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Environmental Surveillance at Hanford for CY 1983



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

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



PNL-5038

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

Printed in the United States of America
Available from
National Technical Information Service
United States Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

NTIS Price Codes
Microfiche A01

Printed Copy

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

Environmental Surveillance at Hanford for CY 1983

K. R. Price
J. M. V. Carlile
R. L. Dirkes
M. S. Trevathan

May 1984

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

Pacific Northwest Laboratory
Richland, Washington 99352



PREFACE

The Environmental Surveillance Program at the Hanford Site in Washington State is conducted by the Pacific Northwest Laboratory (PNL) under contract to the Department of Energy (DOE). The data collected by the Environmental Surveillance Program provide an historical record of the levels of radionuclides and radiation attributable to natural causes, worldwide fallout, and Hanford operations. The findings of the present program demonstrate the relatively small impact attributable to either current or past Hanford operations. Where appropriate, the data are compared with applicable standards for air and water quality set forth by the Department of Energy, the Environmental Protection Agency (EPA), and the state of Washington. Summaries and interpretations of the data are published annually; this document is for calendar year 1983. Previous reports in this series for the past ten years are listed below and referenced at the end of this report.

1982	PNL-4657	M. J. Sula, J. M. V. Carlile, K. R. Price, and W. D. McCormack	(May 1983)
1981	PNL-4211	M. J. Sula, W. D. McCormack, R. L. Dirkes, K. R. Price and P. A. Eddy	(May 1982)
1980	PNL-3728	M. J. Sula and P. J. Blumer	(April 1981)
1979	PNL-3283	J. R. Houston and P. J. Blumer	(April 1980)
1978	PNL-2932	J. R. Houston and P. J. Blumer	(April 1979)
1977	PNL-2614	J. R. Houston and P. J. Blumer	(April 1978)
1976	BNWL-2142	J. J. Fix, P. J. Blumer, G. R. Hoenes and P. E. Bramson	(April 1977)
1975	BNWL-1979	A. R. Speer, J. J. Fix, P. J. Blumer	(June 1976)
1974	BNWL-1910	J. J. Fix	(April 1975)
1973	BNWL-1811	W. L. Nees and J. P. Corley	(April 1974)

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

- *Environmental Status of the Hanford Site for CY 1983* (to be issued as PNL-5039), and
- *Ground-Water Surveillance at the Hanford Site for CY 1983* (to be issued as PNL-5041).

These reports provide summaries of environmental and ground-water monitoring conducted on the Hanford Site.

ACKNOWLEDGMENTS

The authors wish to acknowledge those at PNL who participated in the operation of the Hanford Environmental Surveillance Program during 1983 and those who helped prepare this report.

Environmental samples were collected by K. Byrne, S. R. Bivins, J. D. Harrison, W. W. King, D. G. Morton, and D. L. Merrill, who were supervised by M. R. Quaders.

Data management was provided by P. J. Blumer and L. E. Bisping.

Technical assistance for data analysis and dose calculations was provided by W. D. McCormack, B. A. Napier and R. A. Peloquin.

Secretarial support was provided by G. L. Dirkes and K. E. Shoop.

Typesetting was performed by M. A. Jochen and S. E. Vickerman.

M. A. McKinney edited this report and arranged for publication.

SUMMARY

Environmental surveillance activities performed by the Pacific Northwest Laboratory for the Department of Energy's Hanford Site for 1983 are discussed in this report. Samples of environmental media were collected in support of the Hanford Environmental Surveillance Program to determine radionuclide concentrations in the Hanford environs. Radiological impacts in terms of radiation dose equivalents as a result of Hanford operations are also discussed. The results provided in this report are summarized in the following highlights.

Airborne Radioactivity—There were no distinguishable differences in either gross radioactivity or specific radionuclide concentrations in air samples collected near the site perimeter as compared with controls collected some distance from the site. Gross beta radioactivity concentrations in airborne particulates at all sampling locations were lower than during 1982 as a result of declining levels of worldwide fallout.

Columbia River Radiological Monitoring—Very low levels of radionuclides were detected in samples of Columbia River water during 1983. Concentration of ^3H , ^{90}Sr , ^{129}I , and U (natural) were slightly higher at the downstream sampling site compared to the upstream site, however, downstream concentrations were considerably below applicable DOE concentration guides. The major source of radionuclides added to the river is assumed to be ground water flowing from beneath the site into the river through natural springs occurring along the shoreline. Both the groundwater near the river and riverbank springs were shown to contain radionuclides. N Reactor effluents are known to be another minor source of ^3H and ^{90}Sr to Columbia River water.

Cesium-137 and $^{239,240}\text{Pu}$ were observed in upstream and downstream samples at approximately the same concentrations. Other radionuclides such as ^{60}Co , ^{131}I , and ^{89}Sr were observed more frequently in downstream samples but not in higher concentrations than upstream samples. All of these radionuclides were reported to be released to the river in N Reactor effluents during 1983. All radionuclides detected in the Columbia also occur naturally or are present in worldwide fallout.

Columbia River Nonradiological Monitoring—Nonradiological water quality parameters were within Washington State Water Quality Standards for the Hanford reach of the Columbia River. Isolated instances of state standards being exceeded were observed during the year; however, there was no apparent association of these occurrences with Hanford operations, nor any indication of reduced river water quality based on a comparison with sampling results from previous years.

Ground Water—An extensive ground-water monitoring program was performed for the Hanford Site during 1983. Detailed results of the program will be reported in PNL-5041 to be published later in 1984.

Foodstuffs—Low levels of radionuclides were observed in most foodstuff samples and are attributable to worldwide fallout. There was no indication in any of the samples that radionuclides associated with Hanford were present.

Wildlife—Low concentrations of radionuclides attributable to operations at Hanford were observed in several samples of ducks, game birds, and deer collected near operating areas. Concentrations were low enough that any resulting radiation dose from consuming the edible portion of an animal containing the highest observed concentration would be well below the applicable radiation protection standard. Although ^{60}Co and ^{90}Sr were identified more frequently in fish collected along the Hanford Site as compared to samples collected upstream of Hanford, the average concentrations of these radionuclides in the samples were too low and too variable to permit any differences to be quantified.

Soil and Vegetation—Low concentrations of naturally occurring and fallout radionuclides were observed in samples of soil and vegetation collected in the Hanford environs. There were no indications of any geographical differences in radionuclide concentrations and thus no discernible effect from Hanford operations.

External Radiation—Dose rates in the vicinity of residential areas due to external penetrating radiation were similar to those observed in the previous years, and no contribution from

Hanford activities could be identified. Measurements made in the vicinity of onsite operating areas and along the Columbia River indicated several locations where dose rates were somewhat higher than those attributable to background sources.

Radiological Impact—An assessment of potential radiological impacts attributable to 1983 operations at Hanford indicated that radiation doses to the public were similar to 1982, i.e., well below all applicable regulatory limits, and significantly less than doses potentially received from other common sources of radiation. The fifty-

year whole body cumulative dose equivalent potentially received by an assumed maximally exposed individual was calculated to be 1 mrem. This dose can be compared to the DOE Radiation Protection Standard of 500 mrem per year. The fifty-year whole body cumulative dose equivalent to the population living within 80-km of the site was calculated to be 4 man-rem. These doses also can be compared to the approximate 100 millirem and 34,000 man-rem received annually by an average individual and the surrounding population, respectively, as a result of naturally occurring and worldwide fallout radiations in the Hanford environs.

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INTRODUCTION

For the past 41 years, an environmental surveillance program has been conducted for the Hanford Site. The results of this program have been publicly recorded since January of 1948 in quarterly reports. Since 1958, the results have been available in annual reports. This report summarizes the data collected for calendar year 1983. The Hanford Environmental Surveillance Program is conducted by PNL, which is operated for the DOE by Battelle Memorial Institute.

The objectives of the program include:

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

Environmental surveillance at the Hanford Site involves numerous measurements of a variety of environmental media for potential contaminants. Samples are collected in accordance with

a master schedule published each year (Blumer et al. 1982). Most radionuclide analyses of samples were performed by United States Testing Company, Inc., Richland, Washington. Some analyses were performed by PNL. Individual sample results or summaries of the individual results are presented in the following sections of this report.

Because all of the radioactive and nonradioactive pollutants considered in this report are present in the environment, either naturally or as a result of non-Hanford activities such as atmospheric nuclear weapons testing (fallout radionuclides) and agricultural activities (nitrates, coliforms, etc.), measurements made in the vicinity of the site were compared to background or control measurements. Any contribution to air or waterborne radionuclide concentrations or external dose rate levels considered to be attributable to Hanford operations was compared with applicable guides and standards in DOE Order 5480.1 Chapter XI (USDOE 1980). Concentrations of nonradioactive pollutants were compared with applicable standards of the Washington State Department of Ecology or the U.S. Environmental Protection Agency.

Appendices provide additional detailed information on applicable standards, analytical and calculational procedures, and quality assurance.

DESCRIPTION OF THE HANFORD SITE

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

SITE CHARACTERISTICS

The desert plain on which Hanford is located has a sparse covering of vegetation and is 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, and the most abundant small game animal is the cottontail rabbit. The raccoon is the most

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

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

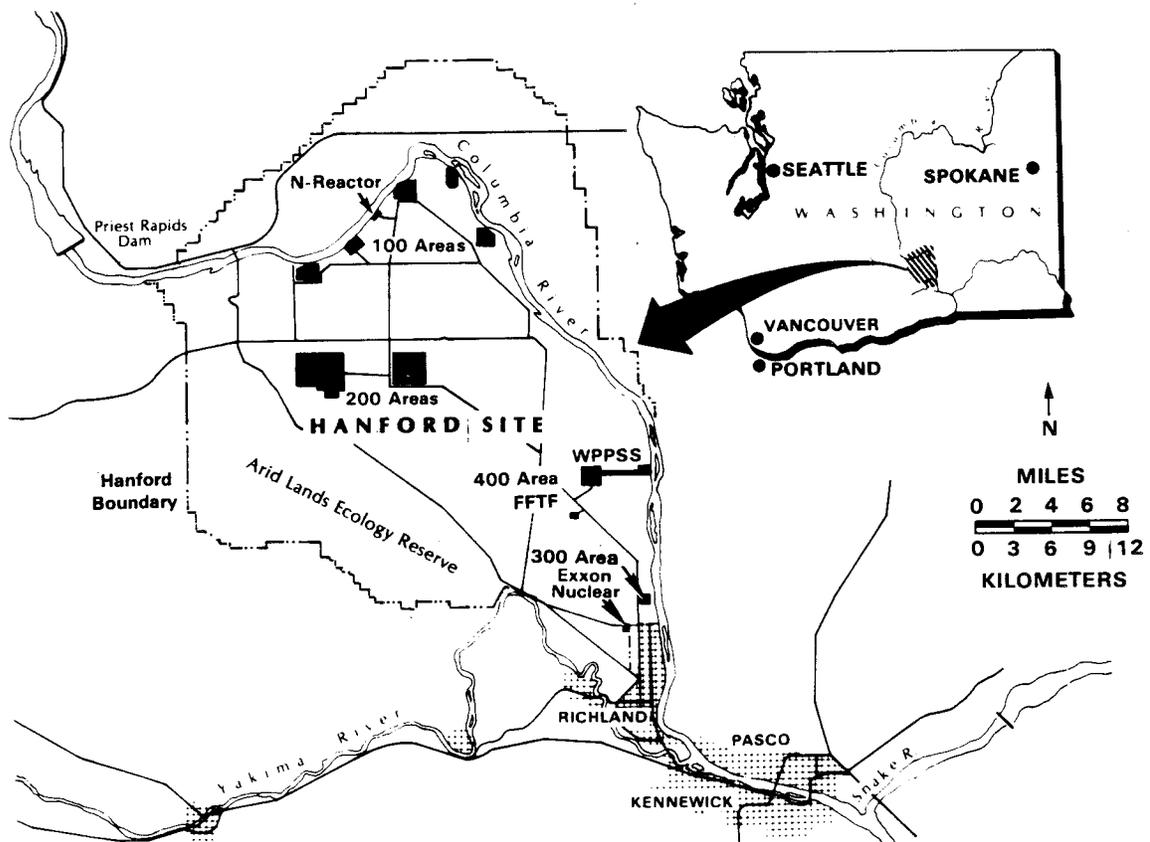


FIGURE 1. DOE's Hanford Site in Washington State

September. The average maximum and minimum temperatures in July are 32°C (90°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/h in the summer to 10 km/h in the winter. The prevailing regional winds are from the northwest with strong drainage and crosswinds causing complicated surface flow patterns. The region is a typical desert area with frequent strong inversions that occur at night and break during the day, causing unstable and turbulent conditions.

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

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

MAJOR ACTIVITIES

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

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

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

Privately owned facilities located within the Hanford Site boundaries include the Washington Public Power Supply System generating station adjacent to N Reactor, the Washington Public Power Supply System power reactor and office buildings, and a radioactive waste burial site operated by U.S. Ecology. The Exxon fuel fabrication facility is located immediately adjacent to the southern boundary of the Hanford Site.

Principal DOE Contractors operating at Hanford are:

Rockwell Hanford Operations (RHO)—responsible for fuel reprocessing, waste management, and site support services such as plant security, fire protection, central stores, and electrical power distribution.

Battelle Memorial Institute—responsible for operating PNL for DOE. This includes research and development in the physical, life and environmental sciences, chemistry, and advanced methods of nuclear waste management. Environmental surveillance also is a part of PNL activities.

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

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

Hanford Environmental Health Foundation (HEHF)—responsible for occupational medicine and environmental health support services.

Highlights of operational activities at Hanford during 1983 were:

- N Reactor operated for 201 days during which time it supplied steam used by the Washington Public Power System to generate 870 MW of electrical power. Since its startup, N Reactor

tor has supplied steam for the production of over 50 billion kilowatt-hours of electric power, which has been supplied to the Bonneville Power Administration grid covering the Pacific Northwest.

- The PUREX fuel reprocessing facility in 200-E Area began routine operations during the month of November.

- The FFTF completed two 100-day full power operating campaigns.

Work at Hanford during 1983 also included Hanford National Environmental Research Park studies, Arid Land Ecology studies, and Basalt Waste Isolation Program activities, as well as continued operation of a variety of national research and laboratory facilities.

ATMOSPHERIC MONITORING

Radioactivity in air was measured by a network of continuously operating air samplers at twenty locations near the site perimeter and five locations somewhat distant from the site. The site perimeter samplers provided for general coverage in all directions but with emphasis in the prevailing downwind directions to the south and east of the site including the communities of Benton City, Richland, Pasco, Connell, and Othello. The distant air sample locations provided background airborne radioactivity data for comparison. These samplers were located at Sunnyside, Moses Lake, Washtucna, Walla Walla, and at McNary Dam.

Data on airborne radioactivity did not indicate the presence of detectable levels of radionuclides in the offsite environs during 1983 that could have originated from Hanford.

The emission of nonradiological pollutants consisting of NO_x and particulates did not exceed EPA and local limits.

SAMPLE COLLECTION AND ANALYSIS

Air samples were collected on a continuous basis at a number of locations near to and distant from the Hanford Site (see Figure 2). Particulate and radioiodine samples were collected at all sampling locations. Several of the air sampling locations contained tritium, ^{14}C , and ^{85}Kr collection units.

Particulate airborne radionuclides were sampled by drawing air at a flow rate of $2.6 \text{ m}^3/\text{h}$ through a 5-cm diameter high-efficiency particulate filter. (a) The filters were collected biweekly and analyzed for gross beta radioactivity after a

(a) Measured efficiencies exceed 99% for DOP (dioctylphthalate) particles.

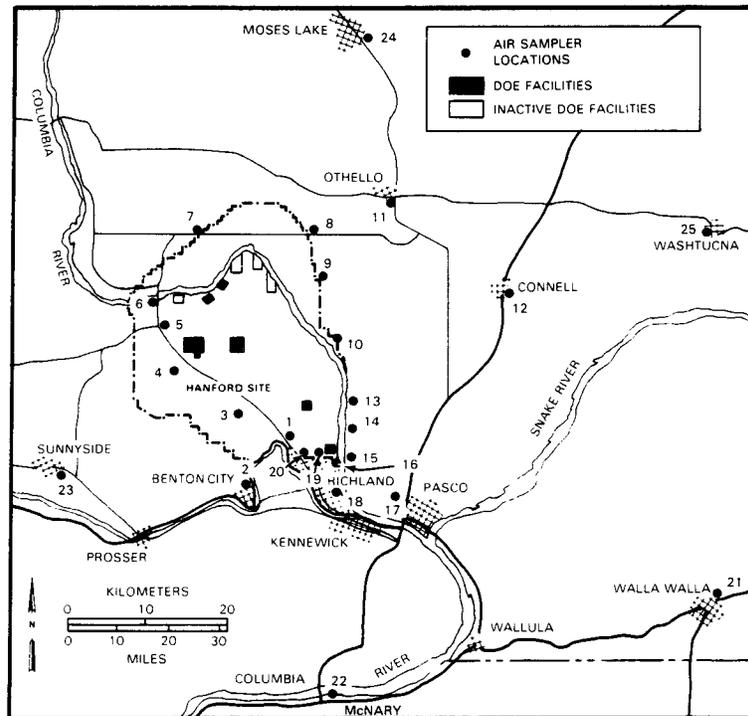


FIGURE 2. Air Sampling Locations

seven-day holding period during which short-lived naturally occurring radon and thoron daughters collected by the filter decay.

In addition, various filters were also analyzed in a similar manner for gross alpha radioactivity. The air filters were then combined monthly by geographical location and analyzed as a composite for gamma-emitting radionuclides, primarily ^{137}Cs . On a quarterly basis, the monthly composites for each geographical group were combined and analyzed for strontium and plutonium.

Radioiodines were collected using 4.4-cm diameter by 5.5-cm deep cartridges containing activated charcoal.^(a) These cartridges were placed downstream of the particulate filter at each of the air sampling stations. Charcoal cartridges from several of the sampling locations were exchanged on a biweekly frequency and analyzed for ^{131}I . The remaining cartridges were exchanged monthly to maintain fresh adsorption media, but were analyzed only if ^{131}I was identified in one of the routinely analyzed samples or if there was any other indication of an effluent release that could result in detectable concentrations.

The tritium collection unit consisted of three cartridges containing silica gel through which a stream of air was passed at a flow rate of $0.01\text{ m}^3/\text{h}$. The silica gel removes tritium in the form of water vapor (HTO). Moisture was removed from the silica gel by heating and then condensing the trapped water. Next, the water was analyzed for tritium using liquid-scintillation counting. The silica gel cartridges were exchanged every two weeks.

The ^{14}C (CO_2) collection units consisted of a single cartridge containing sufficient soda lime to collect about 5 g of carbon over an eight-week sampling period. The sample flow rate was $0.03\text{ m}^3/\text{h}$. The CO_2 was released from the soda lime absorbant into a benzene synthesizing instrument for purification and subsequent analysis by liquid scintillation counting.

Samples of ambient air for ^{85}Kr analysis were collected by a compressor that cycled on and off every 50 minutes transferring 10-second-duration

samples into a pressure tank. Samples of about 0.5 m^3 were collected over four-week sampling periods. Krypton was removed from the sample at the laboratory by a chromatographic method and analyzed by liquid scintillation counting.

RESULTS

Results of gross beta and gross alpha radioactivity in airborne particulate samples are shown in Table 1. Gross beta concentrations as well as gross alpha concentrations were similar at all sampling locations, averaging $0.02\text{ pCi}/\text{m}^3$ and $0.001\text{ pCi}/\text{m}^3$ respectively. No contribution to the general level of airborne particulate radioactivity could be identified as a result of Hanford operations based on a comparison of samples collected near the site perimeter and at distant locations. Therefore, airborne radioactivity levels observed in 1983 were attributed to worldwide fallout and natural sources.

A comparison of long-lived gross beta radioactivity in airborne particulate samples collected during 1983 with samples collected in previous years (Figure 3) shows that airborne radioactivity levels have decreased markedly. The elevated airborne radioactivity levels, which began in late 1980 and continued until late 1981, were attributed to an atmospheric nuclear test conducted by the People's Republic of China in October 1980.

Table 2 provides analytical results of air samples for specific radionuclides of potential Hanford origin. In all cases, radionuclide concentrations were similar regardless of the sample location, indicating the source to be worldwide fallout. As with the measured gross-radioactivity concentrations, specific radionuclides were observed at lower concentrations in 1983 than in 1982. The shorter-lived radionuclides, ^{95}Zr ($T_{1/2} = 64\text{d}$) and $^{144}\text{CePr}$ ($T_{1/2} = 284\text{d}$), that had been observed consistently following the 1980 atmospheric test were not detectable in air samples by the end of 1983. Iodine-131 was not detected in air samples during 1983.

NONRADIOLOGICAL AIR MONITORING

Nonradiological pollutants in routine gaseous emissions from chemical processes and fossil-fueled steam plants at Hanford consist primarily of the oxides of nitrogen (NO_x) and particulates.

(a) The charcoal is impregnated with potassium iodide (KI) and triethylene diamine (TEDA). Retention efficiencies are 99% for both elemental and methyl-iodide.

TABLE 1. Airborne Radioactivity in the Hanford Environs

Locations	Loca- tion(c)	No. of Samples	100			0.02			
			Maximum	Minimum	Average	No. of Samples	Maximum	Minimum	Average
Perimeter Stations									
Prosser Barricade	1	26	0.04 ± 0.005	0.01 ± 0.004	0.02 ± 0.003	26	0.001 ± 0.0005	0.0003 ± 0.0003	0.0009 ± 0.0001
Benton City	2	26	0.04 ± 0.005	0.009 ± 0.004	0.02 ± 0.003	26	0.002 ± 0.0007	<0.0003 ± 0.0004	0.0009 ± 0.0002
ALE	3	26	0.04 ± 0.005	0.007 ± 0.004	0.02 ± 0.003	---	---	---	---
Rattlesnake Springs	4	26	0.05 ± 0.005	0.009 ± 0.004	0.02 ± 0.004	---	---	---	---
Yakima Barricade	5	25	0.04 ± 0.005	0.007 ± 0.004	0.02 ± 0.004	25	0.002 ± 0.0006	<0.0002 ± 0.0004	0.0009 ± 0.0002
Vernita Bridge	6	26	0.04 ± 0.005	0.009 ± 0.004	0.02 ± 0.004	---	---	---	---
Wahluke #2	7	26	0.05 ± 0.005	0.009 ± 0.004	0.02 ± 0.004	26	0.002 ± 0.0006	<0.0002 ± 0.0003	0.0009 ± 0.0002
Berg Ranch	8	26	0.05 ± 0.005	0.01 ± 0.004	0.02 ± 0.004	26	0.002 ± 0.0006	0.0004 ± 0.0003	0.0009 ± 0.0001
Sagehill	9	26	0.04 ± 0.005	0.007 ± 0.004	0.02 ± 0.005	---	---	---	---
Ringold	10	25	0.04 ± 0.005	0.008 ± 0.004	0.02 ± 0.004	---	---	---	---
Othello	11	26	0.05 ± 0.005	0.006 ± 0.004	0.02 ± 0.005	---	---	---	---
Connell	12	25	0.06 ± 0.005	0.01 ± 0.004	0.03 ± 0.005	25	0.002 ± 0.0006	<0.0003 ± 0.0003	<u>0.0009 ± 0.0002</u>
Overall Average					0.02 ± 0.001				0.0009 ± 0.00007
Downwind Perimeter									
Fir Road	13	24	0.04 ± 0.005	0.006 ± 0.004	0.02 ± 0.004	---	---	---	---
Pettett	14	26	0.04 ± 0.005	0.007 ± 0.004	0.02 ± 0.004	26	0.002 ± 0.0006	<0.0001 ± 0.0002	0.0009 ± 0.0002
Byers Landing	15	26	0.04 ± 0.005	0.008 ± 0.004	0.02 ± 0.004	26	0.002 ± 0.0006	0.0005 ± 0.0004	0.001 ± 0.0002
RRC #64	16	26	0.05 ± 0.005	0.007 ± 0.004	0.02 ± 0.004	26	0.001 ± 0.0005	0.0003 ± 0.0003	0.0008 ± 0.0001
Pasco	17	25	0.04 ± 0.005	0.01 ± 0.004	0.03 ± 0.004	---	---	---	---
Richland	18	25	0.05 ± 0.005	0.01 ± 0.004	0.02 ± 0.004	25	0.002 ± 0.0006	0.0004 ± 0.0003	0.0009 ± 0.0002
Horn Rapids - Mi. 12	19	20	0.04 ± 0.005	0.008 ± 0.004	0.02 ± 0.005	20	0.001 ± 0.0006	<0.0003 ± 0.0004	0.0008 ± 0.0002
Horn Rapids Substation	20	15	0.04 ± 0.005	0.007 ± 0.004	0.02 ± 0.005	---	---	---	---
Overall Average					0.02 ± 0.001				0.0009 ± 0.00007
Distant Stations									
Walla Walla	21	24	0.06 ± 0.005	0.01 ± 0.004	0.02 ± 0.005	21	0.001 ± 0.0005	-0.002 ± 0.0005	0.0007 ± 0.0003
McNary Dam	22	24	0.05 ± 0.005	0.009 ± 0.004	0.02 ± 0.005	---	---	---	---
Sunnyside	23	26	0.03 ± 0.005	0.01 ± 0.004	0.02 ± 0.003	26	0.002 ± 0.0006	0.0004 ± 0.0003	0.0009 ± 0.0002
Moses Lake	24	25	0.04 ± 0.004	0.008 ± 0.004	0.02 ± 0.004	25	0.002 ± 0.0006	<0.0003 ± 0.0003	0.0009 ± 0.0002
Washtucna	25	25	0.04 ± 0.004	0.008 ± 0.004	0.02 ± 0.004	---	---	---	---
Overall Average					0.02 ± 0.002				0.0008 ± 0.0001

(a) Maximum and minimum values include the ± two-sigma counting error. Averages include ± two standard error of the calculated mean (95% confidence interval).

(b) From DOE ORDER 5480.1 (Appendix A).

(c) Locations are identified in Figure 2.

(d) Dashed line indicates no analysis was performed.

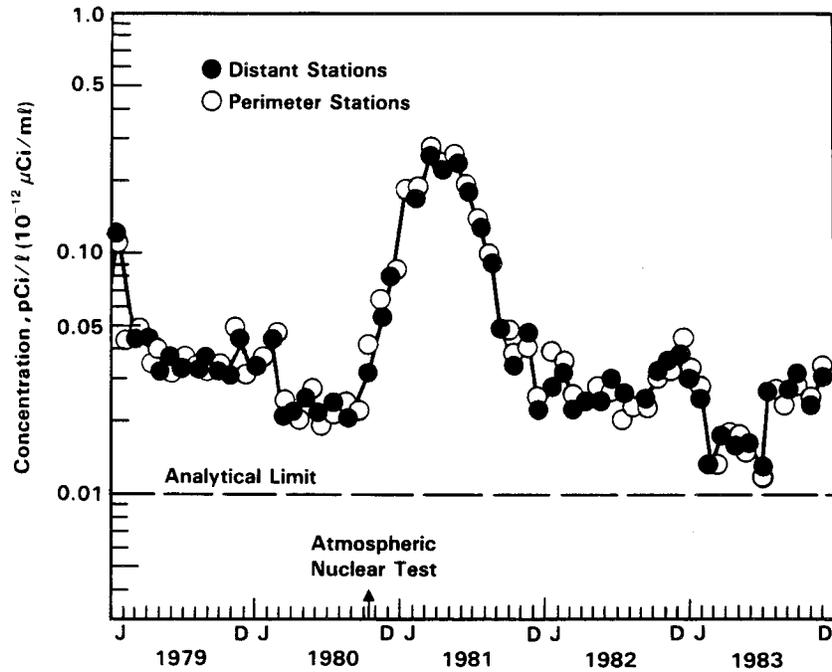


FIGURE 3. Monthly Averaged Air Concentrations for Long-Lived Gross Beta Particulates

The Clean Air Act of 1977 (42 U.S.C. 1857 et seq.) provides for the prevention of significant deterioration of air quality in areas considered to have clean air. Prevention of Significant Deterioration (PSD) permits are required for facilities emitting pollutants which may affect air quality. A PSD permit was issued by EPA in 1980 (No. PSD-X80-14) and limits the amount of NO_x released annually from PUREX operations to 424 MT. The UO_3 Plant is limited to 50 MT per year. The PUREX and UO_3 Plants resumed operations in November 1983 and emissions of NO_x did not exceed the permit limits for annual releases.

During 1981 baghouses were installed to reduce particulate emissions at two coal-fired steam plants located in the 200 Areas. Initial particulate emission testing of the plants by HEHF was completed in 1982. The tests indicated particulate emissions to be well within applicable state and

local limits (Washington State Department of Ecology, 1981; Benton-Franklin-Walla Walla Counties Air Pollution Control Authority, 1980). No further tests for particulate emissions were performed in 1983.

A nine-station ambient nitrogen dioxide (NO_2) sampling network, operated by HEHF in support of PUREX preoperational surveillance programs, was restarted in August 1982. The network last operated in December 1980 and was restarted in an effort to collect a full year's NO_2 background data immediately prior to PUREX startup in late 1983. Data collected by the network in 1983 indicated a maximum observed average NO_2 concentration per station of less than 0.007 parts per million (ppm). The applicable national ambient air standard for NO_2 is 0.05 ppm as an annual arithmetic mean (National Primary and Secondary Ambient Air Quality Standards 1973).

TABLE 2. Selected Airborne Radionuclide Concentrations in the Hanford Environs

Radionuclide	Composite Group(a)	Fraction of Results >DL	Concentration, pCi/m ³ (10 ⁻¹² μCi/m ³)(b)			Concentration Guide, pCi/m ³ (e)
			Maximum	Minimum	Average(c)	
³ H (HTO)(d)	Perimeter	29/43	7.8 ± 3.5	<DL	(2.8 ± 0.6)	200,000
	Downwind Perimeter	14/28	8.7 ± 2.4	<DL	(2.7 ± 1.0)	
	Distant	5/10	7.7 ± 3.1	<DL	(2.9 ± 1.8)	
¹⁴ C(CO ₂)	Perimeter	13/13	1.6 ± 0.2	1.2 ± 0.009	1.4 ± 0.08	1,000,000
	Downwind Perimeter	12/12	1.5 ± 0.1	1.3 ± 0.1	1.4 ± 0.005	
	Distant	5/5	1.5 ± 0.1	1.2 ± 0.2	1.4 ± 0.2	
⁸⁵ Kr	Perimeter	3/3	28 ± 5.5	18 ± 4.4	22 ± 7.5	300,000
	Downwind Perimeter	3/3	21 ± 3.3	18 ± 4.8	20 ± 3.3	
	Distant	5/5	20 ± 3.9	15 ± 4.2	17 ± 2.7	
⁹⁰ Sr	Perimeter	14/28	0.001 ± 0.0002	<DL	(0.0003 ± 0.0001)	30
	Downwind Perimeter	5/16	0.002 ± 0.0003	<DL	(0.0003 ± 0.0002)	
	Distant	3/12	<DL	<DL	(0.0001 ± 0.0001)	
¹³¹ I	Perimeter	0/52	<DL	<DL	(0.0006 ± 0.001)	100
	Downwind Perimeter	0/76	<DL	<DL	(-0.0001 ± 0.001)	
	Distant	0/26	<DL	<DL	(0.001 ± 0.002)	
¹³⁷ Cs	Perimeter	18/91	0.006 ± 0.004	<DL	(0.0003 ± 0.0003)	500
	Downwind Perimeter	10/52	0.003 ± 0.002	<DL	(0.0003 ± 0.0003)	
	Distant	10/39	0.007 ± 0.006	<DL	(0.0007 ± 0.0005)	
U (Natural)	Perimeter	12/12	0.00004 ± 0.00002	0.000005 ± 0.000003	0.00002 ± 0.000007	2
	Downwind Perimeter	12/12	0.00005 ± 0.00002	0.000007 ± 0.000003	0.00003 ± 0.000008	
	Distant	3/3	0.00008 ± 0.00003	0.00004 ± 0.00001	0.00006 ± 0.00003	
²³⁸ Pu	Perimeter	5/28	<DL	<DL	(0.000006 ± 0.000005)	0.07
	Downwind Perimeter	4/16	0.00003 ± 0.00002	<DL	(0.000006 ± 0.000005)	
	Distant	5/12	<DL	<DL	(0.000007 ± 0.000005)	
^{239,240} Pu	Perimeter	18/28	0.00006 ± 0.00003	<DL	(0.00002 ± 0.000008)	0.06
	Downwind Perimeter	10/16	0.00008 ± 0.00005	<DL	(0.00003 ± 0.00001)	
	Distant	11/12	0.00006 ± 0.00005	<DL	0.00002 ± 0.00001	

>DL = Greater than detection level, i.e., radionuclide concentration was greater than its associated ± two sigma counting error.

<DL = Less than detection level, i.e., radionuclide concentration was less than or equal to its associated ± two sigma counting error.

(a) Perimeter, Downwind Perimeter, and Distant sampling locations are identified in Table 1.

(b) Maximum and minimum values include ± two sigma counting error. Averages include ± two standard error of the calculated mean (95% confidence interval).

(c) Parenthesis enclosing an average value indicates the radionuclide was not detectable (see Appendix B).

(d) Values for ³H are reported for August through December 1983. ³H data for January through July 1983 were unavailable due to equipment failure.

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

COLUMBIA RIVER RADIOLOGICAL MONITORING

The Columbia River, which runs through the northern part of the Hanford Site and forms the site's eastern boundary, constitutes the primary environmental exposure pathway for radioactivity in liquid effluents. In the early years of Hanford operations, substantial quantities of radioactivity were released to the river from the production reactors located along the shoreline. However, the shutdown of the old production reactors and the addition of liquid effluent control systems at N Reactor (the only currently operating reactor) have substantially reduced radionuclide discharges to the river.

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

Samples collected during 1983 showed that the impact of Hanford on radionuclide levels in the Columbia River was very small. Slightly higher concentrations were observed downstream for ^3H , ^{90}Sr , ^{129}I and uranium.

SAMPLE COLLECTION AND ANALYSIS

Samples of Columbia River water were collected throughout 1983 at the upstream and downstream locations shown in Figure 4. Two types of samplers were used: a conventional cumulative-type sampler that intermittently collected a measured volume of river water in a large container, and a specially designed large-volume sampler that continuously collected waterborne radionuclides from the river on a series of filters and ion-exchange resins.

The cumulative sampler consisted of a timer-activated solenoid valve that intermittently diverted a continuously flowing stream of Columbia River water into a container. Approximately 30 ml of water were diverted into the container every 30 minutes so that by the end of each monthly sampling period about 40 liters were accumulated. The cumulative sampler was used to collect river water samples for tritium, ^{89}Sr , ^{90}Sr , and uranium analyses.

The large-volume sampler has been described by Fix and Robertson (1976). River water was continuously pumped through the sampler at a rate of 50 ml/min. Particulates greater than 0.45 μm in diameter were removed from the sample stream by a series of filters, and dissolved radionuclides were accumulated on a mixed-bed ion-exchange resin column. The filtration media were exchanged at two-week intervals during which time approximately 1000 liters of river water were pumped through the sampler.

Samples were analyzed for gamma-emitting radionuclides, ^{129}I , and plutonium.

RESULTS

Results of the analysis of Columbia River water samples for 1983 are summarized in Tables 3 and 4. Results for samples collected using the large-volume sampler are provided for both the particulate and dissolved components. The data

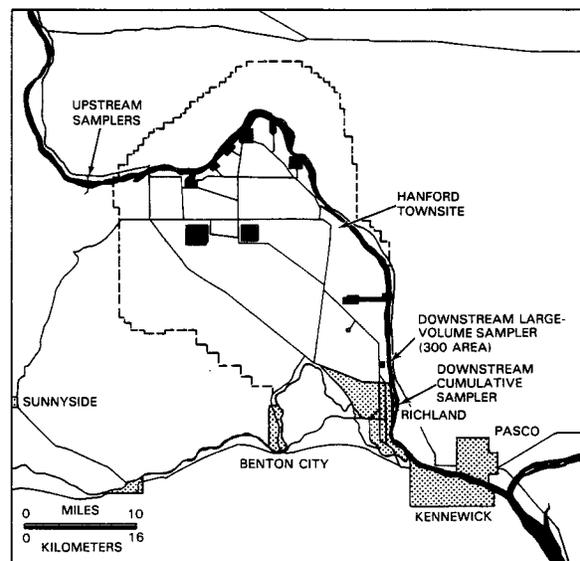


FIGURE 4. Columbia River Water and Spring Sampling Locations

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

Radionuclide(b)	Fraction of Results >DL	Concentration, pCi/l (10^{-9} μ Ci/ml)(a)		
		Minimum Result(c)	Maximum Result	Average(c)
^3H	13/13	40 ± 11	200 ± 22	100 ± 26
^{60}Co	Particulate	<DL	0.0075 ± 0.0067	(0.0021 ± 0.0012)
	Dissolved	<DL	0.0099 ± 0.0078	(0.0042 ± 0.0025)
^{89}Sr	3/13	<DL	0.18 ± 0.11	(0.063 ± 0.050)
^{90}Sr	12/13	<DL	0.46 ± 0.034	0.18 ± 0.061
^{95}Zr	Particulate	<DL	0.0050 ± 0.0044	(-0.00036 ± 0.0015)
	Dissolved	<DL	<DL	(-0.00014 ± 0.0033)
^{95}Nb	Particulate	<DL	0.0058 ± 0.0045	(0.0018 ± 0.00094)
	Dissolved	<DL	0.018 ± 0.013	(0.0019 ± 0.0027)
^{106}Ru	Particulate	<DL	0.033 ± 0.024	(0.0023 ± 0.0082)
	Dissolved	<DL	<DL	(0.0016 ± 0.019)
^{129}I	Dissolved	$1.4 \times 10^{-5} \pm 1.6 \times 10^{-6}$	$3.8 \times 10^{-5} \pm 4.1 \times 10^{-6}$	$2.4 \times 10^{-5} \pm 1.3 \times 10^{-5}$
^{131}I	Particulate	<DL	<DL	($-2.4 \times 10^{-4} \pm 1.6 \times 10^{-3}$)
	Dissolved	<DL	0.014 ± 0.012	(0.0013 ± 0.0041)
^{137}Cs	Particulate	<DL	0.030 ± 0.0053	0.018 ± 0.0025
	Dissolved	0.023 ± 0.0044	0.084 ± 0.013	0.039 ± 0.0058
^{144}Ce	Particulate	<DL	0.0072 ± 0.0072	(0.00032 ± 0.0024)
	Dissolved	<DL	<DL	(0.00017 ± 0.0052)
U (natural)	12/13	<DL	0.44 ± 0.15	0.27 ± 0.080
^{238}Pu	Particulate	<DL	<DL	($-8.9 \times 10^{-6} \pm 2.4 \times 10^{-6}$)
	Dissolved	<DL	$9.9 \times 10^{-5} \pm 7.5 \times 10^{-5}$	($-2.0 \times 10^{-6} \pm 2.6 \times 10^{-5}$)
$^{239,240}\text{Pu}$	Particulate	$1.8 \times 10^{-5} \pm 6.0 \times 10^{-6}$	$2.8 \times 10^{-5} \pm 4.0 \times 10^{-6}$	$2.3 \times 10^{-5} \pm 6.3 \times 10^{-6}$
	Dissolved	<DL	$9.3 \times 10^{-5} \pm 7.0 \times 10^{-5}$	($-6.0 \times 10^{-6} \pm 2.0 \times 10^{-5}$)

>DL = Greater than detection level, i.e., radionuclide concentration was greater than the associated \pm two sigma counting error.

<DL = Less than detection level, i.e., radionuclide concentration was less than or equal to the associated \pm two sigma counting error.

(a) Maximum and minimum values include \pm two sigma counting error. Averages include \pm two standard error of the calculated mean (95% confidence interval).

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

(c) Parenthesis enclosing an average indicates the radionuclide was not detected (see Appendix B).

show that in every case downstream radionuclide concentrations were well below the applicable DOE Concentration Guide. Measured releases of radioactive liquid effluents to the Columbia River during 1983 are listed in Table 25.

Radionuclides consistently observed (i.e., in more than 75% of the samples) both upstream and downstream of the site were ^3H , ^{90}Sr , ^{129}I , ^{137}Cs , U, and $^{239,240}\text{Pu}$. While ^3H and U occur natu-

rally, all are present in worldwide fallout, and all are associated with nuclear operations at Hanford.

The Hanford contribution of low levels of radionuclides to the river was partially attributed to the flow of ground water from the unconfined aquifer underlying the site into which process cooling water and low-level liquid wastes have been discharged. Results of routine ground-water

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

Radionuclide(b)	Fraction of Results >DL	Concentration, pCi/l (10^{-9} μ Ci/ml)(a)			Concentration Guide(d)	
		Minimum Result(c)	Maximum Result	Average(c)		
^3H		13/13	39 \pm 12	240 \pm 21	130 \pm 28	3,000,000
^{60}Co	Particulate	15/26	<DL	0.054 \pm 0.0070	(0.0078 \pm 0.0045)	30,000
	Dissolved	12/26	<DL	0.021 \pm 0.0071	(0.0085 \pm 0.0030)	
^{89}Sr		6/12	<DL	0.89 \pm 0.29	(0.23 \pm 0.16)	3,000
^{90}Sr		11/11	0.10 \pm 0.034	0.35 \pm 0.068	0.22 \pm 0.048	300
^{95}Zr	Particulate	1/26	<DL	0.011 \pm 0.0098	(0.0026 \pm 0.0050)	60,000
	Dissolved	1/26	<DL	0.010 \pm 0.0092	(0.0016 \pm 0.0032)	
^{95}Nb	Particulate	3/26	<DL	0.76 \pm 0.60	(0.031 \pm 0.063)	100,000
	Dissolved	5/26	<DL	0.011 \pm 0.0078	(0.0031 \pm 0.0022)	
^{106}Ru	Particulate	0/26	<DL	<DL	(-0.0021 \pm 0.0068)	10,000
	Dissolved	0/26	<DL	<DL	(0.0082 \pm 0.014)	
^{129}I	Dissolved	4/4	3.9 $\times 10^{-5}$ \pm 4.1 $\times 10^{-6}$	1.2 $\times 10^{-4}$ \pm 1.2 $\times 10^{-5}$	7.5 $\times 10^{-5}$ \pm 3.9 $\times 10^{-5}$	60
^{131}I	Particulate	3/26	<DL	0.0067 \pm 0.0058	(0.0017 \pm 0.0013)	300
	Dissolved	9/26	<DL	0.035 \pm 0.014	(0.012 \pm 0.0048)	
^{137}Cs	Particulate	26/26	1.3 $\times 10^{-4}$ \pm 3.0 $\times 10^{-5}$	0.027 \pm 0.0041	0.017 \pm 0.0026	20,000
	Dissolved	26/26	0.022 \pm 0.0066	0.063 \pm 0.011	0.036 \pm 0.0038	
^{144}Ce	Particulate	0/26	<DL	<DL	(3.4 $\times 10^{-4}$ \pm 2.2 $\times 10^{-3}$)	10,000
	Dissolved	0/26	<DL	<DL	(-0.0030 \pm 0.0048)	
U (Natural)		12/13	<DL	1.0 \pm 0.37	0.50 \pm 0.15	600
^{238}Pu	Particulate	0/4	<DL	<DL	(-1.4 $\times 10^{-5}$ \pm 1.2 $\times 10^{-6}$)	5,000
	Dissolved	0/4	<DL	<DL	(-0.00014 \pm 0.000025)	
$^{239,240}\text{Pu}$	Particulate	4/4	1.4 $\times 10^{-5}$ \pm 2.0 $\times 10^{-6}$	3.3 $\times 10^{-5}$ \pm 6.0 $\times 10^{-6}$	2.3 $\times 10^{-5}$ \pm 9.5 $\times 10^{-6}$	5,000
	Dissolved	3/4	<DL	1.4 $\times 10^{-4}$ \pm 8.0 $\times 10^{-5}$	(6.2 $\times 10^{-5}$ \pm 7.3 $\times 10^{-5}$)	

>DL =Greater than detection level, i.e., radionuclide concentration was greater than the associated \pm two sigma counting error.

<DL =Less than detection level; i.e., radionuclide concentration was less than or equal to the associated \pm two sigma counting error.

(a) Maximum and minimum values include \pm two sigma counting error. Averages include \pm two standard error of the calculated mean (95% confidence interval).

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

(c) Parenthesis enclosing an average value indicates the radionuclide was not detectable (see Appendix B).

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

monitoring of the Hanford aquifer have indicated that water discharged to the aquifer in various operating areas, along with the soluble contaminants, has flowed toward the Columbia River.

Seepage of ground water from the aquifer into the Columbia River was evident from natural springs occurring along the Hanford shoreline both at and below the waterline. Some sampling of

these springs was performed in the past. Additional sampling of 47 shoreline springs exposed during low river flow in the fall and winter was performed in 1983. Springs sampled from the Vernita Bridge downstream to the 300 Area were analyzed for tritium. Springs in the vicinity of the 300 Area were analyzed for uranium. Other springs were analyzed for gross beta and ^{129}I . A summary of the results is presented in Table 5.

TABLE 5. Concentration of Radionuclides in Shoreline Surface Springs Sampled in 1983

Radionuclide	Area of Spring Sampling	Concentration, pCi/l (10^{-9} μ Ci/ml)(a)	
		Maximum Result	Minimum Result
^3H	Vernita to 300 Area	110,000 \pm 995	(66 \pm 200)
U (natural)	300 Area Vicinity	16 \pm 5.7	3.0 \pm 1.1
Gross Beta	100-H to past Hanford Townsite	35 \pm 4.4	0.21 \pm 1.3
^{129}I	Hanford Townsite Vicinity	0.062 \pm 0.0068	0.00003 \pm 0.000002

(a) Maximum and minimum values include \pm two sigma counting error. Values are enclosed in parenthesis if concentration is less than or equal to the associated two sigma counting error.

The highest concentrations of ^3H , ^{129}I , and gross beta were observed in springs near the Hanford Townsite (see Figure 4). This information substantiates results in past ground-water reports indicating that ground water from the 200 Areas has reached the Columbia River near the Hanford Townsite. The uranium concentrations measured in the springs near the 300 Area were slightly elevated above concentrations measured in the river (see Table 4). Uranium is a primary constituent in the ground water beneath the 300 Area. The maximum concentrations of all radionuclides observed in the springs were well below the applicable DOE Concentration Guides.

Figure 5 provides a comparison of ^{129}I upstream and downstream of the site during the past five years and shows the effect of river flow rate on the observed downstream levels. As shown in this figure, the differences between the upstream and downstream locations during 1983 were similar to previous years. However, as noted in Tables 3 and 4, the error terms associated with the results indicate no quantifiable difference between average upstream and downstream concentrations for 1983. The dose impact due to ^{129}I in Columbia River water was negligible, as discussed in the "Radiological Impact of Hanford Operations" section.

The amount of tritium in 100-N effluents discharged to the river in 1983 (180 Ci) was half that released in 1982. Concentrations observed upstream and downstream were lower than those observed in 1982. Tritium was also present in the Hanford aquifer; however, the contribution from the aquifer was difficult to distinguish in the presence of 100 N effluents and the relatively

high background concentration of tritium in the Columbia River.

An apparent difference in ^{90}Sr concentrations between upstream and downstream sampling locations was reported in 1981 (Sula et al. 1982). The sampling frequency for ^{90}Sr was increased from quarterly to monthly in 1982 as a result of the 1981 measurements, and monthly sampling was continued through 1983. Strontium-90 concentrations during 1983 for the monthly cumulative samples averaged 0.18 pCi/l and 0.22 pCi/l at the upstream and downstream locations, respectively. Observation of ^{90}Sr concentrations for the past 5 years (see Table 6) indicates that, other than 1981, differences between upstream and downstream locations have been very slight.

Cesium-137 and $^{239,240}\text{Pu}$ concentrations upstream and downstream were virtually identical. Other radionuclides were observed only occasionally in river water samples, and as a result, annual average concentrations could not be determined with any degree of certainty. Mean values for these radionuclides are reported in Tables 3 and 4 but are enclosed within parentheses to emphasize the relatively high degree of uncertainty associated with the result. Of these radionuclides, ^{60}Co , ^{131}I , and ^{89}Sr were observed more frequently in the downstream than in the upstream samples, indicating a possible Hanford influence. Potential Hanford sources of ^{60}Co are effluents from N Reactor (2.2 Ci during 1983) and resuspension of ^{60}Co deposited in the riverbed during past operations of the single-pass production reactors. Concentrations in the downstream samples were similar to those observed in previous years.

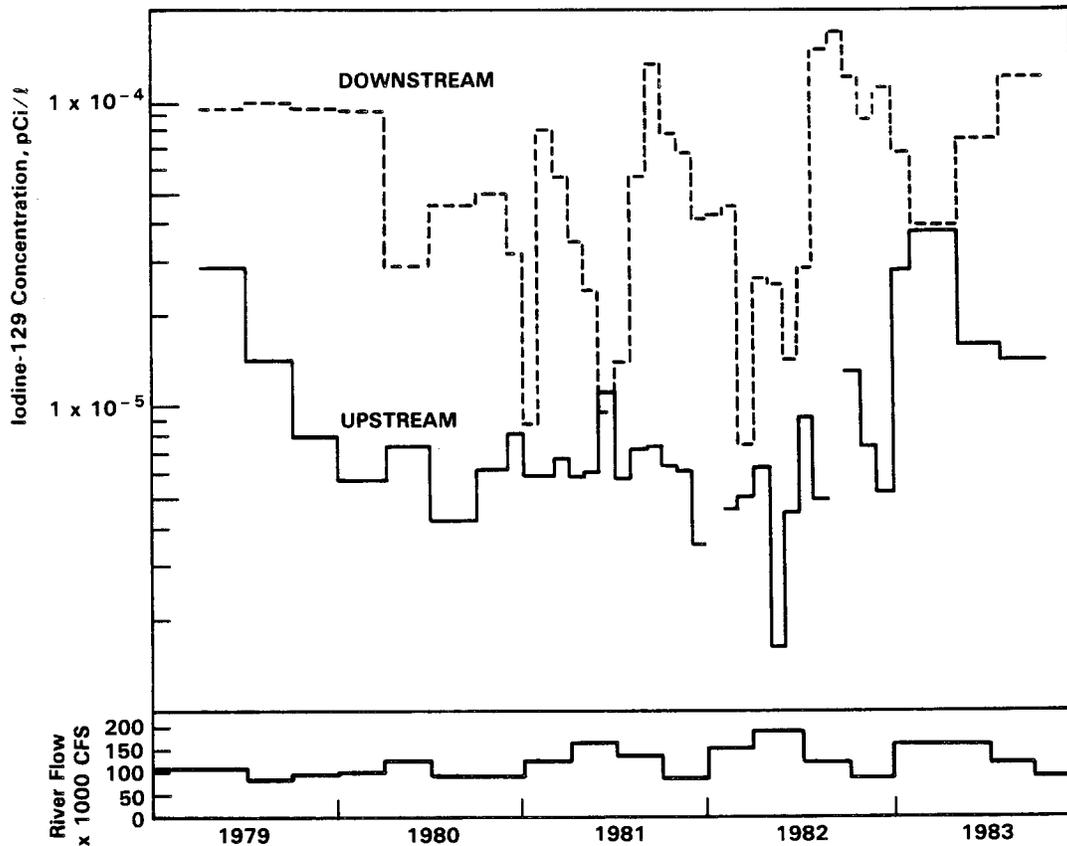


FIGURE 5. Columbia River Flow Rates and Iodine-129 Concentrations

TABLE 6. Strontium-90 in Columbia River Water

Year	Average Annual Concentration, pCi/l (10^{-9} μ Ci/ml)(a)	
	Upstream	Downstream
1979	$0.36 \pm 0.12^{(b)}$	0.34 ± 0.18
1980	0.23 ± 0.12	0.20 ± 0.079
1981	0.15 ± 0.043	0.23 ± 0.055
1982	0.18 ± 0.052	0.17 ± 0.068
1983	0.18 ± 0.061	$0.22 \pm 0.048^{(b)}$

(a) Averages include \pm two standard error of the calculated mean (95% confidence interval).

(b) The data set included one extreme outlier value which was excluded in the calculation of the average.

Iodine-131 was observed at very low concentrations in several downstream samples, similar to previous years. The maximum observed ^{131}I concentration during 1983 was 0.035 pCi/l. The N Reactor, which reported 1.3 Ci discharged to

the river during 1983, is the only Hanford source of ^{131}I to the river. The positive ^{131}I identifications in the downstream samples correlated with extended periods of N Reactor operations and seasonally low river flow rates. Concentrations of ^{89}Sr in several downstream samples were slightly higher than concentrations in upstream samples. The only Hanford source of ^{89}Sr to the river is the N Reactor, which discharged 1.0 Ci to the river in 1983. Because of the low concentrations of radionuclides in the river water, dose impacts in the "Radiological Impact of Hanford Operations" section were calculated based on the reported 1983 releases from N Reactor and not the measured river concentrations.

Cumulative raw water samples collected at the Richland water treatment plant were analyzed for gross alpha and gross beta radioactivity. Washington State water quality standards (Washington State Department of Ecology 1983) require that radionuclide concentrations in

drinking water not exceed 15 pCi/l of gross alpha activity and that the average annual concentration of beta particle and photon radioactivity from manmade radionuclides not produce an annual dose equivalent to the total body or to any internal organ greater than 4 mrem/yr. Compliance with 4 mrem/yr dose

limitation may be assumed if the average annual concentration for gross beta activity, tritium, and ⁹⁰Sr is less than 50 pCi/l, 20,000 pCi/l and 8 pCi/l, respectively. Compliance with the state standard is demonstrated by comparing the above concentration limits with the applicable 1983 sampling data in Tables 4 and 7.

TABLE 7. Radiological Analyses of Richland Raw Water

Measurement	No. of Samples	No. of Results >DL	Concentration, pCi/l (10 ⁻⁹ μCi/ml) ^(a)			
			Maximum	Minimum	Average ^(b)	State Standard
Gross Alpha	13	9	0.93 ± 0.47	<DL	0.52 ± 0.18	15
Gross Beta	13	3	11 ± 5.5	<DL	(3.7 ± 2.0)	50

(a) Maximum and minimum values include ± two sigma counting error. Averages include ± two standard error of the calculated mean (95% confidence interval).

(b) If fewer than 75% of the results were >DL, the average was enclosed in parenthesis.

COLUMBIA RIVER NONRADIOLOGICAL 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. This designation requires that industrial uses of the river be compatible with all other uses of the water, including drinking water, recreation, and wildlife.

Waste water from Hanford activities is discharged at eight points along the Hanford reach of the Columbia River. These discharges consist of backwash water from water intake screens, cooling water, water storage tank overflow, fish laboratory waste water, and man-made riverbank springs. Each discharge point is identified in an existing National Pollutant Discharge Elimination System (NPDES) permit issued by the EPA. Effluents from each of these outfalls were routinely monitored and reported by the operating contractors as required by the NPDES permit.

Measurements of several Columbia River water quality parameters were conducted routinely during 1983 both upstream and downstream of the Hanford Site to monitor any effects on the river that may be attributable to Hanford discharges and to determine compliance with the Class A designation requirements. The measurements indicated that Hanford operations had minimal, if any, impact on the quality of the Columbia River water.

SAMPLE COLLECTION AND ANALYSIS

Grab samples of Columbia River water were collected weekly at the Vernita Bridge (upstream of Hanford) and at Richland (downstream) and analyzed to indicate the general water quality changes along the Hanford reach of the river. Analyses were performed by PNL personnel in the field for dissolved oxygen, and in the laboratory for turbidity, pH, and nitrate content. Monthly samples were delivered to HEHF for biological oxygen demand (BOD) and coliform bacteria analyses.

Water quality measurements of the Columbia River were also performed by the United States Geological Survey (USGS) at the same upstream and downstream locations. The USGS samples consisted of cross-section composites collected bimonthly at the Vernita Bridge and quarterly at Richland. Analyses were performed at the USGS laboratory in Denver, Colorado for numerous physical, biological, and chemical constituents. The USGS was also contracted to provide continuous temperature monitoring of the river upstream and downstream and flow-rate measurements upstream of the site.

RESULTS

Figure 6 illustrates sampling results for constituents for which state water quality regulations exist. Average monthly values are shown except

for fecal coliform and pH values which are shown individually. Average monthly river flow and periods of N Reactor operation are included to aid in the interpretation of the results. The standard for pH was exceeded slightly both upstream and downstream in a few instances, but the two locations were in general agreement throughout the year. Downstream fecal coliform values were higher than those upstream for the latter half of 1983. The median fecal coliform values for these data, as well as that gathered by the USGS (Table 8) at the upstream and downstream locations, showed general agreement. No substantial differences were apparent between upstream versus downstream measurements of turbidity or dissolved oxygen.

No substantial difference existed between upstream and downstream temperatures, and monthly averages remained within the standard during 1983. While the highest downstream temperatures coincided with periods of low river flow and N Reactor operation, upstream temperatures exhibited the same trend. This suggests that heat contributed from N Reactor effluents was, at best, a small fraction of the temperature increases observed. Insolation, therefore, appeared to be the major cause of water temperature increases along the Hanford reach.

Table 8 summarizes the results of water quality analyses including a number of parameters for

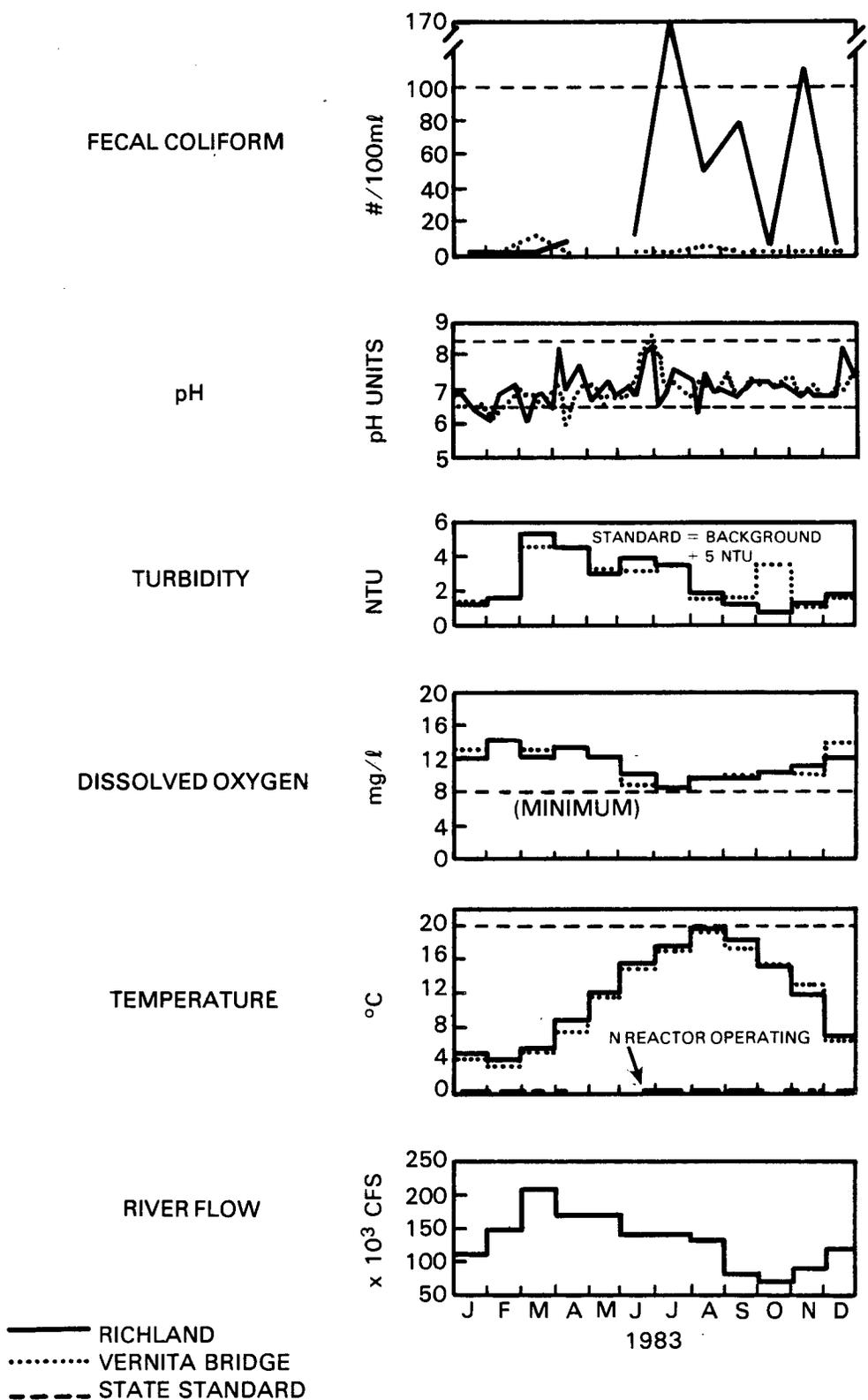


FIGURE 6. Columbia River Water Quality and Flow Rates for 1983

TABLE 8. Columbia River Water Quality Data

Analysis	Units	Vernita Bridge (Upstream)				Richland (Downstream)				
		No. of Samples	Maximum	Minimum	Annual Average(a)	No. of Samples	Maximum	Minimum	Annual Average(a)	State Standard(b)
Environmental Surveillance Sampling Program										
Dissolved O ₂	mg/l	49	17	7.8	11 ± 0.57	52	15	6.9	11 ± 0.50	8 (minimum)
Turbidity	NTU(c)	50	8.1	0.70	2.5 ± 0.5	48	7.2	0.70	2.4 ± 0.5	5 + background
pH		50	8.6	5.9	N/A	49	8.2	6.3	N/A	8.5 - 6.5
Fecal coliform	#/100 ml	11	11	<2.0	2.0(d)	11	170	0	8.0(d)	100
Total coliform	#/100 ml	11	240	5.0	27(d)	11	920	16	49(d)	
Biological Oxygen Demand	mg/l	11	4.0	2.0	2.9 ± 0.39	11	4.5	0.8	2.3 ± 0.64	
Nitrate	mg/l	46	0.48	0.028	0.23 ± 0.042	46	1.7	0.038	0.27 ± 0.077	
USGS Sampling Program (e)										
Temperature(f)	°C	365	20	2.5	11.2 ± 0.6	346	21	2.9	12 ± 0.6	20 (maximum)
Dissolved O ₂	mg/l	6	13.0	9.6	11 ± 1.2	4	14	8.2	11 ± 2.5	8 (minimum)
Turbidity	NTU(c)	6	2.1	0.80	1.3 ± 0.46	4	1.8	1.0	1.4 ± 0.46	5 + background
pH		6	8.4	7.5	N/A	3	7.8	7.4	N/A	8.5 - 6.5
Fecal coliform	#/100 ml	6	2	<1	1.5(d)	4	5000	<1	1.5(d)	100
Suspended solids, 105°C	mg/l	6	400	<1	69 ± 130	4	12	<1	6.5 ± 4.5	
Dissolved solids, 180°C	mg/l	6	89	69	78 ± 6.1	4	93	64	81 ± 13	
Specific conductance	µmhos	6	160	120	142 ± 10.9	4	160	120	140 ± 19	
Hardness, as CaCO ₃	mg/l	6	76	58	66 ± 5.6	4	78	56	66 ± 9.7	
Phosphorus, total	mg/l	6	0.04	0.010	0.025 ± 0.0086	4	0.080	0.020	0.043 ± 0.026	
Chloride, dissolved	mg/l	6	6.0	0.9	2.2 ± 1.6	4	3.4	1.0	1.9 ± 1.1	
Chromium, total	mg/l	1	—	—	<10	3	<10	<10	<10	
Nitrogen, Kjeldahl	mg/l	6	1.2	0.20	0.53 ± 0.29	4	0.70	0.50	0.58 ± 0.096	

(a) Average values include ± two standard error of the calculated mean (95% confidence interval).

(b) See Appendix A.

(c) Nephelometric Turbidity Units.

(d) Annual median.

(e) Provisional data subject to revision.

(f) Each value represents a daily average.

N/A = Not Applicable.

which state standards do not currently exist. Data for a number of the constituents were provided by the USGS. Results of USGS analyses that duplicate onsite analyses were generally comparable. None of the analytical results indicated a significant deterioration in water quality at the downstream sampling locations.

The NPDES-permitted discharge locations and the parameters routinely measured are included in Table 9. One high monthly flow average was

reported at one of the 100-N Area discharges in late 1983. There were no other permit violations reported in 1983.

As discussed in the "Columbia River Radiological Monitoring" section, 47 natural springs along the river shoreline were sampled during periods of low river flow in 1983. All of the springs were analyzed for nitrate. Concentrations ranged from 0.18 to 17 ppm, the highest occurring in the vicinity of the Hanford townsite.

TABLE 9. Measurements for NPDES Permitted Discharges at Hanford^(a)

Measurement	Location		
	100-K Area (2 Discharges)	100-N Area (5 Discharges)	300 Area (1 Discharge)
Flow Rate	X	X	X
Suspended Solids	X	X	X
Temperature	X	X	---
pH	X	X	X
Chlorine	X	X	---
Oil and Grease	---(b)	X	---
Heat Discharged	---	X	---
Settleable Solids	---	---	X
Iron	---	X	---
Ammonia	---	X	---
Chromium	---	X	---

(a) NPDES Permit No. WA-000374-3 (USEPA 1983b).

(b) Dashed line indicates no measurement.

GROUND WATER

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

The Hanford ground water is sampled at a large number of locations on the site, and results of the sampling program are provided in annual reports titled "Ground-Water Surveillance at the Hanford Site." Results of ground-water monitoring for 1983 showed that water discharged to the ground in the 200 Areas had gradually moved to the Columbia River and that ^3H and other highly mobile contaminants were entering the river. The overall effect of the ground-water contribution to currently existing radionuclide concentrations in the Columbia River was small.

Contaminants in the ground water were monitored by analysis of samples collected from a system of wells located throughout the Hanford Site. The results of these analyses provide information concerning the distribution of radionuclides and other contaminants in the ground water. Movement of contaminants with the ground water was inferred from interpretation of trends in the measured concentrations.

The primary analyses performed on ground-water samples were for ^3H and NO_3 , with additional analyses for ^{90}Sr , ^{137}Cs , ^{60}Co , ^{129}I , ^{99}Tc , U, F⁻, Cr⁺⁶, gross alpha, gross beta and gamma performed on selected wells. Figure 7 shows isopleths of ^3H concentrations greater than 1000 pCi/l based on interpretation of ground-water sample analyses performed during 1983. As illustrated in this figure, ^3H contamination in Hanford ground water has migrated to the east and south east from the 200 Areas.

As discussed in the "Columbia River Radiological Monitoring" section, measured concentrations of ^{129}I in the river indicated a contribution from Hanford that was attributed to the flow of ground water into the river. However, the net increase in the downstream concentration of ^{129}I was not quantifiable for 1983. The concentration of ^{129}I in the river was very low and would produce a negligible dose impact as discussed in the "Radiological Dose Impact of Hanford Operations" section.

Analyses of ground-water samples collected during 1983 from wells near the Columbia River, directly east of the 200 Areas, indicated a range in ^3H concentrations of approximately 1000 to 200,000 pCi/l. Although this ground water is entering the river, the input of ^3H from the aquifer during 1983 was not enough to be accurately measured in the presence of background concentrations of ^3H normally found in the Columbia River.

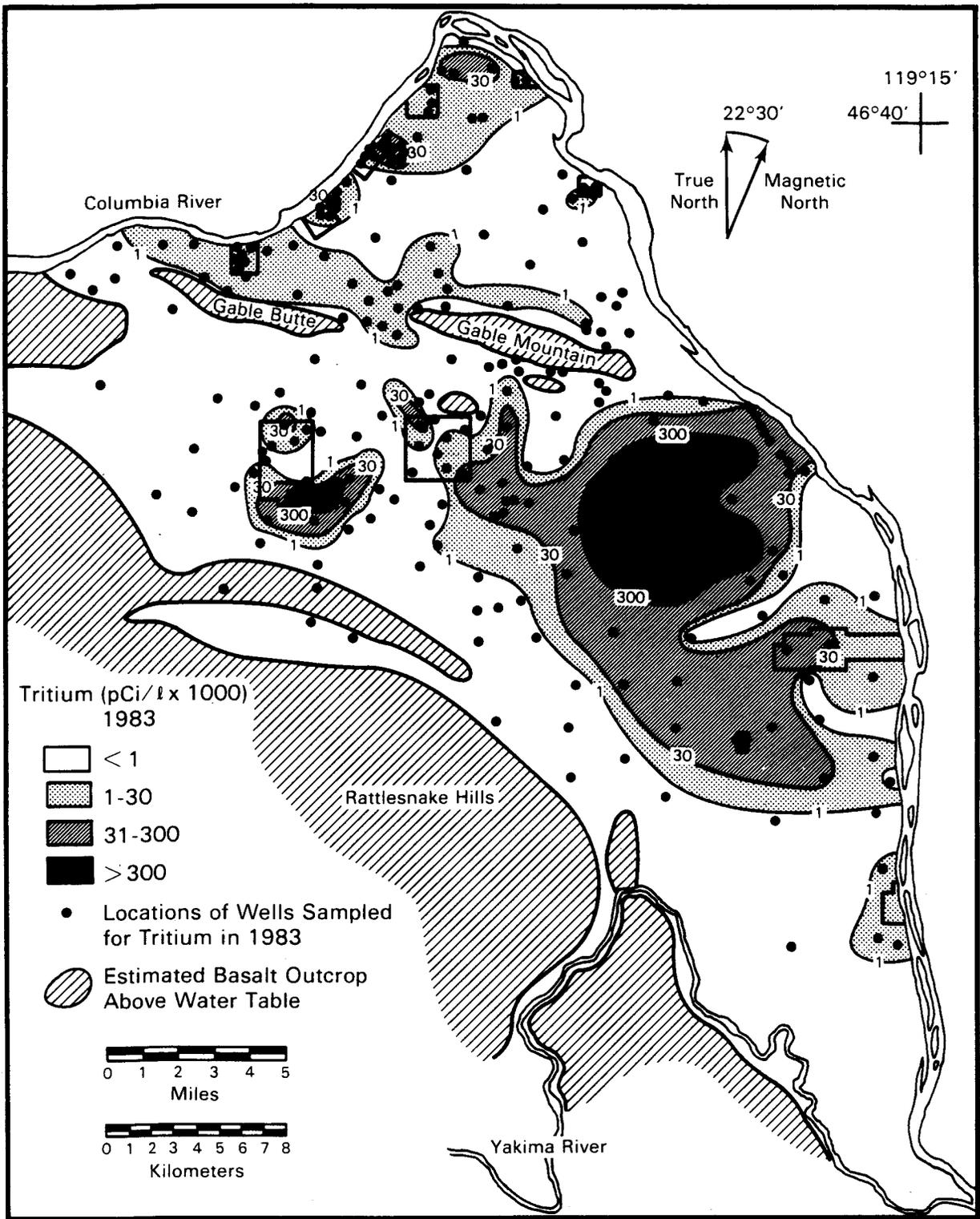


FIGURE 7. Tritium Distribution in the Unconfined Hanford Aquifer

FOODSTUFFS

Alfalfa and several types of foodstuffs, including milk, leafy vegetables, fruits, beef, chickens, eggs, and wheat were collected at several locations in the Hanford Site environs during 1983. All samples were analyzed for ^{90}Sr and ^{137}Cs . Milk samples were analyzed for ^{131}I , ^{129}I , ^{89}Sr , and tritium. Fruit samples were analyzed for tritium. Samples were collected primarily from locations in the prevalent downwind directions from the site, i.e., to the south and east of the site. Samples also were collected in generally upwind directions somewhat distant from the site to provide information on radioactivity levels that could be attributed to worldwide fallout. Foodstuffs collected in the Riverview Area were irrigated with Columbia River water and thus provided information regarding radionuclide concentrations potentially attributable to radionuclides in the river.

Samples collected during 1983, as in recent years, indicated no apparent Hanford contribution to radioactivity levels in locally produced foodstuffs. Tritium, ^{90}Sr and ^{137}Cs were found to be present in a number of the samples; however, the concentrations observed in samples collected near the Hanford Site were similar to background levels observed in samples collected away from the site.

MILK

Samples of raw, whole milk were collected from several local dairy farms near the site perimeter in the prevalent downwind directions to evaluate possible Hanford impacts. Samples also were collected from dairy farms near Sunnyside and Moses Lake to provide indications of the general concentrations of radionuclides in milk attributable to worldwide fallout. The sampling locations are shown in Figure 8 and listed in Table 10. Samples were collected biweekly throughout the year from the Sagemoor and Sunnyside areas. Samples from the other areas were collected monthly during the year.

As shown in Table 10, there was no indication of the presence of ^{131}I in any of the milk samples collected during 1983. Cesium-137 was identified in about 20% of the samples, but concentrations in all cases were low and within the range attributable to worldwide fallout (USEPA 1983a).

A portion of the milk samples was analyzed for ^{89}Sr and ^{90}Sr . Strontium-89 was not regularly detected in the milk; however, ^{90}Sr was observed in most samples analyzed. Maximum and average concentrations were similar at all locations both near and distant and compared favorably with concentrations observed in recent years. Results of ^{89}Sr and ^{90}Sr analyses in milk were comparable to those measured nationwide by the EPA (USEPA 1983) and thus were attributable to worldwide fallout.

Analyses for ^{129}I and tritium were performed on selected milk samples in 1983. Tritium was identi-

fied in nearly half of the samples, and ^{129}I in all of the samples. Concentrations, however, were low, and no differences were apparent between near-site and distant sampling locations.

LEAFY VEGETABLE

Samples of leafy vegetables (i.e., spinach, leaf lettuce, turnip greens or mustard greens) were obtained once during the summer from gardens located within the sampling areas listed in Table 11. The leafy vegetables provide an indication of radionuclides present in locally grown produce. Three replicate samples, each composed of mixtures of the edible portions of the various leafy vegetables grown at the sampling location, were obtained. Samples were analyzed for ^{90}Sr and ^{137}Cs , and results are provided in Table 11. Strontium-90 was identified in most samples but with no apparent difference between distant and near-site locations. Cesium-137 was identified in about 17% of the samples without any indication of a difference between locations. There were no obvious changes in ^{90}Sr and ^{137}Cs concentrations when compared to recent years.

FRUIT

Samples of apples, cherries, or grapes were collected at picking time from the areas listed in Table 12. Three replicate samples were collected at each sampling location, and the edible portions were analyzed for ^3H , ^{90}Sr and ^{137}Cs . Results are provided in Table 12.

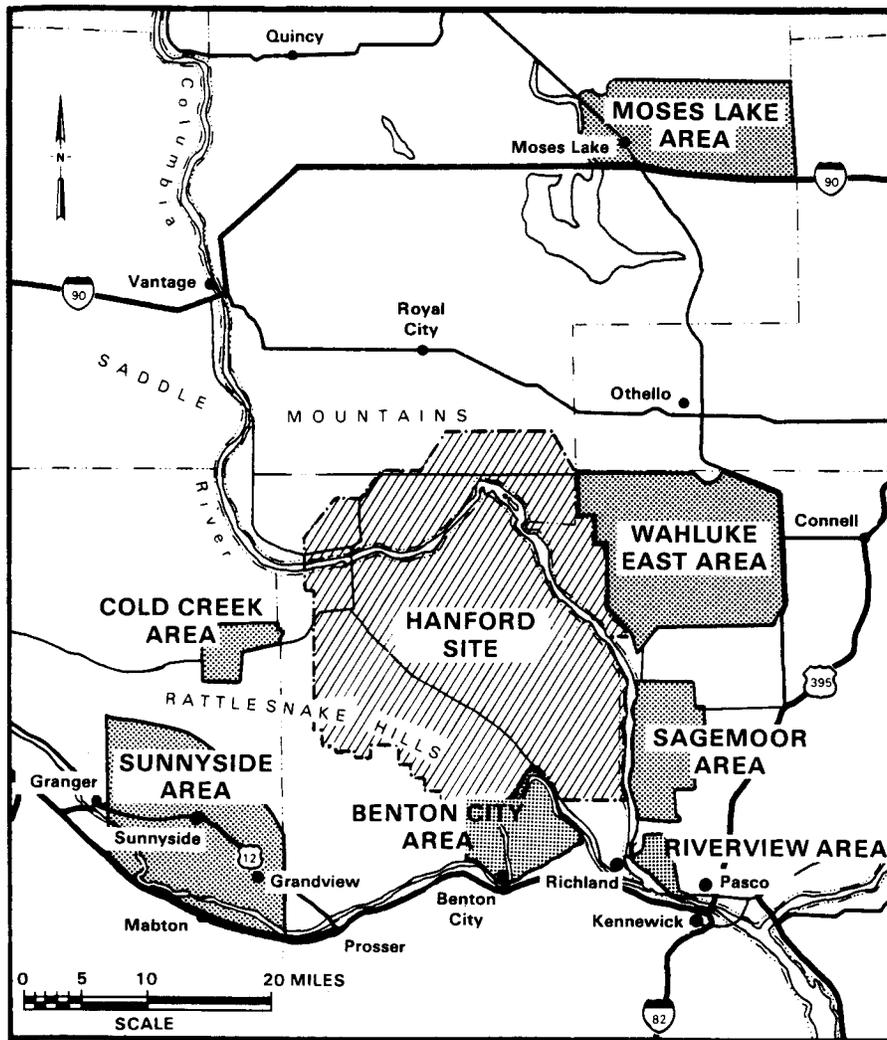


FIGURE 8. Foodstuffs Sampling Areas

Tritium was identified in about one-third of the samples analyzed, and ^{90}Sr in about three-quarters of the samples. Apples had slightly higher tritium concentrations than the other fruits, but otherwise there were no apparent differences between fruit types or sampling locations. As in recent years, ^{137}Cs was generally not detectable in fruit samples.

WHEAT AND ALFALFA

Samples of field-dried wheat and alfalfa were collected from the areas listed in Table 13. Three replicate samples each of wheat and alfalfa were

collected at each location following the final cutting of the growing season and analyzed for ^{90}Sr and ^{137}Cs . Results of the analysis are shown in Table 13.

When sampling of wheat and alfalfa began in 1982, variable moisture content in the samples from different locations may have contributed to the variability in results. Measurements of moisture content obtained for 1983 samples generally did not vary between sample locations. Wheat moisture content averaged 8%, and alfalfa averaged 10%, with the exception of two locations which were higher. Results for 1983

TABLE 10. Radionuclides in Milk Samples

Location(b)	Concentration, pCi/l(a)					
	¹³¹ I			¹³⁷ Cs		
	Fraction of Results >DL	Maximum	Average(d)	Fraction of Results >DL	Maximum	Average(d)
Wahluke East Area Composite	0/13	<DL	(-0.21 ± 0.11)	1/13	3.8 ± 3.7	(-0.53 ± 1.6)
Sagemoor Area Composite	0/26	<DL	(-0.27 ± 0.091)	8/26	7.9 ± 4.2	(2.0 ± 1.4)
Riverview Area(c)	0/13	<DL	(-0.24 ± 0.15)	5/13	14 ± 8.5	(2.9 ± 2.8)
Benton City Area	0/13	<DL	(-0.26 ± 0.17)	1/13	6.1 ± 4.4	(0.46 ± 1.9)
Sunnyside Area	0/26	<DL	(-0.30 ± 0.12)	1/26	13 ± 8.1	(0.38 ± 1.6)
Moses Lake Area	0/13	<DL	(-0.29 ± 0.15)	5/13	14 ± 8.3	(2.6 ± 3.1)

Location(b)	⁸⁹ Sr			⁹⁰ Sr		
	Fraction of Results >DL	Maximum	Average(d)	Fraction of Results >DL	Maximum	Average(d)
	Wahluke East Area Composite	0/4	<DL	(-0.012 ± 0.27)	4/4	1.1 ± 0.32
Sagemoor Area Composite	1/3	0.88 ± 0.55	(0.40 ± 0.63)	4/5	1.7 ± 0.47	0.94 ± 0.66
Riverview Area(c)	1/4	0.64 ± 0.38	(0.64 ± 0.50)	3/4	1.1 ± 0.33	0.91 ± 0.38
Benton City Area	1/3	0.74 ± 0.35	(-0.24 ± 0.71)	5/5	2.4 ± 0.53	1.8 ± 0.46
Sunnyside Area	1/4	0.43 ± 0.35	(0.19 ± 0.41)	3/4	1.4 ± 0.33	0.85 ± 0.45
Moses Lake Area	1/3	0.94 ± 0.55	(0.21 ± 1.0)	3/4	1.6 ± 0.39	1.1 ± 0.61

Location(b)	³ H			¹²⁹ I		
	Fraction of Results >DL	Maximum	Average(d)	Fraction of Results >DL	Maximum	Average(d)
	Wahluke East Area Composite	4/13	420 ± 230	(180 ± 97)	2/2	0.0058 ± 0.00060
Sagemoor Area Composite	7/13	580 ± 260	(260 ± 120)	2/2	0.0076 ± 0.00076	(0.0045 ± 0.0078)
Riverview Area(c)	6/13	420 ± 220	(180 ± 88)	2/2	0.0026 ± 0.00016	0.0021 ± 0.0011
Benton City Area	4/13	700 ± 230	(220 ± 150)	2/2	0.0021 ± 0.00022	(0.0014 ± 0.0017)
Sunnyside Area	5/13	350 ± 220	(150 ± 110)	2/2	0.0033 ± 0.00048	(0.0019 ± 0.0035)
Moses Lake Area	8/13	730 ± 220	(280 ± 110)	2/2	0.00099 ± 0.00011	(0.00060 ± 0.00096)

>DL =Greater than detection level, i.e., radionuclide concentration was greater than the associated ± two sigma counting error.

<DL =Less than detection level, i.e., radionuclide concentration was less than or equal to the associated ± two sigma counting error.

(a) Maximum values include ± two sigma counting error. Averages include ± two standard error of the calculated mean (95% confidence interval).

(b) Refer to Figure 8.

(c) Drinking and irrigation water obtained from the Columbia River.

(d) Parenthesis enclosing an average value indicates the radionuclide was not detectable (see Appendix B).

samples are reported on a dry weight basis, eliminating any effect due to different moisture contents. As in 1982, ⁹⁰Sr was identified in nearly all of the samples, and ¹³⁷Cs was identified in very few samples. No distinct difference in radionuclide concentrations was apparent in the samples from near the site compared to samples collected far from the site.

BEEF, POULTRY AND EGGS

Samples of locally produced chicken and eggs were collected twice and beef once during 1983 from the areas listed in Table 14. Table 14 provides results of analysis of the samples for ¹³⁷Cs and ⁹⁰Sr. Results were all very low, generally near detection levels.

TABLE 11. Radionuclides in Leafy Vegetables

Location(b)	Concentration, pCi/g, wet weight(a)					
	⁹⁰ Sr			¹³⁷ Cs		
	Fraction of Results >DL	Maximum	Average(c)	Fraction of Results >DL	Maximum	Average(c)
Wahluke East Area	2/3	0.004 ± 0.002	(0.001 ± 0.005)	2/3	0.025 ± 0.018	0.019 ± 0.013
Sagemoor Area	2/3	0.003 ± 0.003	(0.001 ± 0.003)	0/3	<DL	(0.002 ± 0.010)
Riverview Area(d)	3/3	0.038 ± 0.004	0.031 ± 0.010	1/3	0.016 ± 0.014	(0.007 ± 0.014)
Benton City Area	3/3	0.020 ± 0.002	0.016 ± 0.005	0/3	<DL	(-0.002 ± 0.007)
Sunnyside Area	3/3	0.015 ± 0.002	(0.006 ± 0.009)	0/3	<DL	(0.003 ± 0.008)
Moses Lake Area	3/3	0.015 ± 0.002	0.010 ± 0.005	0/3	<DL	(0.007 ± 0.008)

>DL =Greater than detection level, i.e., radionuclide concentration was greater than the associated ± two sigma counting error.

<DL =Less than detection level, i.e., radionuclide concentration was less than or equal to the associated ± two sigma counting error.

(a) Maximum values include ± two sigma counting error. Averages include ± two standard error of the calculated mean (95% confidence interval).

(b) Refer to Figure 9.

(c) Parenthesis enclosing an average value indicates the radionuclide was not detectable (see Appendix B).

(d) Irrigated with Columbia River water.

TABLE 12. Radionuclides in Fruit

Fruit/ Location(c)	Concentration, pCi/g, wet weight(a,b)								
	¹³⁷ Cs			⁹⁰ Sr			³ H		
	Fraction of Results >DL	Maximum	Average(d)	Fraction of Results >DL	Maximum	Average(d)	Fraction of Results >DL	Maximum	Average(d)
Apples									
Sagemoor Area	0/3	<DL	(-0.002 ± 0.004)	2/3	0.010 ± 0.005	(0.005 ± 0.007)	1/3	1400 ± 930	970 ± 760
Cold Creek Area	0/3	<DL	(0.003 ± 0.005)	3/3	0.005 ± 0.002	0.004 ± 0.002	0/3	<DL	(650 ± 530)
Sunnyside Area	0/3	<DL	(0.0008 ± 0.006)	3/3	0.006 ± 0.0008	0.004 ± 0.003	3/3	500 ± 220	360 ± 190
Cherries									
Sagemoor Area	0/3	<DL	(0.006 ± 0.007)	2/3	0.006 ± 0.002	(0.003 ± 0.004)	1/3	250 ± 210	(140 ± 180)
Sunnyside Area	0/3	<DL	(-0.010 ± 0.008)	1/3	0.007 ± 0.002	(0.003 ± 0.005)	0/3	<DL	(66 ± 120)
Grapes									
Sagemoor Area	0/3	<DL	(0.002 ± 0.003)	3/3	0.010 ± 0.002	0.009 ± 0.002	1/3	350 ± 200	(170 ± 270)
Cold Creek Area	0/3	<DL	(-0.0004 ± 0.002)	3/3	0.010 ± 0.003	0.006 ± 0.004	1/3	200 ± 200	(120 ± 180)
Sunnyside Area	0/3	<DL	(0.002 ± 0.004)	2/3	0.008 ± 0.002	(0.004 ± 0.007)	0/3	<DL	340 ± 320

>DL =Greater than detection level, i.e., radionuclide concentration was greater than the associated ± two sigma counting error.

<DL =Less than detection level, i.e., radionuclide concentration was less than or equal to the associated ± two sigma counting error.

(a) Except for ³H, which is given in pCi/l of water.

(b) Maximum values include ± two sigma counting error. Averages include ± two standard error of the calculated mean (95% confidence interval).

(c) Refer to Figure 9.

(d) Parenthesis enclosing an average value indicates the radionuclide was not detectable (see Appendix B).

TABLE 13. Radionuclides in Wheat and Alfalfa

Type/Location(b)	Concentration, pCi/g, dry weight(a)					
	⁹⁰ Sr			¹³⁷ Cs		
	Fraction of Results >DL	Maximum	Average(c)	Fraction of Results >DL	Maximum	Average(c)
Wheat						
Wahluke East Area	2/3	0.015 ± 0.0028	(0.0097 ± 0.0089)	1/3	0.0076 ± 0.0059	(0.0025 ± 0.0072)
Sagemoor Area	3/3	0.015 ± 0.0039	0.011 ± 0.0068	0/3	<DL	(-0.00066 ± 0.0027)
Benton City Area	2/3	0.0039 ± 0.00071	(0.0018 ± 0.0031)	1/3	0.0080 ± 0.0044	(0.0021 ± 0.0087)
Sunnyside Area	3/3	0.011 ± 0.0025	0.0078 ± 0.0052	0/3	<DL	(-0.0033 ± 0.0035)
Moses Lake Area	3/3	0.0099 ± 0.0026	0.0093 ± 0.0019	0/3	<DL	(0.0013 ± 0.0034)
Riverview Area(d)	3/3	0.016 ± 0.0021	0.012 ± 0.0064	0/3	<DL	(0.00024 ± 0.00026)
Alfalfa						
Wahluke East Area	3/3	0.11 ± 0.0047	0.066 ± 0.051	1/3	0.046 ± 0.036	(0.015 ± 0.050)
Sagemoor Area	3/3	0.025 ± 0.0022	0.020 ± 0.0078	0/3	<DL	(0.016 ± 0.029)
Benton City Area	3/3	0.068 ± 0.0052	0.052 ± 0.028	2/3	0.053 ± 0.032	(0.041 ± 0.031)
Sunnyside Area	3/3	0.12 ± 0.0060	0.072 ± 0.056	0/3	<DL	(-0.0086 ± 0.030)
Moses Lake Area	3/3	0.054 ± 0.0061	0.040 ± 0.016	0/3	<DL	(-0.021 ± 0.024)
Riverview Area(d)	3/3	0.068 ± 0.0038	0.061 ± 0.011	0/3	<DL	(-0.0034 ± 0.020)

>DL = Greater than detection level, i.e., radionuclide concentration was greater than the associated ± two sigma counting error.

<DL = Less than detection level, i.e., radionuclide concentration was less than or equal to the associated ± two sigma counting error.

(a) Maximum values include ± two sigma counting error. Averages include ± two standard error of the calculated mean (95% confidence interval).

(b) Refer to Figure 9.

(c) Parenthesis enclosing an average value indicates the radionuclide was not detectable (see Appendix B).

(d) Irrigated with Columbia River water.

TABLE 14. Radionuclides in Beef, Chickens, and Eggs

Type/Location(b)	Concentration, pCi/g, wet weight(a)					
	⁹⁰ Sr			¹³⁷ Cs		
	Fraction of Results >DL	Maximum	Average(c)	Fraction of Results >DL	Maximum	Average(c)
Beef						
Sagemoor Area	0/1	---(d)	(-0.003 ± 0.0024)	0/1	---	(0.005 ± 0.006)
Riverview Area(e)	0/1	---	(-0.031 ± 0.031)	0/1	---	(0.0048 ± 0.0049)
Horn Rapids Area	1/1	---	0.008 ± 0.004	0/1	---	(-0.001 ± 0.005)
Sunnyside Area	0/1	---	(0.00077 ± 0.0026)	0/1	---	(-0.001 ± 0.005)
Chickens						
Sagemoor Area	1/2	0.0079 ± 0.0022	(0.0044 ± 0.0087)	0/2	<DL	(-0.0036 ± 0.0071)
Sunnyside Area	0/2	<DL	(0.00098 ± 0.0014)	0/2	<DL	(0.0025 ± 0.0058)
Eggs						
Sagemoor Area	1/2	0.0033 ± 0.0032	(0.0025 ± 0.0035)	0/2	<DL	(-0.00096 ± 0.0030)
Sunnyside Area	0/2	<DL	(0.0014 ± 0.0015)	0/2	<DL	(-0.0042 ± 0.0043)

>DL =Greater than detection level, i.e., radionuclide concentration was greater than the associated ± two sigma counting error.

<DL =Less than detection level, i.e., radionuclide concentration was less than or equal to the associated ± two sigma counting error.

(a) Maximum values include ± two sigma counting error. Averages include ± two standard error of the calculated mean (95% confidence interval).

(b) Refer to Figure 9.

(c) Parenthesis enclosing an average value indicates the radionuclide was not detectable (see Appendix B).

(d) Single samples were obtained.

(e) Water supplied from the Columbia River.

WILDLIFE

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

Fish sampling was also performed routinely along the Hanford reach of the Columbia River. Results provided an indication of the average radionuclide concentrations attributable to Hanford in local fish so the potential dose impact to humans for this pathway could be evaluated.

Analytical results of terrestrial wildlife samples collected during 1983 were very similar to those observed in recent years. Samples of fish collected from the Columbia River along the Hanford Site showed no discernible difference in radionuclide concentration compared to samples collected upstream of the site. The dose that could be received by a person who consumed any of the sampled species at the maximum radionuclide concentration observed in 1983 would be well below applicable DOE dose standards.

DEER

Samples from deer accidentally killed by vehicles on site roads were used to provide an indication of general levels of radionuclides in the herd residing on the site. Five road-killed deer were sampled and analyzed for ^{137}Cs and $^{239,240}\text{Pu}$, in muscle and liver tissue, respectively. Results indicated the presence of identifiable levels of ^{137}Cs in only one deer at 0.02 pCi/g, and the liver of the same animal contained 0.003 pCi $^{239,240}\text{Pu}$ /g. The concentrations were in the range generally associated with worldwide fallout.

A specially selected deer was collected in the vicinity of B-Pond near the 200 Areas (Figure 9). This animal was part of a group studied during 1981-1982 to determine the probable maximum ^{137}Cs concentration in muscle tissue of deer residing on the Hanford Site (Eberhardt, Hanson, Cadwell 1982). As part of the study, deer were captured and fitted with radio transmitting collars to track their movements. Data from radio tracking indicated the sampled deer tended to reside in the B-Pond Area during 1983. Results (Table 15) showed a slightly higher concentration of ^{137}Cs (0.20 pCi/g) in muscle compared to the road killed deer. The $^{239,240}\text{Pu}$ concentration (0.002 pCi/g) in liver was similar to the road kills.

FISH

Fish were caught at various locations along the Columbia River, and boneless fillets were analyzed for ^{60}Co , ^{90}Sr , and ^{137}Cs . Results are shown in Table 16. Whitefish were collected both upstream of Hanford near Priest Rapids Dam and along the Hanford reach of the river near 100-D Area, the Hanford townsite, and Ringold (Figure 9). Bass were collected near 100-F Area.

Cobalt-60 was identified more frequently in whitefish samples collected along the Hanford reach of the river near 100-D Area than in samples collected upstream of the site. The presence of the ^{60}Co in the fish may be associated with residual radioactivity in sediments of the Columbia River from past operations at Hanford or current releases from N Reactor (2.2 Ci during 1983). Concentrations of ^{90}Sr in edible whitefish tissue were very low, with a maximum of 0.007 pCi/g observed in a fish collected upstream of the site. No quantifiable difference in average ^{90}Sr concentrations between locations was indicated by the data, although ^{90}Sr was positively detected in a greater percentage of the fish collected along the Hanford reach of the river. Cesium-137 concentrations in fish were either undetectable or very low, and were similar to levels noted in previous years.

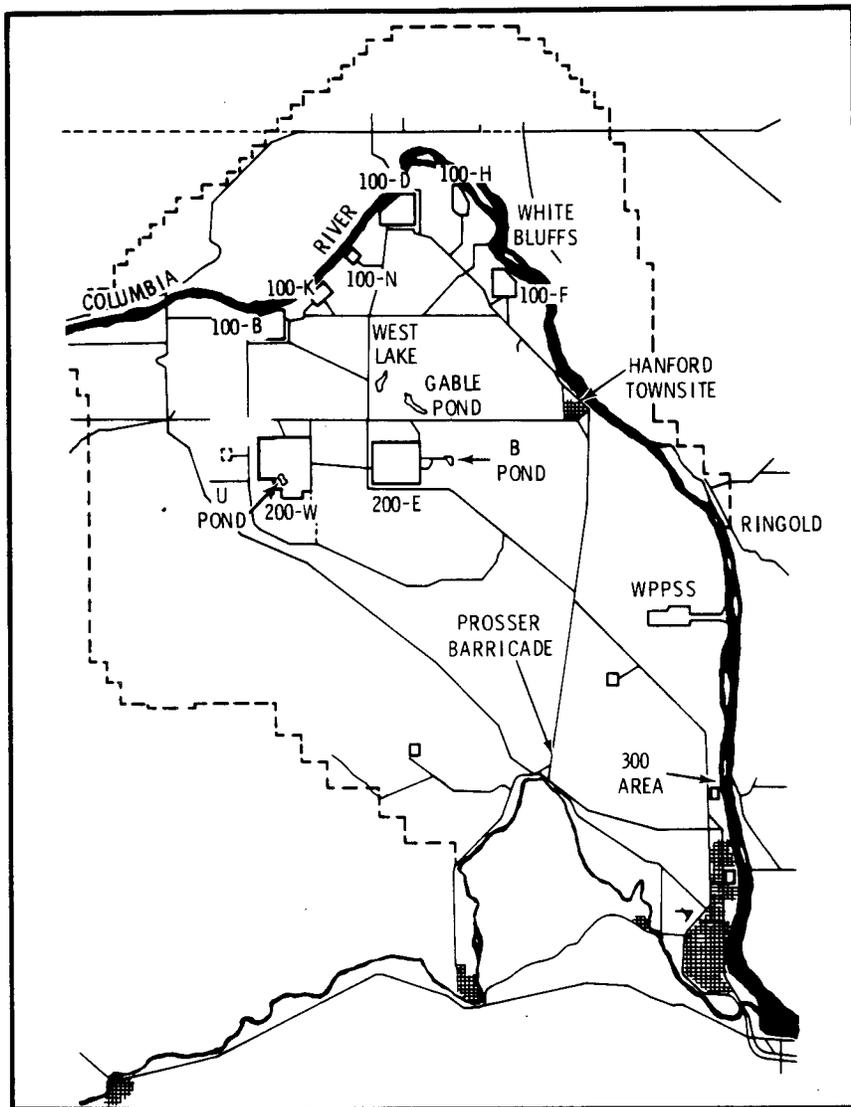


FIGURE 9. Wildlife Sampling Areas

UPLAND GAME BIRDS

Upland game birds including pheasant and chukar were obtained on the Hanford Site during 1983. Samples were collected in the 100, 200 and 300 Areas (Figure 9). Samples of breast meat from each bird were analyzed for ^{60}Co and ^{137}Cs . Results are provided in Table 17. Cobalt-60 and ^{137}Cs concentrations were low, and near the minimum detectable concentration for all samples.

WATERFOWL

Waterfowl samples (ducks and geese) were collected along the Columbia River in the vicinity of 100-N and 300 Areas as well as from three onsite ponds shown in Figure 9. An approximately 0.5-kg sample of breast meat from each bird was analyzed for ^{137}Cs . Results of the analyses are shown in Table 18.

Each year a number of waterfowl remain in the region throughout the year instead of migrating

TABLE 15. Cesium-137 in Deer Muscle and Plutonium-239,240 in Deer Liver

Location	Type	Concentration, pCi/g, wet weight ^(a)					
		¹³⁷ Cs			^{239,240} Pu		
		Fraction of Results >DL	Maximum	Average ^(b)	Fraction of Results >DL	Maximum	Average ^(b)
Random (road kills)	Muscle	4/5	0.02 ± 0.007	(0.01±0.01)	--- ^(d)	---	---
	Liver	---	---	---	4/5	0.003 ± 0.0008	(0.001 ± 0.001)
Specially Selected	Muscle	1/1	---	0.20 ± 0.01 ^(c)	---	---	---
	Liver	---	---	---	1/1	---	0.002 ± 0.0004 ^(c)

>DL = Greater than detection level, i.e., radionuclide concentration was greater than the associated ± two sigma counting error.

(a) Maximum values include ± two sigma counting error. Averages include ± two standard error of the calculated mean (95% confidence interval).

(b) Parenthesis enclosing an average value indicates the radionuclide was not detectable (see Appendix B).

(c) Single sample.

(d) Dashed lines indicated no analysis or no calculation.

to warmer latitudes. Gable Mountain Pond, a waste-water pond located near the 200 Areas, is a favorite refuge for waterfowl. A special collection of 20 mallard ducks from Gable Mountain Pond was performed in 1983 to provide a more representative estimate of ¹³⁷Cs concentration in duck meat. Sampling was performed prior to normal waterfowl migration and preceding the hunting season. Five ducks were collected each week over a four-week period during the month of September. Results of these samples, shown in Table 18, indicate accumulation of ¹³⁷Cs in

tissue at levels similar to those observed in recent years. The maximum concentration was 77 pCi/g with an average of 21 pCi/g for the twenty ducks sampled. The potential cumulative dose commitment resulting from consumption of 0.5 kg of meat at this maximum concentration was calculated to be less than 1 mrem to the total body.^(a)

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

TABLE 16. Radionuclides in Columbia River Fish

Type	Location	Concentration, pCi/g, wet weight(a)											
		⁶⁰ Co				⁹⁰ Sr				¹³⁷ Cs			
		Fraction of Results >DL	Maximum	Average(b)	Fraction of Results >DL	Maximum	Average(b)	Fraction of Results >DL	Maximum	Average(b)	Fraction of Results >DL	Maximum	Average(b)
Whitefish	Upstream of Site Boundary	1/5	0.02 ± 0.01	(-0.006 ± 0.02)	1/5	0.007 ± 0.005	(-0.0003 ± 0.006)	4/5	0.03 ± 0.01	(0.01 ± 0.01)	0.03 ± 0.01	(0.01 ± 0.01)	
	100-D Area Vicinity	2/14	0.04 ± 0.02	(0.0008 ± 0.03)	3/14	0.005 ± 0.003	(0.0008 ± 0.007)	9/14	0.03 ± 0.02	(0.02 ± 0.02)	0.03 ± 0.02	(0.02 ± 0.02)	
	Hanford Townsite Vicinity	5/7	0.08 ± 0.04	(0.03 ± 0.03)	3/6	0.006 ± 0.003	(0.002 ± 0.003)	5/7	0.04 ± 0.03	(0.02 ± 0.02)	0.04 ± 0.03	(0.02 ± 0.02)	
	Ringold Vicinity	2/5	0.06 ± 0.05	(0.02 ± 0.03)	0/4	<DL	(0.001 ± 0.005)	4/5	0.26 ± 0.05	(0.07 ± 0.11)	0.26 ± 0.05	(0.07 ± 0.11)	
Bass	100F Floodplain	2/5	<DL	(0.01 ± 0.02)	2/5	0.005 ± 0.002	(0.002 ± 0.003)	3/5	0.16 ± 0.03	(0.07 ± 0.06)	0.16 ± 0.03	(0.07 ± 0.06)	

>DL = Greater than detection level, i.e., radionuclide concentration was greater than the associated ± two sigma counting error.

<DL = Less than detection level, i.e., radionuclide concentration was less than or equal to the associated ± two sigma counting error.

(a) Maximum values include ± two sigma counting error. Averages include ± two standard error of the calculated mean (95% confidence interval).

(b) Parenthesis enclosing an average value indicates the radionuclide was not detectable (see Appendix B).

TABLE 17. Cobalt-60 and Cesium-137 in Muscle Tissue of Upland Gamebirds

Location	Concentration, pCi/g, wet weight ^(a)					
	Fraction of Results >DL	⁶⁰ Co		Fraction of Results >DL	¹³⁷ Cs	
		Maximum	Average ^(b)		Maximum	Average ^(b)
100 Areas Pheasant	1/6	0.013 ± 0.010	(0.0015 ± 0.011)	5/6	0.021 ± 0.009	0.015 ± 0.0065
200 Areas Chukar	0/3	<DL	(-0.0070 ± 0.0086)	3/3	0.023 ± 0.010	0.021 ± 0.0069
300 Area Pheasant	0/1	--- ^(c)	(-0.017 ± 0.016) ^(d)	0/1	---	(0.011 ± 0.015) ^(d)

>DL = Greater than detection level, i.e., radionuclide concentration was greater than the associated ± two sigma counting error.

<DL = Less than detection level, i.e., radionuclide concentration was less than or equal to the associated ± two sigma counting error.

(a) Maximum values include ± two sigma counting error. Averages include ± two standard error of the calculated mean (95% confidence interval).

(b) Parenthesis enclosing an average value indicates the radionuclide was not detectable (see Appendix B).

(c) Dashed line indicates no value.

(d) Single sample.

TABLE 18. Cesium-137 in Muscle Tissue of Waterfowl

Location	Type	Fraction of Samples >DL	Concentration, pCi/g, wet weight ^(a)		
			Maximum	Minimum	Average ^(b)
100 N Area 100 N Trench	Ducks	1/2	0.020 ± 0.0067	<DL	(0.0084 ± 0.029)
200 Area B Pond	Geese	2/2	0.96 ± 0.031	0.83 ± 0.028	0.90 ± 0.16
B Pond	Ducks	6/6	20 ± 0.14	4.3 ± 0.069	11 ± 5.0
Gable Pond	Ducks	20/20	77 ± 0.33	0.15 ± 0.017	21 ± 8.5
300 Area Pond	Ducks	4/4	0.76 ± 0.011	0.015 ± 0.014	0.034 ± 0.030
Columbia River	Ducks	0/1	--- ^(c)	---	(0.0095 ± 0.0098) ^(d)

>DL = Greater than detection level, i.e., radionuclide concentration was greater than the associated ± two sigma counting error.

<DL = Less than detection level, i.e., radionuclide concentration was less than or equal to the associated ± two sigma counting error.

(a) Maximum values include ± two sigma counting error. Averages include ± two standard error of the calculated mean (95% confidence interval).

(b) Parenthesis enclosing an average value indicates the radionuclide was not detectable (see Appendix B).

(c) Dashed line indicates no value.

(d) Single sample.

SOIL AND VEGETATION

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

The contribution of radionuclides from Hanford operations was assessed by comparing the results of samples collected in prevalent downwind locations, primarily to the south and east of the site, with samples collected from distant or generally upwind directions. Based on routine samples collected during 1983, there was no indication of a detectable contribution from Hanford to radionuclide concentrations in soil and vegetation in the offsite environment.

SAMPLE COLLECTION AND ANALYSIS

Soil and vegetation samples were collected at 16 locations in the offsite environs as shown in Figure 10. The majority of the samples were collected in a generally downwind direction of the site where any Hanford contribution to radionuclide levels in offsite soil would be expected to be most easily detected. Samples were also collected in a generally upwind direction for comparison.

Single samples of surface soil were collected at each location. Each sample consisted of a composite of five "plugs" of soil approximately 2.5 cm deep and 10 cm in diameter obtained within a 100-m² area at the sampling site. The composites were dried, sieved to pass through a 2-mm screen, and thoroughly mixed. Aliquots of the composite samples were analyzed.

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

sample was then dried and ground and aliquots were taken for analysis. Samples were analyzed for ¹³⁷Cs and other gamma-emitting radionuclides, ⁹⁰Sr, plutonium and uranium.

SOIL

Results of soil analyses for samples collected during 1983 are shown in Table 19. Although some variability exists between sampling locations, concentrations of the long-lived radionuclides ⁹⁰Sr, ¹³⁷Cs and ^{239,240}Pu are similar to those observed in previous years. No geographical distribution pattern indicative of a Hanford source could be identified.

VEGETATION

Results of analyses for radionuclides in samples of mature vegetation collected during 1983 are shown in Table 20. Trace concentrations of radionuclides associated with worldwide fallout were observed in all samples collected both upwind and downwind from the site.

Radionuclide concentrations in the vegetation, were similar to those observed in previous years. No geographical patterns were apparent. Hanford contributions, if any, to the radionuclide concentrations in the sampled vegetation were negligible compared to contributions from worldwide sources.

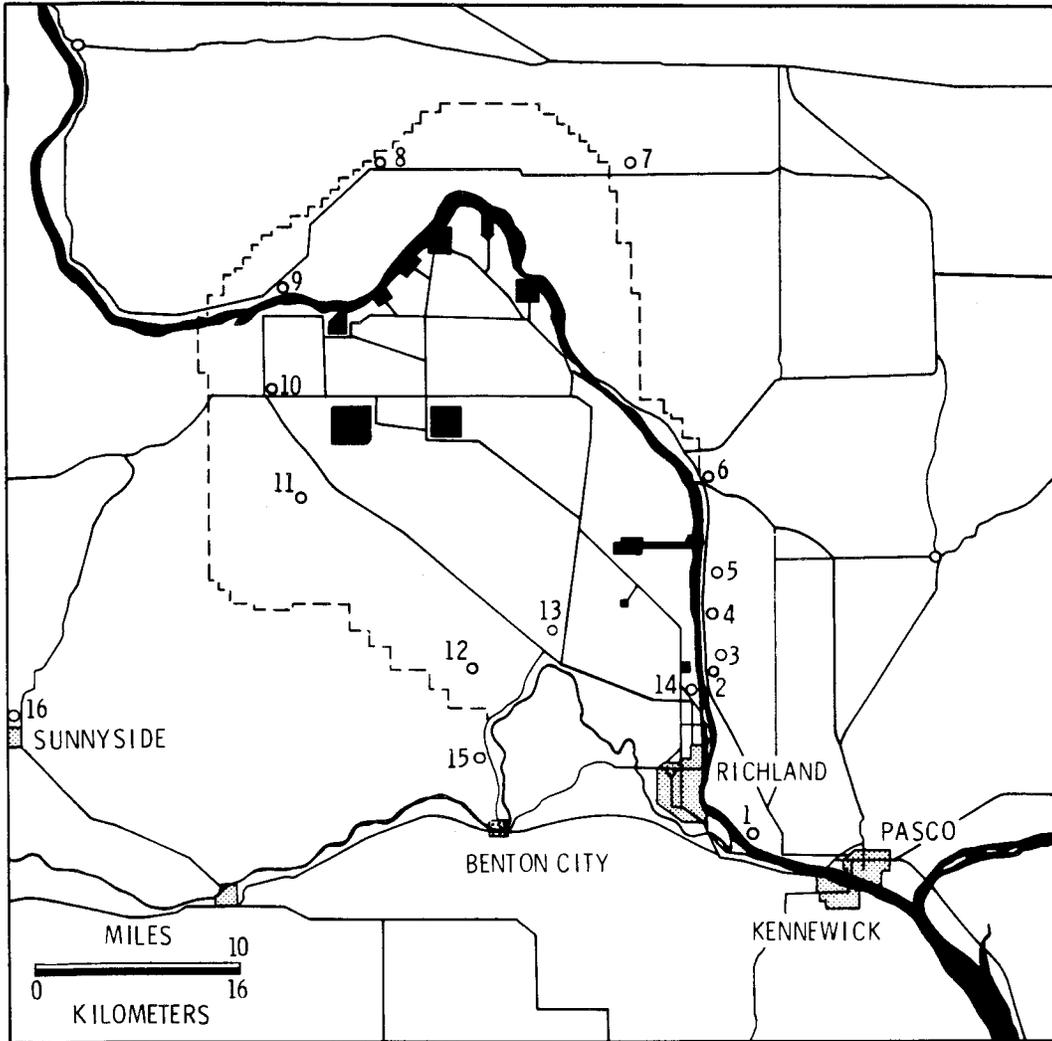


FIGURE 10. Soil and Vegetation Sampling Locations

TABLE 19. Radionuclides in Soil^(a)

Location	Map Location ^(c)	Concentration, pCi/g, dry weight ^(b)			
		⁹⁰ Sr	¹³⁷ Cs	^{239,240} Pu	U (Natural)
Riverview	1	0.90 ± 0.044	1.2 ± 0.065	0.021 ± 0.0050	0.37 ± 0.10
Byers Landing	2	0.30 ± 0.020	0.59 ± 0.048	0.012 ± 0.0021	0.32 ± 0.090
Sagemoor	3	0.28 ± 0.017	0.14 ± 0.026	0.0079 ± 0.0014	0.38 ± 0.10
Taylor Flats #2	4	2.3 ± 0.039	2.2 ± 0.070	0.031 ± 0.0053	0.47 ± 0.13
W. End Fir Road	5	1.2 ± 0.031	0.25 ± 0.034	0.0059 ± 0.0017	0.47 ± 0.13
Ringold	6	1.8 ± 0.032	1.6 ± 0.080	0.028 ± 0.0052	0.37 ± 0.10
Berg Ranch	7	0.92 ± 0.023	0.61 ± 0.045	0.014 ± 0.0028	0.24 ± 0.066
Wahluke #2	8	0.65 ± 0.023	0.25 ± 0.029	0.0096 ± 0.0022	0.35 ± 0.098
Vernita Bridge	9	0.52 ± 0.017	0.55 ± 0.048	0.015 ± 0.0026	0.37 ± 0.10
Yakima Barricade	10	0.59 ± 0.023	0.70 ± 0.054	0.014 ± 0.0020	0.25 ± 0.071
Rattlesnake Springs	11	0.89 ± 0.033	0.52 ± 0.045	0.026 ± 0.0049	0.25 ± 0.070
ALE	12	1.6 ± 0.032	1.5 ± 0.069	0.031 ± 0.0050	0.28 ± 0.078
Prosser Barricade	13	1.1 ± 0.027	0.77 ± 0.054	0.020 ± 0.0044	0.25 ± 0.069
S. of 300 Area	14	1.4 ± 0.039	1.1 ± 0.062	0.022 ± 0.0013	0.31 ± 0.084
Benton City	15	0.42 ± 0.018	0.54 ± 0.045	0.015 ± 0.0017	0.44 ± 0.12
Sunnyside	16	1.6 ± 0.040	1.1 ± 0.063	0.026 ± 0.0045	0.20 ± 0.10

- (a) Single samples were obtained at each location.
(b) Individual results include ± two sigma counting error.
(c) Locations are identified in Figure 10.

TABLE 20. Radionuclides in Vegetation^(a)

Location	Map Location ^(c)	Concentration, pCi/g, dry weight ^(b)			
		⁹⁰ Sr	¹³⁷ Cs	^{239,240} Pu	U (Natural)
Riverview	1	1.1 ± 0.033	0.021 ± 0.0067	0.0022 ± 0.00086	0.014 ± 0.0052
Byers Landing	2	0.12 ± 0.0064	0.013 ± 0.011	0.00040 ± 0.00038	0.015 ± 0.0056
Sagemoor	3	(-0.0063 ± 0.017)	(0.012 ± 0.012)	(0.00024 ± 0.00056)	0.013 ± 0.0048
Taylor Flats #2	4	0.037 ± 0.024	0.025 ± 0.012	0.0056 ± 0.00036	0.016 ± 0.0059
W. End Fir Road	5	0.086 ± 0.020	0.021 ± 0.010	(0.00021 ± 0.00029)	0.020 ± 0.0068
Ringold	6	0.65 ± 0.026	0.020 ± 0.0083	0.00 ± 0.00	0.026 ± 0.0089
Berg Ranch	7	(0.023 ± 0.027)	0.014 ± 0.0090	0.00051 ± 0.00034	0.012 ± 0.0048
Wahluke #2	8	0.018 ± 0.016	0.020 ± 0.0079	(-0.000011 ± 0.000022)	0.011 ± 0.0046
Vernita Bridge	9	0.10 ± 0.011	0.014 ± 0.010	(0.000084 ± 0.00032)	0.013 ± 0.0051
Yakima Barricade	10	0.041 ± 0.0082	0.012 ± 0.010	0.00038 ± 0.00029	0.0078 ± 0.0035
Rattlesnake Springs	11	0.69 ± 0.026	(0.0037 ± 0.0088)	(0.00083 ± 0.00096)	0.012 ± 0.0047
ALE	12	(0.017 ± 0.023)	(0.0093 ± 0.0094)	0.00033 ± 0.00028	0.0055 ± 0.0029
Prosser Barricade	13	(0.021 ± 0.022)	0.011 ± 0.0075	(0.00034 ± 0.00034)	0.011 ± 0.0045
S. of 300 Area	14	0.050 ± 0.011	(0.0050 ± 0.012)	(0.00014 ± 0.00021)	0.012 ± 0.0056
Benton City	15	0.12 ± 0.013	0.022 ± 0.0070	0.00069 ± 0.00048	0.015 ± 0.0058
Sunnyside	16	0.18 ± 0.026	(0.0060 ± 0.0095)	0.00031 ± 0.00029	0.0093 ± 0.0038

- (a) Single samples were obtained at each location.
(b) Individual results include ± two sigma counting error. Value enclosed within parenthesis when concentration less than or equal to its associated two sigma counting error.
(c) Locations are identified in Figure 10.

PENETRATING RADIATION

Dose rates from penetrating radiations (primarily gamma-rays) were measured at a number of locations in the Hanford environs during 1983. The measurements were made using thermoluminescent dosimeters (TLDs) to provide estimates of the dose rates from external radiation sources. Naturally occurring sources, including radiations of cosmic origin and natural radioactive materials in the air and ground, as well as fallout from the atmospheric testing of nuclear weapons, resulted in a certain amount of penetrating radiation being recorded at all dosimeter locations. Increases in the measured dose rates above these "background levels" could have resulted from the exposure of the dosimeter to radioactive materials associated with activities at Hanford.

Dose rates measured in the vicinity of residential areas during 1983 were similar to those observed since 1970 when external dose rate monitoring with TLDs began. Measurements made near operating areas and along the Columbia River indicated several locations where dose rates were somewhat higher than background levels. The highest measured dose rate in a publicly accessible location was observed at the 300 Area's west fence and averaged 0.28 mrem/h during the first nine months of 1983. This was attributed to onsite research activities involving a radioactive steam generator housed in a nearby facility.

DOSE MEASUREMENTS

Environmental radiation dosimeters consisted of three $\text{CaF}_2:\text{Mn}$ thermoluminescent chips encased in a plastic capsule. The capsule incorporated a lead/tantalum filter to provide uniform dose response characteristics for penetrating radiations above 60 keV (Fix and Miller 1978). The dosimeters were mounted one meter above ground level and were exchanged every four weeks. Measured doses are reported in dose equivalent units (mrem) to enable comparison to dose standards and dose equivalents reported elsewhere in this document. The TLDs record radiation exposure from natural and fallout sources as well as any local contribution (NCRP 1975).

HANFORD VICINITY

Dosimeters were located at numerous locations in the Hanford vicinity and also in several locations somewhat distant from the site as shown in Figure 11. The dose rates measured at each location during 1983 are shown in Table 21. Since most of the dosimeter locations were in or near areas that could be inhabited continuously, dose measurements performed at these locations were reported in units of mrem/yr.

Dose measurements were, in general, similar to those observed in previous years for the respective locations. The background dose rate, calculated from the annual average dose rates

observed at distant locations, was similar to past years at 66 mrem/yr (0.008 mrem/h). Figure 12 shows average annual dose rates measured at perimeter and distant locations during the past 10 years. (a) The figure illustrates the year-to-year variability of penetrating radiations in the environs at both near and distant locations. The figure also demonstrates that dose rates at perimeter stations generally averaged several mrem/yr higher than the distant locations. These differences were most likely due to natural geographical variations in local environmental radiation levels. The possibility of an historic release of radioactive material (prior to 1974) as a cause for the observed differences in dose rate was not substantiated by soil and vegetation sampling data provided in this and previous annual reports. A comparison of measured dose rates during periods of N Reactor and FFTF Reactor operation with measured dose rates during periods of reactor shutdown showed no influence from these facilities.

COLUMBIA RIVER IMMERSION DOSE RATE

Dosimeters were submerged in the Columbia River at Coyote Rapids and at the Richland pumphouse (Figure 13) to provide a comparison of penetrating dose rates that could be received

(a) Penetrating dose rate measurements using TLDs were begun at Hanford in 1970.

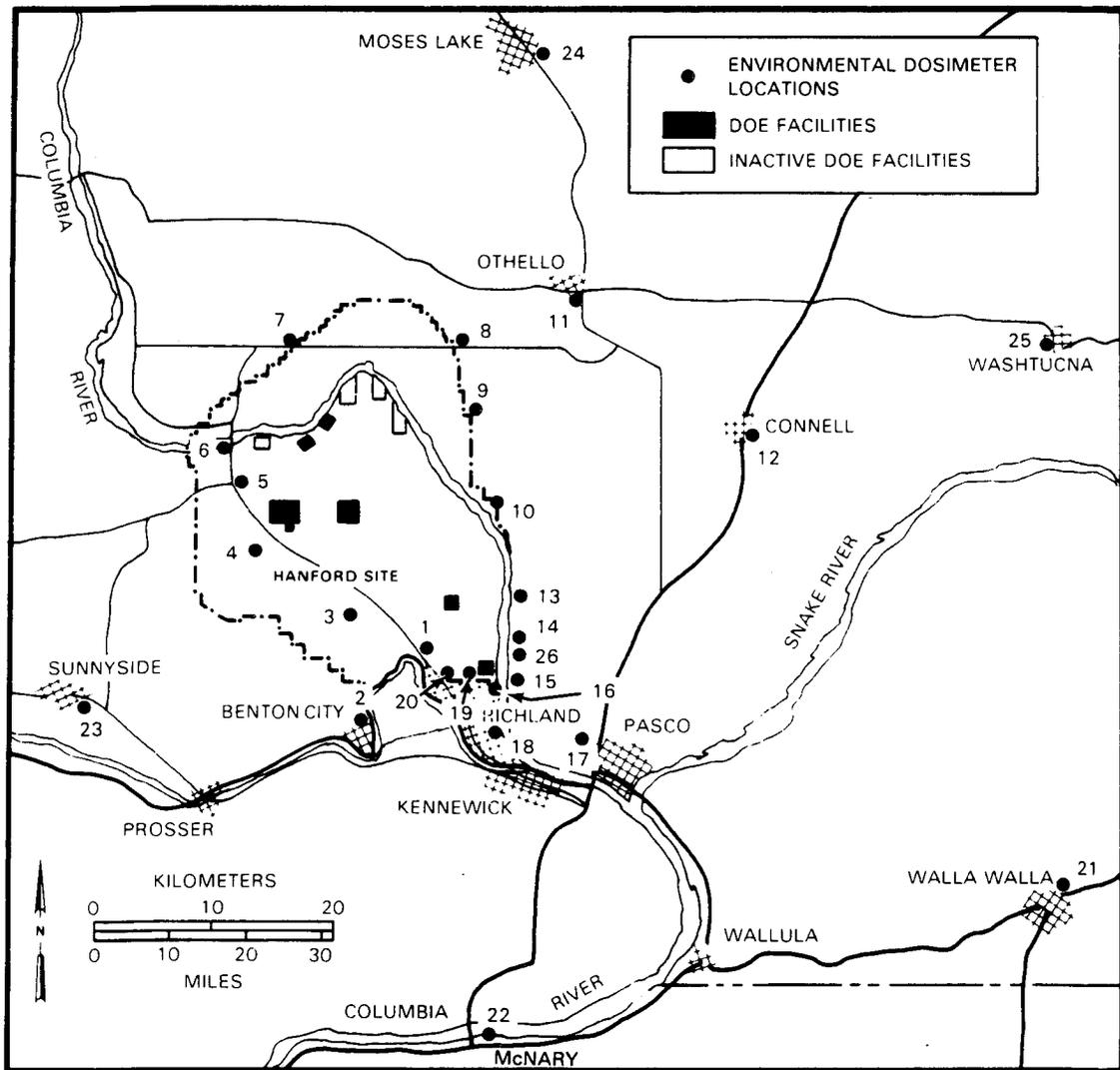


FIGURE 11. Environmental Dosimeter Locations at the Site Perimeter and Distant Communities

by a person immersed in the river upstream and downstream of the Hanford Site. Results of the measurements, shown in Table 22, were less than the background dose rate of 0.008 mrem/h measured on land. The average dose rates at the Coyote Rapids and Richland pumphouse locations were 0.005 mrem/h and 0.004 mrem/h, respectively.

OPERATIONS AREA BOUNDARIES

Dosimeters were placed at several publicly accessible locations near the perimeter of operating areas on the Hanford Site as shown in Figure 14. These locations included the shoreline of the

Columbia River near 100-N Area, parking lots near the west perimeter of the 300 Area, and the parking lot near the visitors center at the 400 Area (FFTF). Results of these measurements for 1983 are shown in Table 23.

Dose rates near the 100-N Area on the river shoreline were similar to those observed in previous years. The maximum dose rate observed was 0.046 mrem/h while the average varied between 0.020 and 0.025 mrem/h.

Dose rates at publicly accessible locations along the west perimeter of the 300 Area were elevated slightly compared to normal background levels of 0.008 mrem/h. The highest dose rate mea-

TABLE 21. Environmental Dosimeter Measurements - Perimeter and Community

Location	Map Location ^(b)	No of Samples	Dose Rate, mrem/yr ^(a)		
			Maximum	Minimum	Average ^(c)
Perimeter Stations					
Prosser Barricade	1	12	77	66	69 ± 2
ALE	3	12	77	66	69 ± 2
Rattlesnake Springs	4	13	102	73	80 ± 4
Yakima Barricade	5	13	95	73	80 ± 3
Vernita Bridge	6	13	84	69	73 ± 3
Wahlake #2	7	12	99	69	77 ± 3
Berg Ranch	8	13	91	69	80 ± 4
Sagehill	9	13	84	66	77 ± 3
Ringold	10	13	88	62	77 ± 4
Fir Road	13	12	77	66	69 ± 2
Pettett	14	12	77	58	66 ± 3
Sagemoor	26	11	77	66	73 ± 2
Byer's Landing	15	12	80	69	73 ± 2
RRC #64	16	12	77	66	69 ± 2
Horn Rapids Rd - Mi 12	19	9	84	66	73 ± 4
Horn Rapids Rd - Substation	20	7	66	62	66 ± 1
Range of annual averages 66-80 mrem/yr					
Nearby Communities					
Benton City	2	12	62	51	55 ± 2
Othello	11	13	73	51	62 ± 3
Connell	12	13	77	55	66 ± 3
Pasco	17	12	73	58	66 ± 3
Richland	18	12	69	62	66 ± 2
Range of annual averages 55-66 mrem/yr					
Distant Communities					
Walla Walla	21	13	73	58	66 ± 3
McNary	22	13	77	69	73 ± 4
Sunnyside	23	12	66	55	62 ± 3
Moses Lake	24	12	69	51	62 ± 3
Washtucna	25	12	73	58	66 ± 3
Range of annual averages 62-73 mrem/yr					

- (a) Monthly integrated readings in mR were converted to annual dose equivalent rates.
 (b) Locations are identified in Figure 11.
 (c) Averages include ± two standard error of the calculated mean (95% confidence level).

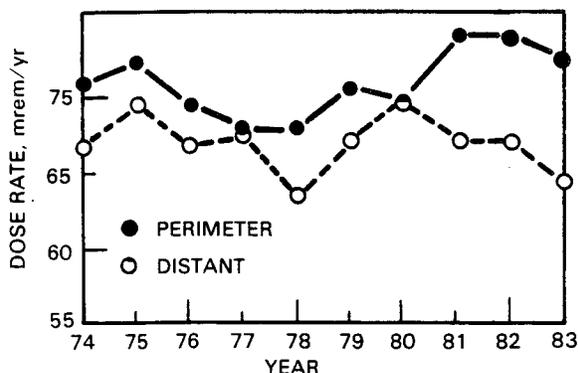


FIGURE 12. Annual Average External Dose Rates at Perimeter and Distant Locations 1974 to 1983

sured was 0.29 mrem/h at a location just west of a research facility housing a radioactive steam generator under study. Access to this location was permanently restricted in September 1983 thereby eliminating potential exposure to the public. Average dose rates at the other two 300 Area perimeter locations near publicly accessible areas were found to be 0.015 mrem/h and 0.018 mrem/h.

Dose rates near the visitors center at the 400 Area (FFTF) were at background levels, indicating no additional penetrating dose rate could be attributed to FFTF activities during 1983.

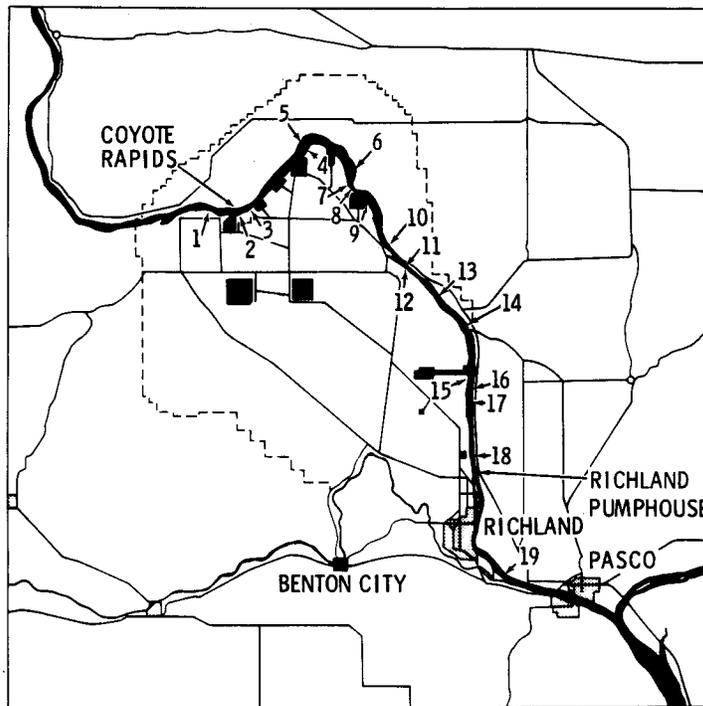


FIGURE 13. Environmental Dosimeter Locations Along the Hanford Reach of the Columbia River

TABLE 22. Immersion Dose Rates in the Columbia River

Location	Number of Measurements	Dose Rate, mrem/h ^(a)		
		Maximum	Minimum	Average ^(b)
Coyote Rapids	10	0.006	0.003	0.005 ± 0.0006
Richland Pumphouse	11	0.005	0.003	0.004 ± 0.0004

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

(b) Averages include ± two standard error of calculated mean (95% confidence level).

COLUMBIA RIVER SHORELINES

Cooling water containing radioactive materials was discharged to the Columbia River during reactor operations at Hanford from 1944 to 1972. These radionuclides were diluted and dispersed in the river, which averaged a flow rate of 130,000 cubic feet per second. Low levels of residual radioactivity (primarily ⁶⁰Co and ¹⁵⁴Eu) can still be measured at several locations along the shorelines and on islands in the Hanford reach of the river. Radiation dose rates from these radio-

nuclides were the subject of an extensive radiological survey of the Hanford reach of the river performed in 1979 (Sula 1980).

In 1980, based upon findings of the survey, dosimeters were located in areas along the river, shown in Figure 13, where dose rates due to the residual radioactivity deposits were determined to be highest.

Table 24 provides results of measurements at these locations during 1983. In general, dose

rates measured during 1983 were similar to those observed in 1982 and 1981. The consistency of the dose rate measurements during the past three years indicated the radionuclides in the ground to be relatively immobile and resistant to

resuspension and redistribution by the mechanical forces of wind and water. Dose rates along the river are expected to gradually decrease at a rate commensurate with the radioactive half-lives of the radionuclide present.

Figure removed as per DOE guidance.

FIGURE 14. Environmental Dosimeter Location at Publicly Accessible Locations Onsite

TABLE 23. Environmental Dosimeter Measurements at Publicly Accessible Onsite Locations

Location	Map Location ^(b)	No of Measurements	Dose Rate, mrem/h ^(a)		
			Maximum	Minimum	Average ^(c)
100-N Area Shoreline					
100-N Trench Springs	1	12	0.046	0.014	0.020 ± 0.005
Below 100-N Main Stack	2	13	0.033	0.015	0.024 ± 0.003
Upstream Tip 100-N Berm	3	13	0.035	0.016	0.025 ± 0.003
Downstream 100-N Outfall	4	13	0.038	0.020	0.025 ± 0.003
300 Area Perimeter Fence					
377-W Fence ^(d)	5	9	0.290	0.250	0.275 ± 0.010
377-S Fence ^(e)	6	3	0.020	0.017	0.018 ± 0.003
3705 West Fence	7	13	0.016	0.014	0.015 ± 0.0004
400 Area (FFTF) Perimeter Fence					
400 East	8	13	0.010	0.008	0.008 ± 0.0003

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

(b) Locations are identified in Figure 14.

(c) Averages include ± two standard error of the calculated mean (95% confidence level).

(d) Discontinued in September due to fenceline modifications.

(e) Established during September as a result of fenceline modifications.

TABLE 24. Environmental Dosimeter Measurements Along the Hanford Reach of the Columbia River

Location	Map Location ^(b)	No of Measurements	Dose Rate, mrem/h ^(a)		
			Maximum	Minimum	Average ^(c)
Upriver 100-B Area	1	13	0.008	0.005	0.007 ± 0.0006
Below 100-B Retention Basin	2	13	0.019	0.010	0.016 ± 0.0016
Above 100-K Boat Ramp	3	13	0.009	0.007	0.008 ± 0.0005
Downriver 100-D	4	13	0.013	0.010	0.011 ± 0.0005
Downriver opposite 100-D	5	13	0.008	0.007	0.008 ± 0.0002
Lower end Locke Island	6	13	0.009	0.008	0.008 ± 0.0003
White Bluffs Slough	7	13	0.016	0.010	0.014 ± 0.0012
White Bluffs Ferry Landing	8	13	0.010	0.008	0.008 ± 0.0003
Below 100-F	9	13	0.009	0.008	0.008 ± 0.0002
Hanford powerline crossing	10	13	0.010	0.008	0.009 ± 0.0003
Hanford ferry landing	11	13	0.008	0.007	0.008 ± 0.0003
Hanford railroad track	12	13	0.013	0.011	0.012 ± 0.0005
Savage Island Slough	13	12	0.013	0.009	0.010 ± 0.0007
Ringold Island	14	13	0.009	0.008	0.008 ± 0.0003
Powerline crossing	15	13	0.011	0.009	0.010 ± 0.0003
North end Wooded Island	16	12	0.009	0.005	0.007 ± 0.0009
South end Wooded Island	17	13	0.010	0.008	0.009 ± 0.0003
Island RM 344	18	13	0.014	0.005	0.010 ± 0.0017
Island RM 333	19	13	0.013	0.008	0.010 ± 0.0005

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

(b) Locations are identified in Figure 13.

(c) Averages include ± two standard error of the calculated mean (95% confidence level).

RADIOLOGICAL IMPACT OF HANFORD OPERATIONS

An assessment of potential radiological impact indicated that radiation doses to the public attributable to 1983 operations at Hanford were well below all applicable regulatory limits and were significantly less than doses potentially received from common sources of radiation. The fifty-year whole body cumulative dose potentially received by an assumed maximum exposed individual was calculated to be about 1 mrem, as compared to the DOE Radiation Protection Standard of 500 mrem per year. The fifty-year whole body cumulative dose to the surrounding population was calculated to be 4 man-rem. These doses can be compared to the approximate 100 mrem and 34,000 man-rem doses received annually by an average individual and the surrounding population, respectively, as a result of naturally occurring radiations in our environment. The assessment of potential radiation doses due to residual radionuclides from past Hanford operations also revealed no significant impacts on the public.

RADIOLOGICAL IMPACT FROM 1983 OPERATIONS

Hanford operations during 1983 resulted in the release of small quantities of radioactive materials to the environment. In addition, certain Hanford facilities were potential sources of direct radiation exposure. The radiological impacts of 1983 operations were assessed to determine compliance with pertinent regulations as required by DOE Order 5484.1. (USDOE 1981).

The radiological impact of 1983 Hanford operations was assessed in terms of the following:

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

To the extent possible, these radiological impacts were evaluated based on the direct measurement of dose rates or of radionuclide concentrations in the environment. The "fence-post" dose rate during 1983 was based on direct measurements of external radiation made near the operating areas. However, the quantities of radionuclide releases associated with 1983 operations were too small to be measured once dispersed in the offsite environment. As a result, the potential offsite doses could only be estimated by using computerized models that predict concentrations of radioactive materials in the environment and subsequent radiation doses on the basis of radionuclides released to the

environment. These models are described in Appendix E, and the reported Hanford effluents for 1983 are shown in Table 25. The radiation doses estimated by these models were quite small and well below the sensitivity of direct measurement. Although the uncertainty associated with these calculations has not been specified, it is relatively large. As a result, the doses calculated using these models should be viewed as conservative estimates (i.e., over-estimates) of the potential dose impact of 1983 Hanford operations.

Maximum "Fence-Post" Dose Rate

The "fence-post" dose rate provides a measure of the maximum external radiation dose rate that existed in publicly accessible locations on or near the site during 1983. The "fence-post" dose rate was based on measurements made by fixed environmental dosimeters placed at locations of expected maximum dose rates and does not represent a dose actually received by any member of the public. "Fence-post" dose rates were measured in the vicinity of the 100-N, 300 and 400 (FFTF) operating areas as described in the "Penetrating Radiation" section of this report.

Near the 100-N Area, the Columbia River provides access to within a few hundred meters of the N Reactor and its associated facilities. Measurements made at the 100-N Area shoreline (Table 23) were consistently above background due to the proximity of N Reactor facilities for radioactive liquid waste handling. The maximum monthly averaged dose rate observed along the shoreline during 1983 was 0.046 mrem/h, or about six times the dose rate normally observed at offsite locations (0.008 mrem/h).

TABLE 25. Radionuclide Composition of Hanford Effluents for Calendar Year 1983

Radionuclide	Half-Life	Effluent, Ci ^(a)				
		Liquid to River	Airborne			
			100 Area	200 Area	300 Area	400 Area
³ H (HTO)	12.3 yr	180	9.9	180		
¹⁴ C	5730 yr			1.2		
²⁴ Na	15.0 h	.13	0.17			
³² P	14.3 d	.023				
⁴¹ Ar	1.8 h		121,000			
⁵¹ Cr	27.8 d	0.17				
⁵⁴ Mn	303 d	.58	.0031			
⁵⁶ Mn	2.6 h		.15			
⁵⁹ Fe	46.0 d	.61	.0011			
⁵⁸ Co	71.0 d	.11	.0013			
⁶⁰ Co	5.3 yr	2.2	.0063		3.2 x 10 ⁻⁶ (b)	
⁷⁶ As	26.4 h		1.0			
^{85m} Kr	4.4 h		170			
⁸⁵ Kr	10.7 yr			17,600		220
⁸⁷ Kr	76.0 min		430			
⁸⁸ KrRb	2.8 h		670			
⁸⁹ Sr	52.7 d	1.0	.0010			
⁹⁰ Sr	27.7 yr	4.0	.0007	.003	4.0 x 10 ⁻⁵ (c)	1.7 x 10 ⁻⁵
⁹¹ Sr	9.7 h		.024			
⁹⁵ ZrNb	65.5 d	.42				
⁹⁵ Nb	35.0 d		6.5 x 10 ⁻⁴			
^{99m} MoTc	66.7 h	.26	.059			
¹⁰³ Ru	39.5 d	.21	.0017			
¹⁰⁶ Ru	368 d	.22	3.0 x 10 ⁻⁴			
¹²⁴ Sb	60 d	0.043				
¹²⁵ Sb	2.7 yr	.19				
¹³¹ I	8.1 d	1.3	.34		3.4 x 10 ⁻⁴	7.0 x 10 ⁻⁶
¹³² I	2.3 h		.54			
¹³³ I	20.3 h	.14	.72			
¹³⁵ I	6.7 h		.11			
¹³³ Xe	5.3 d	.91				
¹³⁵ Xe	9.1 h		630			
¹³⁷ Cs	30.0 yr	.13	2.4 x 10 ⁻⁴	.029		
¹³⁸ Cs	32.2 min		540			
¹⁴⁰ BaLa	12.8 d	1.1	.028			
¹⁴¹ Ce	33 d	0.020				
¹⁴⁴ CePr	284 d	.0084	.0055			
¹⁵⁵ Eu	1.8 yr		4.2 x 10 ⁻⁵			
U-nat	4.4 x 10 ⁹ yr			1.5 x 10 ⁻⁵	2.1 x 10 ⁻⁴	
²³⁸ Pu	86.4 yr	1.3 x 10 ⁻⁴	2.9 x 10 ⁻⁶			
²³⁹⁻²⁴⁰ Pu	2.4 x 10 ⁴ yr	1.8 x 10 ⁻⁴	2.2 x 10 ⁻⁵	6.2 x 10 ⁻⁴ (d)	1.8 x 10 ⁻⁵	3.5 x 10 ⁻⁶
²⁴⁴ Cm	18.1 yr				9.9 x 10 ⁻⁸	

(a) Except as specifically noted in this table, all Ci values are as reported by operating contractors via the DOE's Effluent Information System.

(b) 2.95 x 10⁻⁶ Ci reported as ⁶⁰Co. 2.5 x 10⁻⁷ Ci reported as mixed activation products and assumed to be ⁶⁰Co for dose calculations.

(c) 2.7 x 10⁻⁵ Ci reported as ⁹⁰Sr. 1.3 x 10⁻⁵ Ci reported as mixed fission products and assumed to be ⁹⁰Sr for dose calculations.

(d) Reported as total Pu and assumed to be ²³⁹Pu for dose calculations.

Access to the 400 Area was possible at the Visitors Information Center located southeast of the FFTF reactor building. Penetrating dose rate measurements in the vicinity of this area during 1983 (Table 23) did not indicate any identifiable dose rate above normal background levels.

Dose rates along the perimeter of the 300 Area were slightly elevated at locations accessible to the public during 1983 (Table 23). Direct radiation from onsite research activities involving a radioactive steam generator was the cause. Dose rates averaged 0.28 mrem/h during 1983. Access to this location was permanently restricted during September resulting in a new maximum of 0.018 mrem/h. Average dose rate at the other 300 Area perimeter location accessible to the public was 0.015 mrem/h.

The reporting of maximum "fence-post" dose rates is required by DOE Order 5484.1. The actual incurrence of any environmental radiological impact at these locations in terms of dose received by the public is not to be interpreted as a true or real exposure. In fact, there is no evidence to support actual recurring or protracted usage by a member of the public at any of the previously discussed locations.

Maximum Exposed Individual Dose

The maximum exposed individual (MI) doses are those calculated, based only on 1983 operations at Hanford, to be potentially received by an imaginary individual whose location and characteristics are chosen so as to maximize the combined doses from all realistically available exposure pathways. The particular characteristics of the assumed MI are specified annually upon evaluation of numerous influencing factors such as the magnitude and composition of radioactive effluents from the various potential release points at Hanford, atmospheric dispersion of airborne releases, and river dispersion of liquid releases.

The following exposure pathways were included in the calculation of the potential MI dose based on 1983 operation; inhalation and submersion in airborne effluents; consumption of foodstuffs contaminated by effluents deposited on the ground via airborne deposition and irrigation with Columbia River water; direct exposure to radionuclides deposited on the ground; use of drinking water obtained from the Columbia

River; consumption of fish taken from the Columbia River; and direct exposure to radionuclides during Columbia River recreation. In consideration of the possible combinations of the above exposure pathways, the hypothetical MI for 1983 was postulated to be an individual who:

- was a long-term resident in an area approximately 13 km south-southeast of the 300 Area,
- consumed foodstuffs grown in the north-western part of the Riverview district using Columbia River water for irrigation,
- consumed drinking water obtained from the Columbia River and,
- used the Columbia River extensively for recreational activities including boating, swimming and fishing (including consumption of the fish).

All MI doses were calculated using the effluents shown in Table 25. Because these effluents included small quantities of long-lived radionuclides, the MI was appropriately assumed to be a long-term resident in consideration of the environmental persistence of these materials. Thyroid doses were calculated for a one-year-old infant in addition to an adult because the potential thyroid doses to an infant from radioiodine releases is calculated to be slightly higher than an adult. Other organ doses were appropriately calculated for an adult MI only.

Calculated 50-year cumulative doses for the MI are summarized in Table 26 and include that dose received from exposure to liquid and airborne effluents during 1983 as well as potential exposure beyond 1983 to that fraction of the 1983 effluents estimated to be deposited on the ground via airborne deposition and irrigation with Columbia River water. Appendix E provides detailed information concerning the computer models and input parameters used to calculate the doses in Table 26.

All potential MI doses resulting from effluents discharged to the environment during operations at Hanford in 1983 were well below the applicable Radiation Protection Standards in DOE Order 5480.1. The organ receiving the largest fraction of the standard was the bone, for which a maximum individual 50-year cumulative dose of 4 mrem was calculated as compared to

TABLE 26. Dose to the Maximum Exposed Individual from 1983 Hanford Operations

Pathway	50-Year Cummulative Dose, mrem					
	Whole Body	GI ^(a)	Bone	Lung	Thyroid	
					Adult	Infant
Direct Airborne ^(b)	<.01	<.01	<.01	<.01	<.01	<.01
Foodstuffs ^(c)	.9	.08	4	<.01	.06	.3
Drinking Water	<.01	<.01	.02	<.01	.01	.04
River Recreation ^(d)	.06	.06	.2	<.01	.02	—
Total	1	.2	4	.01	.09	.3

(a) Gastrointestinal tract (lower large intestine).

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

(c) Includes consumption of all foodstuffs contaminated via irrigation water and dry deposition.

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

the DOE Radiation Protection Standard for the bone of 1500 mrem. The bone dose was primarily the result of exposure to ⁹⁰Sr in the soil.

A comparison of the MI dose impacts attributed to 1983 Hanford operations with estimates of the MI doses for the previous five years is provided in Table 27. Dose equivalents presented in the table are the calculated 50-year cumulative doses, that assume long-term residency of the MI.

The numerical values of doses presented in Table 27 for the years 1978 to 1981 differ to some extent from the dose values originally reported for these years in the annual environmental surveillance report.^(a) Consistent with the available environmental dose calculation capabilities, the previously calculated doses did not include consideration of the persistence of long-lived radionuclides in environmental pathways beyond the year of release. Potential dose impacts for those years were thus recalculated for Table 27 using presently available methodologies (McCormack, Carlile and Napier 1983). Although the recalculated doses in Table 27 vary somewhat from the values originally reported, the conclusions remain unchanged: radiological impacts from Hanford operations were well below applicable dose guidelines and contributed only a small fraction of the dose received by the public from naturally occurring radiations.

(a) A bibliography of the annual reports is provided in the Preface to this document.

Population Dose

The regional dose impact from 1983 Hanford operations was estimated by calculating the collective dose to the population residing within an 80-km radius of any of the onsite operating areas. Collective population doses are expressed in units of man-rem and are the sum, for all possible pathways, of the product of the average individual dose and the number of persons potentially exposed. Both airborne and river-related pathways were considered in the calculation for which results are shown in Table 28. Site-specific population distributions and other dose calculation parameters are detailed in Appendix E.

A comparison of 80-km population doses attributed to 1983 Hanford operations with estimated doses for the five previous years is provided in Table 29. As discussed in the section on "Maximum Exposed Individual," the doses due to operations during 1978 through 1981 were recalculated for comparison with 1983. For recalculation of the population doses, the 1978 through 1981 80-km population distributions were updated consistent with the 1980 census data.

The primary airborne pathway contribution to the population dose was immersion in short-lived noble gases from N Reactor. The consumption of foodstuffs irrigated with water obtained from the Columbia River downstream of Hanford was the principal dose pathway for liquid effluents, the primary radionuclide being ⁹⁰Sr. A

TABLE 27. Comparison of Estimated Maximum Exposed Individual Doses Due to Hanford Operations from 1978 to 1983(a)

Organ	50-Year Cumulative Dose (mrem)(b)					
	1978	1979	1980	1981	1982	1983
Whole Body	.5	.7	.6	.5	.7	1
GI(c)	.1	.2	.1	.06	.07	.2
Bone	2	3	2	2	2	4
Lung	.02	.4	<.01	.01	.02	.01
Thyroid	1	.8	.2	.2	.2	.09

(a) McCormack, Carlile, and Napier 1983.

(b) Total dose to each organ from exposure to all available pathways.

(c) Gastrointestinal Tract (lower large intestine).

TABLE 28. Dose to the Population from 1983 Hanford Operations

Pathway	80 km Population 50-Year Cumulative Dose, man-rem				
	Whole Body	GI(a)	Bone	Lung	Thyroid
Direct Airborne(b)	3	3	3	3	3
Foodstuffs(c)	<1	<1	3	*(d)	4
Drinking Water	<1	*	<1	*	<1
River Recreation(e)	*	*	*	*	*
Total	4	3	7	3	7

(a) Gastrointestinal tract (lower large intestine).

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

(c) Includes consumption of all foodstuffs contaminated via irrigation water and dry deposition.

(d) Doses were calculated to be less than 0.1 man-rem and are not reported in the summary table but are included in the dose total.

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

TABLE 29. Comparison of Estimated 80-km Population Dose Due to Hanford Operations from 1978 to 1983(a)

Organ	50-Year Cumulative Dose (man-rem)(b)					
	1978	1979	1980	1981	1982	1983
Whole Body	7	4	2	3	4	4
GI(c)	3	3	<1	3	3	3
Bone	20	10	5	5	7	7
Lung	5	5	1	3	4	3
Thyroid	12	12	4	5	7	7

(a) McCormack, Carlile, and Napier 1983.

(b) Total dose to each organ from exposure to all available pathways.

(c) Gastrointestinal tract (lower large intestine).

“per capita” whole body cumulative dose from 1983 Hanford operations based on the 80-km population of 340,000 persons is calculated to be 0.01 mrem/person.

These dose estimates can be compared with doses from other routinely encountered sources of radiation such as natural background radiation (Oakley 1972), medical diagnostic procedures (USEPA 1972), and a five-hour commercial jet flight (NCRP 1975). The average doses from these sources and the average per capita whole body cumulative dose from Hanford operations for 1983 are compared in Figure 15. The estimated population dose (in man-rem) may also be compared with the approximately 34,000 man-rem received annually by the same population from background radiation.

RADIOLOGICAL IMPACT FROM PAST HANFORD OPERATIONS

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

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

For the purpose of evaluating the potential impact of these elevated dose rates on the regional population, a survey of Columbia River recreation was conducted during 1980. The survey area extended from the Vernita Bridge to Columbia Point at the confluence of the Yakima River. Through aerial and ground observations, the survey estimated annual population man-hours spent in recreational activities along the Columbia River. By applying the population shoreline man-hours per year to the measured net dose rates (in excess of background), an estimate of collective population whole body dose per year was obtained. The potential population dose due to exposure to residual radionuclides, derived by this method, was estimated to be approximately 1 man-rem per year as reported for 1982 (Sula et al. 1983). Results obtained for 1983 do not alter this estimate.

As discussed in previous sections, low concentrations of ^3H , U, and ^{129}I associated with the unconfined aquifer underlying the Hanford Site

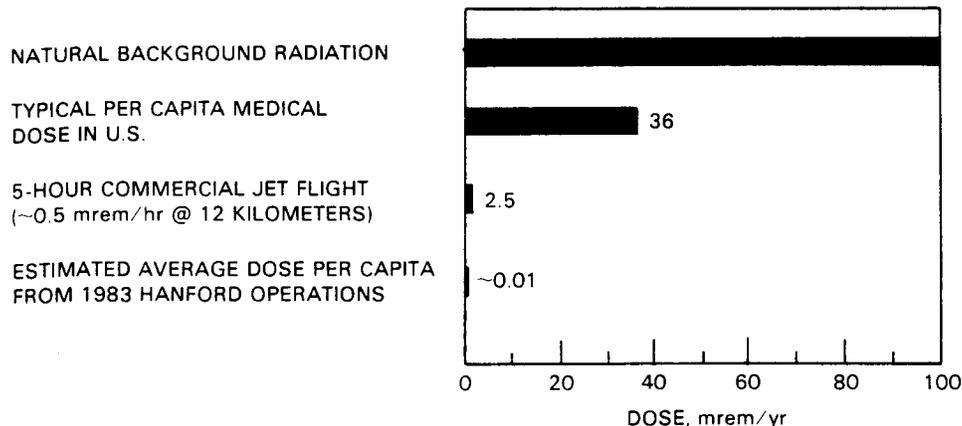


FIGURE 15. Whole Body Doses Received from Various Radiation Sources

are entering the river. Increased concentrations in the river cannot be detected for ^3H or U but can be measured for ^{129}I by using extremely sensitive sampling and analytical techniques. However, the dose impact from ^{129}I entering the river, based on measured differences in river concen-

trations upstream and downstream of the site (see the "Columbia River Radiological Monitoring" section), was calculated to be only 0.002 mrem to the thyroid of an assumed maximum exposed individual, as compared to the DOE thyroid dose standard of 1500 mrem.

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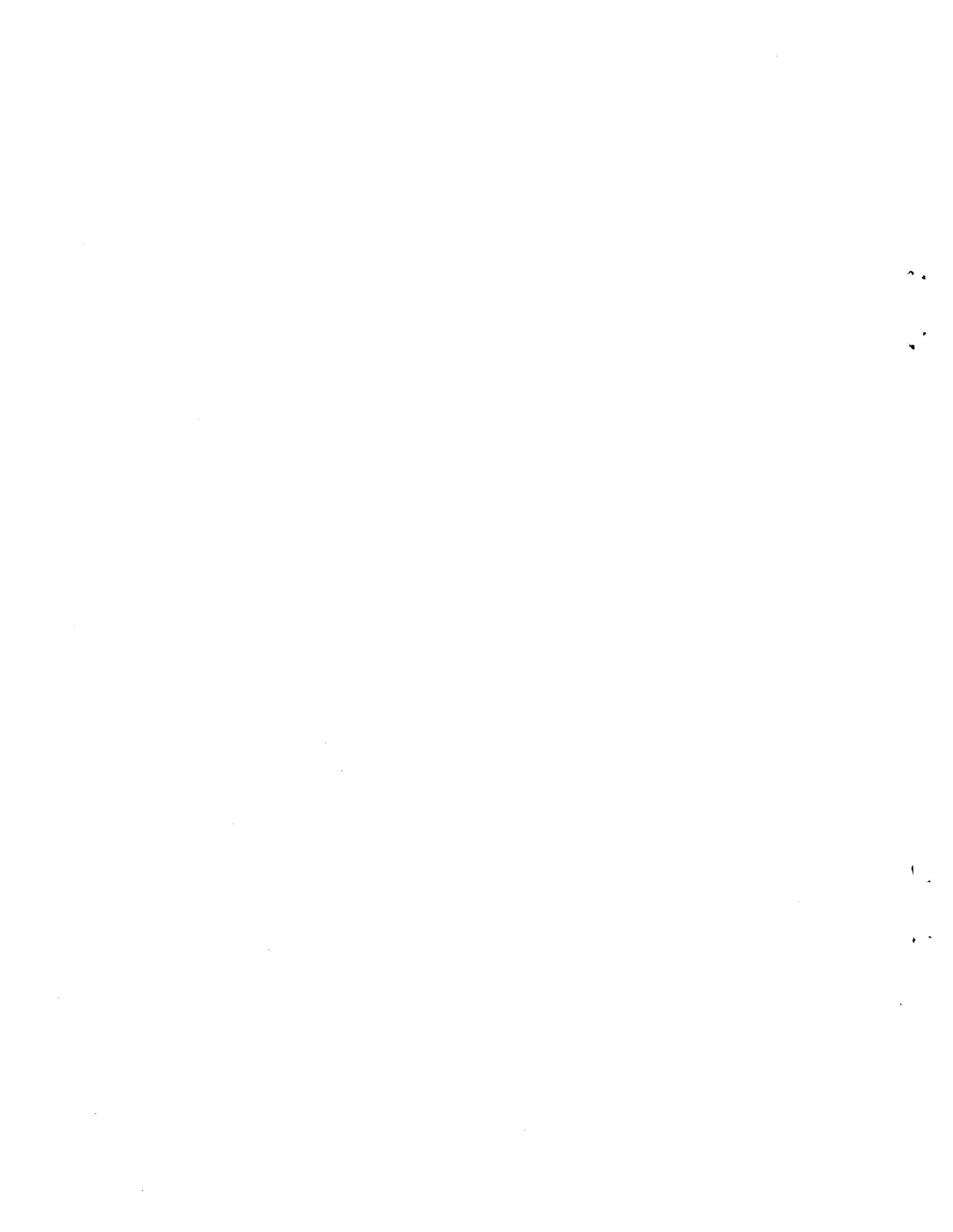
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APPENDIX A
APPLICABLE STANDARDS



APPENDIX A APPLICABLE STANDARDS

Operations at the Hanford Site must conform to a variety of federal and state standards designed to ensure the radiological, chemical, biological, and physical quality of the environment for either aesthetic or public health considerations. The state of Washington has promulgated water quality standards for the Columbia River (Washington State Department of Ecology 1982). Of interest to Hanford operations is the designation of the Hanford reach of the Columbia River as Class A excellent. This designation requires that the water be usable for substantially all needs including drinking water, recreation, and wildlife. Class A water standards are summarized in Table A.1.

Environmental radiation protection standards are published in DOE ORDER 5480.1 *Environmental Protection, Safety, and Health Protection Program for DOE Operations* (USDOE 1981). These standards (shown in Table A.2) are based on guidelines originally recommended by the Federal Radiation Council (FRC) and other scien-

tific groups such as the International Commission on Radiological Protection (ICRP) and the National Commission on Radiation Protection and Measurements (NCRP). The standards govern exposures to ionizing radiation from DOE operations. DOE ORDER 5480.1A also lists radionuclide concentration guides for air and water. Several of the concentration guides for air and water are listed in Table A.3.

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

State of Washington,
Department of Ecology
Olympia, WA 98504

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

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

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

Parameter	Permissible Levels
Fecal coliform organism	1) ≤ 100 organisms/100 ml (median) 2) $\leq 10\%$ of samples may exceed 200 organisms/100 ml
Dissolved oxygen	> 8 mg/l
Temperature	1) $\leq 20^\circ\text{C}$ (68°F) due to human activities 2) When natural conditions exceed 20°C , no temperature increase of greater than 0.3°C allowed. 3) Increases not to exceed $34/(T + 9)$, where T = highest existing temperature in $^\circ\text{C}$ outside of dilution zone
pH	1) 6.5 to 8.5 range 2) < 0.5 unit induced variation
Turbidity	≤ 5 NTU ^(a) over background turbidity
Toxic, radioactive, or deleterious materials	Concentrations shall be below those of public health significance, or which cause acute or chronic toxic conditions to the aquatic biota, or which may adversely affect any water use.
Aesthetic value	Shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch or taste.

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

TABLE A.2. DOE Radiation Protection Standards for External and Internal Exposure

Type of Exposure	Annual Dose Equivalent or Dose Commitment, millirem ^(a)	
	Based on Dose to Individuals at Points of Maximum Probable Exposure	Based on an Average Dose to a Suitable Sample of the Exposed Population ^(b)
Whole body, gonads, or bone marrow	500	170
Other Organs	1500	500

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

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

TABLE A.3. DOE Order 5480.1 Radionuclide Concentration Guides

Radionuclide	Water	Air
	pCi/l (10^{-9} μ Ci/ml)	pCi/m ³ (10^{-12} μ Ci/ml)
Gross Alpha	30	0.02
Gross Beta	3,000	100
³ H	3,000,000	200,000
¹⁴ C (CO ₂)	NS	1,000,000
⁵¹ Cr	2,000,000	80,000
⁵⁴ Mn	100,000	1,000
⁶⁰ Co	30,000	300
⁶⁵ Zn	100,000	2,000
⁸⁵ Kr	NS ^(a)	300,000
⁸⁹ Sr	3,000	300
⁹⁰ Sr	300	30
⁹⁵ ZrNb	60,000	1,000
¹⁰⁶ Ru	10,000	200
¹²⁹ I	60	20
¹³¹ I	300	100
¹³⁷ Cs	20,000	500
¹⁴⁰ BaLa	20,000	1,000
¹⁴⁴ Ce	10,000	200
²³⁸ Pu	5,000	0.07
²³⁹ Pu	5,000	0.06
U (Natural)	600	2

(a) NS indicates no standard

TABLE A.4. Benton-Franklin-Walla Walla Counties Air Pollution Control Authority Ambient Air Quality Standards^(a)

Parameters	Type of Standard ^(b)	Sampling Period	Permissible Levels
NO ₂	Secondary and primary	Annual average	100 µg/m ³
Total particulates	Secondary	24-h average	150 µg/m ³
	Secondary	Annual average	60 µg/m ³

(a) Benton-Franklin-Walla Walla Air Pollution Control Authority 1980.

(b) Primary ambient air quality national standards define levels of air quality to protect the public health. Secondary standards define levels of air quality to protect the public welfare from any known or anticipated adverse effects of a pollutant.



APPENDIX B
DATA ANALYSIS



APPENDIX B

DATA ANALYSIS

The measurement of any physical quantity, be it temperature, distance, time, or radioactivity has some degree of inherent uncertainty associated with the final result. The uncertainty results from the combination of all possible inaccuracies in the measurement process including, for example, the reading of the result, the calibration of the measurement device, numerical rounding errors, etc. In this report, individual radioactivity measurements are accompanied by a plus or minus (\pm) analytical uncertainty term. This term represents the statistical counting error (two-standard deviations) associated with the measurement of the radioactivity in the sample. Reported means also include an uncertainty term. The term used to express the uncertainty associated with the mean is the two-standard error of the mean (95% confidence interval) and includes consideration of the uncertainty of the individual results as well as their variability with respect to each other.

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

Radionuclide concentrations in many environmental type samples are very low, near zero, such that the uncertainty associated with the measurement is large relative to the result of the measurement. Concentrations may, in fact, be so low that the associated analytical uncertainty

is equal to or greater than the reported result. In such cases, the radionuclide concentration was too low to be measured given the analytical technique used, and individual results are reported as being "less than detectable" (<DL). Although results which are less than their associated analytical uncertainty do not represent a physically real quantity in themselves, it is nevertheless appropriate to use the values when calculating the mean (i.e., average) of a set of similarly analyzed samples. Mean concentrations reported in this document therefore are calculated using all reported analytical results including those less than their associated analytical uncertainty.

As an aid to the reader in understanding the quality of such calculated means, the mean value and its two-standard error term are enclosed within parenthesis if a) fewer than three-fourths of the individual results used in the calculation were greater than their analytical uncertainty term (i.e., positively identified), b) the calculated mean was less than its calculated two-standard error term, or c) the mean was calculated to be a negative value. Generally, the use of parenthesis indicates that the concentrations measured in the sample were essentially indistinguishable from zero considering the analytical technique used. The term following the \pm sign provides an indication of the minimum concentration the analytical technique used is capable of achieving under the given circumstances.

Footnotes to the tables further explain the data presented.



APPENDIX C
ANALYTICAL PROCEDURE



APPENDIX C

ANALYTICAL PROCEDURES

RADIOLOGICAL SAMPLES

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

Air Samples

Alpha-, Beta-, and Gamma-Emitting Radionuclides are measured by a direct count of the glass fiber filter; alpha on a low-background gas flow proportional counter, beta on a gas flow proportional counter, and gamma on a Ge(Li) detector with a multichannel pulse height analyzer.

Strontium-90 is determined by leaching the glass fiber filters with nitric acid, scavenging with

barium chromate, precipitating as a carbonate, transferring to a stainless steel planchet, and counting with a low-background gas flow proportional counter.

Uranium is leached from the glass fiber filters with nitric acid and extracted as tetrapropyl ammonium uranyl trinitrate followed by back extraction into water. A portion of the water extract is fused with sodium and lithium fluoride and analyzed with a fluorometer.

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

Tritium in air as HTO is determined by collecting the water vapor with silica gel. The water vapor is

TABLE C.1. Minimum Detectable Concentrations (MDC)(a)

Radionuclide	Air		Water		Water (Resin Sampler)		Foodstuff & Wildlife		Soil & Vegetation	
	Minimum Sample Size, m ³	MDC, pCi/m ³	Minimum Sample Size, l	MDC, pCi/l	Minimum Sample Size, l	MDC, pCi/l	Minimum Sample Size, kg	MDC, pCi/kg	Minimum Sample Size, kg	MDC, pCi/kg
³ H (river)	---(b)	---	1	50	---	---	---	---	---	---
³ H (other)	5(m ³)	300(pCi/l)	0.1	300	---	---	0.01(c)	300	---	---
⁸⁹ Sr	---	---	10	0.6	---	---	4	2	---	---
⁹⁰ Sr	1500	0.001	10	0.06	---	---	4	2	0.5	5
¹²⁹ I	---	---	---	---	1000	0.000001	4	0.0001	---	---
¹³¹ I	1500	0.01	2	1	1000	0.1	4	0.5	---	---
U-nat	1500	0.005	0.1	0.5	---	---	---	---	0.5	10
²³⁸ Pu	---	---	---	---	1000	0.01	---	---	---	---
^{239,240} Pu	1500	0.0001	---	---	1000	0.01	---	---	0.5	0.6
Gamma-Emitters(d)	1500	0.01	5	8	1000	0.1	4	10	0.5	20 soil, 30 vegeta- tion
Gross Alpha	800	0.001	1	4	---	---	---	---	---	---
Gross Beta	800	0.003	1	8	---	---	---	---	---	---

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

(b) Dashed line indicates no value.

(c) Measurement on 10 ml water from sample.

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

removed by heat and vacuum and collected in a freeze trap. The tritium content of the water vapor is determined with a liquid scintillation spectrometer.

Iodine-131 is collected on activated charcoal which is then counted on a Ge(Li) detector with a multichannel pulse height analyzer.

Carbon-14 is collected as carbon dioxide gas trapped in soda lime. The carbon dioxide is released from the soda lime sample with acid and injected into a "Benzene Synthesizer" instrument. The carbon dioxide is quantitatively converted to benzene through a series of catalyzed reactions. The benzene product is mixed with scintillator fluid and counted on a low temperature liquid scintillation counter.

Krypton-85 is removed from the air sample and purified using a specially constructed cryogenic chromatography instrument. The sample is passed through a series of cold traps. The purified krypton is mixed with scintillation fluid and counted on a low temperature liquid scintillation counter.

Water Samples

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

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

Gamma-Emitting Radionuclides are determined by a direct count of 500 ml of sample concentrate using a Ge(Li) detector with a multichannel pulse height analyzer.

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 counted with a low-background gas flow proportional counter. After a 15-day period the yttrium-90 daughter is separated and then counted with a proportional counter.

Tritium samples are either counted directly with a liquid scintillation spectrometer or the sample

is enriched by alkaline electrolysis and then counted with a liquid scintillation spectrometer.

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

Milk

Gamma-Emitting Radionuclides are measured by a direct count of the sample on a Ge(Li) detector with a multichannel pulse height analyzer.

Tritium in water distilled from milk is counted directly with a liquid scintillation spectrometer.

Iodine-129 is separated from milk with an anion exchange resin, purified, and analyzed by the neutron activation method.

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

Strontium-89,90 is removed from milk with a cation resin, eluted with sodium chloride, precipitated as a carbonate, and transferred to a stainless steel planchet for counting with a low-background gas flow proportional counter.

Foodstuffs

Gamma-Emitting Radionuclides are determined by a direct count of the sample on a Ge(Li) detector with a multichannel pulse height analyzer.

Tritium in water distilled from farm produce is counted directly with a liquid scintillation spectrometer.

Plutonium is determined as in air filter samples after drying, ashing in a furnace, and treating with nitric acid prior to the anion exchange step.

Uranium is determined as in water samples after drying, ashing in a furnace, and treating with nitric acid prior to the ether extraction step.

Strontium-90 is determined as in air samples after drying, ashing in a furnace, and treating with nitric acid prior to the fuming nitric acid step.

Vegetation and Wildlife

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

Soil

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

Plutonium and Strontium-89,90 are determined after the soil is dried, mixed thoroughly, leached with nitric acids, and then precipitated as strontium oxalate. The sample is then precipitated as a carbonate, transferred to a planchet and counted as with water samples.

After removal of strontium from the sample, plutonium is co-precipitated with calcium oxalate, dissolved and loaded onto an ion exchange resin column.

The plutonium is eluted from the resin column with nitric and hydrofluoric acids and analyzed

by a method similar to the procedure described for air filter samples.

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

NONRADIOLOGICAL SAMPLES

Water samples collected to monitor water quality of the Columbia River are analyzed according to standard methods. The most applicable methods recommended by the American Public Health Association in their publication *Standard Methods for the Examination of Water and Wastewater (APHA 1975)* are used for most onsite analyses. Supplemental USGS samples are analyzed according to approved USGS standard methods.



APPENDIX D
QUALITY ASSURANCE



APPENDIX D

QUALITY ASSURANCE

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

ANALYTICAL LABORATORY QUALITY ASSURANCE

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

pared and distributed to participating laboratories. Replicate analyses are performed on each sample, and the results are forwarded to EML and EPA for comparison with known values and with the results from other laboratories. This program enables the laboratory to demonstrate that it is capable of performing accurate analyses. The TLDs in routine use were included in the 6th International Environmental Dosimeter Project.

Summarized in Table D.1 is a comparison of UST and EPA results. The EPA results, while not necessarily the true values, were the mean of replicate analyses by the participating laboratories and were used as the reference values in the program. Table D.2 summarizes results from the EML intercomparison program.

In addition to these programs, the laboratory is provided, without their knowledge, replicate environmental samples from the Hanford environs. Replicate TLDs also were submitted for analysis.

SAMPLE COLLECTION QUALITY ASSURANCE

Of primary importance in the operation of an environmental surveillance program is the collection of representative samples. To check on the precision of samples, replicate air particulate filters were collected at several locations. Table D.3 shows the average biases and the range of individual biases for gross beta and gross alpha analyses of the replicate air filters. Due to the very small amounts of radioactive particulate material in the Hanford environs, results of individual replicate pairs of air filter samples may vary by more than 100 percent. However, the average biases, representing 12 monthly sampling periods, show good agreement between replicate air sample composites for the analysis of ^{137}Cs , ^{60}Co , ^{90}Sr , $^{239,240}\text{Pu}$, and natural uranium (Table D.4). The observed degree of bias is acceptable because it is much less than the minimum detectable concentrations given in Table C.1. Tables D.5 and D.6 show the individual results of replicate water and soil samples. Each month three pairs of replicate TLDs were

TABLE D.1 Environmental Protection Agency Laboratory Intercomparison Results for 1983

Sample Media	Radionuclide	Month	Concentrations ^(a)			
			UST ^(b)	Expected ^(b)	Other Laboratories ^(c)	
Air Filters	Gross Alpha	March	27 ± 1	26 ± 11	28 ± 7	
	Gross Beta		75 ± 2	68 ± 9	69 ± 10	
	⁹⁰ Sr		20 ± 3	20 ± 3	19 ± 4	
	¹³⁷ Cs		28 ± 3	27 ± 9	31 ± 9	
	Gross Alpha	August	14 ± 0	13 ± 9	14 ± 5	
	Gross Beta		39 ± 5	36 ± 9	39 ± 10	
	⁹⁰ Sr		15 ± 4	10 ± 3	10 ± 2	
	¹³⁷ Cs		18 ± 2	15 ± 9	19 ± 7	
	Gross Alpha	November	19 ± 1	19 ± 15	20 ± 7	
	Gross Beta		55 ± 4	50 ± 15	54 ± 10	
	⁹⁰ Sr		18 ± 4	15 ± 5	15 ± 5	
	¹³⁷ Cs		22 ± 1	20 ± 15	24 ± 9	
Water	Gross Alpha	January	38 ± 10	29 ± 13	26 ± 10	
	Gross Beta		30 ± 2	31 ± 9	32 ± 9	
	⁸⁹ Sr		24 ± 4	29 ± 9	27 ± 12	
	⁹⁰ Sr		16 ± 1	17 ± 3	17 ± 3	
	²³⁹ Pu		8 ± 5	9 ± 2	8 ± 3	
	³ H	February	2330 ± 92	2560 ± 620	2530 ± 470	
	⁵¹ Cr		44 ± 4	45 ± 9	48 ± 17	
	⁶⁰ Co		22 ± 1	22 ± 9	23 ± 5	
	⁶⁵ Zn		21 ± 2	21 ± 9	22 ± 9	
	¹⁰⁶ Ru		38 ± 29	48 ± 9	47 ± 17	
	¹³⁴ Cs		18 ± 2	20 ± 9	20 ± 5	
	¹³⁷ Cs		18 ± 2	19 ± 9	19 ± 5	
	U (total)		27 ± 3	31 ± 10	30 ± 10	
	Gross Alpha		March	34 ± 3	31 ± 14	27 ± 14
	Gross Beta			25 ± 3	28 ± 9	28 ± 7
	²²⁶ Ra	9 ± 5		13 ± 3	12 ± 4	
	²²⁸ Ra	0 ± 1		0 ± 0	1 ± 4	
	³ H	April	3170 ± 100	3330 ± 630	3300 ± 420	
	¹³¹ I		19 ± 10	27 ± 10	27 ± 8	
	Gross Alpha	May	66 ± 9	64 ± 28	58 ± 28	
	Gross Beta		150 ± 7	150 ± 13	140 ± 30	
	⁸⁹ Sr		21 ± 4	24 ± 9	25 ± 9	
	⁹⁰ Sr		12 ± 2	13 ± 3	13 ± 4	
	²²⁶ Ra		8 ± 1	9 ± 2	8 ± 2	
	²²⁸ Ra		10 ± 1	5 ± 1	6 ± 5	
	⁶⁰ Co		28 ± 1	30 ± 9	31 ± 7	
	¹³⁴ Cs		28 ± 2	33 ± 9	31 ± 7	
	¹³⁷ Cs		26 ± 2	27 ± 9	28 ± 7	
	U (total)		22 ± 6	25 ± 10	24 ± 7	
	Gross Alpha		June	12 ± 1	11 ± 9	11 ± 5
	Gross Beta	61 ± 3		57 ± 9	54 ± 14	
	⁸⁹ Sr	52 ± 3		57 ± 9	57 ± 17	
⁹⁰ Sr	31 ± 1	38 ± 3		37 ± 8		
³ H	1290 ± 46	1530 ± 580		1555 ± 350		
⁵¹ Cr	60 ± 2	60 ± 9		62 ± 20		
⁶⁰ Co	12 ± 1	13 ± 9		14 ± 4		
⁶⁵ Zn	37 ± 1	36 ± 9		37 ± 10		
¹⁰⁶ Ru	35 ± 5	40 ± 9		40 ± 12		
¹³⁴ Cs	41 ± 3	47 ± 9		44 ± 7		
¹³⁷ Cs	25 ± 1	76 ± 9		28 ± 9		

TABLE D.1 Environmental Protection Agency Laboratory Intercomparison Results for 1983 (Contd)

Sample Media	Radionuclide	Month	Concentrations ^(a)		
			UST ^(b)	Expected ^(b)	Other Laboratories ^(c)
Water (contd)	Gross Alpha	July	7 ± 2	7 ± 9	8 ± 4
	Gross Beta		22 ± 2	22 ± 9	22 ± 7
	²³⁹ Pu		5 ± 14	9 ± 2	8 ± 2
	¹³¹ I	August	13 ± 3	14 ± 10	14 ± 5
	U (total)		33 ± 4	26 ± 10	27 ± 7
	Gross Alpha	September	6 ± 1	5 ± 9	5 ± 4
	Gross Beta		8 ± 1	9 ± 9	10 ± 5
	⁸⁹ Sr		20 ± 2	15 ± 9	15 ± 5
	⁹⁰ Sr		11 ± 2	10 ± 3	10 ± 4
	²²⁶ Ra		3 ± 1	3 ± 1	3 ± 1
	²²⁸ Ra		2 ± 1	2 ± 1	2 ± 2
	³ H	October	1440 ± 100	1210 ± 570	1230 ± 320
	⁶⁰ Co		18 ± 4	19 ± 9	19 ± 4
	¹⁰⁶ Ru		37 ± 12	52 ± 9	48 ± 14
	¹³⁴ Cs		13 ± 4	15 ± 9	15 ± 5
	¹³⁷ Cs		22 ± 2	22 ± 9	22 ± 5
	Gross Alpha	November	29 ± 5	22 ± 10	21 ± 10
	Gross Beta		56 ± 7	63 ± 9	58 ± 14
	²²⁶ Ra		9 ± 1	5 ± 1	5 ± 1
	²²⁸ Ra		7 ± 1	3 ± 1	3 ± 2
	⁸⁹ Sr		20 ± 4	17 ± 9	17 ± 5
	⁹⁰ Sr		7 ± 1	8 ± 3	8 ± 2
	⁶⁰ Co		10 ± 2	11 ± 9	11 ± 4
	¹³⁴ Cs		14 ± 2	15 ± 9	14 ± 4
	¹³⁷ Cs		15 ± 7	15 ± 9	15 ± 4
	U (total)		10 ± 2	11 ± 10	11 ± 5
	Gross Alpha		December	15 ± 2	14 ± 9
Gross Beta	19 ± 5			16 ± 9	17 ± 7
³ H	2020 ± 170	2390 ± 610		2340 ± 460	
¹³¹ I	12 ± 2	20 ± 10		20 ± 7	
²²⁶ Ra	6 ± 1	7 ± 2		7 ± 3	
²²⁸ Ra	5 ± 1	4 ± 1		4 ± 2	
Milk	⁸⁹ Sr	February	27 ± 2	37 ± 9	32 ± 12
	⁹⁰ Sr		14 ± 2	18 ± 3	17 ± 6
	¹³¹ I		59 ± 10	55 ± 10	55 ± 8
	¹³⁷ Cs		29 ± 5	26 ± 9	26 ± 7
	⁸⁹ Sr	October	11 ± 9	15 ± 9	14 ± 7
	⁹⁰ Sr		10 ± 5	14 ± 3	14 ± 4
	¹³¹ I		51 ± 3	40 ± 10	41 ± 14
	¹³⁷ Cs		38 ± 3	33 ± 9	34 ± 7
Food	⁸⁹ Sr	March	43 ± 10	35 ± 9	33 ± 11
	⁹⁰ Sr		26 ± 4	28 ± 3	29 ± 4
	¹³¹ I		36 ± 3	37 ± 10	37 ± 7
	¹³⁷ Cs		32 ± 5	31 ± 9	33 ± 5

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

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

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

TABLE D.2. Environmental Measurements Laboratory (DOE) Results for 1983

Sample Media	Radionuclide	Month	Concentrations ^(a)		
			UST ^(b)	Expected ^(c)	Other Laboratories ^(c)
Air Filters	⁹⁰ Sr	May	27 ± 3	32 ± 3	27
	¹³⁷ Cs		430 ± 1	340 ± 3	330
	²³⁹ Pu		3.1 ± 6	3.0 ± 1	3.0
	²⁴¹ Am		4.7 ± 28	3.5 ± 6	3.7
	U (Natural)		0.36 ± 36	4.1 ± 3	4.5
	⁹⁰ Sr	November	1.9 ± 10	2.4 ± 12	2.4
	¹³⁷ Cs		390 ± 1	390 ± 7	400
	²³⁹ Pu		1.9 ± 4	2.1 ± 7	1.8
	U (Natural)		6.1 ± 12	6.1 ± 5	6.6
Water	³ H	May	8.9 ± 3	11 ± 2	13
	⁹⁰ Sr		0.12 ± 4	0.12 ± 4	0.12
	¹³⁷ Cs		2.3 ± 1	2.4 ± 8	2.3
	¹⁴⁴ Ce		11 ± 1	11 ± 6	10
	U (Natural)		0.040 ± 34	0.034 ± 29	0.029
	³ H	November	63 ± 1	69 ± 9	68
	⁵¹ Cr		45 ± 2	42 ± 6	43
	⁶⁰ Co		4.6 ± 3	4.5 ± 2	4.6
	⁹⁰ Sr		0.18 ± 8	0.22 ± 6	0.24
	¹³⁷ Cs		5.6 ± 2	5.5 ± 0	5.5
	²³⁹ Pu		0.010 ± 8	0.015 ± 13	0.012
	U (Natural)		0.015 ± 17	0.018 ± 2	0.020
	Vegetation	⁹⁰ Sr	May	3.9 ± 4	4.9 ± 3
¹³⁷ Cs		2.2 ± 3		1.8 ± 2	2.1
²³⁸ Pu		0.087 ± 16		0.081 ± 6	0.088
²³⁹ Pu			0.026 ± 30	0.020 ± 5	0.023
U (Natural)			0.012 ± 34	0.030 ± 6	0.050
⁹⁰ Sr		November	3.0 ± 19	3.6 ± 5	3.6
¹³⁷ Cs			1.6 ± 3	1.4 ± 2	1.5
²³⁸ Pu			0.063 ± 10	0.065 ± 9	0.060
²³⁹ Pu			0.015 ± 8	0.016 ± 12	0.017
U (Natural)	0.016 ± 34		0.039 ± 10	0.022	
Tissue	⁹⁰ Sr	May	22 ± 17	30 ± 3	26
	¹³⁷ Cs		23 ± 1	20 ± 2	23
	²³⁸ Pu		0.013 ± 66	0.013 ± 7	0.012
	²³⁹ Pu		0.13 ± 19	0.15 ± 6	0.14
	⁹⁰ Sr	November	3.2 ± 58	4.4 ± 9	5.6
	¹³⁷ Cs		2.3 ± 1	1.8 ± 5	1.9
	²³⁸ Pu		0.034 ± 16	0.074 ± 10	0.074
	²³⁹ Pu		0.020 ± 24	0.019 ± 21	0.020
Soil	⁹⁰ Sr	May	0.11 ± 8	0.15 ± 6	0.14
	¹³⁷ Cs		0.23 ± 9	0.24 ± 5	0.25
	²³⁸ Pu		0.014 ± 22	0.027 ± 14	.025
	²³⁹ Pu		0.86 ± 2	1.6 ± 9	1.5
	²⁴¹ Am		0.20 ± 22	0.18 ± 18	0.22
	⁹⁰ Sr	November	2.5 ± 31	2.6 ± 13	2.5
	¹³⁷ Cs		1.3 ± 1	1.0 ± 5	1.1
	²³⁸ Pu		0.052 ± 5	0.040 ± 15	0.045
	²³⁹ Pu		0.013 ± 27	0.011 ± 18	0.011

(a) Picocuries (micrograms U Natural) per milliliter for water; picocuries (micrograms U Natural) per sample for air; picocuries (micrograms U Natural) per gram dry weight for all others.

(b) Concentration plus or minus percent standard deviation based on counting statistics.

(c) Concentration plus or minus percent standard error of the mean.

(d) Mean value reported by all participating laboratories. No uncertainty was reported.

TABLE D.3. Evaluation of Replicate Air Samples Analyzed for Gross Beta and Gross Alpha(a)

Analysis(b)	Average Bias, pCi/m ³	Average Bias, %	Range of Individual Biases, %
Beta	.00044	2.4	-51 to 100
Alpha	.000056	6.4	-90 to 150

(a) Expressed as result of replicate sample minus result of record sample.

(b) 25 replicate pairs of samples for each analysis.

TABLE D.4. Replicate Air Sample Results for Compositing Particulate Samples

Radio-nuclide	Date	Concentration, pCi/m ³ (a)	
		Record ± 2 σ	Replicate ± 2 σ
¹³⁷ Cs	1-10-83	(.0007 ± .005)	(.002 ± .003)
	2-7-83	.008 ± .005	(.004 ± .006)
	3-7-83	.002 ± .001	(-.0009 ± .002)
	4-4-83	(-.0006 ± .001)	(.0004 ± .0009)
	5-2-83	(.001 ± .002)	(-.001 ± .003)
	5-31-83	.00008 ± .0007	---(b)
	6-27-83	.001 ± .001	(.0006 ± .002)
	7-25-83	.002 ± .001	(.0002 ± .0008)
	8-22-83	(-.0006 ± .002)	(.00009 ± .001)
	9-19-83	(-.0005 ± .002)	.001 ± .001
	10-17-83	(.0004 ± .001)	(.00009 ± .001)
⁶⁰ Co	11-14-83	(.0003 ± .001)	(-.003 ± .002)
	12-12-83	(-.001 ± .001)	(-.001 ± .002)
	1-10-83	.005 ± .003	(-.007 ± .005)
	2-7-83	(-.003 ± .006)	(-.006 ± .005)
	3-7-83	(-.002 ± .002)	.003 ± .002
	4-4-83	(.0005 ± .001)	(.0002 ± .001)
	5-2-83	(-.0001 ± .003)	(.0004 ± .002)
	5-31-83	.002 ± .0009	---
	6-27-83	(-.001 ± .001)	.003 ± .002
	7-25-83	(.0008 ± .002)	(.0004 ± .0005)
	8-22-83	(.002 ± .001)	---
⁹⁰ Sr	9-19-83	(.0006 ± .0009)	(.0002 ± .002)
	10-17-83	(-.0004 ± .002)	(-.001 ± .003)
	11-14-83	(-.001 ± .019)	(.0007 ± .002)
	12-12-83	(.0003 ± .0006)	(-.0007 ± .002)
	3-7-83	(.0001 ± .0002)	(.00008 ± .0002)
	5-31-83	.0002 ± .0002	.0003 ± .0002
	8-22-83	.0004 ± .0004	.0008 ± .0005
^{239,240} Pu	11-4-83	(-.00002 ± .0001)	(.00008 ± .0002)
	3-7-83	.0001 ± .00009	(.0001 ± .00008)
	5-31-83	.00003 ± .00002	.0001 ± .00004
	8-22-83	.00003 ± .00002	(.000003 ± .000006)
U	11-4-83	(.000002 ± .000003)	(.000008 ± .00002)
	3-7-83	.00001 ± .0000005	.000008 ± .000003
	(Natural) 5-31-83	.00002 ± .0000006	.000006 ± .000002
	8-22-83	.00008 ± .00003	.00004 ± .00002
11-14-83	.00002 ± .00001	.00002 ± .00001	

(a) Values are enclosed in parenthesis if result was negative or less than or equal to the associated two sigma counting error.

(b) Dashed line indicates no sample result.

TABLE D.5. Replicate Water Sample Results

Analysis or Radionuclide	Date	Concentration, pCi/l(a)	
		Record ± 2 σ	Replicate ± 2 σ
Beta	4-19-83	(4.7 ± 5.4)	(4.0 ± 5.1)
	9-27-83	10. ± 5.4	(1.4 ± 5.2)
Alpha	4-19-83	.78 ± .44	.90 ± .47
	9-27-83	.65 ± .42	.64 ± .43
¹³⁷ Cs	4-19-83	(.19 ± .62)	(.05 ± .76)
	9-27-83	.95 ± .67	(-.30 ± .69)
⁶⁰ Co	4-19-83	(.22 ± .76)	(-.76 ± .89)
	9-27-83	(-.25 ± 1.1)	(-.25 ± 1.1)
⁹⁰ Sr	4-19-83	.12 ± .04	.14 ± .03
	9-27-83	.26 ± .09	.27 ± .07
U (Natural)	4-19-83	.63 ± .22	.48 ± .17
	9-27-83	.35 ± .12	.53 ± .17
³ H	4-19-83	180 ± 17	250 ± 90
	9-27-83	110 ± 14	140 ± 15

(a) Values are enclosed in parenthesis if result was negative or less than or equal to the associated two sigma counting error.

exposed at one of three levels of radiation representing environmental levels. These results, shown in Table D.7, also show an acceptable degree of bias. Table D.8 lists the results of the 6th International Environmental Dosimeter Project and further confirm the acceptable performance of the environmental TLD's.

DOSE CALCULATIONS QUALITY ASSURANCE

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

TABLE D.6. Replicate Soil Sample Results

Radionuclide	Date	Concentration, pCi/g (dry weight) ^(a)		
		Record $\pm 2\sigma$	Replicate $\pm 2\sigma$	Replicate $\pm 2\sigma$
¹³⁷ Cs	8-11-83	.84 \pm .05	.77 \pm .05	.88 \pm .05
	8-25-83	.14 \pm .03	.09 \pm .02	.13 \pm .03
⁶⁰ Co	8-11-83	(.0005 \pm .03)	(-.02 \pm .03)	(-.06 \pm .03)
	8-25-83	(.01 \pm .03)	(-.02 \pm .03)	(-.01 \pm .03)
⁹⁰ Sr	8-11-83	.81 \pm .11	.92 \pm .12	.94 \pm .12
	8-25-83	.28 \pm .04	.45 \pm .06	.41 \pm .06
^{239,240} Pu	8-11-83	.017 \pm .003	.011 \pm .002	.017 \pm .002
	8-25-83	.008 \pm .002	.005 \pm .001	.002 \pm .001
²⁴¹ Am	8-11-83	(.004 \pm .005)	(.002 \pm .004)	.010 \pm .008
	8-25-83	---(b)	(.001 \pm .005)	(.001 \pm .006)

(a) Values are enclosed in parenthesis if result is less than or equal to the associated two sigma counting error.

(b) Dashed line indicates no sample result.

TABLE D.7. Individual and Average Percent Bias for the Analysis of Replicate TLDs

Month	Bias, %(a)		
	High(b)	Medium	Low
January	0.8	2.1	-2.5
February	2.6	1.0	-1.3
March	1.4	0.6	14.
April	-1.4	-3.2	0.0
May	-2.2	-4.5	-3.3
June	-4.8	-4.2	-2.9
July	-2.9	-1.6	-2.9
August	-0.5	-0.6	-0.6
September	4.0	3.9	2.8
October	1.5	0.6	0.0
November	2.5	3.0	2.7
December	3.6	1.9	2.1
Average Bias, %	0.4	-0.1	0.7

(a) Average of two observed values minus expected value.

(b) Relative levels of exposures (between 12 and 23 mR).

TABLE D.8. Results of 6th International Environmental TLD Intercomparison

Type Exposure	Exposure, mR		
	Expected	Participant Average	PNL
Field	44 \pm 2.2	42 \pm 9.1	41 \pm 3
Pre-Irradiated Field	200 \pm 10	190 \pm 9.5	200 \pm 20
Laboratory Irradiated	160 \pm 8	150 \pm 9.4	160 \pm 10

APPENDIX E
DOSE CALCULATIONS

APPENDIX E

DOSE CALCULATIONS

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

For certain types of exposure pathways, the dose equivalent results from the inhalation or ingestion of radionuclides in the air, water, foods, etc., such that the radionuclides may be metabolically absorbed by the body and retained for some time. In addition, long-lived radionuclides may be deposited on the ground and become a source of long-term exposure. To fully account for the dose equivalent received in these cases, the dose impact is expressed as the "cumulative dose equivalent" (or, cumulative dose), also reported in units of millirem.

The cumulative dose includes the total dose received for a period of 50 years following release of the radionuclide to the environment including the dose incurred as a result of residual radionuclides remaining in the environment beyond the year of their release. The calculation of cumulative dose thus considers the long-term residency of the individual or population for which it is presented.

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

tration factors as appropriate for the various possible exposure pathways. Exposure pathways considered in dose calculations are illustrated in Figure E.1.

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

TYPES OF DOSE CALCULATIONS PERFORMED

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

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

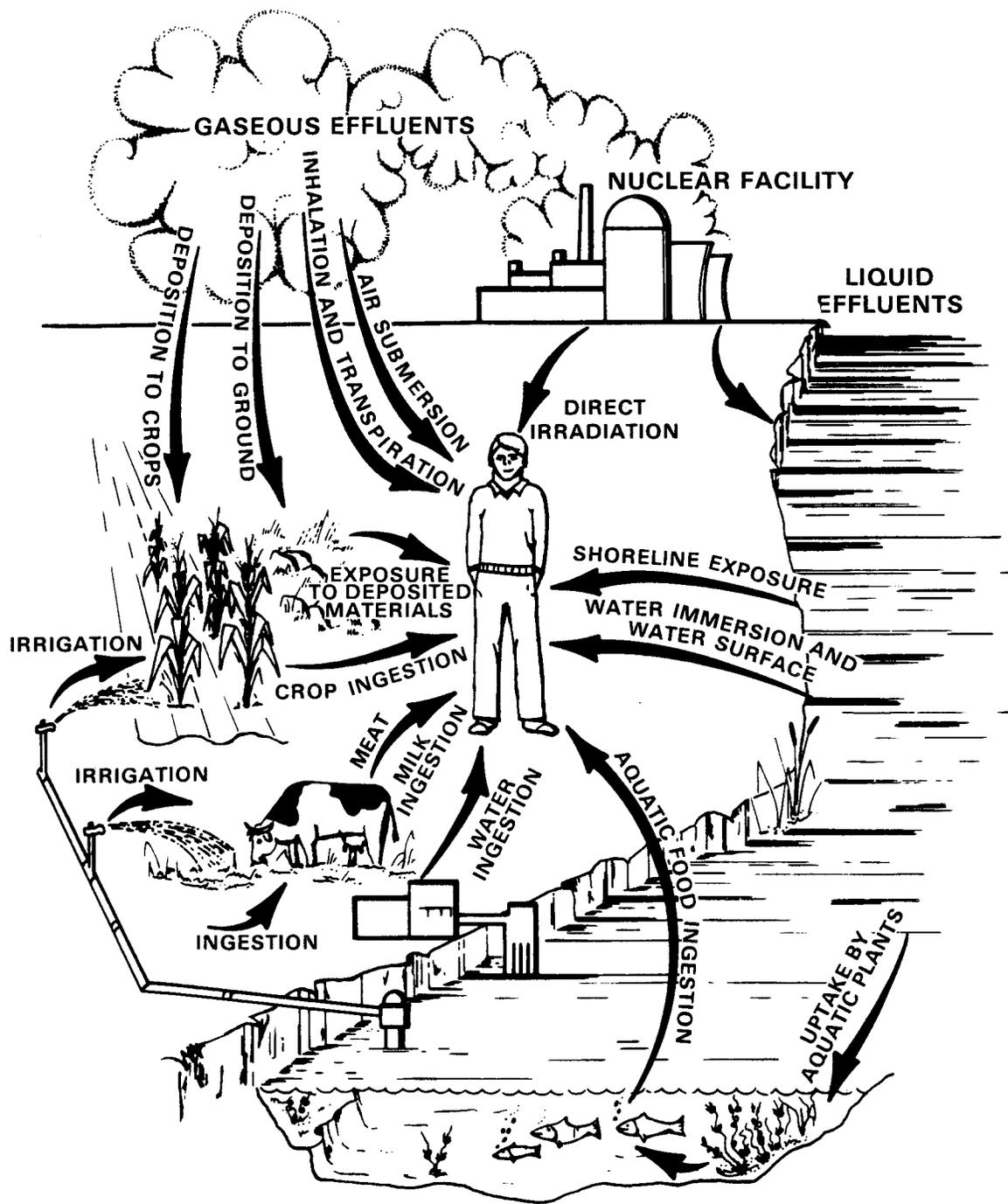


FIGURE E.1 Potential Environmental Dose Pathways

- inhalation of radioactive airborne effluents
 - submersion in radioactive airborne effluents
 - ingestion of foodstuffs contaminated by effluents deposited on the ground by airborne deposition and by irrigation with Columbia River water
 - drinking sanitary water obtained from the Columbia River
 - exposure to ground contaminated by airborne deposition and by irrigation with Columbia River water
 - ingestion of fish taken from the Columbia River
 - recreation along the Columbia River—boating, swimming and shoreline activities.
3. **80-km Population Doses.** While there are no regulatory limits for collective population doses, such an evaluation provides an indication of the overall impact of Hanford operations. The 80-km population dose represents the summed products of average dose and number of individuals involved for all possible pathways. The units are man-rem.

The MI exposure pathways depicted in Figure E.1 are also assumed to be available to the offsite population. However, in the case of releases to the Columbia River, only that portion of the full 80-km population using river water are potentially exposed. The river related exposure pathways are drinking water, irrigated food stuff, fish consumption, and river recreation. Descriptions of river related pathways are as follows:

- **Drinking Water**—The cities of Richland and Pasco obtain their municipal water from the Columbia River downstream from Hanford. The city of Kennewick began drawing a portion of its municipal water from the river in late 1980. During 1983, approximately 40% of Kennewick drinking water was drawn from the Columbia River. The total affected population was approximately 70,000.
- **Irrigated Foodstuff**—Columbia River water is withdrawn for irrigation of home vegetable gardens in the Riverview District of Franklin County of Pasco. Approximately 2,000 people are estimated to be affected.

- **River Recreation**—These activities include swimming, boating, and shoreline recreation. The population residing adjacent to the river within 80 km of Hanford is assumed to be effected by these pathways and is estimated to number 125,000.
- **Fish Consumption**—Population doses due to consumption of fish obtained locally from the Columbia River are calculated based on an estimated total annual catch of 15,000 kg/yr without reference to a specific population group.

DATA

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

POPULATION DISTRIBUTION

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

ATMOSPHERIC DISPERSION

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

TABLE E.1. Distribution of Population in 80-km Radius of the 100-N Reactor by Population Grid Sector(a)

Compass Direction	Number of People					Totals
	0-16 km	16-32 km	32-48 km	48-64 km	64-80 km	
NORTH	36	953	420	1,492	7,583	10,484
NNE	5	285	561	18,531	1,350	20,732
NE	0	624	1,013	2,691	259	4,587
ENE	0	620	5,884	1,129	429	8,062
EAST	0	294	625	2,742	605	4,266
ESE	0	306	1,493	596	247	2,642
SE	0	54	2,113	28,922	5,001	36,090
SSE	0	0	35,127	50,292	3,354	88,773
SOUTH	0	127	4,592	2,041	176	6,936
SSW	0	258	1,676	12,603	625	15,162
SW	0	547	4,946	16,747	469	22,709
WSW	0	680	1,699	8,297	15,274	25,950
WEST	18	395	936	5,149	75,686	82,184
WNW	54	573	377	490	1,598	3,092
NW	74	277	425	515	683	1,974
NNW	64	277	438	1,030	4,696	6,505
TOTALS	251	6,270	62,325	153,267	118,035	340,148

(a) Based on 1980 census data.

TABLE E.3. Distribution of Population in 80-km Radius of the FFTF by Population Grid Sector(a)

Compass Direction	Number of People					Totals
	0-16 km	16-32 km	32-48 km	48-64 km	64-80 km	
NORTH	0	78	859	811	16,267	18,015
NNE	20	343	5,728	2,945	1,021	10,057
NE	114	377	760	1,033	217	2,501
ENE	211	1,041	2,644	492	451	4,839
EAST	229	600	183	169	183	1,364
ESE	229	442	544	292	1,060	2,567
SE	344	25,267	13,654	2,105	952	42,322
SSE	10,829	40,933	5,688	719	2,364	60,533
SOUTH	11,760	9,385	1,525	5,611	15,691	43,972
SSW	1,446	4,550	583	185	1,927	8,691
SW	179	1,538	5,234	535	239	7,725
WSW	0	1,206	7,748	14,956	481	24,391
WEST	0	190	3,339	6,089	17,171	26,789
WNW	0	0	932	1,221	3,176	5,329
NW	0	0	295	903	705	1,903
NNW	0	0	264	1,302	1,182	2,748
TOTALS	25,361	85,950	49,980	39,368	63,087	263,746

(a) Based on 1980 census data.

TABLE E.2. Distribution of Population in 80-km Radius of 200 Area Hanford Meteorological Tower by Population Grid Sector(a)

Compass Direction	Number of People					Totals
	0-16 km	16-32 km	32-48 km	48-64 km	64-80 km	
NORTH	0	174	1,124	772	1,957	4,027
NNE	0	92	656	5,547	14,822	21,117
NE	0	262	5,930	2,963	596	9,751
ENE	0	235	773	2,366	435	3,809
EAST	0	340	1,329	1,659	588	3,916
ESE	0	283	1,374	230	652	2,539
SE	0	6,757	48,661	50,519	3,474	109,411
SSE	0	1,997	13,161	2,717	5,218	23,093
SOUTH	0	1,532	1,489	195	1,799	5,015
SSW	0	905	5,283	652	129	6,969
SW	0	1,190	19,786	2,182	459	23,617
WSW	5	1,840	5,063	15,088	4,573	26,569
WEST	32	648	949	6,874	78,635	87,138
WNW	73	444	802	833	2,833	4,985
NW	0	555	398	493	1,454	2,900
NNW	0	246	456	864	4,521	6,087
TOTALS	110	17,500	107,234	93,954	122,145	340,943

(a) Based on 1980 census data.

TABLE E.4. Distribution of Population in 80-km Radius of 300 Area by Population Grid Sector(a)

Compass Direction	Number of People					Totals
	0-16 km	16-32 km	32-48 km	48-64 km	64-80 km	
NORTH	289	241	989	5,655	5,317	12,491
NNE	307	475	841	1,950	2,269	5,842
NE	18	966	2,583	562	205	4,334
ENE	307	465	349	470	238	1,829
EAST	291	114	137	174	687	1,403
ESE	338	288	863	594	17,891	19,974
SE	2,549	26,150	2,922	877	1,235	33,733
SSE	7,161	30,357	1,114	1,117	1,113	40,862
SOUTH	15,561	6,651	96	17,223	5,127	44,658
SSW	11,124	4,034	99	1,209	2,038	18,504
SW	10,066	3,931	706	182	181	15,066
WSW	4,429	1,810	5,531	8,988	621	21,379
WEST	294	984	2,226	16,878	16,293	36,675
WNW	0	0	692	1,543	1,679	3,914
NW	0	0	74	923	785	1,782
NNW	0	0	8	875	1,212	2,095
TOTALS	52,734	76,466	19,230	59,220	56,891	264,541

(a) Based on 1980 census data.

centrations for the year. Annual average dispersion factors for the 100, 200, 300, and 400 Areas during 1983 are listed in Tables E.5 through E.8.

TERRESTRIAL AND AQUATIC PATHWAYS

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

Other parameters affecting the movement of radionuclides within potential exposure path-

ways include irrigation rates, growing period, hold up, etc. These parameters are listed in Table E.9. Note that certain parameters are specific to maximum and average individuals.

PUBLIC EXPOSURE

Offsite radiation dose impact is related to the extent of public exposure to or consumption of radionuclides associated with Hanford operations. Parameters describing assumed diet, residency and river recreation for maximum and average individuals are provided in Tables E.10 through E.12, respectively.

DOSE CALCULATION DOCUMENTATION

Assurance of quality in dose calculations is provided in several ways. First, comparisons are made against doses calculated for previous annual reports and differences are validated. Second, all computed doses are reviewed through the Hanford Dose Overview Program. Third, computer codes and inputs to the codes are documented. Summaries of this information are provided in Tables E.13 through E.17.

TABLE E.5 Annual Average Atmospheric Dispersion Around The 100-N Area During 1983 for an 89-m Release Height^(a)

Direction	sec/m ³									
	0.8 km	2.4 km	4.0 km	5.6 km	7.2 km	12 km	24 km	40 km	56 km	72 km
N	1.41E-07	1.18E-07	8.06E-08	5.81E-08	4.43E-08	2.52E-08	1.13E-08	6.24E-09	4.23E-09	3.19E-09
NNE	1.13E-07	9.47E-08	6.58E-08	4.82E-08	3.71E-08	2.16E-08	9.95E-09	5.58E-09	3.81E-09	2.89E-09
NE	2.01E-07	1.56E-07	1.05E-07	7.63E-08	5.82E-08	3.35E-08	1.53E-08	8.48E-09	5.77E-09	4.37E-09
ENE	2.71E-07	2.02E-07	1.40E-07	1.04E-07	8.04E-08	4.82E-08	2.30E-08	1.31E-08	9.06E-09	6.95E-09
E	3.08E-07	2.22E-07	1.59E-07	1.19E-07	9.29E-08	5.60E-08	2.68E-08	1.54E-08	1.07E-08	8.20E-09
ESE	2.43E-07	1.37E-07	8.99E-08	6.51E-08	5.00E-08	2.95E-08	1.38E-08	7.83E-09	5.38E-09	4.11E-09
SE	2.21E-07	9.44E-08	5.94E-08	4.28E-08	3.29E-08	1.97E-08	9.39E-09	5.39E-09	3.74E-09	2.87E-09
SSE	1.96E-07	8.31E-08	5.01E-08	3.52E-08	2.67E-08	1.55E-08	7.17E-09	4.03E-09	2.76E-09	2.11E-09
S	1.81E-07	9.19E-08	5.79E-08	4.10E-08	3.12E-08	1.79E-08	8.16E-09	4.55E-09	3.11E-09	2.36E-09
SSW	1.01E-07	5.26E-08	3.35E-08	2.37E-08	1.79E-08	1.02E-08	4.60E-09	2.55E-09	1.73E-09	1.31E-09
SW	7.61E-08	5.34E-08	3.75E-08	2.79E-08	2.16E-08	1.29E-08	6.13E-09	3.50E-09	2.42E-09	1.85E-09
WSW	6.71E-08	5.79E-08	4.14E-08	3.08E-08	2.39E-08	1.42E-08	6.71E-09	3.81E-09	2.63E-09	2.01E-09
W	1.67E-07	1.46E-07	1.04E-07	7.70E-08	5.95E-08	3.52E-08	1.65E-08	9.32E-09	6.41E-09	4.89E-09
WNW	1.60E-07	1.21E-07	8.18E-08	5.90E-08	4.50E-08	2.58E-08	1.17E-08	6.47E-09	4.40E-09	3.33E-09
NW	1.44E-07	1.19E-07	8.26E-08	6.03E-08	4.63E-08	2.70E-08	1.24E-08	6.93E-09	4.73E-09	3.59E-09
NNW	1.11E-07	7.44E-08	5.15E-08	3.78E-08	2.91E-08	1.71E-08	7.99E-09	4.52E-09	3.11E-09	2.37E-09

(a) Calculated from meteorological data collected at the 100-N Area and the Hanford Meteorological Station.

TABLE E.6. Annual Average Dispersion Around The 200 Areas During 1983 for an 89-m Release Height^(a)

Direction	sec/m ³									
	0.8 km	2.4 km	4.0 km	5.6 km	7.2 km	12 km	24 km	40 km	56 km	72 km
N	8.79E-08	6.26E-08	4.52E-08	3.39E-08	2.64E-08	1.58E-08	7.50E-09	4.29E-09	2.97E-09	2.27E-09
NNE	6.02E-08	3.67E-08	2.55E-08	1.91E-08	1.49E-08	9.14E-08	4.44E-09	2.57E-09	1.79E-09	1.38E-09
NE	9.64E-08	5.94E-08	4.06E-08	3.00E-08	2.33E-08	1.40E-08	6.74E-09	3.87E-09	2.68E-09	2.06E-09
ENE	1.00E-07	6.80E-08	4.91E-08	3.72E-08	2.93E-08	1.80E-08	8.84E-09	5.14E-09	3.58E-09	2.76E-09
E	1.16E-07	9.01E-08	6.59E-08	5.05E-08	3.99E-08	2.50E-08	1.24E-08	7.24E-09	5.06E-09	3.91E-09
ESE	9.73E-08	1.29E-07	9.57E-08	7.15E-08	5.54E-08	3.26E-08	1.51E-08	8.50E-09	5.82E-09	4.24E-09
SE	1.85E-07	1.70E-07	1.18E-07	8.62E-08	6.61E-08	3.81E-08	1.73E-08	9.63E-09	6.55E-09	4.95E-09
SSE	1.40E-07	1.07E-07	7.21E-08	5.22E-08	3.99E-08	2.32E-08	1.06E-08	5.92E-09	4.04E-09	3.06E-09
S	2.14E-07	1.18E-07	7.39E-08	5.12E-08	3.82E-08	2.09E-08	8.98E-09	4.82E-09	3.22E-09	2.40E-09
SSW	1.48E-07	8.24E-08	5.05E-08	3.45E-08	2.55E-08	1.37E-08	5.74E-09	3.03E-09	2.00E-09	1.48E-09
SW	1.21E-07	6.00E-08	3.65E-08	2.50E-08	1.86E-08	1.01E-08	4.29E-09	2.29E-09	1.52E-09	1.13E-09
WSW	8.93E-08	4.78E-08	3.02E-08	2.11E-08	1.59E-08	8.79E-08	3.83E-09	2.08E-09	1.40E-09	1.04E-09
W	1.20E-07	6.80E-08	4.48E-08	3.20E-08	2.43E-08	1.38E-08	6.23E-09	3.45E-09	2.35E-09	1.78E-09
WNW	8.91E-08	6.23E-08	4.29E-08	3.13E-08	2.40E-08	1.39E-08	6.36E-09	3.56E-09	2.43E-09	1.85E-09
NW	1.20E-07	7.21E-08	4.58E-08	3.26E-08	2.47E-08	1.43E-08	6.55E-09	3.66E-09	2.50E-09	1.90E-09
NNW	7.80E-08	5.98E-08	4.23E-08	3.12E-08	2.41E-08	1.41E-08	6.56E-09	3.71E-09	2.55E-09	1.94E-09

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

TABLE E.7. Annual Average Atmospheric Dispersion Around The 300 Area During 1983 for a Ground-Level Release Height^(a)

Direction	sec/m ³									
	0.8 km	2.4 km	4.0 km	5.6 km	7.2 km	12 km	24 km	40 km	56 km	72 km
N	8.17E-06	1.25E-06	5.72E-07	3.46E-07	2.50E-07	1.27E-07	5.50E-08	3.08E-08	2.14E-08	1.61E-08
NNE	5.96E-06	9.16E-07	4.16E-07	2.51E-07	1.81E-08	9.16E-08	3.95E-08	2.20E-08	1.52E-08	1.15E-08
NE	7.35E-06	1.13E-06	5.15E-07	3.11E-07	2.25E-07	1.14E-07	4.92E-08	2.74E-08	1.90E-08	1.43E-08
ENE	4.24E-06	6.51E-07	2.97E-07	1.79E-07	1.30E-07	6.56E-08	2.84E-08	1.58E-08	1.10E-08	8.30E-09
E	4.98E-06	7.66E-07	3.51E-07	2.12E-07	1.54E-07	7.81E-08	3.40E-08	1.91E-08	1.33E-08	1.00E-08
ESE	3.61E-06	5.55E-07	2.55E-07	1.54E-07	1.12E-07	5.69E-08	2.49E-08	1.40E-08	9.77E-09	7.38E-09
SE	5.37E-06	8.29E-07	3.78E-07	2.29E-07	1.65E-07	8.33E-08	3.58E-08	1.99E-08	1.38E-08	1.04E-08
SSE	5.49E-06	8.50E-07	3.86E-07	2.33E-07	1.67E-07	8.38E-08	3.55E-08	1.96E-08	1.35E-08	1.01E-08
S	5.71E-06	8.79E-07	3.99E-07	2.41E-07	1.73E-07	8.73E-08	3.74E-08	2.08E-08	1.43E-08	1.08E-08
SSW	8.64E-07	1.31E-07	5.79E-08	3.46E-08	2.45E-08	1.21E-08	5.04E-09	2.73E-09	1.86E-09	1.39E-09
SW	6.97E-07	1.05E-07	4.70E-08	2.82E-08	2.02E-08	1.02E-08	4.35E-09	2.41E-09	1.66E-09	1.25E-09
WSW	4.52E-07	6.83E-08	3.02E-08	1.81E-08	1.28E-08	6.29E-09	2.58E-09	1.39E-09	9.42E-09	7.02E-10
W	1.53E-06	2.31E-07	1.03E-07	6.15E-08	4.38E-08	2.18E-08	9.19E-09	5.02E-09	3.44E-09	2.57E-09
WNW	3.53E-06	5.39E-07	2.45E-07	1.48E-07	1.07E-07	5.40E-08	2.33E-08	1.30E-08	9.03E-09	6.81E-09
NW	6.90E-06	1.06E-06	4.84E-07	2.92E-07	2.11E-07	1.07E-07	4.65E-08	2.60E-08	1.81E-08	1.36E-08
NNW	5.99E-06	9.18E-07	4.20E-07	2.53E-07	1.84E-07	9.36E-08	4.09E-08	2.30E-08	1.60E-08	1.21E-08

(a) Calculated from meteorological data collected at the 300 Area and the Hanford Meteorological Station.

TABLE E.8. Annual Average Dispersion Around The 400 Area During 1983 for a Ground-Level Release Height^(a)

Direction	sec/m ³									
	0.8 km	2.4 km	4.0 km	5.6 km	7.2 km	12 km	24 km	40 km	56 km	72 km
N	8.70E-06	1.33E-06	6.08E-07	3.67E-07	2.66E-07	1.35E-07	5.84E-08	3.27E-08	2.27E-08	1.71E-08
NNE	6.12E-06	9.37E-07	4.25E-07	2.56E-07	1.85E-07	9.31E-08	4.00E-08	2.23E-08	1.54E-08	1.16E-08
NE	4.34E-06	6.65E-07	3.03E-07	1.83E-07	1.32E-07	6.68E-08	2.89E-08	1.61E-08	1.12E-08	8.42E-09
ENE	2.70E-06	4.14E-07	1.88E-07	1.14E-07	8.22E-08	4.17E-08	1.80E-08	1.00E-08	6.94E-09	5.23E-09
E	4.56E-06	7.02E-07	3.20E-07	1.93E-07	1.39E-07	7.03E-08	3.03E-08	1.68E-08	1.16E-08	8.76E-09
ESE	5.08E-06	7.84E-07	3.56E-07	2.15E-07	1.55E-07	7.79E-08	3.32E-08	1.84E-08	1.27E-08	9.50E-09
SE	5.46E-06	8.44E-07	3.84E-07	2.32E-07	1.67E-07	8.42E-08	3.61E-08	2.00E-08	1.38E-08	1.04E-08
SSE	3.91E-06	6.02E-07	2.74E-07	1.65E-07	1.19E-07	6.01E-08	2.57E-08	1.43E-08	9.86E-09	7.42E-09
S	5.36E-06	8.21E-07	3.75E-07	2.26E-07	1.64E-07	8.32E-08	3.62E-08	2.03E-08	1.41E-08	1.07E-08
SSW	2.64E-06	4.03E-07	1.83E-07	1.10E-07	7.95E-08	4.01E-08	1.74E-08	9.66E-09	6.71E-09	5.06E-09
SW	1.70E-06	2.59E-07	1.17E-07	7.05E-08	5.07E-08	2.56E-08	1.10E-08	6.11E-09	4.22E-09	3.18E-09
WSW	8.95E-07	1.37E-07	6.16E-08	3.66E-08	2.62E-08	1.30E-08	5.47E-08	2.97E-09	2.04E-09	1.52E-09
W	1.74E-06	2.66E-07	1.22E-07	7.30E-08	5.31E-08	2.69E-08	1.17E-08	6.56E-09	4.58E-09	3.45E-09
WNW	1.15E-06	1.77E-07	7.97E-08	4.78E-08	3.43E-08	1.71E-08	7.21E-09	3.96E-09	2.72E-09	2.03E-09
NW	2.06E-06	3.15E-07	1.43E-07	8.58E-08	6.19E-08	3.12E-08	1.34E-08	7.44E-09	5.16E-09	3.89E-09
NNW	3.81E-06	5.84E-07	2.66E-07	1.60E-07	1.16E-07	5.86E-08	2.53E-08	1.41E-08	9.78E-09	7.37E-09

(a) Calculated from meteorological data collected at the 400 Area and the Hanford Meteorological Station.

TABLE E.9. Pathway Parameters

	Holdup (days, except as noted) ^(a)		Growing Period, days	Yield, kg/m ²	Irrigation Rate, ℓ/m ² /month
	Maximum Individual	Average Individual			
Leafy vegetables	1	14	90	1.5	150
Other above-ground vegetables	1	14	60	0.7	160
Potatoes	10	14	90	4	180
Other root vegetables	1	14	90	5	150
Berries	1	14	60	2.7	150
Melons	1	14	90	0.8	150
Orchard fruit	10	14	90	1.7	150
Wheat	10	14	90	0.72	0
Other grains	1	14	90	1.4	150
Eggs	1	18	90	0.84	150
Milk	1	4	30	1.3	200
Beef	15	34	90	0.84	140
Pork	15	34	90	0.84	140
Poultry	1	34	90	0.84	140
Fish	24 h	24	—	—	—
Drinking water	24	24	—	—	—

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

TABLE E.10. Dietary Parameters

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

(a) Units l/yr.

(b) 330 l/yr for infant.

(c) Average individual consumption not identified; radiation doses were calculated based on estimated total annual catch of 15,000 kg.

TABLE E.11. Residency Parameters

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

(a) Inhalation Rates:

Adult - 250 cm³/sec routineInfant - 44 cm³/sec**TABLE E.12.** Recreational Activities

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

(a) Assumes 8-h holdup for maximum individual and 13 h for average.

TABLE E.13. Documentation of 100 Area Airborne Release Dose Calculation

Facility name:	100 Area
Releases:	See Table 25
Meteorological conditions:	1983 annual average, calculated from data collected at 100 N Area and the Hanford Meteorological Station from 1-83 through 12-83. See Table E.5
X/Q:	Maximum individual 2.8 x 10 ⁻⁹ sec/m ³ at 53 km SSE for direct airborne pathways and 1.2 x 10 ⁻⁸ sec/m ³ at 41 km SSE for food pathways, 80-km population 1.4 x 10 ⁻³ person-sec/m ³ 82.3 meters effective (60.96 meters actual stack height)
Release height:	82.3 meters effective (60.96 meters actual stack height)
Population distribution:	340,000, see Table E.1
Computer code:	DACRIN, Rev. 1.2, 1980
Calculated dose:	Chronic inhalation, maximum individual and 80-km population, 50-yr dose commitment
Files addressed:	Organ Data Library, Rev. 2-5-81 Radionuclide Library, Rev. 1-15-81
Computer code:	PABLM, Rev. 2.2, 10-1-80
Calculated dose:	Chronic ingestion and ground contamination exposure, maximum individual and 80-km population, 50-year cumulative dose
Files addressed:	Radionuclide Library, Rev. 1-15-81 Food Transfer Library, Rev. 8-26-82 Organ Data Library, Rev. 2-5-81 Ground Dose Factor Library, Rev. 3-15-78
Computer code:	KRONIC, Rev. 3-11-83
Calculated dose:	Chronic air submersion, maximum individual and 80-km population, first year dose
Files addressed:	RNDBET GISLIB

TABLE E.14. Documentation of 100 Area Liquid Release Dose Calculation

Facility name:	100 Area
Releases:	See Table 25
River flow:	130,000 cfs
Mixing ratio:	1
Reconcentration formula:	3
Shore-width factor:	0.2
Population:	70,000—drinking water pathway 125,000—fish and direct exposure 2,000—irrigated foodstuff
Computer code:	PABLM, Rev. 2.2, 10-1-80
Calculated dose:	Chronic ingestion, direct exposure to water and shoreline, maximum individual and 80-km population, 50-year cumulative dose
Files addressed:	Radionuclide Library, Rev. 1-15-81 Organ Data Library, Rev. 2-5-81 Hanford Specific Bio. Accum. Library Ground Dose Factor Library, Rev. 3-15-78
Computer code:	PABLM, Rev. 2.2, 10-1-80
Calculated dose:	Chronic ingestion and ground contamination, maximum individual and 80-km population, 50-year cumulative dose
Files addressed:	Radionuclide Library, Rev. 1-15-81 Food Transfer Library, Rev. 8-26-82 Organ Data Library, Rev. 2-5-81 Ground Dose Factor Library, Rev. 3-15-78

TABLE E.15. Documentation of 200 Areas Airborne Release Dose Calculation

Facility name:	200 Area
Releases:	See Table 25
Meteorological conditions:	1983 annual average, calculated from data collected at the Hanford Meteorological Station from 1-82 through 12-82. See Table E.6
X/Q:	Maximum individual 3.1×10^{-9} sec/m ³ at 43 km SE for direct airborne pathways and 1.3×10^{-8} sec/m ³ at 32 km SE for food pathways, 80-km population 1.6×10^{-3} person-sec/m ³
Release height:	89.2 meters effective (60.96 meters actual stack height)
Population distribution:	341,000, see Table E.2
Computer code:	DACRIN, Rev. 1.2, 1980
Calculated dose:	Chronic inhalation, maximum individual and 80-km population, 50-yr dose commitment
Files addressed:	Organ Data Library, Rev. 2-5-81 Radionuclide Library, Rev. 1-15-81
Computer code:	PABLM, Rev. 2.2, 10-1-80
Calculated dose:	Chronic ingestion and ground contamination exposure, maximum individual and 80-km population, 50-year cumulative dose
Files addressed:	Radionuclide Library, Rev. 1-15-81 Food Transfer Library, Rev. 8-26-82 Organ Data Library, Rev. 2-5-81 Ground Dose Factor Library, Rev. 3-15-78
Computer code:	KRONIC, Rev. 3-11-83
Calculated dose:	Chronic air submersion, maximum individual and 80-km population, first year dose
Files addressed:	RNDBET GISLIB

TABLE E.16. Documentation of 300 Area Airborne Release Dose Calculation

Facility name:	300 Area
Releases:	See Table 25
Meteorological conditions:	1983 annual average, calculated from data collected at 300 Area and the Hanford Meteorological Station from 1-83 through 12-83. See Table E.7
X/Q:	Maximum individual 8.2×10^{-8} sec/m ³ at 1.3 km SSE for direct airborne pathways and 2.9×10^{-6} sec/m ³ at 1.6 km E for food pathways, 80-km population 7.4×10^{-3} person-sec/m ³
Release height:	Ground level
Population distribution:	265,000, see Table E.4
Computer code:	DACRIN, Rev. 1.2, 1980
Calculated dose:	Chronic inhalation, maximum individual and 80-km population, 50-yr dose commitment
Files addressed:	Organ Data Library, Rev. 2-5-81 Radionuclide Library, Rev. 1-15-81
Computer code:	PABLM, Rev. 2.2, 10-1-80
Calculated dose:	Chronic ingestion and ground contamination exposure, maximum individual and 80-km population, 50-year cumulative dose
Files addressed:	Radionuclide Library, Rev. 1-15-81 Food Transfer Library, Rev. 8-26-82 Organ Data Library, Rev. 2-5-81 Ground Dose Factor Library, Rev. 3-15-78
Computer code:	KRONIC, Rev. 3-11-83
Calculated dose:	Chronic air submersion, maximum individual and 80-km population, first year dose
Files addressed:	RNDBET GISLIB

TABLE E.17. Documentation of 400 Area Airborne Release Dose Calculation

Facility name:	400 Area
Releases:	See Table 25
Meteorological conditions:	1983 annual average, calculated from data collected at 400 Area and the Hanford Meteorological Station from 1-83 through 12-83. See Table E.8
X/Q:	Maximum individual 2.6×10^{-8} sec/m ³ at 29 km SSE for direct airborne pathways and 1.0×10^{-7} sec/m ³ at 11 km SE for food pathways, 80-km population 6.7×10^{-3} person-sec/m ³
Release height:	Ground level
Population distribution:	264,000, see Table E.3
Computer code:	DACRIN, Rev. 1.2, 1980
Calculated dose:	Chronic inhalation, maximum individual and 80-km population, 50-yr dose commitment
Files addressed:	Organ Data Library, Rev. 2-5-81 Radionuclide Library, Rev. 1-15-81
Computer code:	PABLM, Rev. 2.2, 10-1-80
Calculated dose:	Chronic ingestion and ground contamination exposure, maximum individual and 80-km population, 50-year cumulative dose
Files addressed:	Radionuclide Library, Rev. 1-15-81 Food Transfer Library, Rev. 8-26-82 Organ Data Library, Rev. 2-5-81 Ground Dose Factor Library, Rev. 3-15-78
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