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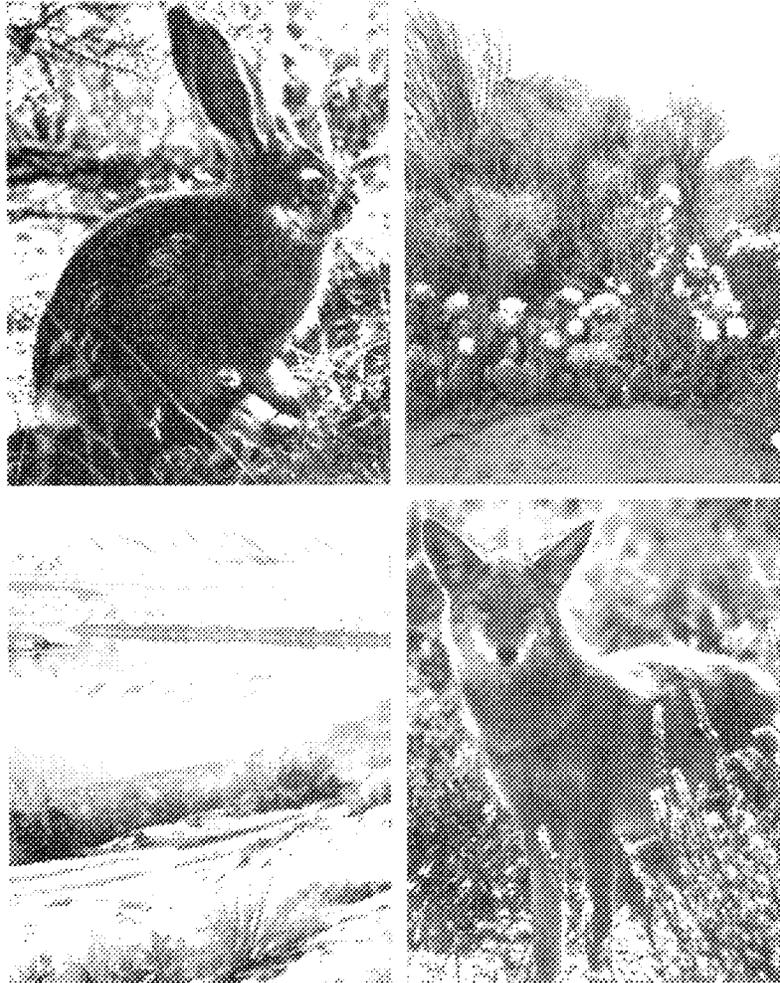
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Environmental Surveillance at Hanford for CY 1982



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

Pacific Northwest Laboratory
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Environmental Surveillance at Hanford for CY 1982

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May 1983

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

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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 1982. Previous reports in this series for the past ten years are:

| | | | |
|------|-----------|--|--------------|
| 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) |
| 1972 | BNWL-1727 | P. E. Bramson and J. P. Corley | (April 1973) |

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

- *Environmental Status of the Hanford Site* (to be issued as PNL-4658 for 1982), and
- *Ground-Water Surveillance at the Hanford Site for CY 1982* (to be issued as PNL-4659 for 1982).

These reports provide summaries of environmental and ground-water monitoring programs 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 1982 and those who helped prepare this report.

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

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

M. A. McKinney and S. Chadez-Hartley edited this report and arranged for its publication.

SUMMARY

Environmental surveillance activities performed by the Pacific Northwest Laboratory for the Department of Energy's Hanford Site for 1982 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 1981 as a result of declining fallout levels associated with a foreign atmospheric nuclear test conducted during late 1980. Several short-lived radionuclides associated with the test that had been consistently observed in 1981 decreased to below detectable levels during 1982.

Columbia River Radiological Monitoring - A difference in ^{129}I concentrations in Columbia River water downstream of the Hanford Site as compared to river water upstream of the Site was observed. The difference, attributed to seepage from the unconfined Hanford aquifer, was similar to that which has been observed since sampling for ^{129}I in the river began in 1977. Nevertheless, ^{129}I concentrations in the Columbia River downstream of the Hanford Site were only one-millionth of the applicable DOE Concentration Guides. Cobalt-60 and ^{131}I were identified more frequently in downstream than in upstream samples; however, observed concentrations were well below applicable Concentration Guides and too low to enable quantification of the difference. Samples collected during 1982 did not show any quantifiable difference in ^{90}Sr levels between upstream and downstream samples although a slight difference had been indicated from samples collected in 1981. Tritium was observed in all upstream and downstream river water samples but no difference due to

Hanford contributions could be quantified. Cobalt-60, ^{131}I , and ^{90}Sr are present at low concentrations in N Reactor effluents; and tritium is present in both N Reactor effluents and in seepage from the unconfined Hanford aquifer. However, the dilution of these effluents by the large quantity of river water flowing past the Site makes the Hanford contributions nearly undetectable, especially since these radionuclides are already present in the river to some extent either naturally or due to worldwide fallout.

Columbia River Water Quality Monitoring - Nonradiological water quality parameters were normally 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 1982. Results of the program are reported in PNL-4659 (Eddy, Prater, and Rieger 1983).

Foodstuffs - Low levels of fallout radionuclides were observed in most foodstuff samples and are probably attributable to weapons test fallout. There was no indication in any of the samples of the presence of radioactivity associated with Hanford.

Wildlife - Low concentrations of radionuclides attributable to operations at Hanford were observed in several samples of ducks and game birds collected near operating areas. Concentrations were low enough that any resulting radiation dose from consumption of an animal containing the highest observed concentration would be well below the applicable DOE 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. A special effort

to collect onsite deer with maximum radioactivity levels was completed during 1982, and results show that the radiation dose which could be received by consumption of the animal with the highest ^{137}Cs concentration observed during this two-year study would be less than 1% of the applicable DOE radiation protection standard.

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 in the samples with the exception of uranium. A special sampling program conducted during 1982 showed that uranium concentrations were slightly higher in surface soils across the Columbia River from the 300 Area than in other sampling locations; however, it has not yet been determined whether the differences are due to naturally occurring uranium in the soil or to operations in the 300 Area.

External Radiation - Dose rates in the vicinity of residential areas due to external penetrating radiation were similar to those observed in 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 that attributable to background sources. The highest dose rate in a publicly accessible location was observed near the west fence of the 300 Area where measured dose equivalent rates averaged 0.3 mrem/hr.

Radiological Impact - An assessment of potential radiological impacts attributable to 1982 operations at Hanford indicated that radiation doses to the public were well below all applicable regulatory limits and were 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 0.7 mrem, as compared to the applicable DOE Radiation Protection Standard of 500 mrem. 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 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 40 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 1982. The Hanford Environmental Surveillance Program is conducted by PNL, which is operated for the DOE by Battelle Memorial Institute.

The objectives of the program include:

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

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

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

DESCRIPTION OF THE HANFORD SITE

The U. S. Department of Energy's Hanford Site is located in a rural region of southeastern Washington and occupies an area of 1500 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

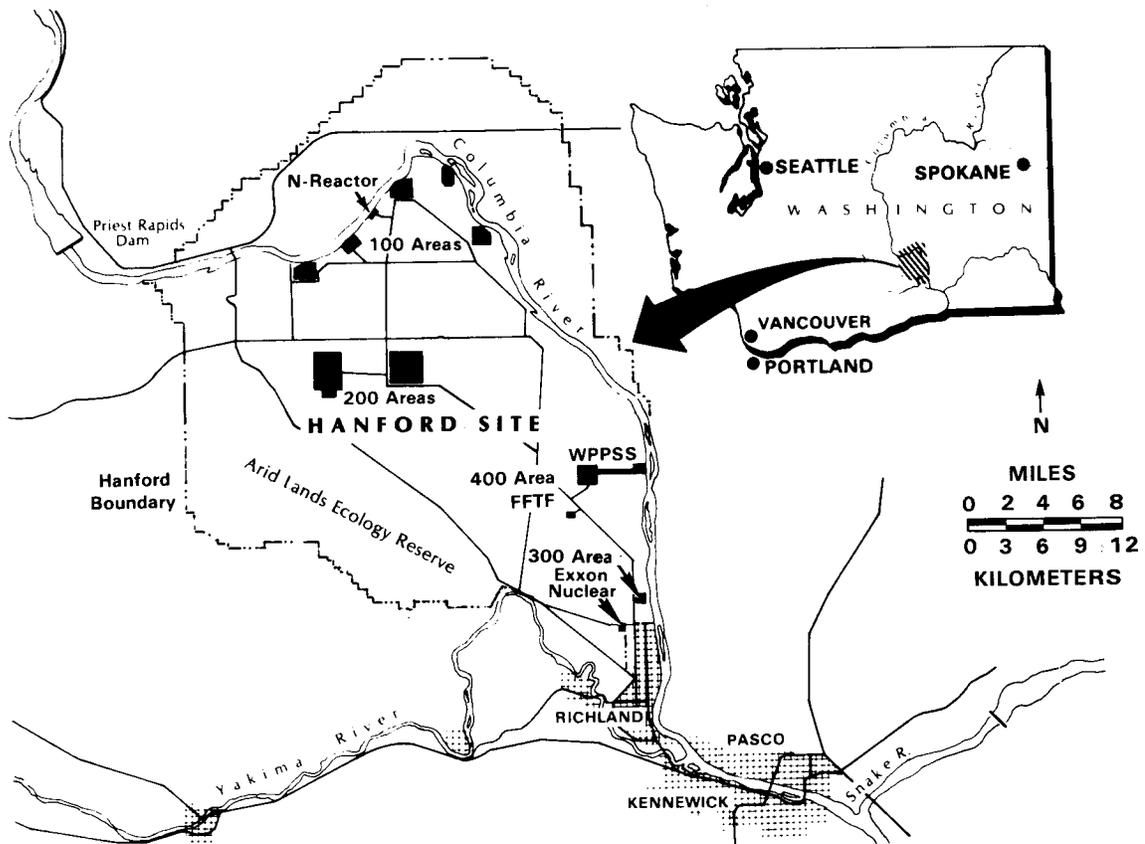


FIGURE 1. DOE's Hanford Site in Washington State

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

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

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

The population center nearest to the Hanford site is the Tri-Cities area (Richland, Pasco, and Kennewick), 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 for Waste Management Operations at Hanford* (ERDA 1975).

MAJOR ACTIVITIES

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

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

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

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

Principal DOE Contractors operating at Hanford are:

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

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

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

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

Highlights of operational activities at Hanford during 1982 were:

- N Reactor operated for 204 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 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 FFTF completed its first 100-day full power operating campaign.
- New, double-walled underground tanks for storage of high-level radioactive liquid wastes were put into service in the 200 areas.

- N reactor began operating in a 6% ^{240}Pu production mode in support of national defense program commitments.

Work at Hanford during 1982 also included Hanford National Environmental Research Park (NERP) studies, Arid Land Ecology (ALE) Studies, and Basalt Waste Isolation Program (BWIP) activities, as well as continued operation of a variety of national research and laboratory facilities.



ATMOSPHERIC MONITORING

Radioactivity in air was measured by a network of continuously operating air samplers at nineteen 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 prevalent 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.

Airborne radionuclide concentrations during 1982 were lower than those observed in 1981 because of the gradual decline of atmospheric fallout associated with a foreign atmospheric nuclear test that occurred in the fall of 1980. Airborne radioactivity data collected during 1982 did not indicate the presence of detectable levels of Hanford origin radionuclides in the offsite environs.

SAMPLE COLLECTION AND ANALYSIS

Air samples are 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 are collected at all sampling locations. Samplers at the Fir Road, Richland, and Benton City locations also contain a tritium collection unit. Particulate airborne radionuclides are sampled by drawing air at a flow rate of 2.6 m³/hr through a 5-cm diameter high-

efficiency particulate filter. (a) The filters are collected biweekly and analyzed for gross beta radioactivity after a seven-day holding period during which short-lived naturally occurring radon and thoron daughters collected by the filter decay.

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

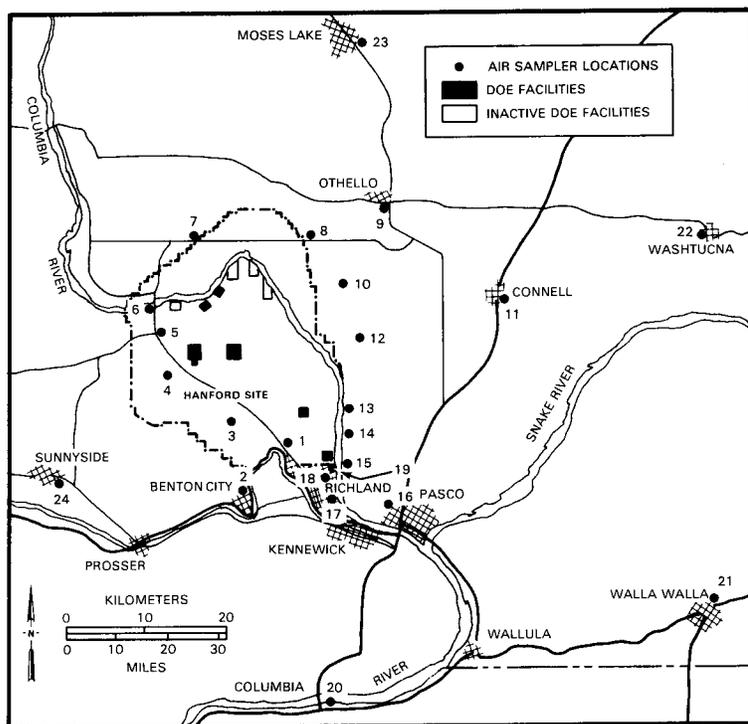


FIGURE 2. Air Sampling Locations

In addition, several of the filters are also analyzed in a similar manner for gross alpha radioactivity. The air filters are 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 are combined and analyzed for ^{90}Sr and plutonium. Analytical methods are summarized in Appendix C.

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

The tritium collection unit consists of two cartridges containing silica gel through which a stream of air is passed at a flow rate of $0.03\text{ m}^3/\text{hr}$. The first silica gel cartridge removes tritium in the form of water vapor (HTO). A catalytic oxidizer located downstream of the first silica gel cartridge then converts gaseous hydrogen and hydrocarbons in the air to water vapor that is collected by the second silica gel cartridge. Airborne tritium (^3H) results are thus reported for ^3H (HTO) and ^3H (HT). Moisture is removed from the silica gel by heating and then condensing the trapped water. Next the water is analyzed for tritium using liquid-scintillation counting methods as described in Appendix C. The silica gel cartridges are replaced every two weeks.

RESULTS

Results of gross-beta and gross-alpha radioactivity in airborne particulate samples are shown in Table 1. Both gross beta and gross alpha concen-

trations were similar at all sampling locations, averaging $0.03\text{ pCi}/\text{m}^3$ and $0.001\text{ pCi}/\text{m}^3$ respectively. No contribution to general airborne particulate radioactivity concentrations as a result of Hanford operations could be identified based on a comparison of samples collected near the Site perimeter and at distant locations. Therefore, airborne radioactivity levels observed in 1982 are attributed to worldwide fallout and natural sources.

A comparison of long-lived gross-beta radioactivity in airborne particulate samples collected during 1982 with samples collected in previous years (Figure 3) shows that airborne radioactivity levels have decreased markedly from those observed in 1981. The elevated airborne radioactivity levels, which began in late 1980 and continued until late 1981, are attributed to an atmospheric nuclear test conducted by the People's Republic of China in October 1980. Similar trends have been observed in varying degrees following previous atmospheric tests as shown in the figure.

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 1982 than in 1981. 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 generally not detectable in air samples by the end of 1982. No radioiodines were detected in air samples during 1982.

NONRADIOLOGICAL AIR MONITORING

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

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 Hanford Environmental Health Foundation (HEHF) was completed in 1982. The tests indicated particulate emissions to be well within applicable state and local limits (Washington State Department of

(a) Manufactured by Nuclear Consulting Services, Inc. The charcoal is impregnated with potassium iodide (KI) and triethylenediamine (TEDA), and retention efficiencies are 99% for both elemental and methyl-iodide.

TABLE 1. Airborne Radioactivity in the Hanford Environs

| Concentration Guide(b) Locations | Map No. | Gross Beta Concentrations(a) pCi/m ³ (10 ⁻¹² μCi/ml) | | | Gross Alpha Concentrations(a) pCi/m ³ (10 ⁻¹² μCi/ml) | | | | |
|--------------------------------------|------------|--|----------------|---------------|---|-------------------|-----------------|-----------------|----------------|
| | | No. of Samples | 100 Maximum | Minimum | Average | No. of Samples | 0.03 Maximum | Minimum | Average |
| Perimeter Stations | | | | | | | | | |
| Prosser Barricade | 1 | 25 | 0.05 ± 0.005 | 0.02 ± 0.004 | 0.03 ± 0.005 | 25 | 0.002 ± 0.0007 | 0.0005 ± 0.0003 | 0.001 ± 0.0002 |
| Benton City | 2 | 25 | 0.05 ± 0.005 | 0.01 ± 0.004 | 0.03 ± 0.005 | 25 | 0.002 ± 0.0007 | 0.0003 ± 0.0003 | 0.001 ± 0.0002 |
| ALE | 3 | 26 | 0.05 ± 0.005 | 0.01 ± 0.004 | 0.03 ± 0.006 | | | | |
| Rattlesnake Springs | 4 | 25 | 0.07 ± 0.006 | 0.008 ± 0.004 | 0.03 ± 0.006 | | | | |
| Yakima Barricade | 5 | 25 | 0.06 ± 0.005 | 0.02 ± 0.004 | 0.03 ± 0.004 | | | | |
| Vernita Bridge | 6 | 25 | 0.06 ± 0.005 | 0.02 ± 0.004 | 0.03 ± 0.005 | | | | |
| Wahluke #2 | 7 | 26 | 0.06 ± 0.005 | 0.02 ± 0.004 | 0.03 ± 0.004 | | | | |
| Berg Ranch | 8 | 25 | 0.06 ± 0.003 | 0.01 ± 0.004 | 0.03 ± 0.006 | 25 | 0.005 ± 0.003 | 0.0004 ± 0.0003 | 0.001 ± 0.0004 |
| Othello | 9 | 25 | 0.05 ± 0.005 | 0.005 ± 0.004 | 0.03 ± 0.004 | | | | |
| Wahluke Watermaster | 10 | 22 | 0.05 ± 0.005 | 0.01 ± 0.004 | 0.03 ± 0.004 | | | | |
| Connell | 11 | 24 | 0.05 ± 0.005 | 0.005 ± 0.004 | 0.03 ± 0.004 | | | | |
| Cooke Bros. | 12 | 26 | 0.06 ± 0.005 | 0.01 ± 0.004 | 0.03 ± 0.004 | | | | |
| Fir Road | 13 | 27 | 0.05 ± 0.005 | 0.01 ± 0.005 | 0.03 ± 0.005 | | | | |
| Pettett | 14 | 26 | 0.07 ± 0.005 | 0.02 ± 0.004 | 0.03 ± 0.005 | | | | |
| Byers Landing | 15 | 26 | 0.05 ± 0.005 | 0.01 ± 0.004 | 0.03 ± 0.005 | 26 | 0.002 ± 0.0006 | 0.0006 ± 0.0004 | 0.001 ± 0.0002 |
| Pasco | 16 | 25 | 0.06 ± 0.005 | 0.02 ± 0.004 | 0.03 ± 0.005 | | | | |
| Richland | 17 | 24 | 0.06 ± 0.005 | 0.007 ± 0.004 | 0.03 ± 0.006 | 24 | 0.002 ± 0.0006 | 0.0003 ± 0.0003 | 0.001 ± 0.0002 |
| 1100 Area | 18 | 26 | 0.05 ± 0.005 | 0.02 ± 0.004 | 0.03 ± 0.004 | | | | |
| RRC #64 | 19 | 26 | 0.05 ± 0.005 | 0.02 ± 0.004 | 0.03 ± 0.006 | 26 | 0.002 ± 0.0007 | 0.0005 ± 0.0003 | 0.001 ± 0.0005 |
| Overall Perimeter Station Average | | | | 0.03 ± 0.001 | | | | 0.001 ± 0.0001 | |
| Distant Stations | | | | | | | | | |
| McNary | 24 | 20 | 0.06 ± 0.005 | 0.02 ± 0.004 | 0.03 ± 0.005 | | | | |
| Walla Walla | 21 | 26 | 0.05 ± 0.005 | 0.02 ± 0.004 | 0.03 ± 0.004 | | | | |
| Washtucna | 22 | 26 | 0.06 ± 0.005 | 0.02 ± 0.004 | 0.03 ± 0.004 | | | | |
| Moses Lake | 23 | 26 | 0.06 ± 0.004 | 0.02 ± 0.004 | 0.03 ± 0.004 | | | | |
| Sunnyside | 24 | 24 | 0.05 ± 0.005 | 0.01 ± 0.004 | 0.03 ± 0.004 | | | | |
| Overall Distant Station Average | | | | 0.03 ± 0.002 | | | | | |

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

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

No entry indicates no analysis was performed.

Ecology, 1981; Benton-Franklin-Walla Walla Counties Air Pollution Control Authority, 1975). An eight-station ambient nitrogen dioxide (NO₂) 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 NO₂ background

data immediately prior to projected PUREX start-up in late 1983. Data collected by the network from August through December 1982 indicated a maximum observed average NO₂ concentration per station of less than 0.007 parts per million (ppm). The applicable national ambient air standard for NO₂ (U.S. EPA 40 CFR 50, 1973) is 0.05 ppm as an annual arithmetic mean.

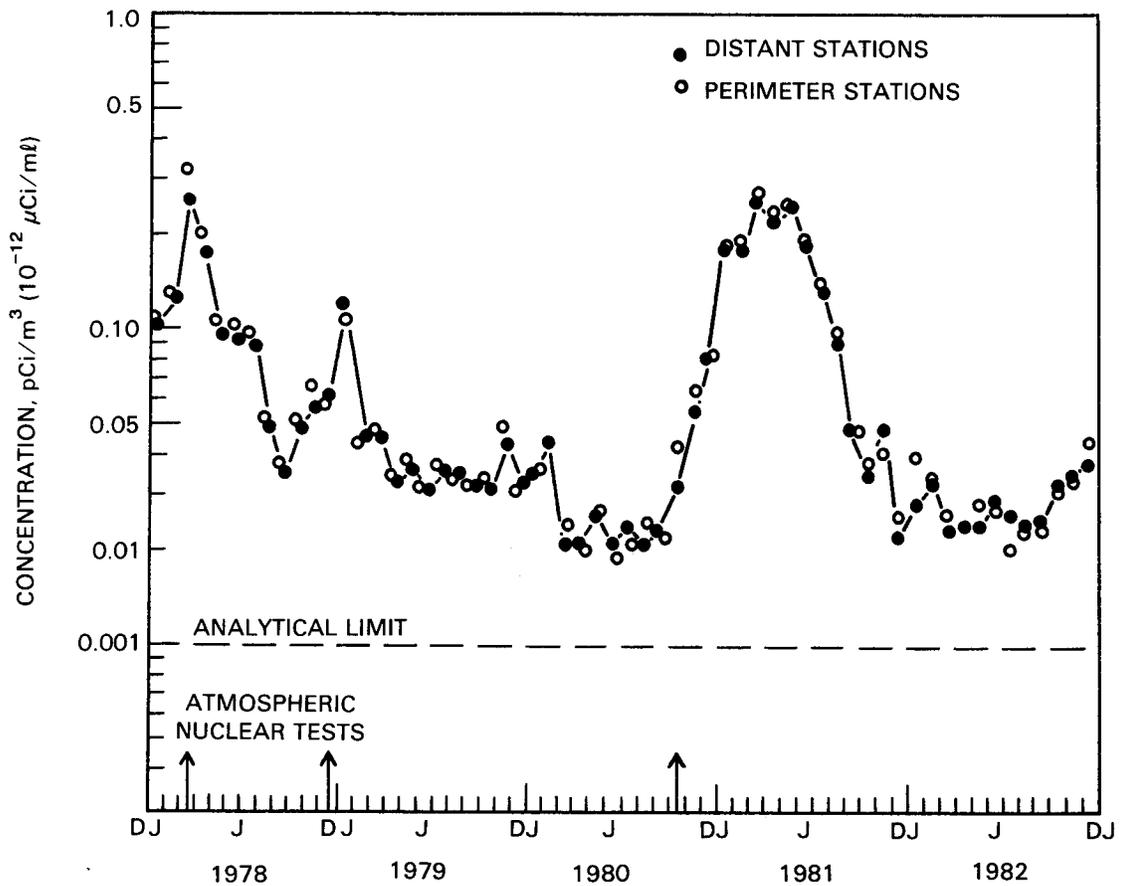


FIGURE 3. Monthly Averaged Long-Lived Gross-Beta Particulate Air Concentrations

TABLE 2. Selected Airborne Radionuclide Concentrations in the Hanford Environs

| Radionuclide | Concentration Guide, pCi/m ³ (a) | Composite Group(b) | No. of Analyses | No. Results >DL | Concentration, pCi/m ³ (10 ⁻¹² μCi/ml)(c) | | |
|-----------------------|---|--------------------|-----------------|-----------------|---|---------|----------------------|
| | | | | | Maximum | Minimum | Average |
| ³ H (HTO) | 200,000 | Distant | — | — | — | — | — |
| | | Perimeter | 74 | 53 | 2.0 ± 0.6 | <DL | 0.6 ± 0.1 |
| | | Downwind Perimeter | 49 | 35 | 1.7 ± 0.9 | <DL | 0.6 ± 0.1 |
| ³ H (HT) | 200,000 | Distant | — | — | — | — | — |
| | | Perimeter | 73 | 51 | 1.5 ± 0.3 | <DL | 0.5 ± 0.1 |
| | | Downwind Perimeter | 48 | 32 | 1.5 ± 0.7 | <DL | 0.4 ± 0.2 |
| ⁹⁰ Sr | 30 | Distant | 11 | 3 | 0.0004 ± 0.0003 | <DL | (0.0001 ± 0.0001) |
| | | Perimeter | 16 | 11 | 0.0002 ± 0.00007 | <DL | (0.0001 ± 0.00004) |
| | | Downwind Perimeter | 4 | 3 | 0.0001 ± 0.00007 | <DL | 0.0001 ± 0.00005 |
| ⁹⁵ ZrNb | 1,000 | Distant | 39 | 6 | 0.03 ± 0.02 | <DL | (<0.01) |
| | | Perimeter | 54 | 8 | 0.03 ± 0.004 | <DL | (<0.01) |
| | | Downwind Perimeter | 14 | 3 | 0.007 ± 0.003 | <DL | (<0.01) |
| ¹³¹ I | 100 | Distant | 25 | 0 | <DL | <DL | (<0.01) |
| | | Perimeter | 124 | 0 | <DL | <DL | (<0.01) |
| | | Downwind Perimeter | 99 | 0 | <DL | <DL | (<0.01) |
| ¹³⁷ Cs | 500 | Distant | 39 | 9 | 0.008 ± 0.005 | <DL | (<0.005) |
| | | Perimeter | 54 | 20 | 0.004 ± 0.002 | <DL | (0.0008 ± 0.0003) |
| | | Downwind Perimeter | 14 | 7 | 0.003 ± 0.001 | <DL | (0.0007 ± 0.0007) |
| ¹⁴⁴ CePr | 200 | Distant | 39 | 4 | 0.11 ± 0.05 | <DL | (<0.05) |
| | | Perimeter | 54 | 14 | 0.03 ± 0.02 | <DL | (0.002 ± 0.003) |
| | | Downwind Perimeter | 14 | 4 | 0.02 ± 0.01 | <DL | (0.003 ± 0.005) |
| ^{239,240} Pu | 0.06 | Distant | 12 | 5 | 0.00009 ± 0.00006 | <DL | (0.00003 ± 0.00002) |
| | | Perimeter | 16 | 7 | 0.00005 ± 0.00002 | <DL | (0.00001 ± 0.000008) |
| | | Downwind Perimeter | 4 | 0 | <DL | <DL | (<0.00001) |

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

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

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

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

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

Perimeter Stations include the downwind perimeter locations above, plus Wahluke #2, Berg Ranch, Othello, Vernita, Wahluke Watermaster, Connell, Cooke, Yakima Barricade, Rattlesnake Springs, ALE, Benton City, and Prosser Barricade. No result indicates no analysis performed.

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



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—thousands of curies per day of largely short-lived radionuclides—were released to the river from the production reactors located along the shoreline. However, since the 1972 shutdown of the old production reactors and considering the liquid effluent control systems at N Reactor (the only currently operating reactor), radionuclide discharges to the river have decreased by several orders of magnitude.

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

Samples collected during 1982 show that the impact of Hanford on radionuclide levels in the Columbia River is very small. Statistically higher concentrations were observed at the downstream sampling location for ^{129}I , but observed levels were very low and well below applicable DOE Concentration Guides. Although the 1981 annual report indicated a difference in ^{90}Sr concentrations upstream and downstream of the Site, this was not substantiated by samples collected during 1982.

SAMPLE COLLECTION AND ANALYSIS

Samples of Columbia River water were collected throughout 1982 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 filtration and ion-exchange media.

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

The large-volume sampler has been described by Fix and Robertson (1976). River water is continuously pumped through the sampler at a rate of 50 ml/min. Particulates greater than $0.45\ \mu\text{m}$ in diameter are removed from the sample stream by a series of filters, and dissolved radionuclides

are accumulated in an ion-exchange resin column. The filtration media are exchanged at two-week intervals during which time approximately 1000 liters of river water have been pumped through the sampler. Samples are analyzed for gamma-emitting radionuclides, ^{129}I , and plutonium. Analyses are performed by PNL as described in Appendix C.

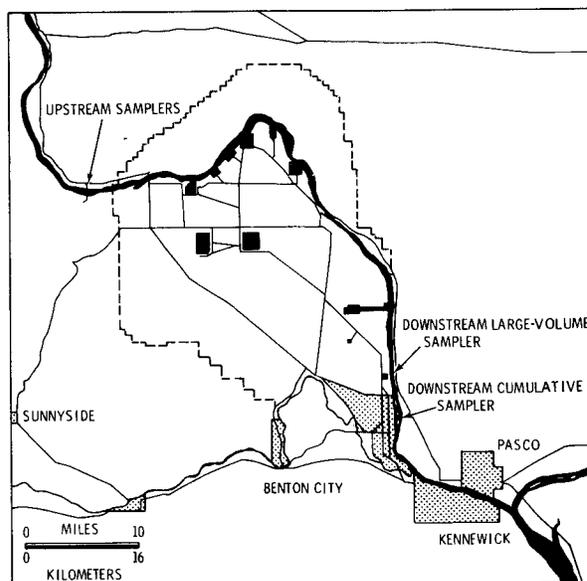


FIGURE 4. Columbia River Water Sampling Locations

RESULTS

Results of the analysis of Columbia River water samples for 1982 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 show that in every case downstream radionuclide concentrations were well below the applicable DOE Concentration Guide.

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 these radionuclides are naturally occurring (^3H , U) and/or are present in worldwide fallout resulting from atmospheric nuclear tests, all are potentially associated with nuclear operations at Hanford. Of these radionuclides only concentrations of ^{129}I were perceptibly higher at the downstream location.

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

| Radionuclide(b) | No. of Analyses | No. Results >DL | Concentration, pCi/l (10^{-9} $\mu\text{Ci}/\text{ml}$)(a) | | |
|-----------------------|-----------------|-----------------|--|--|--|
| | | | Minimum Result | Maximum Result | Average(c) |
| ^3H | 18 | 18 | 71 ± 18 | 330 ± 20 | 160 ± 40 |
| ^{60}Co | Particulate | 20 | <DL | 0.006 ± 0.003 | (<0.005) |
| | Dissolved | 20 | <DL | 0.023 ± 0.021 | (<0.01) |
| ^{89}Sr | 13 | 1 | <DL | 0.14 ± 0.13 | (<0.15) |
| ^{90}Sr | 13 | 12 | <DL | 0.36 ± 0.06 | 0.18 ± 0.05 |
| ^{95}Zr | Particulate | 20 | <DL | <DL | (<0.007) |
| | Dissolved | 20 | <DL | <DL | (<0.01) |
| ^{95}Nb | Particulate | 20 | <DL | 0.005 ± 0.004 | (0.002 ± 0.002) |
| | Dissolved | 20 | <DL | 0.008 ± 0.007 | (0.005 ± 0.004) |
| ^{106}Ru | Particulate | 20 | <DL | <DL | (<0.03) |
| | Dissolved | 20 | <DL | <DL | (<0.07) |
| ^{129}I | Dissolved | 12 | <DL | 1.6×10^{-6} $\pm 2.2 \times 10^{-7}$ | (6.2×10^{-6} $\pm 7.8 \times 10^{-6}$) |
| ^{131}I | Particulate | 20 | <DL | <DL | (<0.01) |
| | Dissolved | 20 | <DL | <DL | (<0.02) |
| ^{137}Cs | Particulate | 20 | 0.014 ± 0.002 | 0.081 ± 0.012 | 0.033 ± 0.007 |
| | Dissolved | 20 | 0.031 ± 0.006 | 0.19 ± 0.03 | 0.069 ± 0.017 |
| $^{144}\text{CePr}$ | Particulate | 20 | <DL | <DL | (<0.01) |
| | Dissolved | 20 | <DL | <DL | (<0.02) |
| Uranium | 13 | 13 | 0.20 ± 0.07 | 0.64 ± 0.22 | 0.36 ± 0.08 |
| ^{238}Pu | Particulate | 4 | <DL | <DL | (< 3.5×10^{-6}) |
| | Dissolved | 4 | <DL | 7.0×10^{-5} $\pm 5.0 \times 10^{-5}$ | (< 9.3×10^{-6}) |
| $^{239,240}\text{Pu}$ | Particulate | 4 | 2.2×10^{-5} $\pm 3.0 \times 10^{-6}$ | 4.7×10^{-5} $\pm 4.0 \times 10^{-5}$ | 3.0×10^{-5} $\pm 1.2 \times 10^{-5}$ |
| | Dissolved | 4 | <DL | 1.5×10^{-5} $\pm 1.0 \times 10^{-5}$ | 9.0×10^{-6} $\pm 7.0 \times 10^{-6}$ |

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

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

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

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

(c) If fewer than 75% of the results were >DL, the average was enclosed in parenthesis except that if fewer than 25% of the results were >DL, no average was calculated and the average minimum detectable concentration is shown. Averages were also enclosed within parenthesis if less than their associated two-standard error term.

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

| Radionuclide ^(b) | No. of Analyses | No. Results >DL | Concentration, pCi/l (10^{-9} μ Ci/ml) ^(a) | | | Concentration Guide ^(d) |
|-----------------------------|-----------------|-----------------|--|--|--|------------------------------------|
| | | | Minimum Result ^(c) | Maximum Result | Average ^(c) | |
| ³ H | 19 | 19 | 100 \pm 10 | 670 \pm 20 | 220 \pm 60 | 3,000,000 |
| ⁶⁰ Co | Particulate | 25 | <DL | 0.01 \pm 0.005 | (0.004 \pm 0.001) | 30,000 |
| | Dissolved | 25 | <DL | 0.12 \pm 0.02 | 0.015 \pm 0.009 | |
| ⁸⁹ Sr | 12 | 2 | <DL | 0.14 \pm 0.12 | (<0.18) | 3,000 |
| ⁹⁰ Sr | 12 | 10 | <DL | 0.40 \pm 0.30 | 0.17 \pm 0.07 | 300 |
| ⁹⁵ Zr | Particulate | 25 | <DL | 0.010 \pm 0.009 | (<0.005) | 60,000 |
| | Dissolved | 25 | <DL | 0.013 \pm 0.012 | (<0.011) | |
| ⁹⁵ Nb | Particulate | 25 | <DL | 0.009 \pm 0.004 | (0.003 \pm 0.001) | 100,000 |
| | Dissolved | 25 | <DL | 0.016 \pm 0.010 | (0.006 \pm 0.002) | |
| ¹⁰⁶ Ru | Particulate | 25 | <DL | 0.025 \pm 0.023 | (<0.026) | 10,000 |
| | Dissolved | 25 | <DL | 0.095 \pm 0.007 | (<0.054) | |
| ¹²⁹ I | Dissolved | 11 | 7.5 $\times 10^{-6}$ $\pm 1.0 \times 10^{-6}$ | 1.7 $\times 10^{-4}$ $\pm 1.4 \times 10^{-5}$ | 6.5 $\times 10^{-5}$ $\pm 3.3 \times 10^{-5}$ | 60 |
| ¹³¹ I | Particulate | 25 | <DL | 0.007 \pm 0.004 | (<0.005) | 300 |
| | Dissolved | 25 | <DL | 0.035 \pm 0.015 | (0.013 \pm 0.006) | |
| ¹³⁷ Cs | Particulate | 25 | 0.018 \pm 0.003 | 0.054 \pm 0.007 | 0.028 \pm 0.004 | 20,000 |
| | Dissolved | 25 | 0.036 \pm 0.008 | 0.097 \pm 0.012 | 0.055 \pm 0.006 | |
| ¹⁴⁴ CePr | Particulate | 25 | <DL | 0.010 \pm 0.008 | (<0.009) | 10,000 |
| | Dissolved | 25 | <DL | <DL | (<0.018) | |
| Uranium | 13 | 13 | 0.19 \pm 0.07 | 0.51 \pm 0.18 | 0.38 \pm 0.07 | 20,000 |
| ²³⁸ Pu | Particulate | 4 | <DL | <DL | (<2.2 $\times 10^{-6}$) | 30,000 |
| | Dissolved | 4 | <DL | <DL | (<8.0 $\times 10^{-6}$) | |
| ^{239,240} Pu | Particulate | 4 | 1.7 $\times 10^{-5}$ $\pm 2.0 \times 10^{-6}$ | 5.4 $\times 10^{-5}$ $\pm 5.0 \times 10^{-6}$ | 3.0 $\times 10^{-5}$ $\pm 1.8 \times 10^{-5}$ | 5,000 |
| | Dissolved | 4 | <DL | 1.6 $\times 10^{-5}$ $\pm 6.0 \times 10^{-6}$ | 1.0 $\times 10^{-5}$ $\pm 6.9 \times 10^{-6}$ | |

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

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

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

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

(c) If fewer than 75% of the results were >DL, the average was enclosed in parenthesis except that if fewer than 25% of the results were >DL, no average was calculated and the average minimum detectable concentration is shown. Averages were also enclosed within parenthesis if less than their associated two-standard error term.

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

The Hanford contribution to ¹²⁹I in the river is 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 at the 200 Areas. Figure 5 provides a comparison of ¹²⁹I 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

1982 were similar to previous years. The dose impact due to the average net increase in ¹²⁹I in the river water (6×10^{-5} pCi/l) is negligible as discussed in the "Radiological Impact of Hanford Operations" section. Since tritium is also present throughout the Hanford aquifer, there is some contribution of tritium to the river; however, the contribution from the aquifer during 1982 was too small to be accurately measured in the presence of relatively high background concentration of tritium in the Columbia River.

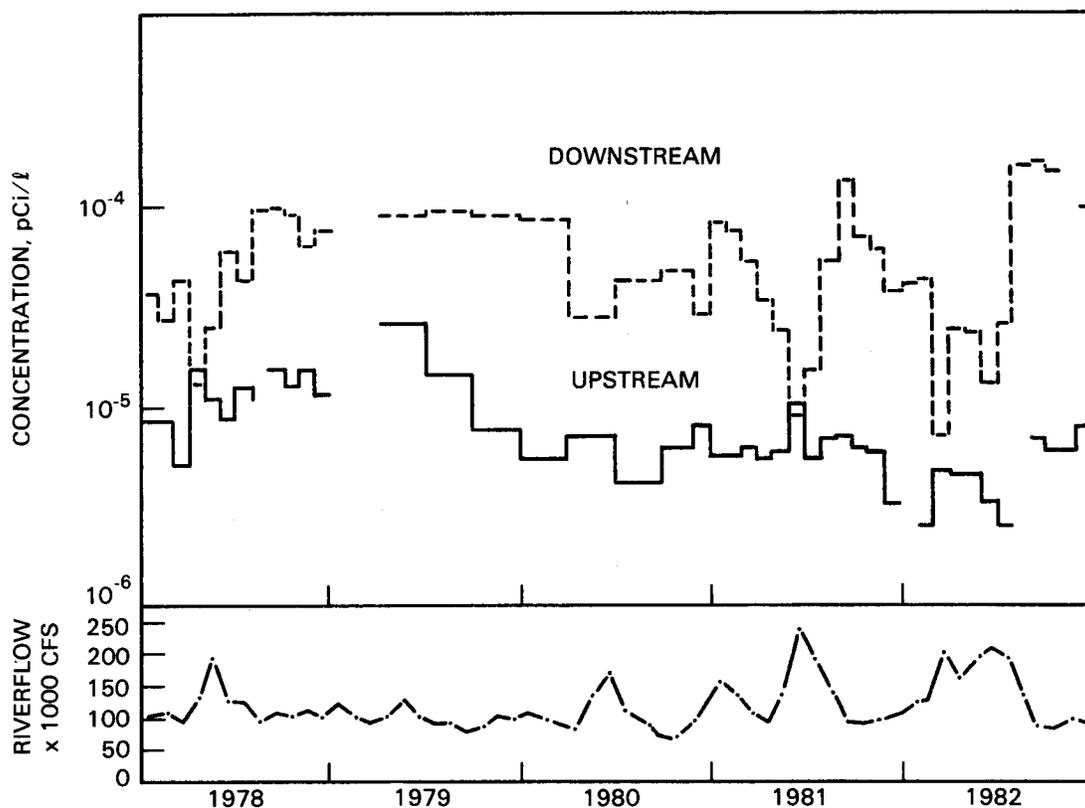


FIGURE 5. Iodine-129 in Columbia River Water

Other radionuclides included in the tables were observed only occasionally in river water samples, and as a result, annual averaged concentrations could not be determined with any degree of certainty. Where it was possible, mean values for these radionuclides are reported but are enclosed within brackets to emphasize that a relatively high degree of uncertainty is associated with the result. Of these radionuclides, ^{60}Co and ^{131}I 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 (0.58 Ci during 1982) 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. The maximum ^{60}Co concentration observed during 1982 (0.12 pCi/l) was well below the applicable DOE Concentration Guide of 30,000 pCi/l.

Iodine-131 was observed at very low concentrations in several downstream samples, similar to previous years. The maximum observed ^{131}I concentration during 1982 was 0.035 pCi/l, which was well below the DOE Concentration Guide of 300 pCi/l. The N Reactor, which reported 2.2 Ci discharged to the river during 1982, 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.

Because of the infrequent observation of ^{131}I and ^{60}Co in the river water, dose impacts in the "Radiological Impact of Hanford Operations" section were calculated based on the reported 1982 releases from N Reactor.

An apparent difference in ^{90}Sr concentrations between upstream and downstream sampling locations, indicated by samples collected during 1981, was not observed during 1982. The analysis

frequency for ⁹⁰Sr was increased from quarterly to monthly in 1982 as a result of 1981 measurements. Strontium-90 concentrations during 1982 for the monthly cumulative samples averaged 0.18 pCi/l and 0.17 pCi/l at the upstream and downstream locations, respectively. Strontium-90 analysis will be continued on a monthly basis during 1983.

Cumulative water samples collected at the Richland sanitary water treatment plant were analyzed for gross alpha and gross beta radioactivity. Washington State water quality standards require that radionuclide concentrations in

drinking water not exceed 15 pCi/l of gross alpha activity and that the average annual concentration of beta particle and photon radioactivity from manmade radionuclides not produce an annual dose equivalent to the total body or to any internal organ greater than 4 mrem/yr. Compliance with the 4 mrem/yr dose limitation 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 1982 sampling data in Tables 4 and 5.

TABLE 5. Radiological Analyses of Richland Drinking Water

| Measurement | No. of Samples | No. of Results >DL | Concentration, pCi/l (10^{-9} μ Ci/ml)(a) | | | |
|-------------|----------------|--------------------|--|---------|-----------------|----------------|
| | | | Maximum | Minimum | Average | State Standard |
| Gross Alpha | 13 | 5 | 0.7 \pm 0.4 | <DL | (0.4 \pm 0.1) | 15 |
| Gross Beta | 13 | 3 | 8.0 \pm 5.4 | <DL | (<5.2) | 50 |

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



COLUMBIA RIVER WATER QUALITY 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, as indicated in Appendix A.

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, river bank springs, water storage tank overflow, and fish laboratory waste water. Each discharge point is identified in an existing National Pollutant Discharge Elimination System (NPDES) permit issued by the EPA. Effluents from each of these outfalls are routinely monitored and reported by the operating contractors as required by their NPDES permits.

Measurements of several Columbia River water quality parameters were conducted routinely during 1982 both upstream and downstream of the Hanford Site to monitor any effects on the river that may be attributable to Hanford discharges and to determine compliance with the Class A designation requirements. The measurements indicated that Hanford operations had a minimal, if any, impact on the quality of the Columbia River water.

SAMPLE COLLECTION AND ANALYSIS

Grab samples of Columbia River water were collected weekly at the Vernita Bridge (upstream of Hanford) and at Richland (downstream) 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 and flow-rate monitoring of the river upstream and downstream 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.

Although isolated instances of pH and fecal coliform standards being exceeded occurred at both the upstream and downstream locations, the figure demonstrates a generally good agreement between values at the two sampling locations. A slight increasing trend in fecal coliform levels at the downstream location noted in recent years was not apparent during 1982. Dissolved oxygen values at the downstream location fell slightly below the standard in October, perhaps due to low river flow that month (the upstream average was also at its lowest that month). No substantial differences were apparent between upstream versus downstream turbidity measurements.

No substantial difference exists between upstream and downstream temperatures, and monthly averages remained within the standard during 1982. Although several isolated instances of NPDES temperature limits being exceeded occurred at N Reactor during 1982, no apparent relationship exists between the downstream river temperatures, flow rate, and N Reactor operation. This suggests that any contribution of heat from N Reactor effluents is, at best, a small fraction of the minor heat increases observed. Insolation, therefore, appears to be the major cause of water temperature increases along the Hanford reach.

Table 6 summarizes the results of water quality analyses including a number of parameters for 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 analyses performed onsite are generally comparable. None of the analytical results indicate a substantial deterioration in water quality at the downstream sampling locations.

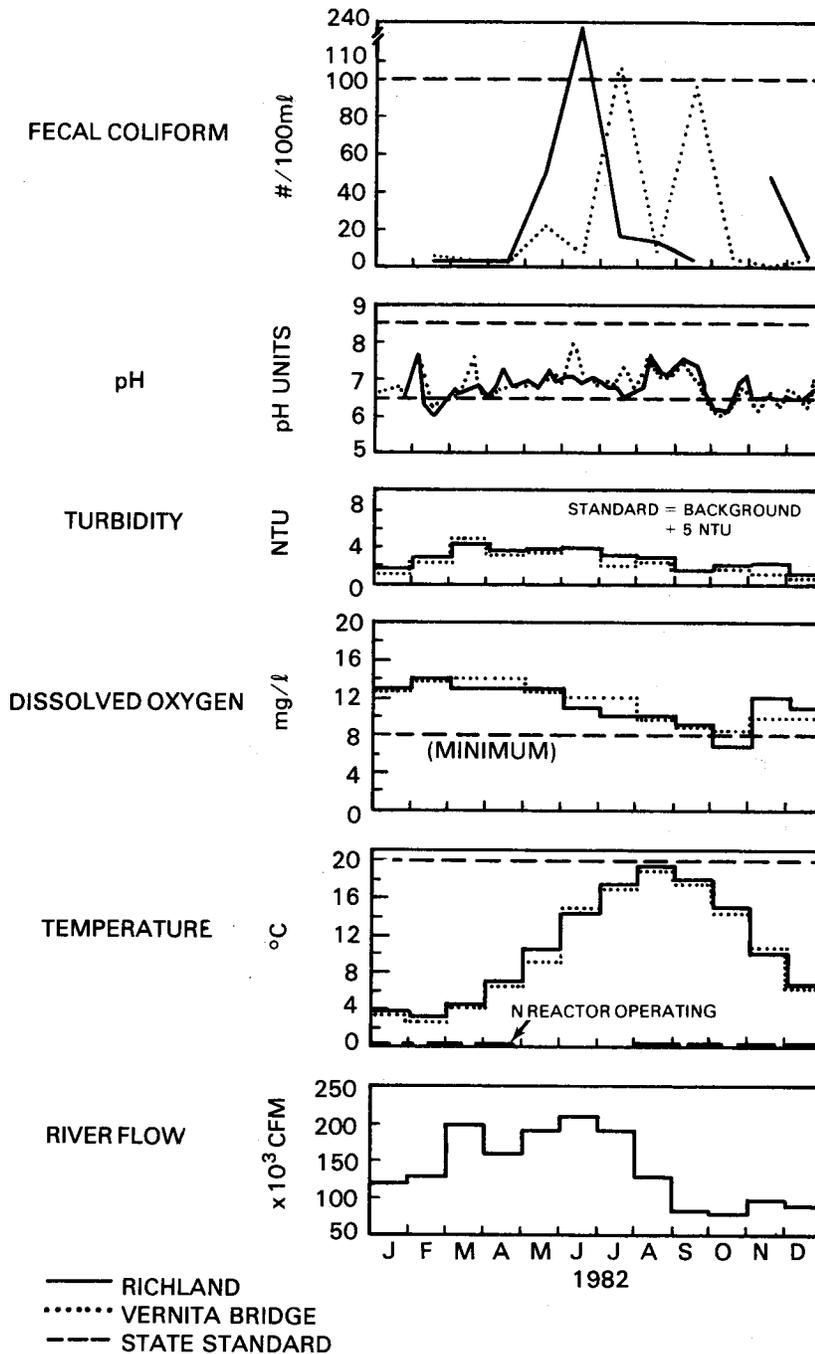


FIGURE 6. Columbia River Water Quality Data

TABLE 6. 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 | 6.8 | 12 ± 1.2 | 48 | 17 | 6.8 | 11 ± 1.3 | 8 (minimum) |
| Turbidity | NTU(c) | 51 | 8.7 | 0.1 | 2.5 ± 0.8 | 49 | 7.4 | 1.0 | 2.9 ± 0.9 | 5 + background |
| pH | | 48 | 8.0 | 6.0 | N/A | 49 | 7.7 | 5.4 | N/A | 8.5 - 6.5 |
| Fecal Coliform | #/100 ml | 11 | 110 | 0 | 5.0(d) | 10 | 240 | 2 | 7.0(d) | 100 |
| Total Coliform | #/100 ml | 10 | 2400 | 2 | 79(d) | 10 | 240 | 4 | 33(d) | |
| BOD(e) | mg/l | 11 | 7.1 | 1.0 | 3.2 ± 2.2 | 11 | 7.2 | 0.8 | 3.3 ± 2.2 | |
| Nitrogen (as NO ₃) | mg/l | 52 | 0.92 | 0.10 | 0.22 ± 0.08 | 52 | 7.6 | 0.10 | 0.58 ± 0.68 | |
| USGS Sampling Program | | | | | | | | | | |
| Temperature | °C | 343 | 20.2 | 1.8 | 10.7 ± 0.6 | 350 | 21.0 | 2.0 | 10.9 ± 0.6 | 20 (maximum) |
| Dissolved O ₂ | mg/l | 5 | 14.1 | 11.6 | 12 ± 2 | 4 | 12 | 10 | 11 ± 1 | 8 (minimum) |
| Turbidity | NTU(c) | 6 | 2.6 | 0.6 | 1.4 ± 0.7 | 3 | 3.5 | 0.6 | 2.4 ± 1.8 | 5 + background |
| pH | | 6 | 9.0 | 7.7 | N/A | 4 | 8.1 | 7.7 | N/A | 8.5 - 6.5 |
| Fecal Coliform | #/100 ml | 5 | 8 | <1 | 3(d) | 3 | 5 | <1 | 2(d) | 100 |
| Suspended Solids, 105°C | mg/l | 6 | 7 | <1 | 4 ± 1.9 | 4 | 11 | 3 | 6 ± 3 | |
| Dissolved Solids, 180°C | mg/l | 6 | 93 | 58 | 76 ± 12.1 | 4 | 88 | 64 | 78 ± 12 | |
| Specific Conductance | µmhos | 6 | 150 | 113 | 130 ± 11.4 | 4 | 148 | 122 | 135 ± 13.9 | |
| Hardness, as CaCO ₃ | mg/l | 6 | 76 | 55 | 65 ± 7.7 | 4 | 77 | 55 | 66 ± 12 | |
| Phosphorus, total | mg/l | 6 | 0.060 | <0.010 | 0.03 ± 0.020 | 4 | 0.050 | 0.020 | 0.032 ± 0.015 | |
| Chloride, dissolved | mg/l | 6 | 1.6 | 0.8 | 1.2 ± 0.2 | 4 | 1.4 | 0.9 | 1.1 ± 0.2 | |
| Chromium total(f) | mg/l | 3 | 20 | 20 | 20 ± 0 | 4 | 10 | <10 | 10 ± 0 | |
| Iron, total(f) | mg/l | 3 | 360 | 120 | 223 ± 142 | 4 | 230 | 60 | 145 ± 92.6 | |
| Nitrogen, Kjeldahl | mg/l | 4 | 0.49 | 0.22 | 0.36 ± 0.12 | 4 | 0.70 | 0.34 | 0.50 ± 0.15 | |

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

(b) See Appendix A.

(c) Nephelometric Turbidity Units.

(d) Annual median.

(e) Biological Oxygen Demand.

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

N/A = Not Applicable.

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 an annual report *Ground-Water Surveillance at the Hanford Site for CY 1982*. Results of ground-water monitoring for 1982 (Eddy, Prater and Rieger 1983) show that water discharged to the ground in the 200 Areas has gradually migrated to the Columbia River and that ^3H and other mobile contaminants are entering the river. The overall effect of the ground-water contribution to currently existing radionuclide concentrations is small as discussed in the "Columbia River Radiological Monitoring" section.

Contaminants in the ground water are 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 is inferred from interpretation of trends in the measured concentrations.

The primary analyses performed on ground-water samples are 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 30,000 pCi/l based on interpretation of ground-water sample analyses performed during 1982 (Eddy, Prater and Rieger 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 concentra-

tions of ^{129}I in the river indicate a contribution from Hanford that is attributed to the flow of ground water into the river. The net increase in the average downstream concentration of ^{129}I was 6×10^{-5} pCi/l during 1982 (6.5×10^{-5} pCi/l downstream compared to 6.2×10^{-6} pCi/l upstream). This concentration is very low and would result in a negligible dose impact as discussed in the "Radiological Dose Impact of Hanford Operations" section. The estimated ^{129}I input to the river via ground water necessary to produce this increase was 0.008 Ci during 1982.

Analyses of ground-water samples collected during 1982 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 1982 was not enough to be accurately measured in the presence of the normal background concentration of ^3H in the Columbia River.

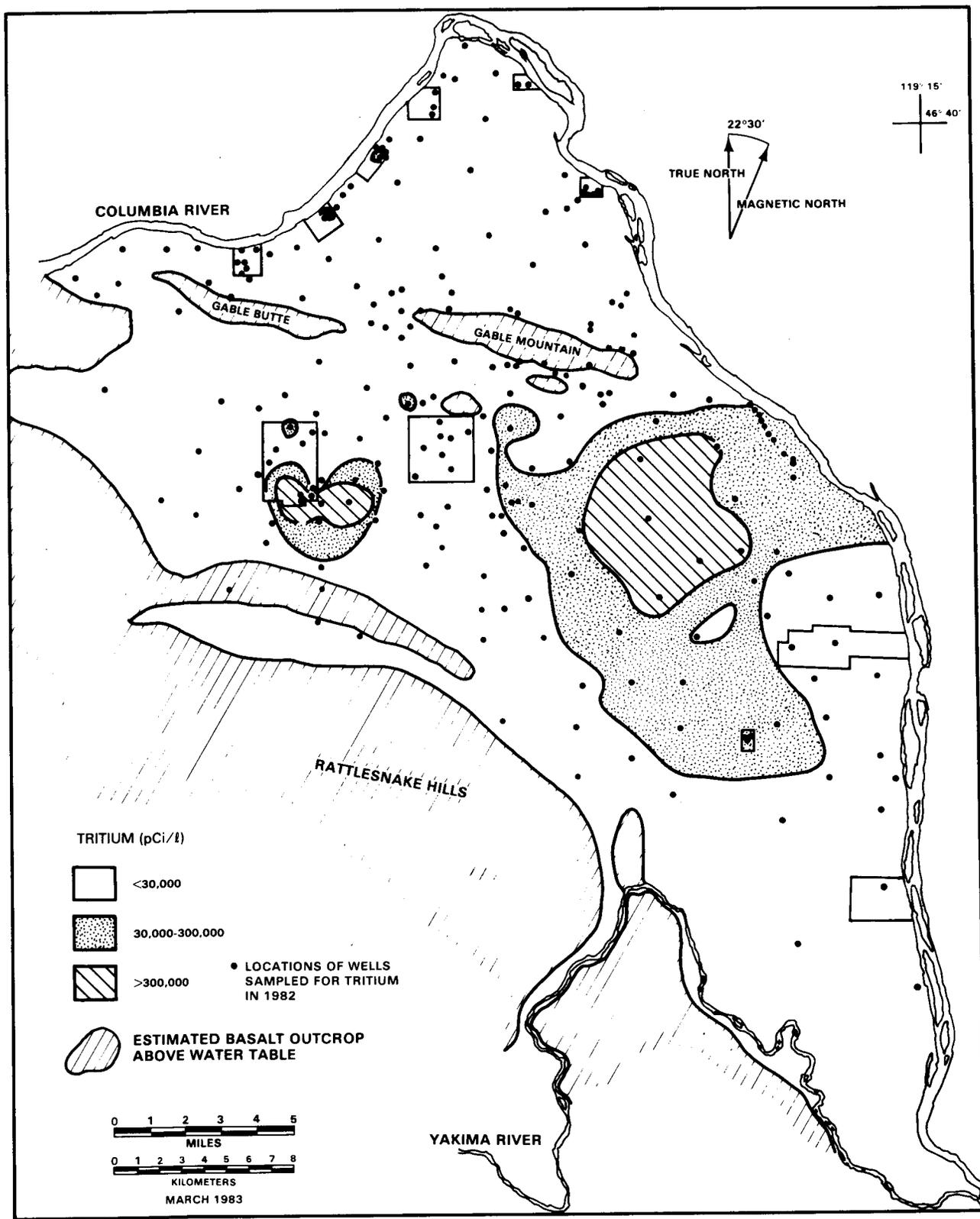


FIGURE 7. Tritium Distribution in the Unconfined Hanford Aquifer

FOODSTUFFS

Several types of foodstuffs, including milk, leafy vegetables, fruits, beef, chickens, eggs, wheat and alfalfa, were collected at several locations in the Hanford Site environs during 1982. All samples were analyzed for ^{90}Sr and ^{137}Cs . In addition, milk samples were analyzed for ^{131}I and 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 were also collected in generally upwind directions somewhat distant from the Site to provide information on radioactivity levels in the various products that could be attributed to worldwide fallout. Foodstuffs collected in the Riverview Area were grown using Columbia River water and thus provide information regarding potential radionuclide concentrations attributable to radionuclides in the river.

Samples collected during 1982, as in recent previous 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 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 were also 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 listed in Table 7 and shown in Figure 8. Samples were collected biweekly throughout the year from the Sagemoor and Sunnyside areas. Samples from the other areas were collected biweekly during the first half of the year and monthly during the last half of the year. Several sampling location changes were made during the year as described in the notes to Table 7.

As shown in Table 7, there was no indication of the presence of ^{131}I in any of the milk samples collected during 1982. Cesium-137 was identified in about 12% of the samples, but concentrations in all cases were low and within the range attributable to worldwide fallout (EPA 1981).

A portion of the milk samples were analyzed for ^{89}Sr and ^{90}Sr . Strontium-89 was not regularly detected in the milk; however ^{90}Sr was observed in nearly all samples analyzed. Maximum and average concentrations were similar at all locations both near the Site and distant and compared favorably with concentrations observed in recent previous years. Results of ^{89}Sr and ^{90}Sr analyses in milk were comparable to those measured nationwide by the EPA (EPA 1981) and thus are attributable to worldwide fallout.

LEAFY VEGETABLE

Samples of leafy vegetables (spinach, leaf lettuce, turnip greens and mustard greens) were obtained once during the summer from gardens located within the sampling areas listed in Table 8. Three replicate samples, each composed of mixtures of the edible portions of the various leafy vegetables grown at the sampling location, were obtained. The leafy vegetables provide an indication of radionuclides present in locally grown produce. Samples were analyzed for ^{90}Sr and ^{137}Cs , using methods described in Appendix C, and results are provided in Table 8. Strontium-90 was identified in nearly all samples but with no apparent difference between locations near the Site and distant locations. Cesium-137 was identified in about one third 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 previous years.

FRUIT

Samples of apples, cherries and grapes were collected at picking time from the areas listed in Table 9. Three replicate samples were collected at each sampling location and the edible portions were analyzed for ^3H , ^{90}Sr and ^{137}Cs by methods described in Appendix C. Results are provided in Table 9.

Tritium was identified in about two-thirds of the samples analyzed and ^{90}Sr identified in half of the samples. However, there were no apparent differences between fruit types or sampling

TABLE 7. Radionuclides in Milk Samples

| Location ^(b) | Concentration, pCi/l ^(a) | | | | | |
|---|-------------------------------------|---------|------------------------|-------------------------|-----------|------------------------|
| | ¹³¹ I | | | ¹³⁷ Cs | | |
| | Fraction of Results >DL | Maximum | Average ^(c) | Fraction of Results >DL | Maximum | Average ^(e) |
| Wahluke East Area Composite | 0/6 | <DL | (<0.2) | 1/6 | 15 ± 8 | (<4.7) |
| Wahluke Area Farm | 0/13 | <DL | (<0.3) | 1/13 | 13 ± 7 | (<6.2) |
| Sagemoor Area Composite | 0/13 | <DL | (<0.3) | 2/13 | 15 ± 10 | (<5.6) |
| Sagemoor Area Farm | 0/13 | <DL | (<0.2) | 2/13 | 12 ± 10 | (<7.6) |
| Columbia Basin Composite ^(c) | 0/13 | <DL | (<0.2) | 1/13 | 3.3 ± 3.2 | (<7.4) |
| Riverview Area ^(d) | 0/18 | <DL | (<0.3) | 1/18 | 5.1 ± 3.9 | (<6.3) |
| Benton City Area | 0/20 | <DL | (<0.2) | 5/20 | 20 ± 8 | (<7.8) |
| Sunnyside Area | 0/26 | <DL | (<0.3) | 1/26 | 12 ± 8 | (<5.7) |
| Moses Lake Area | 0/6 | <DL | (<0.3) | 1/6 | 5.3 ± 3.3 | (<4.0) |

| Location ^(b) | ⁸⁹ Sr | | | ⁹⁰ Sr | | |
|---|-------------------------|-------------|------------------------|-------------------------|-----------|------------------------|
| | Fraction of Results >DL | Maximum | Average ^(c) | Fraction of Results >DL | Maximum | Average ^(e) |
| Wahluke East Area Composite | 1/2 | 0.71 ± 0.47 | (-0.1 ± 2.1) | 2/2 | 2.0 ± 0.4 | (1.4 ± 1.5) |
| Wahluke Area Farm | 0/3 | <DL | (<1.1) | 3/3 | 1.6 ± 0.5 | 1.4 ± 0.4 |
| Sagemoor Area Composite | 0/2 | <DL | (<1.3) | 2/2 | 1.7 ± 0.5 | 1.7 ± 0.7 |
| Sagemoor Area Farm | 0/7 | <DL | (<1.2) | 7/7 | 1.7 ± 0.6 | 1.4 ± 0.3 |
| Columbia Basin Composite ^(c) | 0/2 | <DL | (<1.3) | 2/2 | 1.1 ± 0.6 | 1.0 ± 0.5 |
| Riverview Area ^(d) | 0/4 | <DL | (<1.3) | 4/4 | 1.9 ± 0.4 | 1.6 ± 0.6 |
| Benton City Area | 0/4 | <DL | (<1.0) | 4/4 | 1.6 ± 0.4 | 1.3 ± 0.4 |
| Sunnyside Area | 0/9 | <DL | (<1.1) | 8/9 | 1.8 ± 0.5 | 1.4 ± 0.4 |
| Moses Lake Area | 0/2 | <DL | (<1.8) | 2/2 | 2.0 ± 0.8 | 1.9 ± 0.6 |

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

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

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

(b) Refer to Figure 8. Because of a change in the sampling program in July 1982, several sample locations were added and deleted. Locations added in July were Wahluke East Area Composite, Sagemoor Area Composite, and Moses Lake Area. Deleted locations were Wahluke Area Farm, Sagemoor Area Farm, and the Columbia Basin Composite. Composite samples consisted of a blend of milk collected from three different farms within the sampling area.

(c) The Columbia Basin Composite consists of a blend of milk collected at farms in the Wahluke East and Sagemoor Areas.

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

(e) Averages were enclosed within parenthesis if the ± two standard error was greater than its associated mean. If fewer than 25% of the analyses yielded a positive identification, the average 2σ counting error for the analyses is shown within parenthesis.

locations. As in recent previous years, ¹³⁷Cs 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 10. Three replicate samples each of wheat and alfalfa were collected at each location following the final cutting of the growing season and analyzed for

⁹⁰Sr and ¹³⁷Cs using methods described in Appendix C. Results of the analysis are shown in Table 10.

Samples of wheat and alfalfa have not previously been collected as part of the routine environmental sampling program, and therefore, some limitations exist at the current time with respect to interpreting the data. There appears to be more variability associated with the data than

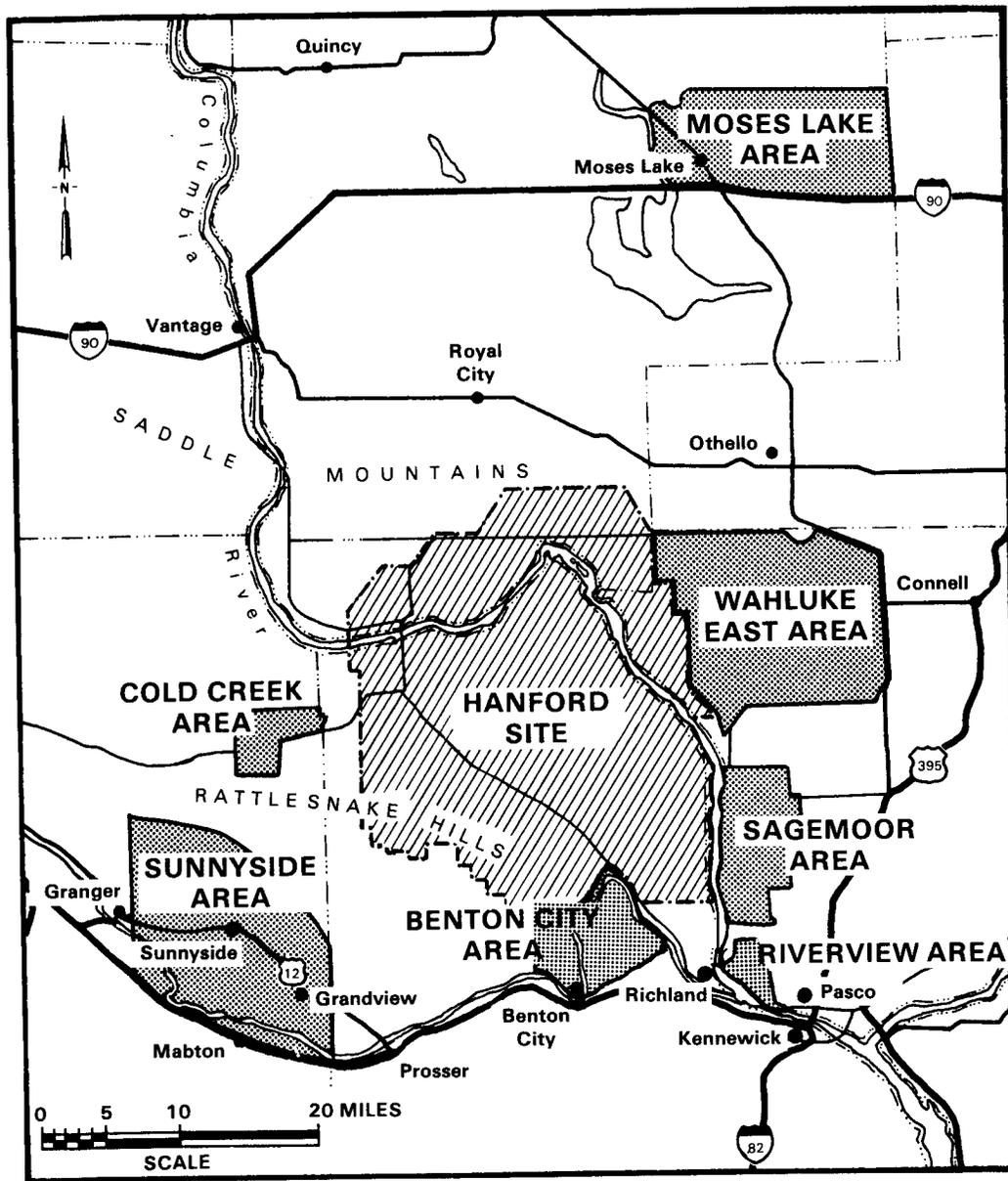


FIGURE 8. Foodstuffs Sampling Areas

with foodstuffs previously discussed. This is thought to be due in part to the variability of moisture content in the wheat and alfalfa at the different sampling locations. Nevertheless, the current data do demonstrate this variability both among the sample locations near the Site and those at distant locations. No distinct difference in radionuclide concentrations is apparent in the samples near the Site versus distant samples.

BEEF, CHICKENS AND EGGS

Samples of locally produced beef, chickens and eggs were collected twice during 1982 from the areas listed in Table 11. Table 11 provides results of analysis of the samples for ^{137}Cs and except as noted, ^{90}Sr . Results were all very low, generally near detection levels.

TABLE 8. 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 | 3/3 | 0.009 ± 0.003 | 0.007 ± 0.003 | 3/3 | 0.10 ± 0.05 | 0.07 ± 0.05 |
| Sage Moor Area | 3/3 | 0.007 ± 0.002 | 0.005 ± 0.004 | 2/3 | 0.05 ± 0.04 | (0.03 ± 0.04) |
| Riverview Area(d) | 5/5 | 0.021 ± 0.003 | (0.005 ± 0.007) | 1/5 | 0.03 ± 0.02 | (0.02 ± 0.02) |
| Benton City Area | 2/3 | 0.007 ± 0.001 | 0.007 ± 0.003 | 0/3 | <DL | (<0.02) |
| Sunnyside Area | 3/3 | 0.003 ± 0.0006 | 0.003 ± 0.0008 | 1/3 | 0.10 ± 0.03 | (0.03 ± 0.09) |
| Moses Lake Area | 3/3 | 0.019 ± 0.002 | 0.011 ± 0.010 | 1/3 | 0.09 ± 0.04 | (0.03 ± 0.09) |

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

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

(a) Maximum values shown with the ± two sigma counting error term. Averages are shown with the ± two standard error of the mean (95% confidence interval).

(b) Refer to Figure 9.

(c) Averages were enclosed within parenthesis if the ± two standard error was greater than its associated mean. If fewer than 25% of the analyses yielded a positive identification, the average 2σ counting error for the analyses is shown within parenthesis.

(d) Irrigated with Columbia River water.

TABLE 9. Radionuclides in Fruit

| Fruit/Location | Concentration, pCi/g, wet weight(a,b) | | | | | | | | |
|-----------------|---------------------------------------|---------------|------------------|-------------------------|----------------|-------------------|-------------------------|-----------|-------------|
| | ¹³⁷ Cs | | | ⁹⁰ Sr | | | ³ H | | |
| | Fraction of Results >DL | Maximum | Average | Fraction of Results >DL | Maximum | Average | Fraction of Results >DL | Maximum | Average |
| Apples | | | | | | | | | |
| Sage Moor Area | 0/3 | <DL | (<0.008) | 0/3 | <DL | (<0.001) | 2/3 | 500 ± 310 | 350 ± 290 |
| Cold Creek Area | 0/3 | <DL | (<0.008) | 1/3 | 0.003 ± 0.001 | (0.0005 ± 0.004) | 2/3 | 340 ± 140 | 250 ± 180 |
| Sunnyside Area | 0/3 | <DL | (<0.007) | 2/3 | 0.004 ± 0.001 | 0.003 ± 0.002 | 0/3 | <DL | (<350) |
| Cherries | | | | | | | | | |
| Sage Moor Area | 1/3 | 0.025 ± 0.017 | (-0.002 ± 0.037) | 3/3 | 0.002 ± 0.0004 | 0.001 ± 0.0005 | 3/3 | 200 ± 160 | 190 ± 110 |
| Sunnyside Area | 0/3 | <DL | (<0.017) | 2/3 | 0.001 ± 0.0004 | (-0.0006 ± 0.004) | 3/3 | 470 ± 140 | 420 ± 110 |
| Grapes | | | | | | | | | |
| Sage Moor Area | 0/3 | <DL | (<0.006) | 2/3 | 0.005 ± 0.003 | 0.004 ± 0.002 | 2/3 | 390 ± 260 | 270 ± 180 |
| Cold Creek Area | 0/3 | <DL | (<0.005) | | | | 1/3 | 510 ± 280 | (280 ± 290) |
| Sunnyside Area | 0/3 | <DL | (<0.005) | 0/3 | <DL | (<0.007) | 3/3 | 480 ± 260 | 420 ± 160 |

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

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

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

(b) Individual result shown with the ± two sigma counting error. Averages show the two-standard error of the calculated mean (95% confidence interval). If no results were positive, the average reported counting error is shown as an indication of the sensitivity of the analysis.

TABLE 10. Radionuclides in Wheat and Alfalfa

| Type/Location | Concentration, pCi/g, wet weight ^(a) | | | | | |
|-------------------|---|---------------|---------------|-------------------------|---------------|-----------------|
| | ⁹⁰ Sr | | | ¹³⁷ Cs | | |
| | Fraction of Results >DL | Maximum | Average | Fraction of Results >DL | Maximum | Average |
| Wheat | | | | | | |
| Wahluke East Area | 3/3 | 0.005 ± 0.004 | 0.004 ± 0.002 | 0/3 | <DL | (<0.016) |
| Sagemoor Area | 3/3 | 0.008 ± 0.002 | 0.008 ± 0.002 | 0/3 | <DL | (<0.014) |
| Benton City Area | 3/3 | 0.006 ± 0.002 | 0.005 ± 0.002 | 2/3 | 0.007 ± 0.004 | (0.0007 ± 0.01) |
| Sunnyside Area | 3/3 | 0.018 ± 0.011 | 0.011 ± 0.009 | 1/3 | 0.005 ± 0.005 | (0.004 ± 0.007) |
| Moses Lake Area | 3/3 | 0.006 ± 0.003 | 0.004 ± 0.002 | 1/3 | 0.012 ± 0.011 | (0.008 ± 0.009) |
| Alfalfa | | | | | | |
| Wahluke East Area | 3/3 | 0.014 ± 0.002 | 0.009 ± 0.008 | 0/3 | <DL | (<0.03) |
| Sagemoor Area | 3/3 | 0.16 ± 0.013 | 0.12 ± 0.04 | 2/3 | 0.21 ± 0.13 | 0.15 ± 0.14 |
| Benton City Area | 3/3 | 0.10 ± 0.01 | 0.097 ± 0.013 | 1/3 | 0.016 ± 0.011 | (.010 ± 0.014) |
| Sunnyside Area | 3/3 | 0.032 ± 0.004 | 0.029 ± 0.005 | 2/3 | 0.019 ± 0.014 | (0.005 ± 0.030) |
| Moses Lake Area | 3/3 | 0.038 ± 0.007 | 0.032 ± 0.011 | 1/3 | 0.026 ± 0.023 | (0.022 ± 0.035) |

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

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

(a) Individual results shown with the ± two sigma counting error. Averages show the two-standard error of the calculated mean (95% confidence interval). If no results were positive, the average reported counting error is shown as an indication of the sensitivity of the analysis. Averages were enclosed within parenthesis if the associated uncertainty was equal to or greater than the calculated average concentration.

TABLE 11. Radionuclides in Beef, Chickens, and Eggs

| | Concentration, pCi/g, wet weight ^(a) | | | | | |
|-------------------------------|---|---------------|------------------------|-------------------------|--------------|------------------------|
| | ⁹⁰ Sr | | | ¹³⁷ Cs | | |
| | Fraction of Results >DL | Maximum | Average ^(b) | Fraction of Results >DL | Maximum | Average ^(b) |
| Beef | | | | | | |
| Sagemoor Area | | | N.A. | 1/2 | 0.03 ± 0.02 | (0.02 ± 0.03) |
| Riverview Area ^(c) | 0/1 | <DL | (<0.001) | 1/1 | — | 0.01 ± 0.008 |
| Horn Rapids Area | | | N.A. | 0/1 | <DL | (<0.02) |
| Chickens | | | | | | |
| Sagemoor Area | 2/2 | 0.013 ± 0.002 | (0.007 ± 0.016) | 1/2 | 0.02 ± 0.009 | (0.01 ± 0.03) |
| Sunnyside Area | 2/2 | 0.003 ± 0.001 | (0.002 ± 0.003) | 0/2 | <DL | (<0.01) |
| Eggs | | | | | | |
| Sagemoor Area | 2/2 | 0.004 ± 0.002 | (0.003 ± 0.003) | 1/2 | 0.03 ± 0.02 | (0.02 ± 0.03) |
| Sunnyside Area | 2/2 | 0.009 ± 0.001 | 0.007 ± 0.006 | 2/2 | 0.04 ± 0.01 | (0.03 ± 0.03) |

N.A. = Not Analyzed.

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

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

(a) Maximum values shown with the ± two sigma counting error term. Averages are shown with the ± two standard error of the mean.

(b) Averages were enclosed within parenthesis if the ± two standard error was greater than its associated mean. If fewer than 25% of the analyses yielded a positive identification, the average 2σ counting error for the analyses is shown within parenthesis.

(c) 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 wastewater ponds) that contain low levels of radionuclides attributable to site operations. Sampling is 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 is small compared to the total population in the area, and, as a result, human consumption of an animal from one of the sampling locations is unlikely. Nevertheless, these samples help provide an estimate of the maximum potential dose impact if onsite game were consumed.

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

Analytical results of terrestrial wildlife samples collected during 1981 were very similar to those observed in recent previous years. Samples of fish collected from the Columbia River along the Hanford Site showed no discernible difference in radionuclide concentration compared to samples collected upstream of the Site. The dose that would be received by a person following consumption of any of the sampled species at the maximum radionuclide concentration observed in 1982 would be well within the applicable DOE dose standards.

DEER

Samples from deer that have accidentally been killed by vehicles on Site roads are used to provide an indication of radionuclide levels for the herd residing on the Site. During 1982 samples of muscle tissue were collected from three road-killed deer and analyzed for ^{137}Cs . The analyses indicated the presence of identifiable levels of ^{137}Cs in only one deer at 0.009 ± 0.008 pCi/g, wet weight. This concentration was barely detectable (as indicated by the large analytical uncertainty) and in the range generally associated with worldwide fallout.

Although Hanford mule deer tend to have defineable home-ranges, long-distance movements within or off the Site are common; therefore, the specific foraging locations for the "randomly sampled" road-killed deer are unknown. As a supplement to the routinely collected road-killed samples, a special sampling program was conducted 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). Thirty-seven deer were captured in the vicinity of the 200 Area waste management sites and fitted with transmitting radiocollars. The movements of these deer were followed for a year, and during this period, deer that foraged consistently in the vicinity of the 200 Areas were

collected and analyzed for ^{137}Cs . Several deer that had foraged away from the 200 Areas were also collected to provide an indication of background ^{137}Cs concentrations in local deer.

Table 12 provides the results of this special sampling program and shows that deer residing near waste management sites had higher ^{137}Cs concentrations than deer foraging elsewhere. The maximum observed concentration of 1.4 pCi/g was the highest ^{137}Cs level observed in a sample of deer meat at Hanford since 1976. An individual consuming the entire edible portion of a deer (~45 kg) at the maximum observed concentration would be expected to receive a dose commitment of about 4 millirems to the total body as compared to the applicable DOE Radiation Protection Standard of 500 mrem (Appendix A).(a)

FISH

Fish were caught at various locations along the Columbia River, and boneless fillets were analyzed for ^{60}Co , ^{90}Sr , and ^{137}Cs using the methods described in Appendix C. Results of the analyses are shown in Table 13.

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

TABLE 12. Concentrations of ¹³⁷Cs in Muscle of Specially Selected Deer Collected on the Hanford Site 1981-1982^(a)

| Location, Forage Pattern | No. of Samples | No. of Results >DL | Concentration, pCi/g wet weight ^(b) | | |
|--|----------------|--------------------|--|---------|------------------------|
| | | | Maximum | Minimum | Average ^(c) |
| Residing near 200 Areas with >50% of time within 2 km of a waste management site | 6 | 6 | 1.4 ± 0.2 | <DL | (0.5 ± 0.5) |
| Residing near 200 Areas with <50% of time within 2 km of a waste management site | 6 | 6 | 0.02 ± 0.008 | <DL | (0.004 ± 0.008) |
| Residing away from 200 Areas | 5 | 5 | 0.02 ± 0.008 | <DL | (0.006 ± 0.010) |

(a) From Eberhardt, Hanson, and Cadwell 1982.

(b) Concentration in pCi/g, wet weight calculated from dry weight data using a wet to dry weight conversion factor of .264.

(c) Average includes an estimate of the two standard error of the mean (95% confidence interval).

Bass and whitefish were collected both upstream of Hanford near Priest Rapids Dam and along the Hanford reach of the river near the location of the old Hanford townsite (Figure 9). Whitefish were also collected near D Area and Ringold.

Radionuclide concentrations in the fish were either undetectable or very low. The highest ¹³⁷Cs result was observed upstream of the Hanford Site and, generally, observed concentrations were either below detection level or too low to make a statistical comparison between the upstream and downstream locations.

As in recent previous years, ⁶⁰Co was identified more frequently in whitefish samples collected along the Hanford reach of the river than in samples collected upstream of the Site. The presence of the ⁶⁰Co in the fish may be associated with residual radioactivity in sediments of the Columbia River from past operations at Hanford or current releases from Hanford's N Reactor (0.58 Ci during 1982).

Analysis of edible whitefish tissue for ⁹⁰Sr was initiated during the year and results are provided in Table 13. Concentrations were very low in all samples with a maximum of 0.03 pCi/g observed in a fish collected in the vicinity of 100-D Area (Figure 9). No quantifiable difference in average ⁹⁰Sr concentrations between locations was indicated by the data although ⁹⁰Sr was positively identified in a greater percentage of the fish collected along the Hanford Reach.

UPLAND GAME BIRDS

Upland game birds including pheasant and quail were obtained on the Hanford Site during 1982. Samples were collected in the 100, 200 and 300 Areas (Figure 9).

Samples of breast meat from each bird were analyzed for ¹³⁷Cs and ⁶⁰Co, using methods described in Appendix C. Results are provided in Table 14. Cobalt-60 concentrations were fairly low, and near the minimum detectable concentration for all samples. Cesium-137 concentrations were similarly low except for a single bird collected in the vicinity of 200-W Area in which a concentration of 40 ± 0.2 pCi/g was observed. The potential dose commitment resulting from consumption of 0.1 kg of meat at this concentration is calculated to be less than 1 mrem to the total body.^(a)

WATERFOWL

Waterfowl samples (ducks and geese) were collected along the Columbia River in the vicinity of 100-N Area as well as from each of the five onsite ponds shown in Figure 9. An approximately 0.5-kg sample of breast meat from each bird was analyzed for ¹³⁷Cs using the methods described in Appendix C. Results of the analyses are shown in Table 15.

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

TABLE 13. 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) |
| Whitefish | Upstream of Site Boundary | 0/9 | <DL | (<0.04) | 0/4 | <DL | <0.007 | 2/9 | 0.33 ± 0.09 | (<0.04) |
| | 100-D Area Vicinity | 4/9 | 0.06 ± 0.04 | (0.01 ± 0.04) | 7/8 | 0.03 ± 0.02 | (0.007 ± 0.008) | 4/9 | 0.15 ± 0.07 | (0.04 ± 0.04) |
| | Hanford Townsite Vicinity | 2/5 | 0.07 ± 0.04 | 0.04 ± 0.03 | 1/5 | 0.004 ± 0.004 | (<0.009) | 2/5 | 0.11 ± 0.05 | (0.04 ± 0.05) |
| | Ringold Vicinity | 2/7 | 0.06 ± 0.02 | (0.02 ± 0.03) | 1/3 | 0.003 ± 0.002 | (0.000 ± 0.003) | 5/7 | 0.07 ± 0.03 | (0.03 ± 0.03) |
| Bass | Upstream of Site Boundary | 0/2 | <DL | (<0.10) | | N.A. | | 1/2 | 0.12 ± 0.06 | (0.07 ± 0.14) |
| | Hanford Townsite Vicinity | 0/5 | <DL | (<0.04) | | N.A. | | 4/5 | 0.12 ± 0.04 | 0.08 ± 0.04 |

N.A. = Not Analyzed.

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

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

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

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

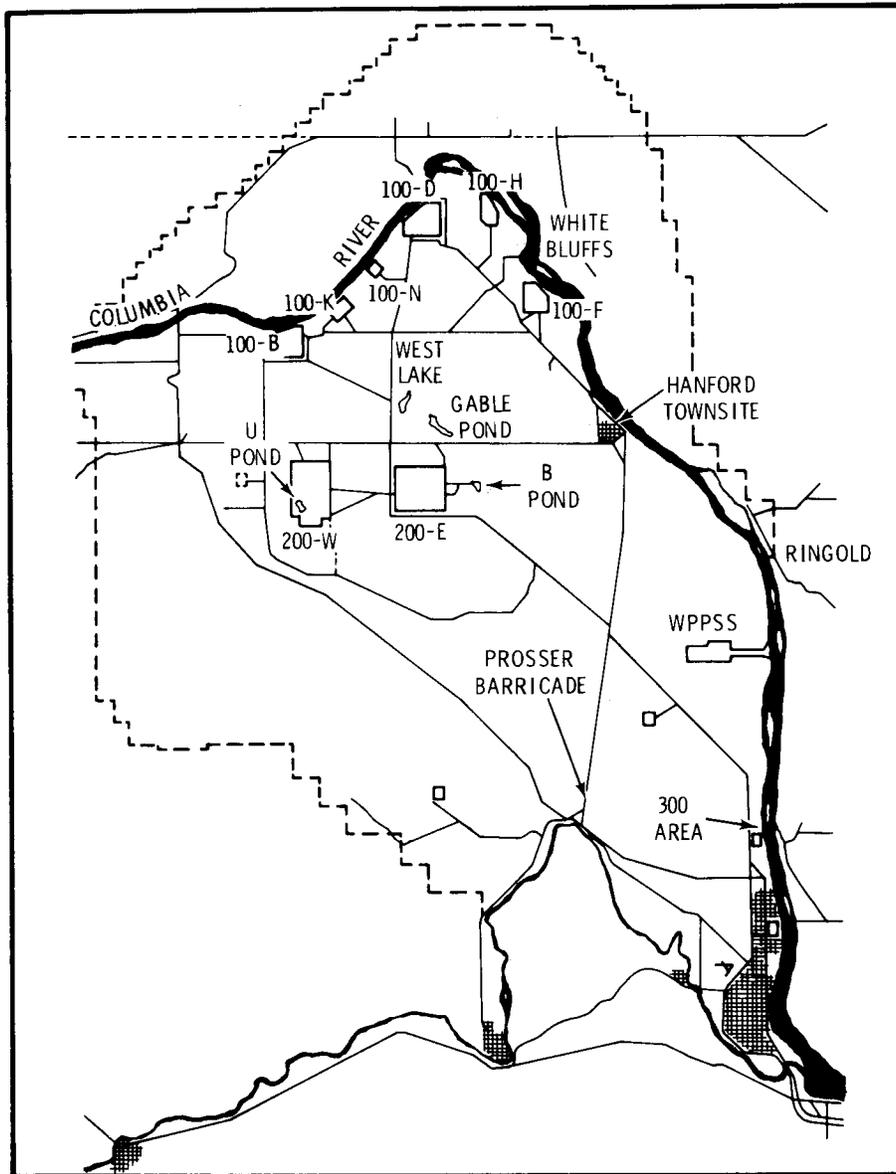


FIGURE 9. Wildlife Sampling Areas

Samples collected on the waste-water ponds near the 200 Areas showed an accumulation of ^{137}Cs in tissue at levels similar to that observed in recent years. The maximum concentration observed was 160 pCi/g in a duck collected on U pond. Concentrations observed in samples collected from the Columbia River near 100-N Area and from the 300 Area pond showed lower concentrations, generally in the range attributable to worldwide fallout.

The number of waterfowl frequenting the onsite ponds is an extremely small fraction of the total

population available for hunting; therefore, there is little probability that a hunter would shoot a bird that has spent a long time on these ponds. (a) Nevertheless, if an individual were to eat 0.5 kg of meat at the highest observed concentration (160 pCi/g), a dose commitment of about 6-mrem total body would be received. (b)

(a) The effective half life of ^{137}Cs in waterfowl tissue (i.e., the time it takes for ^{137}Cs in waterfowl meat to decrease by one half) is about 14 days (Halford, Millard, and Schreckhise 1978).

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

TABLE 14. Cobalt-60 and Cesium-137 in Upland Gamebirds

| | Concentration, pCi/g, wet weight ^(a) | | | | | |
|------------------|---|-------------|------------------------|-------------------------|-------------|------------------------|
| | ⁶⁰ Co | | | ¹³⁷ Cs | | |
| | Fraction of Results >DL | Maximum | Average ^(b) | Fraction of Results >DL | Maximum | Average ^(b) |
| 100 Areas | | | | | | |
| Quail | 1/3 | 0.07 ± 0.06 | (0.02 ± 0.06) | 2/3 | 0.11 ± 0.08 | 0.08 ± 0.04 |
| Pheasant | 2/8 | 0.03 ± 0.02 | (<0.02) | 3/8 | 0.05 ± 0.02 | 0.01 ± 0.02 |
| 200 Areas | | | | | | |
| Pheasant | 0/2 | <DL | (<0.01) | 2/2 | 40 ± 0.2 | [21 ± 48] |
| 300 Area | | | | | | |
| Quail | 0/4 | <DL | (<0.06) | 1/4 | 0.17 ± 0.06 | (<0.05) |

[] = Average significantly biased by single high result.

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

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

(a) Maximum values shown with the ± two sigma counting error term. Averages are shown with the ± two standard error of the mean.

(b) Averages were enclosed within parenthesis if the ± two standard error was greater than its associated mean.

TABLE 15. 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 | | | | | |
| Columbia River | Geese | 1/2 | 0.05 ± 0.01 | <DL | (0.03 ± 0.04) |
| Columbia River | Ducks | 3/3 | 0.04 ± 0.02 | 0.01 ± 0.01 | 0.03 ± 0.01 |
| 200 Area | | | | | |
| B Pond | Ducks | 5/5 | 38 ± 1 | 12.0 ± 0.2 | 23 ± 10 |
| U Pond | Ducks | 7/7 | 160 ± 1 | 12.0 ± 0.2 | 58 ± 18 |
| Gable Pond | Ducks | 4/4 | 9.8 ± 0.2 | 0.09 ± 0.03 | (3 ± 5) |
| West Lake | Ducks | 6/6 | 62 ± 0.6 | 0.2 ± 0.06 | 23 ± 20 |
| 300 Area | | | | | |
| Pond | Ducks | 5/7 | 0.26 ± 0.05 | <DL | 0.12 ± 0.04 |

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

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

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

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



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.

Contributions from Hanford operations to background levels of radionuclides are determined 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 1982, there was no indication of a detectable contribution from Hanford to radionuclide concentrations in soil and vegetation in the offsite environment. Although no difference could be discerned based on the routine samples collected in 1982, a special study involving the collection of a large number of soil samples showed that concentrations of uranium in surface soils east of the Columbia River near the 300 Area were slightly higher than concentrations normally observed at several offsite sampling locations west of the river. The study, however, did not provide conclusive evidence regarding the reason for the difference. Although the possibility of a 300 Area source must be considered, the observed uranium concentrations were all within the range of concentrations normally found in soils in eastern Washington. Additional samples will be collected in 1983 to determine the naturally occurring uranium concentrations in soils on the east bank of the Columbia River.

SAMPLE COLLECTION AND ANALYSIS

Soil and vegetation samples were collected at 16 locations in the offsite environs as shown in the map 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.

Three soil sampling locations were added in 1982. These were the "Vernita Bridge" location, the "Rattlesnake Springs" location, and the "South of 300 Area" location, shown as locations 9, 11 and 14, respectively, in Figure 10. The additional locations provide a more uniform coverage of the Site perimeter. The "Taylor Flats #1" sample, which had been collected just south of the "Taylor Flats #2" location, was eliminated from the sampling program in 1982 because of surface soil erosion.

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 mixed and dried and aliquots were taken for analysis.

Samples of perennial vegetation were collected in the immediate vicinity of the soil sampling locations at the same time soil sampling was performed. Vegetation samples included a mixture of rabbitbrush, sagebrush and bitterbrush in rough proportions according to the natural relative abundance of the three plants at the particular sampling location. No single species of perennial vegetation 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, plutoniums and uranium. The analytical methods are described in Appendix C.

SOIL

Results of soil sample analyses for samples collected during 1982 are shown in Table 16. Although some variability exists between sampling locations, concentrations of the long-lived radionuclides ⁹⁰Sr, ¹³⁷Cs and ²³⁹⁻²⁴⁰Pu are similar to those observed in previous years. No geographical distribution pattern indicative of a Hanford source could be discerned.

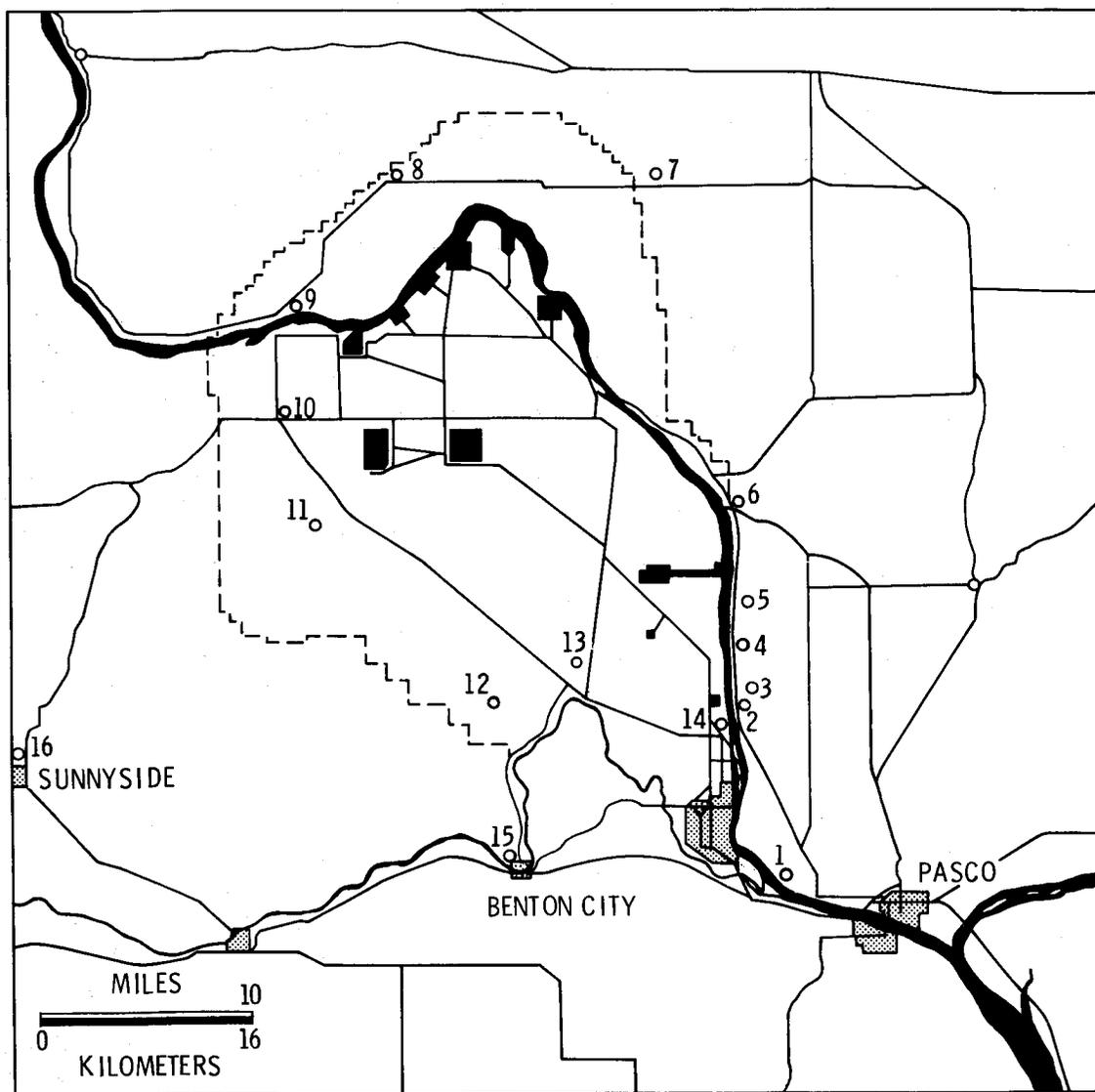


FIGURE 10. Soil and Vegetation Sampling Locations

Short-lived radionuclides ($^{95}\text{ZrNb}$ and ^{144}Ce) that had been observed in soil samples collected in 1981 were not observed in the current year's samples. The presence of these radionuclides in soil and vegetation samples collected in 1981 was attributed to worldwide fallout associated with an atmospheric nuclear detonation by the People's Republic of China in the fall of 1980.

To develop a better baseline for concentrations of uranium in soils on the east bank of the Columbia River across from the 300 Area, a number of soil samples were collected from this

area during 1982 as part of a special study (Price and Kinneson 1982). The special study was specifically designed to test the hypothesis that uranium and other heavy metals associated with deactivated process ponds located on the north side of the 300 Area had been resuspended by winds and transported across the river. Soil samples collected for the study showed statistically higher natural uranium concentrations than comparable samples from control sites (an average 1.4 pCi/g compared to 0.5 pCi/g), but there was no statistical difference in lead, silver, zinc or copper concentrations despite the fact that these

TABLE 16. Radionuclides in Soil

| Location | Map No. | Concentration, pCi/g, dry weight ^(a) | | | |
|---------------------|---------|---|-------------------|-----------------------|-------------|
| | | ⁹⁰ Sr | ¹³⁷ Cs | ²³⁹⁻²⁴⁰ Pu | U |
| Riverview | 1 | 0.12 ± 0.04 | 0.49 ± 0.07 | 0.006 ± 0.002 | 0.14 ± 0.05 |
| Byers Landing | 2 | 0.02 ± 0.01 | 0.28 ± 0.07 | 0.002 ± 0.0009 | 0.55 ± 0.19 |
| Sagemoor | 3 | 0.06 ± 0.02 | 0.06 ± 0.04 | 0.003 ± 0.0009 | 0.31 ± 0.11 |
| Taylor Flats #2 | 4 | 0.23 ± 0.06 | 0.61 ± 0.05 | 0.016 ± 0.003 | 0.59 ± 0.21 |
| W. End Fir Road | 5 | 0.07 ± 0.007 | 0.35 ± 0.05 | 0.005 ± 0.001 | 0.28 ± 0.10 |
| Ringold | 6 | 0.08 ± 0.04 | 0.83 ± 0.06 | 0.013 ± 0.002 | 0.43 ± 0.15 |
| Berg Ranch | 7 | 0.20 ± 0.09 | 0.83 ± 0.05 | 0.012 ± 0.002 | 0.26 ± 0.09 |
| Wahluke #2 | 8 | 0.10 ± 0.03 | 0.34 ± 0.07 | 0.006 ± 0.002 | 0.36 ± 0.13 |
| Vernita Bridge | 9 | 0.11 ± 0.07 | 0.58 ± 0.07 | 0.009 ± 0.002 | 0.38 ± 0.13 |
| Yakima Barricade | 10 | 0.09 ± 0.003 | 0.42 ± 0.04 | 0.011 ± 0.001 | 0.23 ± 0.08 |
| Rattlesnake Springs | 11 | 0.17 ± 0.04 | 0.70 ± 0.05 | 0.019 ± 0.002 | 0.30 ± 0.11 |
| ALE | 12 | 0.30 ± 0.06 | 1.1 ± 0.10 | 0.030 ± 0.002 | 0.35 ± 0.12 |
| Prosser Barricade | 13 | 0.29 ± 0.02 | 1.2 ± 0.06 | 0.033 ± 0.004 | 0.20 ± 0.07 |
| S. of 300 Area | 14 | 0.24 ± 0.15 | 1.1 ± 0.06 | 0.019 ± 0.003 | 0.51 ± 0.18 |
| Benton City | 15 | 0.21 ± 0.03 | 0.75 ± 0.05 | 0.024 ± 0.003 | 0.56 ± 0.19 |
| Sunnyside | 16 | 0.12 ± 0.03 | 0.41 ± 0.06 | 0.009 ± 0.002 | 0.17 ± 0.06 |

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

heavy metals are present in concentrations comparable to uranium in the process ponds. In addition, there was no difference observed in uranium or other heavy metals among samples of vegetation collected in the study area.

The conclusion from the study was that materials in the 300 Area process ponds had not been transported offsite in detectable quantities and that the uranium concentrations observed in the study area were possibly normal for soils in that particular area. Uranium concentrations in soil samples from both the study area and the control area were within the range that would be considered representative of naturally occurring uranium in the environment. Additional sampling will be performed during 1983 to determine if the observed concentrations in the study are normal for the particular types of soils in that area.

VEGETATION

Results of analyses for radionuclides in samples of mature vegetation collected during 1982 are shown in Table 17. Trace concentrations of radionuclides associated with worldwide fallout were observed in all samples collected both upwind and downwind from the Site. Several short-lived radionuclides attributed to the 1980 foreign atmospheric nuclear test that had been observed in 1981 samples were not observed in 1982 samples.

Radionuclide concentrations in the vegetation, except for the absence of shortlived fallout radionuclides, 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.

TABLE 17. Radionuclides in Vegetation

| Location | Map No. | Concentration, pCi/g, dry weight(a,b) | | | |
|---------------------|---------|---------------------------------------|-------------------|-----------------------|---------------|
| | | ⁹⁰ Sr | ¹³⁷ Cs | ^{239,240} Pu | U |
| Riverview | 1 | 0.01 ± 0.002 | (<0.03) | (<0.0007) | 0.02 ± 0.006 |
| Byers Landing | 2 | 0.008 ± 0.002 | 0.08 ± 0.06 | (<0.0008) | 0.04 ± 0.01 |
| Sagemoor | 3 | 0.01 ± 0.004 | 0.05 ± 0.03 | (<0.0004) | 0.02 ± 0.006 |
| Taylor Flats #2 | 4 | 0.06 ± 0.003 | (<0.04) | (<0.0004) | 0.03 ± 0.009 |
| W. End Fir Road | 5 | 0.05 ± 0.005 | (<0.04) | (<0.0009) | 0.03 ± 0.01 |
| Ringold | 6 | (<0.019) | (<0.08) | (<0.0004) | 0.03 ± 0.01 |
| Berg Ranch | 7 | 0.04 ± 0.002 | 0.05 ± 0.04 | (<0.0004) | (<0.06) |
| Wahluke #2 | 8 | 0.01 ± 0.004 | (<0.07) | 0.003 ± 0.0008 | 0.01 ± 0.005 |
| Vernita Bridge | 9 | 0.03 ± 0.003 | 0.09 ± 0.03 | 0.002 ± 0.0009 | 0.01 ± 0.005 |
| Yakima Barricade | 10 | 0.05 ± 0.01 | (<0.02) | 0.002 ± 0.001 | 0.01 ± 0.003 |
| Rattlesnake Springs | 11 | 0.024 ± 0.004 | 0.03 ± 0.02 | 0.0004 ± 0.0003 | 0.004 ± 0.001 |
| ALE | 12 | 0.05 ± 0.005 | 0.03 ± 0.02 | (<0.0006) | 0.008 ± 0.003 |
| Prosser Barricade | 13 | 0.05 ± 0.02 | (<0.02) | (<0.0005) | 0.01 ± 0.003 |
| S. of 300 Area | 14 | 0.03 ± 0.004 | 0.02 ± 0.01 | 0.001 ± 0.0007 | 0.006 ± 0.002 |
| Benton City | 15 | 0.05 ± 0.008 | (<0.08) | 0.001 ± 0.0009 | 0.01 ± 0.004 |
| Sunnyside | 16 | 0.005 ± 0.003 | 0.04 ± 0.02 | 0.001 ± 0.0008 | 0.01 ± 0.005 |

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

(b) Counting error shown in parenthesis in cases where the radionuclide was not positively identified.

PENETRATING RADIATION

Dose rates from penetrating radiations (primarily gamma-rays) were measured at a number of locations in the Hanford environs during 1982. The measurements were made using thermoluminescent dosimeters (TLDs) to provide estimates of the dose rates from external radiation sources. Naturally occurring sources, including radiations of cosmic origin and natural radioactive materials in the air and ground as well as fallout from the atmospheric testing of nuclear weapons, result in the measurement of a certain amount of penetrating radiation at all dosimeter locations (NCRP 1975). Increases in the measured dose rates above these "background levels" could be the result of exposure of the dosimeter to radioactive materials associated with activities at Hanford.

Dose rate measurements at locations in the vicinity of residential areas during 1982 were similar to those observed in previous years since external dose rate monitoring with TLDs began in 1970. 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 0.3 mrem/hr during 1982.

DOSE MEASUREMENTS

The environmental radiation dosimeters consist of three $\text{CaF}_2:\text{Mn}$ thermoluminescent chips encased in a plastic capsule. The capsule incorporates 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. Preparations and readout of the dosimeters were performed by PNL. Measured doses are reported in dose equivalent units (mrem) to enable comparison to dose standards and dose equivalents reported elsewhere in this document.

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 1982 are shown in Table 18. Since most of the dosimeter locations were in or near areas that could be inhabited continuously, dose measurements performed at these locations are reported in units of mrem/year.

Dose measurements were, in general, similar to those observed in previous years for the respective locations. Figure 12 shows average annual dose rates measured at perimeter locations 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 the Site and at distant locations. The figure also demonstrates that dose rates at perimeter stations generally averaged several mrem/year higher than the distant locations. These differences are most likely due to natural geographical variations in local environmental radiation levels, and the difference between the two groups of locations is thus an artifact of the selection of monitoring sites. 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. The possibility of an historic release of radioactive material (prior to 1973) as a cause for the observed differences in dose rate is not substantiated by soil and vegetation sampling data provided in this and previous years' annual reports.

COLUMBIA RIVER IMMERSION DOSE RATE

Dosimeters were submerged in the Columbia River at Coyote Rapids and at the Richland pump house (Figure 13) to provide a comparison of penetrating dose rates that would be received by a person immersed in the river before and after it passes through the Hanford Site. Results of the measurements, shown in Table 19, were similar at both locations and were 0.005 mrem/hr, less than the background dose rate of 0.008 mrem/hr measured on land.

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

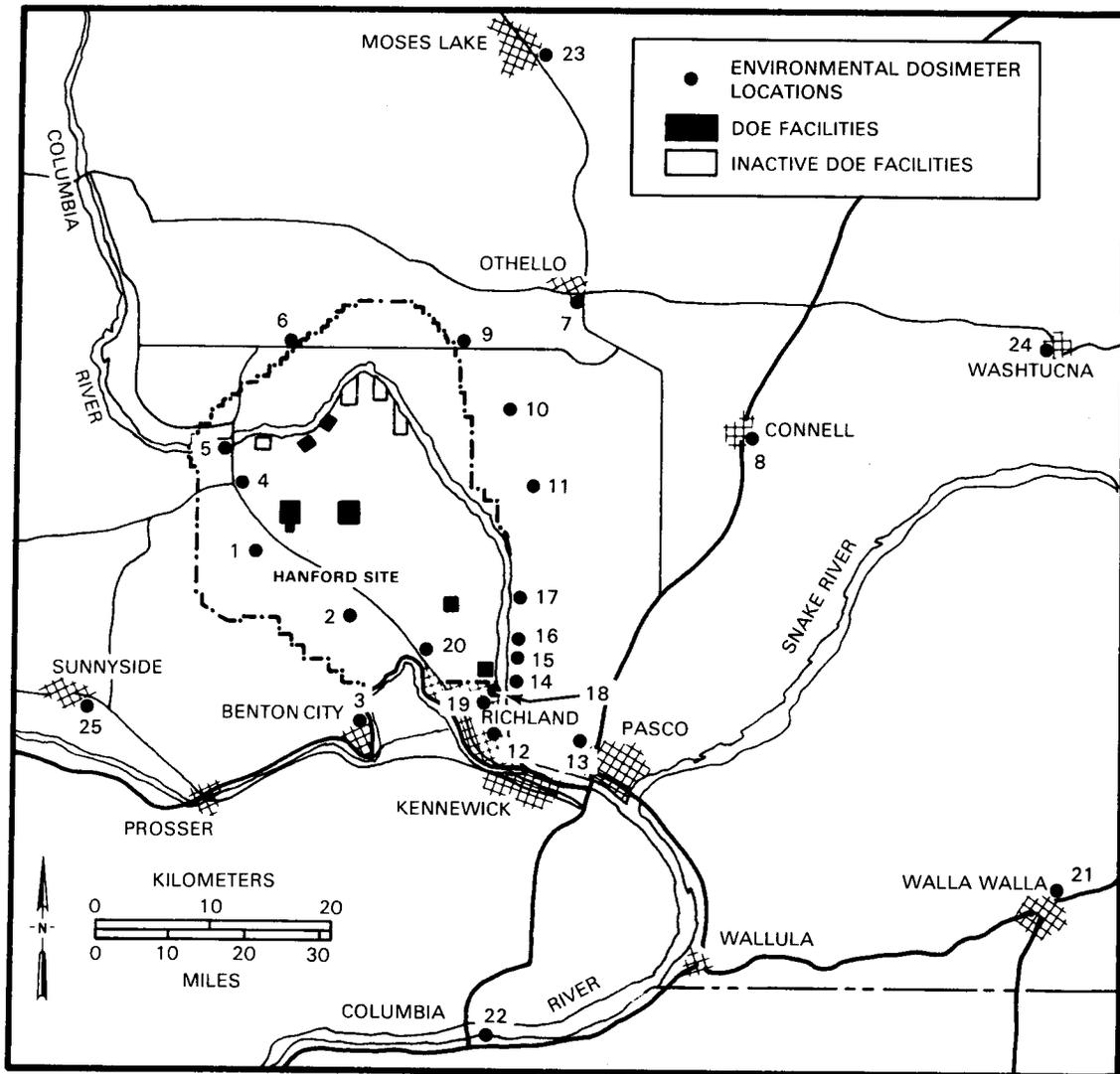


FIGURE 11. Environmental Dosimeter Locations - Perimeter and Community

OPERATIONS AREA BOUNDARIES

Dosimeters were placed near publicly accessible locations at operating areas on the Hanford Site as shown in Figure 14. Results for 1982 are shown in Table 20.

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

Dose rates in the 300 Area were at normal background levels (~0.008 mrem/hr) at three of the

six locations monitored, but were elevated at the other three locations as a result of direct radiation from onsite research activities involving a radioactive steam generator from a nuclear power plant. The highest readings were observed at the fence of the 300 Area just west of the steam generator examination facility (location 10 in Figure 14) where measured dose rates averaged 0.3 mrem/hr during 1982.

Dose rates at the 400 Area locations were at background levels, indicating no measurable penetrating dose rate contribution from FFTF activities during 1982.

TABLE 18. External Radiation Dose Measurements in The Hanford Vicinity

| Location | Map No.(b) | No of Samples | Dose Rate, mrem/y(a) | | |
|---|------------|---------------|----------------------|---------|------------|
| | | | Maximum | Minimum | Average(c) |
| Perimeter Stations | | | | | |
| Rattlesnake Springs | 1 | 12 | 88 | 69 | 77 ± 4 |
| ALE | 2 | 12 | 88 | 66 | 77 ± 4 |
| Benton City | 3 | 12 | 66 | 51 | 54 ± 3 |
| Yakima Barricade | 4 | 13 | 84 | 66 | 77 ± 4 |
| Vernita Bridge | 5 | 11 | 91 | 66 | 73 ± 5 |
| Wahluke #2 | 6 | 13 | 91 | 69 | 80 ± 4 |
| Othello | 7 | 13 | 69 | 58 | 62 ± 3 |
| Connell | 8 | 13 | 91 | 58 | 69 ± 5 |
| Berg Ranch | 9 | 13 | 102 | 73 | 80 ± 4 |
| Wahluke Watermaster | 10 | 13 | 91 | 69 | 80 ± 4 |
| Cooke Bros. | 11 | 13 | 84 | 58 | 69 ± 5 |
| Richland | 12 | 13 | 77 | 58 | 66 ± 3 |
| Pasco | 13 | 13 | 73 | 58 | 66 ± 3 |
| Byers Landing | 14 | 13 | 84 | 66 | 73 ± 3 |
| Sagemoor | 15 | 12 | 91 | 66 | 77 ± 4 |
| Pettett Farm | 16 | 13 | 69 | 55 | 66 ± 3 |
| Fir Road | 17 | 13 | 84 | 58 | 73 ± 3 |
| RRC CP #64 | 18 | 13 | 95 | 58 | 73 ± 5 |
| 1100 Area | 19 | 13 | 69 | 55 | 62 ± 3 |
| Prosser Barricade | 20 | 12 | 99 | 66 | 75 ± 5 |
| Range of annual averages 54 - 80 mrem/y | | | | | |
| Distant Stations | | | | | |
| Walla Walla | 21 | 13 | 69 | 47 | 58 ± 3 |
| McNary | 22 | 13 | 84 | 55 | 69 ± 4 |
| Moses Lake | 23 | 13 | 77 | 55 | 66 ± 4 |
| Washtucna | 24 | 12 | 80 | 58 | 69 ± 4 |
| Sunnyside | 25 | 12 | 69 | 58 | 62 ± 2 |
| Range of annual averages 58 - 69 mrem/y | | | | | |

- (a) Monthly integrated readings in mR were converted to annual dose equivalent rates.
- (b) See Figure 11.
- (c) Average shown includes ± two standard error term (95% confidence level).

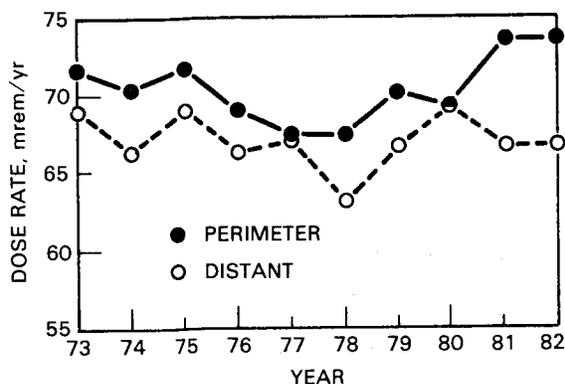


FIGURE 12. Annual Average External Dose Rates at Perimeter and Distant Locations 1973-1982

COLUMBIA RIVER SHORELINES

During reactor operations at Hanford from 1944 to 1972, radionuclides were discharged to the Columbia River along with the reactor cooling water. These radionuclides were diluted and dispersed in the river, which averaged a flow rate of 120,000 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 radionuclides were the subject of an extensive radiological survey of the Hanford reach of the river performed in 1979 (Sula 1980).

TABLE 19. Immersion Dose Rates in the Columbia River

| Location | No of Measurements | Dose Rate, mrem/hr ^(a) | | |
|--------------------|--------------------|-----------------------------------|---------|------------------------|
| | | Maximum | Minimum | Average ^(b) |
| Coyote Rapids | 8 | 0.007 | 0.003 | 0.005 ± 0.003 |
| Richland Pumphouse | 12 | 0.007 | 0.004 | 0.005 ± 0.001 |

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

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

TABLE 20. External Radiation Dose Rate Measurements Near Publicly Accessible Locations At Hanford Operating Areas

| Location | Map No. ^(b) | No of Measurements | Dose Rate, mrem/hr ^(a) | | |
|--|------------------------|--------------------|-----------------------------------|---------|------------------------|
| | | | Maximum | Minimum | Average ^(c) |
| 100-N Area Shoreline | | | | | |
| 100-N Trench Springs | 1 | 11 | 0.022 | 0.008 | 0.017 ± 0.002 |
| Below 100-N Main Stack | 2 | 11 | 0.030 | 0.010 | 0.023 ± 0.004 |
| Upstream Tip 100-N Berm | 3 | 10 | 0.029 | 0.010 | 0.022 ± 0.0004 |
| Downstream 100 N Outfall | 4 | 10 | 0.040 | 0.012 | 0.025 ± 0.001 |
| 300 Area Perimeter Fence | | | | | |
| 3705 West Fence | 5 | 14 | 0.019 | 0.010 | 0.016 ± 0.001 |
| 300 Area SW Gate | 6 | 13 | 0.010 | 0.008 | 0.008 ± 0.0004 |
| 300 Area South Gate | 7 | 12 | 0.010 | 0.008 | 0.008 ± 0.0004 |
| ACRMS | 8 | 13 | 0.009 | 0.008 | 0.008 ± 0.0002 |
| 300 Area Pond | 9 | 13 | 0.046 | 0.008 | 0.012 ± 0.006 |
| 377-W Fence | 10 | 10 | 0.34 | 0.28 | 0.31 ± 0.007 |
| 400 Area (FFTF) Perimeter Fence | | | | | |
| 400 East | 11 | 13 | 0.009 | 0.007 | 0.008 ± 0.0004 |
| 400 South | 12 | 13 | 0.010 | 0.007 | 0.008 ± 0.001 |
| 400 North | 13 | 13 | 0.010 | 0.007 | 0.008 ± 0.0005 |
| 400 West | 14 | 12 | 0.010 | 0.006 | 0.008 ± 0.001 |
| FFTF North | 15 | 13 | 0.010 | 0.007 | 0.009 ± 0.001 |
| FFTF SE | 16 | 13 | 0.010 | 0.008 | 0.008 ± 0.0003 |

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

(b) See Figure 14.

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

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 21 provides results of measurements at these locations during 1982. In general, dose rates measured during 1982 were similar to those

observed in 1981. The consistency of the dose rate measurements during the past two years indicates the radionuclides in the ground to be relatively immobile and resistant to resuspension and redistribution by the mechanical forces of wind and water. Dose rates along the river thus are expected to gradually decrease at a rate commensurate with the radioactive half-lives of the radionuclides present.

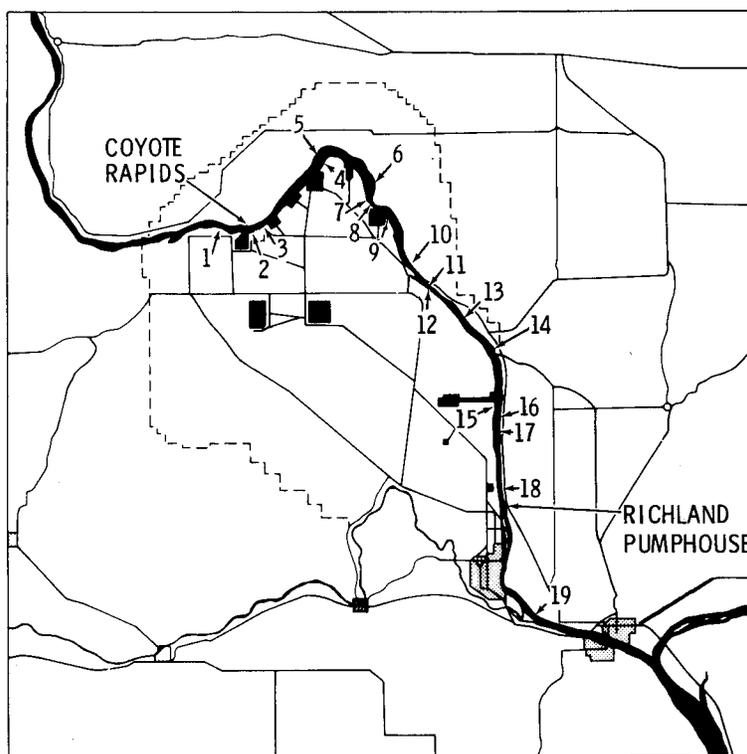


FIGURE 13. Environmental Dosimeter Locations—Hanford Reach of Columbia River

TABLE 21. External Radiation Dose Rate Measurements Along the Columbia River Shoreline and Islands

| Location | Map No.(b) | No of Measurements | Dose Rate, mrem/hr(a) | | |
|-----------------------------|------------|--------------------|-----------------------|---------|----------------|
| | | | Maximum | Minimum | Average(c) |
| Upriver 100-B Area | 1 | 10 | 0.013 | 0.004 | 0.008 ± 0.0002 |
| Below 100-B Retention Basin | 2 | 10 | 0.023 | 0.009 | 0.017 ± 0.0003 |
| Above 100-K Boat Ramp | 3 | 11 | 0.012 | 0.004 | 0.008 ± 0.001 |
| Downriver 100-D | 4 | 11 | 0.015 | 0.006 | 0.012 ± 0.002 |
| Downriver Opposite 100-D | 5 | 11 | 0.012 | 0.004 | 0.008 ± 0.001 |
| Lower End Locke Island | 6 | 10 | 0.013 | 0.004 | 0.009 ± 0.0002 |
| White Bluffs Slough | 7 | 11 | 0.017 | 0.008 | 0.013 ± 0.002 |
| White Bluffs Ferry Landing | 8 | 11 | 0.015 | 0.005 | 0.009 ± 0.002 |
| Below 100-F | 9 | 11 | 0.013 | 0.004 | 0.008 ± 0.002 |
| Hanford Powerline Crossing | 10 | 11 | 0.013 | 0.005 | 0.009 ± 0.001 |
| Hanford Ferry Landing | 11 | 8 | 0.011 | 0.006 | 0.008 ± 0.001 |
| Hanford Railroad Track | 12 | 10 | 0.016 | 0.006 | 0.012 ± 0.001 |
| Savage Island Slough | 13 | 11 | 0.013 | 0.005 | 0.010 ± 0.001 |
| Ringold Island | 14 | 11 | 0.013 | 0.004 | 0.009 ± 0.001 |
| Powerline Crossing | 15 | 11 | 0.014 | 0.005 | 0.010 ± 0.001 |
| North End Wooded Island | 16 | 10 | 0.009 | 0.004 | 0.006 ± 0.0002 |
| South End Wooded Island | 17 | 10 | 0.014 | 0.005 | 0.010 ± 0.0002 |
| Island RM 344 | 18 | 10 | 0.016 | 0.005 | 0.011 ± 0.0002 |
| Island RM 333 | 19 | 9 | 0.012 | 0.005 | 0.010 ± 0.002 |

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

(b) See Figure 13.

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

Figure removed as per DOE guidance.

FIGURE 14. Environmental Dosimeter Location—Publicly Accessible Locations Onsite

RADIOLOGICAL IMPACT OF HANFORD OPERATIONS

An assessment of potential radiological impact indicated that radiation doses to the public attributable to 1982 operations at Hanford were well below all applicable regulatory limits and were significantly less than doses potentially received from some other common sources of radiation. The fifty-year whole body cumulative dose potentially received by an assumed maximum exposed individual was calculated to be 0.7 mrem, as compared to the DOE Radiation Protection Standard of 500 mrem. 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. An assessment of potential radiation doses due to residual radionuclides from past Hanford operations also revealed no significant impacts on the public.

RADIOLOGICAL IMPACT FROM 1982 OPERATIONS

Hanford operations during 1982 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 1982 operations were assessed to determine compliance with pertinent regulations as required by DOE Order 5484.1.

The radiological impact of 1982 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 are evaluated based on the direct measurement of dose rates or of radionuclide concentrations in the environment. The "fence-post" dose rate during 1982 was based on direct measurements of external radiation made near the operating areas. However, the quantities of radionuclide releases associated with 1982 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 1982 are shown in Table 22. The radiation doses estimated by these models were quite small and well below our ability to measure directly. Although the uncertainty associated with these calculations has not been specified, it is relatively large. As a result, these doses should be viewed as conservatively calculated best estimates of potential dose impact of 1982 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 1982. The "fence-post" dose rate is 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 20) 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 1982 was 0.04 mrem/hr, or about five times the dose rate normally observed at offsite locations (0.008 mrem/hr).

Access to the 400 Area was possible at the Visitors Information Center located southeast of the FFTF reactor building and at several parking lots

TABLE 22. Radionuclide Composition of Hanford Effluents for Calendar Year 1982

| Radionuclide | Half-Life | Effluent, Ci(a) | | | | |
|----------------------|--------------------------|------------------------|------------------------|----------------------------|----------------------------|------------------------|
| | | Liquid to River | Airborne | | | |
| | | | 100 Area | 200 Area | 300 Area | 400 Area |
| ³ H (HTO) | 12.3 yr | 360 | 22 | | | |
| ²⁴ Na | 15.0 hr | | 0.22 | | | |
| ³² P | 14.3 d | 0.059 | | | | |
| ⁴¹ Ar | 1.8 hr | | 114,000 | | | |
| ⁵⁴ Mn | 303 d | 0.017 | 0.008 | | | |
| ⁵⁶ Mn | 2.6 hr | 1.7 | 0.099 | | | |
| ⁵⁹ Fe | 46.0 d | 0.12 | 0.007 | | | |
| ⁵⁸ Co | 71.0 d | | 0.005 | | | |
| ⁶⁰ Co | 5.3 yr | 0.58 | 0.015 | | 3.0 x 10 ⁻⁶ (b) | |
| ⁷⁶ As | 26.4 hr | | 1.3 | | | |
| ^{85m} Kr | 4.4 hr | | 130 | | | |
| ⁸⁵ Kr | 10.7 yr | | | | 5.0 x 10 ⁻¹ | |
| ⁸⁷ Kr | 76.0 min | | 520 | | | |
| ⁸⁸ KrRb | 2.8 hr | | 550 | | | 140 |
| ⁸⁹ Sr | 52.7 d | 0.6 | 0.005 | | | |
| ⁹⁰ Sr | 27.7 yr | 2.7 | 0.001 | 0.012 | 4.6 x 10 ⁻⁵ (c) | 1.9 x 10 ⁻⁵ |
| ⁹¹ Sr | 9.7 hr | | 0.33 | | | |
| ⁹⁵ ZrNb | 65.5 d | | 0.003 | | | |
| ⁹⁵ Nb | 35.0 d | | 0.003 | | | |
| ^{99m} MoTc | 66.7 hr | 2.4 | 0.29 | | | |
| ¹⁰³ Ru | 39.5 d | 0.15 | 0.01 | | | |
| ¹⁰⁶ Ru | 368 d | 0.31 | | | | |
| ¹²⁵ Sb | 2.7 yr | 0.11 | | | | |
| ¹³¹ I | 8.1 d | 2.2 | 0.25 | | 5.1 x 10 ⁻⁴ | 9.6 x 10 ⁻⁵ |
| ¹³² I | 2.3 hr | | 2.5 | | | |
| ¹³³ I | 20.3 hr | | 1.5 | | | |
| ¹³⁵ I | 6.7 hr | | 0.29 | | | |
| ¹³³ Xe | 5.3 d | 2.2 | 840 | | | |
| ¹³⁵ Xe | 9.1 hr | | 610 | | | |
| ¹³⁷ Cs | 30.0 yr | 0.15 | 2.5 x 10 ⁻⁴ | 0.16 | | |
| ¹³⁸ Cs | 32.2 min | | 17,200 | | | |
| ¹⁴⁰ BaLa | 12.8 d | | 0.15 | | | |
| ¹⁴⁴ CePr | 284 d | | 0.05 | | | |
| ¹⁵⁵ Eu | 1.8 yr | | 2.7 x 10 ⁻⁴ | | | |
| U-nat | 4.4 x 10 ⁹ | | | | 2.1 x 10 ⁻⁴ | |
| ²³⁸ Pu | 86.4 yr | 4.7 x 10 ⁻⁴ | 1.0 x 10 ⁻⁴ | | | |
| ²³⁹ Pu | 2.4 x 10 ⁴ yr | 3.0 x 10 ⁻⁴ | 6.2 x 10 ⁻⁴ | 4.9 x 10 ⁻⁴ (b) | 1.9 x 10 ⁻⁵ | 7.3 x 10 ⁻⁶ |
| ²⁴⁴ Cm | 18.1 yr | | | | 5.5 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) Reported as mixed activation products. Cobalt-60 was assumed for dose calculations.

(c) 3.3 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.

and access roads around the perimeter fence. Penetrating dose rate measurements in the vicinity of these accessible areas during 1982 (Table 20) did not indicate any identifiable dose rate above normal background levels.

Dose rates in the 300 Areas were at normal background levels (~0.008 mrem/hr) at three of the

six locations monitored, but were elevated at the other three locations as a result of direct radiation from onsite research activities involving a radioactive steam generator from a nuclear power plant. The highest readings were observed at the fence of the 300 Area just west of the steam generator examination facility (location 10 in

Figure 14) where the maximum monthly averaged dose rate was 0.3 mrem/hr during 1982.(a)

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 construed as a basis for reporting these doses. In fact, there is no evidence to support the inclusion of a scenario involving 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 1982 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: 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 1982 was postulated to be an individual who:

- is a long-term resident in an area approximately 13 km southsoutheast of the 300 Area,

- consumes foodstuffs grown in the northwestern part of the Riverview district using Columbia River water for irrigation,
- consumes drinking water obtained from the Columbia River and,
- uses 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 22. Because these effluents include 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 dose 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 23 and include that dose received from exposure to liquid and airborne effluents during 1982 as well as potential exposure beyond 1982 to that fraction of the 1982 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 23. The appendix also includes a table showing the doses calculated to be committed as a result of exposures incurred during 1982 only.

All potential MI doses resulting from effluents discharged to the environment during operations at Hanford in 1982 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 2.4 mrem was calculated as compared to the DOE Radiation Protection Standard of 1,500 mrem for the bone. The bone dose was primarily the result of exposure to ⁹⁰Sr in the soil.

A comparison of the MI dose impacts attributed to 1982 Hanford operations with estimates of the MI doses for the previous five years is provided in Table 24. Doses presented in the table are the

(a) Measures to reduce the 300 Area "fence-post" dose rate are being considered.

TABLE 23. Dose to the Maximum Individual from 1982 Hanford Operations

| Pathway | 50-Year Cummulative Dose, mrem | | | | | |
|---------------------|--------------------------------|-------|------|------|---------|--------|
| | Whole Body | GI(a) | Bone | Lung | Thyroid | |
| | | | | | Adult | Infant |
| Direct Airborne(b) | .01 | .01 | .01 | .02 | .01 | <.01 |
| Foodstuffs(c) | .6 | .06 | 2 | <.01 | .1 | .4 |
| Drinking Water | <.01 | <.01 | .01 | <.01 | .02 | .06 |
| River Recreation(d) | .04 | <.01 | .1 | <.01 | .02 | — |
| Total | .7 | .07 | 2 | .02 | .2 | .5 |

(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.

TABLE 24. Comparison of Estimated Maximum Individual Doses Due to Hanford Operations 1977-1982(a)

| Organ | 50-Year Cumulative Dose (man-rem)(b) | | | | | |
|------------|--------------------------------------|------|------|------|------|------|
| | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 |
| Whole Body | .8 | .5 | .7 | .6 | .5 | .7 |
| GI(c) | .2 | .1 | .2 | .1 | .06 | .07 |
| Bone | 3 | 2 | 3 | 2 | 2 | 2 |
| Lung | .03 | .02 | .4 | <.01 | .01 | .02 |
| Thyroid | .4 | 1 | .8 | .2 | .2 | .2 |

(a) McCormack, et al. 1983.

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

(c) Gastrointestinal Tract (lower large intestine).

calculated 50-year cumulative doses that assume long-term residency of the MI.

The numerical values of doses presented in Table 24 for the years 1977 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 24 using presently available methodologies (McCormack, Carlile, and Napier 1983). Although the recalculated doses in Table 24 vary somewhat from the values originally reported, the conclusions remain unchanged: radiological impacts from Hanford operations are well below applicable dose guidelines and contribute only a small fraction of the dose received by the public from naturally occurring radiations.

Population Dose

The regional dose impact from 1982 Hanford operations was estimated by calculating the collective dose to the population residing within an 80-km radius of any of the onsite operating

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

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 25. Site-specific population distributions and other dose calculation parameters are detailed in Appendix E. The appendix also includes a table showing the doses calculated to be committed as a result of exposures incurred during 1982 only.

A comparison of 80-km population doses attributed to 1982 Hanford operations with estimated

doses for the five previous years is provided in Table 26. As discussed in the section on "Maximum Exposed Individual," the doses due to operations during 1977 through 1981 were recalculated for comparison with 1982. For recalculation of the population doses, the 1977 through 1981 80-km population distributions were updated consistent with the 1980 census data.

The primary airborne pathway contributing 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

TABLE 25. Dose to the Population from 1982 Hanford Operations

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

* 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.

(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.

TABLE 26. Comparison of Estimated 80-km Population Dose Due to Hanford Operations 1977-1982(a)

| Organ | 50-Year Cumulative Dose (man-rem)(b) | | | | | |
|------------|--------------------------------------|------|------|------|------|------|
| | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 |
| Whole Body | 7 | 7 | 4 | 2 | 3 | 4 |
| GI(c) | 4 | 3 | 3 | <1 | 3 | 3 |
| Bone | 7 | 20 | 10 | 5 | 5 | 7 |
| Lung | 6 | 5 | 5 | 1 | 3 | 4 |
| Thyroid | 13 | 12 | 12 | 4 | 5 | 7 |

(a) McCormack, et al. 1983.

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

(c) Gastrointestinal Tract (lower large intestine).

effluents, the primary radionuclide being ^{90}Sr . A "per capita" dose from 1982 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 1982 are compared graphically 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 are residual radionuclides deposited along the Columbia River shoreline and in the river sediments, and the seepage of water containing tritium and ^{129}I from the unconfined Hanford aquifer into the river.

Environmental radiation dose rates along the Columbia River shorelines 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 upstream to Columbia Pt. at the confluence of the Yakima River, downstream from the Hanford Site. 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 manhours 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 discussed in previous sections, low concentrations of tritium and ^{129}I associated with the unconfined aquifer underlying the Hanford Site are entering the river. Increased concentrations in the river cannot be detected for tritium 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 concentrations upstream and downstream of the Site (see the "Columbia River Radiological Monitoring" section), is 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 (Appendix A).

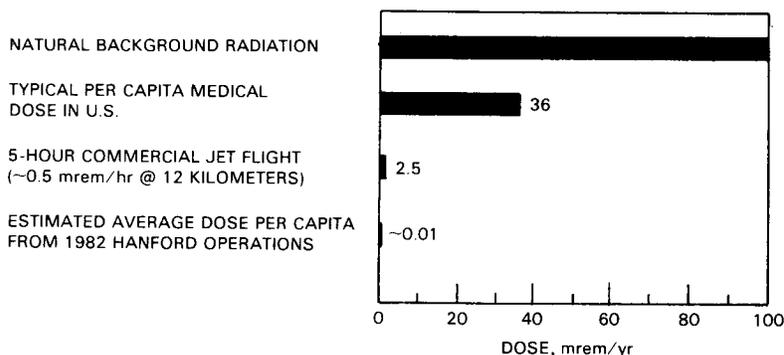


FIGURE 15. Whole Body Doses Received from Various Radiation Sources

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APPENDIX A
APPLICABLE STANDARDS



APPENDIX A APPLICABLE STANDARDS

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

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

such as the International Commission on Radiological Protection (ICRP) and the National Commission on Radiation Protection and Measurements (NCRP). The standards govern exposures to ionizing radiation from DOE operations. DOE ORDER 5480.1 also lists radionuclide concentration guides for air and water. Several of the concentration guides for air and water are listed in Table A.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) Increases not to exceed $34/(T + 9)$, where T = highest existing temperature in $^\circ\text{C}$ outside of mixing zone |
| pH | 1) 6.5 to 8.5 range 2) <0.5 unit induced variation |
| Turbidity | ≤ 5 NTU ^(a) over background turbidity |
| Toxic, Radioactive, or Deleterious Materials | Concentrations shall be below those of public health significance, or which cause acute or chronic toxic conditions to the aquatic biota, or which may adversely affect any water use. |
| Aesthetic Value | Shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch or taste. |

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

TABLE A.2. 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. Radionuclide Concentration Guides

| Radionuclide | Water, 10^{-9} $\mu\text{Ci}/\text{ml}$ | Air, 10^{-12} $\mu\text{Ci}/\text{ml}$ |
|---------------------|---|--|
| Gross Alpha | 30 | 0.2 |
| Gross Beta | 3,000 | 100 |
| ³ H | 3,000,000 | 200,000 |
| ⁵⁴ Mn | 100,000 | 1,000 |
| ⁵¹ Cr | 2,000,000 | 80,000 |
| ⁶⁰ Co | 30,000 | 300 |
| ⁶⁵ Zn | 100,000 | 2,000 |
| ⁹⁰ Sr | 300 | 30 |
| ⁹⁵ ZrNb | 60,000 | 1,000 |
| ¹⁰⁶ Ru | 10,000 | 200 |
| ¹³¹ I | 300 | 100 |
| ¹³⁷ Cs | 20,000 | 500 |
| ¹⁴⁰ BaLa | 20,000 | 500 |
| ¹⁴⁴ Ce | 10,000 | 200 |
| ²³⁹ Pu | 5,000 | 0.06 |

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 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) or b) the calculated mean was less than its calculated two-standard error term. Furthermore, if fewer than one-fourth of the individual results indicated a positive identification, no average was calculated and instead, the average analytical uncertainty term was shown preceded by a less than sign (<) and enclosed within parenthesis. 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 or < 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 PROCEDURES



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

counting with a low-background gas flow proportional counter.

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 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.

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) | | | 1 | 50 | | | | | | |
| ³ H (other) | 5 ml | 300 pCi/l | 0.1 | 300 | | | 0.02 ^(b) | 1500 | | |
| ⁸⁹ Sr | 1500 | 0.06 | 10 | 0.6 | | | 0.5 | 5 | | |
| ⁹⁰ Sr | 1500 | 0.006 | 10 | 0.06 | | | 0.5 | 2 | 0.5 | 5 |
| ¹²⁹ I | | | | | 1000 | 0.00001 | 4 | 0.0001 | | |
| ¹³¹ I | 1500 | 0.01 | 1 | 4 | 1000 | 0.1 | 4l (milk) | 0.5 (pCi/l) | | |
| U-nat | 1500 | 0.005 | 0.01 | 0.5 | | | | | 0.5 | 10 |
| ²³⁸ Pu | | | | | 1000 | 0.01 | | | 0.5 | 0.6 |
| ^{239,240} Pu | 1500 | 0.0001 | | | 1000 | 0.01 | | | 0.5 | 0.6 |
| Gamma-Emitters | 1500 | 0.1 ^(c) | 5 | 8 ^(c) | 1000 | 0.1 ^(c) | 0.5 | 15 ^(c) | 0.5 | 20 soil, 30 vege- tation |
| Gross Alpha | 800 | 0.001 | 1 | 5 | | | | | | |
| Gross Beta | 80 | 0.01 | 1 | 10 | | | | | | |

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

(b) 20 ml water from sample.

(c) 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.

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

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.

Farm Produce

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

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

Strontium-89,90 analyses are made like those for air samples after drying, ashing in a furnace, and treating with nitric acid prior to the fuming nitric acid step.

Vegetation

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

Soil

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

Plutonium and Strontium-89,90 are determined after the soil is dried, mixed thoroughly, leached with a mixture of nitric and hydrochloric acids, and then passed through an ion exchange resin in nitric acid.

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

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

Uranium analysis is conducted after the sample is dried, ashed in a furnace, and leached with hot nitric acid. Uranium is extracted from the acid leachate as tetrapropyl ammonium uranyl trinitrate and then extracted back into water. A

portion of the water extract is fused with sodium and lithium fluoride and analyzed with a fluorometer.

NONRADIOLOGICAL SAMPLES

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



APPENDIX D
QUALITY ASSURANCE

10/10/2019

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APPENDIX D

QUALITY ASSURANCE

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

ANALYTICAL LABORATORY QUALITY ASSURANCE

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

EPA. Replicate analyses are performed on each sample, and the results are forwarded to the 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.

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

In addition to these programs, the laboratory is provided, without their knowledge, quantitatively spiked samples. During 1982, spiked samples of milk, meat, produce, soil, and water were submitted routinely for analysis. Some results clearly indicated the need for a review of analytical methods and procedures, and as a result, the methods used for analyzing ^{90}Sr , plutonium, and gamma-emitting radionuclides were improved.

SAMPLE COLLECTION QUALITY ASSURANCE

Of primary importance in the operation of an environmental surveillance program is the collection of representative samples. To check on the precision of samples, duplicate air particulate filters were collected at several locations. Tables D.2 and D.3 show the average biases and the range of individual biases for gross beta and gross alpha analyses of the duplicate air filters. Due to the very small amounts of radioactive particulate material in the Hanford environs, results of individual duplicate pairs of air filter samples may vary by more than 100 percent. However, the average biases, representing 12 monthly sampling periods, show good agreement between duplicates. Table D.4 shows the results obtained from duplicate air sample composites for the analysis of ^{137}Cs , ^{90}Sr , and $^{239/240}\text{Pu}$. The observed degree of bias is acceptable because it is much less than the minimum detectable concentrations given in Table C.1. Table D.5 shows the individual and average percent biases for the results of duplicate TLDs. Each month three pairs of duplicate TLDs were

TABLE D.1 Environmental Protection Agency Laboratory Intercomparison Results for 1982

| Sample Media | Radionuclide | Month | Concentrations ^(a) | | | |
|-------------------|-------------------|------------|-------------------------------|-------------------------|--------------------------|---------|
| | | | UST ^(b) | Expected ^(b) | Other Lab ^(c) | |
| Air Filters | Gross Alpha | March | 24 ± 4 | 27 ± 21 | 26 ± 12 | |
| | Gross Beta | | 65 ± 5 | 55 ± 15 | 59 ± 24 | |
| | ⁹⁰ Sr | | 14 ± 1 | 16 ± 4 | 16 ± 6 | |
| | ¹³⁷ Cs | | 23 ± 21 | 23 ± 15 | 27 ± 18 | |
| Water | Gross Alpha | January | 34 ± 3 | 24 ± 18 | 21 ± 18 | |
| | Gross Beta | | 48 ± 4 | 32 ± 15 | 31 ± 18 | |
| | ⁸⁹ Sr | | 24 ± 2 | 21 ± 15 | 20 ± 12 | |
| | ⁹⁰ Sr | | 10 ± 1 | 12 ± 4 | 11 ± 6 | |
| | ¹³¹ I | | 9.0 ± 0.9 | 8.4 ± 5.0 | 8.3 ± 3.0 | |
| | ²³⁹ Pu | | 6.4 ± 0.6 | 6.7 ± 2.1 | 6.1 ± 2.7 | |
| | ³ H | February | 1632 ± 222 | 1820 ± 1026 | 1858 ± 687 | |
| | ⁵¹ Cr | | 0 ± 17 | (d) | 5 ± 27 | |
| | ⁶⁰ Co | | 35 ± 8 | 20 ± 5 | 20 ± 15 | |
| | ⁶⁵ Zn | | 39 ± 12 | 15 ± 15 | 15 ± 12 | |
| | ¹⁰⁶ Ru | | 43 ± 22 | 20 ± 15 | 19 ± 24 | |
| | ¹³⁴ Cs | | 24 ± 6 | 22 ± 15 | 21 ± 9 | |
| | ¹³⁷ Cs | | 36 ± 4 | 23 ± 15 | 24 ± 12 | |
| | U(total) | | 32 ± 3 | 35 ± 18 | 33 ± 24 | |
| | Gross Alpha | | March | 16 ± 4 | 19 ± 15 | 18 ± 12 |
| | Gross Beta | | | 15 ± 5 | 19 ± 15 | 20 ± 12 |
| | ²²⁶ Ra | 10 ± 0.5 | | 12 ± 5.1 | 11 ± 5.1 | |
| | ²²⁸ Ra | 24 ± 3.3 | | 10 ± 4.5 | 10 ± 9 | |
| | Gross Alpha | April | 102 ± 12 | 85 ± 63 | 75 ± 48 | |
| | Gross Beta | | 158 ± 30 | 106 ± 16 | 106 ± 39 | |
| | ³ H | | 2525 ± 321 | 2860 ± 1080 | 2812 ± 726 | |
| | ⁶⁰ Co | | 1 ± 2 | (d) | 5 ± 30 | |
| | ⁸⁹ Sr | | 28 ± 3 | 24 ± 15 | 24 ± 12 | |
| | ⁹⁰ Sr | | 10 ± 3 | 12 ± 4.5 | 12 ± 6 | |
| | ¹³¹ I | | 72 ± 7 | 62 ± 12 | 63 ± 24 | |
| | ¹³⁴ Cs | | 13 ± 6 | 15 ± 15 | 15 ± 12 | |
| | ¹³⁷ Cs | | 15 ± 6 | 16 ± 15 | 17 ± 12 | |
| | ²²⁶ Ra | | 11 ± 2.4 | 11 ± 4.8 | 11 ± 5.1 | |
| | ²²⁸ Ra | | 17 ± 5.1 | 11 ± 5.1 | 12 ± 13 | |
| | U(total) | | 34 ± 9.6 | 17 ± 18 | 16 ± 15 | |
| | Gross Alpha | | May | 33 ± 6 | 28 ± 21 | 25 ± 21 |
| | Gross Beta | | | 40 ± 5 | 29 ± 15 | 30 ± 18 |
| ⁸⁹ Sr | 28 ± 2 | 22 ± 15 | | 22 ± 15 | | |
| ⁹⁰ Sr | 12 ± 1 | 13 ± 4 | | 12 ± 6 | | |
| ³ H | June | 1550 ± 211 | 1830 ± 590 | 1765 ± 687 | | |
| ⁵¹ Cr | | 31 ± 19 | 23 ± 15 | 25 ± 39 | | |
| ⁶⁰ Co | | 29 ± 5 | 29 ± 15 | 31 ± 12 | | |
| ⁶⁵ Zn | | 29 ± 8 | 26 ± 15 | 27 ± 18 | | |
| ¹⁰⁶ Ru | | 3 ± 20 | (d) | 10 ± 33 | | |
| ¹³¹ I | | 4.0 ± 3.9 | 4.4 ± 2.1 | 4.5 ± 1.1 | | |
| ¹³⁴ Cs | | 31 ± 4 | 35 ± 9 | 34 ± 12 | | |
| ¹³⁷ Cs | | 27 ± 4 | 25 ± 8 | 27 ± 12 | | |
| Gross Alpha | July | 18 ± 2 | 16 ± 15 | 16 ± 15 | | |
| Gross Beta | | 14 ± 1 | 23 ± 15 | 21 ± 15 | | |
| ²³⁹ Pu | | 7.3 ± 0.6 | 6.9 ± 2.1 | 7.3 ± 2.4 | | |
| ³ H | August | 2037 ± 277 | 2890 ± 1140 | 2847 ± 810 | | |
| ¹³¹ I | | 109 ± 8 | 87 ± 26 | 86 ± 30 | | |
| U (total) | | 66 ± 4 | 30 ± 18 | 29 ± 12 | | |

TABLE D.1 Environmental Protection Agency Laboratory Intercomparison Results for 1982 (Contd)

| Sample Media | Radionuclide | Month | Concentrations ^(a) | | | | |
|-------------------|-------------------|-------------------|-------------------------------|-------------------------|--------------------------|-----------|----------|
| | | | UST ^(b) | Expected ^(b) | Other Lab ^(c) | | |
| Milk | ²²⁶ Ra | September | 10 ± 0.4 | 11 ± 4.8 | 11 ± 5.4 | | |
| | ²²⁸ Ra | | 11 ± 1.9 | 11 ± 5.1 | 11 ± 6.9 | | |
| | Gross Alpha | October | 65 ± 15 | 55 ± 42 | 47 ± 42 | | |
| | Gross Beta | | 75 ± 18 | 81 ± 15 | 76 ± 33 | | |
| | ⁶⁰ Co | | 0.4 ± 1 | (d) | 3 ± 21 | | |
| | ⁸⁹ Sr | | -1 ± 2 | (d) | 13 ± 60 | | |
| | ⁹⁰ Sr | | 16 ± 2.7 | 17 ± 4.5 | 16 ± 6.3 | | |
| | ¹³⁴ Cs | | 1 ± 3 | 2 ± 15 | 6 ± 33 | | |
| | ¹³⁷ Cs | | 21 ± 3 | 20 ± 15 | 20 ± 6 | | |
| | ²²⁶ Ra | | 10 ± 5.1 | 13 ± 5.7 | 12 ± 6.3 | | |
| | ²²⁸ Ra | | 15 ± 17 | 3.6 ± 1.5 | 5.7 ± 7.8 | | |
| | U (total) | | 15 ± 3 | 16 ± 18 | 15 ± 9 | | |
| | Gross Alpha | November | 17 ± 3 | 19 ± 15 | 17 ± 12 | | |
| | Gross Beta | | 18 ± 9 | 24 ± 15 | 24 ± 9 | | |
| | ⁵¹ Cr | | 48 ± 10 | 51 ± 15 | 51 ± 45 | | |
| | ⁶⁰ Co | | 19 ± 2 | 20 ± 15 | 20 ± 9 | | |
| | ⁶⁵ Zn | | 25 ± 1 | 24 ± 15 | 24 ± 12 | | |
| | ¹⁰⁶ Ru | | 27 ± 2 | 30 ± 15 | 31 ± 24 | | |
| | ¹³⁴ Cs | | 15 ± 1 | 19 ± 15 | 18 ± 9 | | |
| | ¹³⁷ Cs | | 19 ± 2 | 20 ± 15 | 21 ± 9 | | |
| | ³ H | December | 1940 ± 264 | 1990 ± 1035 | 2009 ± 699 | | |
| | ²²⁶ Ra | | 7.6 ± 0.3 | 11 ± 5.1 | 11 ± 4.5 | | |
| | ²²⁸ Ra | | 2.5 ± 2.1 | (d) | 3 ± 9 | | |
| | Milk | ⁸⁹ Sr | April | 24 ± 4 | 25 ± 15 | 22 ± 15 | |
| | | ⁹⁰ Sr | | 11 ± 2 | 16 ± 4 | 14 ± 12 | |
| | | ⁶⁰ Co | | 32 ± 2 | 30 ± 15 | 31 ± 12 | |
| | | ¹³⁷ Cs | | 30 ± 2 | 28 ± 15 | 30 ± 12 | |
| | | ¹⁴⁰ Ba | | 0 ± 29 | (d) | 5 ± 21 | |
| | | ¹³¹ I | July | 3.3 ± 3.2 | 5.4 ± 2.4 | 5.7 ± 4.5 | |
| | | ⁸⁹ Sr | October | -5.8 ± 12 | (d) | 3 ± 9 | |
| | | ⁹⁰ Sr | | 22 ± 9.8 | 18 ± 4.5 | 16 ± 9.3 | |
| | | ¹³¹ I | | 43 ± 16 | 42 ± 18 | 40 ± 21 | |
| | | ¹³⁷ Cs | | 37 ± 9 | 34 ± 15 | 35 ± 9 | |
| | | ¹⁴⁰ Ba | | 11 ± 46 | (d) | 2 ± 15 | |
| | | Food | ⁸⁹ Sr | July | 30 ± 10 | 26 ± 9 | 29 ± 21 |
| | | | ⁹⁰ Sr | | 18 ± 5 | 20 ± 3 | 23 ± 6 |
| | | | ⁶⁰ Co | | 107 ± 24 | 94 ± 16 | 100 ± 27 |
| | ¹³⁷ Cs | | | 28 ± 12 | 20 ± 9 | 26 ± 12 | |
| | ¹⁴⁰ Ba | | | -3.8 ± 20 | (d) | (d) | |
| | ⁸⁹ Sr | | November | -3.6 ± 1 | (d) | 7 ± 39 | |
| ⁹⁰ Sr | 27 ± 11 | | | 28 ± 4 | 26 ± 21 | | |
| ¹³¹ I | | | 26 ± 15 | 25 ± 18 | 25 ± 15 | | |
| ¹³⁷ Cs | | | 24 ± 7 | 27 ± 15 | 29 ± 12 | | |
| ¹⁴⁰ Ba | | | 3 ± 15 | (d) | (d) | | |

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

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

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

(d) Sample did not contain the radionuclide.

TABLE D.2. Evaluation of Duplicate Air Samples—Gross Beta Analyses. (Expressed as results of duplicate sample minus result of record sample.)

| Location(a) | Average Bias, pCi/m ³ | Average Bias, % | Range of Individual Biases, % |
|-------------|----------------------------------|-----------------|-------------------------------|
| A (23) | .001 | 2.0 | -32 to 24 |
| B (24) | .001 | 6.2 | -18 to 92 |
| C (22) | .004 | 19. | -11 to 65 |
| D (24) | -.004 | -6.2 | -77 to 11 |

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

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

| Location(a) | Average Bias, pCi/m ³ | Average Bias, % | Range of Individual Biases, % |
|-------------|----------------------------------|-----------------|-------------------------------|
| A (23) | -.0009 | -3.2 | -80 to 67 |
| B (22) | -.0001 | 8.0 | -70 to 150 |
| C (24) | .0002 | 20. | -44 to 220 |

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

TABLE D.4. Duplicate Air Sample Results for Compositing Samples

| Constituent | Date | Record | Duplicate | Bias, pCi/m ³ |
|-----------------------|-------|-------------------|--------------------|--------------------------|
| ¹³⁷ Cs | 1-18 | *.0007 ± .001 | *.0004 ± .0009 | — |
| | 2-16 | .002 ± .001 | .001 ± .001 | -.001 |
| | 3-15 | *.0002 ± .002 | *.001 ± .002 | — |
| | 4-12 | .003 ± .001 | .010 ± .002 | .007 |
| | 5-10 | .003 ± .002 | *.003 ± .0008 | -.003 |
| | 6-7 | .0004 ± .0003 | .005 ± .002 | .0046 |
| | 7-6 | *.0009 ± .002 | *-.0007 ± .002 | — |
| | 8-30 | .002 ± .0007 | .001 ± .0005 | -.001 |
| | 9-27 | .001 ± .0005 | *.0002 ± .0003 | -.001 |
| | 10-25 | *-.0007 ± .0007 | *-.002 ± .002 | — |
| | 11-22 | .0005 ± .0003 | .0023 ± .0015 | .0018 |
| | 12-22 | .0008 ± .0007 | .001 ± .0009 | .0002 |
| ⁹⁰ Sr | 3-15 | .0002 ± .0001 | *.00005 ± .0001 | -.0002 |
| | 6-7 | .0002 ± .0001 | .0003 ± .0001 | .0001 |
| | 8-30 | .0002 ± .0001 | .0002 ± .0001 | 0 |
| | 11-22 | .0003 ± .0001 | .0002 ± .0001 | -.0001 |
| ^{239/240} Pu | 3-15 | .000020 ± .00001 | .000004 ± .000009 | -.000016 |
| | 6-7 | *.000008 ± .00001 | *.000004 ± .000001 | — |
| | 8-30 | *.000009 ± .00001 | .00002 ± .00001 | .00002 |
| | 11-22 | .000012 ± .000011 | *.000002 ± .000009 | -.000012 |

*2 sigma counting error exceeds value.

TABLE D.5 Individual and Average Percent Bias for the Analysis of Duplicate TLDs

| Month | Individual Bias, %(a) | | | Average Bias, % |
|----------|-----------------------|------|------|-----------------|
| January | -6.7 | -3.6 | -6.1 | -5.5 |
| February | 0.0 | 0.2 | 0.3 | 0.3 |
| March | 3.6 | 3.2 | 4.7 | 3.8 |
| April | 2.2 | 1.3 | -1.8 | 0.6 |
| May | 0.9 | -1.3 | -2.0 | 0.8 |
| June | 0.5 | 2.1 | 2.0 | 1.5 |
| July | 6.3 | 7.2 | 4.5 | 6.0 |
| August | 1.3 | -4.8 | -2.6 | -2.0 |
| October | -2.9 | -4.5 | -1.8 | -3.1 |
| November | 0.4 | 2.8 | 1.2 | 1.5 |
| December | 0.0 | -2.7 | -1.4 | -1.4 |

(a) Each pair of TLDs was exposed at one of three different levels between 10 and 23 mR.

exposed at one of three levels of radiation representing environmental levels. These results also show an acceptable degree of bias.

DOSE CALCULATIONS QUALITY ASSURANCE

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

APPENDIX E
DOSE CALCULATIONS

APPENDIX E

DOSE CALCULATIONS

The impact on the public from operations involving radioactive materials at Hanford 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. That portion of the cumulative dose committed to the individual or population during the year of release only is termed the "dose commitment."

Dose commitments calculated using 1982 radionuclide releases from Hanford (Table 22) are provided in Tables E.1 and E.2 for the maximum individual and the population, respectively. The difference in value between the "cumulative dose" and the "dose commitment" is that dose calculated to be the result of any uptake or exposure to 1982 Site effluents beyond 1982.

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 reconcentration 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

TABLE E.1. Maximum Individual Dose Commitment from 1982 Hanford Operations

| Pathway | 50-Year Dose Commitment, mrem | | | | | |
|---------------------|-------------------------------|-------|------|------|---------|--------|
| | Whole Body | GI(a) | Bone | Lung | Thyroid | |
| | | | | | Adult | Infant |
| Direct Airborne(b) | <.01 | <.01 | .01 | .01 | <.01 | <.01 |
| Foodstuffs(c) | .06 | <.01 | .2 | <.01 | .1 | .4 |
| Drinking Water | <.01 | <.01 | .01 | <.01 | .02 | .06 |
| River Recreation(d) | .04 | <.01 | .1 | <.01 | .02 | — |
| Total | .1 | .02 | .4 | .02 | .2 | .5 |

(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.

TABLE E.2. Population Dose Commitment from 1982 Hanford Operations

| Pathway | 50-Year Dose Commitment, man-rem | | | | |
|---------------------|----------------------------------|-------|------|------|---------|
| | Whole Body | GI(a) | Bone | Lung | Thyroid |
| Direct Airborne(b) | 3 | 3 | 4 | 4 | 3 |
| Foodstuffs(c) | <1 | * | <1 | * | 3 |
| Drinking Water | <1 | * | <1 | * | <1 |
| River Recreation(d) | * | * | * | * | * |
| Total | 3 | 3 | 4 | 4 | 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) Includes consumption of fish taken from the Columbia River.

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 be 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:

- inhalation of radioactive airborne effluents
- submersion in radioactive airborne effluents
- ingestion of foodstuffs contaminated by effluents deposited on the ground by air-

borne deposition and by irrigation with contaminated Columbia River water

- drinking sanitary water obtained from the Columbia River
 - exposure to ground contaminated by airborne deposition and by irrigation with Columbia River water
 - ingestion of fish taken from the Columbia River
 - recreation along the Columbia River—boating, swimming and shoreline activities.
3. **80-km Population Doses.** While there are no regulatory limits for collective population doses, such an evaluation provides an indication of the overall impact of Hanford opera-

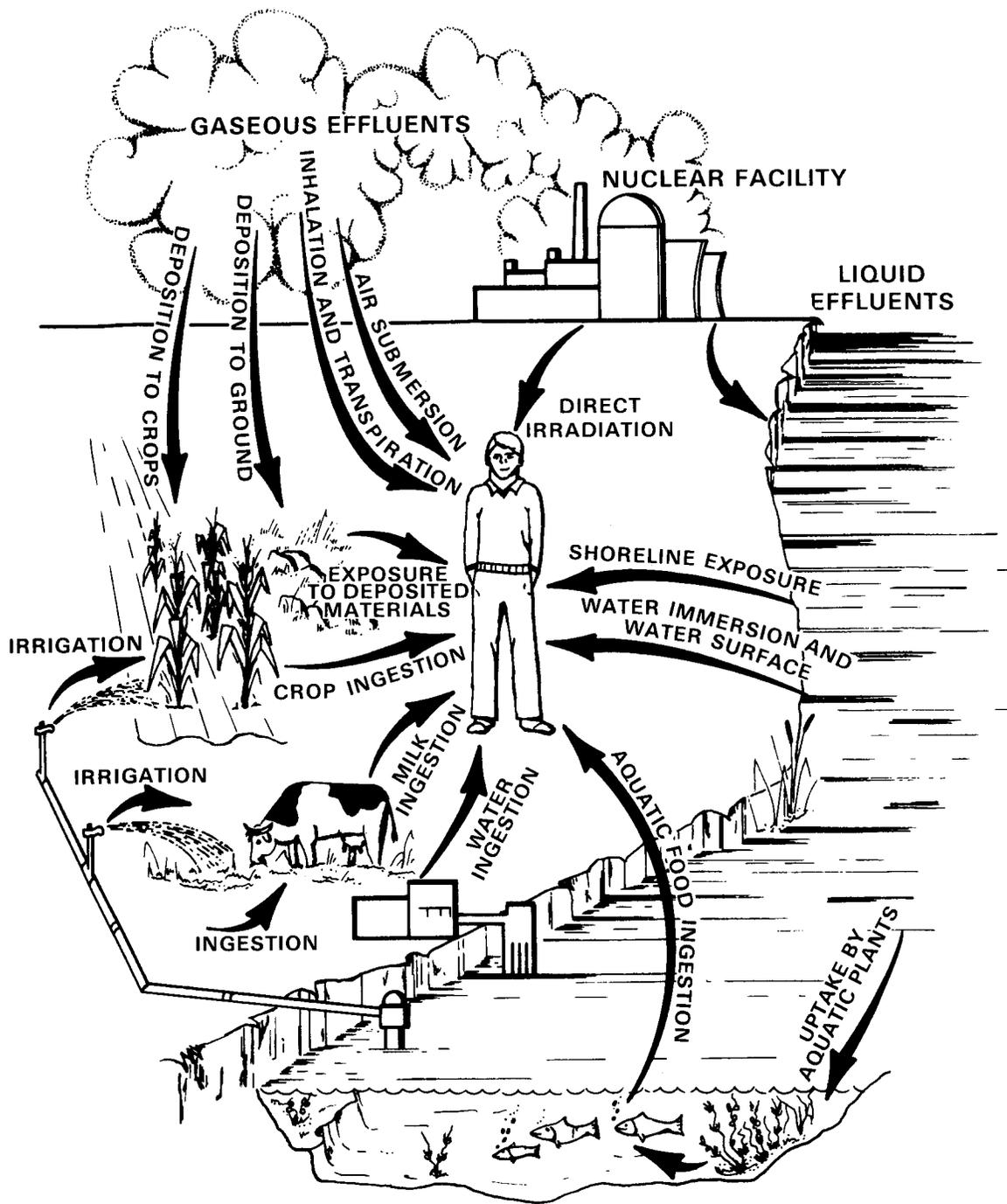


FIGURE E.1. Potential Environmental Dose Pathways

tions. 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 1982, 40% of Kennewick drinking water was drawn from the Columbia River. The total affected population was approximately 70,000 during 1982.
 - **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.
4. **Maximum Hypothetical Dose.** This is an evaluation of the maximum dose that could possibly be received by a member of the public regardless of the actual probability of the dose ever being incurred. Maximum hypothetical doses are calculated based on **observed maximum radionuclide concentrations** in onsite wildlife that could potentially

move offsite and be hunted. Doses reported are based on the assumption that a single individual consumes the entire edible portion of a single animal with the stated radionuclide concentrations. The calculation of the dose enables comparison of such hypothetical scenarios with DOE dose standards. However, these scenarios are not considered to be credible and are thus not included in the overall assessment of “realistic” dose impacts discussed in the “Radiological Impact of Hanford Operations” section.

DATA

Input data necessary to perform dose calculations 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.3 through E.6. 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/Q_s 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 concentrations for the year. Annual average disper-

TABLE E.3. Distribution of Population in 80-km Radius of the 100-N Reactor by Population Grid Sector for 1980

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

TABLE E.4. Distribution of Population in 80-km Radius of 200 Area Hanford Meteorological Tower by Population Grid Sector for the Year 1980

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

TABLE E.5. Distribution of Population in 80-km Radius of the FFTF by Population Grid Sector for the Year 1980

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

TABLE E.6. Distribution of Population in 80-km Radius of 300 Area by Population Grid Sector for the Year 1980

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

sion factors for the 100, 200, and 300/400 Areas during 1982 are listed in Tables E.7 through E.10.

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 pathways include irrigation rates, growing period,

hold up, etc. These parameters are listed in Table E.11. 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.12 through E.14, 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.15 through E.19.

TABLE E.7. Annual Average Atmospheric Dispersion Around The 100-N Area During 1982 for an 89-m Release Height (units are sec/m³)(a)

| Direction | Range in Miles, km | | | | | | | | | |
|-----------|--------------------|-----------|-----------|-----------|-----------|----------|----------|----------|----------|----------|
| | 0.5 (0.8) | 1.5 (2.4) | 2.5 (4.0) | 3.5 (5.6) | 4.5 (7.2) | 7.5 (12) | 15 (24) | 25 (40) | 35 (56) | 45 (72) |
| N | 7.81E-08 | 1.11E-07 | 8.56E-08 | 6.50E-08 | 5.08E-08 | 3.02E-08 | 1.42E-08 | 8.04E-09 | 5.55E-09 | 4.23E-09 |
| NNE | 6.14E-08 | 8.80E-08 | 6.95E-08 | 5.34E-08 | 4.21E-08 | 2.54E-08 | 1.21E-08 | 6.94E-09 | 4.82E-09 | 3.68E-09 |
| NE | 1.12E-07 | 1.23E-07 | 9.79E-08 | 7.63E-08 | 6.06E-08 | 3.76E-08 | 1.84E-08 | 1.07E-08 | 7.49E-09 | 5.76E-09 |
| ENE | 1.81E-07 | 1.70E-07 | 1.32E-07 | 1.02E-07 | 8.09E-08 | 5.04E-08 | 2.49E-08 | 1.45E-08 | 1.02E-08 | 7.83E-09 |
| E | 3.20E-07 | 2.50E-07 | 1.84E-07 | 1.38E-07 | 1.08E-07 | 6.44E-08 | 3.05E-08 | 1.74E-08 | 1.21E-08 | 9.22E-09 |
| ESE | 2.24E-07 | 1.33E-07 | 9.22E-08 | 6.79E-08 | 5.25E-08 | 3.10E-08 | 1.45E-08 | 8.24E-09 | 5.71E-09 | 4.36E-09 |
| SE | 2.01E-07 | 1.19E-07 | 8.05E-08 | 5.85E-08 | 4.50E-08 | 2.62E-08 | 1.21E-08 | 6.82E-09 | 4.69E-09 | 3.56E-09 |
| SSE | 1.26E-07 | 8.94E-08 | 6.39E-08 | 4.72E-08 | 3.65E-08 | 2.13E-08 | 9.87E-09 | 5.55E-09 | 3.83E-09 | 2.90E-09 |
| S | 1.44E-07 | 9.23E-08 | 6.35E-08 | 4.62E-08 | 3.55E-08 | 2.04E-08 | 9.30E-09 | 5.19E-09 | 3.56E-09 | 2.70E-09 |
| SSW | 7.23E-08 | 4.11E-08 | 2.83E-08 | 2.07E-08 | 1.60E-08 | 9.37E-09 | 4.37E-09 | 2.48E-09 | 1.72E-09 | 1.31E-09 |
| SW | 6.48E-08 | 5.17E-08 | 3.83E-08 | 2.88E-08 | 2.25E-08 | 1.34E-08 | 6.31E-09 | 3.60E-09 | 2.50E-09 | 1.91E-09 |
| WSW | 4.84E-08 | 5.40E-08 | 4.13E-08 | 3.15E-08 | 2.47E-08 | 1.49E-08 | 7.10E-09 | 4.06E-09 | 2.82E-09 | 2.15E-09 |
| W | 1.17E-07 | 1.36E-07 | 1.06E-07 | 8.18E-08 | 6.46E-08 | 3.95E-08 | 1.91E-08 | 1.10E-08 | 7.67E-09 | 5.89E-09 |
| WNW | 9.90E-08 | 1.35E-07 | 9.87E-08 | 7.27E-08 | 5.59E-08 | 3.18E-08 | 1.42E-08 | 7.83E-09 | 5.32E-09 | 3.99E-09 |
| NW | 8.47E-08 | 1.22E-07 | 9.21E-08 | 6.89E-08 | 5.35E-08 | 3.10E-08 | 1.42E-08 | 7.91E-09 | 5.41E-09 | 4.09E-09 |
| NNW | 8.26E-08 | 9.26E-08 | 6.77E-08 | 5.02E-08 | 3.88E-08 | 2.24E-08 | 1.02E-08 | 5.71E-09 | 3.91E-09 | 2.95E-09 |

(a) Calculated from meteorological data collected at 100-N Area and the Hanford Meteorological Station from 1-82 through 12-82.

TABLE E.8. Annual Average Dispersion Around The 200 Areas During 1982 for an 89-m Release Height
(units are sec/m³)(a)

| Direction | Range in Miles, km | | | | | | | | | |
|-----------|--------------------|-----------|-----------|-----------|-----------|----------|----------|----------|----------|----------|
| | 0.5 (0.8) | 1.5 (2.4) | 2.5 (4.0) | 3.5 (5.6) | 4.5 (7.2) | 7.5 (12) | 15 (24) | 25 (40) | 35 (56) | 45 (72) |
| N | 5.64E-08 | 6.84E-08 | 5.09E-08 | 3.79E-08 | 2.94E-08 | 1.71E-08 | 7.88E-09 | 4.42E-09 | 3.03E-09 | 2.30E-09 |
| NNE | 3.76E-08 | 4.56E-08 | 3.24E-08 | 2.36E-08 | 1.81E-08 | 1.02E-08 | 4.57E-09 | 2.51E-09 | 1.69E-09 | 1.27E-09 |
| NE | 5.48E-08 | 5.57E-08 | 3.90E-08 | 2.83E-08 | 2.16E-08 | 1.23E-08 | 5.46E-09 | 2.99E-09 | 2.02E-09 | 1.52E-09 |
| ENE | 5.26E-08 | 5.72E-08 | 4.23E-08 | 3.14E-08 | 2.43E-08 | 1.41E-08 | 6.48E-09 | 3.62E-09 | 2.48E-09 | 1.88E-09 |
| E | 6.15E-08 | 5.20E-08 | 6.60E-08 | 5.12E-08 | 4.06E-08 | 2.48E-08 | 1.20E-08 | 6.91E-09 | 4.82E-09 | 3.70E-09 |
| ESE | 5.59E-08 | 9.74E-08 | 8.10E-08 | 6.33E-08 | 5.04E-08 | 3.08E-08 | 1.49E-08 | 8.61E-09 | 6.01E-09 | 4.61E-09 |
| SE | 1.12E-07 | 1.36E-07 | 1.08E-07 | 8.38E-08 | 6.63E-08 | 4.04E-08 | 1.95E-08 | 1.12E-08 | 7.83E-09 | 6.00E-09 |
| SSE | 1.06E-07 | 1.03E-07 | 7.81E-08 | 5.91E-08 | 4.62E-08 | 2.76E-08 | 1.30E-08 | 7.40E-09 | 5.12E-09 | 3.90E-09 |
| S | 1.62E-07 | 1.19E-07 | 8.30E-08 | 6.05E-08 | 4.64E-08 | 2.67E-08 | 1.22E-08 | 6.77E-09 | 4.63E-09 | 3.50E-09 |
| SSW | 1.26E-07 | 9.31E-08 | 6.17E-08 | 4.39E-08 | 3.32E-08 | 1.85E-08 | 8.10E-09 | 4.38E-09 | 2.95E-09 | 2.20E-09 |
| SW | 7.73E-08 | 8.17E-08 | 5.61E-08 | 4.02E-08 | 3.05E-08 | 1.69E-08 | 7.30E-09 | 3.92E-09 | 2.62E-09 | 1.94E-09 |
| WSW | 5.40E-08 | 5.66E-08 | 3.85E-08 | 2.73E-08 | 2.06E-08 | 1.13E-08 | 4.81E-09 | 2.56E-09 | 1.70E-09 | 1.26E-09 |
| W | 7.63E-08 | 6.68E-08 | 4.62E-08 | 3.35E-08 | 2.55E-08 | 1.45E-08 | 6.49E-09 | 3.58E-09 | 2.44E-09 | 1.84E-09 |
| WNW | 5.43E-08 | 6.69E-08 | 4.79E-08 | 3.49E-08 | 2.67E-08 | 1.51E-08 | 6.69E-09 | 3.65E-09 | 2.47E-09 | 1.85E-09 |
| NW | 5.46E-08 | 7.74E-08 | 5.79E-08 | 4.31E-08 | 3.33E-08 | 1.92E-08 | 8.71E-09 | 4.84E-09 | 3.31E-09 | 2.49E-09 |
| NNW | 4.80E-08 | 5.18E-08 | 3.86E-08 | 2.89E-08 | 2.25E-08 | 1.33E-08 | 6.19E-09 | 3.50E-09 | 2.41E-09 | 1.83E-09 |

(a) Calculated from meteorological data collected at the Hanford Meteorological Station from 1-82 through 12-82.

TABLE E.9. Annual Average Atmospheric Dispersion Around The 300 Area During 1982 for a Ground-Level Release Height
(units are sec/m³)(a)

| Direction | Range in Miles, km | | | | | | | | | |
|-----------|--------------------|-----------|-----------|-----------|-----------|----------|----------|----------|----------|----------|
| | 0.5 (0.8) | 1.5 (2.4) | 2.5 (4.0) | 3.5 (5.6) | 4.5 (7.2) | 7.5 (12) | 15 (24) | 25 (40) | 35 (56) | 45 (72) |
| N | 5.93E-06 | 9.05E-07 | 4.11E-07 | 2.51E-07 | 1.81E-07 | 9.19E-08 | 3.97E-08 | 2.23E-08 | 1.54E-08 | 1.16E-08 |
| NNE | 4.18E-06 | 6.42E-07 | 2.90E-07 | 1.76E-07 | 1.26E-07 | 6.30E-08 | 2.66E-08 | 1.46E-08 | 1.00E-08 | 7.52E-09 |
| NE | 4.47E-06 | 6.85E-07 | 3.10E-07 | 1.89E-07 | 1.35E-07 | 6.84E-08 | 2.92E-08 | 1.63E-08 | 1.12E-08 | 8.44E-09 |
| ENE | 3.24E-06 | 4.97E-07 | 2.25E-07 | 1.37E-07 | 9.81E-08 | 4.96E-08 | 2.12E-08 | 1.18E-08 | 8.10E-09 | 6.10E-09 |
| E | 4.58E-06 | 6.98E-07 | 3.17E-07 | 1.94E-07 | 1.40E-07 | 7.17E-08 | 3.12E-08 | 1.76E-08 | 1.22E-08 | 9.26E-09 |
| ESE | 3.34E-06 | 5.10E-07 | 2.32E-07 | 1.42E-07 | 1.03E-07 | 5.25E-08 | 2.30E-08 | 1.30E-08 | 9.04E-09 | 6.86E-09 |
| SE | 5.21E-06 | 7.97E-07 | 3.63E-07 | 2.22E-07 | 1.60E-07 | 8.14E-08 | 3.53E-08 | 1.99E-08 | 1.38E-08 | 1.04E-08 |
| SSE | 5.53E-06 | 8.51E-07 | 3.86E-07 | 2.36E-07 | 1.69E-07 | 8.53E-08 | 3.64E-08 | 2.03E-08 | 1.39E-08 | 1.05E-08 |
| S | 4.99E-06 | 7.65E-07 | 3.45E-07 | 2.10E-07 | 1.50E-07 | 7.55E-08 | 3.21E-08 | 1.78E-08 | 1.22E-08 | 9.18E-09 |
| SSW | 8.49E-07 | 1.29E-07 | 5.62E-08 | 3.34E-08 | 2.32E-08 | 1.12E-08 | 4.42E-09 | 2.31E-09 | 1.53E-09 | 1.13E-09 |
| SW | 7.51E-07 | 1.12E-07 | 4.98E-08 | 3.01E-08 | 2.13E-08 | 1.07E-08 | 4.50E-09 | 2.49E-09 | 1.71E-09 | 1.28E-09 |
| WSW | 6.52E-07 | 9.83E-08 | 4.30E-08 | 2.56E-08 | 1.77E-08 | 8.51E-09 | 3.34E-09 | 1.74E-09 | 1.16E-09 | 8.56E-10 |
| W | 1.82E-06 | 2.77E-07 | 1.23E-07 | 7.34E-08 | 5.13E-08 | 2.50E-08 | 1.01E-08 | 5.34E-09 | 3.57E-09 | 2.64E-09 |
| WNW | 3.48E-06 | 5.29E-07 | 2.37E-07 | 1.44E-07 | 1.02E-07 | 5.14E-08 | 2.18E-08 | 1.21E-08 | 8.28E-09 | 6.24E-09 |
| NW | 5.60E-06 | 8.57E-07 | 3.88E-07 | 2.37E-07 | 1.70E-07 | 8.63E-08 | 3.71E-08 | 2.07E-08 | 1.43E-08 | 1.08E-08 |
| NNW | 4.20E-06 | 6.39E-07 | 2.89E-07 | 1.77E-07 | 1.27E-07 | 6.45E-08 | 2.78E-08 | 1.56E-08 | 1.08E-08 | 8.17E-09 |

(a) Calculated from meteorological data collected at 300 Area and the Hanford Meteorological Station from 1-82 through 12-82.

TABLE E.10. Annual Average Dispersion Around The 400 Area During 1982 for a Ground-Level Release Height (units are sec/m³)(a)

| Direction | Range in Miles, km | | | | | | | | | |
|-----------|--------------------|-----------|-----------|-----------|-----------|----------|----------|----------|----------|----------|
| | 0.5 (0.8) | 1.5 (2.4) | 2.5 (4.0) | 3.5 (5.6) | 4.5 (7.2) | 7.5 (12) | 15 (24) | 25 (40) | 35 (56) | 45 (72) |
| N | 6.54E-06 | 9.99E-07 | 4.52E-07 | 2.76E-07 | 1.98E-07 | 1.00E-07 | 4.30E-08 | 2.40E-08 | 1.66E-08 | 1.25E-08 |
| NNE | 5.28E-06 | 8.12E-07 | 3.66E-07 | 2.22E-07 | 1.58E-07 | 7.90E-08 | 3.31E-08 | 1.82E-08 | 1.24E-08 | 9.31E-09 |
| NE | 3.90E-06 | 6.02E-07 | 2.72E-07 | 1.65E-07 | 1.17E-07 | 5.87E-08 | 2.46E-08 | 1.35E-08 | 9.22E-09 | 6.90E-09 |
| ENE | 2.50E-06 | 3.83E-07 | 1.74E-07 | 1.06E-07 | 7.59E-08 | 3.84E-08 | 1.64E-08 | 9.16E-09 | 6.31E-09 | 4.76E-09 |
| E | 4.23E-06 | 6.46E-07 | 2.92E-07 | 1.79E-07 | 1.28E-07 | 6.49E-08 | 2.78E-08 | 1.55E-08 | 1.07E-08 | 8.07E-09 |
| ESE | 5.00E-06 | 7.65E-07 | 3.47E-07 | 2.12E-07 | 1.52E-07 | 7.73E-08 | 3.32E-08 | 1.86E-08 | 1.28E-08 | 9.69E-09 |
| SE | 3.88E-06 | 5.96E-07 | 2.70E-07 | 1.65E-07 | 1.18E-07 | 5.99E-08 | 2.57E-08 | 1.43E-08 | 9.87E-09 | 7.44E-09 |
| SSE | 3.39E-06 | 5.19E-07 | 2.34E-07 | 1.42E-07 | 1.02E-07 | 5.14E-08 | 2.19E-08 | 1.22E-08 | 8.41E-09 | 6.33E-09 |
| S | 5.03E-06 | 7.65E-07 | 3.46E-07 | 2.10E-07 | 1.51E-07 | 7.65E-08 | 3.29E-08 | 1.84E-08 | 1.27E-08 | 9.61E-09 |
| SSW | 3.14E-06 | 4.79E-07 | 2.17E-07 | 1.32E-07 | 9.46E-08 | 4.80E-08 | 2.07E-08 | 1.16E-08 | 8.01E-09 | 6.05E-09 |
| SW | 1.64E-06 | 2.51E-07 | 1.12E-07 | 6.79E-08 | 4.84E-08 | 2.42E-08 | 1.02E-08 | 5.61E-09 | 3.84E-09 | 2.88E-09 |
| WSW | 1.23E-06 | 1.87E-07 | 8.36E-08 | 5.07E-08 | 3.62E-08 | 1.82E-08 | 7.74E-09 | 4.29E-09 | 2.95E-09 | 2.22E-09 |
| W | 1.41E-06 | 2.17E-07 | 9.71E-08 | 5.86E-08 | 4.16E-08 | 2.07E-08 | 8.65E-09 | 4.73E-09 | 3.22E-09 | 2.41E-09 |
| WNW | 1.08E-06 | 1.65E-07 | 7.39E-08 | 4.47E-08 | 3.17E-08 | 1.57E-08 | 6.54E-09 | 3.57E-09 | 2.43E-09 | 1.81E-09 |
| NW | 2.00E-06 | 3.06E-07 | 1.38E-07 | 8.32E-08 | 5.95E-08 | 2.98E-08 | 1.26E-08 | 6.98E-09 | 4.79E-09 | 3.60E-09 |
| NNW | 3.04E-06 | 4.65E-07 | 2.10E-07 | 1.27E-07 | 9.05E-08 | 4.54E-08 | 1.92E-08 | 1.06E-08 | 7.25E-09 | 5.44E-09 |

(a) Calculated from meteorological data collected at 400 Area and the Hanford Meteorological Station from 1-82 through 12-82.

TABLE E.11. 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 hours | 24 | — | — | — |
| Drinking water | 24 | 24 | — | — | — |

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

TABLE E.12. Dietary Parameters

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

(a) Units l/yr.

(b) 330 l/yr for infant.

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

TABLE E.13. Residency Parameters

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

(a) Inhalation Rates:

Adult - 250 cm³/sec routineInfant - 44 cm³/sec**TABLE E.14. Recreational Activities**

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

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

TABLE E.15. Documentation of 100 Area Airborne Release Dose Calculation

| | |
|----------------------------|--|
| Facility name: | 100 Area |
| Releases: | See Table 19 |
| Meteorological conditions: | 1982 annual average, calculated from data collected at 100 N Area and the Hanford Meteorological Station from 1-82 through 12-82. See Table E.7 |
| Dispersion model: | Gaussian, Hanford parameters (ERDA 1975) |
| X/Q: | Maximum individual 4.2 x 10 ⁻⁹ sec/m ³ at 53 km SSE for direct airborne pathways and 5.4 x 10 ⁻⁹ sec/m ³ at 41 km SSE for food pathways, 80-km population 1.7 x 10 ⁻³ person-sec/m ³ |
| Release height: | 82.3 meters effective (60.96 meters actual stack height) |
| Population distribution: | 340,000, 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 |
| 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 100 Area Liquid Release Dose Calculation

| | |
|--------------------------|---|
| Facility name: | 100 Area |
| Releases: | See Table 22 |
| River flow: | 140,000 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.17. Documentation of 200 Areas Airborne Release Dose Calculation

| | |
|----------------------------|--|
| Facility name: | 200 Area |
| Releases: | See Table 22 |
| Meteorological conditions: | 1982 annual average, calculated from data collected at the Hanford Meteorological Station from 1-82 through 12-82. See Table E.8 |
| Dispersion model: | Gaussian, Hanford parameters (ERDA 1975) |
| X/Q: | Maximum individual 1.1×10^{-8} sec/m ³ at 43 km SE for direct airborne pathways and 1.5×10^{-8} sec/m ³ at 32 km SE for food pathways, 80-km population 1.8×10^{-3} person-sec/m ³ |
| Release height: | 89.2 meters effective (60.96 meters actual stack height) |
| Population distribution: | 341,000, see Table E.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.18. Documentation of 300 Area Airborne Release Dose Calculation

| | |
|----------------------------|--|
| Facility name: | 300 Area |
| Releases: | See Table 22 |
| Meteorological conditions: | 1982 annual average, calculated from data collected at 300 Area and the Hanford Meteorological Station from 1-82 through 12-82. See Table E.9 |
| Dispersion model: | Gaussian, Pasquill parameters |
| X/Q: | Maximum individual 8.1×10^{-8} sec/m ³ at 1.3 km SSE for direct airborne pathways and 2.6×10^{-6} sec/m ³ at 1.6 km E for food pathways, 80-km population 8.1×10^{-3} person-sec/m ³ |
| Release height: | Ground level |
| Population distribution: | 265,000, see Table E.6 |
| 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.19. Documentation of 400 Area Airborne Release Dose Calculation

| | |
|----------------------------|---|
| Facility name: | 400 Area |
| Releases: | See Table 22 |
| Meteorological conditions: | 1982 annual average, calculated from data collected at 400 Area and the Hanford Meteorological Station from 1-82 through 12-82. See Table E.10 |
| Dispersion model: | Gaussian, Pasquill parameters |
| X/Q: | Maximum individual 1.9×10^{-8} sec/m ³ at 29 km SSE for direct airborne pathways and 7.2×10^{-8} sec/m ³ at 11 km SE for food pathways, 80-km population 6.3×10^{-3} person-sec/m ³ |
| Release height: | Ground level |
| Population distribution: | 264,000, see Table E.5 |
| 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 |

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