90}Sr	4	0.4	0.2	0.3	300
$^{95}\text{ZrNb}$	26	0.08	0.006	0.03 ± 0.04	60,000
^{129}I	6	9.4×10^{-5}	4.3×10^{-5}	6.4×10^{-5}	60
^{106}Ru	26	0.19	0.03	0.08 ± 0.10	10,000
^{137}Cs	26	0.04	*	<0.02	20,000
^{152}Eu	26	*	*	*	60,000
Pu Total	4	3.9×10^{-4}	*	$<2.4 \times 10^{-4}$	5,000

- (a) Samples collected at 300 Area forebay and City of Richland sanitary intake.
 (b) Annual average \pm two standard deviations is shown if all analyses were positive. Otherwise, a less-than-detectable value was calculated from all results, assuming that all less-than-detectable results were equal to the detection limit for the analysis.
 (c) Manual Chapter 0524 standards apply only to radionuclide concentrations above those from worldwide fallout or naturally-occurring radiation.
 * Less than detectable.

with guidelines for the environment presented in Manual Chapter 0524, Table II. In all cases, the observed concentrations are less than 1% of the guideline limits.

The radiological impact from the observed concentrations of Hanford-origin radionuclides is evaluated in the "Radiological Impact of Hanford Operations" section of this report, along with the impact calculated for radionuclides released from other sources (p. 23).

SANITARY WATER

In addition to Columbia River water samples, a cumulative sanitary water sample (30 ml/every 30 min) was collected at the Richland sanitary water treatment plant for radiological analysis. Richland is the first community downstream from Hanford and uses the Columbia River for drinking water. The analyses performed on sanitary water samples have a much higher detection limit than those done on river samples; the river sampling system employs a resin column through which

are passed approximately 1000 liters of river water before they are analyzed, while the sanitary samples involve only a few liters. However, all of the analytical sensitivities shown in Table 5 are consistent with the procedures generally used and are well below the applicable guidelines.

During 1977, the only activity detected in the sanitary water analyses was gross alpha and gross beta activity attributable to naturally-occurring ^{40}K and U in the river. The sanitary water would also contain tritium at the same concentrations as those shown for Columbia River water in Table 4.

TEMPERATURE

One of the parameters of the Columbia River most likely to be affected by Hanford operations is temperature. Figure 5 shows the average monthly water temperatures measured at Vernita Bridge and at Richland during 1977. Some of the difference between (6) the two locations is due to natural causes

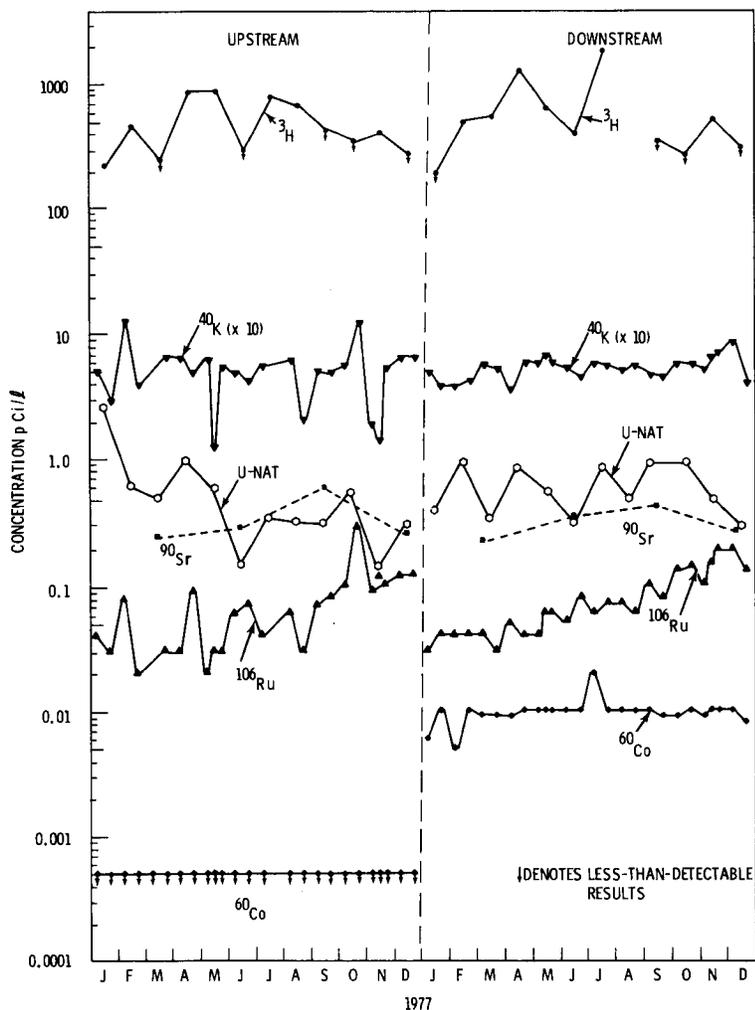


FIGURE 4. Upstream and Downstream Concentrations of Radionuclides in Columbia River Water

TABLE 5. Radiological Analyses of Richland Drinking Water

Radionuclide	No. of Samples	Concentration (10^{-9} $\mu\text{Ci/ml}$)				Concentration Guide ^(b)
		Detection Limit	Maximum	Minimum	Annual Average ^(a)	
Gross Alpha	52	0.4	1.9	*	<0.7	30
Gross Beta	52	5	6.9	*	<5.0	30
⁴⁶ Sc	13	40	*	*	*	40,000
⁵¹ Cr	13	500	*	*	*	2,000,000
⁶⁰ Co	13	30	*	*	*	30,000
⁶⁵ Zn	13	60	*	*	*	100,000
¹³⁷ Cs	13	30	*	*	*	20,000

(a) A less-than-detectable value was calculated for the average, assuming that all less-than-detectable results were equal to the detection limit.

(b) Manual Chapter 0524 standards apply only to radionuclide concentrations above those from worldwide fallout or naturally-occurring radiation.

* Less than detectable.

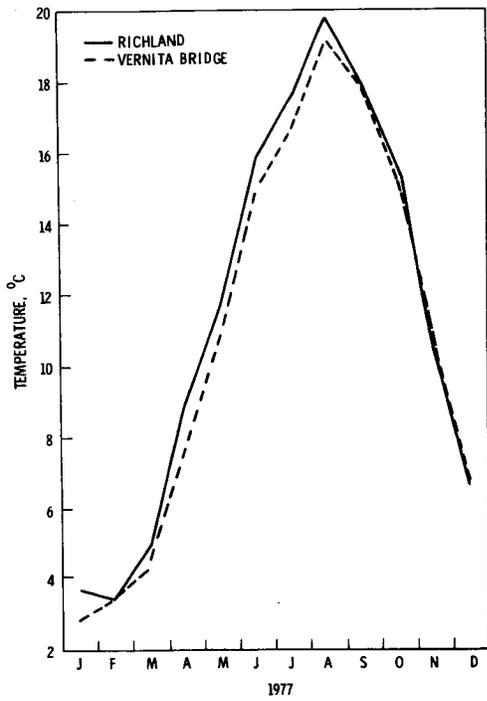


FIGURE 5. Average Monthly Water Temperatures at Richland and Vernita

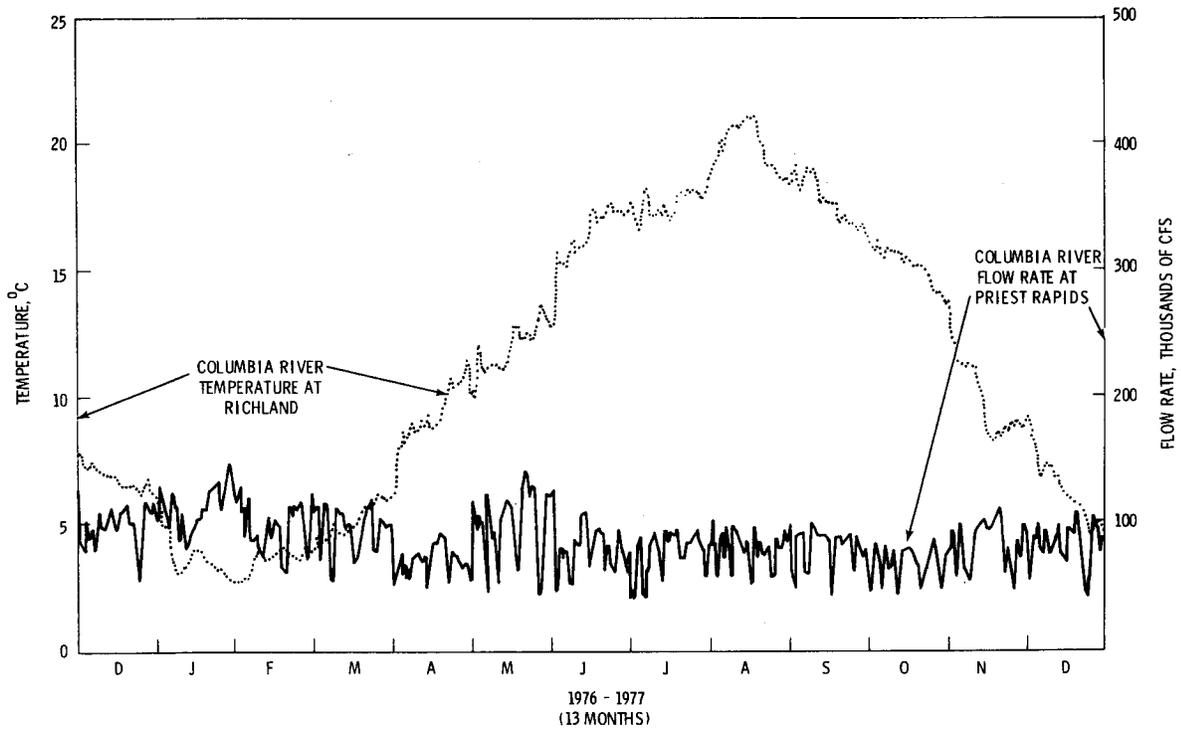


FIGURE 6. Daily Variation in Mean Temperature and Flow Rate

while some is attributable to operations on the Hanford Site. Figure 6 illustrates the daily and seasonal variations in river temperature and flow rate during 1977. The greatest difference observed occurred during the summer months when N Reactor was not in operation. Insolation appears to be the major source of heat for the river. Any heat contribution from N Reactor operations would be a small fraction of the seasonal increases attributable to insolation.

BIOLOGICAL ANALYSES

Monthly measurements of total coliforms, fecal coliforms, and biological oxygen demand (BOD) were made on grab samples taken at Vernita Bridge (upstream from Hanford) and at Richland. The data, summarized in Table 6, indicate an increase in total and fecal coliform concentrations downstream from Hanford. These increases are attributed to drainage from farm activities and to wildlife. The Hanford stretch of the river serves as a refuge for large populations of waterfowl, especially in the autumn.

CHEMICAL ANALYSES

Grab samples taken at Vernita Bridge and Richland during 1977 were also subjected to

chemical analyses. The nitrate concentration, pH, turbidity, and dissolved oxygen content were determined. The results were similar at the two locations and were well within applicable standards adopted by the State of Washington for Class A rivers. (See Appendix A.)

Virtually all of the pH measurements were well within the 6.5 to 8.5 standard, although two measurements on October 5 showed pHs of 10 and 9 at upstream and downstream locations, respectively. Given the numerous samples showing a pH between 7 and 8, the two high pH determinations are suspect.

The State of Washington turbidity standard requires that any increase due to use of the river will be less than or equal to 5 JTU (Jackson turbidity units) above the background levels. No differences were observed between Vernita Bridge and Richland, hence the values in Table 6 are assumed to represent normal background turbidity in the river.

The average values for dissolved oxygen in the river are well above the standard's minimum of 8 mg/ℓ, as are the minimum concentrations at both Vernita Bridge and Richland.

TABLE 6. Columbia River Chemical and Biological Analyses

Analysis	Units	Standard	Vernita				Richland ^(a)			
			No. of Samples	Maximum	Minimum	Annual Average ^(b)	No. of Samples	Maximum	Minimum	Annual Average ^(b)
NO ₃ ⁻	ppm	45	50	0.43	<0.10	<0.25	51	0.74	<0.10	<0.25
pH		6.5 to 8.5	46	10	7.2		38	9.0	7.2	
Turbidity	JTU ^(c)	5 + Bkgd	44	5.3	0.08	2.1 ± 1.8	41	5.5	1.1	2.3 ± 2.0
Dissolved O ₂	mg/ℓ	8	33	14.0	9.2	11.7 ± 3.0	31	14.8	9.2	11.8 ± 3.0
Total Coliforms	No./100 ml	240 ^(e)	13	350	2.0	33 ^(e)	13	350	4	130 ^(e)
Fecal Coliforms	No./100 ml	--	13	17	<2.0	2.0 ^(e)	13	130	<2	23 ^(e)
BOD ^(d)	mg/ℓ	--	13	2.67	0.63	1.6 ± 1.4	13	2.39	0.15	1.5 ± 1.5

(a) pH, turbidity and dissolved O₂ samples were obtained from 300 Area sanitary water pumping dock.

(b) Average ± two standard deviations is shown if all analyses were positive. Otherwise, a less-than-detectable value was calculated from all results, assuming that all less-than-detectable results were equal to the detection limit for the analysis.

(c) Jackson turbidity units.

(d) Biological oxygen demand.

(e) Annual median. State standard in 1977 was based on annual median.

The ^{131}I concentrations in milk observed during September and October at a milk sampling location in the vicinity of the Hanford Site are shown in Figure 8.

An assessment was made of the maximum thyroid dose that would be received by an infant who consumed 1 liter per day of milk containing the average ^{131}I concentrations shown in Figure 8. The total potential dose to the thyroid is estimated to be 8 mrem. This dose was computed using the techniques of the Environmental Protection Agency.⁽⁷⁾

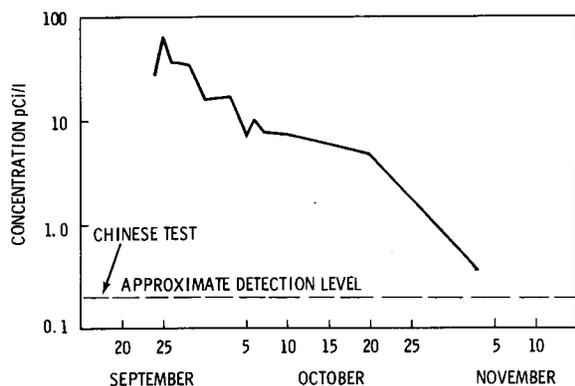


FIGURE 8. Iodine-131 Concentrations in Milk Following September Chinese Test

BEEF, CHICKEN, AND EGGS

Samples of beef, chicken, and eggs were collected from the Riverview area and from a commercial source for analysis by gamma spectrometry and specific analysis for ^{90}Sr . The results of these analyses are shown in Table 8.

Naturally-occurring ^{40}K is the radionuclide present in the greatest concentrations. All other artificially-produced gamma-emitting radionuclides such as ^{60}Co , ^{65}Zn , and ^{137}Cs were found to be at less-than-detectable concentrations. Strontium-90 from worldwide fallout was detected in several samples of beef, chicken, and eggs. No observable difference exists between the Riverview samples and the commercially obtained samples, indicating that any cumulative impact of past Hanford releases is indistinguishable from the variability observed in radionuclide concentrations attributed to worldwide fallout.

LEAFY VEGETABLES

Leafy vegetables (spinach, leaf lettuce, turnip greens, and mustard greens) were obtained during the growing season from the Riverview area, Benton City, and commercial sources for analysis by gamma spectrometry and specific analysis for ^{90}Sr . A few samples were also analyzed for ^{131}I . The results are summarized in Table 9.

TABLE 8. Radionuclides in Meat, Chicken and Eggs

Location	No. of Samples	Concentration (10^{-6} $\mu\text{Ci/g}$, Wet Weight)								
		^{40}K			^{90}Sr			^{137}Cs		
		Maximum	Minimum	Average ^(a)	Maximum	Minimum	Average ^(a)	Maximum	Minimum	Average ^(a)
Meat										
Commercial	4	2.5	1.7	2.0 ± 0.7	0.005	*	<0.002	*	*	*
Riverview	2	2.1	2.0	2.1 ± 0.1	*	*	*	*	*	*
Chicken										
Commercial	2	1.7	1.4	1.5 ± 0.5	0.003	*	<0.002	*	*	*
Riverview	4	2.2	0.9	1.8 ± 1.3	0.003	*	<0.002	*	*	*
Taylor Flat	1			1.8			*			*
Ringold	1			2.7			*			*
Sunnyside	1			1.6			0.001			*
Eggs										
Commercial	2	1.0	0.7	0.8 ± 0.4	0.003	0.002	0.003 ± 0.001	*	*	*
Riverview	13	0.9	0.6	0.8 ± 0.2	0.004	0.001	0.002 ± 0.003 ^{(b)*}	*	*	*
Taylor Flat	1			0.9			0.002			*
Ringold	1			0.9			0.002			*
Sunnyside	1			0.8			*			*

(a) Average \pm two standard deviations is shown if all analyses were positive. Otherwise, a less-than-detectable value was calculated from all results, assuming that all less-than-detectable results were equal to the detection limit for the analysis.

(b) Strontium-90 analysis was done on only five samples.

* Less than detectable. Approximate detection limits were: ^{40}K , 0.6; ^{90}Sr , 0.001; ^{137}Cs , 0.04.

TABLE 9. Radionuclides in Leafy Vegetables

Location	No. of Samples	Concentration (10^{-6} μ Ci/g, Wet Weight)											
		^{40}K			^{90}Sr			^{131}I (a)			^{137}Cs		
		Maximum	Minimum	Average (b)	Maximum	Minimum	Average (b)	Maximum	Minimum	Average (b)	Maximum	Minimum	Average (b)
Riverview	5	4.0	1.4	2.6 \pm 2.4	0.02	0.008	0.01 \pm 0.01	*	*	*	*	*	*
Ringold	1			3.7			0.007	*	*	*	*	*	*
Benton City	1			4.0			0.02	*	*	*	*	*	*
Sunnyside	1			3.4			0.01	*	*	*	*	*	*
Commercial	6	3.6	1.2	2.1 \pm 1.8	0.009	*	<0.01	*	*	*	*	*	*

(a) One sample from Riverview and one from commercial suppliers were analyzed for ^{131}I .
 (b) Average \pm two standard deviations is shown if all analyses were positive. Otherwise, a less-than-detectable value was calculated from all the results, assuming that all less-than-detectable results were equal to the detection limit for the analysis.
 * Less than detectable. Approximate detection limits were: ^{40}K , 0.8; ^{90}Sr , 0.002; ^{131}I , 0.2; ^{137}Cs , 0.05.

Potassium-40 was observed in the greatest concentrations. Variations between commercially obtained samples and those obtained from local farms are believed to be due to differences in regional fallout from weapons testing and a difference in treatment following harvest. Leafy vegetables in the commercial outlets are usually rinsed periodically with water, whereas those obtained directly from the farm are not. Comparison of distant farm samples with the Riverview

samples shows that there is no observable difference and that any Hanford contribution is indistinguishable from the variability in levels of worldwide fallout.

The results of analyses for ^{131}I indicate levels less than the detection limit of 0.2 pCi/g. Since most local leafy vegetables would already have been harvested, no samples were analyzed for ^{131}I following the September 17 Chinese nuclear test.

WILDLIFE

Wildlife--deer, game birds, and fish--were collected from the Hanford environs and analyzed for gamma-emitting radionuclides and ⁹⁰Sr. The wildlife represent a potential pathway for the exposure of small groups of people who hunt or fish near the Hanford Site. In addition, oysters were collected from Willapa Bay along the coast of Washington to assess the status of ⁶⁵Zn activity attributable to past Hanford operation of once-through-cooled production reactors. The 1977 measurements did not show any distinguishable impact from Hanford operations.

DEER

Deer samples analyzed during 1977 were obtained from "road kills" on the Hanford Site. Samples of muscle tissue were analyzed to determine the concentration of gamma-emitting radionuclides and ⁹⁰Sr. The resulting data are shown in Table 10.

Naturally-occurring ⁴⁰K and the fission product ¹³⁷Cs were measured in samples of deer muscle. The concentrations observed were similar to those found in other types of wildlife. Only one of the three deer samples contained ¹³⁷Cs in an amount over the detection limit; this amount was 0.7 pCi/g. The same sample also showed small concentrations of the activation products ⁵⁴Mn and ⁶⁰Co, while the other samples did not. In general, radionuclide concentrations in deer samples collected during 1977 were lower than those observed in the past.

GAME BIRDS

Pheasants, quail, ducks, and geese were collected onsite during 1977, from along the Hanford reach of the Columbia River. Most of the samples were taken during the late fall and early winter months. Samples of muscle tissue were analyzed for gamma-emitting radio-

nuclides and ⁹⁰Sr. Results for each type of game bird are summarized in Table 10.

Of the 44 game birds analyzed for gamma-emitters, only one contained a detectable concentration of ¹³⁷Cs, and this concentration was only slightly above the detection limit. No statistically positive ⁶⁰Co results were obtained. The naturally-occurring ⁴⁰K concentrations were similar in all of the game birds.

All game bird samples except for the geese were analyzed for ⁹⁰Sr. Two of these samples were positive and the levels found are attributed to world wide fallout. The highest ⁹⁰Sr concentration observed, 0.09 ± 0.01 pCi/g, was found in a duck collected on December 15, 1977.

FISH

Several varieties of fish (suckers, white fish, sturgeon, bass, squawfish, steelhead, and carp) were collected during 1977. Along with the naturally-occurring ⁴⁰K, relatively low concentrations of ⁹⁰Sr and ¹³⁷Cs were detected in a few samples. All other gamma-emitting radionuclides were less than detectable. The observed activity is attributed to worldwide fallout.

TABLE 10. Radionuclides in Muscle Tissue of Wildlife

Wildlife	No. of Samples	Concentration (10 ⁻⁶ μCi/g, Wet Weight)											
		⁴⁰ K			⁶⁰ Co			⁹⁰ Sr			¹³⁷ Cs		
		Maximum	Minimum	Average ^(a)	Maximum	Minimum	Average ^(a)	Maximum	Minimum	Average ^(a)	Maximum	Minimum	Average ^(a)
Deer	3	2.0	*	<1.8	0.3	*	<0.1	*	*	*	0.7	*	<0.3
Pheasants	7	3.4	*	<4.4	*	*	*	0.01	*	<0.006	*	*	*
Quail	9	*	*	*	*	*	*	0.05	*	<0.02	*	*	*
Ducks	18	2.7	*	<3.7	*	*	*	0.09	*	<0.01	0.18	*	*
Geese	10	3.2	1.9	2.5 ± 0.8	*	*	*	*	*	*	*	*	*
Fish	7	3.7	*	<2.8	*	*	*	0.02	*	<0.006	0.29	*	<0.16

(a) Average ± two standard deviations is shown if all analyses were positive. Otherwise, a less-than-detectable value was calculated from all results, assuming that all less-than-detectable results were equal to the detection limit for the analysis.

* Less than detectable.

WILLAPA BAY OYSTERS

Oysters were collected from Willapa Bay along the coast of Washington during 1977 and analyzed by gamma spectrometry. The results are shown in Table 11. Only naturally-occurring ⁴⁰K was detected. All analy-

ses for ⁶⁵Zn indicate levels less than the detection limit. Figure 9 shows the decreasing levels of ⁶⁵Zn in Willapa Bay oysters since 1972; the decline closely approximates the 245-day radioactive half life of ⁶⁵Zn. No further oyster sample analyses are planned.

TABLE 11. Gamma-Emitting Radionuclides in Willapa Bay Oysters

No. of Samples	Concentration (10^{-6} μ Ci/g, Wet Weight)								
	⁴⁰ K			⁶⁵ Zn			¹³⁷ Cs		
	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
3	1.6	1.3	1.4 \pm 0.3	*	*	<0.08	*	*	<0.04

* Less than detectable.

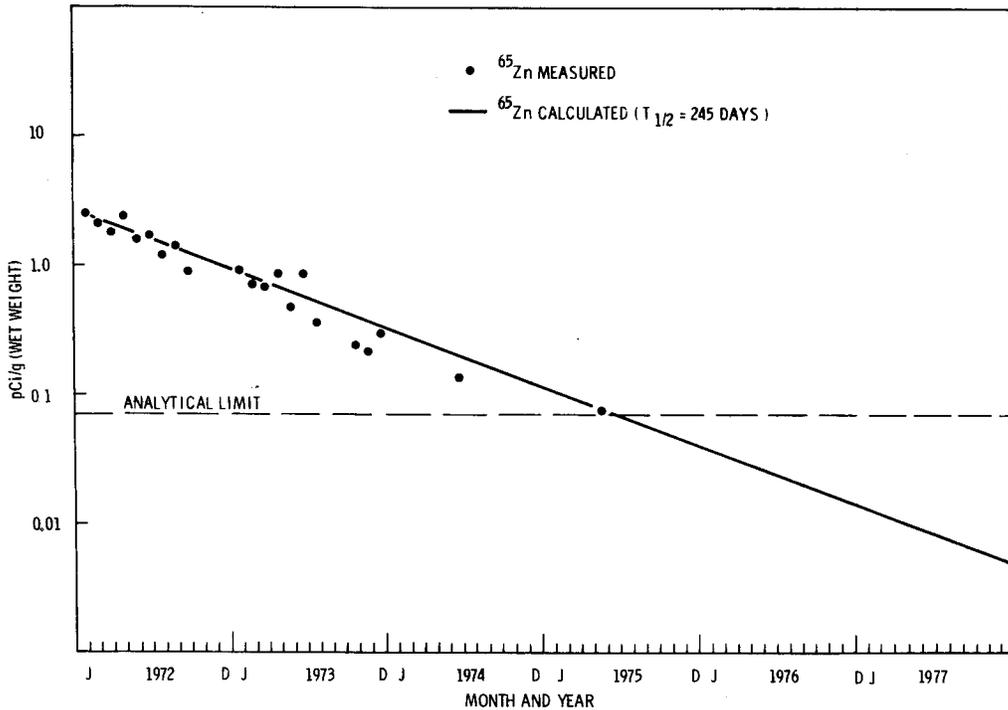


FIGURE 9. Zinc-65 Activity in Willapa Bay Oysters

SOIL AND VEGETATION

Surface soil and vegetation samples are collected annually from a few locations for the purpose of measuring the radionuclide concentrations from worldwide fallout, natural causes, and any cumulative buildup of activity from Hanford operations. The data collected during 1977 indicate that any Hanford contribution to the radionuclide concentrations was indistinguishable from the variability observed in levels of worldwide fallout.

COLLECTION AND ANALYSIS

Each soil sample analyzed was a composite of five "plugs" of soil collected from an area approximately 10 m². The plugs were approximately 2.5 cm in depth and 10 cm in diameter. Samples of perennial vegetation, primarily the growth from rabbit brush plants, were collected in the immediate vicinity of each soil sampling location. Both sets of samples were analyzed for gamma-emitting radionuclides using a lithium-drifted germanium detector; for plutonium isotopes using alpha spectroscopy; and for ⁹⁰Sr and uranium by specific analysis.

The location of the sample plots is shown in Figure 10. Hanford operations would be expected to contribute much more to the radionuclide concentrations at predominantly downwind locations (Riverview, Byers Landing, Sagemore, Pettett, Baxter Substation, West End Fir Road, Ringold--locations 1-7) than to sampling locations lying in other directions (Yakima Barricade, Wahluke #2, etc.).

SOIL

Summarized in Table 12 are the data obtained during 1977 for soil. The naturally-occurring radionuclides, ⁴⁰K, ²²⁴Ra, ²²⁶Ra, and U were observed in the highest concentrations in soil. The distribution of artificially-produced radionuclides revealed no geographical pattern, indicating that any Hanford contribution was indistinguishable from the variability observed in radionuclide concentrations from worldwide fallout. Strontium-90, cesium-137 and plutonium were detected in all samples analyzed. The highest soil concentration of ⁹⁰Sr, 0.17 pCi/g, occurred at Riverview and Byers Landing, while the highest plutonium concentration, 0.067 pCi/g, occurred at Berg Ranch, a predominantly upwind location. These results, although much higher than those from other locations, are similar to maximum values

measured in past years and indicate the variability of soil concentrations attributed to worldwide fallout.

Analysis of soil samples for ²⁴¹Am was performed for the first time on a routine basis during 1977. The two slightly positive results are not supported by any other results from samples taken in the vicinity and are ascribed to statistically false positive values or worldwide fallout.

VEGETATION

Table 13 shows the data obtained during 1977 from vegetation samples. Here again, the naturally-occurring radionuclide ⁴⁰K was observed in the highest concentrations in vegetation.

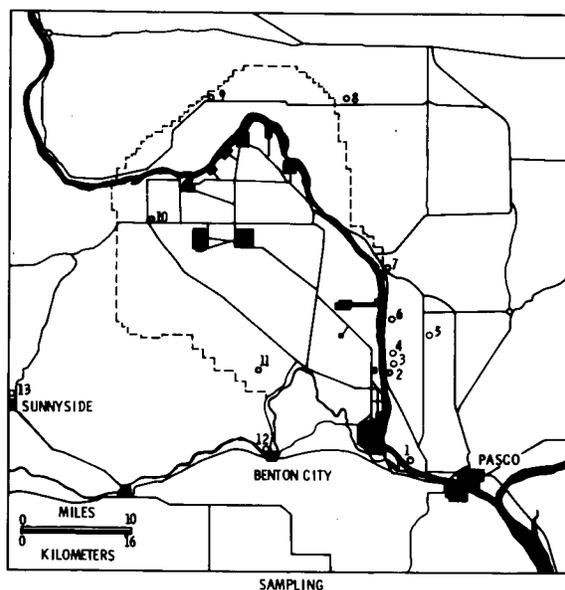


FIGURE 10. Soil and Vegetation Sampling Locations

TABLE 12. Radionuclides in Soil

PART A

Location	Map Location	Concentration (10^{-6} $\mu\text{Ci/g}$, Dry Weight)			
		Naturally-Occurring			
		^{40}K	^{224}Ra	^{226}Ra	Total U
Average					
Detection Limit		0.5	0.1	0.1	0.07
Riverview	1	13	1.1	0.6	0.29
Byers Landing	2	16	1.1	0.8	0.28
Sagemore	3	13	0.8	0.5	0.24
Pettett	4	15	1.0	0.7	0.47
Baxter Substation	5	13	1.1	0.7	0.32
W. End Fir Road	6	15	1.0	0.7	0.33
Ringold	7	17	1.2	0.8	0.21
Berg Ranch	8	14	1.2	0.8	0.32
Wahluke #2	9	13	1.2	0.8	0.17
Yakima Barricade	10	12	1.0	0.6	0.12
ALE	11	12	1.1	0.8	*
Benton City	12	12	1.0	0.8	0.33
Sunnyside	13	11	1.0	0.7	0.47
Average ^(a)		14 ± 3.5	1.1 ± 0.2	0.7 ± 0.2	<0.28

PART B

Location	Map Location	Concentration (10^{-6} $\mu\text{Ci/g}$, Dry Weight)							
		Artificially-Produced							
		^{90}Sr	$^{95}\text{ZrNb}$	^{134}Cs	^{137}Cs	^{144}Ce	^{238}Pu	$^{239-240}\text{Pu}$	^{241}Am
Average									
Detection Limit		0.003	0.04	0.03	0.02	0.1	0.001	0.001	0.07
Riverview	1	0.17	0.15	*	0.2	0.4	0.003	0.004	*
Byers Landing	2	0.17	0.06	0.03	0.4	0.3	*	0.006	0.10
Sagemore	3	0.01	0.06	0.04	0.07	0.2	*	0.002	*
Pettett	4	*	0.10	*	0.3	0.5	*	0.020	*
Baxter Substation	5	0.03	*	*	0.2	*	*	0.003	*
W. End Fir Road	6	0.15	0.11	0.04	0.4	0.4	*	0.006	*
Ringold	7	*	0.05	*	0.2	0.3	0.003	0.005	*
Berg Ranch	8	*	0.20	*	1.4	0.5	0.004	0.067	*
Wahluke #2	9	0.02	0.23	0.03	0.2	0.3	*	0.003	0.09
Yakima Barricade	10	0.01	0.06	0.06	0.6	0.4	0.004	0.008	*
ALE	11	0.08	0.08	0.06	1.0	0.3	*	0.017	*
Benton City	12	0.03	0.12	*	0.5	0.2	*	0.008	*
Sunnyside	13	0.03	0.04	0.04	0.01	0.3	0.001	0.004	0.07
Average ^(a)		<0.05	<0.10	<0.04	0.4 ± 0.8	<0.3	<0.002	0.01 ± 0.04	<0.07

(a) Average \pm two standard deviations is shown if radionuclide was detected at all locations. Otherwise, a less-than-detectable value was calculated from all results, assuming that all less-than-detectable results were equal to the detection limit.

* Less than detectable.

TABLE 13. Radionuclides in Vegetation

Location	Map Location	Concentration (10^{-6} $\mu\text{Ci/g}$, Dry Weight)								
		Naturally-Occurring		Artificially-Produced						
		^{40}K	Total U	^{90}Sr	$^{95}\text{ZrNb}$	^{137}Cs	^{141}Ce	^{144}Ce	^{238}Pu	^{239}Pu
Average		3.0	0.004	0.003	0.4	0.1	0.1	0.7	0.004	0.001
Detection Limit		3.0	0.004	0.003	0.4	0.1	0.1	0.7	0.004	0.001
Riverview	1	17	0.01	0.17	1.6	*	*	0.8	0.01	0.002
Byers Landing	2	31	0.006	0.06	0.8	*	*	*	0.03	0.02
Sagemore	3	25	0.009	0.02	*	*	*	*	*	0.004
Pettett	4	63	0.01	0.03	0.9	*	*	*	0.06	0.05
Baxter Substation	5	23	0.01	0.06	0.8	*	*	*	*	0.003
W. End Fir Road	6	65	0.02	0.05	*	*	*	*	*	0.008
Ringold	7	12	0.005	0.03	1.1	*	*	*	0.003	0.006
Berg Ranch	8	15	0.03	0.06	2.2	*	*	1.3	0.003	0.003
Wahluke #2	9	14	0.01	0.02	2.3	*	*	0.8	*	0.001
Yakima Barricade	10	11	0.004	0.01	3.3	0.16	0.4	1.9	0.01	0.004
ALE	11	3.8	*	0.16	3.6	0.24	0.3	2.0	0.01	0.02
Benton City	12	12	*	0.04	3.1	0.04	0.3	0.7	0.006	0.005
Sunnyside	13	20	0.01	0.03	0.4	*	*	*	0.002	0.002
Average ^(a)		24 \pm 38	<0.01	0.06 \pm 0.1	<1.7	<0.1	<0.2	<0.6	<0.01	0.01 \pm 0.03

(a) Average \pm two standard deviations is shown if radionuclide was detected at all locations. Otherwise, a less-than-detectable value was calculated from all results, assuming that all less-than-detectable results were equal to the detection limit.

* Less than detectable.

EXTERNAL RADIATION

External radiation levels were measured using thermoluminescent dosimeters at all air sampling locations in the Hanford environs. The spatial pattern of recorded doses was used to determine any contribution attributable to Hanford operations, since releases from Hanford would contribute primarily to measurements made at downwind locations. Dosimeters were also used to measure the dose received along the Columbia River islands and shoreline near the Hanford Site, and the immersion dose in the Columbia River water at four locations. The 1977 measurements at air sampling locations showed no observable impact from Hanford operations. However, several measurements on the Columbia River islands and along the shoreline showed slightly elevated doses attributed predominantly to residual ^{60}Co activity in river sediments. This activity remains from past direct use of river water to cool production reactors. The maximum dose rate observed was 0.014 mrad/hr in addition to the dose rate of approximately 0.008 mrad/hr from natural background radiation.

HANFORD ENVIRONS

Thermoluminescent dosimeters (TLDs) were located at all of the perimeter and distant air sampling locations shown in Figure 2 (page 4). The dosimeters consisted of $\text{CaF}_2\text{:Mn}$ chips (Harshaw TLD-400) encased in an opaque plastic capsule lined with 0.01 in. (0.025 cm) of tantalum and 0.002 in. (0.005 cm) of lead to flatten the low-energy response.⁽⁸⁾ The dosimeters were mounted 1 m above ground level and changed every 4 weeks.

The results presented in Table 14 show that the average annual dose is identical for perimeter locations and distant stations. A log normal probability plot of the individual data points for distant and perimeter locations (Figure 11) shows the similarity of the measurements, indicating that Hanford contributions were indistinguishable from the background dose.

From information in Table 14, the external background dose received by the population in the Hanford environs can be estimated. The average measured dose was about 67 mrem per year (here, 1 mrem equals 1 mrad). To this dose, 6 mrem per year must be added to account for the fast neutron component of cosmic radiation.⁽⁹⁾ Thus the population would receive a dose of about 73 mrem per year from external radiation. In order to estimate the total background dose (external plus internal), the 25 mrem received by the body from naturally-occurring radionuclides, primarily ^{40}K , must be included. Therefore, the total background dose received in the Hanford environs during 1977 was approximately 100 mrem per year.

**TABLE 14. Ambient Radiation (a)
Dose Measurements**

Location	No. of Samples	Dose (mrad/yr) ^(b)		
		Maximum	Minimum	Average
Perimeter Stations				
Rattlesnake	11	88	55	68 ± 10
ALE	13	80	58	72 ± 14
Benton City	12	66	40	55 ± 14
Yakima Barricade	13	84	58	72 ± 15
Vernita	13	91	58	76 ± 18
Wahluke #2	13	88	62	75 ± 18
Othello	12	66	47	57 ± 10
Connell	13	73	55	61 ± 13
Berg Ranch	13	95	62	78 ± 22
Wahluke Watermaster	12	77	55	69 ± 16
Cooke Brothers	13	80	47	65 ± 18
Richland	13	77	47	59 ± 18
Pasco	13	91	47	66 ± 24
Byers Landing	13	95	58	77 ± 20
Baxter Substation	11	80	51	67 ± 17
Pettett	8	69	47	60 ± 13
Fir Road	9	73	55	66 ± 12
RRC CP #63	13	84	51	67 ± 18
RRC CP #64	12	77	47	62 ± 16
Average				67
Distant Stations				
Walla Walla	12	88	58	74 ± 14
McNary	12	88	58	73 ± 17
Moses Lake	12	69	55	62 ± 10
Washtucna	13	77	58	65 ± 12
Sunnyside	13	73	51	62 ± 14
Average				67

(a) Total background dose from external irradiation would include an additional dose from the neutron component of cosmic radiation. This is estimated to be equivalent to 6 mrem/yr at the elevation of the Hanford region.

(b) Monthly measurements were converted to equivalent annual dose. Average ± two standard deviations is shown for each location.

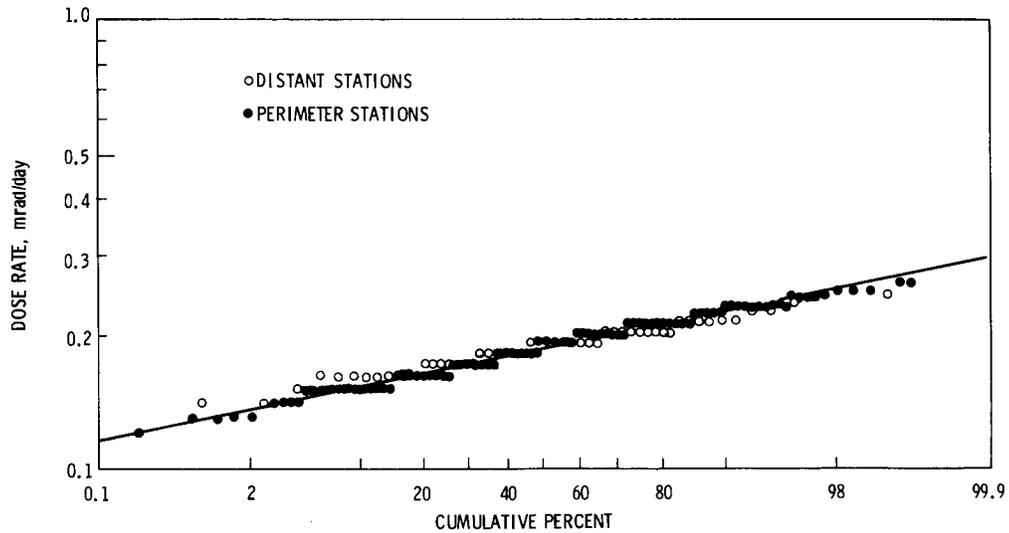


FIGURE 11. Log Normal Probability Plot of Monthly Dose Measurements at Perimeter and Distant Locations

COLUMBIA RIVER IMMERSION DOSE

Environmental dosimeters were submerged in the Columbia River at the four locations labeled in Figure 12: at Coyote Rapids (above the 100-K Area), below the 100-N Area, at the Hanford powerline, and at the Richland pumphouse. These dosimeters were collected monthly. The results (shown in Table 15) are similar to those obtained in previous years and show that a swimmer immersed in the Columbia River at Richland would receive a radiation dose rate of approximately 0.004 mrad/hr. By comparison, approximately 0.007 mrad/hr would be received on land.

COLUMBIA RIVER SEDIMENT

Past analyses of sediment samples collected along the Columbia River have shown the presence of a few long-lived radionuclides, primarily ⁶⁰Co, attributable to the past operation of production reactors cooled directly by river water. A 1974 aerial radiation monitoring survey showed low-level deposition of ⁶⁰Co over much of the Hanford reach of the river.⁽¹⁰⁾ This activity occurs in sediments along the river's islands, shoreline, and slough areas, gradually decreasing downstream from the old production reactor sites and becoming undetectable below North Richland.

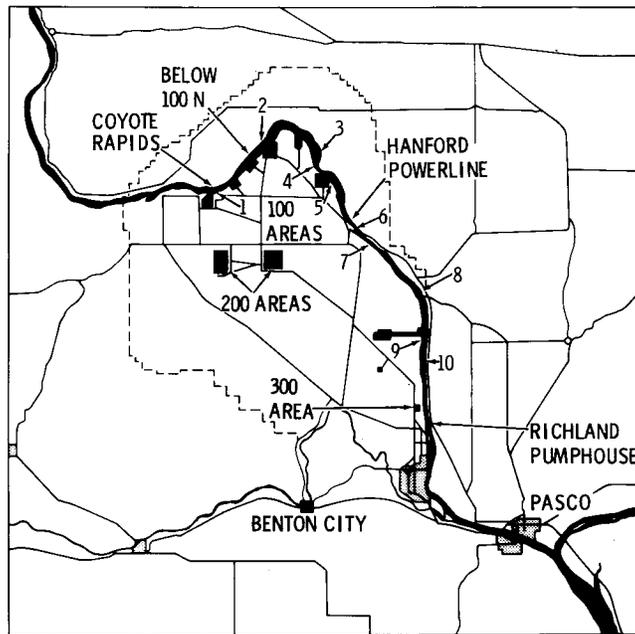


FIGURE 12. TLD Locations for Columbia River Immersion and Sediment Measurements

TABLE 15. Columbia River Immersion Dose

Location	Number of Measurements	Radiation Dose (mrad/hr) ^(a)		
		Maximum	Minimum	Average ^(b)
Coyote Rapids	12	0.008	0.004	0.005 ± 0.001
Below 100 N	10	0.016	0.006	0.01 ± 0.003
Hanford Powerline	9	0.007	0.004	0.006 ± 0.001
Richland Pump House	13	0.005	0.003	0.004 ± 0.001

(a) Monthly measurements in mrad were converted to equivalent hourly dose.

(b) Average ± two standard deviations is shown for each location.

In Table 16, the data from environmental dosimeters placed at 10 locations along the Columbia River shoreline and at three of the larger islands during 1977 are summarized. The placement of these dosimeters is shown by the numbered locations in Figure 12. The wide variation in results from the different locations is due to differences in the ⁶⁰Co activity in the sediment. The rather large variation between the maximum and minimum dose rate observed at each location is attrib-

uted to shielding provided by the water as the river's flow rate changes. Correcting the maximum dose rate observed in the 1974 aerial survey for decay of the ⁶⁰Co yields a maximum dose rate in 1977 of about 0.01 mrad/hr (~90 mrad/yr). The maximum dose rate actually observed for 1977, 150 mrad/yr, is approximately equal to the dose rate from the ⁶⁰Co (~90 mrad/yr) plus that from natural background (~70 mrad/yr). The measured maximum external dose rate corresponds to about 0.017 mrad/hr.

TABLE 16. Environmental Dosimeter Measurements Along the Columbia River Shoreline and Islands

Location	Map Number	No. of Samples	Dose Rate (mrad/yr) ^(a)		
			Maximum	Minimum	Average ^(b)
Above 100-K	1	12	84	62	74 ± 16
Opposite 100-D	2	12	77	58	67 ± 13
Locke Island	3	12	98	69	83 ± 15
White Bluffs	4	12	88	66	79 ± 14
Below 100-F	5	12	84	62	75 ± 14
Hanford Ferry	6	11	91	66	80 ± 15
Hanford RR	7	11	150	117	134 ± 23
Ringold Island	8	12	91	69	80 ± 14
Powerline Crossing	9	12	105	77	92 ± 17
Wooded Island	10	11	95	69	84 ± 15

(a) Monthly measurements in mrad were converted to equivalent annual dose.

(b) Average ± two standard deviations is shown for each location.

RADIOLOGICAL IMPACT OF HANFORD OPERATIONS

The preceding sections on environmental data collected during 1977 provide information for differentiating between sources of environmental radiation arising from past or current Hanford operations and those due to worldwide fallout or natural radioactivity. Contributions from Hanford operations were distinguishable from other sources in only two areas. These include the residual levels of long-lived radionuclides, primarily ^{60}Co , associated with sediments along the Columbia River islands and shoreline near the Hanford Site, and the very low concentrations of radionuclides in Columbia River water as a result of current N Reactor operations. The radiological impact of Hanford operations is evaluated based on measured radionuclides in effluents from operating facilities in 1977, and on the residual radionuclides in river sediments from the past operations. A comparison of the estimated impact from Hanford operations with the impacts from other sources of radiation exposure routinely encountered is included in the summary at the end of this section.

RADIOLOGICAL IMPACT FROM 1977 EFFLUENTS

The radionuclide effluent reported for 1977 by all Hanford contractors is shown in Table 17. Since these quantities of radionuclides, when dispersed in large volumes of air and water, were generally undetectable in the off-site environment, empirical dose models^(11,12) were used to assess the resulting radiological dose impact. These models are considered to provide the best estimate of the dose impact from Hanford operations during 1977. Small differences in the calculated doses may appear from year to year, depending on the quantity and type of effluents and the flow rate of the Columbia River. During 1977, for instance, the river flow was considerably below normal, hence calculated doses for exposure via river pathways are higher than in recent years.

Manual Chapter 0513⁽¹³⁾ states that a radiological impact assessment should provide realistic estimates of:

- The exposure rate on the site boundary where the maximum exposure rates exist ("fence-post" exposure)
- the maximum dose to an individual member of the public
- the total-body dose to the entire population within an 80-km (50 mile) radius of the site (person-rem).

The assessment of these impacts for 1977 follows.

Maximum "Fence-Post" Exposure Rate

The maximum exposure rate for 1977 was calculated to be 1.5×10^{-5} mR/hr along the northwest boundary of the site from the gaseous effluent shown in Table 17. For an individual continuously present on the boundary (8766 hr), the calculated exposure rate translates to an annual total-body exposure of 0.14 mR. The ^{138}Cs and the short-lived noble gas ^{41}Ar from N Reactor operations are the major contributors to this exposure. This potential exposure amounts to 0.03% of the 500 mrem standard for the annual dose to individuals at points of maximum probable exposure in uncontrolled areas, as stated in Manual Chapter 0524. No one lives in this area, however.

Maximum Individual Dose

Computation of the maximum annual individual dose is complicated by a number of factors: the facilities on the Hanford Site are several miles apart and discharge varying quantities of effluents; separate calculations must be made to determine the relative contributions of liquid and gaseous effluent; and various locations and dietary habits of the maximum individual must be assumed. In the past, radionuclides released to the Columbia River were the dominant mode of exposure. Recently, the airborne pathway has become increasingly important. The maximum dose to an individual member of the public resulting from the release of the radionuclides in Table 17 was computed assuming contributions from a number of exposure pathways.

TABLE 17. Radionuclide Composition of Effluents for Calendar Year 1977

Radionuclide	Half Life	Effluent (Ci)			
		Liquid To River	Gaseous		
			100 Area	200 Areas	300 Area
³ H(HTO)	12.3 yr	430	18	--	9.0
²⁴ Na	15 hr	1.4	0.18	--	--
³² P	14.3 d	0.018	--	--	--
⁴¹ Ar	1.8 hr	--	1.31 x 10 ⁵	--	--
⁵¹ Cr	27.8 d	0.19	0.017	--	--
⁵⁴ Mn	303 d	0.19	0.016	--	--
⁵⁶ Mn	2.6 hr	--	2.4	--	--
⁵⁹ Fe	46 d	--	0.018	--	--
⁵⁸ Co	71 d	0.02	0.0029	--	--
⁶⁰ Co	5.3 yr	1.2	0.029	--	1.2 x 10 ⁻⁴ (a)
⁶⁵ Zn	245 d	--	4.55 x 10 ⁻⁴	--	--
⁷⁶ As	26.4 hr	--	0.66	--	--
^{85m} Kr	4.4 hr	--	825	--	--
⁸⁷ Kr	76 min	--	2510	--	--
⁸⁸ KrRb	2.8 hr	--	1980	--	--
⁸⁹ Sr	52.7 d	1.5	0.0079	--	--
⁹⁰ Sr	27.7 yr	1.8	1.73 x 10 ⁻⁴	0.21 ^(b)	2.5 x 10 ⁻⁴ (b)
⁹¹ Sr	9.7 hr	--	0.58	--	--
⁹⁵ Zr	65.5 d	0.045	0.0038	--	--
⁹⁵ Nb	35 d	0.15	0.0030	--	--
⁹⁷ ZrNb	17 hr	--	0.0021	--	--
⁹⁹ MoTc	66.7 hr	1.0	0.62	--	--
¹⁰³ Ru	39.5 hr	0.25	0.0082	--	--
¹⁰⁶ Ru	368 d	0.68	0.019	--	--
¹²² Sb	2.8 d	--	0.0054	--	--
¹²⁴ Sb	60.4 d	0.079	0.0033	--	--
¹²⁵ Sb	2.7 yr	0.25	1.42 x 10 ⁻⁴	--	--
¹³² Te	77.7 hr	--	0.0056	--	--
¹²⁹ I	1.7 x 10 ⁷ yr	8.2 x 10 ⁻⁶	2.1 x 10 ⁻⁷	--	--
¹³¹ I	8.1 d	4.2	0.55	--	4.4 x 10 ⁻⁴
¹³² I	2.3 hr	--	9.6	--	--
¹³³ I	20.3 hr	0.44	4.0	--	--
¹³⁵ I	6.7 hr	--	8.6	--	--
¹³³ Xe	5.3 d	7.6	684	--	--
¹³⁵ Xe	9.1 hr	--	3380	--	--
¹³⁷ Cs	30.0 yr	0.03	0.0015	--	--
¹³⁸ Cs	32.2 min	--	1.31 x 10 ⁴	--	--
¹⁴⁰ Ba	12.8 d	0.064	0.20	--	--
¹⁴⁰ La	40.2 hr	0.038	0.36	--	--
¹⁴¹ Ce	32.5 d	--	0.0013	--	--

TABLE 17. (contd)

Radionuclide	Half Life	Effluent (Ci)			
		Liquid To River	Gaseous		
			100 Area	200 Areas	300 Area
¹⁴⁴ CePr	284 d	--	0.030	--	--
¹⁴⁷ Nd	11.1 d	--	0.013	--	--
¹⁵³ Sm	46.8 hr	--	0.0017	--	--
¹⁵⁴ Eu	16 yr	--	0.010	--	--
¹⁵⁵ Eu	1.8 yr	--	0.0062	--	--
¹⁸⁷ W	23.9 hr	--	0.069	--	--
U-Nat.	4.4 x 10 ⁹ yr	--	--	--	5.2 x 10 ⁻⁵
²³⁹ Np	2.3 d	--	0.0032	--	--
²³⁸ Pu	86.4 yr	0.069	1.08 x 10 ⁻⁶	--	--
²³⁹ Pu	24,390 yr	0.0099	5.72 x 10 ⁻⁶	0.0028 ^(c)	3.2 x 10 ^{-5(c)}
²⁴¹ Am	458 yr	--	0.004	--	--
²⁴⁴ Cm	17.6 yr	--	--	--	8.4 x 10 ⁻⁸

(a) Actually reported as mixed activation products. Cobalt-60 was assumed for simplicity and was used in dose calculations.

(b) Actually reported as mixed fission products. Strontium-90 was assumed for simplicity and was used in dose calculations.

(c) Actually reported as gross alpha. Plutonium-239 was assumed for simplicity and was used in dose calculations.

Maximum individual dose calculations for 1977 include estimates of the dose received from 1) airborne contaminants at a location 1 mile east of the 300 Area, 2) drinking water at Richland, 3) irrigated foodstuffs at Riverview, and 4) aquatic recreation along the Hanford reach of the Columbia River. The results of these calculations are shown in Tables 18 and 19 for the annual dose and the 50-yr dose commitment, respectively. The doses shown in these tables are not strictly additive, since the location of the maximum dose received from any one pathway is separated by many miles from the location of the dose from any other pathway. A discussion of the dose from each pathway follows.

Airborne Releases

The maximum dose received offsite as a result of Hanford's airborne effluents in 1977 was estimated for a location 1 mile east of the 300 Area. Within this area are located the nearest dairy and farming operations in a downwind direction from the Hanford Site. Doses calculated include those received from inhalation of airborne radionuclides and from submersion in the plume for 8766 hr/yr (continuous occupancy); and that received from exposure to ground contamination for 2922 hr/yr (one-third of the total exposure time possible). In addition, the dose resulting

from ingestion of a variety of foodstuffs (e.g., garden vegetables, milk, etc.) was calculated because of the foodstuffs grown in that area.

All of the annual doses resulting from exposure to the 1977 airborne effluents were far below Manual Chapter 0524 standards. The calculated annual total-body dose (0.03 mrem) represents 0.006% of the standard for the maximum individual in an uncontrolled area. Table 19 shows the 50-yr dose commitment from 1977 airborne effluents. The increase in the dose received by the whole body and bone after 1977 is attributable to the 1977 release of a few long-lived radionuclides.

Drinking Water

Richland is the first city downstream from the Hanford Site and obtains some of its drinking water from the Columbia River. Tables 18 and 19 list the estimated annual dose and 50-yr dose commitment for an individual who drinks 730 liters of water obtained from the Columbia River. The water treatment plant's efficiency in removing part of the activity from the river water was considered in the calculation. This efficiency varies with the radionuclide. (See reference 11 for details.) The maximum annual dose calculated (0.06 mrem to the thyroid) represents 0.004%

TABLE 18. Annual Dose to the Maximum Individual From Effluents Released During 1977

Environmental Pathway	Dose (mrem) ^(a)					
	Skin	Total Body	GI ^(b)	Thyroid	Bone	Lung
Airborne ^(c)	0.03	0.03	0.03	0.06	0.02	0.03
Drinking Water	--	<0.01	<0.01	0.06	<0.01	<0.01
Irrigated Foodstuff	<0.01	<0.01	0.02	0.20	0.02	<0.01
Aquatic Recreation ^(d)	<0.01	<0.01	0.06	0.06	0.01	<0.01

- (a) The doses shown are not strictly additive. The dose received is dependent on the location and assumed living habits of the hypothetical maximum individual. The location of the maximum individual varies for the pathways shown, which are separated by many miles.
- (b) Gastrointestinal tract (lower large intestine).
- (c) Includes dose contributions from inhalation, submersion, ingestion of foodstuffs contaminated by airborne deposition, and exposure to ground contamination.
- (d) Includes consumption of fish from the Columbia River.

TABLE 19. 50-Year Dose Commitment for the Maximum Individual from Effluents Released During 1977

Environmental Pathway	Dose (mrem) ^(a)					
	Skin	Total Body	GI ^(b)	Thyroid	Bone	Lung
Airborne ^(c)	0.03	0.03	0.03	0.06	0.07	0.03
Drinking Water	--	0.01	<0.01	0.06	0.03	<0.01
Irrigated Foodstuff	<0.01	0.13	0.02	0.20	0.52	<0.01
Aquatic Recreation ^(d)	<0.01	0.06	0.06	0.06	0.23	<0.01

- (a) The doses shown are not strictly additive. The dose received is dependent on the location and assumed living habits of the hypothetical maximum individual. The location of the maximum individual varies for the pathways shown, which are separated by many miles.
- (b) Gastrointestinal tract (lower large intestine).
- (c) Includes dose contributions from inhalation, submersion, ingestion of foodstuffs contaminated by airborne deposition, and exposure to ground contamination.
- (d) Includes consumption of fish from the Columbia River.

of the Manual Chapter 0524 standard for the maximum individual in an uncontrolled area.

Irrigated Foodstuffs

The Riverview Area is the first area downstream from the Hanford Site that is extensively irrigated with Columbia River water. The annual dose and 50-yr dose commitments shown in Tables 18 and 19 were calculated for an individual who consumes foodstuffs irrigated with Columbia River water, livestock raised on irrigated pasture, and a

variety of other farm products that involve Columbia River water. Many of the assumptions made about the maximum individual's diet, the crops irrigated, etc., are described in Appendix D. The maximum annual dose calculated (0.2 mrem to the thyroid) represents 0.013% of the Manual Chapter 0524 standard for the maximum individual in an uncontrolled area.

Aquatic Recreation

The Columbia River is used extensively for recreation. Estimates of the dose received

from recreational activities, shown in Tables 18 and 19, are based on an individual who annually spends 500 hr along the shoreline, 100 hr swimming, and 100 hr boating, and who consumes 40 kg of fish from the Hanford reach of the Columbia River. All of the radionuclides released to the river were considered in the dose estimates. (Appendix D should be consulted for additional detail.) The maximum annual dose calculated (0.06 mrem to the gastrointestinal tract and thyroid) represents 0.004% of the Manual Chapter standard for the maximum individual in an uncontrolled area.

80-Kilometer-Radius Population Dose

Dose computations from effluents released during 1977 for all of the radionuclides listed in Table 17 were made for the population within an 80-km radius of the Hanford Site. Since the population affected by the effluents differs with each environmental pathway considered, an estimated dose is provided for each pathway-population combination. In addition, a population dose is given for each major operating area since the population within an 80-km radius of each of these areas differs.

Summarized in Table 20 are the estimated population doses resulting from 1977 releases to the Columbia River. The greatest dose

would be received by a population group that obtained their drinking water from the Columbia River.

Shown in Table 21 are the doses to the population within an 80-km radius of the 100-N Area, 200 Areas, and 300 Area, from airborne effluents. The estimated population affected by the release from each area is also shown.

RADIOLOGICAL IMPACT FROM PAST HANFORD OPERATIONS

Previous sections of this report showed that, in general, any Hanford contributions to the levels of radiation observed in the environment were indistinguishable from pre-existing levels attributable to fallout or natural causes. Two exceptions to this finding were 1) the detection of a few radionuclides released from N Reactor to the Columbia River at concentrations less than 1% of the most restrictive guidelines in Manual Chapter 0524, and 2) the continued presence of a few long-lived radionuclides, notably ⁶⁰Co, along the Columbia River islands and shoreline near the Hanford Site. The radionuclides attributable to N Reactor were included in Table 17 and in the evaluation of the dose impact just discussed. The impact from the activity on the Columbia River islands and shoreline is evaluated here.

TABLE 20. Dose to the Population from Liquid Effluents Released During 1977

<u>Exposure Mode</u>	<u>Population Affected</u>	<u>Population Dose (Person-Rem)</u>			
		<u>Total Body</u>	<u>GI^(a)</u>	<u>Thyroid</u>	<u>Bone</u>
			<u>First-Year Dose</u>		
Drinking Water	50,000	0.02	0.08	1.72	0.04
Fish	(b)	<0.01	0.02	0.02	<0.01
Aquatic Recreation	125,000	<0.01	<0.01	<0.01	<0.01
Irrigated Farm Products	2,000	<0.01	0.02	0.2	0.02
<u>50-Year Commitment</u>					
Drinking Water	50,000	0.21	0.08	1.80	0.84
Fish	(b)	0.02	0.02	0.02	0.09
Aquatic Recreation	125,000	<0.01	<0.01	<0.01	<0.01
Irrigated Farm Products	2,000	0.13	0.02	0.2	0.52

(a) Gastrointestinal tract (lower large intestine).

(b) The population dose is based on consumption of 15,000 kg of fish during 1977. The population dose would be numerically the same regardless of the number of people eating the fish.

TABLE 21. Dose to the Population from Airborne Effluents Released During 1977

Effluent Release Point	80-Kilometer Population	Population Dose (Person-Rem)				
		Total Body	GI ^(a)	Thyroid	Bone	Lung
			<u>First-Year Dose</u>			
100-N Area	236,000	2.0	1.9	4.0	2.0	2.1
200 Areas	258,000	<0.01	0.02	<0.01	0.02	0.02
300 Area	171,000	<0.01	<0.01	0.03	<0.01	0.01
			<u>50-Year Commitment</u>			
100-N Area	236,000	2.0	1.9	4.1	2.4	2.1
200 Areas	258,000	0.16	0.02	<0.01	1.5	0.06
300 Area	171,000	0.02	<0.01	0.03	0.15	0.02

(a) Gastrointestinal tract (lower large intestine).

The contributions of the ⁶⁰Co activity in Columbia River sediments to the maximum "fence-post" exposure rate, about 0.01 mR/hr, is significantly larger than that due to 1977 effluents (1.5×10^{-5} mR/hr).

The ⁶⁰Co activity in island sediments would contribute to the maximum individual dose in proportion to the amount of time spent on the islands and exactly where it was spent, since the distribution of activity is highly variable. An individual spending 500 hr/yr at the location of the highest observed exposure rate would receive an annual dose of about 5 mrem due to ⁶⁰Co; this amounts to 1% of the 500 mrem standard from Manual Chapter 0524 for uncontrolled areas.

The contributions of the ⁶⁰Co in the island sediments to the population dose computed for 1977 is insignificant because of the low levels of radioactivity in other areas, the remoteness of the islands, and the small number of people potentially affected.

IMPACT SUMMARY

The maximum "fence-post" exposure rate for 1977, about 0.01 mR/hr, occurred at selected locations on the Columbia River islands and shorelines. Residual long-lived radionuclides, principally ⁶⁰Co in sediments deposited on the islands and shoreline during periods of high water flow, were responsible for the majority of the "fence-post" exposure rates. These radionuclides are due to past operation of once-through-cooled production reactors, the last of which were shut down in January 1971.

The maximum annual total-body dose to an individual member of the public from 1977 effluents is estimated to be less than 0.1 mrem, including contributions from airborne, drinking-water, irrigated foodstuff, and aquatic recreation pathways. The annual organ dose potentially received by the maximum individual from all pathways is estimated to be less than 0.5 mrem. These doses represent 0.02% of the maximum annual total-body dose standard and 0.03% of the maximum annual organ dose standard in Manual Chapter 0524.

Airborne effluents from the Hanford Site's three operating areas resulted in an annual total-body dose to the population within an 80-km (50-mile) radius of Hanford of about 2 person-rem. Liquid effluents during 1977 contributed very little (about 0.02 person-rem) to the total population dose. The total population dose is equivalent to an annual average per capita total-body dose of about 0.01 mrem (2 person-rem/250,000 people).

These dose estimates can be compared with doses from other routinely encountered sources of radiation. These sources include natural background radiation,⁽¹⁴⁾ medical procedures,⁽¹⁴⁾ and a 5-hr commercial jet flight.⁽⁹⁾ Compared graphically in Figure 13 are average doses from these sources and the maximum individual and average per capita total-body dose from Hanford operations in 1977. The population dose estimate of 2 person-rem may also be compared with the approximately 25,000 person-rem received annually from natural background radiation by the same population.

Hanford contributions clearly represent a small fraction of the average dose received from other sources. Moreover, the maximum

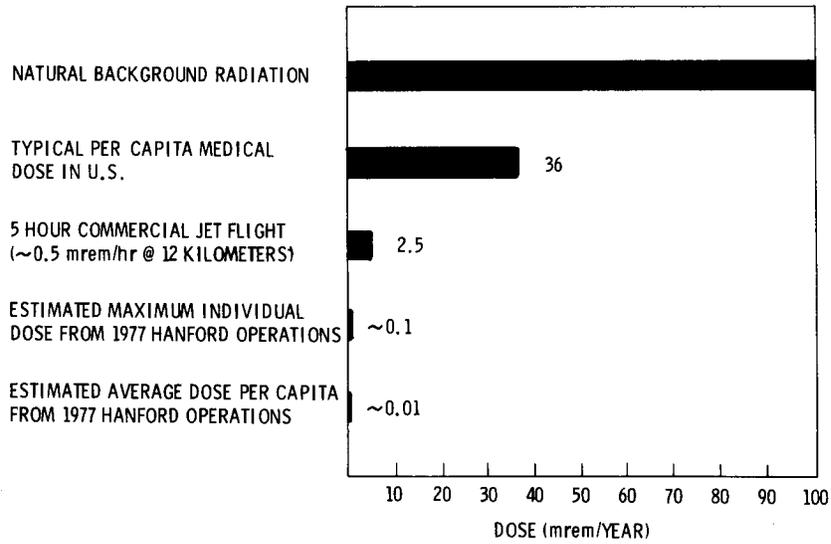


FIGURE 13. Comparative Doses Received from Various Radiation Sources

dose potentially received from natural background radiation, medical procedures, and commercial jet flights could be much greater than the values shown, depending on an individual's lifestyle.^(9,14) The dose contri-

bution to the maximum individual from Hanford operations is less than the variability in other doses received by people with different lifestyles.

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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.⁽⁴⁾ Of interest to Hanford operations is the design-

nation of the Hanford reach of the Columbia River as Class A or excellent. This designation requires that the water be usable for substantially all needs including sanitary 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)⁽⁵⁾ and are summarized in Table A-2.

TABLE A-1. Washington State Water Quality Standards for the Hanford Reach of the Columbia River⁽⁴⁾

CLASS A WATER CHARACTERISTIC

Meets or exceeds requirements for all uses.

USES

- Include but not limited to:
- Water supply--domestic, industrial, agricultural
- Wildlife habitat, stock watering
- General recreation and aesthetic enjoyment
- Commerce and navigation
- Fish and shellfish reproduction, rearing and harvesting

WATER QUALITY STANDARDS

<u>Parameter</u>	<u>Permissible Levels</u>
Total coliform organism	1) < 240 (median) 2) $< 20\%$ of samples may exceed 1000 when associated with a local source
Dissolved oxygen	> 8.0 mg/l
Temperature	1) $< 68^{\circ}\text{F}$ (21°C) due to measurable increases 2) Cumulative total of all measurable increases from non-natural sources shall be $< 110/(T-15)$ where T = the water temperature in $^{\circ}\text{F}$ resulting from these increases
pH	1) 6.5 - 8.5 2) induced variation < 0.25 units
Turbidity	≤ 5 JTU ^(a) over natural conditions
Toxic, radioactive or deleterious materials	$<$ levels that are significant for public health or that cause acute or chronic toxic conditions in aquatic biota or adversely affect any water use
Aesthetic value	Shall not be impaired by materials of non-natural origin that offend smell, sight, touch or taste

(a) JTU = Jackson Turbidity Units - Standard Candle.

TABLE A-2. Air Quality Standards

Parameter	Maximum Permissible Level	Period
SO ₂ (a)	0.10 ppm	24-hr average
	0.02 ppm	Annual average
NO ₂ (b)	100 µg/m ³ (c)	Annual arithmetic mean
	250 µg/m ³ (c)	24-hr average
Suspended particulates (a)	60 µg/m ³ (d)	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.

Environmental radiation protection standards are published in Manual Chapter 0524, "Standards for Radiation Protection." (3) These standards 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 for DOE and DOE contractor personnel and for members of the public who may be exposed to ionizing radiation resulting from DOE and DOE contractor operations. Several concentration guides for air and water are listed in Table A-3.

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

TABLE A-3. Radionuclide Concentration Guides (a)

Radionuclide	Water µCi/ml (Multiply by 10 ⁻⁹)	Air µCi/ml (Multiply by 10 ⁻¹²)
Alpha	30	0.02
³ H	3,000,000	200,000
⁵⁴ Mn	100,000	1,000
⁵¹ Cr	2,000,000	80,000
⁶⁰ Co	30,000	300
⁶⁵ Zn	100,000	2,000
⁹⁰ Sr	300	30
⁹⁵ Zr-Nb	60,000	1,000
¹⁰⁶ Rn	10,000	200
¹³¹ I	300	100
¹³⁷ Cs	20,000	500
¹⁴⁰ BaLa	20,000	500
¹⁴⁴ Ce	10,000	200
²³⁹ Pu	5,000	0.06

(a) Obtained from Manual Chapter 0524, Table II. Most restrictive guide assumed.

- U.S. Department of Energy
Richland Operations Office
P.O. Box 999
Richland, WA 99352

APPENDIX B

ANALYTICAL PROCEDURES

APPENDIX B

ANALYTICAL PROCEDURES

AIR SAMPLES

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

Strontium-89, 90 collected on filter paper are determined by leaching the filters with nitric acid, precipitating with fuming nitric acid, scavenging with barium chromate, precipitating as a carbonate, transferring to a stainless steel planchet and counting with a gas flow proportional counter.

Plutonium is leached from the filter paper with fuming nitric acid and passed through an anion exchange resin. The resin column is eluted with 0.4 N HNO₃ - 0.01 N HF and the plutonium in the eluate is electro-deposited 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 the well of a 9-in. x 9-in. (23-cm x 23-cm) NaI(Tl) well detector.

WATER SAMPLES

Beta-Emitting Radionuclides are measured by a direct count of dried residue.

Uranium and Plutonium (Total Alpha) are extracted into ether from strong nitric acid. The ether phase is evaporated off and the residue 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 the well of a 9-in. x 9-in. (23-cm x 23-cm) NaI(Tl) well detector with a multi-channel 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 a stainless steel planchet and beta-counted with a low-level beta proportional counter. After a 15-day period the yttrium-90 daughter is separated and counted with a low-level beta proportional counter.

Tritium is measured in distilled water samples with a liquid scintillation spectrometer.

MILK

Gamma-Emitting Radionuclides are measured by a direct count of the sample in the well of a 9-in. x 9-in. (23-cm x 23-cm) NaI(Tl) detector.

Iodine-131 is removed from milk with anion exchange resin, Cl⁻ form. The iodine is leached off the resin with sodium hypochlorite, precipitated as palladium chloride and beta-counted with a low-background beta 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 beta counting.

FARM PRODUCE

Gamma-Emitting Radionuclides are determined by a direct count of the sample in the well of a 9-in. x 9-in. (23-cm x 23-cm) NaI(Tl) well detector.

Plutonium analyses are made as those for air samples after drying, ashing in furnace and wet ashing with nitric acid.

Uranium analyses are made as those for water samples after drying, ashing in furnace and wet ashing with nitric acid.

Strontium-90 analyses are made as those for air samples after the pretreatment described for uranium and plutonium.

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 approximately 500 grams of sample into a marinelli beaker and counting on a lithium-drifted germanium detector, with a multichannel pulse height analyzer.

Plutonium and Strontium-90 are measured when the soil is dried, mixed thoroughly, leached with a mixture of nitric and hydrochloric acids, and then passed through an ion exchange resin in 8 N nitric acid.

The nitric acid retains strontium and other metal ions. This phase is precipitated with fuming nitric acid, scavenged with barium chromate, precipitated as a carbonate, and transferred to a stainless steel planchet. The ⁹⁰Sr sample is counted with a low-background beta proportional counter.

The plutonium is eluted from the resin column with a 0.4N HNO₃ - 0.01 N HF and electro-deposited on a stainless steel disk for alpha spectrometric analyses.

APPENDIX C

QUALITY ASSURANCE

APPENDIX C

QUALITY ASSURANCE

Several methods are used to assure that the data collected each year are representative of actual concentrations in the environment. First, extensive environmental data are collected to eliminate an unrealistic reliance on only a few results. Second, newly collected data are compared with historical data for each environmental medium to assure that current values are consistent with previous results. This allows for timely investigation of any unusual result. Third, measurements are collected using identical methods, near to and far from the Hanford Site, as well as upstream and downstream on the river, to provide for identification of any net difference that may be attributable to Hanford operations. These procedures, in conjunction with a program to demonstrate the accuracy of radiochemical analyses, assure that the data taken accurately represent environmental conditions.

ANALYTICAL LABORATORY QUALITY ASSURANCE

The majority of the routine radioanalyses for the Hanford environmental surveillance program are performed by the United States Testing Company in 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 assure purity of all

chemicals. The accuracy of radionuclide determination is assured 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, 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 forwarded to the sponsoring laboratory for comparison with known values and with the results from other laboratories. These programs enable a laboratory to demonstrate that it is capable of performing precise, accurate analyses.

QUALITY ASSURANCE IN DOSE CALCULATIONS

Assurance of the dose calculation quality is provided in several ways. First, since doses are similar from year to year, a comparison is made against past calculated doses and any differences are validated. 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. Synopses of the information for the 1977 calculations are shown in Tables C-1 through C-4.

TABLE C-1. QA Data for 100 Area Airborne
Release Dose Calculations

Facility name: 100 Area
Releases: See Table 17
Meteorology: 100 N meteorological tower, annual average, see Table D-1
Dispersion model: Hanford
Population distribution: 236,000, see Figure D-1
Release height: 82.3 meters effective (60.96 meters actual stack height)
Computer code: TGAUCH, Rev. 3-3-77
Calculated dose: Chronic inhalation--maximum individual and population--
first-year dose and 50-yr dose commitment
Files addressed: DFINH1, Rev. 2-7-77
DCFINH, Rev. 2-7-77
Computer code: GRONK, Rev. 8-5-75
Calculated dose: Chronic air submersion--maximum individual and population--
first-year dose and 50-yr dose commitment
Files addressed: DFEXT1, Rev. 11-17-77
Computer code: TVITTL, Rev. 9-20-76
Calculated dose: Chronic ingestion and ground contamination exposure--
maximum individual and population--first-year dose and
50-yr dose commitment
Files addressed: DFING1, Rev. 2-7-77
DCFING, Rev. 2-7-77
DFEXT1, Rev. 11-17-77

TABLE C-2. QA Data for 100 Area Liquid
Release Dose Calculations

Facility name: 100 Area
Releases: See Table 17
River flow: 84,500 cfs
Mixing ratio: 1
Reconcentration formula: 3
Shore-width factor: 0.2
Population: 50,000--drinking-water pathway
125,000--fish and direct exposure
Computer code: TLIKOR, Rev. 10-5-76
Calculated dose: Chronic ingestion, water immersion and surface exposure,
shoreline exposure--maximum individual and population--
first-year dose and 50-yr dose commitment
Files addressed: DFING1, Rev. 2-7-77
DCFING, Rev. 2-7-77
DFEXT1, Rev. 11-17-77
BIOACH, Rev. 2-7-77

TABLE C-3. QA Data for 200 Areas Airborne Release Dose Calculations

Facility name: 200 Areas
Releases: See Table 17
Meteorology: HMS historical, annual average, see Table D-2
Dispersion model: Hanford
Population distribution: 258,000, see Figure D-2
Release height: 89.2 meters effective (60.96 meters actual stack height)
Computer code: TGAUCH, Rev. 3-3-77
 Calculated dose: Chronic inhalation--maximum individual and population--
 first-year dose and 50-yr dose commitment
 Files addressed: DFINH1, Rev. 2-7-77
 DCFINH, Rev. 2-7-77
Computer code: GRONK, Rev. 8-5-75
 Calculated dose: Chronic air submersion--maximum individual and population--
 first-year dose and 50-yr dose commitment
 Files addressed: DFEXT1, Rev. 11-17-77
Computer code: TVITTL, Rev. 9-20-76
 Calculated dose: Chronic ingestion and ground contamination exposure--
 maximum individual and population--first-year dose and
 50-yr dose commitment
 Files addressed: DFING1, Rev. 2-7-77
 DCFING, Rev. 2-7-77
 DFEXT1, Rev. 11-17-77

TABLE C-4. QA Data for 300 Area Airborne Release Dose Calculations

Facility name: 300 Area
Releases: See Table 17
Meteorology: WPPSS historical, annual average, see Table D-3
Dispersion model: Hanford
Population distribution: 171,000, see Figure D-3
Release height: Ground level
Computer code: TGAUCH, Rev. 3-3-77
 Calculated dose: Chronic inhalation--maximum individual and population--
 first-year dose and 50-yr dose commitment
 Files addressed: DFINH1, Rev. 2-7-77
 DCFINH, Rev. 2-7-77
Computer code: GRONK, Rev. 8-5-75
 Calculated dose: Chronic air submersion--maximum individual and population--
 first-year dose and 50-yr dose commitment
 Files addressed: DFEXT1, Rev. 11-17-77
Computer code: TVITTL, Rev. 9-20-76
 Calculated dose: Chronic ingestion and ground contamination exposure--
 maximum individual and population--first-year dose and
 50-yr dose commitment
 Files addressed: DFING1, Rev. 2-7-77
 DCFING, Rev. 2-7-77
 DFEXT1, Rev. 11-17-77

APPENDIX D

RADIATION DOSE CALCULATIONS

APPENDIX D

RADIATION DOSE CALCULATIONS

The methods used to compute environmental radiation doses from Hanford operations can be categorized as follows:

1. Whenever environmental monitoring data show the presence of radionuclides, the dose impact is calculated using standard techniques described in the text (e.g., the infant thyroid dose of 8 mrem from fallout ^{131}I is calculated using methods of the Environmental Protection Agency, as described on page 13 of this report).
2. The liquid and gaseous radionuclide effluent released during the year by all Hanford facilities is included in the report. Since the quantities shown are generally undetectable in the environment, the dose impact is calculated using the effluent quantities as source terms and using theoretical dispersion, uptake and dose models to compute the radiation dose. All of the models have been used previously to calculate doses from Hanford facilities and are considered to provide the best estimates of the generally undetectable dose impact attributable to Hanford operations.

Because the calculation of doses resulting from situations in Category 1 is an infrequent occurrence and sufficient detail is included in the text in such cases, no supporting information is considered necessary here.

Category 2 dose calculations, because of their complex nature, require considerable supporting information, to which the balance of this appendix is devoted. In computing the overall impact of Hanford operations, each major operating area (100-N Area, 200 Areas, 300 Area) is considered separately. The distance between these areas results in differences in the population distribution, the meteorological conditions, and the location of the maximum offsite impact. The assumptions used to calculate the dose impact during 1977 were as follows:

AIRBORNE EFFLUENTS

Separate impacts were calculated for releases from the 100-N Area, the 200 Areas and the 300 Area (see Table 17). The source term used for each area was the 1977 release

from that area. Specific information on the meteorology, demography, and release height for each area is given below.

100-N Area

Gaseous effluent was released at an effective height of 82 m above ground level. The population distribution shown in Figure D-1 for the area within an 80-km radius of the 100-N Area was used in the calculations. The annual average atmospheric dispersion data used are shown in Table D-1 for the 100-N Area and are based on a year's worth of meteorological data collected several years ago (the only data available).

200 Areas

Gaseous effluent was assumed to be released at the center of the 200 Areas at an effective height of 89 m above ground level. Calculations used the population distribution shown in Figure D-2 for the area within an 80-km radius of the Hanford Meteorological Station (HMS: located on the east side of 200-West Area). Annual average atmospheric dispersion data used in the calculations are based on past meteorological data (the 15-yr average from 1955 to 1970) from HMS and are presented in Table D-2.

300 Area

Gaseous effluent was assumed to be released at ground level since most stacks in the 300 Area are rather short. Population distribution data shown in Figure D-3 for the area within an 80-km radius of the 300 Area were used in the calculations. Annual average atmospheric dispersion data developed from meteorological data collected by the Washington Public Power Supply System^(a) for the WNP-2 reactor were used. These data are shown in Table D-3.

Doses were then calculated for exposure via the following sources:

- inhalation
- submersion
- ground deposition
- eating vegetables, fruits, etc., grown in the vicinity of Hanford
- eating meat and poultry products from animals raised in the vicinity of Hanford.

(a) We wish to thank WPPSS for permission to use their meteorological data.

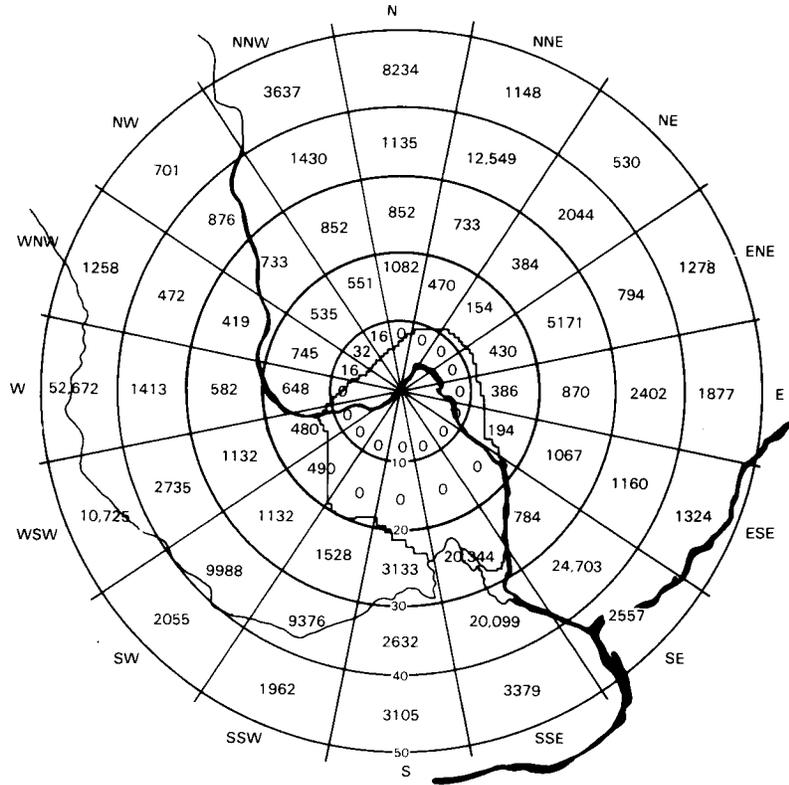


FIGURE D-1. Estimated Geographic Distribution of the Population (236,000) Within a 50-Mile (80-km) Radius of the 100-N Area

TABLE D-1. Annual Average Atmospheric Dispersion Around the 100-N Area for an 82-m Release Height (Units are sec/m^3)

Direction	Range in Miles (km)									
	0.5 (0.8)	1.5 (2.4)	2.5 (4.0)	3.5 (5.6)	4.5 (7.2)	7.5 (12.0)	15 (24)	25 (40)	35 (56)	45 (72)
N	3.68E-08	1.60E-08	9.02E-09	5.69E-09	4.05E-09	2.49E-09	1.91E-09	1.44E-09	1.10E-09	8.69E-10
NNE	5.24E-08	2.05E-08	1.08E-08	6.64E-09	4.62E-09	2.68E-09	1.94E-09	1.46E-09	1.12E-09	8.90E-10
NE	1.44E-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	1.60E-08	1.10E-08	5.95E-09	3.81E-09	2.74E-09	2.07E-09	1.63E-09
SSE	7.94E-08	4.40E-08	2.27E-08	1.37E-08	9.28E-09	4.73E-09	2.72E-09	1.85E-09	1.36E-09	1.05E-09
S	9.41E-08	4.26E-08	2.14E-08	1.27E-08	8.58E-09	4.25E-09	2.32E-09	1.55E-09	1.13E-09	8.70E-10
SSW	1.61E-07	5.84E-08	2.82E-08	1.65E-08	1.10E-08	5.38E-09	2.89E-09	1.93E-09	1.41E-09	1.09E-09
SW	7.78E-08	3.33E-08	1.77E-08	1.08E-08	7.49E-09	4.13E-09	2.67E-09	1.89E-09	1.41E-09	1.10E-09
WSW	5.39E-08	2.74E-08	1.62E-08	1.04E-08	7.39E-09	4.34E-09	2.99E-09	2.14E-09	1.59E-09	1.24E-09
W	7.20E-08	3.48E-08	1.97E-08	1.25E-08	8.81E-09	5.20E-09	3.64E-09	2.62E-09	1.95E-09	1.52E-09
WNW	8.53E-08	3.75E-08	2.07E-08	1.29E-08	9.02E-09	5.09E-09	3.39E-09	2.41E-09	1.80E-09	1.40E-09
NW	8.32E-08	3.48E-08	1.90E-08	1.18E-08	8.24E-09	4.62E-09	3.60E-09	2.19E-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

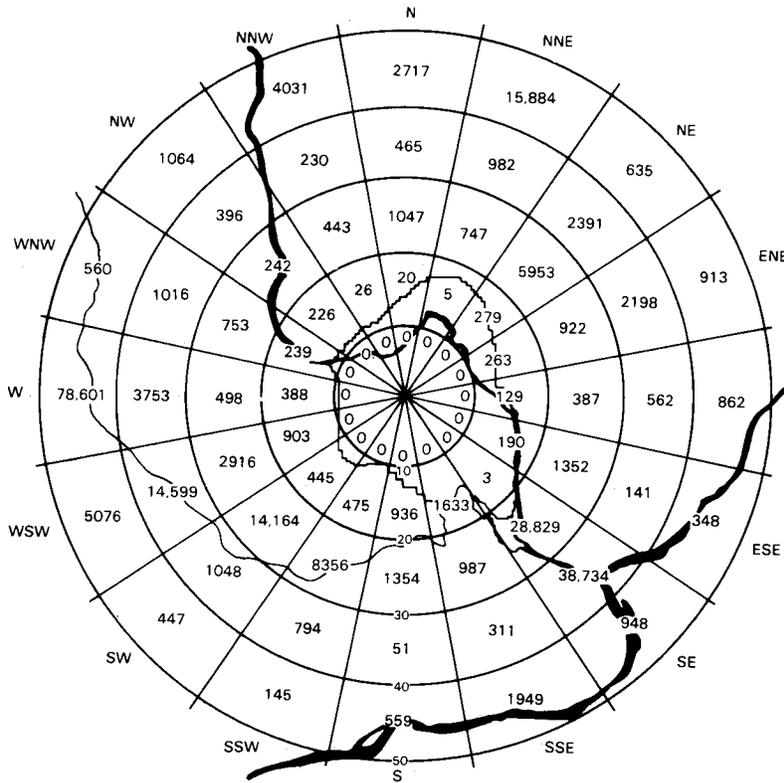


FIGURE D-2. Estimated Geographic Distribution of the Population (258,000) Within a 50-Mile (80-km) Radius of the Hanford Meteorological Station

TABLE D-2. Annual Average Atmospheric Dispersion Around the 200 Areas for an 89-m Release Height (Units are sec/m³)

Direction	Range in Miles (km)									
	0.5 (0.8)	1.5 (2.4)	2.5 (4.0)	3.5 (5.6)	4.5 (7.2)	7.5 (12.0)	15 (24)	25 (40)	35 (56)	45 (72)
N	3.29E-08	1.76E-08	1.04E-08	6.91E-09	4.87E-09	2.29E-09	1.08E-09	7.81E-10	6.23E-10	5.10E-10
NNE	4.70E-08	1.90E-08	1.05E-08	6.82E-09	4.76E-09	2.22E-09	1.08E-09	8.11E-10	6.60E-10	5.47E-10
NE	8.05E-08	3.02E-08	1.54E-08	9.44E-09	6.40E-09	2.92E-09	1.50E-09	1.19E-09	9.26E-10	8.26E-10
ENE	7.61E-08	2.84E-08	1.45E-08	8.94E-09	6.07E-09	2.85E-09	1.64E-09	1.37E-09	1.15E-09	9.64E-10
E	4.61E-08	2.28E-08	1.32E-08	8.72E-09	6.17E-09	3.18E-09	2.22E-09	1.95E-09	1.65E-09	1.39E-09
ESE	7.97E-08	4.00E-08	2.17E-08	1.36E-08	9.38E-09	4.77E-09	3.60E-09	3.37E-09	2.93E-09	2.50E-09
SE	1.67E-07	7.60E-08	4.02E-08	2.49E-08	1.70E-08	7.97E-09	4.54E-09	3.73E-09	3.12E-09	2.62E-09
SSE	8.34E-08	4.19E-08	2.47E-08	1.64E-08	1.16E-08	5.42E-09	2.40E-09	1.60E-09	1.22E-09	9.76E-10
S	8.65E-08	4.38E-08	2.55E-08	1.68E-08	1.18E-08	5.40E-09	2.14E-09	1.33E-09	9.81E-10	7.71E-10
SSW	7.93E-08	3.88E-08	2.19E-08	1.42E-08	9.89E-09	4.43E-09	1.65E-09	9.59E-10	6.90E-10	5.35E-10
SW	6.89E-08	4.06E-08	2.36E-08	1.54E-08	1.08E-08	4.82E-09	1.73E-09	9.64E-10	6.79E-10	5.19E-10
WSW	3.74E-08	2.39E-08	1.49E-08	1.01E-08	7.20E-09	3.30E-09	1.24E-09	7.20E-10	5.18E-10	4.02E-10
W	3.72E-08	2.57E-08	1.64E-08	1.13E-08	8.13E-09	3.76E-09	1.44E-09	8.57E-10	6.24E-10	4.87E-10
WNW	3.42E-08	2.37E-08	1.58E-08	1.12E-08	8.09E-09	3.84E-09	1.63E-09	1.07E-09	8.20E-10	6.56E-10
NW	4.17E-08	2.69E-08	1.82E-08	1.29E-08	9.41E-09	4.55E-09	2.08E-09	1.45E-09	1.13E-09	9.10E-10
NNW	2.68E-08	1.57E-08	1.03E-08	7.27E-09	5.27E-09	2.56E-09	1.22E-09	8.79E-10	6.94E-10	5.64E-10

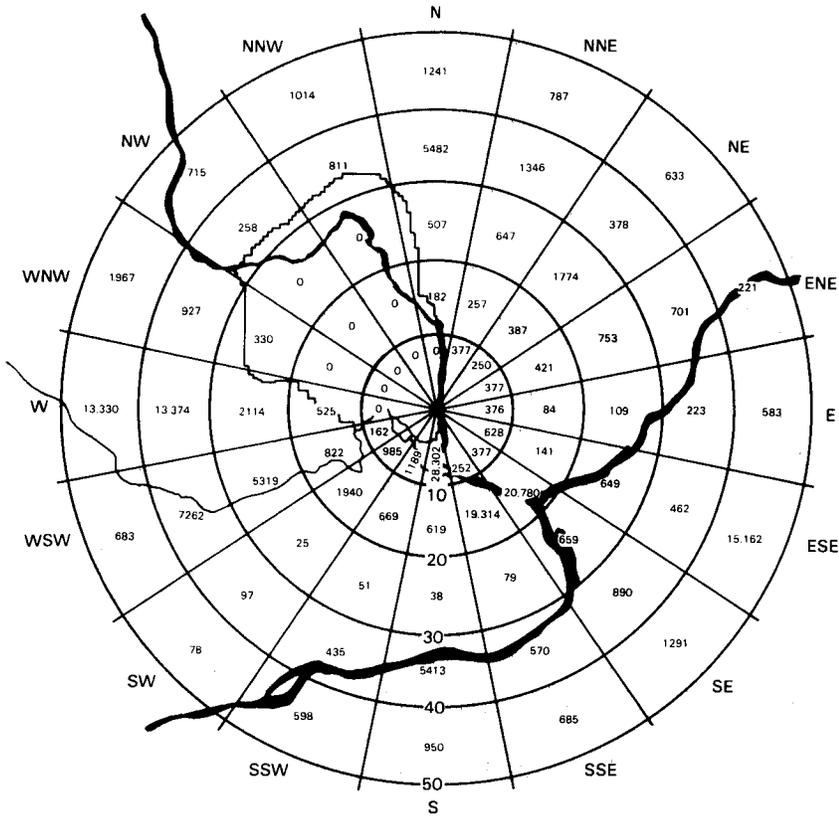


FIGURE D-3. Estimated Geographic Distribution of the Population (171,000) Within a 50-Mile (80-km) Radius of the 300 Areas

TABLE D-3. Annual Average Atmospheric Dispersion Around the 300 Area for a Ground-Level Release (Units are sec/m³)

Direction	Range in Miles (km)									
	0.5 (0.8)	1.5 (2.4)	2.5 (4.0)	3.5 (5.6)	4.5 (7.2)	7.5 (12.0)	15 (24)	25 (40)	35 (56)	45 (72)
N	4.97E-06	7.55E-07	3.31E-07	1.99E-07	1.36E-07	6.50E-08	2.48E-08	1.26E-08	8.14E-09	5.89E-09
NNE	4.24E-06	6.39E-07	2.79E-07	1.67E-07	1.14E-07	5.41E-08	2.05E-08	1.04E-08	6.75E-09	4.90E-09
NE	3.80E-06	5.78E-07	2.54E-07	1.53E-07	1.04E-07	4.99E-08	1.91E-08	9.70E-09	6.31E-09	4.57E-09
ENE	3.62E-06	5.52E-07	2.43E-07	1.46E-07	1.00E-07	4.80E-08	1.84E-08	9.32E-09	6.04E-09	4.37E-09
E	3.34E-06	5.06E-07	2.22E-07	1.33E-07	9.07E-08	4.32E-08	1.64E-08	8.27E-09	5.35E-09	3.86E-09
ESE	5.16E-06	7.85E-07	3.43E-07	2.05E-07	1.40E-07	6.62E-08	2.50E-08	1.25E-08	8.08E-09	5.82E-09
SE	6.41E-06	9.81E-07	4.32E-07	2.60E-07	1.77E-07	8.49E-08	3.24E-08	1.64E-08	1.06E-08	7.69E-09
SSE	6.34E-06	9.70E-07	4.27E-07	2.57E-07	1.76E-07	8.43E-08	3.23E-08	1.64E-08	1.07E-08	7.72E-09
S	5.95E-06	9.12E-07	4.03E-07	2.44E-07	1.68E-07	8.07E-08	3.12E-08	1.60E-08	1.04E-08	7.54E-09
SSW	4.95E-06	7.61E-07	3.38E-07	2.05E-07	1.41E-07	6.81E-08	2.65E-08	1.36E-08	8.84E-09	6.42E-09
SW	4.93E-06	7.67E-07	3.42E-07	2.07E-07	1.43E-07	6.92E-08	2.70E-08	1.38E-08	9.02E-09	6.54E-09
WSW	3.96E-06	6.15E-07	2.73E-07	1.65E-07	1.14E-07	5.50E-08	2.14E-08	1.10E-08	7.14E-09	5.18E-09
W	3.53E-06	5.48E-07	2.44E-07	1.48E-07	1.02E-07	4.92E-08	1.92E-08	9.82E-09	6.40E-09	4.65E-09
WNW	3.51E-06	5.40E-07	2.38E-07	1.44E-07	9.84E-08	4.72E-08	1.82E-08	9.23E-09	6.04E-09	4.38E-09
NW	3.19E-06	4.84E-07	2.12E-07	1.27E-07	8.68E-08	4.14E-08	1.57E-08	7.99E-09	5.19E-09	3.76E-09
NNW	4.44E-06	6.78E-07	2.98E-07	1.79E-07	1.22E-07	5.85E-08	2.23E-08	1.13E-08	7.32E-09	5.29E-09

LIQUID EFFLUENTS

The 1977 releases, shown in Table 17 in the text, were assumed to be mixed with the total annual flow of the Columbia River. For 1977, the United States Geological Survey reported that the mean annual flow rate was 84,500 cubic feet per second.

Doses were then calculated for intakes or exposure via the following sources:

- drinking sanitary water obtained from the river
- eating fish obtained from the river
- eating vegetables, fruits, etc., grown using river water for irrigation
- eating meat and poultry products from animals fed on irrigated pasture

- swimming, boating, or recreating on the shoreline.

DIETARY ASSUMPTIONS

All calculations were made using the models described in References 11 and 12. The transfer and bioaccumulation factors are too numerous to be presented here but can be obtained from the references. Data on the consumption of the various foodstuffs considered in computing both the hypothetical maximum individual and the population doses are summarized in Tables D-4 and D-5. The values shown in Table D-4 are also used to estimate the ingestion and external dose resulting from deposition of radionuclides released to the atmosphere.

TABLE D-4. Quantities of Various Foodstuffs Consumed

<u>Foodstuff</u>	<u>Hold-Up Days</u>	<u>Consumption (in kg/yr except as otherwise noted)</u>	
		<u>Maximum Individual</u>	<u>Population</u>
Leafy vegetables	1.0	30	15
O.A.G. (a) vegetables	1.0	30	15
Potatoes	10.0	110	55
Other root vegetables	1.0	72	36
Berries	1.0	30	15
Melons	1.0	40	20
Orchard fruit	10.0	265	133
Wheat	10.0	80	40
Other grain	1.0	8.3	4.2
Eggs	1.0 ^(b)	30	15
Milk	1.0 ^(b)	274 l/yr	137 l/yr
Beef	15.0	40	20
Pork	15.0	40	20
Poultry	1.0 ^(b)	18	9
Ground contamination	--	2922 hr/yr	1461 hr/yr

(a) Other above-ground.

(b) A 2-day hold-up time was assumed for the population dose calculations.

TABLE D-5. Consumption and Usage Factors for Calculation of Exposures from the Columbia River

<u>Exposure Mode</u>	<u>Hold-Up Hours</u>	<u>Usage</u>	
		<u>Maximum Individual</u>	<u>Population</u>
Fish	24	40 kg/yr	15,000 kg/yr ^(a)
Drinking water	24	730 L/yr	438 L/yr
Shoreline	8 ^(b)	500 hr/yr	17 hr/yr
Swimming	8 ^(b)	100 hr/yr	10 hr/yr
Boating	8 ^(b)	100 hr/yr	5 hr/yr

(a) The population dose is based on the consumption of 15,000 kg of fish and would be numerically the same regardless of the number of people eating the fish.

(b) A 13-hr hold-up time was assumed for the population dose calculations.

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