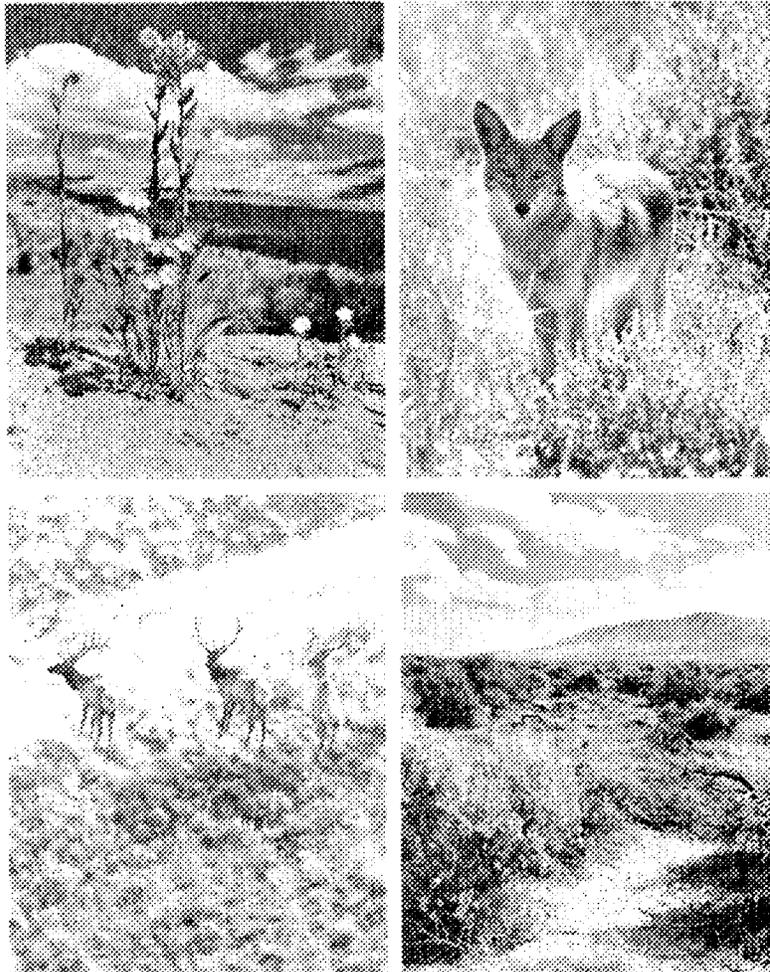


## Environmental Surveillance at Hanford for CY-1976



April 1977

Prepared for the Energy Research  
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 **Battelle**  
Pacific Northwest Laboratories

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ENVIRONMENTAL SURVEILLANCE AT HANFORD FOR CY-1976

by

J. J. Fix  
P. J. Blumer  
G. R. Hoenes  
P. E. Bramson

April 1977

BATTELLE  
Pacific Northwest Laboratories  
Richland, Washington 99352



## FOREWORD

The Environmental Surveillance Program at Hanford is conducted by Battelle, Pacific Northwest Laboratories (also referred to as Battelle-Northwest or BNW) under contract to the Energy Research and Development Administration (ERDA). U.S. Government operations at Hanford have always included support for environmental surveillance studies, and the data collected provide a historical record of the levels of radiation attributable to natural causes, worldwide fallout, and Hanford operations. The present program demonstrates the relatively small impact attributable to either current Hanford operations or a cumulative environmental effect from past Hanford operations. When appropriate, the data are compared with applicable standards for air and water quality set forth by the Energy Research and Development Administration, the Environmental Protection Agency (EPA), the U. S. Public Health Service and the State of Washington. Summaries and interpretations of the data are published annually; the present document is for calendar year 1976.



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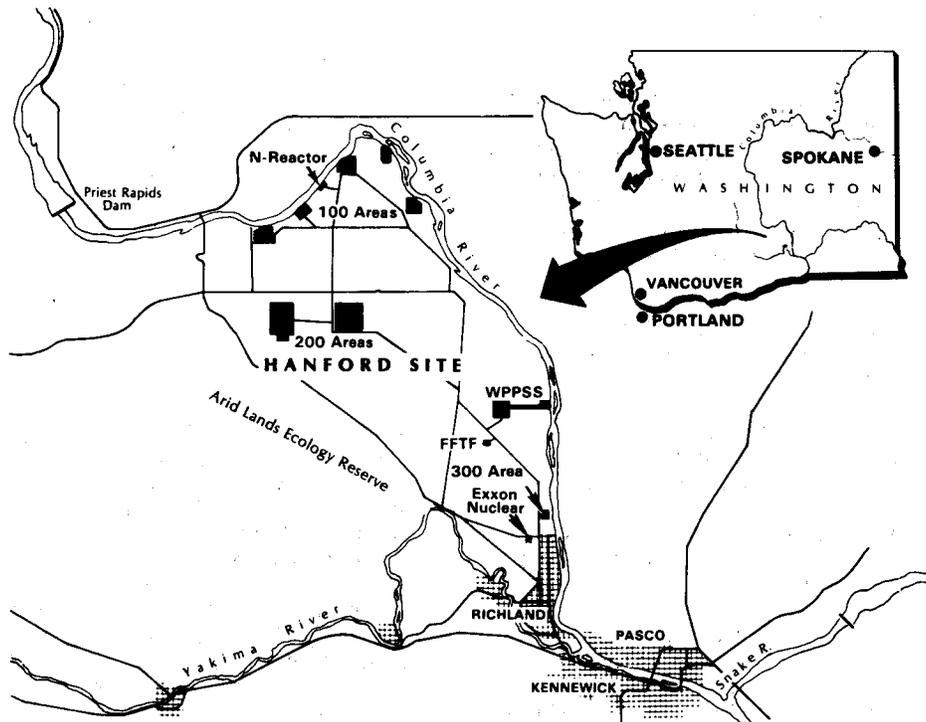


FIG. 1. ERDA's Hanford Site in Washington State

## INTRODUCTION

The Energy Research and Development Administration's (ERDA) Hanford Site is located in a rural region of southeastern Washington State and occupies an area of 1500 square kilometers (560 square miles). The site, shown in Figure 1, lies about 320 kilometers (200 miles) east of Portland, Oregon, 270 kilometers (170 miles) southeast of Seattle, Washington, and 200 kilometers (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 1976, N Reactor had supplied enough steam to produce nearly 35 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 4.3 kilometers (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 3.8 kilometers (2.1 miles) northwest of the 300 Area, and the WPPSS power reactor site is about 4.3 kilometers (2.7 miles) north 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 ERDA contractors operating at Hanford are:

- Atlantic Richfield Hanford Company (ARHCO)--responsible for fuel processing, waste management, and all site support services such as plant security, fire protection, central stores, electrical power distribution, etc.

- Battelle, Pacific Northwest Laboratories (BNW)--responsible for operating the Pacific Northwest Laboratories of Battelle Memorial Institute, 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 1976, work at Hanford included N Reactor operation, nuclear fuel fabrication, liquid waste solidification, continued construction of the Fast Flux Test Facility and of WPPSS No. 1, No. 2 and No. 4 power reactors, 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% following 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-kilometer (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 BNW under contract to ERDA. The program is designed to measure the levels of radiation in the Hanford environs and to determine what portions are attributable to natural causes, worldwide fallout, and Hanford operations. Other environmental data collected deal with the chemical and biological quality of the Columbia River and sanitary water.

All data are presented and evaluated in a series of annual reports; this report evaluates data collected during 1976. Any contribution to radioactivity in air or water that is attributable to Hanford operations is compared with the regulations in ERDA Manual Chapter 0524.<sup>(1)</sup> Concentrations of nonradioactive pollutants are compared with applicable standards of the State of Washington<sup>(2)</sup> or the Environmental Protection Agency.<sup>(3)</sup>

## SUMMARY

Environmental data collected during 1976 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, meat, eggs, poultry, and produce) and wildlife (deer, fish, game birds, and oysters from Willapa Bay), as well as a few soil and vegetation samples. The following highlights summarize the data.

- Hanford's 1976 operations caused no distinguishable impact on air samples and environmental dosimeter measurements taken near and far from the Hanford Site. (See pages 4-6.)
- The maximum concentrations of radionuclides in the air were observed in the fall of 1976 following an atmospheric nuclear detonation on September 26, 1976, by the People's Republic of China. (See page 4.)
- Iodine-131 was observed in milk following the September 26 atmospheric test by the People's Republic of China. The maximum concentration observed was 8 pCi/l. Estimates of dose to the infant thyroid were made using methods described in Federal Radiation Council Report #5 and indicate a maximum dose of about 1.9 mrem. (See pages 12 and 13.)
- Radionuclides observed in all foodstuff, wildlife and soil samples were attributed to either fallout or natural causes. (See pages 12-18.)
- Low level concentrations of a few radionuclides released to the Columbia River from N Reactor during 1976 were observed at the downstream sampling location. All of the observed concentrations were less than 1% of the most restrictive ERDA Manual Chapter 0524 guidelines for unrestricted areas. (See pages 7 and 8.)
- 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, notably  $^{60}\text{Co}$ , from the past operation of once-through cooling production reactors. (See pages 20 and 21.)

With only two exceptions (the last two items just noted), offsite levels of radionuclides possibly attributable to Hanford

operations were indistinguishable from pre-existing levels due to worldwide fallout or natural causes.

The impact of the radionuclide levels observed was estimated in terms of radiological dose to both the maximum individual and the population around Hanford. (The maximum individual is a hypothetical person situated so as to receive the maximum radiation exposure possible.) Impacts were also estimated for other radionuclides known to have been released but not detectable in the environment. The following highlights summarize the estimated impacts during 1976.

- The maximum "fence-post" exposure rate for 1976, 0.014 mR/hr, occurred at selected locations along the Columbia River islands and shorelines. The elevated exposure is attributable to residual levels of long-lived radionuclides, notably  $^{60}\text{Co}$ , resulting from past once-through cooling production reactor operations. The last of these reactors was retired in January, 1971. (See page 26.)
- The maximum individual dose from 1976 effluents was estimated for airborne, drinking water, irrigated foodstuff, and aquatic recreation environmental pathways. The dose potentially received from any pathway was less than 1 mrem to any organ of the body. These doses can be compared with the dose of approximately 100 mrem/year received from natural background radiation. (See pages 22-25.)
- Population doses resulting from airborne effluents within 80-kilometer radii from N-Reactor, the 200 Areas and the 300 Area were estimated for 1976 to be 0.5 person-rem, <0.01 person-rem, and <0.01 person-rem, respectively. These dose estimates may be compared with the dose of approximately 25,000 person-rem received annually from natural background radiation. (See page 25.)
- 1976 population doses resulting from liquid effluents to the Columbia River were estimated to be <0.01 person-rem from irrigated foodstuffs, <0.01 person-rem from aquatic recreation, about 0.01 person-rem from drinking water, and 0.15 person-rem from ingestion of fish. (See page 25.)

## ATMOSPHERIC MONITORING

Numerous radionuclides are present in the atmosphere from both natural sources and worldwide fallout. Potential contributions to radionuclide levels from Hanford operations would be similar to those already present from worldwide fallout. Air is routinely sampled at several locations close to and distant from the Hanford Site to determine the existence and make-up of any Hanford contributions. During 1976, no apparent difference was observed between radionuclide concentrations measured at sampling locations near to and distant from the Hanford Site. This finding indicates that Hanford contributions were indistinguishable from the regional levels attributed to worldwide fallout. The maximum levels of airborne activity were measured following a nuclear detonation in the atmosphere by the People's Republic of China on September 26, 1976.

### AIR SAMPLING

Radioactivity in the atmosphere was sampled during 1976 by a network of 18 perimeter and 5 distant continuous air samplers, as shown in Figure 2. Each air sampler maintains a flow of 2.5 m<sup>3</sup>/hr through a particle filter (Hollingsworth & Vose Company, HV-70) and a 15-cm long, 5-cm diameter charcoal cartridge. The system is expected to collect approximately 85% of the radioactivity associated with airborne dust. Essentially 100% of the elemental form of radioiodine and a small percentage of any organic forms of radioiodine are collected by the system, which does not collect noble gases.

The filters were collected biweekly and analyzed for gross beta and alpha activity after a wait of 7 days to allow the short-lived radon and thoron daughters to decay. The filters were grouped according to geographical location and analyzed monthly by gamma spectrometry and quarterly for <sup>90</sup>Sr and plutonium.

### BETA, ALPHA AND <sup>131</sup>I

The results of gross beta, gross alpha, and <sup>131</sup>I analyses for perimeter and distant sampling locations are shown in Table 1. The distant stations are sufficiently remote from Hanford operations to insure that observed levels of radiation are due to natural causes or fallout.

Figure 3 shows the annual patterns of beta activity for the years 1972 through 1976. In Figure 3, the average monthly beta concentrations observed at eastern quadrant stations (usually downwind from Hanford) are

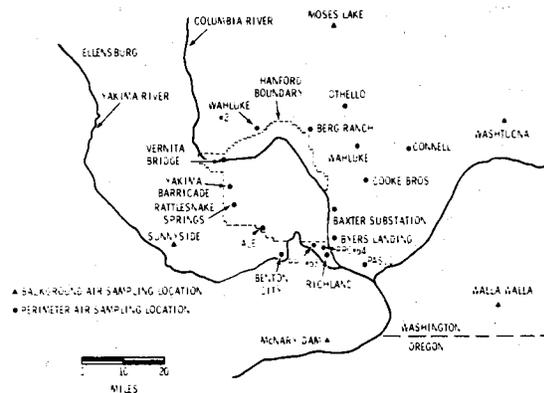


FIG. 2. Air Sampling Locations

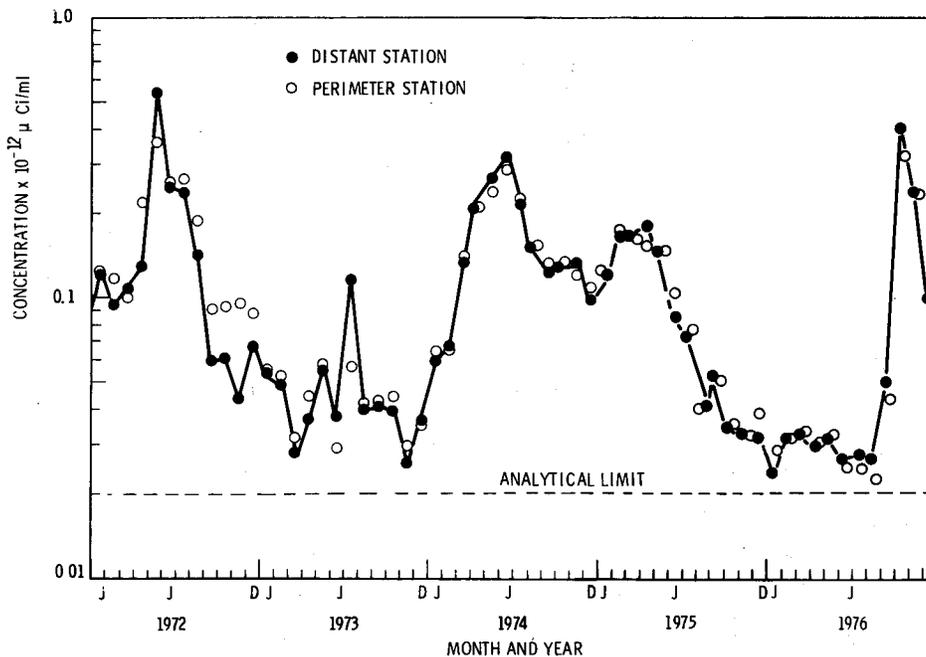
compared with the concentrations observed at the distant stations. The gross beta concentration in the atmosphere usually rises each spring following an increase in the rate at which natural and fallout radioactivity is transferred from the lower stratosphere to the troposphere.

During 1976, the maximum airborne beta concentrations were observed in the fall following an atmospheric nuclear test by the People's Republic of China on September 26, 1976. The highest gross beta concentration observed was  $0.9 \times 10^{-12}$   $\mu\text{Ci}/\text{ml}$ . This sample was taken at Walla Walla, a station distant from Hanford, during the October 15 to October 29 sampling period and is largely attributable to the Chinese test, as indicated in Figure 3. The average beta concentration observed at all perimeter stations during 1976,  $0.09 \times 10^{-12}$   $\mu\text{Ci}/\text{ml}$ , was the same as the average observed at all distant stations.

**TABLE 1. Radioactivity in Air**

Analytical Limit Concentration Guide <sup>(c)</sup>	Concentration ( $10^{-12}$ $\mu\text{Ci/ml}$ ) <sup>(a)</sup>											
	Gross Beta			Gross Alpha <sup>(b)</sup>			Iodine-131					
	0.005	0.003	0.02									
	100				100							
Location	No. of Samples	Max.	Min.	Average	No. of Samples	Max.	Min.	Average	No. of Samples	Max.	Min.	Average
<b>Perimeter Stations</b>												
Baxter Substation	24	0.30	0.01	0.06 ± 0.16					25	0.03	*	<0.02
Benton City	25	0.66	0.02	0.10 ± 0.31	26	0.005	*	<0.002	26	*	*	*
Berg Ranch	23	0.50	0.02	0.10 ± 0.29	25	0.004	*	<0.002				
Byers Landing	26	0.52	0.01	0.08 ± 0.23	25	0.003	0.0003	0.002 ± 0.001	26	*	*	*
Connell	25	0.73	0.02	0.10 ± 0.33								
Cooke Bros.	24	0.24	0.02	0.05 ± 0.11								
ALE	26	0.63	0.02	0.09 ± 0.28								
Othello	25	0.39	0.02	0.08 ± 0.21								
Pasco	25	0.42	0.02	0.07 ± 0.18								
Rattlesnake Springs	24	0.78	0.01	0.11 ± 0.36								
Richland	24	0.44	0.01	0.08 ± 0.22	24	0.003	0.0007	0.002 ± 0.001	26	0.03	*	<0.02
Vernita Bridge	26	0.70	0.02	0.09 ± 0.29								
Wahluke Watermaster	24	0.53	0.02	0.09 ± 0.25								
Mahluke #2	26	0.38	0.02	0.08 ± 0.20								
Yakima Barricade	23	0.75	0.02	0.10 ± 0.34								
RRC CP #63	26	0.70	0.02	0.11 ± 0.32	25	0.004	*	<0.002				
RRC CP #64	25	0.32	0.02	0.08 ± 0.19								
				0.09 ± 0.03				<0.002				<0.02
<b>Distant Stations</b>												
McNary Dam	26	0.65	0.02	0.10 ± 0.32								
Moses Lake	22	0.46	0.02	0.09 ± 0.23								
Sunnyside	24	0.34	0.02	0.08 ± 0.19								
Walla Walla	26	0.90	0.02	0.11 ± 0.37								
Washtucna	26	0.51	0.02	0.09 ± 0.25								
				0.09 ± 0.02								

- (a)  $1 \text{ pCi/m}^3 = 10^{-12} \text{ } \mu\text{Ci/ml}$ . Average : two standard deviations is shown if all analyses had positive results. Otherwise, a less-than number was calculated from all results, assuming that all less-than-detectable values were equal to the detection limit.
- (b) 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.
- (c) ERDAM-0524 standards only apply to concentrations of radioactivity that exceed the levels from naturally occurring or fallout radioactivity.
- (d) Richland Research Complex control plot.
- No entry indicates no analysis.
- \* Less than detectable.



**FIG. 3. Average Monthly Gross Beta Activity in the Atmosphere**

Only 2 of the 103 analyses for radioiodine made in 1976 were statistically positive. Both results were  $0.03 \pm 0.02$  at the 95% confidence level. The samples were taken during biweekly collections, at Baxter Substation on January 26, and at Richland on April 12. A few positive results are expected each year because of the statistical uncertainty of low-level counting.

#### SPECIFIC RADIONUCLIDES

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

fission products that result from worldwide fallout and, potentially, from Hanford operations.

The data show that all the radionuclides observed occurred at similar concentrations at distant and perimeter locations. This finding holds also for concentrations compared at downwind and distant locations. The only statistically positive count for  $^{137}\text{Cs}$  occurred in the October composite group from the inner northeast geographical area. This positive result,  $0.01 \pm 0.002$ , is attributed to the Chinese nuclear test in September. The maximum observed concentrations of  $^{106}\text{Ru}$  and  $^{144}\text{CePr}$  also occurred during the fall and are attributed to the Chinese test.

TABLE 2. Selected Radionuclide Concentrations in Air ( $10^{-12}$   $\mu\text{Ci/ml}$ )

Radionuclide	ERDAM-0524 Table II <sup>(a)</sup>	Composite Group <sup>(b)</sup>	Maximum Observed	Minimum Observed	Annual Average <sup>(c)</sup>
$^7\text{Be}$	40,000	Distant	0.46	*	<0.09
		Perimeter	0.64	*	<0.08
		Downwind	0.23	*	<0.07
$^{90}\text{Sr}$	30	Distant	0.001	*	<0.0006
		Perimeter	0.002	*	<0.0007
		Downwind	0.001	*	<0.0005
$^{106}\text{Ru}$	200	Distant	1.6	*	<0.2
		Perimeter	0.8	*	<0.2
		Downwind	0.7	*	<0.2
$^{137}\text{Cs}$	500	Distant	*	*	*
		Perimeter	0.01	*	<0.01
		Downwind	*	*	*
$^{144}\text{CePr}$	200	Distant	0.3	*	<0.1
		Perimeter	0.18	*	<0.1
		Downwind	0.11	*	<0.1
Pu	0.06	Distant	$2 \times 10^{-4}$	*	$<2 \times 10^{-5}$
		Perimeter	$5 \times 10^{-5}$	*	$<1 \times 10^{-5}$
		Downwind	$3 \times 10^{-5}$	*	$<1 \times 10^{-5}$

(a) ERDAM-0524 standards only apply to concentrations of radioactivity that exceed the levels from naturally occurring or fallout radioactivity.

(b) Distant stations include Moses Lake, Washtucna, Walla Walla, McNary Dam and Sunnyside. Perimeter stations include the 18 stations shown in Figure 2. Downwind stations are Baxter Substation, Byers Landing, Pasco, Richland, RRC #63 and RRC #64.

(c) Annual average calculated by assuming all less-than results were equal to the detection limit.

\* 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 were  $^7\text{Be}$ : 0.05,  $^{90}\text{Sr}$ :  $3 \times 10^{-4}$ ,  $^{106}\text{Ru}$ : 0.1,  $^{137}\text{Cs}$ : 0.01,  $^{144}\text{CePr}$ : 0.1, and Pu:  $2 \times 10^{-6}$ .

## 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.<sup>(2)</sup> 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. Numerous measurements of radioactivity, temperature, nitrate ion, pH, turbidity, dissolved oxygen, fecal and total coliforms, and biological oxygen demand are routinely conducted upstream and downstream from Hanford to monitor any effects that may be attributable to Hanford operations. The 1976 measurements show that Hanford operations had a relatively minimal impact on the quality of Columbia River water and all parameters monitored were well within state or federal limits.

### RADIONUCLIDES

Since shutdown of the last once-through cooling production reactor in January 1971, radionuclide concentrations attributable to Hanford operations have generally been undetectable in Columbia River water. Analyses for gamma-emitting radionuclides, tritium, strontium-90, iodine-129, total plutonium and natural uranium are routinely performed on samples collected upstream and downstream from Hanford.

Table 3 summarizes the 1976 concentrations of natural and fallout radionuclides measured in a stretch of the Columbia before it reaches the Hanford Site. Table 4 presents analogous data obtained downstream from Hanford. The tables show that several shortlived radionuclides detected at the downstream sampling location were not observed upstream from Hanford. These radionuclides are primarily <sup>99</sup>Mo, <sup>131</sup>I, and <sup>133</sup>I. Trace amounts of several other radionuclides (<sup>54</sup>Mn, <sup>60</sup>Co, <sup>65</sup>Zn, <sup>95</sup>ZrNb, and <sup>140</sup>BaLa) were also detected.

Figure 4 compares graphically the upstream and downstream data for all radionuclides observed consistently at concentrations greater than 0.001 pCi/l. Only <sup>60</sup>Co shows a marked difference between upstream and downstream concentrations. The other radionuclide concentrations are similar at both locations and are due to worldwide fallout (<sup>3</sup>H, <sup>90</sup>Sr, <sup>106</sup>Ru) or natural causes (<sup>40</sup>K, U-Nat).

The peak <sup>60</sup>Co concentrations observed in early April and November are attributable to elevated releases from Hanford's N Reactor following spill cooler failures on March 25 and November 20, 1976. All the other radionuclides detected at elevated concentrations downstream (<sup>54</sup>Mn, <sup>65</sup>Zn, <sup>95</sup>ZrNb, <sup>99</sup>Mo, <sup>131</sup>I,

**TABLE 3. Radionuclide Concentrations Upstream from Hanford Operations**

Radionuclide	No. of Analyses	Concentration (10 <sup>-9</sup> μCi/ml)		Annual Average <sup>(a)</sup>
		Maximum Observed	Minimum Observed	
<u>Naturally Occurring</u>				
<sup>40</sup> K	24	0.8	0.2	0.5 ± 0.3
<sup>226</sup> Ra	24	0.04	<0.002	<0.02
<sup>228</sup> Th	24	0.009	<0.001	<0.004
U-Nat.	9	0.6	0.1	0.4 ± 0.3
<u>Worldwide Fallout</u>				
<sup>3</sup> H	12	860	<280	<562
<sup>54</sup> Mn	24	*	*	<0.01
<sup>60</sup> Co	24	0.006	*	<0.001
<sup>65</sup> Zn	24	*	*	<0.01
<sup>90</sup> Sr	12	0.4	0.2	0.27 ± 0.14
<sup>95</sup> ZrNb	24	*	*	<0.01
<sup>106</sup> Ru	24	0.07	0.03	0.05 ± 0.03
<sup>129</sup> I	12	9 x 10 <sup>-5</sup>	*	<2 x 10 <sup>-5</sup>
<sup>137</sup> Cs	24	*	*	<0.05
<sup>140</sup> BaLa	24	*	*	<0.01
<sup>152</sup> Eu	24	*	*	<0.02
Pu-Total	4	8 x 10 <sup>-4</sup>	4 x 10 <sup>-5</sup>	(3±7) x 10 <sup>-4</sup>

<sup>(a)</sup> Annual average ± two standard deviations is shown if all analyses were positive. Otherwise, a less-than average is shown assuming all less-than-detectable results were equal to the detection limit for the analysis.

\* Less than detectable.

<sup>131</sup>I, <sup>140</sup>BaLa) coincide in timing with the <sup>60</sup>Co peaks and are also attributed to the N Reactor's spill cooler failures. The <sup>60</sup>Co activity observed downstream during the rest of the year is attributable to routine N Reactor releases.

All of the radionuclides detected downstream from the Hanford Site and attributed to Hanford operations are included in Table 17 (p. 23), which lists all radionuclides released to the environs during 1976. Figure 4 can be used to compare the relative concentrations of these radionuclides with radionuclides routinely observed in the

**TABLE 4. Radionuclide Concentrations Downstream from Hanford Operations**

Radionuclide	No. of Analyses	Concentration ( $10^{-9}$ $\mu$ Ci/ml)			ERDAM-0524 Guidelines (b)
		Maximum Observed	Minimum Observed	Annual Average (a)	
<u>Naturally Occurring</u>					
$^{40}\text{K}$	26	0.7	0.01	$0.4 \pm 0.3$	-
$^{226}\text{Ra}$	26	0.04	<0.001	<0.02	30
$^{228}\text{Th}$	26	0.009	<0.001	<0.004	7,000
U-Nat	10	0.8	0.3	$0.5 \pm 0.4$	30,000
<u>Artificially Produced</u>					
$^3\text{H}$	12	880	<230	<540	3,000,000
$^{54}\text{Mn}$	26	0.1	*	<0.01	100,000
$^{60}\text{Co}$	26	0.1	*	<0.02	30,000
$^{65}\text{Zn}$	26	0.2	*	<0.02	100,000
$^{90}\text{Sr}$	12	0.3	0.2	$0.24 \pm 0.08$	300
$^{95}\text{Zr-Nb}$	26	0.2	*	<0.02	60,000
$^{99}\text{Mo}$	26	1.5	*	<0.1	40,000
$^{106}\text{Ru}$	26	0.1	0.02	$0.05 \pm 0.04$	10,000
$^{129}\text{I}$	12	$8 \times 10^{-4}$	*	$1 \times 10^{-4}$	60
$^{131}\text{I}$	26	0.2	*	<0.02	300
$^{133}\text{I}$	26	29	*	<1	10,000
$^{137}\text{Cs}$	26	0.02	*	<0.01	20,000
$^{140}\text{BaLa}$	26	0.1	*	<0.02	20,000
$^{152}\text{Eu}$	26	*	*	<0.02	60,000
Pu-Total	4	$9 \times 10^{-4}$	$1 \times 10^{-5}$	$(4 \pm 7) \times 10^{-4}$	5,000

(a) Annual average = two standard deviations is shown if all analyses were positive. Otherwise, a less-than average is shown assuming all less-than-detectable results were equal to the detection limit for the analysis.

(b) ERDAM-0524 guidelines apply only to concentrations above those from worldwide fallout or naturally occurring radionuclides.

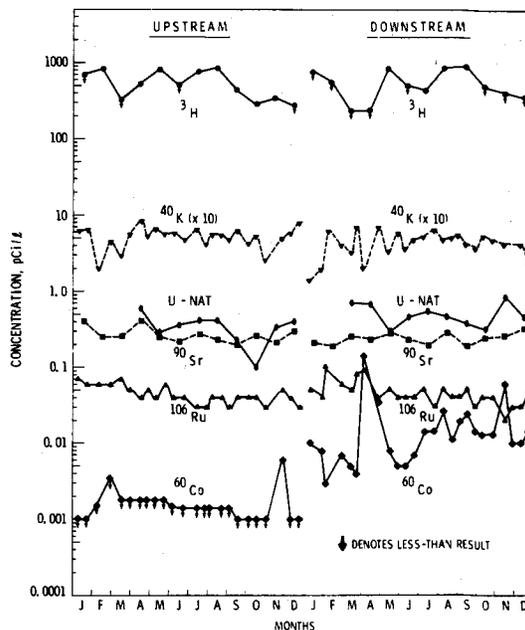
\* Less than detectable.

Columbia River. Table 4 also compares the radionuclide concentrations detected with guidelines for the environment presented in ERDAM-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. 22).

**SANITARY WATER**

In addition to Columbia River water samples, a cumulative sanitary water sample (30 ml every 30 minutes) 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 higher analytical sensitivity than those done on river samples; the river sampling system employs a resin column that filters approximately 1,000 liters of river water before the resin is analyzed, while



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

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 1976, the only activity detected was gross alpha and gross beta activity attributable primarily to naturally occurring <sup>40</sup>K and U in the river.

TABLE 5. Radiological Analyses of Richland Drinking Water

Analysis	Analytical Limit	No. of Samples	Concentration (pCi/l)			
			Max.	Min.	Average(a)	Guideline(b)
Gross Alpha	0.4	52	2	*	<0.6	30
Gross Beta	5.	52	7	*	<3	30
<sup>46</sup> Sc	40.	12	*	*	*	40,000
<sup>51</sup> Cr	500.	12	*	*	*	2,000,000
<sup>60</sup> Co	30.	12	*	*	*	30,000
<sup>65</sup> Zn	60.	12	*	*	*	100,000
<sup>137</sup> Cs	30.	12	*	*	*	20,000

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

(b) Radiological standards were obtained from ERDA Manual Chapter 0524 and apply only to concentrations in excess of natural or fallout activity.

\* Less than detectable.

### 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 1976. Some of the temperature difference between the two locations is due to natural causes(4) 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 1976. The greatest difference observed occurred during the summer months when N Reactor was not in operation. Solar 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 solar insolation.

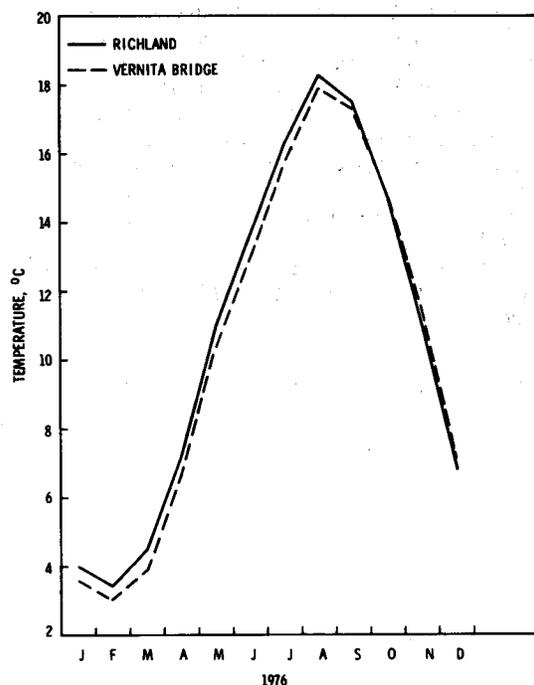


FIG. 5. Average Monthly Water Temperatures at Richland and Vernita

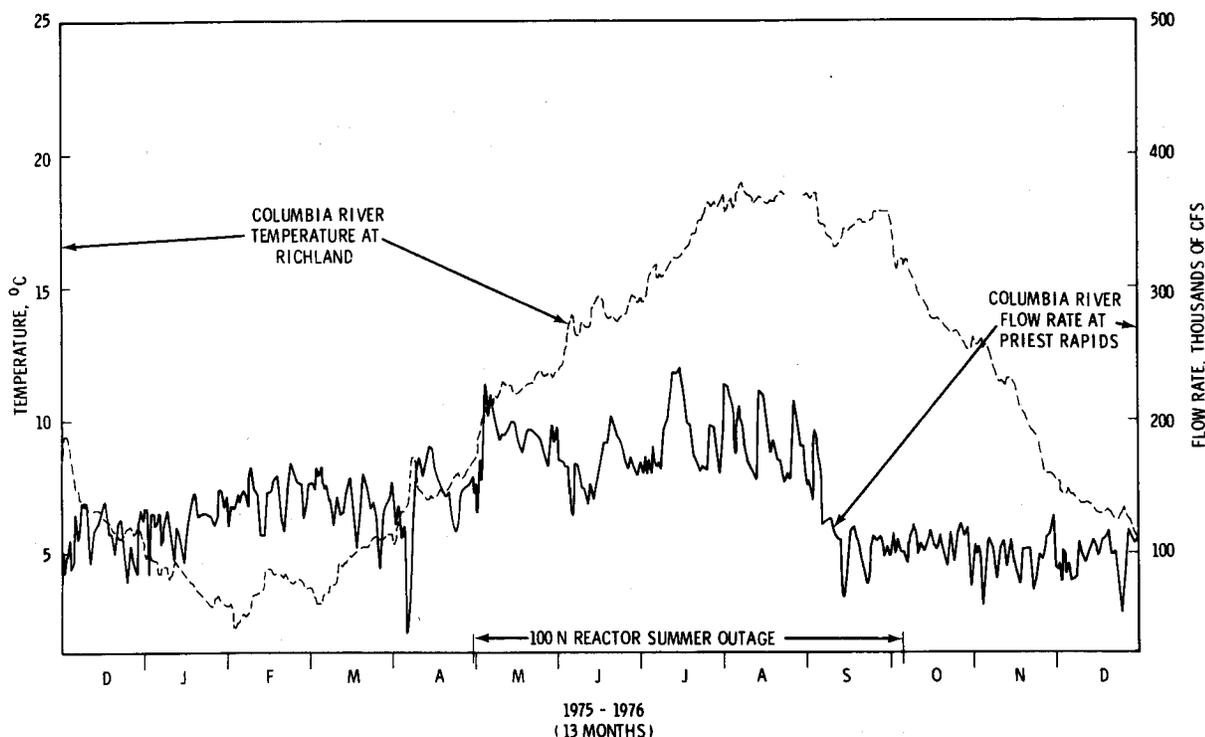


FIG. 6. Daily Variation in Mean Temperature and Flow Rate

BIOLOGICAL ANALYSES

During 1976, monthly measurements of total coliforms, fecal coliforms, and biological oxygen demand (BOD) were made on grab samples from Vernita Bridge (upstream from Hanford) and Richland. The data, summarized in Table 6, indicate an increase in total and fecal coliforms downstream from Hanford. These increases are believed to be the result of drainage from farm activities and wildlife. The Hanford stretch of the river serves as a refuge for large populations of water fowl, especially in the autumn.

CHEMICAL ANALYSES

Results of the chemical analyses done during 1976 are shown in Table 6. Nitrates, pH, turbidity, and dissolved oxygen were measured at both Vernita Bridge and Richland. The results are similar at the two locations and well within applicable standards adopted by the State of Washington for Class A rivers. Average nitrate concentrations are less than 1% of the 45 ppm standard.

TABLE 6. Columbia River Chemical and Biological Analyses

Analysis	Units	Standard	Vernita				Richland <sup>(a)</sup>			
			No. of Samples	Max.	Min.	Annual Average <sup>(b)</sup>	No. of Samples	Max.	Min.	Annual Average <sup>(b)</sup>
NO <sub>3</sub>	ppm	45	52	0.7	*	<0.3	52	0.7	*	<0.3
pH		6.5 to 8.5	31	9.2	7.1	--	115	8.3	7.1	--
Turbidity	JTU <sup>(c)</sup>	5 + Bkgd	31	5.5	1.0	2.2 ± 2.3	91	5.0	0.4	2.9 ± 2.3
Dissolved O <sub>2</sub>	mg/l	5	31	14	5.8	11.7 ± 3.6	91	14	6.7	12.4 ± 2.5
Total Coliforms	no./100ml	240	11	130	10	53 ± 53	11	110	20	56 ± 63
Fecal Coliforms	no./100ml	--	12	11	2	6 ± 7	12	60	2	20 ± 36
BOD <sup>(d)</sup>	mg/l	--	12	9	1	4 ± 5	12	7	1	4 ± 4

<sup>(a)</sup> pH, turbidity and dissolved O<sub>2</sub> samples obtained from 300 Area sanitary water pumping dock.  
<sup>(b)</sup> Average ± two standard deviations is shown if all analyses were positive. Otherwise a less-than number was calculated from all results, assuming less-than-detectable values were equal to the detection limit.  
<sup>(c)</sup> Jackson turbidity units.  
<sup>(d)</sup> Biological oxygen demand.  
 \* Less than detectable. Detection limit would be a value of 0.1 for NO<sub>3</sub> analysis.

The majority of all pH measurements are well within the 6.5 to 8.5 standard, although a single measurement on March 30 showed a pH of 9.2. This was the maximum pH observed and it was found upstream from Hanford; the measurement is suspect, given the numerous samples showing a pH between 7 and 8. All downstream measurements are within the Washington State standard.

The turbidity standard requires that any increase be less than or equal to 5 JTU (Jackson turbidity units) above the background level. Since no differences were observed between Vernita Bridge and Richland, the values in Table 6 are assumed to represent background.

Average values for dissolved oxygen in the river are well above the standard's minimum of 8 mg/l. The minimum concentrations shown in Table 6 for Vernita and Richland are both less than the standard allows. However, these measurements were taken on November 24, 1976, just after the instrument used to take measurements had reportedly been repaired; it is likely that these two measurements are errors. All other measurements showed concentrations greater than 9 mg/l, well above the 8 mg/l minimum for dissolved oxygen set by the standard.

## FOODSTUFFS

Foodstuffs, including milk, meat, chicken, eggs and leafy vegetables, were collected from local farms and commercial outlets, for analysis for gamma-emitting radionuclides and  $^{90}\text{Sr}$ . Since the Riverview farming area is irrigated with Columbia River water that has passed the Hanford Site, samples of each foodstuff were obtained from this area. The 1976 measurements did not show any observable impact from current or past Hanford operations. Elevated levels of  $^{131}\text{I}$  were observed in local milk samples following a nuclear detonation in the atmosphere on September 26, 1976 by the People's Republic of China. The maximum dose to the infant thyroid was calculated to be 1.9 mrem.

### MILK

Milk was sampled every two weeks at five farms near the Hanford Site and at one of four other farms across the Columbia River from the Hanford Site. Monthly samples were also taken from two commercial suppliers. The farm locations are shown in Figure 7. Each milk sample was analyzed by gamma spectrometry for gamma-emitting radionuclides and by a specific analysis for iodine-131. Strontium-90 analyses were made quarterly.

The results obtained during 1976 are summarized in Table 7. Potassium-40, a naturally occurring radionuclide, was present in the largest concentration in all milk samples. Strontium-90 was found in several samples at levels attributed to worldwide fallout. The maximum concentrations of  $^{131}\text{I}$  were all found following the September 26 Chinese nuclear detonation in the atmosphere.

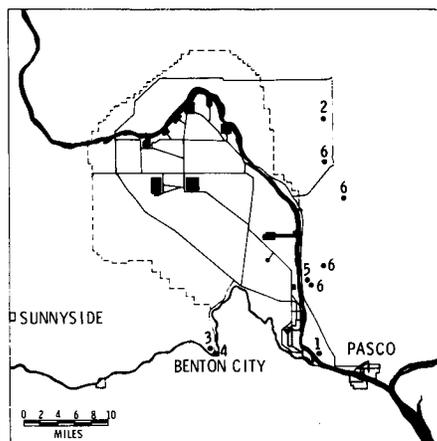


FIG. 7. Milk Sampling Locations

TABLE 7. Radionuclides in Milk

Detection Limit	Concentration ( $10^{-9}$ $\mu\text{Ci/ml}$ )										
	$^{90}\text{Sr}$			$^{131}\text{I}$							
	700			0.5			0.4				
Concentration Guide <sup>(a)</sup>			200			100.0					
Samples	Map Location	No. of Samples <sup>(b)</sup>	Max.	Min.	Average <sup>(c)</sup>	Max.	Min.	Average <sup>(c)</sup>	Max.	Min.	Average <sup>(c)</sup>
Riverview	1	40	1200	760	954 ± 237	3.3	*	<2.0	7.8	*	<1.6
Wahluke	2	26	1500	820	984 ± 309	4.2	1.1	2.2 + 2.7	3.5	*	<0.7
Benton City #1	3	34	2700	*	<970	5.2	*	<2.7	0.9	*	<0.4
Benton City #2	4	19	2400	700	1094 ± 691	3.0	*	<1.5	*	*	*
Byers Landing	5	7	5700	830	1670 ± 3567	*	*	*	1.6	*	<0.8
Composite	6	26	2300	730	1082 ± 792	1.3	1.1	1.2 + 0.3	2.1	*	<0.6
Commercial #1	(d)	13	4600	870	1262 ± 2010	6.7	*	<2.9	0.5	*	<0.4
Commercial #2	(d)	13	2200	810	1052 ± 721	5.5	*	<2.2	*	*	*

(a) Strontium-90 and iodine-131 concentration guides in milk are established by the Federal Radiation Council. Potassium-40 is a naturally occurring radionuclide.

(b) Total number of samples collected. All samples were analyzed for  $^{131}\text{I}$ , with a lesser number analyzed for gamma-emitting radionuclides and  $^{90}\text{Sr}$ .

(c) The arithmetic mean ± two standard deviation is shown if positive results were observed for each analysis. Otherwise a less-than average was calculated from all the results, assuming that less-than-detectable values were equal to the detection limit.

(d) Commercial sources obtain milk from two different watersheds: Commercial #1, west of the Cascades mountain range; Commercial #2, east of the Cascades.

The averages of the  $^{131}\text{I}$  concentrations observed between September and November at all milk sampling locations in the Hanford environs are shown in Figure 8. The three peaks correspond to the movement of separate air masses and follow the  $^{131}\text{I}$  peaks measured daily in air by a high volume sampler at Hanford. (5)

An assessment was made of the maximum thyroid dose that would be received by an infant who drank daily 1 liter of milk containing the average  $^{131}\text{I}$  concentrations shown in Figure 8. The doses were calculated using the methods of the Federal Radiation Council Report #5(6) and are shown in Table 8. The calculation assumes that deposition of  $^{131}\text{I}$  occurs on three different occasions, with each deposition contributing a maximum iodine concentration and then gradually decreasing. The total dose to the thyroid is estimated to be 1.9 mrem. The contribution from each deposition is shown in Table 8.

#### MEAT, CHICKEN, AND EGGS

Samples of meat, chicken, and eggs were collected from the Riverview area and from a commercial outlet, for analysis by gamma spectroscopy and a specific analysis for  $^{90}\text{Sr}$ . The results are shown in Table 9.

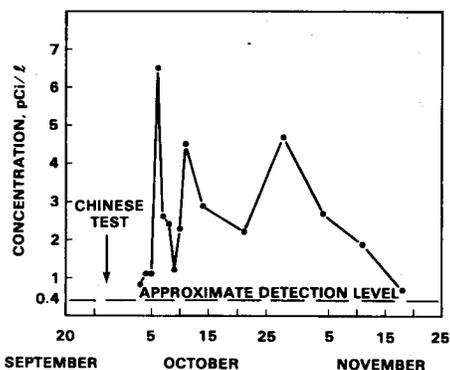


FIG. 8. Iodine-131 Concentrations in Milk Following September Chinese Test

TABLE 8. Maximum Infant Thyroid Dose From Fallout  $^{131}\text{I}$  in Milk(a)

Estimated Max. Daily Intake	Projected Total Intake	Projected Thyroid Dose
6.5 pCi	45 pCi	0.8 mrem
4.5	31	0.5
4.7	32	0.6
		1.9

(a) Based on Federal Radiation Council Report Number 5. (6)

TABLE 9. Radionuclides in Meat, Chicken and Eggs

Sample Location	No. of Samples	Concentration ( $10^{-6}$ $\mu\text{Ci/gm}$ , wet weight)								
		$^{40}\text{K}$			$^{90}\text{Sr}$			$^{137}\text{Cs}$		
		Max.	Min.	Average(a)	Max.	Min.	Average(a)	Max.	Min.	Average(a)
<b>Meat</b>										
Commercial	5	2.5	1.9	$2.3 \pm 0.5$	0.02	*	<0.01	0.05	*	<0.04
Riverview	2	2.1	2.0	$2.1 \pm 0.1$	*	*	*	*	*	*
<b>Chicken</b>										
Commercial	2	1.6	1.4	$1.5 \pm 0.3$	0.004	*	<0.003	*	*	*
Riverview	4	2.4	1.7	$1.9 \pm 0.7$	0.03	*	<0.01	*	*	*
<b>Eggs</b>										
Commercial	2	1.0	0.8	$0.9 \pm 0.3$	0.004	*	<0.003	*	*	*
Riverview	13	1.9	0.6	$0.8 \pm 0.6$	0.005	*	<0.003 <sup>(b)</sup>	*	*	*

(a) The arithmetic mean  $\pm$  two standard deviations is shown if positive results were observed for each analysis. Otherwise, a less-than average was calculated from all the results, assuming that less-than-detectable values were equal to the detection limit.

(b) Strontium-90 analysis done on only 4 samples.

\* Less than detectable. Approximate detection limits would be:  $^{40}\text{K}$ , 0.6;  $^{90}\text{Sr}$ , 0.002;  $^{137}\text{Cs}$ , 0.04.

The radionuclide present in the largest concentrations is naturally occurring  $^{40}\text{K}$ . All other gamma-emitting radionuclides such as  $^{60}\text{Co}$  and  $^{65}\text{Zn}$  were less than detectable. Only one meat sample, collected on August 19, showed a statistically positive result for  $^{137}\text{Cs}$ . This result,  $0.05 \pm 0.04$ , is barely above the detection limit. Strontium-90 from fallout was detected in several meat, chicken, and egg samples. No observable difference was found 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 outlets, for analysis by gamma spectroscopy and specific analyses for  $^{90}\text{Sr}$ . A few samples were also analyzed for  $^{131}\text{I}$ . The results are summarized in Table 10.

Potassium-40 was observed in the greatest concentrations. The data in Table 10

indicate that leafy vegetables contain higher amounts of  $^{90}\text{Sr}$  in Riverview than elsewhere, but this is not consistent with the data shown in Table 9.

Since the amount of data collected in any year is small, large variations can be expected, as appears in Table 9. Compared with other sample locations, the Riverview area shows a low  $^{90}\text{Sr}$  concentration in meat, a high concentration in chicken, and an equivalent level in eggs. However, the historical record reveals no trends that indicate a Hanford contribution to the cumulative buildup of activity from world-wide fallout. The  $^{90}\text{Sr}$  observed in leafy vegetables during 1976, like that found in meat, chicken and eggs, is attributed to worldwide fallout; any Hanford contributions are indistinguishable from the variability in fallout levels.

The results of analyses for  $^{131}\text{I}$  indicate levels less than the detection limit of 0.2 pCi/gram. The samples were collected during the summer growing season. No samples were analyzed following the September 26 Chinese test; although the presence of  $^{131}\text{I}$  in milk after this date would be directly related to the radionuclide's presence on pasture grass, most local leafy vegetables would already have been harvested.

TABLE 10. Radionuclides in Leafy Vegetables

Sample Location	No. of Samples	Concentration ( $10^{-6}$ $\mu\text{Ci/gm}$ , wet weight)								
		$^{40}\text{K}$			$^{90}\text{Sr}$			$^{131}\text{I}$ (a)		
		Max.	Min.	Average (b)	Max.	Min.	Average (b)	Max.	Min.	Average (b)
Riverview	6	7.5	2.0	3.4 + 4.2	0.07	0.004	0.02 + 0.05	*	*	*
Benton City	1			3.3			0.01			
Commercial	5	3.9	*	< 2.1	0.007	0.003	0.005 + 0.004	*	*	*

(a) Not every sample was analyzed for  $^{131}\text{I}$ . The number of samples analyzed was 2 from Riverview and 2 from commercial suppliers.

(b) Average + two standard deviations.

No entry indicates no analysis.

\*Less than detectable. Detection limits would be approximately:  $^{40}\text{K}$ , 0.8;  $^{90}\text{Sr}$ , 0.003;  $^{131}\text{I}$ , 0.2.

## WILDLIFE

Wildlife - deer, gamebirds, and fish - were collected from the Hanford environs and analyzed for gamma-emitting radionuclides and <sup>90</sup>Sr. 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 <sup>65</sup>Zn activity attributable to past Hanford operation of once-through production reactors. The 1976 measurements did not show any distinguishable impact from Hanford operations. The only detectable radionuclide in Willapa Bay oysters was naturally occurring <sup>40</sup>K; <sup>65</sup>Zn was not detectable.

### DEER

Deer samples analyzed during 1976 were obtained from "road-kills" on the Hanford Site. Samples of muscle tissue were analyzed to determine the concentration of gamma-emitting radionuclides and <sup>90</sup>Sr. The resulting data are summarized in Table 11.

Naturally occurring <sup>40</sup>K, as well as the fission products <sup>90</sup>Sr and <sup>137</sup>Cs, was measured in at least one of the three samples analyzed. The concentrations observed were similar to the levels found in other types of wildlife. A relatively high <sup>137</sup>Cs result, 4.9 ± 0.3, was found in one of the three deer analyzed. Since only three samples were analyzed, this maximum is reflected heavily in the average. A similar maximum was obtained for the samples of geese, but because 17 goose samples were analyzed, the average is much lower.

### GAME BIRDS

During 1976, pheasants, ducks and geese were collected onsite from along the Hanford reach of the Columbia River. The samples were taken primarily during the late fall and early winter months. Concentrations of naturally occurring <sup>40</sup>K were similar in all of the game birds, as shown in Table 11.

Of the 55 game birds analyzed, only 2 ducks showed a statistically positive <sup>60</sup>Co count. These results, 0.22 ± 0.21 and 0.18 ± 0.16, are just slightly higher than the counting uncertainty of the analysis. Because of the statistical nature of low-level counting, a few results are expected to be positive even if the radionuclide is not present.

TABLE 11. Radionuclides in Muscle Tissue of Wildlife

Wildlife	No. of Samples	<sup>40</sup> K			<sup>60</sup> Co			<sup>90</sup> Sr			<sup>137</sup> Cs		
		Max.	Min.	Average <sup>(a)</sup>	Max.	Min.	Average <sup>(a)</sup>	Max.	Min.	Average <sup>(a)</sup>	Max.	Min.	Average <sup>(a)</sup>
Deer	3	3.4	*	<2.5	*	*	*	0.1	*	<0.04	4.9	*	<1.8
Pheasants	8	2.6	*	<2.1	*	*	*	0.02	*	<0.01	*	*	*
Ducks	33	3.2	*	<2.4	0.2	*	<0.1	0.3	*	<0.01	*	*	*
Geese	14	3.4	2.2	2.7 ± 0.7	*	*	*	-	-	-	3.7	*	<0.5
Fish	7	3.2	1.5	2.5 ± 1.1	*	*	*	0.03	*	<0.009	0.1	*	<0.1

<sup>(a)</sup> Annual average ± two standard deviations is shown if all analyses were positive. Otherwise, a less-than average was calculated from all results, assuming that less-than-detectable values were equal to the detection limit.

\* Less than detectable. Detection limits would be approximately: <sup>40</sup>K, 2.0; <sup>60</sup>Co, 0.1; <sup>90</sup>Sr, 0.005; <sup>137</sup>Cs, 0.1.

Only pheasant and duck samples were analyzed for  $^{90}\text{Sr}$ . Several of the analyses were positive and the observed concentrations are attributed to worldwide fallout. The highest  $^{90}\text{Sr}$  concentration observed,  $0.3 \pm 0.03$ , was found in a duck collected on January 19, 1976. Cesium-137 was not detected in any pheasant or duck samples, although 2 of the 14 geese analyzed showed positive  $^{137}\text{Cs}$  levels. The observed concentrations were attributed to worldwide fallout.

#### FISH

Several varieties of fish (suckers, white fish, salmon, and catfish) were collected during 1976. Potassium-40 was detected in all of the samples analyzed. Relatively low

concentrations of  $^{90}\text{Sr}$  and  $^{137}\text{Cs}$  were detected in a few samples. All other gamma-emitting radionuclides were less than detectable. The observed activity is attributed to fallout.

#### WILLAPA BAY OYSTERS

Oysters were collected from Willapa Bay along the coast of Washington during 1976 and analyzed by gamma spectrometry. The results are shown in Table 12. Only naturally occurring  $^{40}\text{K}$  was detected. All analyses for  $^{65}\text{Zn}$  indicate levels less than the detection limit. Figure 9 shows the decreasing levels of  $^{65}\text{Zn}$  in Willapa Bay oysters since 1971; the decline closely approximates the 245-day radioactive half-life of  $^{65}\text{Zn}$ .

TABLE 12. Gamma-Emitting Radionuclides in Willapa Bay Oysters

Number of Samples	Concentration ( $10^{-6}$ $\mu\text{Ci/gm}$ , wet weight)								
	$^{40}\text{K}$			$^{65}\text{Zn}$			$^{137}\text{Cs}$		
	Max.	Min.	Average	Max.	Min.	Average	Max.	Min.	Average
4	1.6	1.0	$1.4 \pm 0.5$	*	*	<0.08	*	*	<0.04

\* Less than detectable.

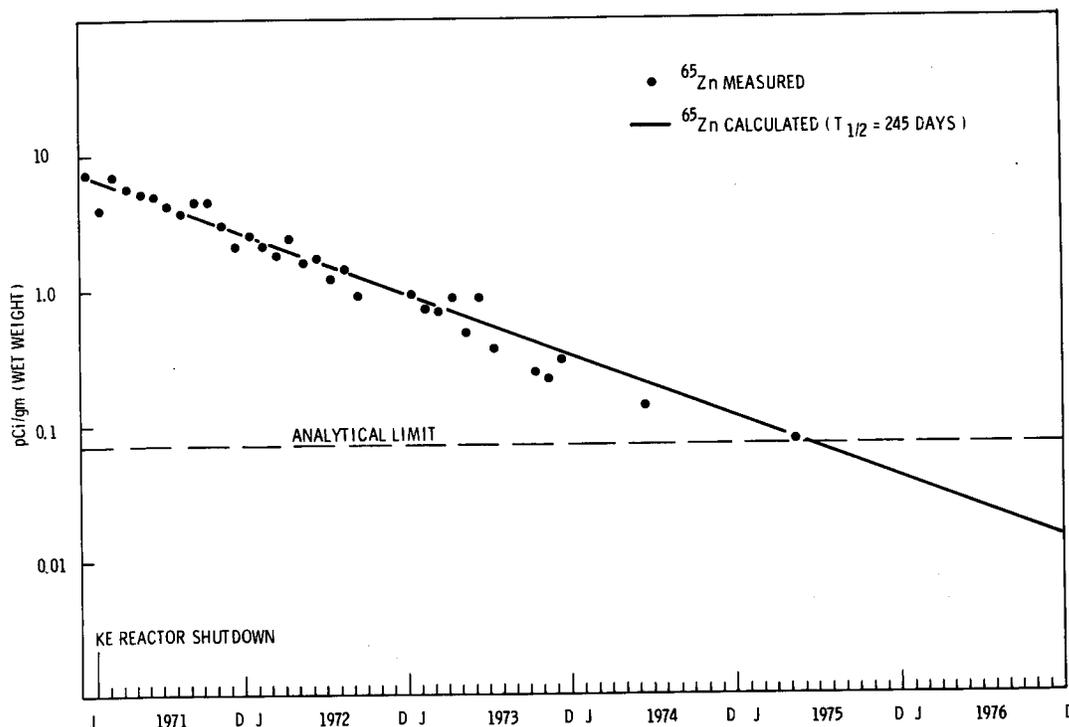


FIG. 9. Zinc-65 Activity in Willapa Bay Oysters

## 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 and natural causes, and any cumulative build-up of activity from Hanford operations. The data collected during 1976 indicate that any Hanford contribution to the radionuclide levels was indistinguishable from the variability observed in worldwide fallout concentrations.

Each soil sample analyzed was a composite of 5 "plugs" of soil collected from an area approximately 10 meters square. Each plug was approximately 2.5 centimeters in depth and 10 centimeters 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  $^{90}\text{Sr}$  and uranium by specific analysis.

The sampling locations are shown in Figure 10. Hanford operations would be expected to contribute much more to radionuclide concentrations at predominantly downwind locations (Ringold, Byers Landing, south 300 Area, Horn Rapids Road - locations 3-6) than to sampling locations lying in other directions (Yakima Barricade, Wahluke #2, etc.).

Table 13 summarizes the data obtained during 1976 for soil and vegetation. The naturally occurring radionuclides  $^{40}\text{K}$ ,  $^{224}\text{Ra}$ ,  $^{226}\text{Ra}$  and U were observed in the highest concentrations in soil. Naturally occurring  $^{40}\text{K}$  was present in the highest concentration in vegetation. The distribution of artificially produced radionuclides revealed no geographical pattern, a finding which indicates that any Hanford

contribution was indistinguishable from the variability observed in radionuclide concentrations from fallout. Strontium-90 was detected in all of the soil and vegetation samples analyzed. The highest soil concentration, 0.25 pCi/g, occurred at the Horn Rapids Road sampling location, and although the result is about a factor of 10 greater than the other results, it is similar to maximum levels measured in past years.

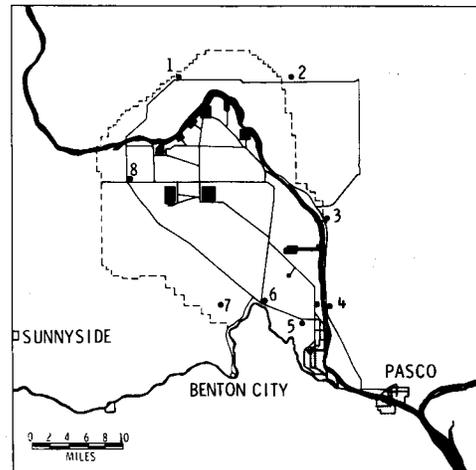


FIG. 10. Soil and Vegetation Sampling Locations

**TABLE 13. Radionuclides in Soil and Vegetation**

Concentration ( $10^{-6}$  Ci/g, dry weight)

Sampling Locations	Map Location	Naturally Occurring				Artificially Produced							
		<sup>40</sup> K	<sup>228</sup> Ra	<sup>226</sup> Ra	U-Total	<sup>90</sup> Sr	<sup>137</sup> Cs	<sup>134</sup> Cs	<sup>137</sup> Cs	<sup>141</sup> Ce	<sup>144</sup> Ce	<sup>238</sup> Pu	<sup>239+240</sup> Pu
<u>Soil</u>													
Detection Limit		0.5	0.1	0.1	0.03	0.002	0.03	0.02	0.04	0.1	0.002	0.001	
Wahluke #2	1	13	1.2	0.7	0.3	0.03	0.04	0.3	0.06	0.2	0.006	0.01	
Berg Ranch	2	13	1.4	0.8	0.3	0.03	0.07	0.3	0.04	0.2	*	*	
Ringold	3	14	1.1	0.8	0.3	0.02	*	0.4	0.09	0.2	*	0.003	
Eyers Landing	4	12	0.8	0.7	0.4	0.02	*	0.2	*	*	*	0.003	
S. 300 Area	5	13	1.0	0.6	0.3	0.06	*	0.5	0.16	0.3	*	0.009	
Horn Rapids Rd.	6	14	0.8	0.5	0.3	0.25	*	0.9	*	0.4	*	0.01	
ALE	7	13	1.5	0.8	0.3	0.02	0.07	0.4	0.10	0.3	*	0.006	
Yakima Barricade	8	14	1.2	0.7	0.2	0.15	*	0.4	0.07	0.3	*	0.006	
Average <sup>(a)</sup>		13 ± 1	1.1 ± 0.5	0.7 ± 0.2	0.3 ± 0.1	0.07 ± 0.17	<0.04	0.4 ± 0.4	<0.08	<0.3	<0.003	<0.006	
<u>Vegetation</u>													
Detection Limit		1.0	0.1	0.1	0.03	0.002	0.2	0.06	0.09	0.3	0.003	0.001	
Wahluke #2	1	44	*	*	*	0.13	*	0.1	*	*	*	*	
Berg Ranch	2	52	*	*	*	0.01	*	0.1	*	*	*	0.002	
Ringold	3	16	*	*	*	0.02	*	*	*	*	*	*	
Eyers Landing	4	16	*	*	*	0.01	*	0.1	*	*	*	*	
S. 300 Area	5	9	*	*	*	0.04	*	*	*	*	*	*	
Horn Rapids Rd.	6	14	*	*	0.04	0.05	*	0.1	*	1.0	*	*	
ALE	7	34	*	*	*	0.02	*	0.1	*	*	*	0.006	
Yakima Barricade	8	10	*	*	*	0.03	*	*	*	*	*	0.002	
Average <sup>(a)</sup>		21 ± 25	<0.1	<0.1	<0.03	0.04 ± 0.08	<0.2	<0.09	<0.09	<0.4	<0.003	<0.002	

<sup>(a)</sup> Average and two standard deviations is shown if radionuclide was detected at all locations. Otherwise, a less-than average was calculated from results, assuming that less-than-detectable values 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 immersion dose in Columbia River water at four locations, and the external dose received along the Columbia River islands and shoreline near the Hanford Site. The 1976 measurements at air sampling locations showed no observable impact from Hanford Operations. However, several measurements along the Columbia River islands and shoreline showed elevated doses attributed to predominantly residual  $^{60}\text{Co}$  activity in river sediments. This activity remains from past operation of once-through cooling production reactors. The maximum dose rate observed was 0.014 mrad/hr in addition to the dose 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 Fig. 2 (page 4). The dosimeters consisted of three chips of  $\text{CaF}_2:\text{Dy}$  (Harshaw TLD-200) encased in an opaque plastic capsule lined with 0.010 inch (0.025 cm) of tantalum and 0.002 inch (0.005 cm) of lead to flatten the lower energy response.<sup>(7)</sup> The dosimeters were mounted 1 meter above ground level and changed every 4 weeks.

The results are shown in Table 14. Although the average annual dose for perimeter locations (69 mrad) is slightly higher than that for distant stations (66 mrad), the variability in the annual dose at the individual locations is much greater. In Figure 11, the individual data points for distant and perimeter locations are plotted separately on log normal probability paper. The similarity of the distant and perimeter dose measurements indicates that contributions from Hanford operations were indistinguishable from the variability in background dose measured at the different locations.

From the 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 69 mrem/year (here, 1 mrem equals 1 mrad). To this number, 6 mrem/year must be added to account for the neutron component of cosmic radiation.<sup>(8)</sup> Thus, the population would receive a dose of about 75 mrem/year from external radiation. An estimate of the total background dose (external plus internal) must include the

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

Location	No. of Measurements	Dose (mrad/yr) <sup>(b)</sup>		
		Max.	Min.	Average
<u>Perimeter</u>				
Wahluke #2	13	84	66	77 ± 15
Othello	13	69	51	62 ± 11
Berg Ranch	13	88	66	77 ± 15
Wahluke	12	77	58	66 ± 11
Connell	13	73	55	62 ± 15
Cooke Bros.	13	80	62	69 ± 11
Baxter Substation	13	73	55	66 ± 15
Byers Landing	13	84	66	77 ± 11
Pasco	13	77	62	69 ± 11
RRC #63	12	73	58	66 ± 11
RRC #64	12	69	55	62 ± 11
Richland	13	69	51	62 ± 11
Benton City	13	62	51	58 ± 7
ALE	13	84	69	77 ± 11
Rattlesnake Springs	13	73	62	69 ± 7
Yakima Barricade	13	77	69	73 ± 7
Prosser Barricade	13	77	66	69 ± 11
Vernita	13	88	69	77 ± 11
Average				69
<u>Distant</u>				
Walla Walla	13	77	62	69 ± 7
Sunnyside	13	73	51	62 ± 11
McNary Dam	13	95	58	69 ± 18
Moses Lake	13	69	55	66 ± 11
Washtucna	12	69	58	66 ± 7
Average				66

(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/year 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.

25 mrem received each year from radioactivity, primarily  $^{40}\text{K}$ , in our bodies.<sup>(8)</sup>

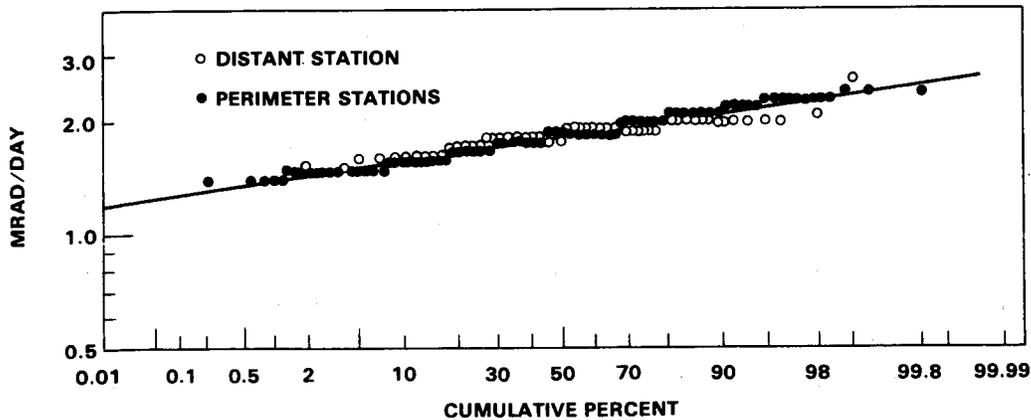


FIG. 11. Log Normal Probability Plot of Monthly Dose Measurements at Perimeter and Distant Locations

Therefore, the total background dose received in the Hanford environs is approximately 100 mrem/year.

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. The dosimeters were collected monthly. The readings (shown in Table 15) are similar to those obtained in previous years and show that a swimmer immersed in the Columbia at Richland would receive a radiation dose of approximately 0.004 mrad/hr. By comparison, approximately 0.008 mrad/hr would be received on land (see Table 14).

COLUMBIA RIVER SEDIMENT

Past analyses of sediment samples collected along the Columbia River have shown the presence of a few long-lived radio-nuclides, primarily <sup>60</sup>Co, attributable to the past operation of once-through production reactors. A 1974 aerial monitoring flight by E.G. & G. of Las Vegas showed low-level deposition of <sup>60</sup>Co over much of the Hanford reach of the river.<sup>(9)</sup> The activity found occurs in sediments along the river's islands, shoreline, and slough areas; it gradually decreases downstream from the historical production reactors, becoming undetectable below North Richland. The maximum exposure rate detected in 1974 was 0.014 mR/hr in addition to the exposure of approximately 0.008 mR/hr (70 mrad/yr) observed from natural background radiation.

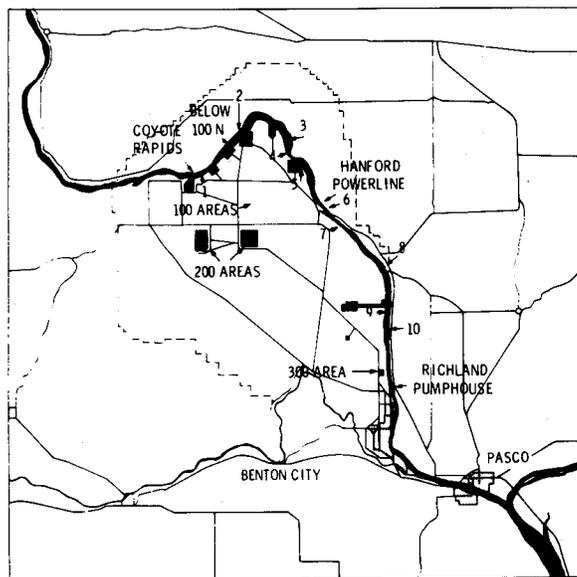


FIG. 12. TLD Locations for Columbia River Immersion and Sediment Measurements

TABLE 15. Columbia River Immersion Dose

Location	No. of Measurements	Radiation Dose (mrad/hr) <sup>(a)</sup>		
		Max.	Min.	Average <sup>(b)</sup>
Coyote Rapids	10	0.005	0.003	0.005 ± 0.001
Below 100-N	12	0.009	0.003	0.006 ± 0.005
Hanford Powerline	8	0.006	0.002	0.005 ± 0.003
Richland Pump House	11	0.004	0.003	0.004 ± 0.001

<sup>(a)</sup> Monthly measurements in mrad were converted to equivalent hourly dose.

<sup>(b)</sup> Average ± two standard deviations is shown for each location.

Table 16 summarizes the data from environmental dosimeters placed at 10 locations along the Columbia River shoreline and at 3 of the larger islands during 1976. The locations are numbered in Figure 12. The wide variation in results among the different locations is attributed to the varying levels of <sup>60</sup>Co activity in the sediment. The variation between the maximum and minimum level observed at each location is

attributed to changes in exposure rate as the river's flow rate changes. The maximum dose rate observed for 1976, 142 mrad/yr, is approximately equal to the maximum of 0.014 mrad/hr observed during the aerial survey in 1974. The total external dose that would result from a dose rate of 0.014 mrad/hr from the <sup>60</sup>Co plus 0.008 mrad/hr from natural background radiation would be 193 mrad/yr.

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

Location	Map Number	No. of Measurements	Dose Rate (mrad/yr) <sup>(a)</sup>		
			Max.	Min.	Average <sup>(b)</sup>
Above 100-K	1	12	80	58	72 ± 15
Opposite 100-N	2	12	77	55	66 ± 15
Locke Island	3	12	91	66	80 ± 18
White Bluffs	4	12	84	62	77 ± 15
Below 100-F	5	12	84	62	73 ± 15
Hanford Ferry	6	6	91	66	77 ± 22
Hanford R R	7	12	142	66	113 ± 51
Ringold Island	8	10	95	69	84 ± 18
Powerline Crossing	9	12	102	73	88 ± 18
Wooded Island	10	12	99	69	84 ± 18

<sup>(a)</sup> Monthly measurements in mrad were converted to equivalent hourly dose.

<sup>(b)</sup> Average ± two standard deviations is shown for each location.

## RADIOLOGICAL IMPACT OF HANFORD OPERATIONS

The preceding sections on monitoring data collected during 1976 provide information for distinguishing between levels of environmental radiation from two sources: those from past or current Hanford operations, and those from worldwide fallout or natural causes. With two exceptions, contributions from Hanford were not distinguishable from the variability observed in fallout and natural radioactivity. The exceptions were: 1) residual levels of long-lived radionuclides, primarily  $^{60}\text{Co}$ , associated with sediments along the Columbia River islands and shoreline near the Hanford Site; and 2) very low concentrations of radionuclides in Columbia River water, resulting from current N Reactor operations. The following section evaluates first, the radiological impact of effluent releases from Hanford during 1976, and second, the impact attributable to residual levels of radionuclides from the past operation of production reactors with once-through cooling. In the summary at the end of the section, the estimated impacts from Hanford operations are compared with the impacts from other sources of radiation exposure routinely encountered.

### RADIOLOGICAL IMPACT FROM 1976 EFFLUENT

The radioactive effluent reported for 1976 by all Hanford contractors contained the radionuclides listed in Table 17. Since these radionuclides were generally undetectable in the offsite environment, empirical dose models<sup>(10,11)</sup> were used to assess the radiological dose impact resulting from these releases. The models are expected to provide a best estimate of the dose impact from Hanford operations during 1976. Small differences in calculated doses may appear from year to year, depending on the quantity and type of effluents released and the flow rate of the Columbia River.

ERDA Manual Chapter 0513<sup>(12)</sup> suggests that three parameters be used to evaluate the radiological impact of ERDA operations on the surrounding region. These parameters are:

- the maximum "fence-post" exposure rate, that is, the rate received at any point on the site boundary
- the maximum dose to an individual member of the public
- the total-body dose (person-rem) to the entire population within an 80-kilometer (50-mile) radius of the site.

An evaluation of each parameter follows.

### Maximum "Fence-Post" Exposure Rate

Based on the 1976 effluent data in Table 17, the maximum exposure rate for 1976 was calculated to be  $8 \times 10^{-6}$  mR/hr along the northwest boundary of the site. The total body dose potentially received by an individual continuously present on the boundary (8766 hr/yr) would be 0.07 mrem. The majority of the dose would be received from  $^{41}\text{Ar}$  (half-life: 1.8 hrs) released at N Reactor.

### Maximum Individual Dose

The maximum dose to an individual member of the public for 1976, resulting from all of the radionuclides listed in Table 17, was calculated for several environmental pathways. The annual calculation of the maximum individual dose is complicated by a number of factors: the facilities on the Hanford Site are miles apart and release varying amounts of effluents; separate calculations must be made to determine the relative amounts of effluent released to the Columbia River and to the atmosphere; and the location 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, other pathways have become increasingly important.

TABLE 17. Radionuclide Composition of Effluent

Radionuclides	Half-life	Effluent (Curies)			
		Liquid To River	100 Areas	Gaseous	
				200 Areas	300 Areas
<sup>3</sup> H(HTO)	12.3 yr	350	2.5		
<sup>24</sup> Na	15 hr	0.9	0.2		
<sup>32</sup> P	14.3 d	1.8			
<sup>41</sup> Ar	1.8 hr		35,440		
<sup>51</sup> Cr	27.8 d		0.02		
<sup>54</sup> Mn	303 d	1.1	0.03		
<sup>56</sup> Mn	2.6 hr	5.0	4.7		
<sup>59</sup> Fe	46 d	1.9	0.03		
<sup>58</sup> Co	71 d	0.3	0.007		
<sup>60</sup> Co	5.3 yr	2.1	0.06		7 x 10 <sup>-5</sup> (a)
<sup>76</sup> As	26.4 hr		0.17		
<sup>85m</sup> Kr	4.4 hr	1.2	121.8		
<sup>87</sup> Kr	76 min	4.3	406.7		
<sup>88</sup> Kr	2.8 hr	4.2	297.5		
<sup>89</sup> Sr	52.7 d	0.3	0.01		
<sup>90</sup> Sr	27.7 yr	0.48	7 x 10 <sup>-4</sup>	0.24(b)	1 x 10 <sup>-3</sup> (b)
<sup>91</sup> Sr	9.7 hr	2.4	0.07		
<sup>95</sup> ZnNb	65.5 d	1.3	0.04		
<sup>99</sup> Mo	66.7 hr	1.5	1.3		
<sup>103</sup> Ru	39.5 d	0.08	0.02		
<sup>106</sup> Ru	368 d	0.4	0.009		
<sup>124</sup> Sb	60.4 d	0.01	0.002		
<sup>125</sup> Sb	2.7 yr	0.3	6 x 10 <sup>-4</sup>		
<sup>131</sup> I	8.1 d	1.5	0.54		1.5 x 10 <sup>-3</sup>
<sup>132</sup> I	2.3 hr	15.6	6.1		
<sup>133</sup> I	20.3 hr	6.6	3.3		
<sup>134</sup> I	52.0 min	20			
<sup>135</sup> I	6.7 hr.	19.7	5.6		
<sup>133</sup> Xe	5.3 d	0.2			
<sup>135</sup> Xe	9.1 hr	13.0	3,620		
<sup>134</sup> Cs	2.0 yr		0.004		
<sup>137</sup> Cs	30.0 yr	0.2	3 x 10 <sup>-3</sup>		
<sup>138</sup> Cs	32.2 min	63.0	1,136		
<sup>140</sup> BaLa	12.8 d	0.1	0.3		
<sup>141</sup> Ce	32.5 d		0.06		
<sup>144</sup> CePr	284 d		0.03		
<sup>153</sup> Sm	46.8 hr	0.009			
<sup>154</sup> Eu	16 yr		0.006		
<sup>155</sup> Eu	1.8 yr		0.01		
<sup>187</sup> W	23.9 hr	3.9			
U-Nat.	4.5 x 10 <sup>9</sup> yr				2.5 x 10 <sup>-5</sup>
<sup>234</sup> U	2.5 x 10 <sup>5</sup> yr				
<sup>235</sup> U	7 x 10 <sup>8</sup> yr				
<sup>238</sup> U	4.5 x 10 <sup>9</sup> yr				
<sup>239</sup> Np	2.3 d	2.2	0.1		
<sup>238</sup> Pu	86.4 yr	0.001	3 x 10 <sup>-6</sup>		
<sup>239</sup> Pu	24,390 yr	0.003	1 x 10 <sup>-5</sup>	2.4 X 10 <sup>-3</sup>	4 x 10 <sup>-5</sup>
<sup>241</sup> Am	458 yr	0.003			

(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.

Calculations for 1976 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. These estimates are summarized in Tables 18 (the annual dose received during 1976) and 19 (the 50-year dose commitment from the effluent released in 1976). The doses in the 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 1976 was estimated for a location 1 mile east of the 300 Area. This location,

downwind from the Hanford Site, is where the nearest orchards, dairy, etc. are located. Doses calculated include those received from inhalation of radionuclides and from submersion in the air plume for 8766 hours/year (continuous occupancy); and that received from exposure to ground contamination for 2922 hours/year (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 various foodstuffs are grown in that area.

Table 18 shows the estimated annual dose from the airborne effluents released in 1976. All of the doses are estimated to be less than 1 mrem to any organ. Table 19 shows the 50-year dose commitment from 1976 airborne effluents. The increase in the dose received by the total body and bone after 1976 is attributable to the 1976 release of a few long-lived radionuclides.

**TABLE 18. Annual Dose to the Maximum Individual From Effluents Released During 1976**

Environmental Pathway	Dose (mrem) <sup>(a)</sup>					
	Skin	Total Body	GI <sup>(b)</sup>	Thyroid	Bone	Lung
Airborne <sup>(c)</sup>	0.01	0.01	0.01	0.07	0.01	0.01
Drinking Water	--	<0.01	<0.01	0.02	<0.01	--
Irrigated Foodstuff	<0.01	0.01	0.01	0.05	0.06	--
Aquatic Recreation <sup>(d)</sup>	<0.01	0.01	0.03	0.02	0.03	--

- (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 1976**

Environmental Pathway	Dose Commitment (mrem) <sup>(a)</sup>					
	Skin	Total Body	GI <sup>(b)</sup>	Thyroid	Bone	Lung
Airborne <sup>(c)</sup>	0.01	0.02	0.01	0.07	0.12	0.01
Drinking Water	--	<0.01	<0.01	0.02	<0.01	--
Irrigated Foodstuff	<0.01	0.02	0.01	0.05	0.14	--
Aquatic Recreation <sup>(d)</sup>	<0.01	0.02	0.03	0.02	0.07	--

- (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.

#### Drinking Water

Richland is the first city downstream from the Hanford Site and obtains its drinking water from the Columbia River. Tables 18 and 19 list the estimated annual dose and 50-year dose commitment for an individual who drinks 730 liters of water annually. The water treatment plant's efficiency in removing part of the activity from the river water was considered in the calculation. The efficiency level varies with the radio-

nuclides listed in Table 17. (See Reference 10 for additional details.) All of the doses are estimated to be less than 0.1 mrem to any organ of the body.

#### 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-year internal dose commitment 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 involved Columbia River water. Many of the assumptions made about the maximum individual's diet, the crops irrigated, etc. are described in Appendix D. All of the estimated doses are less than 1 mrem to any organ.

Aquatic Recreation

The Columbia River is used extensively for recreation. Estimates of the dose received from recreation activities, shown in Tables 18 and 19, are based on an individual who spends 500 hours per year along the shoreline, 100 hours swimming, and 100 hours boating, and who eats 40 kg of fish annually. All of the radionuclides released to the river were considered in the dose estimates. (Appendix D should be consulted for additional detail.) All of the doses are less than 0.1 mrem per year.

80-Kilometer Radius Population Dose

The dose that the population within an 80-kilometer (50-mile) radius of the Hanford Site received from effluents released during

1976 was calculated for all of the radionuclides listed in Table 17. Because the affected population differs according to the dose pathway (drinking water, irrigated foodstuffs, fishing, or recreation), an estimated dose is given for the population affected by each pathway. Again, the population within an 80-kilometer radius of each major facility that released effluents differs with the facility's location, so a population dose is given for each major operating area.

Table 20 summarizes the estimated population doses resulting from 1976 releases to the Columbia River. The greatest dose would be received by a population group that consumed 15,000 kilograms of fish obtained from the Columbia River between the Hanford Site and the confluence of the Columbia and Yakima Rivers. This dose calculation depends not on the number of people affected but on the activity consumed, whether by one person or by many.

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

TABLE 20. Dose to the Population from Liquid Effluents Released During 1976

<u>Exposure Mode</u>	<u>Population Affected</u>	<u>Population Dose (Person-Rem)</u>			
		<u>Total Body</u>	<u>GI<sup>(a)</sup></u>	<u>Thyroid</u>	<u>Bone</u>
<u>First-Year Dose</u>					
Drinking Water	50,000	0.01	0.05	0.54	0.03
Fish	(b)	0.15	0.45	0.01	3.7
Aquatic Recreation	125,000	<0.01	<0.01	<0.01	<0.01
Irrigated Farm Products	2,000	<0.01	0.01	0.05	0.06
<u>50-Year Commitment</u>					
Drinking Water	50,000	0.04	0.05	0.55	0.16
Fish	(b)	0.16	0.45	0.01	4.0
Aquatic Recreation	125,000	<0.01	<0.01	<0.01	<0.01
Irrigated Farm Products	2,000	0.02	0.01	0.05	0.14

(a) Gastrointestinal tract (Lower Large Intestine).

(b) The population dose is based on consumption of 15,000 kilograms of fish during 1976. 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 1976

Effluent Release Point	80-Kilometer Population	Population Dose (Person-Rem)				
		Total Body	GI <sup>(a)</sup>	Thyroid	Bone	Lung
<u>First-Year Dose</u>						
100-N Area	236,000	0.5	0.5	0.7	0.5	0.5
200 Areas	258,000	<0.01	<0.01	<0.01	<0.01	<0.01
300 Area	171,000	<0.01	<0.01	<0.01	<0.01	<0.01
<u>50-Year Commitment</u>						
100-N Area	236,000	0.5	0.5	0.7	0.5	0.5
200 Areas	258,000	0.03	<0.01	<0.01	0.9	0.06
300 Area	171,000	0.01	<0.01	<0.01	0.18	0.01

(a) Gastrointestinal tract (Lower Large Intestine).

RADIOLOGICAL IMPACT FROM OBSERVED RADIO-ACTIVITY DUE TO PAST HANFORD OPERATIONS

Previous sections of this report showed that 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 ERDA Manual Chapter 0524, and 2) the continued presence of a few long-lived radionuclides, notably <sup>60</sup>Co, 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 will be evaluated here.

The 1974 aerial survey by E.G.&G. of Las Vegas<sup>(9)</sup> covered an area from approximately 4 kilometers above Vernita Bridge to approximately 10 kilometers below the intersection of the Snake River and the Columbia River. The highest radiation level observed offsite during the survey occurred on the islands between the old Hanford townsite and the 300 Area. A maximum reading of 0.014 mR/hr of <sup>60</sup>Co was obtained. This exposure rate will gradually decrease due to radioactive decay (<sup>60</sup>Co has a half life of 5.3 years), weathering and scouring by the river. Field measurements in 1976 (see page 20) verified the continued existence of elevated levels of activity.

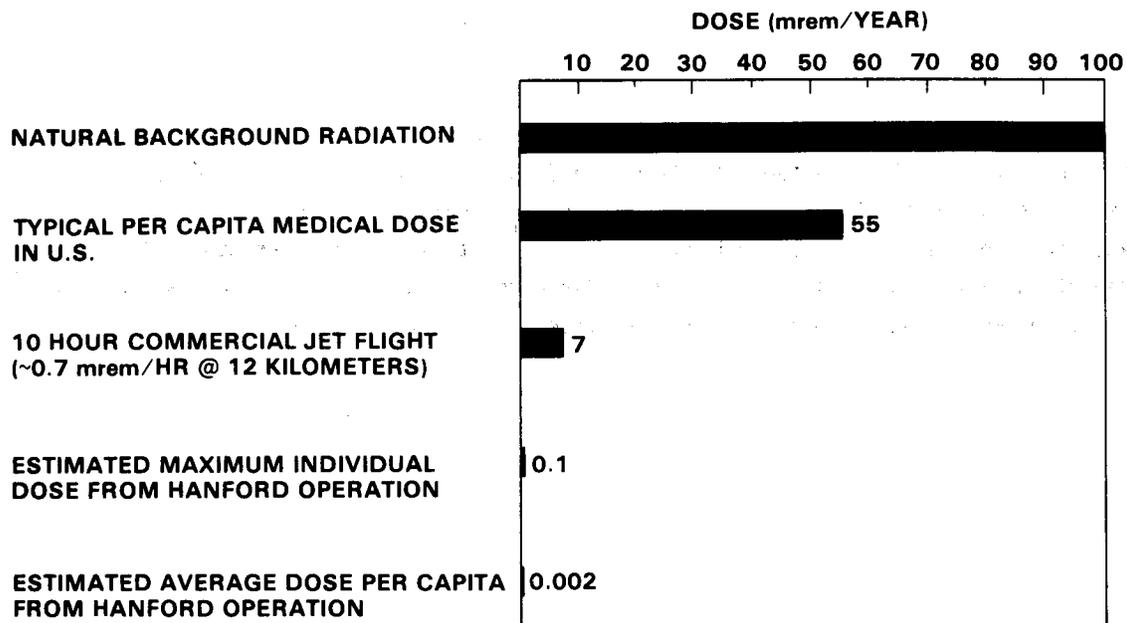
The contributions of the <sup>60</sup>Co activity to the maximum "fence-post" exposure rate, the maximum individual dose, and the 80-kilometer population dose for 1976 range from numerically insignificant to predominant. The maximum "fence-post" exposure rate calculated was 8 x 10<sup>-6</sup> mR/hr along the northwest boundary of the Hanford Site. The highest external exposure rate measured on the Columbia River islands, 0.014 mR/hr,<sup>(9)</sup> is much greater.

The islands' radioactivity would contribute in varying degrees to the dose received by an individual, depending on the amount of time the individual spent on the islands and where this time was spent. The distribution of radioactivity on the islands is quite variable. An individual at the point of the highest observed exposure rate would receive an external dose of approximately 0.014 mrem/hr in addition to the 0.008 mrem/hr from background radiation.

The contribution of the islands' radioactivity to the population dose received in 1976 is insignificant because of the low levels of radioactivity involved, the remoteness of the islands, and the small number of people potentially affected.

SUMMARY

The dose estimates discussed in the previous subsections can be compared with doses from other sources of radiation routinely encountered. These sources include natural background radiation, medical procedures, a 10-hour commercial jet flight, etc.<sup>(13)</sup> Figure 13 compares graphically the average



**FIG. 13.** Comparative Doses Received from Various Radiation Sources

doses from these sources, the maximum individual dose received from Hanford operations during 1976 (~0.1/mrem) and the average per capita dose from N Reactor's airborne effluent (~0.002 mrem, or 0.5/236,000).

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

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. The dose contribution to the maximum individual from Hanford operations is probably less than the variability in the doses received by different people with different lifestyles.

### ACKNOWLEDGMENTS

Acknowledgment is given to several people who participated in the preparation of this report. Harold Oens supplied data regarding the United States Testing Company's participation in the EPA Interlaboratory Comparison Program for environmental sample analyses (Appendix C). Shellie Canada typed the initial report. Jan Baer edited the report and arranged for its publication. Dan Haggard made all of the initial dose calculations using the computer programs described in References 10 and 11.

## REFERENCES

1. U. S. Energy Research and Development Administration, ERDA Manual, Chapter 0524, "Standards for Radiation Protection," with Appendix. U. S. Energy Research and Development Administration, Washington, DC, October 1973.
2. Water Quality Standards. Washington State Department of Ecology, June 1973.
3. "Natural Primary and Secondary Ambient Air Quality Standards," Federal Regulations, 40 CFR 50, Environmental Protection Agency, January 1973.
4. R. T. Jaske and M. R. Synogrud, Effect of Hanford Plant Operations on the Temperature of the Columbia River, 1964 to Present. BNWL-1345, Battelle, Pacific Northwest Laboratories, Richland, WA 99352, November 1970.
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10. U. S. Energy Research and Development Administration, Hanford Waste Management Operations Environmental Impact Statement. ERDA-1538, ERDA Hanford Operations, December 1975.
11. D. A. Baker, G. R. Hoenes and J. K. Soldat, FOOD - An Interactive Code to Calculate Internal Radiation Doses from Contaminated Food Products, BNWL-SA-5523, Battelle, Pacific Northwest Laboratories, Richland, WA 99352, February 1976.
12. U. S. Energy Research and Development Administration, ERDA Manual, Chapter 0513, "Effluents and Environmental Monitoring and Reporting." U. S. Energy Research and Development Administration, February 1974.
13. U. S. Environmental Protection Agency, Estimates of Ionizing Radiation Doses in the United States, 1960 - 2000. ORP/CSD 72-1, Rockville, MD, August 1972.



APPENDIX A

APPLICABLE STANDARDS

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APPENDIX A

APPLICABLE STANDARDS

Operations at the Hanford Site must conform to a variety of federal and state standards designed to insure 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.<sup>(2)</sup> 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)<sup>(3)</sup> and are summarized in Table A-2.

TABLE A-1. Washington State Water Quality Standards for the Hanford Reach of the Columbia River<sup>(2)</sup>

CLASS A WATER CHARACTERISTIC

Meets or exceeds requirements for all uses.

USES

Include but are 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

Parameter	Permissible Levels
Total coliform organism	1) $\leq 240$ (median) 2) $< 20\%$ of samples may exceed 1,000 when associated with a local source
Dissolved oxygen	$> 8.0$ mg/l
Temperature	1) $\leq 68^\circ\text{F}$ ( $21^\circ\text{C}$ ) due to measurable increases 2) Cumulative total of all measurable increases from non-natural sources shall be $\leq 110/(T-15)$ 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	$\leq 5$ JTU <sup>(a)</sup> 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

<sup>(a)</sup> JTU = Jackson Turbidity Units - Standard Candle

**TABLE A-2. Air Quality Standards**

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

(a) Ref: Washington State Department of Ecology

(b) Ref: U.S. EPA

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

(d) Less background east of the Cascades

Environmental radiation protection standards are published in ERDA Manual Chapter 0524, "Standards for Radiation Protection."<sup>(1)</sup> These standards are based on guidelines recommended by the President's Federal Radiation

Council (FRC), whose functions have now been assigned to the EPA, 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 ERDA and ERDA contractor personnel and for members of the public who may be exposed to ionizing radiation resulting from ERDA and ERDA contractor operations. Several concentration guides for air and water are listed in Table A-3.

**TABLE A-3. Concentration Guides for Permissible Ionizing Radiation Levels<sup>(a)</sup>**

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

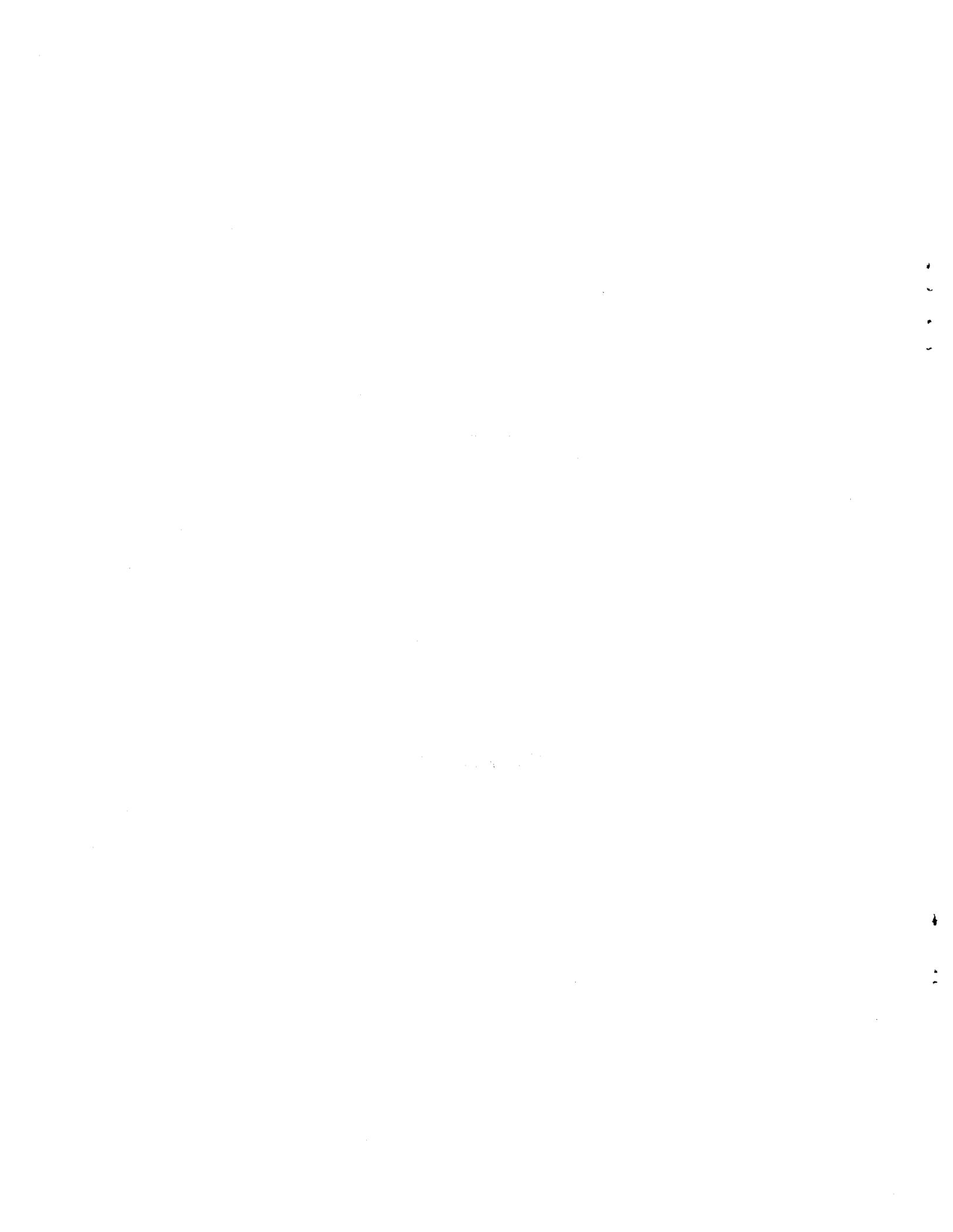
(a) Obtained from ERDA Manual Chapter 0524, Table II. Most restrictive guide assumed.

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

- State of Washington  
Department of Ecology  
Olympia, WA 98504
- U.S. Environmental Protection Agency,  
Region 10  
1200 Sixth Avenue  
Seattle, WA 98101
- U.S. Energy Research and Development  
Administration  
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 inch x 9 inch (23 cm x 23 cm) NaI(Tl) well detector with a multichannel 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 0.4N HNO<sub>3</sub> - 0.01 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 a molecular sieve or 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. A 250-cc aliquot of mixed charcoal is counted in the well of a 9 inch x 9 inch (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 inch x 9 inch (23 cm x 23 cm) NaI(Tl) well detector with a multichannel gamma-ray spectrometer.

Strontium-90 in large volume water samples is precipitated with fuming nitric acid, scavenged with barium chromate, precipitated

as a carbonate, transferred to 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 inch x 9 inch (23 cm x 23 cm) NaI(Tl) detector.

Iodine-131 is removed from milk with anion exchange resin, Cl<sup>-</sup> 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 inch x 9 inch (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 8N nitric acid.

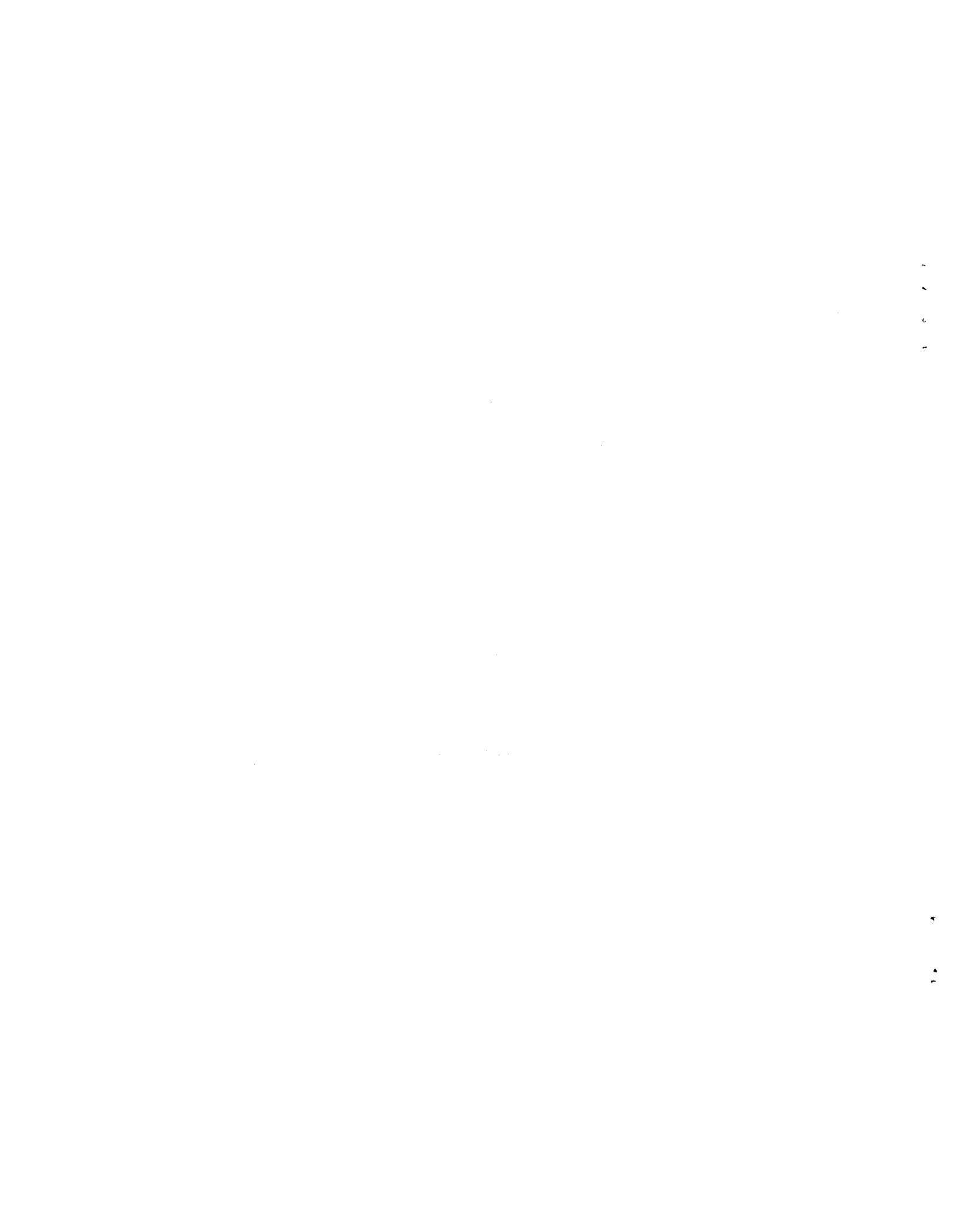
The nitric acid retains strontium and other metal ions. This phase is precipitated

with fuming nitric acid, scavenged with barium chromate, precipitated as a carbonate, and transferred to a stainless steel planchet. The  $^{90}\text{Sr}$  sample is counted with a low-background beta proportional counter.

The plutonium is eluted from the resin column with 0.4N  $\text{HNO}_3$  - 0.01 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 insure that the data collected each year are representative of actual concentrations in the environment. First, extensive environmental data are collected to preclude unrealistic reliance on only a few results. Second, the incoming data are compared with past data for each environmental medium to assure that current readings are consistent with previous results. Third, measurements are collected using identical methods, near to and far from the Hanford Site, as well as upstream and downstream, to allow identification of any net difference that may be attributable to Hanford operations. The procedures, in conjunction with a program to demonstrate the accuracy of radiochemical analyses, assure that the data taken accurately represent environmental conditions.

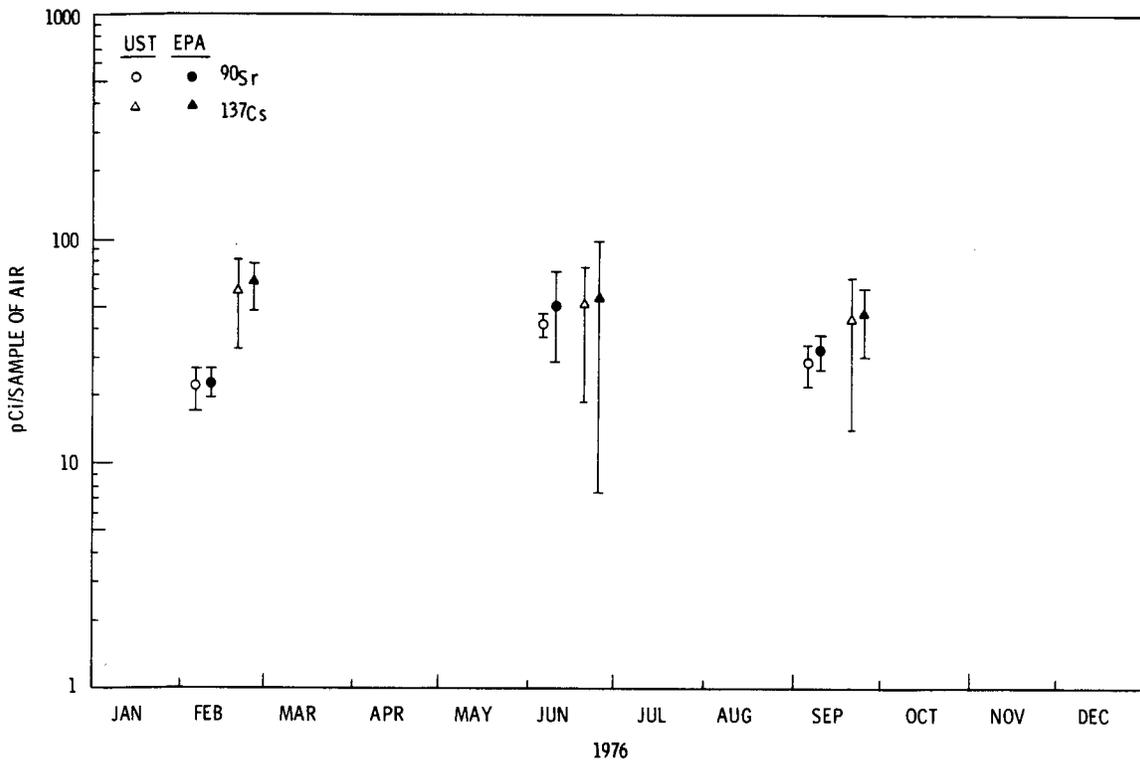
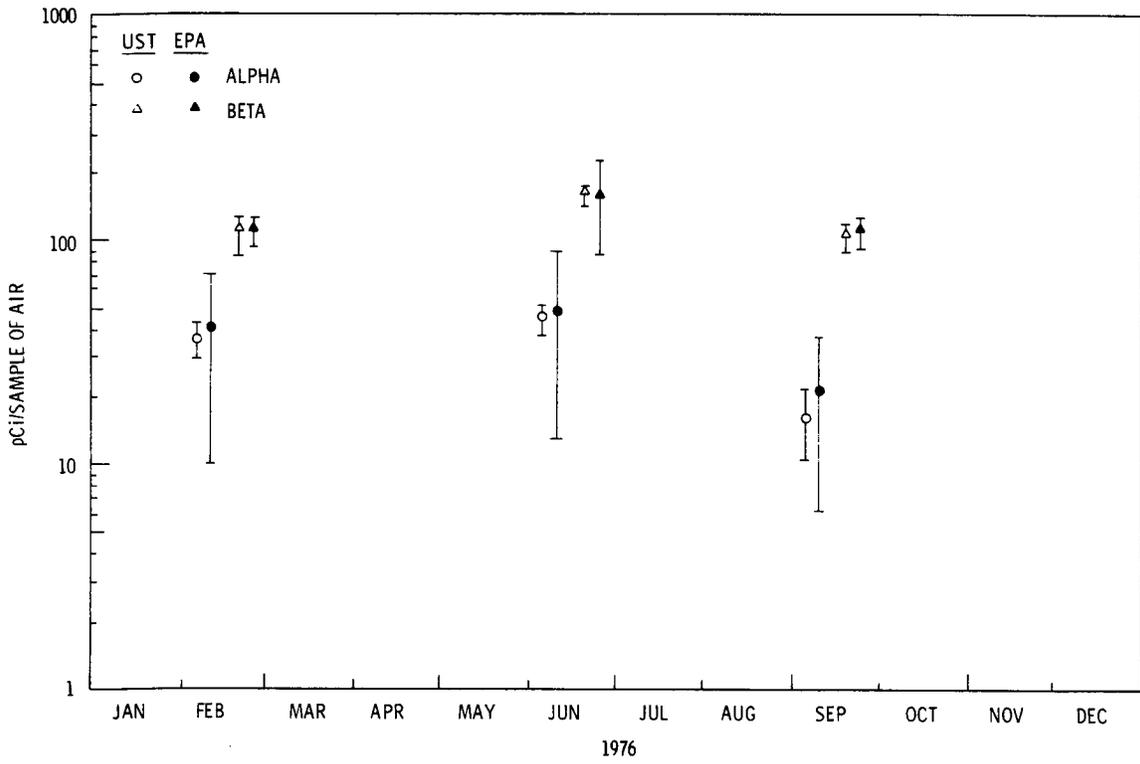
#### LABORATORY ANALYSES OF RADIOLOGICAL DATA

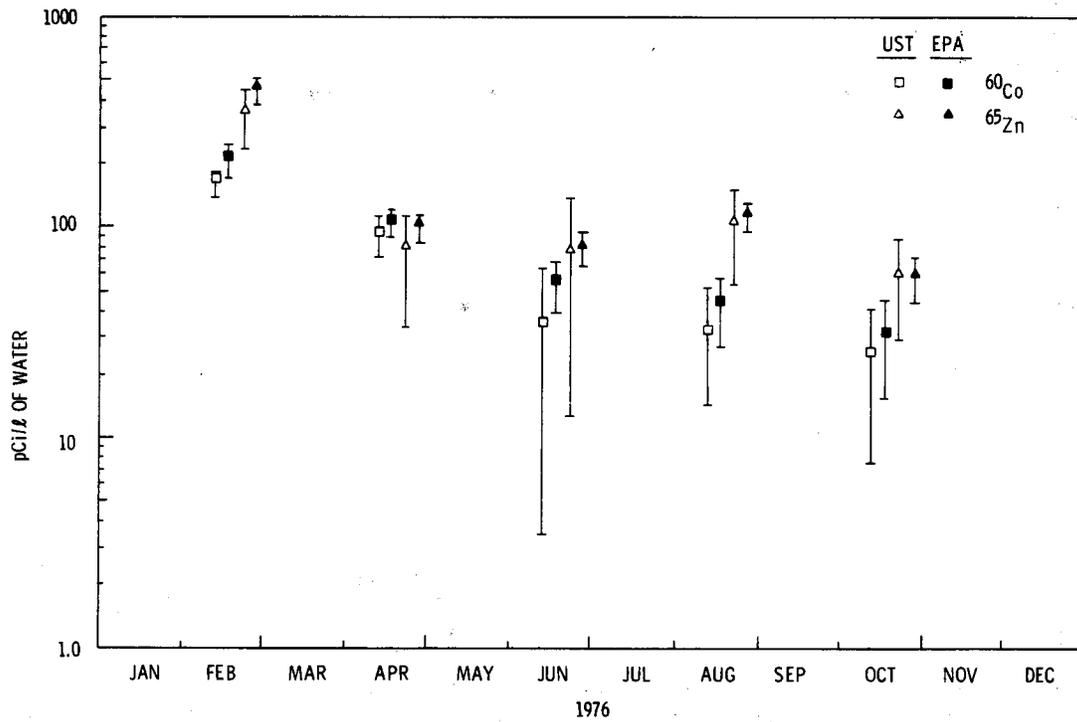
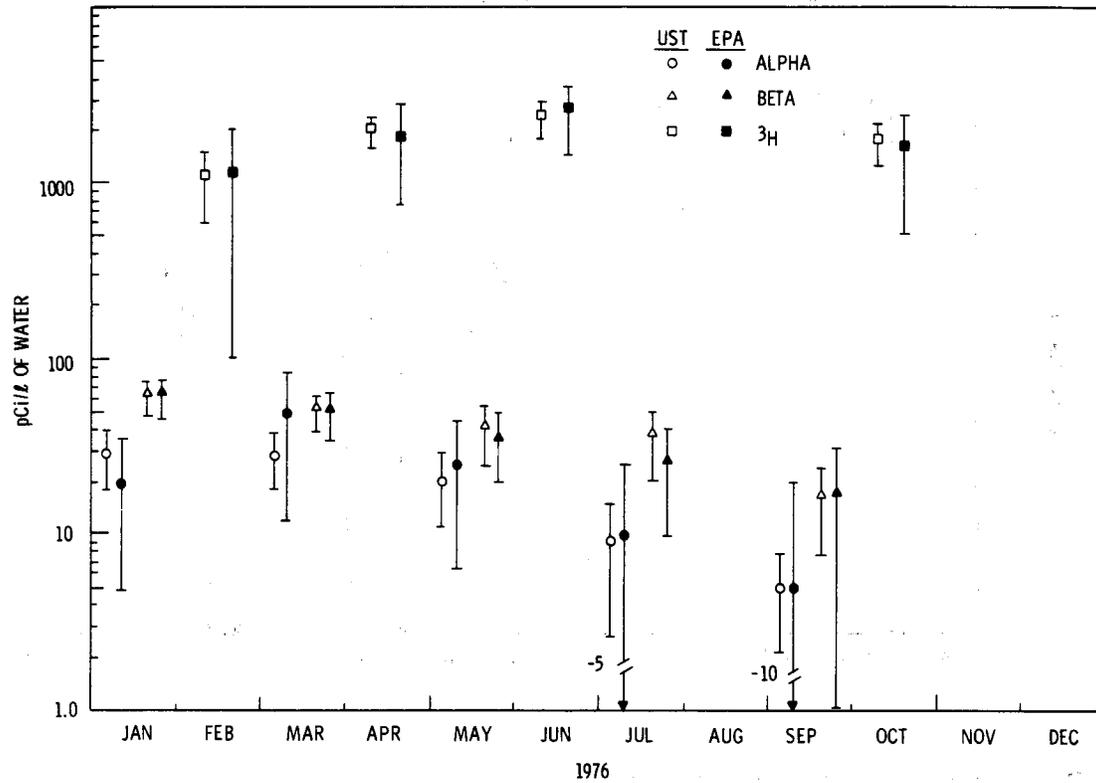
Most routine environmental radioanalyses for the Hanford program are performed by the United States Testing Company in Richland, Washington. Analytical limits are specified in a services contract between United States Testing and the Energy Research and Development Administration (ERDA). The term "analytical limit" is contractually defined as the concentration at which the laboratory can measure a radionuclide with an accuracy of  $\pm 100\%$  at the 90% confidence level, given the required volume of sample material. The detection limit for a specific radionuclide varies with sample type, sample size, counting time, and amounts of interfering radionuclides present. The "analytical limits" represent the upper bounds of the fluctuating detection limits.

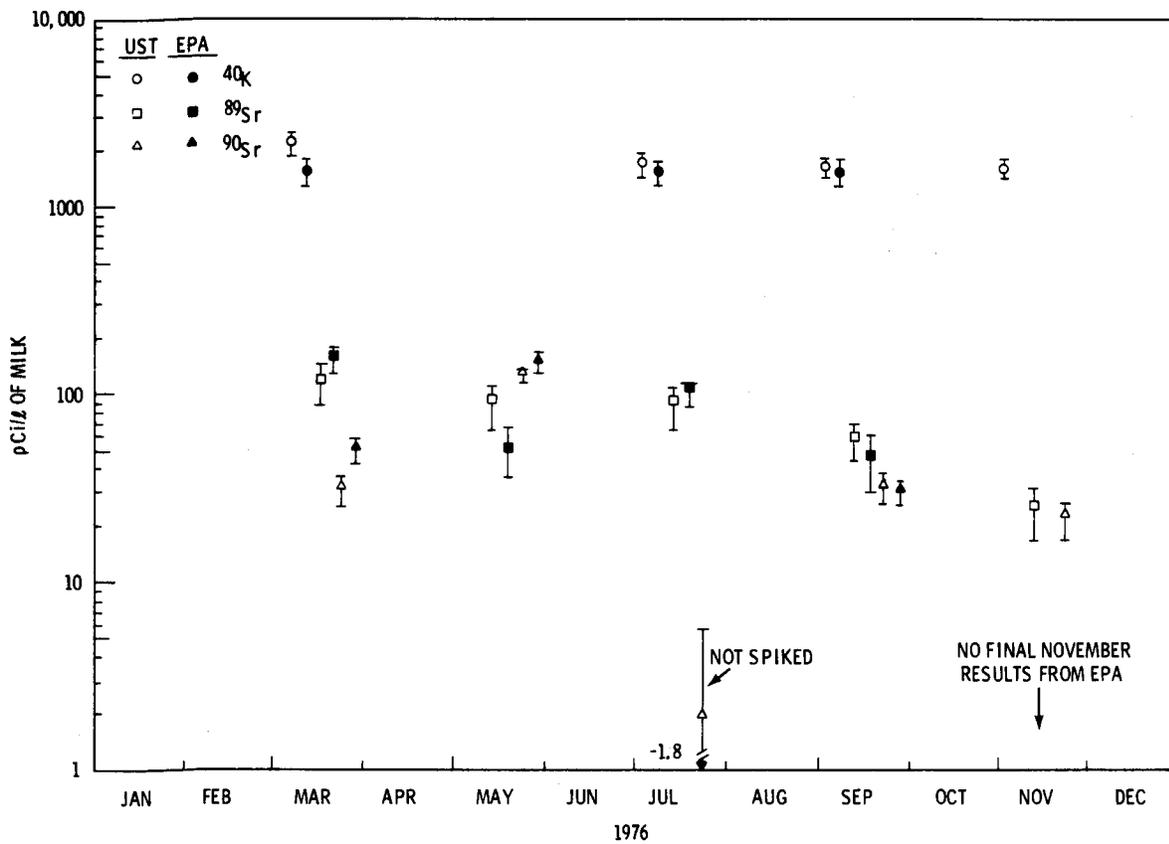
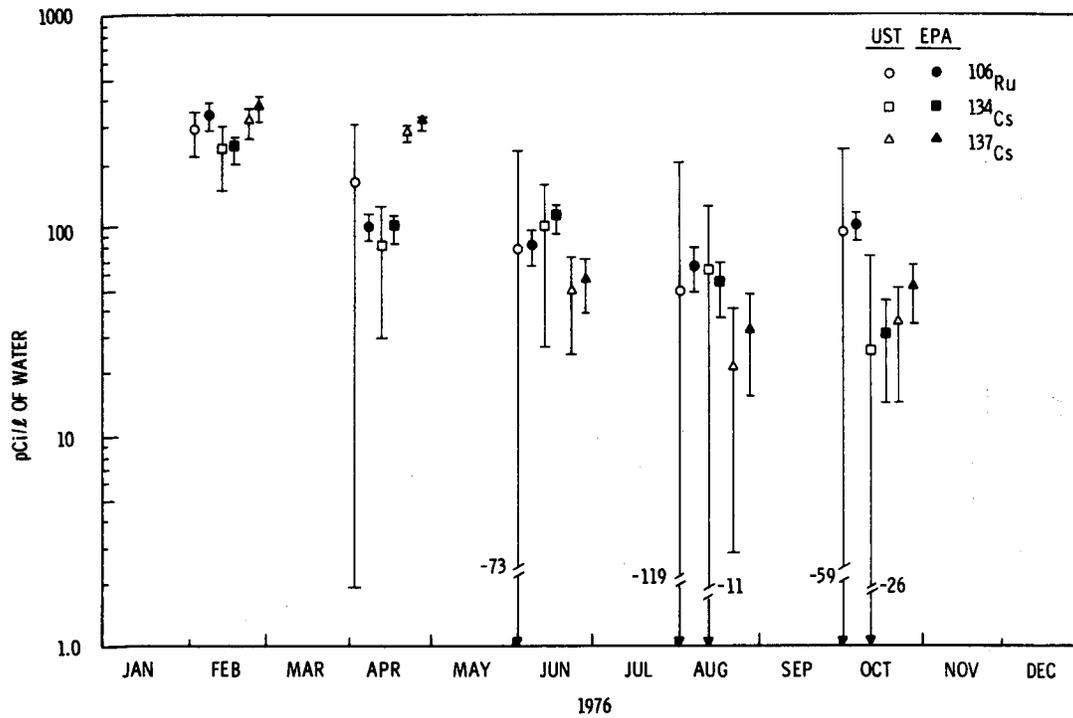
#### QUALITY CONTROL AT UNITED STATES TESTING

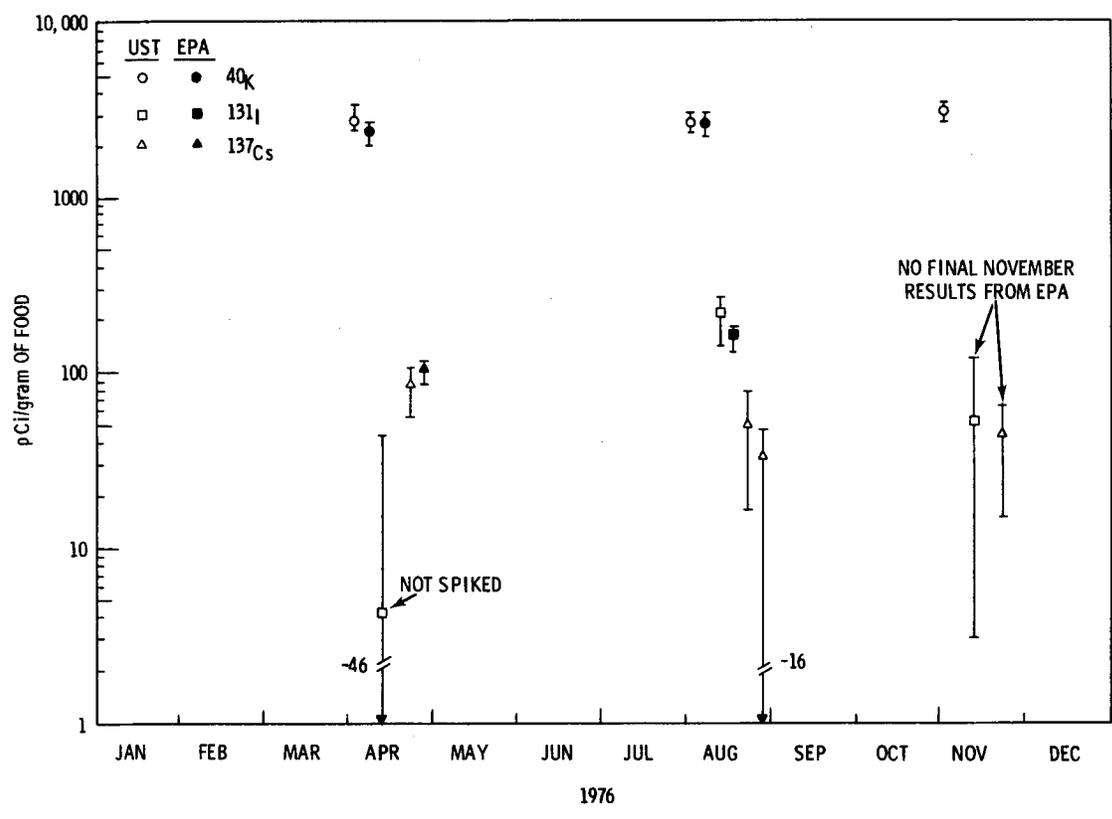
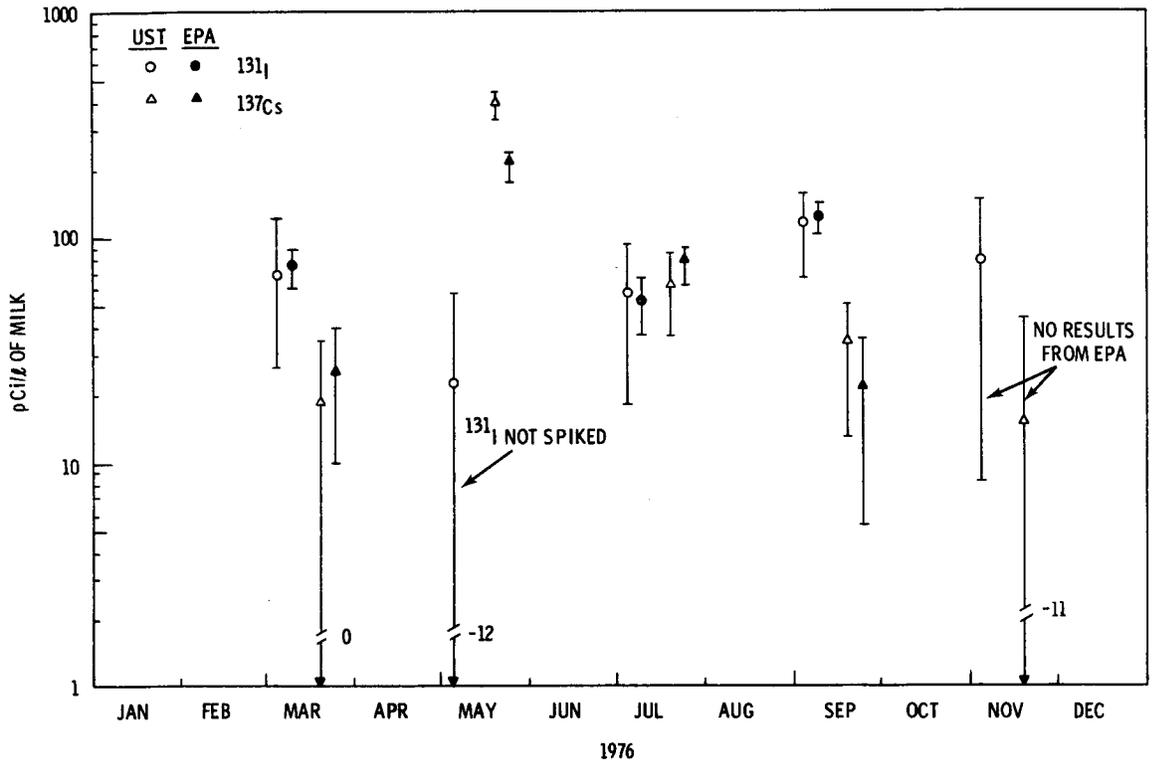
United States Testing maintains an internal quality control program involving routine instrument calibration and background counts to insure the integrity of analyses. The company also participates in the Interlaboratory Comparison Program of the Environmental Protection Agency (EPA). For this program, a number of environmental samples (of milk, water and air) containing one or more radionuclides in amounts known by EPA are routinely prepared and distributed to all participating laboratories. The laboratories perform the required analyses (three separate determinations) and return their results to EPA for comparison with the known values and the results from the other laboratories. If an error is made in the preparation of any sample, the results from the different laboratories should cluster around the correct value. The program thus enables a laboratory to document the precision and accuracy of its results relative to other laboratories.

The data in the following figures have been supplied by United States Testing and provide a comparison between their reported results and the EPA value for each analysis. Each plotted point is the mean value for each analysis; the 3-sigma uncertainty is also shown around each point. United States Testing receives three air filters and each is analyzed individually. Only one sample each of water, milk and foodstuffs is received; each sample is separated into three aliquots and each aliquot is then analyzed individually.





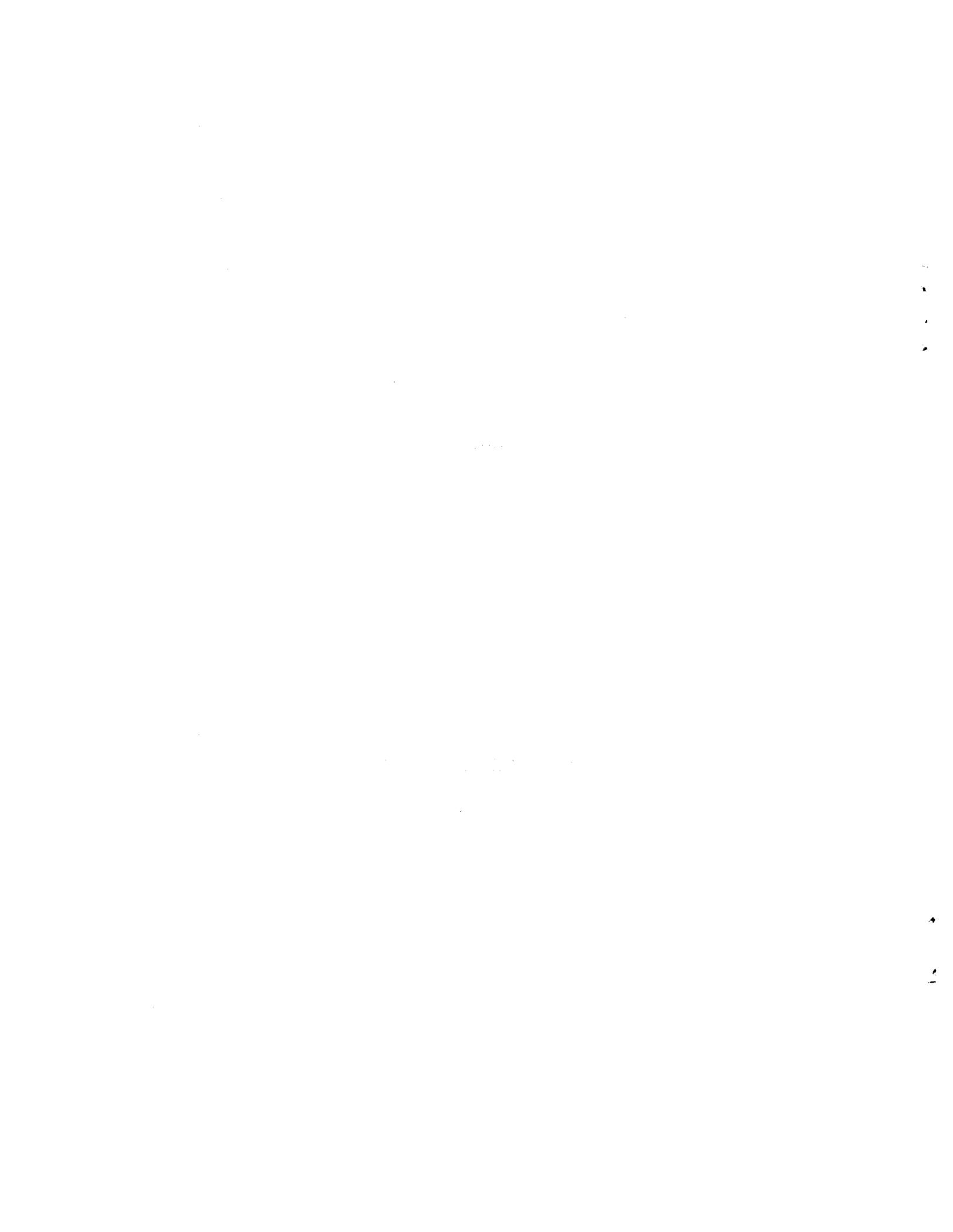






APPENDIX D

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 attributable to past Hanford operations, the dose impact is calculated using the standard techniques described in the text (e.g., the infant thyroid dose of 1.9 mrad from fallout <sup>131</sup>I is calculated using methods in Federal Radiation Council Report #5, as described on page 13).
2. The liquid and gaseous radionuclide effluent released during the year by all Hanford facilities is included in the annual report. Since the listed quantities are generally undetectable in the environment, the dose impact is calculated using the effluent quantities as source terms and using theoretical dose models<sup>(10,11)</sup> to calculate the radiation dose. All of the models have been used previously to calculate doses from Hanford facilities and are expected to provide best estimates of the generally undetectable dose impact attributable to Hanford operations.

Because the calculation of doses resulting from situations in Category 1 is described in detail in the text, little supporting information is needed here. For Category 2 dose calculations, the impact from each major operating area (100-N Area, 200 Areas, 300 Area) is considered separately because of the distance between the areas. The population within a radius of 80 kilometers of an area differs for each area, as does the location of the maximum offsite impact. The following assumptions were used to calculate the dose impact during 1976:

#### AIRBORNE EFFLUENT

Separate impacts were calculated for the releases from the 100 N Area, the 200 Areas and 300 Area (see text Table 17). The source term used for each area was the 1976 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 from a stack 70 meters high. Calculations used the population distribution shown in Figure D-1

for the area within an 80-kilometer radius of the 100-N Area. Past N Reactor meteorological data, for which the annual average Chi/Q values are shown in Table D-1, were also used.

#### 200 Areas

Gaseous effluent was released from the center of the 200 Areas from a stack 70 meters high. Calculations used the population distribution shown in Figure D-2 for the area within an 80-kilometer radius of the Hanford Meteorological Station (HMS; located between the 200 East and 200 West Areas). Past meteorological data (the 15-year average from 1955 to 1970) from HMS were used, with the annual average Chi/Q values as shown in Table D-2.

#### 300 Area

Gaseous effluent was released at ground level. Calculations used the population distribution shown in Figure D-3 for the area within an 80-kilometer radius of the 300 Area. Past meteorological data collected by the Washington Public Power Supply System<sup>(a)</sup> for the WNP-2 Reactor were used; the annual average Chi/Q values are listed in Table D-3.

### LIQUID EFFLUENT

The 1976 releases, shown in Table 17 in the text, were mixed with the Columbia River, which flows at an average rate reported annually by the United States Geological Survey. For 1976, the average flow rate was 141,700 cfs.

The doses from the following sources are among those calculated:

- 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 residing on the shoreline.

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

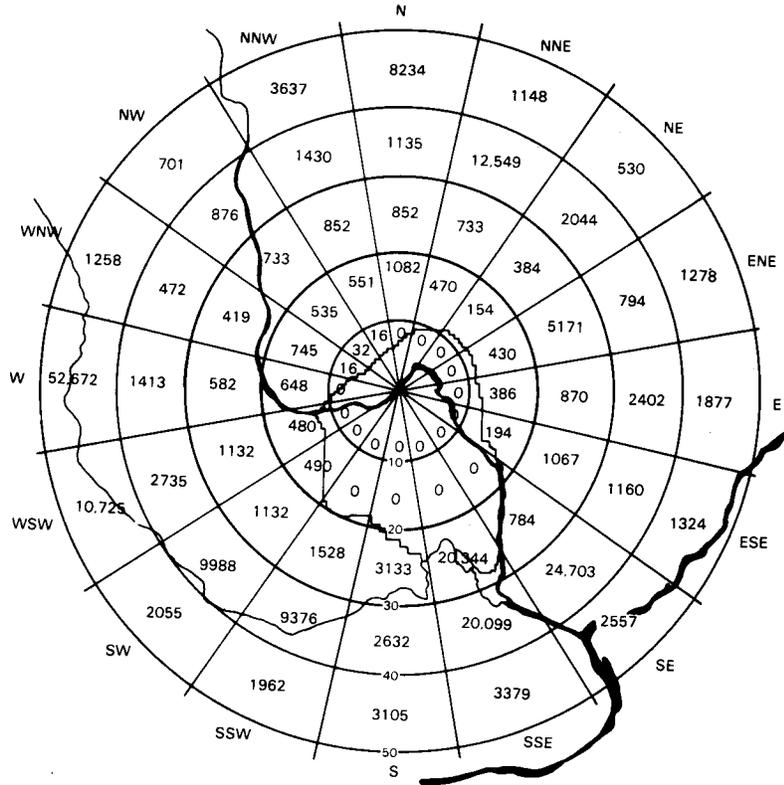
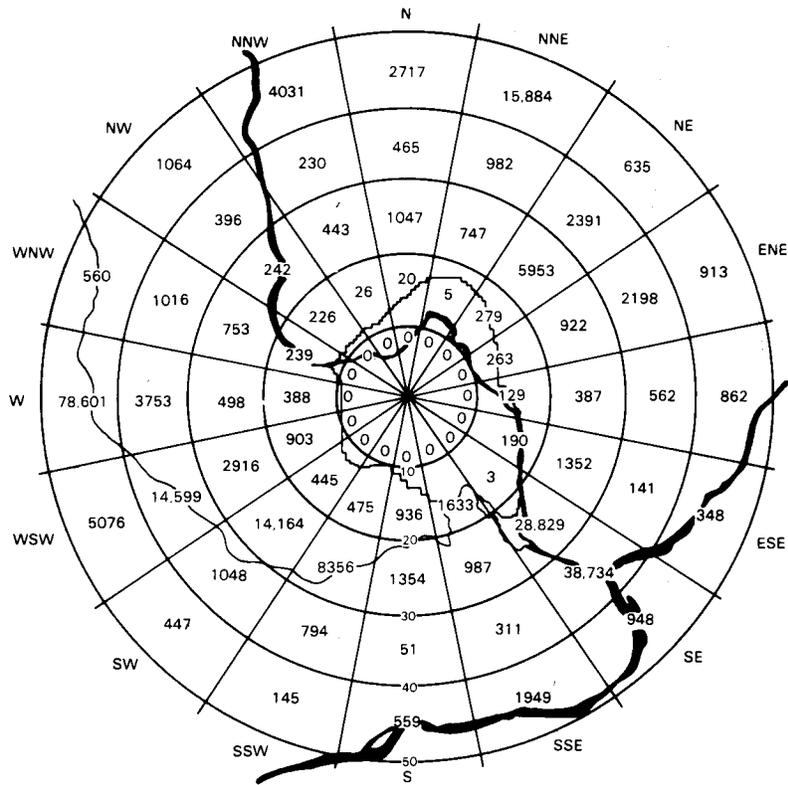


FIG. D-1. Estimated Geographic Distribution of the Population (236,000) Within a 50-Mile (80-Kilometer) Radius of the 100-N Area

TABLE D-1. Chi/Q for the 100-N Area

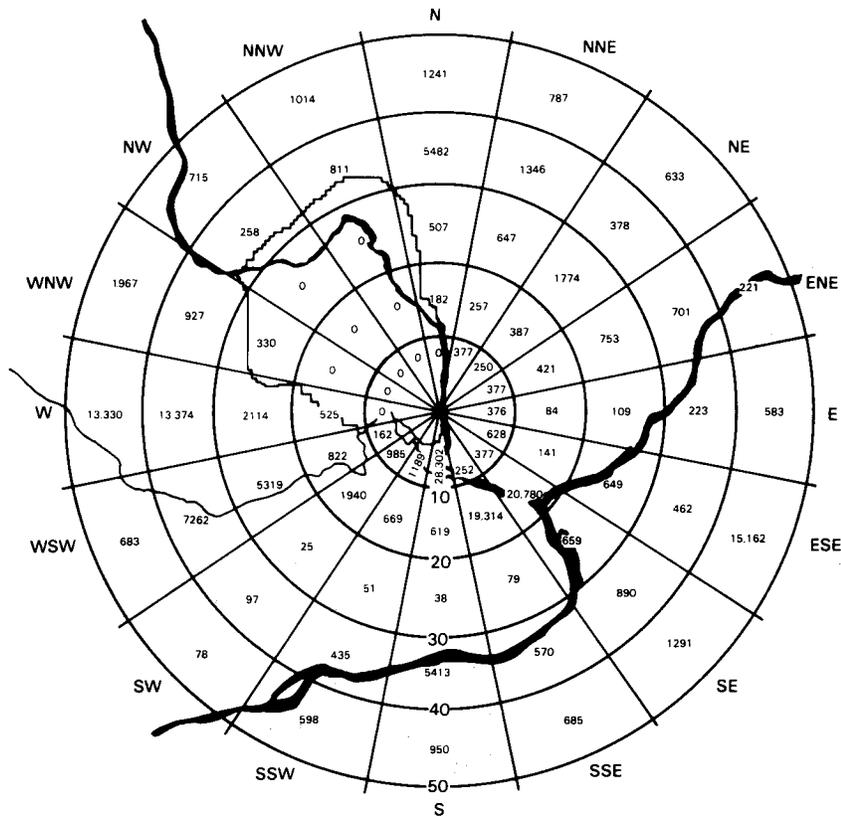
Direction	Range in Miles (km)										Totals
	0.5 (0.8)	1.5 (2.4)	2.5 (4.0)	3.5 (5.6)	4.5 (7.2)	7.5 (12.0)	15 (24)	25 (40)	35 (56)	45 (72)	
N	3.68E-08	1.60E-08	9.02E-09	5.69E-09	4.05E-09	2.49E-09	1.91E-09	1.44E-09	1.10E-09	8.69E-10	7.94E-08
NNE	5.24E-08	2.05E-08	1.08E-08	6.64E-09	4.62E-09	2.68E-09	1.94E-09	1.46E-09	1.12E-09	8.90E-10	1.03E-07
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	2.54E-07
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	2.53E-07
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	2.86E-07
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	2.97E-07
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	1.97E-07
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	1.81E-07
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	1.90E-07
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	2.88E-07
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	1.58E-07
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	1.28E-07
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	1.63E-07
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	1.80E-07
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	1.70E-07
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	1.00E-07
TOTALS	1.42E-06	6.61E-07	3.48E-07	2.13E-07	1.47E-07	8.20E-08	5.57E-08	4.10E-08	3.13E-08	2.47E-08	3.03E-06
CUM TOTAL	1.42E-06	2.08E-06	2.43E-06	2.64E-06	2.79E-06	2.87E-06	2.93E-06	2.97E-06	3.00E-06	3.03E-06	3.03E-06



**FIG. D-2.** Estimated Geographic Distribution of the Population (258,000) Within a 50-mile (80-Kilometer) Radius of the Hanford Meteorological Station

**TABLE D-2.** Chi/Q for the 200 Areas

Direction	Range in Miles (km)										Totals
	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	7.79E-08
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	9.34E-08
NE	8.05E-08	3.02E-08	1.54E-08	9.44E-09	6.40E-09	2.92E-09	1.50E-09	1.19E-09	9.86E-10	8.26E-10	1.49E-07
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	1.42E-07
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	1.07E-07
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	1.82E-07
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	3.48E-07
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	1.90E-07
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	1.95E-07
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	1.72E-07
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	1.68E-07
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	9.97E-08
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	1.06E-07
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	1.01E-07
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	1.19E-07
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	7.13E-08
TOTALS	1.03E-06	5.15E-07	2.97E-07	1.95E-07	1.37E-07	6.43E-08	3.12E-08	2.30E-08	1.85E-08	1.52E-08	2.32E-06
CUM TOTAL	1.03E-06	1.54E-06	1.84E-06	2.03E-06	2.17E-06	2.23E-06	2.26E-06	2.29E-06	2.31E-06	2.32E-06	2.32E-06



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

**TABLE D-3.** Chi/Q for the 300 Area

Direction	Range In Miles (km)										Totals
	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	6.51E-06
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	5.53E-06
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	4.98E-06
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	4.75E-06
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	4.37E-06
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	6.75E-06
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	8.41E-06
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	8.32E-06
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	7.82E-06
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	6.52E-06
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	6.51E-06
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	5.23E-06
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	4.66E-06
WNW	3.51E-06	5.40E-07	2.38E-07	1.44E-07	9.84E-08	4.72E-08	1.82E-08	9.28E-09	6.04E-09	4.38E-09	4.62E-06
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	4.17E-06
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	5.82E-06
TOTALS	7.23E-05	1.11E-05	4.88E-06	2.94E-06	2.01E-06	9.65E-07	3.70E-07	1.88E-07	1.22E-07	8.86E-08	9.50E-05
CUM TOTAL	7.23E-05	8.34E-05	8.83E-05	9.12E-05	9.32E-05	9.42E-05	9.46E-05	9.48E-05	9.49E-05	9.50E-05	9.50E-05

DIETARY ASSUMPTIONS

All calculations were made using the models described in References 10 and 11. The many transfer and bioaccumulation factors needed for the calculations can be obtained from the references. Tables D-4 and D-5

summarize the consumption of the different foodstuffs by the hypothetical maximum individual and the population. The values shown in Table D-4 are also used to estimate the ingestion and external dose resulting from airborne deposition of radionuclides released to the atmosphere.

TABLE D-4. Quantities of Various Foodstuffs Consumed

Foodstuff	Hold Up (days)	Consumption (in kg/yr except as otherwise noted)	
		Maximum Individual	Population
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	30	15
Milk	1.0	274 l/yr	137 l/yr
Beef	15.0	40	20
Pork	15.0	40	20
Poultry	1.0	18	9
Ground Contamination	--	2922 hr/yr	1461 hr/yr

(a) Other Above Ground

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

Exposure Mode	Hold Up (hr)	Usage	
		Maximum Individual	Population
Fish	24	40 kg/yr	15,000 kg/yr (a)
Drinking Water	24	730 l/yr	438 l/yr
Shoreline	8	500 hr/yr	17 hr/yr
Swimming	8	100 hr/yr	10 hr/yr
Boating	8	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.



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