B. M. Gillespie

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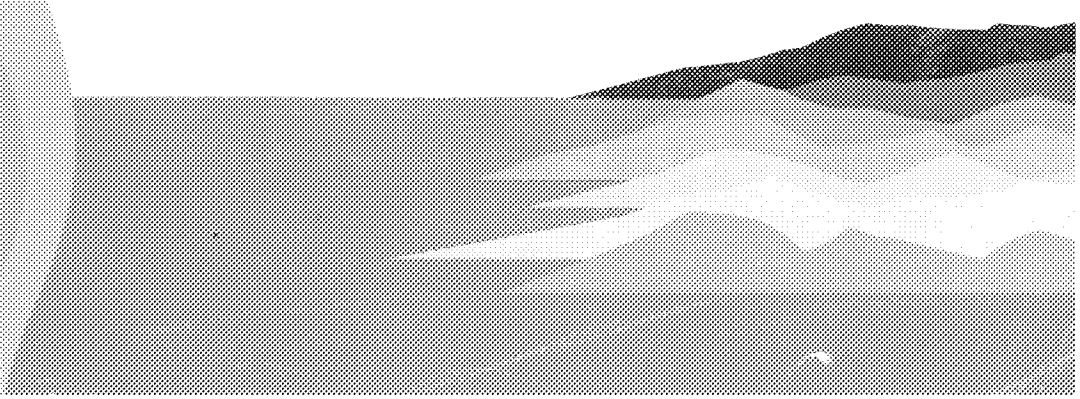
Hanford Site

Environmental Report 1992



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Task Leaders
Distribution

Bill Hanf
Ted Poston
Lynn Bisping
Roger Dirkes
Bill Lusty
Greg Patton
Ernst Antonio
Barbara Gillespie
File/LB

Department of Energy
Richland Field Office
P.O. Box 550
Richland, Washington 99352

DISTRIBUTION: RECIPIENTS OF PNL-8682

HANFORD SITE ENVIRONMENTAL REPORT FOR CALENDAR YEAR 1992 (PNL-8682), PACIFIC NORTHWEST LABORATORY (PNL), RICHLAND, WASHINGTON JUNE 1993

Enclosed is a copy of the 1992 Environmental Report for the U.S. Department of Energy (DOE), Richland Operations Office, Hanford Site. This report is prepared and published annually for distribution to local, State, and Federal government agencies; Congress; the public; and the news media. The purpose of the report is to present a summary of the environmental status of the site. It describes environmental management activities and the continuing programs to achieve compliance with environmental standards and requirements.

In addition, the report contains an addendum summarizing compliance status, current issues and actions, and conformance to environmental permits for the period January 1 through April 1, 1993. The purpose of this addendum is to provide the reader with the most recent information available and thus upgrade the quality and usefulness of the report.

The report was prepared for RL by the Pacific Northwest Laboratory (PNL) and describes programs conducted by PNL and Westinghouse Hanford Company, the operations and engineering contractor for the Hanford Site.

If you have any questions or desire additional information, please contact M. W. Tiernan of the RL Quality, Safety, and Health Programs Division at (509) 376-2044.

Sincerely

for John D. Wagoner
Manager

Enclosure:
Hanford Site Environmental
Report for 1992

Roger — Congratulations to you & your team for an excellent piece of work! Patrin

ENV. SCIENCES DEPT
OCT 29 1993
P.M. IRVING

Battelle
Pacific Northwest Laboratories
Battelle Boulevard
P.O. Box 999
Richland, Washington 99352
Telephone (509) 375-2249

December 30, 1993

TO: Recipients of PNL-8148

CHANGES IN THE *HANFORD SITE ENVIRONMENTAL REPORT FOR CALENDAR YEAR 1992*

Enclosed are a number of corrections to the *Hanford Site Environmental Report for Calendar Year 1992* (PNL-8148). Some of the corrections are being provided to you on self-adhesive paper so that the new information can be cut out and pasted in the report at the appropriate locations. The corrections that are not on self-adhesive paper can be written in the report with a pen or pencil. A copy of these corrections will be printed in the appendix of the 1993 Hanford Site Environmental Report.

Please note that all 1992 Hanford calculated doses remain unaffected by these changes.

We apologize for any inconvenience.

Sincerely,

R.E. Jaquish, Manager
Public Safety and Resource Protection Program
OFFICE OF HEALTH AND ENVIRONMENT

REJ:miz

Enclosure

Department of Energy
Richland Field Office
P.O. Box 550
Richland, Washington 99352

DISTRIBUTION: RECIPIENTS OF PNL-8682

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Sincerely

for John D. Wagoner
Manager

Enclosure:
Hanford Site Environmental
Report for 1992

B. M. Gillespie

PNL-8682
UC-602

Hanford Site Environmental Report for Calendar Year 1992

Scientific Editors
R. K. Woodruff
R. W. Hanf

Technical Editor
R. E. Lundgren

June 1993

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

Pacific Northwest Laboratory
Richland, Washington 99352

Preface

U.S. Department of Energy (DOE) Order 5400.1, "General Environmental Protection Program," establishes the requirement for environmental protection programs. These programs ensure that DOE operations comply with applicable federal, state, and local environmental laws and regulations, executive orders, and department policies. The DOE, Richland Operations Office (RL), has established a plan for implementing this order, *United States Department of Energy Richland Field Office Environmental Protection Implementation Plan, November 9, 1992, to November 9, 1993* (DOE 1992g). This plan is updated annually.

The Hanford Site Environmental Report is prepared annually pursuant to DOE Order 5400.1 to summarize environmental data that characterize Hanford Site environmental management performance and demonstrate compliance status. The report also highlights significant environmental programs and efforts. More detailed environmental compliance, monitoring, surveillance, and study reports may be of value; therefore, to the extent practical, these additional reports have been referenced in the text.

Although this report is written to meet DOE reporting requirements and guidelines, it is also intended to be useful to members of the public, public officials, regulators, and Hanford Site contractors.[a] The Summary has been written with a minimum of technical terminology. The Helpful Information section lists acronyms, abbreviations, conversion information, and nomenclature useful for understanding the report.

This report is prepared for the RL Quality, Safety, and Medical Programs Division as an activity of the Public Safety and Resource Protection Program, Pacific Northwest Laboratory, Office of Health and Environment. Pacific Northwest Laboratory is operated for DOE by Battelle Memorial Institute. Battelle Memorial Institute is a not-for-profit independent contract research institute.

Inquiries regarding this report may be directed to the RL Quality, Safety, and Medical Programs Division, P.O. Box 550, Richland, Washington 99352, or to Pacific Northwest Laboratory, Office of Health and Environment, P.O. Box 999, Richland, Washington 99352.

(a) A brief general summary of this report in pamphlet form is also available by contacting the Pacific Northwest Laboratory at the address given above.

Summary

The Hanford Site Environmental Report is prepared annually to summarize environmental data and information, describe environmental management performance, and demonstrate the status of compliance with environmental regulations. The report also highlights major environmental programs and efforts.

The report is written to meet reporting requirements and guidelines of the U.S. Department of Energy (DOE) and to meet the needs of the public. This summary has been written with a minimum of technical terminology.

The following sections:

- describe the Hanford Site and its mission
- summarize the status in 1992 of compliance with environmental regulations
- describe the environmental programs at the Hanford Site
- discuss public dose estimates from 1992 Hanford activities
- present information on effluent monitoring and environmental surveillance, including ground-water protection and monitoring
- discuss activities to ensure quality.

More detailed information can be found in the body of the report, the appendixes, and the cited references.

The Hanford Site and its Mission

The Hanford Site in southcentral Washington State is about 1,450 square kilometers (560 square miles) of semi-arid shrub-steppe located just north of the confluence of the Snake and Yakima rivers with the Columbia River. This land, with restricted public access, provides a buffer for the smaller areas historically used for the production of nuclear materials, waste storage, and waste disposal. About 6% of the land area has been disturbed and is actively used. This 6% is divided into operational areas:

- the 100-B/C, 100-D, 100-F, 100-H, 100-K, and 100-N Areas, which lie along the Columbia River in the northern portion of the Hanford Site
- the 200-East and 200-West Areas, which lie in the center of the Hanford Site near the basalt outcrops of Gable Mountain and Gable Butte
- the 300 Area, near the southern border of the Hanford Site
- the 400 Area, between the 300 and 200 Areas [home of the Fast Flux Test Facility (FFTF)]
- the 1100 Area, a corridor northwest of the city of Richland used for vehicle maintenance and other support activities.

The 600 Area is the designation for land between the operational areas. Areas used for research and development and administrative functions can be found in Richland, Kennewick, and Pasco, the nearest cities.

The Hanford Site was acquired by the federal government in 1943 and was dedicated for many years primarily to the production of plutonium for national defense and the management of the resulting wastes. With the shutdown of the production facilities, missions were diversified to include research and development in the areas of energy, waste management, and environmental restoration.

The DOE has ended the production of nuclear materials at the Hanford Site for weapons. The mission being implemented by the DOE, Richland Operations Office (RL), includes:

- waste management
- environmental restoration
- research and development
- technology development.

Current waste management activities at the Hanford Site include primarily managing wastes with high and low levels of radioactivity (from the nuclear materials production activities) in the 200-East and 200-West Areas. Key waste management facilities include the waste storage tanks, Plutonium Uranium Extraction (PUREX) Plant, Plutonium Finishing Plant, Central Waste Complex, Low-Level Burial Ground, B Plant, and 242-A Evaporator. In addition, used nuclear fuel is stored in the 100-K fuel storage basins.

Environmental restoration includes activities to decontaminate and decommission facilities and to clean up or restore inactive waste sites. The Hanford surplus facilities program conducts surveillance and maintenance of such facilities, and has begun to clean up and dispose of more than 100 facilities. Current activities include decommissioning of the CX-70-tanks (strontium semiworks) and preparing the 183-H Solar Evaporation Basins for Resource Conservation and Recovery Act (RCRA) closure.

Research and technology development activities are also conducted on the Hanford Site in the 200, 300, and 400 Areas and an administrative area south of the Hanford Site boundary. Many of these activities are intended to improve the techniques and reduce the costs of waste management, environmental protection, and Site restoration.

Operations and activities on the Hanford Site are managed by RL through four prime contractors and numerous subcontractors. Each contractor is responsible for the safe, environmentally sound maintenance and management of its facilities and operations, waste management, and monitoring of operations and effluents for environmental compliance.

The principal contractors include:

- Westinghouse Hanford Company
- Battelle Memorial Institute
- Kaiser Engineers Hanford
- Hanford Environmental Health Foundation.

Non-DOE operations and activities include commercial power production by the Washington Public Power Supply System's WNP-2 Reactor (near the 400 Area) and commercial low-level radioactive waste burial at a site leased and licensed by the state of Washington and operated by U.S. Ecology (near the 200 Areas). Siemens Nuclear Power Corporation operates a commercial nuclear fuel fabrication facility, and Allied Technology Group Corporation operates a low-level radioactive waste decontamination, supercompaction, and packaging disposal facility adjacent to the southern boundary of the Hanford Site.

Compliance With Environmental Regulations

The DOE Order 5400.1, "General Environmental Protection Program," describes the environmental standards and regulations applicable at DOE facilities. These environmental standards and regulations fall into three categories: 1) DOE directives, 2) federal legislation and executive orders, and 3) state and local statutes, regulations, and requirements. The following subsections summarize the status of Hanford's compliance with these applicable regulations and list environmental occurrences for 1992.

A key element in Hanford's compliance program is the Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement). The Tri-Party Agreement is an agreement among the U.S. Environmental Protection Agency (EPA), Washington State Department of Ecology (Ecology), and DOE for achieving the compliance with the remedial action provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [including Superfund Amendments and Reauthorization Act (SARA)] and with treatment, storage, and disposal unit regulation and corrective action provisions of RCRA.

Compliance Status

This section summarizes the activities conducted to ensure that the Hanford Site is in compliance with environmental protection regulations.

Comprehensive Environmental Response, Compensation, and Liability Act

The CERCLA established a program to ensure that sites contaminated by hazardous substances are cleaned up by responsible parties or the government. The SARA broadened CERCLA and established provisions for federal facilities.

The preliminary assessments conducted for the Hanford Site revealed approximately 1,100 known individual waste sites where hazardous substances may have been disposed of in a manner that requires further evaluation to determine impact to the environment.

The DOE is actively pursuing the remedial investigation/ feasibility study (RI/FS) process at some operable units on the Hanford Site. The selection of the operable units currently under investigation is a result of Tri-Party Agreement negotiations. All milestones related to the RI/FS process established for 1992 were achieved, and the Hanford Site was in compliance with these CERCLA/ SARA requirements. This takes into consideration several milestones delayed through the change request process.

Emergency Planning and Community Right-To-Know Act

The Emergency Planning and Community Right-To-Know Act provides the public with information about hazardous chemicals in the community and establishes emergency planning and notification procedures to protect the public from a release. Subtitle A of the law calls for creation of state emergency response commissions to guide planning for chemical emergencies. State commissions have also created local emergency planning committees to ensure community participation and planning.

To provide the public with the basis for emergency planning, Subtitle B of the Act contains requirements for periodic reporting on hazardous chemicals stored and/or used near the community. The *1992 Hanford Tier Two Emergency and Hazardous Chemical Inventory* (DOE 1993a) was issued to the State Emergency Response Commission, local county emergency management committees, and local fire department. The report contained information on hazardous materials in storage across the Hanford Site. The *1991 Hanford Toxic Chemical Release Inventory* (DOE 1992i) was issued July 1, 1992, to the EPA and the state. This report contains information on releases to the environment of chemicals that were used in excess of mandated thresholds. Accordingly, during 1992, the Hanford Site was in compliance with the reporting and notification requirements contained in this Act.

Resource Conservation and Recovery Act

The RCRA establishes regulatory standards for the generation, transportation, storage, treatment, and disposal of hazardous waste. Ecology has been authorized by the EPA to implement its dangerous waste program in lieu of the EPA for Washington State, except for some provisions of the Hazardous and Solid Waste Amendments of 1984. Ecology also implements the state's regulations, which are often more stringent.

At the Hanford Site, approximately 63 treatment, storage, and disposal units have been identified that must be permitted or closed in accordance with RCRA and Washington State regulations. These units are required to operate under Ecology's interim-status compliance requirements. Approximately one-half of the units will be closed.

The Tri-Party Agreement provides the framework for meeting RCRA requirements. Of the 100 milestones scheduled for 1992, 96 were completed, although some were delayed as approved through the change request process. At the end of 1992, 234 Tri-Party Agreement milestones had been completed on or ahead of schedule over the previous 3 years.

During 1992, Ecology issued six noncompliance letters to RL for Hanford contractors for alleged violations on waste management requirements.

A Part B permit application for the Hanford Site was issued for public comment in January 1992. Comments were received from Ecology. Responses to these comments were submitted to DOE-Headquarters (HQ) for final review. No comments have been received from HQ. Twenty-six ground-water monitoring wells were constructed at seven RCRA treatment, storage, and disposal facilities in 1992. This satisfied Tri-Party Agreement milestone M-24-00.

Subtitle I of RCRA deals with regulation of underground storage tank systems. These regulations were added to RCRA by the Hazardous and Solid Waste Amendments of 1984. The EPA has developed regulations implementing technical standards for tank performance and management, including standards governing the cleanup and closure of leaking tanks. These regulations do not apply to the single- and double-shell nuclear waste tanks, which are regulated as treatment, storage, and disposal facilities.

Clean Air Act

The purpose of the Clean Air Act is to protect public health and welfare by safeguarding air quality, bringing polluted air into compliance, and protecting clean air from degradation. In Washington State, the provisions of the Act are implemented by EPA, Washington State Department of Health (DOH), and local air authorities.

The Hanford Site is operated under a Prevention of Significant Deterioration permit (No. PSD-X80-14) issued by the EPA in 1980. The permit sets specific limits for emissions of nitrogen oxides from the PUREX and Uranium Trioxide (UO_3) Plants.

The DOH, Division of Radiation Protection, Air Emissions and Defense Waste Section, has developed regulatory controls for radioactive air emissions under Section 116 of the Clean Air Act. Washington State regulations [Washington Administration Code (WAC) 246-247)] require registration of all radioactive air emission point sources with the DOH. All significant Hanford Site stacks emitting radiation have been registered in accordance with applicable regulations.

Revised Clean Air Act requirements for radioactive air emissions were issued December 15, 1989, under National Emission Standards for Hazardous Air Pollutants (NESHAP), 40 Code of Federal Regulations (CFR) 61, Subpart H. Emissions from the Hanford Site are well within the new EPA offsite emissions standard of 10 millirem/year [effective dose equivalent (see Appendix B, "Glossary")]. However, Hanford Site sources do not yet meet the new procedural requirements for flow measurement, emissions measurement, quality assurance, and sampling documentation. The Pacific Northwest Laboratory completed three emission-point-sampler upgrades to comply with sampling and flow rate measurement requirements of the Clean Air Act.

The EPA issued a compliance order and information request to RL on the basis of noncompliance with the NESHAP. The compliance order requires RL to comply with NESHAP Subpart H in the following manner:

1. evaluate all radionuclide emission points on the Hanford Site

2. measure continuous emissions where applicable.

A plan to describe to the EPA how RL will comply is being written. It will be submitted to EPA by April 30, 1993.

Pursuant to the NESHAP program, EPA has developed regulations specifically addressing asbestos emissions (40 CFR 61, Subpart M). These regulations apply at the Hanford Site in building demolition/disposal and waste disposal operations. During 1992, 998 cubic meters (1,305 cubic yards) of asbestos were removed.

The local air authority, the Tri-Counties Air Pollution Control Authority, enforces General Regulation 80-7. This regulation pertains to detrimental effects, fugitive dust, incineration products, odor, opacity, asbestos, and sulfur oxide emissions. The Authority has also been delegated responsibility to enforce the EPA asbestos regulations under NESHAP. The Site remains in compliance with the regulations.

Hanford Site contractors prepared Facility Effluent Monitoring Plans (FEMPs) in 1991 specific to various facilities across the Site. The FEMPs include sections that outline compliance with 40 CFR 61 (ambient air emissions). A summary of each FEMP has been incorporated into a Sitewide environmental monitoring plan covering effluent monitoring and environmental surveillance. The Westinghouse Hanford Company FEMPs were revised in 1992.

Clean Water Act

The Clean Water Act applies to all discharges to waters of the United States. At the Hanford Site, the regulations are applied through a National Pollutant Discharge Elimination System (NPDES) permit governing effluent discharges to the Columbia River. The NPDES permit (No. WA-000374-3) specifies discharge points (called outfalls, of which there are eight), effluent limitations, and monitoring requirements.

There were two reportable conditions in 1992. Problems were experienced in measuring the total suspended solids at outfall 003 in the 100-K Area. A plan to dispose of the effluent to an alternative site is being evaluated.

The quarterly limit for iron was exceeded in the N Springs outfall. The exceedance was caused by a buildup of iron in a ground-water monitoring well. The well had not been purged since the previous sampling, allowing the buildup. Purge water released to the outfall exceeded the limit for iron. The well was repurged and resampled. No limits were exceeded after repurging.

Safe Drinking Water Act

The National Primary Drinking Water Regulations of the Safe Drinking Water Act apply to the drinking water supplies at the Hanford Site. These regulations are enforced by the DOH under WAC 246-290. During 1992, all Hanford Site water systems were in compliance with the requirements of the applicable regulations.

Toxic Substances Control Act

The application of Toxic Substances Control Act requirements to the Hanford Site essentially involves regulation of the chemicals called polychlorinated biphenyls (PCBs). The Hanford Site is currently in compliance with regulations for nonradioactive PCBs. All radioactive PCB wastes are being stored with EPA approval, pending development of treatment and disposal technologies and capabilities.

Federal Insecticide, Fungicide, and Rodenticide Act

The EPA is responsible for ensuring that a chemical, when used according to label instructions, will not present unreasonable risks to human health or the environment. This Act and the Revised Code of Washington (RCW) 17.21, "Washington Pesticide Application Act," as implemented by WAC 16-228, "General Pesticides Regulations," apply to storage and use of pesticides. The Hanford Site is in compliance with the Act's requirements and WAC 16-228 regulations pertaining to storage and application of pesticides.

Endangered Species Act

A few rare species of native plants and animals are known to occur on the Hanford Site. Some of these are listed by the U.S. Fish and Wildlife Service as endangered or threatened (federally listed). Others are listed by the Washington State Department of Wildlife as endangered, threatened, or sensitive species. The Site monitoring program is discussed in Section 4.2, "Wildlife." Hanford Site activities complied with the Endangered Species Act in 1992.

National Historic Preservation Act and Archaeological Resources Protection Act

Cultural resources on the Hanford Site are subject to the provisions of the National Historic Preservation Act and the Archaeological Resources Protection Act. Compliance with these Acts is accomplished through a monitoring program, which is described in Section 4.3, "Other Environmental Studies and Programs." In 1992, Hanford Site operations complied with these Acts.

National Environmental Policy Act

The National Environmental Policy Act (NEPA) establishes environmental policy to prevent or eliminate damage to the environment and to enrich our understanding of ecological systems and natural resources. The NEPA requires that major federal projects with significant impacts be carefully reviewed and reported to the public in environmental impact statements (EISs). Other NEPA documents such as environmental assessments are also prepared in accordance with NEPA requirements.

Several EISs related to programs or activities on the Hanford Site are in process or in the planning stage. These are:

- a final environmental impact statement as an addendum on the decommissioning of eight surplus production reactors at the Hanford Site
- *Programmatic Environmental Impact Statement for the Office of Environmental Restoration and Waste Management Program*
- *Draft Weapons Complex Modernization Programmatic EIS.*

NEPA assessments also included information on floodplain management and protection of wetlands.

Environmental Occurrences

Onsite and offsite environmental occurrences (spills, leaks, etc.) of radioactive and nonradioactive effluent materials during 1992 were reported to DOE as specified

in DOE Order 5000.3A and to other federal and state agencies as required by law. All emergency, unusual, and off-normal occurrence reports, including event descriptions and corrective actions, are available for review in the RL Public Reading Room, Richland, Washington. There were no emergency occurrences reported in 1992. There were 1,531 off-normal environmental occurrence reports filed at the Hanford Site during 1992, covering everything from leaks from overheated motor vehicle cooling systems to leaking waste oil drums. Because of the volume of reported off-normal occurrences, event summaries are not included here.

The 1992 unusual occurrences with the most potential for environmental impact and their occurrence numbers are:

- Release of Contaminated Water to the Ground (RL-KEH-1992-0061)
- Lithium Release (RL-WHC-300EM-1992-0044)
- Waste Tank Leak (RL-WHC-TANKFARM-1992-0073)
- Discharge to the Columbia River (RL-WHC-NREACTOR-1992-0061)
- Oil Spill (RL-WHC-600EM-1992-0011)
- Radiation Leak (RL-WHC-TANKFARM-1992-0074)
- Waste Oil Contaminated with Lead (RL-WHC-TPLANT-1992-0018).

Environmental Programs

Environmental programs were conducted at the Hanford Site to restore environmental quality, manage waste, develop appropriate technology for cleanup activities, and study the environment. These programs are discussed below.

Wildlife inhabiting the Hanford Site is monitored to determine the status and condition of the populations, and to assess effects of Hanford Site operations. Particular attention is paid to species that are rare, threatened, or endangered nationally or statewide and those species that are of commercial, recreational, or aesthetic importance statewide or locally. These species include the bald eagle, chinook salmon, Canada goose, several species of hawk, Rocky Mountain elk, mule deer, white pelican, and other bird species.

Fluctuations in wildlife and plant species on the Hanford Site appear to be a result of natural ecological factors and management of the Columbia River system. The establishment and management of the Hanford Site has had a net positive effect on wildlife relative to probable alternative uses of the Site.

The Hanford Cultural Resources Laboratory was established by RL in 1987 as part of the Pacific Northwest Laboratory. Cultural resources on the Hanford Site are closely monitored, and projects are relocated in cases where there is a possibility of altering any significant historical sites.

It appears that erosive processes are the most significant factors affecting most of the sites. Wind erosion from off-road-vehicle use plays a big part in the deterioration of sites inside and outside of the security perimeter.

Technical work done in 1992 on the Hanford Environmental Dose Reconstruction Project (HEDR) consisted of restructuring models to enhance their capabilities, developing detailed estimates of releases of radioactive materials, and evaluating additional information needed to produce estimates.

The community-operated environmental surveillance program was initiated in 1990 to increase the public's involvement in and awareness of Hanford's surveillance program. Three surveillance stations continued operation in 1992.

An education outreach program established with the Yakima Indian Nation in 1991 was continued in 1992. This program provided an opportunity for a student to study Columbia River water quality and fish health and environmental monitoring activities conducted at Hanford.

Environmental Monitoring Information

Environmental monitoring of the Hanford Site consists of 1) effluent monitoring and 2) environmental surveillance including ground-water monitoring. Effluent

monitoring is performed as appropriate by the Site facility operators at the facility or at the point of release to the environment. Additional monitoring is conducted in the environment near facilities that discharge or have discharged effluents. Environmental surveillance consists of sampling and analyzing environmental media on and off the Hanford Site to detect and quantify potential contaminants, and to assess their environmental and human health significance.

The overall objectives of the monitoring and surveillance programs are to demonstrate compliance with federal, state, and local regulations; confirm adherence to DOE environmental protection policies; and support environmental management decisions.

The following sections discuss the doses calculated from environmental data, and effluent monitoring and environmental surveillance on or near the Hanford Site in 1992.

Potential Radiation Doses from 1992 Hanford Operations

In 1992, potential public doses resulting from exposure to Hanford liquid and gaseous effluents were evaluated to determine compliance with pertinent regulations and limits. These doses were calculated from reported effluent releases and environmental surveillance data using Version 1.485 of the GENII code (Napier et al. 1988a, 1988b, 1988c) and Hanford Site-specific parameters. Specific information on sample collection and analyses and the sample results used in these calculations are briefly discussed in the summary sections discussing effluent monitoring and environmental surveillance.

The potential dose to the hypothetical maximally exposed individual (MEI) in 1992 from Hanford operations was 0.02 mrem (2×10^{-4} mSv), the same as calculated for 1991. The potential dose to the local population of 380,000 persons from 1992 operations was 0.8 person-rem (0.008 person-Sv), compared to 0.9 person-rem (0.009 person-Sv) reported for 1991. The 1992 average dose to the population was 0.002 mrem (2×10^{-5} mSv) per person. The current DOE radiation limit for an individual member of the public is 100 mrem/yr (1 mSv/yr), and the national average dose from natural sources is 300 mrem/yr (3 mSv/yr). The MEI potentially received 0.02% of the DOE dose limit and 0.007% of the national average background dose from natural sources. The average individual potentially received 0.002% of the standard and 0.0007% of the 300 mrem/yr received from typical natural sources.

Special exposure scenarios not included in the above dose estimates include the potential consumption of game residing on the Hanford Site and exposure to radiation at the publicly accessible location with the maximum exposure rate. Doses from these sources would also have been small compared to the dose limit.

Dose through the air pathways was 0.04% of the EPA limit (40 CFR 61).

In addition to the doses estimated from monitored stack releases, the potential radiation dose to the MEI from diffuse and unmonitored sources was estimated using 1992 data to be about 0.09 mrem/yr (9×10^{-4} mSv/yr).

Effluent Monitoring

Effluent monitoring includes facility effluent monitoring (monitoring effluents at the point of release to the environment) and near-facility environmental monitoring (monitoring the environment near operating facilities).

Facility Effluent Monitoring

Liquid and gaseous effluents, which may contain radioactive and hazardous constituents, are continually monitored at the Hanford Site. Facility operators monitor effluents mainly through analyzing samples collected near points of release into the environment. Effluent monitoring data are evaluated to determine their degree of compliance with applicable federal, state, and local regulations and permits.

Measuring devices are used to quantify most facility effluent flows, with a smaller number of flows calculated using process information. Liquid and gaseous effluents with a potential to contain radioactivity at prescribed threshold levels are monitored for total alpha and total beta activity and, as warranted, specific alpha-, beta-, and gamma-emitting radionuclides. Other hazardous constituents are also monitored, as applicable.

Radioactive effluents from many facilities on the Site are approaching levels practically indistinguishable from the contributions of natural background radioactivity. The new Site mission of environmental restoration rather than nuclear materials production is largely responsible for this trend, which translates to a very small offsite radiation dose effect attributable to Site activities. Consistent with these conditions of diminishing releases, totals of radionuclides in effluents released at the Site in 1992 are not significantly different from totals in 1991.

Near-Facility Environmental Monitoring

The near-facility environmental monitoring program provides environmental monitoring to protect the environment adjacent to facilities and ensure compliance with internal WHC requirements and local, state, and federal environmental regulations.

Specifically, the near-facility environmental monitoring program monitored new and existing sites, processes, and facilities for potential impacts and releases; fugitive emissions and diffuse sources from contaminated areas; and surplus facilities before decontaminating or decommissioning. External radiation dose, ambient air particulates, soil, surface water, sediment, and biota were sampled. Parameters included, as appropriate, radionuclides, radiation exposure, hazardous constituents, pH, and water temperature.

The analytical results showed a large degree of variance; in general, the samples collected from media located on or directly adjacent to the waste disposal and other nuclear facilities had significantly higher concentrations than those farther away. As expected, certain radionuclides were found in higher concentrations within different operational areas. Generally speaking, the predominate radionuclides were activation products/gamma emitters in the 100 Areas, fission products in the 200/600 Areas, and uranium in the 300 Area.

Air Monitoring. Radioactivity in air was sampled by a network of continuously operated samplers at 40 locations near facilities: 4 located in the 100-N Area, 33 in the 200/600 Areas, and 3 background stations collocated with the Pacific Northwest Laboratory (PNL) and the DOH at the Yakima and Wye Barricades and the old Hanford townsite. Air samplers were primarily located at or near (≈500 meters or 1,500 feet) sites and/or facilities having the potential or history for release, with an emphasis on the prevailing downwind directions. Of the radionuclide analyses performed, ^{90}Sr,^{137}Cs, ^{239,240}Pu, and uranium were consistently detectable in the 200 Areas; ^{60}Co was detectable in the 100-N Area. Air concentrations for these radionuclides were elevated near facilities when compared to the concentrations measured offsite by PNL.

Monitoring of Surface-Water Disposal Units and Seeps. Sampling of surface-water disposal units included water, sediment, and aquatic vegetation. Samples taken at river shoreline seeps included water only. Radiological analysis of liquid samples from surface-water disposal units included total alpha, total beta, ^{3}H, ^{239,240}Pu, and gamma-emitting radionuclides. Radiological analysis of sediment and aquatic vegetation included ^{90}Sr, ^{239,240}Pu, uranium, and gamma-emitting radionuclides. Nonradiological analysis performed included pH, temperature, and nitrates.

Radionuclide concentrations in surface-water disposal units were below the applicable Derived Concentration Guides (DCGs) and in most cases at or below the analytical detection limit. Although some elevated levels were seen in both aquatic vegetation and sediment, in all cases the radiological analytical results were well below the standards for radiological control. The results for pH were well within the pH of 2.0 and 12.5 standard for liquid effluent discharges. The analytical results for nitrates were all below the 45-mg/L Drinking Water Standard (DWS).

Ground-water seeps along the 100-N Area shoreline are sampled to verify reported radionuclide releases to the Columbia River from past operations of the N Reactor. Release reporting utilizes conservatively based radionuclide concentrations, multiplied by the estimated ground-water flow into the river. By characterizing the radionuclide concentrations in the seeps along the shoreline, the results can be compared to the concentrations measured in the effluent monitoring well 199-N-8T.

In 1992, the concentrations detected in the seep samples were highest in those seeps nearest well 199-N-8T, although the seep concentrations were considerably lower than those measured in the well.

Radiological Surveys. There were approximately 1,215 hectares (3,000 acres) of outdoor posted surface contamination and 405 hectares (1,000 acres) of posted underground radioactive material Sitewide in 1992. These areas were typically associated with cribs, burial grounds, tank farms, and covered ponds, trenches, and ditches. The number of posted surface contamination areas varied because of an ongoing effort to clean, stabilize, and remediate areas of known contamination while new areas of contamination were being identified. New areas may have been identified because of contamination migration or the increased effort being made to investigate outdoor areas for radiological contamination. It was estimated that the dose rate for 80% of the identified outdoor surface contamination areas was less than 1 millirem/hour, although isolated specks could be considerably higher. Contamination levels of this type would not significantly add to dose rate calculations for the public or Site employees.

Soil and Vegetation Monitoring. Soil and vegetation samples were also collected on or adjacent to waste disposal units and from locations downwind and within the operating environment of facilities. Special samples were taken where physical or biological transport problems were identified. Soil and vegetation sample concentrations for some radionuclides were elevated near facilities when compared to the concentrations measured offsite. The concentrations show a large degree of variance; in general, samples collected on or directly adjacent to waste disposal facilities had significantly higher concentrations than those farther away.

External Radiation. External radiation fields were measured near operating facilities and waste-handling, storage, and disposal sites to measure, assess, and control the impacts of operations.

Hand-held μR meters were used in the 100-N Area to survey points near and within the N Springs area, 1301-N Liquid Waste Disposal Facility (LWDF), and 1325-N LWDF. The radiation rates measured in the N Springs area continued to decline in 1992, reflecting decreased discharges to the 1301-N LWDF and the continuing decay of its radionuclide inventory. Radiation measurements taken at the 1325-N LWDF in 1992 and in the previous year were slightly elevated. Decreased discharges to the facility resulted in the loss of the water that normally provided shielding for the gamma-emitting radionuclides in sediments of the LWDF.

Radiation levels measured with thermoluminescent dosimeters (TLDs) were highest near facilities that had contained or received liquid effluent from N Reactor, primarily the 1325-N LWDF and the 1301-N LWDF. Exposure rates for 1992 for these two facilities decreased approximately 5% compared to 1991.

The highest dose rates measured in the 200/600 Areas were near waste-handling facilities such as tank farms. The average dose rate measured in 1992 by TLDs in the 200/600 Areas was 130 millirem/year, which was 8% above the average dose rate of 120 millirem/year measured in 1991.

The highest dose rates measured in the 300/400 Area were near waste-handling facilities such as the 340 Waste Handling Facility. The average dose rate measured in 1992 by TLDs in the 300/400 Areas was 130 millirem/year, which was 13% below the average dose rate of 150 millirem/year measured in 1991.

Environmental Surveillance

Environmental surveillance at the Hanford Site includes sampling environmental media on and off the Site for potential chemical and radiological contaminants originating from Site operations. The media sampled included air, surface water, soil and vegetation, wildlife, food and farm products, external radiation levels, and ground water.

Air Surveillance

Transport of atmospheric releases of radioactive and nonradioactive materials from the Hanford Site to the surrounding region represents a direct pathway for human exposure. Radioactive materials in air were sampled continuously at 42 locations onsite, at the Site perimeter, and in nearby and distant communities. Samples were also collected at three community-operated environmental surveillance stations that were managed and operated by local school teachers. Air sampling was discontinued at several locations in 1992 to reflect the substantial decrease in Hanford Site air emissions following the 1990 reduction in operations at the PUREX Plant. Particulates were filtered from the air at all locations and analyzed for radionuclides. Air was sampled and analyzed for selected gaseous radionuclides at key locations. Several radionuclides released at the Hanford Site are also found worldwide from two other sources: naturally occurring radionuclides and radioactive fallout from nuclear activities worldwide. The potential influence of emissions from Site activities on local radionuclide concentrations was evaluated by comparing differences between concentrations measured at distant locations within the region and concentrations measured at the Site perimeter.

For 1992, no differences were observed between the average total alpha and total beta air concentrations measured at the Site perimeter and at nearby and distant community locations. This indicates that the observed concentrations were predominantly influenced from natural sources and worldwide fallout. Numerous specific radionuclides in quarterly composite samples were analyzed using gamma scan analysis; however, no radionuclides of Hanford origin were detected consistently. Air concentrations for ^{90}Sr and ^{238}Pu for samples collected at offsite locations were below detection limits. Average uranium and $^{239,240}Pu$ concentrations in airborne particulate matter were similar at the Site perimeter and distant locations. Iodine-129 and ^{3}H were the only radionuclides that showed elevated average concentrations at the Site

perimeter relative to the distant locations. Tritium samples collected from January to May 1992 may have been contaminated during the analytical process because most locations including the distant communities reported unusually high concentrations. From June to December 1992 the average sample results for ^{3}H returned to normal concentrations with little difference between the distant locations and the Site perimeter. Average ^{129}I concentrations at the Site perimeter were higher than the mean concentration reported for the distant locations; however, the average concentration at the Site perimeter was only 0.000002% of the DCG of 70 picocuries/cubic meter. The DCG is the concentration that would result in a radiation dose equal to the DOE public dose limit (100 millirem/year).

Air samples were collected at three Hanford Site locations for volatile organic compounds and PCBs. All measured air concentrations of these organic compounds were well below applicable maximum allowable concentration standards for air contaminants.

Surface-Water Surveillance

The Columbia River was one of the primary environmental exposure pathways to the public during 1992 as a result of operations at the Hanford Site. Radiological and chemical contaminants entered the river along the Hanford Reach as direct effluent discharges and through the seepage of contaminated ground water. Water samples were collected from the river at various locations throughout the year to determine compliance with applicable standards.

Although radionuclides associated with Hanford operations continued to be routinely identified in Columbia River water during the year, concentrations remained extremely low at all locations and were well below applicable standards. The concentrations of ^{3}H, ^{129}I, and uranium were higher at the Richland Pumphouse (downstream from the Site) than at Priest Rapids Dam (upstream from the Site). Differences in concentrations measured at the two locations were statistically significant (5% significance level), indicating a contribution along the Hanford Reach. Chemical water quality constituents measured in Columbia River water during 1992 were generally similar upstream and downstream and in compliance with applicable standards.

During 1992 samples were collected from three Columbia River shoreline springs, contaminated as a result of past waste disposal practices at the Hanford Site. Contaminant concentrations in the springs were similar to those found in the ground water. Radionuclide concentrations were generally less than the DOE DCGs. However, ^{90}Sr in N Springs water was greater than the DCG as well as the DWS. Tritium, while less than the DCG, was greater than the DWS at the old Hanford townsite springs.

Samples of Columbia River surface sediments were collected from behind McNary Dam (downstream from the Site) and Priest Rapids Dam and from four shoreline locations along the Hanford Reach of the Columbia River during 1992. As in the past, radionuclide concentrations in sediments behind McNary Dam were generally slightly higher than those observed in sediments collected from behind Priest Rapids Dam and along the Site.

Three onsite ponds were sampled to determine radionuclide concentrations. These ponds are accessible to migratory waterfowl and other animals. As a result, a potential biological pathway exists for the removal and dispersal of contaminants that may be in the ponds. Concentrations of radionuclides in water collected from these ponds during 1992 were similar to those observed during past years. In all cases, radionuclide concentrations in the onsite pond water were below applicable DOE DCGs.

Offsite water, used for irrigation and/or drinking water, was sampled to determine radionuclide concentrations in water used by the nearby public. Elevated total alpha and total beta concentrations, attributed to naturally occurring uranium, were observed at some locations. Average radionuclide concentrations in offsite water during 1992 were within applicable DWSs.

Soil and Vegetation Surveillance

In 1992, three soil samples were collected from the 100-N Area and six others were collected offsite. Most of the offsite sampling was conducted at the Site's downwind perimeter; other samples were collected at relatively upwind and distant locations (Yakima and Sunnyside) to establish background concentrations. Radionuclides consistently detected were ^{40}K, ^{90}Sr, ^{137}Cs, ^{238}U, and $^{239,240}Pu$.

The analytical results were used to make two comparisons. The first comparison, between the onsite and the combined offsite samples, did not indicate a difference in ^{90}Sr, ^{137}Cs, or $^{239,240}Pu$ concentrations. However, ^{238}U was identified in higher concentrations onsite. The second comparison was between the perimeter and distant

upwind locations. No significant differences in concentrations were found, indicating no measurable effects from Hanford operations.

In 1992, one onsite and six offsite vegetation samples were collected. Vegetation was sampled using the same rationale as soil sampling. Strontium-90 was identified in five out of seven samples. The sample collected from the Yakima area (upwind of Hanford) was identified as containing very low levels of ^{238}U. Also ^{137}Cs and ^{239,240}Pu were found in the Sagemoor sample (downwind from Hanford) at very low concentrations. No radionuclide accumulation could be detected from the vegetation samples taken.

Wildlife Surveillance

The Hanford Site contains large tracts of undeveloped land that serve as a refuge for many species of wildlife. The Columbia River, which borders the Site, also provides habitat for wildlife and fish that are of economic and recreational importance to the area. Terrestrial wildlife like deer, rabbits, and upland gamebirds have access to parts of the Site that contain low levels of radionuclides attributable to current and past Site operations. Wildlife are monitored for radionuclides as indicators of possible exposure to the Site surface contamination. Similarly, Columbia River fish are monitored to detect any radioactivity that may arise from Site activities as well as to help estimate the dose to those who may consume these fish.

Analysis of wildlife for radioactivity indicated that some species had accumulated levels of radioactivity greater than background levels. Background samples collected for a number of species over the past 3 years are summarized in this year's report. Strontium-90 was detected in deer and rabbit bone as well as Columbia River fish carcasses at levels exceeding concentrations reported in background locations. Ducks collected in August from B Pond, a low-level waste pond located near the 200-East Area, had significantly higher concentrations of ^{137}Cs than ducks collected in November after migrating ducks had arrived. Cesium-137 was also detected at higher concentrations in the muscle of deer collected from a background location in Stevens County, north of Spokane, than has been observed in Hanford Site populations of mule deer. The levels of ^{137}Cs in the deer from Stevens County was attributed to past atmospheric fallout from weapons testing. Collectively, the observations of radioactivity in Hanford fish and wildlife indicate accumulation of small amounts of specific radionuclides originating from the Hanford Site.

The radionuclide concentrations measured in fish and wildlife were used to estimate potential doses to sportsmen who may consume Hanford Site game. The resulting doses were much less than applicable guidelines developed to protect the public.

Food and Farm Product Surveillance

The Hanford Site is situated in a large agricultural area that produces a wide variety of food products and alfalfa. Milk, eggs, poultry, beef, vegetables, fruit, wheat, alfalfa, and wine were collected from areas generally downwind from the Site and upwind and distant locations. The principal downwind locations include Wahluke, Sagemoor, and Riverview. Alfalfa and farm products were analyzed for ^{3}H, ^{60}Co, ^{90}Sr, ^{99}Tc, ^{129}I, ^{131}I, ^{137}Cs, ^{234}U, ^{235}U, ^{238}U, ^{238}Pu, and ^{239,240}Pu.

Most of the farm products sampled did not contain measurable concentrations of radionuclides. Tritium was measured at levels very close to the detection level, and there was no apparent upwind or downwind effect noted. Iodine-129 was found at slightly elevated levels in downwind milk samples, but the levels were very low and have been decreasing over the past 5 years. About 0.2% of the 0.02 mrem MEI annual dose results from ^{129}I in milk.

A special study also investigated the apparent elevation of ^{90}Sr in alfalfa irrigated with Columbia River water downstream from the Hanford Site compared to alfalfa, irrigated with other sources of water. The study showed that levels of ^{90}Sr in the downstream study group exceeded concentrations in the other group. There was no monitored difference in ^{90}Sr in Columbia River water upstream and downstream of the Site. The findings are inconclusive; however, the levels of ^{90}Sr in the alfalfa do not constitute a significant dose to farm animals or humans. Overall, the potential offsite dose to consumers of farm products grown near the Hanford Site in 1992 is a very small fraction of the public dose guideline of 100 millirem/year for exposure to environmental radioactivity.

External Radiation Surveillance

In 1992, radiological dose rates were measured at a number of locations on and off the Hanford Site using

TLDs. Contributors to the radiological doses measured include natural (uranium and its progeny in soil and other primordial radionuclides) and artificial sources. Onsite dose rates, as a whole, appear to be decreasing, while offsite dose rates appear to have increased slightly.

The average background radiological dose rate, calculated from TLDs at Yakima and Sunnyside (distant and upwind locations relative to the Hanford Site), was 93 millirem/year±6% as compared to the average of 102 millirem/year±6% measured at the downwind perimeter of the Site. These are increases of 6% and 2%, respectively, over last year's measured dose rates. Dose rates at the Columbia River shoreline around the 100-N Area were approximately two times higher than typical shoreline dose rates. This area of higher dose rates may be attributable to skyshine from the 100-N Area liquid waste disposal facilities (Brown and Perkins 1991). Onsite dose rates measured near operational areas were higher than the average background dose rate.

Various road and railroad contamination surveys were performed during 1992. No contamination on roads or railroads was found.

Ground-Water Protection and Monitoring

Radiological and chemical constituents in ground water were monitored during 1992 throughout the Hanford Site in support of the overall objectives described in Section 5.0. Monitoring activities were conducted to identify and quantify existing, emerging, or potential ground-water quality problems; assess the potential for contaminants to migrate off the Hanford Site; and prepare an integrated assessment of the condition of ground water on the Site. To comply with RCRA, additional monitoring was conducted to assess the impact that specific facilities have had on ground-water quality. During 1992, 720 Hanford Site wells were sampled to satisfy ground-water monitoring needs. As discussed in Sec-tion 5.3, four additional wells located across the Columbia River and east of the Site were sampled to determine whether Hanford operations had affected water quality offsite.

Analytical results for samples were compared with EPA's DWS (Tables C.2 and C.3, Appendix C) and DOE's DCG (Table C.6, Appendix C). Ground water beneath the Hanford Site is used for drinking at five locations. Only the drinking water in the 400 Area at the FFTF Visitors Center is available for public consumption; this source is discussed in Section 5.8. In addition, water supply wells for the city of Richland are located adjacent to the southern boundary of the Hanford Site.

Radiological monitoring results indicated that total alpha, total beta, ^{3}H, ^{60}Co, ^{90}Sr, ^{99}Tc, ^{129}I, ^{137}Cs, and uranium concentrations in wells in or near operating areas were at levels greater than the DWS. Concentrations of uranium in the 200-West Area were greater than the DCG. Concentrations of ^{3}H in the 200 Areas and ^{90}Sr in the 100-N and 200-East Areas were also greater than the DCG. Tritium continued to move slowly with the general ground-water flow and discharge to the Columbia River.

Certain chemicals regulated by the EPA and the State of Washington were also present in Hanford Site ground water near operational areas. Nitrate concentrations exceeded the DWS at isolated locations in the 100, 200, and 300 Areas and in several 600 Area locations. Chromium concentrations were greater than the DWS at the 100-D, 100-H, and 100-K Areas, and in the surrounding areas. Chromium concentrations greater than the DWS were also found in the 200-East and 200-West Areas. Cyanide was present in ground water north of the 200-East Area. High concentrations of carbon tetrachloride and chloroform were found in wells in the 200-West Area. Trichloroethylene was found at levels exceeding the DWS at wells in and near the 100-F, 100-K, 200-West, and 300 Areas. Tetrachloroethylene levels in wells near the Solid Waste Landfill remain just greater than the DWS. Samples from monitoring wells near Richland water supply wells showed that concentrations of regulated ground-water constituents in this area were less than the DWS and, in general, less than detection levels.

A comprehensive review of all ground-water monitoring work on the Site is published annually. Before 1989, these reports contained complete listings of all radiological and chemical data collected during the reporting periods. Currently, complete listings for ground-water environmental surveillance data can be found in a companion volume to this report to complement data listings published by other programs.

Quality Assurance

Comprehensive quality assurance (QA) programs, which include various quality control practices and methods to verify data, are maintained to ensure data quality. The QA programs are implemented through QA plans designed to meet requirements in the American National

Standards Institute/American Society of Mechanical Engineers NQA-1 QA program document and DOE Orders. Quality assurance plans are maintained for all activities, and conformance is verified through auditors. Quality control methods include but are not limited to replicate sampling and analysis, analysis of blanks and reference standards, participation in interlaboratory cross-check studies, and splitting samples with other laboratories. Sample collection and laboratory analyses are conducted using documented and approved procedures. When sample results are received, they are screened for anomalous values by comparing them to recent results and historical data. Analytical laboratory performance on the EPA Laboratory Intercomparison Studies Program and the national DOE Quality Assessment Program indicated that laboratory performance was adequate overall, was excellent in some areas, and needed improvement in others.

Report Contributors

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Section	Authors
1.0 Introduction	R. K. Woodruff
1.1 Site Mission	R. K. Woodruff; J. M. Nickels, WHC
1.2 Introduction to the Hanford Site	C. E. Cushing
1.3 Major Operations and Activities	J. M. Nickels, WHC
2.0 Environmental Compliance Summary	J. M. Nickels, WHC
2.1 Environmental Compliance and Cleanup	J. M. Nickels, WHC
2.2 Compliance Status	J. M. Nickels, WHC
2.3 Current Issues and Actions	J. M. Nickels, WHC
2.4 Environmental Occurrences	R. W. Hanf; J. M. Nickels, WHC
2.5 Compliance Status Update	J. M. Nickels, WHC
3.0 Effluent Monitoring Information	D. J. Rokkan, SAIC; L. P. Diediker, WHC
3.1 Facility Effluent Monitoring	D. J. Rokkan, SAIC; L. P. Diediker, WHC
3.2 Near-Facility Environmental Monitoring	J. W. Schmidt, WHC; A. R. Johnson, WHC; S. M. McKinney, WHC; C. J. Perkins, WHC
3.3 Solid Waste Management and Chemical Inventories	D. J. Rokkan, SAIC; L. P. Diediker, WHC
4.0 Environmental Program Information	R. K. Woodruff
4.1 Climate and Meteorology	D. J. Hoitink
4.2 Wildlife	L. L. Cadwell
4.3 Other Environmental Studies and Programs	W. T. Farris; R. W. Hanf; M. K. Wright; R. K. Woodruff
5.0 Environmental Surveillance Information	R. K. Woodruff
5.1 Environmental Surveillance at Hanford	R. K. Woodruff
5.2 Air Surveillance	G. W. Patton
5.3 Surface-Water Surveillance	R. L. Dirkes
5.4 Food and Farm Product Surveillance	T. M. Poston
5.5 Wildlife Surveillance	T. M. Poston
5.6 Soil and Vegetation Surveillance	E. J. Antonio
5.7 External Radiation Surveillance	E. J. Antonio
5.8 Ground-Water Protection and Monitoring Program	P. E. Dresel; R. W. Bryce; J. C. Evans
6.0 Potential Radiation Doses from 1992 Hanford Operations	J. K. Soldat
7.0 Quality Assurance	T. M. Poston; L. P. Diediker, WHC; J. W. Schmidt, WHC

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Leslie Groves Park, Richland
C. A. Wagner, Manager
T. E. Gilmore, Alternate Manager

Basin City Elementary School, Basin City
C. L. Stevenson, Manager

Edwin Markham Elementary School, North Franklin County
M. P. Madison, Manager
K. A. Darrington, Alternate Manager

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Helpful Information

Helpful Information

The following information is provided to assist the reader in understanding the report. Definitions of technical terms can be found in Appendix B, "Glossary." A public information summary pamphlet is available by following the directions in the "Preface."

Scientific Notation

Scientific notation is used in this report to express very large or very small numbers. For example, the number 1 billion could be written as 1,000,000,000 or using scientific notation as 1×10^9. Translating from scientific notation to a more traditional number requires moving the decimal point either left or right from the number. If the value given is 2.0×10^3, the decimal point should be moved three numbers (insert zeros if no numbers are given) to the right of its present location. The number would then read 2,000. If the value given is 2.0×10^{-5}, the decimal point should be moved five numbers to the left of its present location. The result would become 0.00002.

Metric Units

The primary units used in this report are metric. Table H.1 summarizes and defines the terms and corresponding symbols (metric and nonmetric) found throughout this report.

Radioactivity Units

Much of this report deals with levels of radioactivity in various environmental media. Radioactivity in this report is usually discussed in units of curies (Ci) (Table H.2). The curie is the basic unit used to describe the amount of radioactivity present, and concentrations are generally expressed in terms of fractions of curies per unit mass or volume. One curie is equivalent to 37 billion disintegrations per second or is a quantity of any radionuclide that decays at the rate of 37 billion disintegrations per second. Disintegrations generally produce spontaneous emissions of alpha or beta particles, gamma radiation, or combinations of these. In some instances in this report, radiation values are expressed with two sets of units. One set of units is usually included in parenthesis or footnotes. These units belong to the International System of Units (SI), and their inclusion in this report is mandated by DOE. SI units are the "new" internationally accepted units and will eventually be the standard for reporting radioactivity and radiation dose in the United States. The basic unit for discussing radioactivity, the curie, can be converted to the equivalent SI unit, the becquerel (Bq), by multiplying by 3.7×10^{10}. One becquerel is equivalent to one nuclear disintegration per second.

Radiation Dose Units

The amount of radiation received by a living organism is expressed in terms of radiation dose. Radiation dose in this report is usually written in terms of effective dose equivalent and reported numerically in units of rem or in the SI unit, sievert (Sv) (Table H.3). Rem (sievert) is a term that relates ionizing radiation and biological effect or risk. A dose of 1 millirem has a biological effect similar to the dose received from about one day's exposure to natural background radiation (see "Hanford Public Radiation Dose in Perspective" in Section 6.0 for a more in-depth discussion of risk comparisons). To convert the most commonly used dose term in this report, the millirem, to the SI equivalent, the millisievert, multiply millirem by 0.01.

Additional information on radiation and dose terminology can be found in the glossary of this report (Appendix B). A list of the radionuclides discussed in this report and their half-lives is included in Table H.4.

General information on radiation and radiation dose (as well as Hanford's Environmental Monitoring Program, Hanford's Cultural Resource Program, and Hanford's wildlife) has been compiled in informational pamphlets

Table H.1. Names and Symbols for Units of Measure

Length	
Symbol	Name
cm	centimeter (1 x 10^{-2} m)
ft	foot
in.	inch
km	kilometer (1 x 10^{3} m)
m	meter
mi	mile
mm	millimeter (1 x 10^{-3} m)
µm	micrometer (1 x 10^{-6} m)

Time	
Symbol	Name
d	day
h	hour
min	minute
s	second
yr	year

Area	
Symbol	Name
ha	hectare (1 x 10^{4} m^2)
km^2	square kilometer
mi^2	square mile
ft^2	square foot

Volume	
Symbol	Name
cm^3	cubic centimeter
gal	gallon
L	liter
mL	milliliter (1 x 10^{-3} L)
m^3	cubic meter
ppmv	parts per million volume
qt	quart
yd^3	cubic yard
ft^3	cubic foot

Mass	
Symbol	Name
g	gram
Gg	gigagram (1 x 10^{9} g)
kg	kilogram (1 x 10^{3} g)
mg	milligram (1 x 10^{-3} g)
µg	microgram (1 x 10^{-6} g)
ng	nanogram (1 x 10^{-9} g)
t	metric ton (or tonne; 1 x 10^{3} kg)
lb	pound

Rate	
Symbol	Name
cfs	cubic feet per second
mph	miles per hour

Temperature	
Symbol	Name
°C	degrees Centigrade
°F	degrees Fahrenheit

Table H.2. Names and Symbols for Units of Radioactivity

Radioactivity	
Symbol	Name
Ci	curie
mCi	millicurie (1 x 10^{-3} Ci)
µCi	microcurie (1 x 10^{-6} Ci)
nCi	nanocurie (1 x 10^{-9} Ci)
pCi	picocurie (1 x 10^{-12} Ci)
fCi	femtocurie (1 x 10^{-15} Ci)
aCi	attocurie (1 x 10^{-18} Ci)
Bq	becquerel

Table H.3. Names and Symbols for Units of Radiation Dose

Radiation Dose	
Symbol	Name
mrad	millirad (1 x 10^{-3} rad)
mrem	millirem (1 x 10^{-3} rem)
Sv	sievert
mSv	millisievert (1 x 10^{-3} Sv)
µSv	microsievert (1 x 10^{-6} Sv)
R	roentgen
mR	milliroentgen (1 x 10^{-3} R)
µR	microroentgen (1 x 10^{-6} R)
Gy	gray

Table H.4. Radionuclide Nomenclature

Radionuclide	Symbol	Half-Life	Radionuclide	Symbol	Half-Life
tritium	^{3}H	12.3 yr	cesium-137	^{137}Cs	30.2 yr
beryllium-7	^{7}Be	53.28 d	cerium-144	^{144}Ce	284 d
carbon-14	^{14}C	5730 yr	promethium-147	^{147}Pm	2.62 yr
sodium-22	^{22}Na	2.6 yr	europium-152	^{152}Eu	12 yr
potassium-40	^{40}K	1.26×10^{9} yr	europium-154	^{154}Eu	16 yr
argon-41	^{41}Ar	1.8 h	europium-155	^{155}Eu	1.8 yr
chromium-51	^{51}Cr	27.7 d	thallium-208	^{208}Tl	3.1 min
manganese-54	^{54}Mn	312 d	bismuth-212	^{212}Bi	60.6 min
cobalt-57	^{57}Co	271.8 d	lead-212	^{212}Pb	10.6 h
cobalt-60	^{60}Co	5.3 yr	polonium-212	^{212}Po	0.3×10^{-6} s
nickel-63	^{63}Ni	92 yr	polonium-216	^{216}Po	0.15 s
zinc-65	^{65}Zn	243.8 d	radon-220	^{220}Rn	55.6 s
krypton-85	^{85}Kr	10.7 yr	radium-226	^{226}Ra	1600 yr
strontium-89	^{89}Sr	52 d	radium-228	^{228}Ra	5.75 yr
strontium-90	^{90}Sr	28.8 yr	thorium-232	^{232}Th	1.4×10^{10} yr
niobium-95	^{95}Nb	36 d	uranium total	U or uranium[a]	---
zirconium-95	^{95}Zr	64.0 d	uranium-234	^{234}U	2.4×10^{5} yr
molybdenum-99	^{99}Mo	66.0 h	uranium-235	^{235}U	7×10^{7} yr
technetium-99	^{99}Tc	2.12×10^{5} yr	uranium-236	^{236}U	2.3×10^{7} yr
ruthenium-103	^{103}Ru	39.4 d	uranium-238	^{238}U	4.5×10^{9} yr
ruthenium-106	^{106}Ru	367 d	plutonium-238	^{238}Pu	87.7 yr
tin-113	^{113}Sn	115 d	neptunium-239	^{239}Np	2.4 d
antimony-125	^{125}Sb	2.7 yr	plutonium-239	^{239}Pu	2.4×10^{4} yr
iodine-129	^{129}I	1.6×10^{7} yr	plutonium-240	^{240}Pu	6537 yr
iodine-131	^{131}I	8.0 d	plutonium-241	^{241}Pu	14.4 yr
barium-133	^{133}Ba	10.53 yr	americium-241	^{241}Am	433 yr
cesium-134	^{134}Cs	2.1 yr			

(a) Total uranium may also be indicated by U-natural (U-nat) or U-mass.

that can be obtained, free, by writing to Dr. Robert H. Gray, Manager, Office of Health and Environment, P.O. Box 999, Richland, Washington 99352. More comprehensive readings on radiation and radiation dose can be found in most public libraries and in many local book stores.

Understanding the Data Tables

Measuring any physical quantity (for example, temperature, distance, time, or radioactivity) has some degree of

inherent uncertainty. This uncertainty results from the combination of all possible inaccuracies in the measurement process, including such factors as the reading of the result, the calibration of the measurement device, and numerical rounding errors. In this report, individual radioactivity measurements are accompanied by a plus or minus (±) value (sometimes expressed as a percentage of the related concentration value), which is an uncertainty term known as either the two-sigma counting error or the total propagated error (see Sections 5.4 and 5.6). Total propagated error includes counting error and analytical error. Because measuring a radionuclide requires a process of counting random radioactive emissions from a sample, the counting error gives information on what the measurement might be if the same sample were counted again under identical conditions. The counting error implies that approximately 95% of the time, a recount of the same sample would give a value somewhere between the reported value minus the counting error and the reported value plus the counting error. Values in the tables that are less than the counting error indicate that the reported result might have come from a sample with no radioactivity. Such values are considered as below detection. Also note that each radioactive measurement must have the random background radioactivity of the measuring instrument subtracted; therefore, negative results are possible, especially when the sample has very little radioactivity.

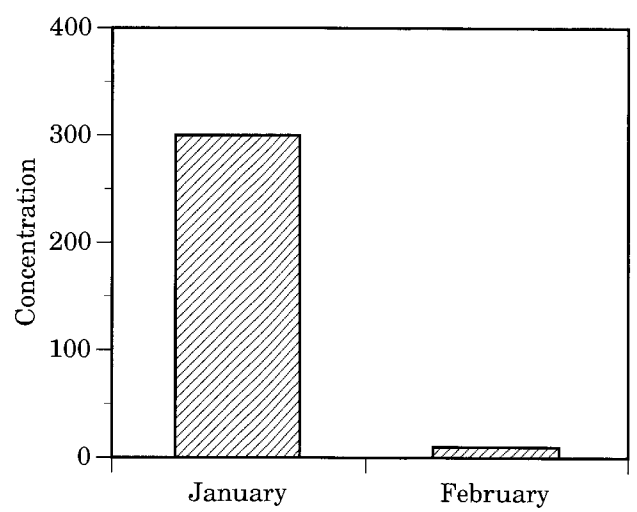
Just as individual values are accompanied by counting errors, mean values are accompanied by two standard errors of the calculated mean (2*SEM). In this report, 2*SEM is sometimes expressed as a percentage of the mean concentration value. If the data fluctuate randomly, then the 2*SEM is a measure of the uncertainty in the estimated mean of the data from this randomness. If trends or periodic (for example, seasonal) fluctuations are present, then the 2*SEM is primarily a measure of the variability in the trends and fluctuations about the mean of the data.

Understanding Graphical Information

Presenting data on a graph is useful when comparing numbers collected at several locations or at one location over time. Graphs make it easier to visualize differences where they exist. However, while graphs may make it easier to evaluate data, they may also lead the reader to incorrect conclusions if they are not interpreted correctly. Careful consideration should be given to the scale (linear or logarithmic) concentration units, and the type of uncertainty used.

Some of the data graphed in this report are plotted using logarithmic (or compressed) scales. Logarithmic scales are useful when plotting two or more numbers that differ greatly in size. For example, a sample with a concentration of 5 g/L would get lost at the bottom of the graph if plotted on a linear scale with a sample having a concentration of 300 g/L (Figure H.1). A logarithmic plot of these same two numbers allows the reader to clearly see both data points (Figure H.2).

The mean values graphed in this report have vertical lines extending above and below the data point. These lines (called error bars), which are usually capped at both ends with a short horizontal line, indicate the amount of uncertainty (2*SEM) in the reported result. The error bars in this report represent a 95% chance that the mean is between the upper and lower ends of the error bar, and a 5% chance that the true mean is either lower or higher than the error bar.[a] For example, in Figure H.3, the first plotted mean is 2.0 ± 1.1, so there is a 95% chance that the actual result is between 0.9 and 3.1, a 2.5% chance it is less than 0.9, and a 2.5% chance it is greater than 3.1. Error bars are computed statistically employing all of the information used to generate the data point plotted on the



S9203058.34

Figure H.1. Data Plotted Using a Linear Scale

(a) Assuming the Normal statistical distribution of the data.

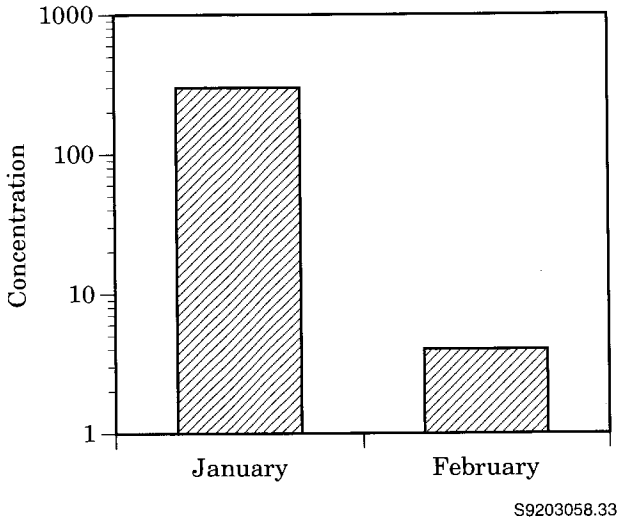


Figure H.2. Data Plotted Using a Logarithmic Scale

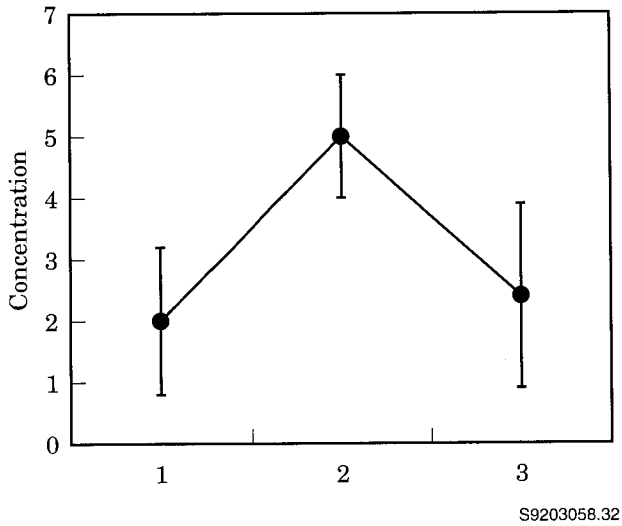


Figure H.3. Data With Error Bars Plotted Using a Linear Scale

graph. These bars provide a quick visual indication that one mean may be statistically similar to or different from another mean. If the error bars (or range of values) of two or more means overlap, as is the case with means 1 and 3 and means 2 and 3, the means may be similar, statistically. If the error bars do not overlap (means 1 and 2), the means may be statistically different. Means that appear to be very different visually (means 2 and 3) may actually be quite similar when compared statistically.

Uncertainties (error bars) are not plotted in Section 5.6, "Soil and Vegetation Surveillance." Instead, sample median, maximum, and minimum values are illustrated. Uncertainties are not used because of the small number of soil and vegetation samples collected and analyzed during the year.

Greater Than (>) or Less Than (<) Symbols

Greater than (>) or less than (<) symbols are used to indicate that the actual value may either be larger than the number given or smaller than the number given. For example, >0.09 would indicate that the actual value is greater than 0.09. An inequality symbol pointed in the opposite direction (<0.09) would indicate that the number is less than the value presented. If an inequality symbol is used in association with an underscore (≤ or ≥), this indicates that the actual value is less-than-or-equal-to or greater-than-or-equal-to the number given, respectively.

Elemental and Chemical Constituent Nomenclature

Constituent	Symbol	Constituent	Symbol
aluminum	Al	iron	Fe
ammonia	NH_3	lead	Pb
ammonium	NH_4^+	lithium fluoride	LiF
antimony	Sb	magnesium	Mg
arsenic	As	manganese	Mn
barium	Ba	mercury	Hg
beryllium	Be	nickel	Ni
bicarbonate	HCO_3^-	nitrate	NO_3^-
boron	B	nitrogen	N
cadmium	Cd	nitrogen dioxide	NO_2
calcium	Ca	phosphate	PO_4^{-3}
calcium fluoride	CaF_2	phosphorus	P
carbon	C	potassium	K
carbonate	CO_3^{-2}	selenium	Se
carbon tetrachloride	CCl_4	silver	Ag
chloride	Cl^-	sodium	Na
chromium (species)	Cr^{+6}	strontium	Sr
chromium (total)	Cr	sulfate	SO_4^{-2}
cobalt	Co	thallium	Tl
copper	Cu	trichloromethane	$CHCl_3$
cyanide	CN^-	vanadium	V
fluoride	F^-	zinc	Zn

Conversion Table

Multiply	By	To Obtain	Multiply	By	To Obtain
in.	2.54	cm	cm	0.394	in.
ft	0.305	m	m	3.28	ft
mi	1.61	km	km	0.621	mi
lb	0.454	kg	kg	2.205	lb
liq qt	0.946	L	L	1.057	liq qt
ft^2	0.093	m^2	m^2	10.76	ft^2
acres	0.405	ha	ha	2.47	acres
mi^2	2.59	km^2	km^2	0.386	mi^2
ft^3	0.028	m^3	m^3	35.7	ft^3
dpm	0.450	pCi	pCi	2.22	dpm
nCi	0.001	pCi	pCi	1,000	nCi
pCi/L	10^{-9}	µCi/mL	µCi/mL	10^9	pCi/L
pCi/m^3	10^{-12}	Ci/m^3	Ci/m^3	10^{12}	pCi/m^3
pCi/m^3	10^{-15}	mCi/cm^3	mCi/cm^3	10^{15}	pCi/m^3
mCi/km^2	1.0	nCi/m^2	nCi/m^2	1.0	mCi/km^2
becquerel	2.7×10^{-11}	curie	curie	3.7×10^{10}	becquerel
gray	100	rad	rad	0.01	gray
sievert	100	rem	rem	0.01	sievert
ppb	0.001	ppm	ppm	1,000	ppb
°F	(°F - 32) ÷ 9/5	°C	°C	(°C x 9/5) + 32	°F

Acronyms and Abbreviations

AALG	ambient air level goals
ALARA	as low as reasonably achievable
ALE	Arid Lands Ecology (Reserve)
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COES	community-operated environmental surveillance
DCE	dichloroethylene
DCG	Derived Concentration Guide
DDT	dichlorodiphenyltrichloroethane
DOE	U.S. Department of Energy
DOH	Washington State Department of Health
DOI	U.S. Department of the Interior
DWS	Drinking Water Standard
EA	environmental assessment
Ecology	Washington State Department of Ecology
EDE	effective dose equivalent
EIS	environmental impact statement
EM-50	Office of Technology Development
EML	environmental measurement laboratory
EMSL	environmental monitoring and surveillance laboratory
EPA	U.S. Environmental Protection Agency
ERA	Expedited Response Actions
ERMC	Environmental Restoration/Remediation Management Contractor
ERRA	Environmental Restoration Remedial Action (Program)
ES&H	environment, safety, and health
ES&QA	Environmental Safety and Quality Assurance
FEMP	Facility Effluent Monitoring Plan
FFCA	Federal Facility Compliance Agreement
FFTF	Fast Flux Test Facility
FR	Federal Register
FY	fiscal year
HCRL	Hanford Cultural Resources Laboratory
HEDR	Hanford Environmental Dose Reconstruction (Project)
HQ	U.S. Department of Energy-Headquarters
HGP	Hanford generating plant
HRA	Hanford remedial action
HMS	Hanford Meteorological Station
HWVP	Hanford waste vitrification plant
ICRP	International Commission on Radiological Protection
IT	International Technology Corporation

KEH	Kaiser Engineers Hanford
LEPS	low-energy photon
LLBG	low-level burial ground
LWDF	liquid waste disposal facility
MCL	maximum contaminant level
MCLG	maximum contaminant level goals
MDA	minimum detectable activity
MDC	minimum detectable concentration
MEI	maximally exposed individual
NASQAN	Natural Stream Quality Accounting Network
NCRP	National Council on Radiation Protection and Measurements
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NOV	notice of violation
NPDES	National Pollutant Discharge Elimination System
NPR	new production reactor
NPS	National Park Service
NRC	U.S. Nuclear Regulatory Commission
NS	no standard or no sample
NTU	nephelometric turbidity unit
NWR	national wildlife refuge
OEMP	Operational Environmental Monitoring Program
PCB	polychlorinated biphenyl
PEIS	programmatic environmental impact statement
PFP	Plutonium Finishing Plant
PNL	Pacific Northwest Laboratory
PQD	Process Quality Department
PSD	prevention of significant deterioration
PUREX	Plutonium Uranium Extraction (Plant)
QA	quality assurance
QATF	Quality Assurance Task Force
QC	quality control
RCA	radiologically controlled area
RCHN	Richland North
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
REDOX	Reduction Oxidation (Plant)
RI/FS	remedial investigation/feasibility study
RL	U.S. Department of Energy Richland Operations Office
SAIC	Science Application International Corporation
SARA	Superfund Amendments and Reauthorization Act
SCA	surface contamination area
SE	standard error
SEM	standard error of the mean
SEN	Secretary of Energy Notice
SI	International System of Units
TCE	trichloroethylene

TLD	thermoluminescent dosimeter
TRIDEC	Tri-Cities Industrial Development Council
TRU	transuranic
TSD	treatment, storage, and disposal
TSS	total suspended solids
TWRS	Tank Waste Remediation Systems
UNSCEAR	United Nations Science Committee on the Effects of Atomic Radiation
UO_3 Plant	Uranium Trioxide Plant
URM	underground radioactive materials
USGS	U.S. Geological Survey
USRADS	Ultrasonic Ranging and Data System
UST	Underground Storage Tank
VOA	volatile organic analyses
VOC	volatile organic compound
WAC	Washington Administrative Code
WIPP	Waste Isolation Pilot Plant
WHC	Westinghouse Hanford Company
WRA	Wildlife Recreation Area

Introduction

1.0 Introduction

The purpose of this report is to summarize information and data that characterize Hanford Site environmental management performance and demonstrate the status of compliance with applicable federal, state, and local environmental laws and regulations. The report also highlights significant environmental programs and efforts.

The report describes the Site mission and activities, general environmental features, radiological and chemical releases from operations, status of compliance with environmental regulations, status of programs to accomplish compliance, and environmental monitoring activities and results.

Those interested in more detail than the summary information presented in this report are referred to the technical reports cited in the text. Report sources include local community libraries and the National Technical Information Center, Springfield, Virginia 22161. Descriptions of analytical and sampling methods, formerly part of this report, are contained in the *Hanford Site Environmental Monitoring Plan* (DOE 1991b). Readers less familiar with the concepts, terminology, and units used in this report may find the preceding Helpful Information section useful.

1.1 Site Mission

The Hanford Site was acquired by the federal government in 1943. In the early years, Hanford Site facilities were dedicated primarily to the production of plutonium for national defense and management of the resulting wastes. In later years, programs at the Hanford Site were diversified to include research and development for advanced reactors, renewable energy technologies, waste disposal technologies, and cleanup of contamination from past practices.

The U.S. Department of Energy (DOE) is establishing a new mission for Hanford including:

- Waste Management of stored defense wastes and the handling, storage, and disposal of radioactive, hazardous, mixed, or sanitary wastes from current activities

- Environmental Restoration of approximately 1,100 inactive radioactive, hazardous, and mixed waste sites and about 100 surplus facilities

- Research and Development in energy, health, safety, environmental sciences, molecular sciences, environmental restoration, waste management, and national security

- Technology Development of new environmental restoration and waste management technologies, including site characterization and assessment methods; waste minimization, treatment, and remediation technology; space energy and isotope production; education outreach programs; and other special initiatives.

The DOE has set a goal of bringing its facilities into compliance with local, state, and federal environmental laws as soon as possible and of completing waste site cleanup by 2018.

1.2 Introduction to the Hanford Site

The Hanford Site lies within the semi-arid Pasco Basin of the Columbia Plateau in southeastern Washington State (see Figure 1.1). The Site occupies an area of about 1,450 km^2 (approximately 560 mi^2) north of the confluences of the Snake and Yakima rivers with the Columbia River. This land, with restricted public access, provides a buffer for the smaller areas historically used for production of nuclear materials, waste storage, and waste disposal; about 6% of the land area has been disturbed and is actively used. The Columbia River flows eastward through the northern part of the Hanford Site and then turns south, forming part of the eastern boundary. The Yakima River runs along part of the southern boundary and joins the Columbia River downstream from the city of Richland. Adjoining lands to the west, north, and east are principally range and agricultural land in Benton, Grant, and Franklin counties. The cities of Richland, Kennewick, and Pasco (Tri-Cities) constitute the nearest population center and are located southeast of the Hanford Site.

Estimates by the U.S. Bureau of the Census for 1990 place the population totals for Benton, Franklin, and Grant counties at 112,560, 37,473, and 53,100, respectively. The 1990 estimates for the Tri-Cities populations are Richland, 32,315; Kennewick, 42,159; and Pasco, 20,337. The populations of Benton City, Prosser, and West Richland totaled 10,244 in 1990. The population of Benton and Franklin counties is young, with 56% of the total population under the age of 35, compared with 54% of the total state population. An examination of age groups in 5-year increments reveals that the largest age group in Benton and Franklin counties ranges from 5 to 9 years old, representing 9.3% of the total bicounty population; the largest group in the state ranges from 30 to 34 years, which represents about 9% of the total state population.

The entire Hanford Site was designated a National Environmental Research Park (one of four nationally) by the former Energy Research and Development Administration, a precursor to DOE.

The major operational areas on the Site include:

- The 100 Areas, bordering on the right bank (south shore) of the Columbia River, are the sites of eight retired plutonium production reactors and the N Reactor, which is currently in a shutdown condition. The 100 Areas occupy about 11 km^2 (4 mi^2).

- The 200-West and 200-East Areas are located on a plateau and are about 8 and 11 km (5 and 7 mi), respectively, south of the Columbia River. These areas historically have been dedicated to fuel reprocessing and waste processing management and disposal activities. The 200 Areas cover about 16 km^2 (6 mi^2).

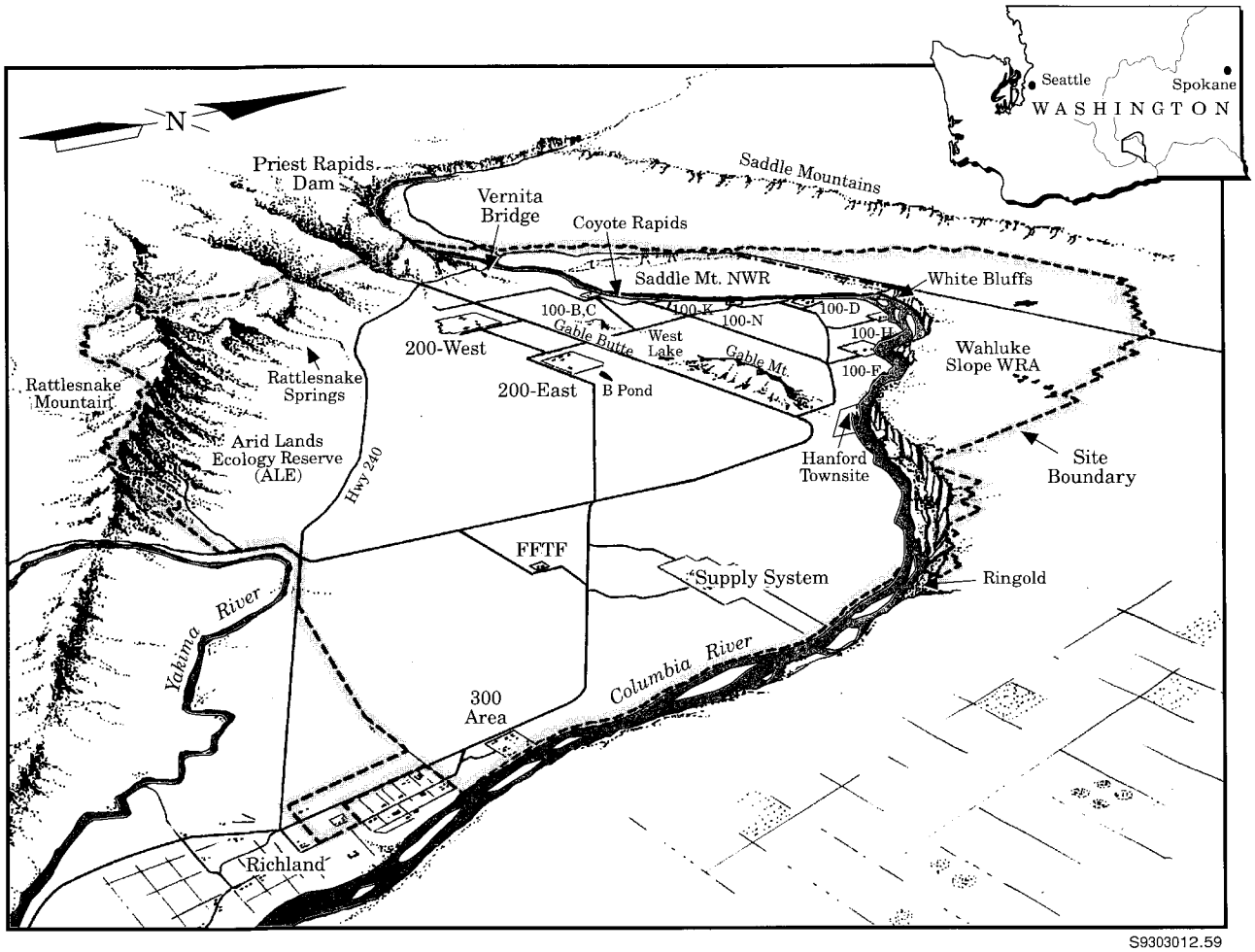
- The 300 Area, located just north of the city of Richland, is the site of nuclear research and development. This area covers 1.5 km^2 (0.6 mi^2).

- The 400 Area is about 8 km (5 mi) northwest of the 300 Area and is the site of the Fast Flux Test Facility (FFTF), used in the testing of breeder reactor systems. Also included in this area is the Fuels and Materials Examination Facility.

- The 600 Area includes all of the Hanford Site not occupied by the 100, 200, 300, and 400 Areas.

Support areas near the Site include the 1100, 3000, and Richland North (RCHN) Areas, located in North Richland. The 1100 Area includes Site support services such as general stores and transportation maintenance. The 3000 Area includes the facilities for Kaiser Engineers Hanford (KEH). The RCHN Area includes the DOE and DOE contractor facilities located between the 300 Area and the city of Richland that are not in the 1100 and 3000 Areas.

Other facilities are located in the Richland Central Area (located south of Saint Street and Highway 240 and north



S9303012.59

Figure 1.1. DOE's Hanford Site and Surrounding Area

of the Yakima River), the Richland South Area (located between the Yakima River and Kennewick) and the Kennewick/Pasco area.

Several areas of the Site, totaling 665 km^2 (257 mi^2), have been designated as the Arid Lands Ecology (ALE) Reserve, the U.S. Fish and Wildlife Service Saddle Mountain National Wildlife Refuge (NWR), and the Washington State Department of Game Reserve Area [Wahluke Slope Wildlife Recreation Area (WRA)] (DOE 1986). The ALE Reserve was established in 1967 by the Atomic Energy Commission, a precursor to DOE. In 1971, the reserve was classified a Research Natural Area as a result of an interagency federal cooperative agreement.

Land use in surrounding environs includes urban and industrial development, irrigated and dry-land farming, and grazing. In 1990, wheat represented the largest single crop in terms of area planted in Benton and Franklin counties, with 190,857 ha (471,600 acres). Corn, alfalfa, potatoes, asparagus, apples, cherries, and grapes are other major crops in Benton, Franklin, and Grant counties. More than 20 processors in Benton and Franklin counties produce food products including potato products, canned fruits and vegetables, wine, and animal feed.

Much of the above information is from Cushing (1992), where more detailed information can be found.

1.3 Major Operations and Activities

The primary DOE operations and activities on the Hanford Site in 1992 included waste management, site restoration, environmental corrective actions, research and technology development, and site management. The majority of these activities were conducted under the Environmental Restoration and Waste Management Program for the Hanford Site. The cornerstone and framework for DOE's strategy for department-wide environmental restoration, waste management, and technology development is the DOE *Hanford Site Environmental Restoration and Waste Management Five-Year Plan, Fiscal Years 1992-1996* (DOE 1990b). This annually updated document was reissued with activity data sheets for fiscal year (FY) 1992 through 1998 on June 1, 1992. The DOE 5-year plan addresses overall philosophy and environmental and waste-related activities that are the responsibility of the Office of Environmental Restoration and Waste Management.

The *Environmental Restoration and Waste Management Site-Specific Plan for the Richland Operations Office: Detailed Information* (DOE 1989b) implements and supports the DOE 5-year plan. This detailed information volume is prepared so it can be used as a stand-alone document. The *Hanford Site Environmental Restoration and Waste Management Five-Year Plan, Fiscal Years 1992-1996* (DOE 1990b) is supported by two companion documents, the Overview of the Hanford Cleanup Five-Year Plan and the *Hanford Site Environmental Restoration and Waste Management Five-Year Plan Activity Data Sheets* (DOE 1990d). The overview provides a general plan description, and the activity data sheets provide supplemental data to the detailed information document.

Waste Management

Waste management is the safe and effective management of active and standby facilities and the treatment, storage, and disposal of radioactive, hazardous, and mixed waste. The waste management goals of the DOE, Richland Operations Office (RL), are to minimize the generation of waste, and to maintain safe and environmentally sound programs for treatment, storage, and disposal of newly generated and stored wastes. The Hanford Site Five-Year Plan (DOE 1990b) provides detailed descriptions of the Site's waste management programs and other activities. Summary descriptions of major programs and activities are presented here.

Waste Minimization

The Hanford Waste Minimization Program is an ambitious program aimed at source reduction, product substitution, recycling, waste treatment, and finally waste disposal. The program is tailored to meet Executive Order 12780, the DOE Orders, the Resource Conservation and Recovery Act (RCRA), and U.S. Environmental Protection Agency (EPA) guidelines. All wastes on the Hanford Site, including radioactive, mixed, hazardous, and nonhazardous regulated wastes are included in the Hanford Waste Minimization Program.

Requirements for the Hanford Site program now include the following:

- the Secretary of Energy Notice (SEN) 37-92 Pollution Prevention report
- a biennial EPA waste minimization report
- an annual EPA source reduction and recycling report attached to the Superfund Amendments and Reauthorization Act (SARA) 313 Report
- an annual DOE-required Hanford Site and contractor-specific waste minimization plan review and update
- update of the Sitewide and facility-specific RCRA Part B permits
- DOE-required process waste assessments following state guidelines

- waste minimization and pollution prevention program plans (updated for the Hanford Site and each contractor).

Each of the above initial reports and/or assessments has been completed.

Waste minimization efforts have reduced the volume of wastewater discharged to process trenches in the 300 Area of the Site by more than 5.7 million L/d (1.5 million gal/d). Modifications included installing closed-loop cooling, plugging drains, lowering thermostats in steam-heated buildings, using water in water-cooled equipment only when required, and putting administrative controls in place where possible.

In addition, a multifunction Tank Space Management Board consisting of plant managers was established to review efforts to reduce wastes generated and sent to the tank farms for storage. Task teams imposed maximum waste-generation limits for each plant, and approval from the management board was necessary to exceed the established volumes. The volume of liquid waste avoided through waste reduction efforts to date exceeds 22 million L (5.8 million gal).

A paper recycling program has expanded to include 194 buildings onsite. In 1992, approximately 200 tons (181,440 kg) of paper were recycled. Current projects include packaging reduction, waste minimization design checklist, and technology transfer.

Soil Column Discharges

A major strategy for Hanford Site's waste management is to discontinue discharges of contaminated liquid effluents to the soil column. Effluent streams containing hazardous and/or radioactive wastes will no longer be discharged or will be treated to remove contaminants before discharge. Thirty-two liquid effluent streams have been identified for which action is required. This action is included as a milestone under the Consent Order DE 91NM-177 (liquid effluent study) and the Tri-Party Agreement (see Section 2.1, "Environmental Compliance and Cleanup").

A plan and schedule have been prepared in accordance with DOE Order 5400.5, "Radiation Protection of the Public and the Environment," and have been implemented to discontinue the disposal of contaminated liquids into the soil at the Hanford Site. Discharge of contaminants in the major waste streams will be discontinued by 1995 either by stopping the discharge or treating the effluent stream to remove contaminants. Technologies for treating the effluent streams are being evaluated to determine which would best meet regulatory requirements.

Stored Wastes

The major effort for cleanup of the Hanford Site will be the disposal of stored wastes generated from past production operations. The strategies for handling and disposing of these wastes, as well as newly generated wastes, have been documented through the National Environmental Policy Act process. The resulting record of decision recommends implementing preferred alternatives, described by the *Final Environmental Impact Statement, Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes* (DOE 1987b). The preferred alternatives recommend disposal of double-shell tank waste, irretrievably stored and newly generated transuranic waste, and encapsulated cesium and strontium waste as follows.

Double-shell tank waste will be separated into three fractions: high-activity waste, transuranic waste, and low-activity waste. The 28 double-shell tanks store more than 91 million L (24 million gal) of radioactive liquid and slurry, much of which has been transferred and concentrated from single-shell tanks. The high-activity waste and transuranic waste will be processed into a solid, vitrified material similar to glass and disposed of in a repository. The low-activity waste will be mixed with a cement-like material and allowed to harden in near-surface concrete vaults.

Solid transuranic waste that has been retrievably stored since 1970 or has been newly generated will be sorted and packaged in the proposed Waste Receiving and Processing Facility for shipment to the Waste Isolation Pilot Plant (WIPP) in New Mexico. WIPP-certified transuranic wastes are currently being stored in the 200 Area Transuranic Waste Storage and Assay Facility.

Cesium and strontium capsules will continue to be stored for eventual disposal in a repository. The cesium and strontium were removed from single shell tank wastes to reduce heat generation. There are currently 961 cesium capsules and 597 strontium capsules stored at the Hanford Site (41,718,000 Ci of cesium and 24,532,000 Ci of strontium).

For single-shell tank waste, transuranic-contaminated soil sites, and pre-1970 buried, suspect, transuranic-contaminated solid waste, the recommended strategy is to continue the development and evaluation of disposal technology before making a disposal decision. Wastes will continue to be stored in a manner that protects the environment and human health.

Storage will continue until treatment and disposal facilities are constructed and treatment processes are implemented. A notice of intent is being prepared for an environmental impact statement on the Tank Waste Remediation System. This document will supersede the environmental impact statement for disposal of the single-shell tank wastes.

Current waste storage activities at the Site primarily include the management of high- and low-activity defense wastes in the 200-East and 200-West Areas (see Figure 1.1) and the storage of irradiated defense fuel in the 100-K Area. Key facilities include the waste storage tanks, Central Waste Complex, Low-Level Burial Grounds (LLBG), 100-K fuel storage basins, Plutonium Uranium Extraction (PUREX) Plant, Plutonium Finishing Plant (PFP), B Plant, 616 Storage Facility, and 242-A Evaporator.

Waste-management activities involving single-shell and double-shell tanks currently include monitoring of the tanks and upgrading monitoring instrumentation. Concerns have been raised about the potential of a ferrocyanide explosion and hydrogen gas accumulation in the waste tanks. One issue is that under certain conditions of chemical concentration, moisture, and temperature, ferrocyanide and nitrates in the single-shell tanks could release heat and potentially become explosive. The other issue is that flammable explosive hydrogen gases may be trapped beneath the crust in five double-shell tanks and 18 single-shell tanks. The DOE and external oversight groups have concluded that there is no imminent danger to the public from either situation. The Tank Waste Remediation System Division has the responsibility to identify any hazards associated with the waste tanks and implement the necessary actions to mitigate or remediate those hazards.

The 100-KE and 100-KW fuel storage basins are currently being used to store N Reactor irradiated fuel. An operational readiness review was prepared by RL, and two readiness schedules are being integrated for efforts to encapsulate the 105-KE basin fuel and clean up the remaining bottom debris and sludge accumulated over the years. Preparations continued on the notification of construction for Washington State Department of Health (DOH) approval of air emissions expected from this activity. Negotiations on arrangements and schedules are continuing.

The PUREX Plant formerly processed irradiated reactor fuel to extract plutonium. Operation of the plant was stopped on December 7, 1988, for safety reasons. From December 1989 through March 1990, the facility completed a stabilization run to process fuel remaining in the plant. The PUREX Plant has not operated since the stabilization run. Inventories of solvent and nuclear materials remain, including liquid uranyl nitrate hydrates, fuel from Hanford single-pass reactors, and organic materials. During 1992, transition of the PUREX Plant from "a standby condition" to an orderly "shutdown" began. The PUREX Plant is currently pursuing a deactivation mode in which preparations have begun to deactivate systems and proceed to permanent shutdown.

The Uranium Trioxide Plant (UO_3) began preparations in 1992 to process the remaining inventories of liquid uranyl nitrate hexahydrate from the PUREX Plant. Westinghouse Hanford Company (WHC) and DOE completed an operational readiness review. The operational campaign for this facility is planned for mid-April 1993 and will be completed by mid-June 1993. Following the campaign, the plant will transition to shutdown.

The PFP was used to convert plutonium liquids from the PUREX Plant to plutonium oxide or metal. The PFP has not produced a product since 1987. The plant also processed and stabilized scrap plutonium materials. Reactivation of the Plutonium Reclamation Facility, one of the operations at the PFP, is scheduled for mid-June 1993. The operational readiness review and training run are progressing toward the scheduled startup; however, a temporary administrative hold on plant activities was initiated March 23, 1993, for safety-related occurrences involving personnel contamination. The readiness review will continue following investigation and resolution of the occurrences.

There are no production activities currently taking place at B Plant but several operating systems are required to accomplish the B Plant facility mission, which is to ensure safe storage and management of radiological inventories.

The Grout Treatment Facility will treat and dispose of low-level mixed waste liquid removed from the double-shell tanks. The facility combines liquid wastes with dry materials such as cement, limestone, fly ash, and blast furnace slag to produce a grout slurry that is pumped into underground concrete vaults, where it solidifies. Approximately 610 million L (160 million gal) of mixed waste are planned to be processed between 1992 and 2014. Facility systems were being prepared during 1992 with construction continuing on four new vaults for a scheduled operation in October 1993.

The 242-A Evaporator is used to reduce the volume of liquid wastes from double-shell waste tanks. The process condensate will then be stored in liquid effluent retention facilities until the liquid effluent treatment facility is complete. The concentrated double-shell tank waste will be returned to the double-shell tanks. Operational readiness reviews are being conducted on the retention facilities. The liquid effluent treatment facility is being designed and constructed in the 200-East Area to remove regulated chemical constituents from the 242-A Evaporator process condensate.

Environmental Restoration

The environmental restoration program has been established to remediate inactive waste sites, and to decontaminate and decommission surplus facilities. The Hanford Site has established the following two major programs for implementing these actions:

1. Environmental Restoration Remedial Action (ERRA) Program

2. Decontamination and Decommissioning Program.

Activities conducted within these programs are summarized in the following subsections. The ERRA and the Decontamination and Decommissioning Program activities will be managed by the Environmental Restoration/Remediation Management Contractor.

Environmental Restoration Remedial Action Program

The ERRA Program was established to comply with regulations for characterization and cleanup of inactive waste sites. The program specifically includes identification and characterization of inactive sites, remedial design and cleanup action, and post-closure activities of inactive radioactive, chemically hazardous, and mixed waste sites.

All of the waste disposal sites at the Hanford Site have been grouped into 78 operable units. An operable unit is a grouping of waste sites for conducting a remedial investigation and carrying out remedial actions. Operable units form the basis for planning, scheduling, budgeting, and establishing the working order for some of the environmental restoration milestones for the Tri-Party Agreement (see Section 2.1, "Environmental Compliance and Cleanup"). Remedial investigations are being conducted at 16 operable units to determine the need for remediation at these units. The ERRA Program also initiated expedited response actions on three individual waste sites in 1991 and 1992: the 618-9 Burial Ground, the 300 Area Process Trenches, and the 200-West Area Carbon Tetrachloride site. In 1992, more than 40 drums containing over 5,678 L (1,500 gal) of solvent were removed from the 618-9 Burial Ground, preventing the liquid from eventually reaching the ground water. In 1992, work was completed at the 300 Area Process Trenches where approximately 5,300 m^3 (7,000 yd^3) of contaminated soil were removed and isolated. A pilot-scale carbon tetrachloride vapor extraction unit was successfully demonstrated at the 200-West Area, and procurement of a full-scale system was initiated.

Decontamination and Decommissioning Program

Many DOE-owned facilities at the Hanford Site that were used to support the defense production mission have been retired from service and declared surplus. The Decontamination and Decommissioning Program manages these facilities for DOE. The program provides for surveillance and maintenance, as well as eventual decontamination and decommissioning of these facilities.

The program manages about 100 separate facilities including large concrete and cement block structures that formerly housed chemical separations processes, underground effluent water systems and storage tanks, and ancillary buildings. Included also are the eight graphite-moderated plutonium production reactors

constructed between 1943 and 1955. These reactors have now been shut down for more than 20 years.

Activities conducted during 1992 include surveillance and maintenance of surplus facilities, decommissioning of the 201-C Strontium Semiworks, and preparation of the *Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington.* The final environmental impact statement (DOE 1992h), which has been released for public review, discusses various alternatives for decommissioning these reactors. The record of decision is scheduled to be published in FY 1993.

Corrective Activities

Corrective activities consist of actions to comply with regulatory requirements or compliance agreements with federal, state, or local regulatory agencies. Corrective actions in 1992 are addressed in Section 2.0, "Environmental Compliance Summary."

Research and Technology Development

Research and technology development activities on the Hanford Site are located in the 200, 300, 400, 3000, and RCHN Areas. Many of these activities are intended to improve the techniques and reduce the costs of waste management, environmental protection, and Site restoration.

One of the main research facilities is the FFTF. The FFTF's normal operating fuel cycle ended, and the facility was shut down on March 19, 1992. A DOE directive was issued mid-April 1992 to place the facility in a "hot" standby condition. This condition means that facility systems can readily start up on demand. FFTF has remained in this condition, pending congressional authorization to fund future operations and determination of a new mission, as directed by DOE.

The Office of Technology Development (EM-50) was established within the Office of Environmental Restoration and Waste Management to develop and deploy new technologies that will support compliance with applicable regulations and agreements, minimize wastes, reduce costs, and improve environmental restoration activities and waste management operations.

EM-50's approach is to manage its technology development activities through mechanisms called integrated demonstrations, integrated programs, and supporting technology programs. An integrated demonstration identifies systems of technologies that can be used to solve high-priority, complex-wide (across DOE sites) problems. This focused approach lowers costs and accelerates acceptance of the new technologies for use. The performance of the technologies is evaluated individually and as part of complete systems for the complete solutions to problems. An integrated program focuses on the initial research and development of new technologies within a key functional area such as characterization or separations. The new technologies from the integrated programs may go on to the integrated demonstrations for testing or to the ultimate user.

The technology development program at the Hanford Site is conducted as a joint effort by RL, Pacific Northwest Laboratory, WHC, and KEH. The integrated demonstrations and integrated programs that are coordinated for EM-50 by contractors at the Hanford Site include the Volatile Organic Compounds in Arid Soils (VOC-Arid) integrated demonstration, the Underground Storage Tank (UST) integrated demonstration, the Efficient Separations and Processing integrated program, and the In Situ Remediation Technology integrated program. The UST integrated demonstration is closely linked to related technology activities and is directed to solve DOE-wide UST problems and demonstrate solutions in tanks at Hanford. The VOC-Arid integrated demonstration is being conducted jointly with an expedited response action on the carbon tetrachloride plume in the 200-West Area.

Site Management

Hanford Site operations and activities are managed by RL through four prime contractors and numerous subcontractors. Each contractor is responsible for safe, environmentally sound maintenance and management of its facilities and operations; for waste management; and for monitoring of operations and effluents to ensure environmental compliance.

The principal contractors and their respective responsibilities include:

- Westinghouse Hanford Company, the operating and engineering contractor, conducts environmental restoration, manages wastes, operates FFTF, maintains N Reactor and its fuel fabrication facilities, and provides support services such as fire protection, stores, and electrical power distribution.

- Battelle Memorial Institute, the research and development contractor, operates the Pacific Northwest Laboratory for DOE, conducting research and development in environmental restoration and waste management, environmental science, molecular science, energy, health and safety, and national security.

- Kaiser Engineers Hanford, the engineering and construction services contractor, provides architectural, construction, and engineering services.

- Hanford Environmental Health Foundation is the occupational and environmental health services contractor.

Non-DOE operations and activities on the Hanford Site include commercial power production by the Washington Public Power Supply System WNP-2 Reactor and commercial low-level radioactive waste burial at a site leased and licensed by the State of Washington and operated by U.S. Ecology. Immediately adjacent to the southern boundary of the Site, Siemens Nuclear Power Corporation operates a commercial nuclear fuel fabrication facility, and Allied Technology Group Corporation operates a low-level radioactive waste decontamination, super compaction, and packaging disposal facility.

Environmental Compliance Summary

2.0 Environmental Compliance Summary

This section briefly describes how environmental compliance is being achieved for the Hanford Site. Included are subsections describing 1) the regulations and oversight of compliance at the Site, 2) the current status of the Site's compliance with the principal regulations, 3) the issues and actions arising from these compliance efforts, and 4) the environmentally significant environmental occurrences. The final subsection provides an update of these issues for January 1 through April 1, 1993, per DOE Orders.

2.1 Environmental Compliance and Cleanup

Many entities have a role in the DOE's new mission of environmental restoration and waste management. These include federal, state, and local regulatory agencies; environmental groups; regional communities; Indian nations; and individual citizens. The following subsections describe the roles of the principal agencies, organizations, and public in environmental compliance and cleanup of the Hanford Site.

Regulatory Oversight

Several federal, state, and local government agencies are responsible for enforcing and overseeing environmental regulations at the Hanford Site. These agencies include the EPA, the Washington State Department of Ecology (Ecology), the DOH, and the Tri-Counties (Benton-Franklin-Walla Walla Counties) Air Pollution Control Authority. These agencies issue permits, review compliance reports, participate in joint monitoring programs, inspect facilities and operations, and oversee compliance with applicable regulations. The DOE, through compliance audits and its directives to operations offices, initiates and assesses actions for conforming to environmental requirements.

The EPA is the principal federal environmental regulator in Washington State. The EPA develops, implements, and enforces environmental protection regulations and technology-based standards as directed by statutes passed by Congress. In some instances, the EPA has delegated environmental regulatory authority to the state or authorized the state program to operate in lieu of the federal program when the state's program meets or exceeds the EPA's requirements. For instance, the EPA has delegated or authorized enforcement authority to Ecology for air pollution control and many areas of hazardous waste management. In other activities, the state program is enforced directly upon federal agencies as provided by federal law. For example, the DOH has authority to implement the state program for radionuclide air emissions to the atmosphere at the Hanford Site in accordance with the federal facilities section of the Clean Air Act. Where regulatory authority is not delegated or authorized to the state, EPA Region 10 is responsible for reviewing and enforcing compliance with EPA regulations as they pertain to the Hanford Site.

The Tri-Party Agreement

The Hanford Federal Facility Consent and Agreement Order (also known as the Tri-Party Agreement) is an agreement among the EPA, Ecology, and DOE for achieving compliance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (including SARA) remedial action provisions and with RCRA treatment, storage, and disposal unit regulation and corrective action provisions. The Tri-Party Agreement 1) defines and ranks RCRA and CERCLA cleanup commitments, 2) establishes responsibilities, 3) provides a basis for budgeting, and 4) reflects a concerted goal of achieving full regulatory compliance and remediation, with enforceable milestones, in an aggressive but achievable manner. The Tri-Party Agreement was established with input from the public. Copies of the agreement and quarterly progress reports of activities are publicly available at the RL Public Reading Room in Richland, Washington, and at information repositories in Seattle and Spokane, Washington, and Portland, Oregon. To get on the mailing list to obtain Tri-Party Agreement updates, contact the EPA or RL directly, or call Ecology at 1-800-321-2008. Requests by mail can be sent to:

Hanford Mailing List
P.O. Box 1970 B3-35
Richland, WA 99352

or

Hanford Update
Department of Ecology
P.O. Box 47600
Olympia, WA 98504-7600

The Tri-Party Agreement consists of a legal agreement and an action plan. The legal agreement establishes jurisdictions, authorities, and other legal determinations among the parties. The five specific areas of involvement defined by the legal agreement are the following:

1. Identify RCRA treatment, storage, and disposal units that require permits, and establish schedules to comply with interim and final status requirements. Where applicable, RCRA Part B permit applications will be completed, closures accomplished, and post-closure care implemented.

2. Identify interim-action alternatives appropriate to implement the final RCRA corrective and CERCLA remedial actions.

3. Establish requirements for performing investigations to determine the nature and extent of threats to public health or the environment caused by actual or possible releases, and perform studies to identify, evaluate, and select alternatives for controlling possible releases.

4. Identify the nature, objective, and schedule of response actions for cleanup of hazardous material spills.

5. Implement the selected interim and final RCRA corrective and CERCLA remedial actions.

The action plan implements the legal agreement by 1) defining how the parties will work together, 2) describing the processes and procedures to be followed, 3) defining the units to be addressed, and 4) scheduling the work. The action plan, through enforceable milestones, establishes a plan and schedule for bringing the Hanford Site into compliance with applicable requirements of RCRA and all remedial action requirements of CERCLA.

The Role of Oregon State at the Hanford Site

Although the State of Oregon does not have a direct regulatory role at the Hanford Site, DOE recognizes that Oregon has an interest in Hanford Site cleanup because of the state's location downstream on the Columbia River and because of the potential for shipping radioactive wastes from the Hanford Site through Oregon. Oregon participates in the State and Tribal Government Working Group for the Hanford Site, which reviews the Site's cleanup plans.

The Oregon Department of Energy has the lead in the state's involvement at the Hanford Site. It is performing a 4-year research program on a contract scheduled to expire in 1993 to determine the effects of Hanford Site radioactive waste activities on the environment and on the health of Oregon residents. The Oregon Department of Energy provides information to the public, Oregon's congressional delegation, and state and local officials on proposed cleanup, transport, and disposal activities and costs. It also supports the Oregon Hanford Waste Board, which recommends policy to the governor and legislature. The board was reauthorized by the 1991 legislature and is composed of agency heads, members of the legislature, and citizens.

The Role of Indian Nations at the Hanford Site

The Hanford Site is located on land ceded in treaties in 1855 with the Yakima Indian Nation and the Confederated Tribes of the Umatilla Indian Reservation (the Umatilla, Cayuse, and Walla Walla Tribes). The Nez Perce Tribe has treaty rights on the Columbia River. The tribes retain rights and privileges in the ceded areas, including the right to take fish at usual and accustomed places.

In addition to the treaties of 1855, the following laws apply to Native American rights and culture at the Hanford Site: the American Indian Religious Freedom Act, the Archaeological Resources Protection Act, the National Historic Preservation Act, and the American Antiquities Preservation Act. The RL implementation program is described in Section 4.3, "Other Environmental Studies and Programs."

RL provides grants to the Yakima Indian Nation, the Confederated Tribes of the Umatilla Indian Reservation, and the Nez Pierce Tribe to ensure their involvement in the Environmental Restoration and Waste Management Five-Year Plan activities for cleanup of the Hanford Site (DOE 1990b). The Umatilla Tribes also have a grant to address their concerns about transporting wastes to the Waste Isolation Pilot Plant in New Mexico.

Public Participation

Individual citizens of Washington State and neighboring states may participate in determining how Hanford Site cleanup is conducted. A plan for community relations and public involvement is included in the Tri-Party Agreement. The community relations plan was developed and negotiated among DOE, Ecology, and EPA Region 10 with public comment and was jointly approved in 1990.

During 1992, quarterly information meetings were held in the Tri-Cities (Kennewick, Pasco, and Richland), Washington, to update the public on Tri-Party Agreement activities. Meeting dates were announced approximately 3 weeks in advance through the quarterly *Hanford Update* newsletter, news releases, and newspapers.

The DOE has also encouraged public participation in the Hanford Five-Year Plan. Before each meeting, the press is informed of the issues to be discussed, and notices are sent to elected officials, community leaders, and interest groups.

The public can obtain up-to-date information on the Hanford Site cleanup effort at the following four repositories:

1. the RL Public Reading Room, Richland, Washington
2. University of Washington Library, Seattle, Washington
3. Crosby Library, Gonzaga University, Spokane, Washington
4. Portland State University Library, Portland, Oregon.

The repositories receive copies of Tri-Party Agreement action plan quarterly progress reports, CERCLA/SARA and RCRA environmental restoration activities reports, closure and post-closure plans, RCRA permit applications, meeting summaries, and other publications related to the Site's cleanup.

2.2 Compliance Status

This section summarizes the activities conducted to ensure the Hanford Site is in compliance with federal environmental protection statutes and related Washington State and local environmental protection regulations, and the status of Hanford's compliance with these requirements. Environmental permits required under the environmental protection regulations are discussed under the applicable statute. Appendix C lists environmental permits currently issued for the Hanford Site.

Comprehensive Environmental Response, Compensation, and Liability Act

The CERCLA requires that specific procedures be implemented to assess inactive waste sites for the release of hazardous substances. The evaluation procedure is divided into three tiers of activity: 1) preliminary assessments, 2) remedial investigation/feasibility studies (RI/FS), and 3) remedial actions. The EPA has established procedures that the Hanford Site must comply with to conduct the three-tiered process.

Preliminary assessments conducted for the Hanford Site revealed that there are approximately 1,100 known individual waste sites where hazardous substances may have been disposed. These 1,100 sites have been grouped into 78 operable units, which have been further grouped into four aggregate areas using identifiable geographic boundaries. The four aggregate areas (Figure 2.1) have been placed on the EPA's National Priorities List, which requires a schedule and actions for their remediation.

The DOE is actively pursuing the RI/FS process at some operable units on the Hanford Site. The selection of the operable units is a result of Tri-Party Agreement negotiations. The Tri-Party Agreement provides the framework for meeting CERCLA cleanup requirements. All milestones related to the RI/FS process established for 1992 were achieved, and the Hanford Site was in compliance with these CERCLA/SARA requirements.

In October 1990, the Secretary of Energy proposed three accelerated cleanup actions. These actions would be completed as expedited response actions (a way to hasten clean up at sites to prevent further spread of contamination). Two of these actions were completed in 1991, and the final reports were issued in 1992. These actions included the removal of drums thought to contain hexone and uranium from a burial ground in the 300 Area and the removal of contaminated sediments from the bottom of the 300 Area Process Trenches. One action, the removal of carbon tetrachloride from the vadose zone of two ground disposal sites in the 200-West Area, began in February 1992. One vacuum system is currently operating 24 hours per day at a 14.2-m^3/min (500-cfm) capacity. A second system of the same size will be operational by the end of February 1993. A third system and upgrades to the two operating systems will provide a 85-m^3/min (3,000-cfm), round-the-clock vapor extraction program by March 31, 1993.

Six more accelerated cleanup actions were proposed by the Secretary of Energy in 1992, some of which have since been agreed to by the EPA and Ecology. These actions would 1) characterize and identify physical hazards associated with the 100 Area North Slope Disposal Site, 2) characterize and identify chemical hazards to the soil from the 100 Area Pickling Acid Cribs, 3) excavate and remove debris in the 100 Area Sodium Dichromate Landfill, 4) characterize and identify residual contamination of the 33.7 km^2 (13 mi^2) area in the northwest corner of the Hanford Site (Riverland), 5) characterize and identify hazards to the soil in the burial grounds north of the 300 Area, and 6) mitigate flow of contamination to the Columbia River.

Lawsuit Filed

The Legal Advocates for Washington and Heart of America Northwest filed a lawsuit against both WHC and RL on April 16, 1992. The suit alleges that WHC and DOE failed to notify the appropriate agencies on releases of hazardous substances from tanks 106-C, 105-A, connected piping, ventilation, infrastructure, duct work, and other connected tanks. Ecology has filed an appeal on the applicability of CERCLA to the discharges.

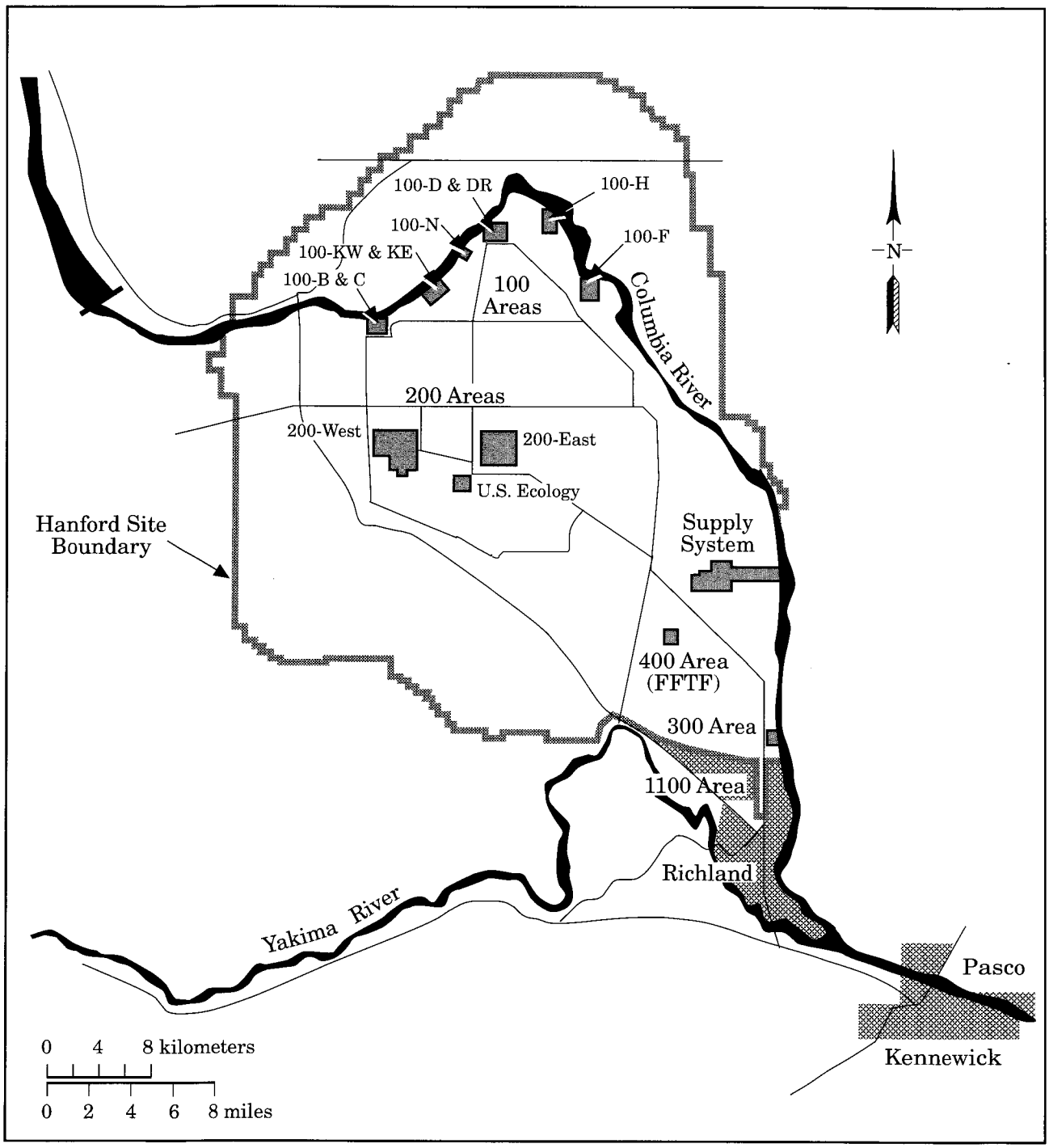


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Figure 2.1. Location of Aggregate Areas of the National Priorities List for the Hanford Site (100 Areas, 200 Areas, 300 Area, and 1100 Area)

Currently, the parties are awaiting adjudication on the defendants' "motion to dismiss." No lawsuits on CERCLA were filed during this time period.

Emergency Planning and Community Right-To-Know Act

The Emergency Planning and Community Right-To-Know Act provides the public with information about hazardous chemicals on the Site and establishes emergency planning and notification procedures to protect the public from a release. Subtitle A of the Act calls for creation of state emergency response commissions to guide planning for chemical release emergencies. State commissions have also created local emergency planning committees to ensure community participation and planning. Subtitle B contains requirements for periodic reporting on hazardous chemicals stored and/or used on the Site, to provide the public with the basis for emergency planning.

The *1992 Hanford Tier Two Emergency and Hazardous Chemical Inventory* (DOE 1993a) was issued to the State Emergency Response Commission, local county emergency management committees, and local fire departments. The report contained information on hazardous materials in storage across the Hanford Site. The *1991 Hanford Toxic Chemical Release Inventory* (DOE 1992i) report was issued July 1, 1992, to the EPA and state. This report contained information on releases to the environment of chemicals that were used in excess of mandated thresholds. Accordingly, during 1992, the Hanford Site was in compliance with the reporting requirements contained in this Act.

Pollution Prevention Program

As part of Section 313 of the Emergency Planning and Community Right-To-Know-Act, toxic chemical release inventory reporting program, a pollution prevention program (33/50) has been established that requires an annual evaluation on the use and release of 17 specific priority chemicals (Table 2.1). DOE's participation in the 33/50 pollution prevention program demonstrates the shift in emphasis in the way DOE generates and manages waste—from pollution control to pollution prevention. This program seeks to reduce releases of pollutants through avoidance or reduction in the generation of pollutants at their source.

Table 2.1. Seventeen Priority Chemicals of the Emergency Planning and Community Right-To-Know Act Pollution Prevention Program

Benzene	Methyl ethyl ketone
Cadmium and compounds	Methyl isobutyl ketone
Carbon tetrachloride	Nickel and compounds
Chloroform	Tetrachlorethylene
Chromium and compounds	Toluene
Cyanides	1,1,1-trichloroethane
Dichloromethane	Trichloroethylene
Lead and compounds	Xylene(s)
Mercury and compounds	

The 17 priority chemicals targeted for reduction in the 33/50 program are a subset of the chemicals listed in Section 313 of this Act. The thresholds listed in the Act are used to determine participation. The DOE is committed to reduce the baseline 1988 releases of these 17 priority chemicals by 50% by 1995. Each DOE site annually evaluates its use and release of the 17 priority chemicals identified for reduction in the 33/50 program. The information is provided to HQ, where it is aggregated for the Annual Progress Report provided to the EPA.

Hanford had not exceeded the reporting threshold for the use of any of the 17 priority chemicals until 1992. During 1992, the Site exceeded the threshold for lead, primarily because of the use of lead shot in ammunition used by Hanford Patrol for target practice. (This use of lead was not considered before 1991 because of the Act's focus on manufacturing and processing activities only for threshold determinations. As the shift in Hanford's mission refocused Site activities, those outside of manufacturing and processing activities were also considered during the threshold determinations.) An annual summary report of the 33/50 program information, containing the use and release of lead during 1992, will be completed for the Hanford Site by August 1993.

Resource Conservation and Recovery Act

The RCRA establishes regulatory standards for the generation, transportation, storage, treatment, and disposal of hazardous waste. Ecology has been authorized by the EPA to implement its own dangerous waste program in lieu of the EPA program for Washington State, except for some provisions of the Hazardous and Solid Waste Amendments of 1984. While Ecology's Dangerous Waste Regulations, contained in the Washington Administrative Code (WAC) 173-303, must be at least as stringent as the RCRA requirements, these regulations are often more stringent.

Approximately 63 treatment, storage, and/or disposal units that must be permitted or closed in accordance with RCRA and WAC 173-303 have been identified on the Hanford Site. Some of the treatment, storage, and/or disposal units contain numerous individual components (for example, the single-shell tank unit includes 149 separate tanks). The existing treatment, storage, and/or disposal units are required to be operated under Ecology's interim-status compliance requirements. Approximately one-half of the treatment, storage, and/or disposal units will be closed within a 10-year period.

The Tri-Party Agreement provides the framework for meeting RCRA requirements. Of 100 milestones scheduled for 1992, 96 were completed. For more information on these milestones, see Section 2.3, "Current Issues and Actions."

Enforcement Action

The DOE and its Hanford contractors are working to resolve several letters of noncompliance from Ecology that were received during 1992. Each of these letters lists specific violations. The following briefly summarizes these noncompliance letters:

1. In May 1992, a noncompliance letter was issued to WHC for an inspection of tank 241-SY-101. The primary violations alleged by Ecology were inadequate secondary containment and failure to inspect the tank monitoring systems.

2. In July 1992, Ecology issued a noncompliance letter to WHC for an overflow of PUREX Plant Tank F18. Alleged violations included lack of spill reporting, failure to inspect monitoring systems, and lack of both adequate secondary containment and overfill prevention controls.

3. In September 1992, Ecology issued a noncompliance letter to WHC for an inspection conducted during May 1992 at T Plant. The alleged violations were primarily related to waste generator requirements.

4. In October 1992, KEH and DOE received a noncompliance letter related to an Ecology inspection of the 200-East Area Slab Yard. The alleged violations were all associated with waste generator and container management requirements.

5. In October 1992, Ecology issued a noncompliance letter to Pacific Northwest Laboratory (PNL) and DOE following an inspection of the 305-B Storage Facility. Alleged violations were related to container management standards.

6. In November 1992, Ecology issued a noncompliance letter to WHC on alleged violations at the single shell tank 241-T-101. The violations were associated with the leak detection capabilities of the tank. With the letter, Ecology initiated a Tri-Party Agreement change request to add new milestones to the Tri-Party Agreement. New milestones have been approved by DOE, EPA, and Ecology, and are being completed on schedule.

Hanford RCRA Part B Permit

The draft permit application was issued for public comment in January 1992. Extensive comments from Ecology were received by DOE and WHC. Responses to Ecology's comments, as well as pertinent changes, were submitted to DOE-Headquarters (HQ) for final review. Comments from HQ have not been received by RL. When the Part B permit is finally issued, the Hanford Site Facility Permit will provide the foundation for all future RCRA permitting at Hanford in accordance with provisions of the Tri-Party Agreement.

Resource Conservation and Recovery Act Ground-Water Monitoring

Twenty-six ground-water monitoring wells were constructed at seven RCRA treatment, storage, and disposal facilities in 1992. This met the Tri-Party Agreement Milestone M-24-00.

For additional information on the ground-water monitoring activities that occurred in 1992, see Section 5.8 and Appendix E.

Resource Conservation and Recovery Act Underground Storage Tanks

Subtitle I of RCRA deals with regulation of underground storage tank systems containing regulated substances that include CERCLA hazardous substances and petroleum products. These regulations were added to RCRA by the Hazardous and Solid Waste Amendments of 1984. The EPA has developed regulations imposing technical standards for tank performance and management, including standards governing the cleanup and closure of leaking tanks. These regulations do not apply to the single- and double-shell nuclear waste tanks, which are regulated as treatment, storage, and disposal facilities. The EPA has authorized Ecology to implement the underground storage tank rules in Washington State. No compliance actions were taken by the EPA and Ecology during 1992 for activities conducted on the Site under this section of RCRA.

Clean Air Act

The EPA has established the Prevention of Significant Deterioration (PSD) program (40 CFR 52) to protect air quality while allowing a margin for future growth. The EPA has delegated authority to Ecology for regulation in Washington State of new emission sources under the PSD program.

The EPA issued a PSD permit to the DOE in 1980 for the Hanford Site. The permit sets specific limits for nitrogen oxides emissions from the PUREX and UO_3 Plants.

Significant increases in emissions from the Hanford Site of any criteria pollutant regulated by the Clean Air Act require agency review of potential impacts to regional air quality. Additional limits may be necessary in accordance with the PSD permit.

The DOH, Division of Radiation Protection, Air Emissions and Defense Waste Section, has developed regulatory controls for radioactive air emissions under Section 116 of the Clean Air Act. These controls are applicable to federal facilities such as the Hanford Site. WAC 246-247 requires registration of all radioactive air emission point sources with the DOH.

The EPA has retained authority in Washington State for regulating certain hazardous pollutants under the National Emission Standards for Hazardous Air Pollutants (NESHAP), in accordance with 40 CFR 61. These standards are designed to protect the public from hazardous air pollutants (for example, arsenic, asbestos, beryllium, mercury, radionuclides, and vinyl chloride).

Pursuant to the NESHAP program within the Clean Air Act, the EPA has developed regulations specifically addressing asbestos emissions. These regulations apply to the Hanford Site in building demolition and/or disposal and waste disposal operations. Approximately 1,400 facilities on the Hanford Site have asbestos-containing material. During 1992, 999 m^3 of asbestos were removed and disposed of in the Hanford Central Landfill in accordance with applicable regulations.

Revised Clean Air Act requirements for radioactive air emissions were issued in December 1989 under 40 CFR 61, Subpart H. Emissions from the Hanford Site are less than the new EPA offsite emission standard of 10 mrem/yr (effective dose equivalent). The 1989 requirements are in the process of being met for flow and emissions measurements, quality assurance, and sampling documentation at all Hanford Site sources.

These specific reporting and monitoring requirements necessitate additional effort. RL received a 2-year compliance extension for the Subpart H requirements until December 15, 1991. During this extension period, ongoing evaluations were conducted to determine the need for any additional continuous sampling equipment and other actions to meet EPA criteria. Negotiations continued with the EPA in 1992 toward the development of a federal facilities compliance agreement regarding continued evaluations and scheduling of any required equipment upgrades.

Hanford Site contractors have prepared Facility Effluent Monitoring Plans (FEMPs) specific to various facilities across the Site. The FEMPs include sections that outline compliance with 40 CFR 61 (atmospheric emissions). The preparation of FEMPs was completed in late 1991. A summary of each FEMP appeared in the site environmental monitoring plan covering effluent monitoring and environmental surveillance (DOE 1991b). Eight of the fifteen WHC FEMPs were revised during 1992 to incorporate DOE and WHC Quality Assurance/Regulatory Analysis comments. The remaining WHC FEMPs will be revised during 1993. No changes were made to the PNL FEMPs in 1992.

The local air authority, Tri-County Air Pollution Control Authority, enforces General Regulation 80-7, which pertains to detrimental effects, fugitive dust, incineration products, odor, opacity, asbestos, and sulfur oxide emissions. They have been delegated authority to enforce EPA asbestos regulations under NESHAP. The Site is in compliance with the regulations.

During 1992, Hanford Site air emissions remained below all regulatory limits set for radioactive and other pollutants. Routine reports of air emissions were provided to each air quality agency, in compliance with requirements.

Clean Water Act

The Clean Water Act applies to all discharges to waters of the United States. At the Hanford Site, the regulations are applied through a National Pollutant Discharge Elimination System (NPDES) permit governing effluent discharges to the Columbia River.

Six permitted outfalls operated within the NPDES permit. Two outfalls had instances of noncompliance: N Springs Outfall (1301-N discharge) and Outfall 003 (181-KE inlet screen backwash).

Conditions resulting from retirement of the N Reactor have affected the sampling and recording procedures associated with the Hanford Site's NPDES permit. Primarily there are reduced flows at the N Reactor outfalls, and in some cases, no flow at all. The situation is being noted on the monthly discharge monitoring reports submitted to the EPA.

Problems were experienced in the measuring of total suspended solids at the 100-K Area 003 Outfall. The discharge at this outfall is from the 181-KE inlet screen backwash. The monthly permit limit for total suspended solids was exceeded on August 6, 1992. With low flows, rust and corrosion products from the associated piping accumulate as loose debris in the meters. As a result of this accumulation of solid materials, discharge has been discontinued. A plan to dispose of the effluent to an alternate site is currently being evaluated.

The N Springs Outfall exceeded the quarterly permit allowance for iron (1 mg/L) on January 2, 1992. The measured value was 5.5 mg/L. Investigations following the occurrence showed that the ground-water well which is normally sampled had not been purged since the last sample, allowing for buildup of iron. Purge water released to the outfall caused the limit for iron to be exceeded. The well was repurged and resampled on February 10, 1992. No increase or exceedance of the permit limit was observed after repurging.

Permit applications have been submitted to the EPA Region 10 for three new facilities (outfalls) planned for the 100 and 300 Areas. These new facilities include a treatment facility for process wastewater (1325-N), as well as filter backwash/ash sluicing wastewater disposal facility (315/384), and the 300 Area Treatment Effluent Disposal Facility (Project L-045H).

Lawsuit Filed

Heart of America Northwest, an environmental group, filed a lawsuit against both WHC and DOE on April 16, 1992. The suit alleges violations of the Clean Water Act from discharges of pollutants without a NPDES permit in the 300 Area Process Trenches, U-17 Crib, and the Z-20 Crib. Ecology has filed an appeal on the applicability to the discharges described. Currently, the parties involved are awaiting adjudication on the defendants' "motion to dismiss."

Safe Drinking Water Act

The National Primary Drinking Water Regulations of the Safe Drinking Water Act apply to the drinking water supplies at the Hanford Site. These regulations are enforced by the DOH (WAC 246-290).

The Hanford Site water supplies are monitored for the contaminants listed in the rules and regulations of the DOH regarding public water systems. In 1992 all water

systems were in compliance with requirements and agreements.

Toxic Substances Control Act

The application of Toxic Substances Control Act requirements to the Hanford Site essentially involves regulation of PCBs. Federal regulations for use, storage, and disposal of PCBs are found in 40 Code of Federal Regulations (CFR) 761. State of Washington dangerous waste regulations for managing PCB waste are listed in WAC 173-303.

Nonradioactive PCB waste is stored and disposed of in accordance with the 40 CFR 761 requirements. The regulations require that PCB waste be disposed of within 1 year of being placed into storage for disposal. At present, the disposal technology and capacity for radioactive PCB waste is very limited or, in many cases, nonexistent. As a result, radioactive PCB wastes are being stored at the Hanford Site in excess of the 1-year regulatory limitation. A compliance agreement remains a critical step in achieving full compliance with PCB regulations.

Various concentrations of PCBs are found in electrical equipment throughout the Hanford Site. Most transformers have been sampled and characterized. Many PCB-containing (those with greater than 500 mg/L) transformers and large capacitors have been replaced or modified.

Defueled, decommissioned submarine reactor compartments shipped by the U.S. Navy to the Hanford Site for disposal contain small quantities of PCBs bound within the matrix of nonmetallic materials such as thermal insulation, electrical cables, and some rubber items. Because of the presence of PCBs, the reactor compartments are regulated under this Act. A compliance agreement between EPA and DOE defines the process by which a permit under this Act will be issued for the disposal trench. Work continues toward achieving a permit under this Act.

The United States Environmental Protection Agency

The EPA issued a Notice of Noncompliance as the result of a polychlorinated biphenyl (PCB) compliance inspection conducted by EPA in September 1991. One violation was cited in the Notice of Noncompliance. This violation was based on a spill that was not cleaned up within the required 48-hour period. A formal response was submitted to the EPA in November 1992. Final resolution is pending.

Federal Insecticide, Fungicide, and Rodenticide Act

Ecology administers the Federal Insecticide, Fungicide, and Rodenticide Act of 1975 certification and storage requirements under authority granted by EPA. This Act and the RCW 17.21, "Washington Pesticide Application Act," as implemented by WAC 16-228, "General Pesticides Regulations," apply to storage and use of pesticides. At the Hanford Site, pesticides are applied by personnel licensed by Ecology as commercial pesticide applicators. The Hanford Site is in compliance with the Act's requirements and WAC 16-228 regulations pertaining to storage and application of pesticides.

Endangered Species Act

A few rare species of native plants and animals are known to occur on the Hanford Site. Some of these are listed by the U.S. Fish and Wildlife Service as endangered or threatened (federally listed). Others are listed by the Washington State Department of Wildlife as endangered, threatened, or sensitive species. The Site monitoring program is discussed in Section 4.2, "Wildlife."

National Historic Preservation Act, Archaeological Resources Protection Act, and American Indian Religious Freedom Act

Cultural resources on the Hanford Site are subject to the provisions of these three Acts. Compliance with the applicable regulations is accomplished through an active monitoring program that includes review of all proposed land-disturbing projects to assess potential impacts on cultural resources, and periodic inspections of known archaeological and historical sites to determine their condition and the effects of land management policies on the sites. The 1992 program activities are described in Section 4.3, "Other Environmental Studies and Programs." The B Reactor has been listed as a National Historic Site.

The American Indian Religious Freedom Act requires federal agencies to help protect and preserve the Native American's right to practice their traditional religion. RL cooperates with Native Americans by providing Site access for organized religious activities.

National Environmental Policy Act

The National Environmental Policy Act (NEPA) establishes a national environmental policy. The Act requires major federal projects with potential to significantly impact the human environment to be carefully reviewed and reported to the public through EIS. Other documents such as environmental assessments are also prepared in accordance with NEPA requirements. Such NEPA documents are prepared and reviewed in accordance with the Council on Environmental Quality regulations in 40 CFR 1500 to 1508, 10 CFR 1021, DOE Order 5440.1E (dated November 10, 1992), and SEN-15-90, "National Environmental Policy Act" (dated February 5, 1990).

The SEN-15-90 documentation directs DOE field offices to conduct early and adequate NEPA planning, and to designate an official to be responsible for overall NEPA compliance. It also terminated the use of memos to document NEPA reviews of certain activities and projects as of September 30, 1990. The RL has complied with these and other requirements of the notice.

Several related programmatic and site-specific EISs, as well as executive orders, are in progress or in the planning and scoping stages. These are summarized below.

Environmental Impact Statement, Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington

Eight plutonium production reactors were built and operated at the Hanford Site between 1943 and 1971. These reactors have been declared surplus by DOE and are now available for decommissioning. The first reactor to operate, B Reactor, has been listed as a National Historic Site.

The draft EIS (DOE 1989a) was published in March 1989 and subsequently went through the required review process. During 1990, responses to agency and public comments on the draft were prepared. The final EIS (1992h) was issued as an addendum in December 1992. A notice of availability was published in the Federal Register on January 18, 1993, to give the public the opportunity to review the final EIS. A record of decision is expected to be issued in spring 1993.

Programmatic Environmental Impact Statement for the Environmental Restoration and Waste Management Program

This EIS will evaluate the potential environmental impacts of DOE's national environmental restoration and waste management program. It will include options for remediation, compliance with RCRA and CERCLA, restoration, waste management, and repositories. Preparations have begun and will continue during 1993.

Weapons Complex Modernization Programmatic Environmental Impact Statement

The RL contractors assisted Argonne National Laboratory in preparing a draft EIS (DOE 1991d), published in April 1991, for siting, construction, and operation of a new production reactor (NPR) to produce tritium. The draft compares potential environmental and socioeconomic impacts from the siting of an NPR at the Hanford Site, Idaho National Engineering Laboratory, and the Savannah River Plant. The technologies proposed for tritium production are the light-water reactor, modular high-temperature gas-cooled reactor, and heavy-water reactor. The sites were evaluated regarding each of the three technologies. At the Hanford Site, the light-water reactor would be WNP-1, which is 63% complete. The fuel/tritium target fabrication and tritium processing would be housed in the existing Fuels and Materials Examination Facility in the 400 Area.

In November 1991, DOE announced that it will incorporate the environmental impact analysis for the DOE NPR capacity proposal into the Weapons Complex Modernization Programmatic Environmental Impact Statement and include NPR siting and technology decisions in the Weapons Complex Modernization Record of Decision. The DOE invited the public to comment on incorporating the tritium capacity analysis on November 29, 1991 [56 Federal Register (FR) 60985]. The implementation plan takes the resulting comments into account. During 1992, public comments were received. No further actions occurred.

Executive Order 11988 - Floodplain Management

To minimize potential harm to or within the 100-year floodplain as it relates to the Columbia River, the potential effects of actions taken in the floodplain at the Hanford Site are evaluated and alternatives are considered when necessary to avoid adverse effects and incompatible development within the floodplain. The evaluations are made in one of two ways: either concurrently with the NEPA process, or separately, with the required public notice and statement of findings published in the FR. If the action requires an environmental assessment, the floodplain assessment must be incorporated. The statement of findings may be incorporated in a finding of no significant impact. If the action does not require an environmental assessment, the floodplain assessment accompanies an information bulletin. Three floodplain/wetlands assessments were written in 1991 and 1992, and included in NEPA documentation.

Executive Order 11990 - Protection of Wetlands

Protection is considered for any action proposed in a wetland at the Hanford Site to minimize the destruction, loss, or degradation of those wetlands. An evaluation takes into account environmental concerns and is conducted either concurrently with the NEPA process or separately, with the required public notice published in the FR. If the action requires an environmental assessment, the wetlands assessment must be incorporated. The statement of findings may be incorporated in the findings of no significant impact. If the action does not require an environmental assessment, the wetlands assessment accompanies an information bulletin.

DOE issued regulations to support compliance with these two executive orders. In 1979, 10 CFR 1022, "Compliance with Floodplain/Wetlands Environmental Review Requirements," was published to address the protection and preservation of floodplains and wetlands. 10 CFR 1022 requires that the documentation for floodplains and wetlands assessment be prepared concurrently with and incorporated into the NEPA documentation.

2.3 Current Issues and Actions

Progress has been made toward achieving full regulatory compliance at the Hanford Site. Ongoing self-assessments of the compliance status, implementation of the Tri-Party Agreement, and public meetings continue to identify environmental compliance issues. These issues are discussed openly with the regulatory agencies and with the public to ensure that all environmental compliance issues are addressed.

Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement)

Originally signed on May 15, 1989, the Tri-Party Agreement is an agreement among EPA, Ecology, and DOE to achieve compliance with CERCLA remedial action provisions and with RCRA treatment, storage, and disposal unit regulation and corrective action provisions. The Tri-Party Agreement 1) defines and ranks RCRA and CERCLA cleanup commitments, 2) establishes responsibilities, 3) provides a basis for budgeting, and 4) reflects a concerted goal of achieving full regulatory compliance and remediation, with enforceable milestones, in an aggressive but achievable manner. Milestones scheduled for 1992 were completed. Included in these completed milestones were the following activities:

- Two RCRA Part B permit applications and four closure plans for Hanford treatment, storage, and disposal facilities were submitted to Ecology.
- Ten Aggregate Area Management Study Reports for the 200 Areas of the Hanford Site were submitted to Ecology.
- Actions to meet 38 Tri-Party Agreement milestones dealing with management of liquid effluents at the Hanford Site were completed.
- Twenty-six RCRA ground-water monitoring wells were installed.

At the end of 1992, a total of 234 enforceable Tri-Party Agreement milestones [to include fiscal years (FY) 1989 through 1992] had been completed on or ahead of schedule. Four milestones in FY 1992 were not completed as planned. DOE was assessed penalties for failure to follow change procedures in the Tri-Party Agreement.

Two of the Tri-Party Agreement milestones (M-05-03 and M-05-04) require the stabilization of 13 single-shell tanks. In August 1991, Headquarters (HQ) halted progress on stabilizing the tanks to resolve the issue of potentially adding liquid to "watch list" (Public Law 101-510, Section 3137 Wyden Amendment) tanks. "Watch list" tanks include those that contain ferrocyanides, hydrogen-gas-generating waste, high-heat-generating waste, and waste with high concentrations of organic chemicals. Safety issues still exist with single-shell tanks, and pumping continues to be affected. Because of these safety issues, a change request was submitted by DOE to delay the milestone for the "Interim Stabilization of an additional nine single-shell tanks" (M-05-04), due in September 1992. This milestone will be completed when the safety issues can be adequately resolved.

Another milestone (M-14-00) requires the construction and operation of a low-level mixed-waste laboratory. DOE proposed redefining the milestone to require DOE to provide the necessary laboratory capacity to handle Tri-Party Agreement analytical requirements through privatization. An agreement was reached to use commercial laboratories, with penalties assessed for failure to comply with the Tri-Party Agreement, if mandated sample turnaround times are not met with commercial laboratories. In addition, the agreement requires the procurement of local laboratory facilities.

An extension was requested for a milestone requiring the evaluation of additional double-shell tank requirements (M-31-02), so that necessary information on future tank needs may be incorporated from the ongoing tank waste remediation system planning and integration effort. This planning and integration effort became necessary in part because of the determination that B Plant could not meet RCRA requirements allowing tank waste pretreatment and because of the need to address tank waste safety

issues. The request for extension was denied by the EPA and Ecology and dispute resolution, as provided by the Tri-Party Agreement, was entered to reach a resolution on this issue.

DOE, EPA, and Ecology approved a third amendment to the Tri-Party Agreement in August 1992 that extends the review and revision time periods for RCRA Part B permit applications and closure plans. This amendment became necessary because of the complexity of permitting and/or closing facilities at the Hanford Site.

DOE, EPA, and Ecology approved a change that added 84 new milestones to the Tri-Party Agreement in the area of liquid effluents in August 1992. Numerous public comments were generated related to continued discharge of liquid effluents at the Hanford Site and the change. Resolution of these comments required renegotiation of some of the 84 milestones and the adoption of restrictions on the volume to be discharged from some of these streams. This change package also deleted the proposed milestones for the decontamination laundry facility because DOE will pursue a private, offsite vendor for those services.

The Tri-Party Agreement requires the preparation of individual work plans for conducting remedial investigation and feasibility study work on the approximately 80 designated operable units. The work is being actively conducted at selected operable units on the Site in accordance with the schedules stipulated in the Tri-Party Agreement action plan.

The liquid effluent study (WHC 1990), which was agreed to as part of the Tri-Party Agreement negotiation, was transmitted to EPA Region 10 and Ecology in the third quarter of 1990. EPA and Ecology reviewed the liquid effluent study documents and provided comments. Ecology has approved all liquid effluent sampling plans and quality assurance project plan for the liquid effluent study.

Hanford Future Site Use/ Cleanup Strategy

Potential long-term future uses of Hanford Site land strongly influence decisions about cleanup strategies and cleanup standards. Understanding public and other affected parties' visions of potential future Site uses will help DOE make cleanup decisions that will be publicly supported and that will stand the test of time.

The DOE, in cooperation with other interested participants, is supporting a process to actively seek public input to the development of cleanup strategies, taking into consideration potential future Site uses.

Hanford Future Site Uses Working Group

The Hanford Future Site Uses Working Group was formed in early 1992 by an organizing committee made up of federal, tribal, state, and local governments. The Working Group was charged with developing a range of future use options for the Site and assessing the implications of those uses on cleanup. The Working Group brought governments and representatives of a wide variety of constituencies together to discuss their respective future visions for the Hanford Site. The Working Group did not seek consensus on one single vision, but endeavored to provide decision makers with a full range of visions for the future. Cleanup decisions necessary to make these future use options possible will be analyzed in depth in an upcoming environmental impact statement.

The members of the Working Group included representatives of federal, state, tribal, and local governments; business, agricultural, and economic interests; academia; environmental groups; and groups with a special interest in the Hanford Site.

The Working Group met monthly from April 1992 to December 1992. The Working Group engaged in a joint education process to bring all of its members to a common base of understanding about the Site.

They accomplished this by bringing in experts to address the Working Group on topics that included the history of the Site from the perspectives of Native Americans, settlers, and the federal government; the habitat that the Site provides for plants and animals; the economic impact of the Site on the Tri-Cities; and the contamination on the Site and technologies available to deal with that contamination.

Using a series of maps to illustrate the various natural and artificial features of six geographic areas of the Site (Figure 2.2), the Working Group considered the distinct features of each area and then developed a list of potential future uses for that area. The Working Group took these future use options and developed cleanup scenarios to describe how clean parts of the Site would need to be to accommodate the future uses. Future uses were described in generic terms, such as agriculture or wildlife, rather than in specific terms such as cherry orchards or elk herds.

The six geographic study areas (see Figure 2.2) are:

- ALE—The southwest section of the site, kept undisturbed for security and safety reasons, is currently the Site of studies into the ecology and habitat of shrub-steppe lands.

- North of the River (Wahluke Slope)—The area north of the Columbia River, kept undeveloped as a security buffer, is currently designated in part as a wildlife refuge managed by the U.S. Fish and Wildlife Service. The remainder is a wildlife recreation area managed by the Washington Department of Wildlife.

- Central Plateau or 200 Areas—These areas are where nuclear materials were processed, much of the wastes are stored, and much of the known contaminants are concentrated.

- Columbia River—The stretch of the river that runs through the Site, known as the Hanford Reach, is home to spawning grounds for more than a third of the river's fall chinook salmon.

- Reactors on the River—The area along the river contains nine retired plutonium production reactors and the land in between. Eight of the reactors were shut down by 1971; the ninth (N Reactor) was shut down in 1988.

- All Other Areas—This area consists of all of the Site that is not included in the other geographic areas. This includes the 300 and 1100 Areas just north of Richland, the Washington Public Power Supply System, the Pacific Northwest Laboratory, as well as large tracts of relatively undisturbed land between those facilities.

The Working Group developed a set of nine major recommendations for the Site as a whole. These recommendations, as well as the future use options and cleanup scenarios, are documented in the Working Group's final report, "The Future of Hanford: Uses and Cleanup."

The Working Group's recommendations were:

- protect the Columbia River—At some locations on the Site, contaminants are known to be entering the river. Stopping actual and potential contamination of the Columbia is a high priority.

- deal realistically and forcefully with ground-water contamination—The Working Group recommended that ground water should not be used if it would jeopardize public health or safety or adversely change hydrologic conditions, increasing the speed of contaminated ground-water flow to the Columbia River. The Working Group expected that ground water would ultimately be cleaned up once technology for ground-water cleanup advances.

- use the Central Plateau wisely for waste management—Wastes from throughout the Site should be concentrated in the Central Plateau (including and surrounding the 200 Areas). Within the Central Plateau, the Working Group suggested that waste storage, treatment, and disposal activities be concentrated to minimize the amount of land devoted to or contaminated by waste management activities.

- do no harm during cleanup or with new development—The primary goal of cleanup is to protect human health and public safety. In addition, environmental values of the Site are to be protected and restored. Decisions dealing with cleanup and possible development should be guided by the principle, "do no harm."

- cleanup of areas of high future use value is important—The Working Group believed that areas of high future use value should be candidates for priority cleanup action. They identified two types: areas that could contribute to the productive development or use of the Site for other purposes and areas that could be cleaned up quickly for a very small percentage of the cleanup budget, making large tracts of land available for other uses.

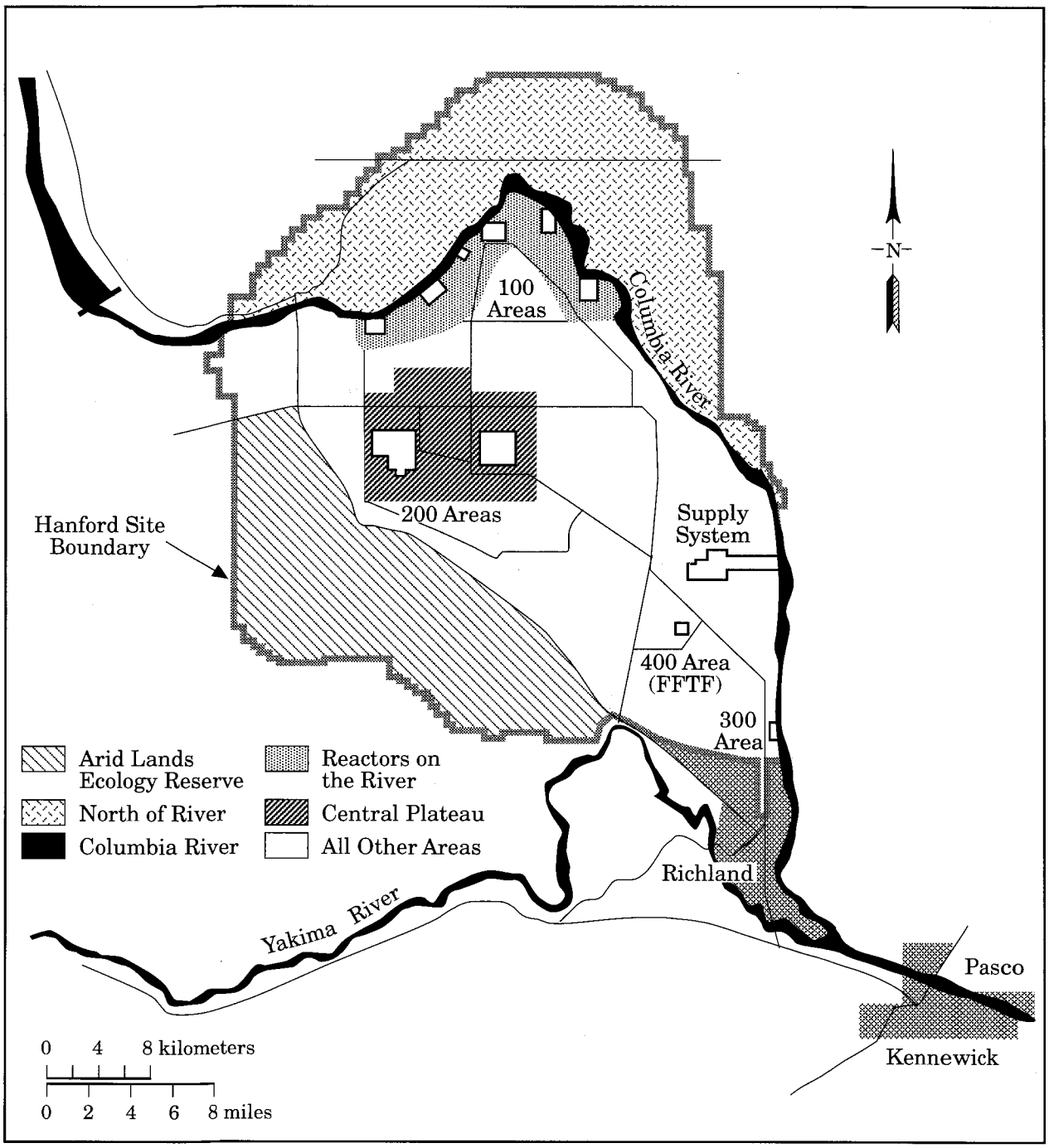

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Figure 2.2. Six Geographic Study Areas for the Hanford Future Site Uses Working Group

- clean only to the level necessary to enable a future use option to occur—The Working Group believed that some future uses could occur even if some residual contamination remained. For example, industrial uses do not require the level of cleanup that agricultural uses would. In some cases the activity required to clean soils or ground water might be detrimental to an area designated for wildlife.

- transport waste safely—The Working Group recognized that decisions related to Hanford cleanup will require the transportation of radioactive and hazardous materials within the Site, as well as to and from the Site. Such transportation will require close cooperation between DOE and tribal, state, and local governments. The Working Group endorsed the Hazardous Materials Management Emergency Response Training Center.

- capture economic development opportunities locally—DOE has announced its intentions to leave Hanford after completing cleanup (Quayle 1993). The Hanford portion of the region's economic base must ultimately be replaced by non-DOE activities within the state. The Working Group urged DOE and its contractors to factor local development and economic diversification into cleanup decisions. Research and development necessary for cleanup should occur in a manner that creates additional private sector economic development opportunities.

- involve the public in future decisions about Hanford—Public involvement and consultation must be incorporated into future decision-making at Hanford. The Working Group process should be a model for involving the public. The public should be consulted on decisions involving transportation and emergency preparedness, economic development, the reservation of parts of the Site by DOE for other missions, use of ground water, and exposure risk resulting from land use decisions.

The Working Group completed its final report in December 1992.

The Columbia River's Hanford Reach

The Hanford Reach is an 84-km (52-mi) stretch of the Columbia River from Priest Rapids Dam to the head of Lake Wallula near Richland. Congress passed a law (Public Law 100-605) in 1988 requiring a comprehensive study of the Hanford Reach. The Secretary of Interior, in consultation with the Secretary of Energy, was to take two actions: 1) inventory and evaluate the river's resources, and 2) develop and analyze a series of protection alternatives, including designation of the Reach in the National Wild and Scenic Rivers system. The Department of Interior was to have presented its study and a final EIS to Congress by November 1991; however, this has not yet occurred.

The law states that for 8 years (beginning 1988), no federal agency may construct any dam, channel or navigation project. It also requires that all other activities, to the extent practicable, be planned and implemented to minimize adverse impacts on the river's resources. As a means of complying with the law, RL notifies the National Park Service of all proposed activities subject to the National Park Service's consultation and coordination process agreed upon by the two involved agencies.

Analysis of the alternatives began in May 1990. Options range from establishing a resource protection area, to taking no action. Which state or federal agencies would manage the area, whether development would be limited, and how far from the shore the protection would extend are among other issues to be addressed in the EIS. For example, if the Hanford Reach were declared a National River, the National Park Service would preserve the river in its natural state and allow its resources to be used but not changed, altered, or depleted.

The National Park Service is the lead agency for the Department of Interior and announced its preferred alternative in a draft EIS in 1992. A public comment period followed, and public hearings were held. The final report to Congress will present the study team's final recommendation.

Tiger Team Assessment Corrective Actions

In June 1989, the Secretary of Energy announced a 10-point initiative to strengthen safety, environmental protection, and waste management activities at DOE production, research, and testing facilities. The initiative was part of the Secretary's overall plan to ensure full accountability in the areas of environment, safety, and health, and to ensure that all DOE facilities achieve and maintain full compliance with applicable federal and state environment, safety, and health requirements.

Tiger Team assessments, one of the 10 points in the initiative, were a high priority for DOE. The assessments included, but were not limited to, the following environment, safety, and health areas:

- compliance with applicable federal, state, and local regulations; permit requirements; agreements; orders; and consent decrees
- compliance with DOE order requirements for environment, safety, and health activities
- adequacy of DOE and Site contractor environment, safety, and health management programs, including planning, organization, resources, training, and relationship with regulatory agencies
- conformance with applicable best and accepted industry practices
- identification of root causes.

The Hanford Site Tiger Team began evaluating Site operations in May 1990. The Tiger Team presented its findings to RL and state officials in July 1990. The team's report listed 105 separate findings, 266 concerns, and 4 special issues; no findings were characterized as representing an imminent danger. Eighty-four findings were related to environmental issues. The documentation of the results of the assessment is published in *Tiger Team Assessment of the Hanford Site* (DOE 1990e). A copy of this document is available at the RL Public Reading Room in Richland, Washington.

In January 1991, RL submitted the draft of the Hanford Site preliminary action plan to HQ. Comments were subsequently received from HQ reviewers. The RL and Hanford Site contractors have responded to those comments. Through March 1991, resolution had been achieved on 95% of all comments received. The Hanford Readiness Task Force, composed of RL and Site contractor personnel, submitted a revised Hanford Site preliminary action plan in April 1991.

Anticipating formal approval of the plan, 766 total actions were initiated in accordance with the plan and the priority levels were assigned to each action. Progress has been carefully tracked on closeout and interim milestones. Delinquent actions have been carefully analyzed to ensure no environmental or safety impact. For 1992, 424 actions out of the total 503 environmental actions have been completed and are awaiting closure by HQ. Seventy-nine actions have been completed but are awaiting verification by WHC Quality Assurance for closure. Once closed, these actions will be reported to HQ.

Plutonium Uranium Extraction and Uranium Trioxide Plants Status

Operation of the PUREX Plant to stabilize certain liquid inventories was completed in FY 1990. Inventories of solvent and nuclear materials remain, including liquid uranyl nitrate hydrates, fuel from Hanford Site production reactors, and organic materials. Transition of the PUREX Plant to a minimum safe standby condition began in FY 1991. Tanks and transfer routes were closed off to prevent spills of remaining liquids and to isolate incoming utilities from the process area. Preparations toward shutdown began in 1992.

Preparation of the UO_3 Plant to process remaining inventories of liquid uranyl nitrate hydrates continues. An operational readiness review team was established, and mechanical work was initiated to ensure safe operations. The operational campaign was planned for mid-April 1993.

Plutonium Finishing Plant Restart

Reactivation of two process areas in the PFP will stabilize materials held in the facility. This materials stabilization campaign is in response to direction from HQ to operate the PFP as necessary to stabilize and prepare materials for long-term storage and to conduct cleanout activities needed to improve the safety of the facility.

A temporary restart of the Plutonium Reclamation Facility, one of two active process facilities and the first step in the stabilization process, will be initiated following completion of the readiness review process. Residual in-process chemically active recyclable liquids, sludges, fluoride, and rags containing plutonium will be processed to produce plutonium nitrate solutions. These plutonium nitrate solutions will then be converted in the other process facility, the Remote Mechanical C Line, to an oxide form. Plutonium oxide is a stable form suitable for extended storage. Restart of the Plutonium Reclamation Facility is scheduled for mid-June 1993.

Evaluation of the PFP status with respect to selected DOE Orders and implementation of the new PFP final safety analysis report will also be performed before Plutonium Reclamation Facility restart.

Hanford Waste Vitrification Plant

The vitrification process is based on technology and engineering developed at PNL. DOE has vitrification plants at Savannah River, South Carolina, and West Valley, New York. In addition, France, Germany, Great Britain, and Japan have vitrification plants built or under construction. Hanford Site engineers interact extensively with engineers at these plants to exchange information and learn from their successes and failures.

The Hanford Waste Vitrification Plant will be constructed to treat much of the waste currently stored in double-shell tanks. The high-activity fraction of waste resulting from pretreatment of the stored waste will be immobilized into borosilicate glass. The vitrified waste will be contained in steel canisters 3 m (10 ft) tall and 60 cm (2 ft) in diameter. Canisters will be stored onsite until a permanent repository is available.

When plant construction is at its peak, approximately 825 construction craft workers will be employed. Peak construction is expected in 1994 and 1995.

The RL advised Ecology in December 1990 of technical and programmatic concerns that may delay the start of plant construction. To address these technical and programmatic concerns, RL initiated a systems engineering risk assessment to evaluate the technical, safety, and regulatory uncertainties in the Hanford waste vitrification program.

Review of the draft findings from the vitrification systems risk assessment and negotiations between DOE, Ecology, and EPA resulted in a decision that the program for remediation of the Hanford Site tank wastes needed to be redefined.

The redefinition of this program resulted in a reestablishment of the programmatic baseline for the project. As a result, the start of construction on the plant was delayed by 9 months, but the date for starting operations remained unchanged (December 1999). The definitive design, approximately 50% complete, is scheduled for completion in June 1994.

Waste Receiving and Processing Facility

The Waste Receiving and Processing Facility will treat radioactive and mixed solid wastes at the Hanford Site. To speed up initial certification of waste for shipment, the project was divided into two phases. The first phase uses established technology, which allows more time to better define the remaining functions to be included in the second phase. The conceptual design for first phase (called Module 1) was completed in FY 1989. For the second phase (Module 2), the design was completed in FY 1992.

Module 1 will include the receipt of contact-handled transuranic, mixed transuranic, low-level, and mixed low-level solid wastes. These wastes will be received

from storage or are newly generated. Newly generated wastes originate either onsite or offsite and will be certified by the generator in accordance with the Hanford Site radioactive solid waste acceptance criteria. Module 1 is scheduled to be operational in FY 1996.

Module 2 will include the receipt of contact-handled low-level mixed wastes, remote-handled transuranic waste, waste in large boxes, and low-level category III waste suitable for nonthermal treatment. Uncertainties in Waste Isolation Pilot Plant acceptance criteria led to consideration of dividing Module 2 into two parts. The low-level mixed waste will be treated to comply with environmental regulations and Hanford Site waste acceptance criteria to permit permanent disposal. Module 2 is scheduled to be operational in FY 1999. Module 1 operation is milestone M-18-00 and Module 2 operation is milestone M-19-00 in the Action Plan of the Tri-Party Agreement.

The retrieval of waste from underground retrievable storage is divided into two phases. The first phase addresses Trench 04C, which is believed to have intact containers without external contamination. The second phase will address the remaining 30,000 drums, located at the Central Waste Complex, and may include degraded containers with significant external contamination.

Waste Tank Safety Issues

Several waste tank safety issues have potential impacts on environmental restoration work planned for the Hanford Site. Funding to perform environmental activities has been redirected to resolve safety issues regarding the tanks. Also, because of these safety issues, work control restrictions have been implemented, which has slowed work in and around the tanks.

A Tank Waste Remediation Systems (TWRS) EIS tiering from the Hanford Defense Waste EIS (DOE 1987b) is planned to evaluate options for disposing of single-shell tank wastes and addressing other tank issues. In the record of decision for that EIS, the decision about how to handle the wastes in the single-shell tanks was deferred. Before a decision can be made, the wastes will need to be characterized and technology will need to be developed for disposing of the wastes. Because of Tri-Party Agreement milestones, this TWRS EIS's schedule is proposed for acceleration.

In December 1991, it was determined by HQ that the TWRS EIS would also address the waste tank safety issue. The TWRS EIS will reassess the entire tank safety and tank waste treatment and disposal program.

Background

Between 1943 and 1964, 149 single-shell tanks were built to store liquid radioactive wastes. Their capacities range from approximately 208,000 L (55,000 gal) to 3.8 million L (100,000 gal). No wastes have been added since November 1980, and much of the originally stored waste has been pumped out. One-hundred and five tanks have been stabilized. A stabilization program is in place and is expected to be completed in 1996. Today, the 149 tanks hold about 140 million L (37 million gal) of waste. The waste is in three general forms: sludge, salt cake, and liquid. The waste is a variety of types: low-activity, high-activity, hazardous, or plutonium-contaminated salt cake and sludge.

Twenty-eight double-shell tanks have been built since 1968 and used since 1970. The double-shell tanks now contain about 76 million L (20 million gal) of liquid radioactive waste. These tanks have a second steel wall, and the space between the two walls is monitored for leaks.

Sixty-six of the single-shell tanks have been classified as suspected leakers. In 1979, to halt or reduce effects of current and future leaks, removal of pumpable liquids from the single-shell tanks to the double-shell tanks began and continues today. Recent research shows that more studies are needed before more liquids containing ferrocyanide or large amounts of ignitable materials are pumped from the single-shell tanks to the double-shell tanks. The risks of concentrating waste in double-shell tanks must also be evaluated.

Issues

Concerns have been raised about the potential of a ferrocyanide explosion and hydrogen gas accumulation in the Hanford Site waste tanks. One issue is that under certain conditions of chemical concentration, moisture, and temperature, ferrocyanide and nitrates in the single-shell tanks could release heat and potentially become explosive. The other issue is that flammable hydrogen gases may be trapped beneath the crust in five double-shell tanks and 18 single-shell tanks. One tank in particular,

101-SY (a double-shell tank), shows the largest accumulation of trapped gases. The tank releases hydrogen gas approximately every 100 days. During a September 1992 venting episode, a thermocouple tree on the tank was contorted and bent. The equipment was removed from the tank in early October 1992 because the condition of the equipment was considered an unacceptable safety hazard in that the long piece of equipment might scrape along the tank interior surface during subsequent venting, possibly resulting in a spark. The DOE and external oversight groups have concluded there is no imminent danger to the public from any of the above situations.

Westinghouse Hanford Company's Tank Waste Remediation System Division has the responsibility to identify any hazards associated with the waste tanks and implement the necessary actions to mitigate or remediate those hazards. Instrumentation to assist in these efforts is being developed for placement in the hydrogen and the ferrocyanide tanks, and ultimately in the tanks containing unstable organic compounds, on an as-needed basis. A mixer pump for tank 101-SY has been designed, which will help reduce the buildup of the gases in the tank. Installation is planned for mid-1993.

Information obtained from core samples, video pictures, and monitoring of tank 101-SY as well as information from detailed studies on the mechanism of flammable gas formation and retention assists in understanding the behavior of tank 101-SY. This understanding supports the development of detailed mitigation strategies for that tank. Work is continuing to characterize the other flammable-gas tanks to determine the severity of the hazard.

Studies with nonradioactive synthetic waste that duplicate the waste streams which generated ferrocyanide wastes have increased the understanding of the risk from the ferrocyanide-containing tanks. This understanding has been summarized in a "position paper" on ferrocyanide that is undergoing HQ peer review in 1993. Work is just being initiated on assessing the risk from organic-containing tanks.

In September 1992, the liquid level in single-shell tank 241-T-101 was noted to have dropped 6.6 cm (2.6 in.) from a previously established liquid level of 112.3 cm (44.2 in.). The level decrease was discovered following maintenance on the liquid level indicating transmitter, which had been operating sporadically since December 1991. A review of the level history was initiated to identify any trends. The in-tank photographs were reviewed as were the drywell monitoring and surface level history data. The level decrease was confirmed by alternate level measurements and corresponded to a 28,388-L (7,500-gal) liquid loss in the tank. In October, this tank was declared an assumed leaker based on liquid level measurements. Similar investigations are under way for tanks 241-SX-103 and 241-SX-105.

In April 1992, an unreviewed safety question concerning criticality safety at the Hanford high-level tank farms was declared. The basis for this determination is that the safety analysis reports for single- and double-shell tanks regard a potential criticality as being incredible. Westinghouse Hanford Company determined that this conclusion was not supported by technical data. Conservative operating limits have been placed on the tanks by RL. Westinghouse Hanford Company is continuing a validation of existing data, in conjunction with newly acquired data pertaining to the contents of each tank.

Waste Minimization

The Hanford Waste Minimization Program was designed to meet the requirements of DOE Orders 5400.1 and 5820.2A, and HQ guidance consistent with EPA guidelines. The major elements of the program are management support; employee training, awareness, and incentives; program scope, objectives, and goals; waste minimization assessments/audits; accurate cost accounting; accurate waste accounting; technology transfer; and program evaluation.

The program focuses on preventing the generation of waste but also implements a strategy to reduce the volume and toxicity of wastes that are nevertheless generated. In order of priority, the program advocates 1) waste prevention using source reduction and recycling techniques, 2) treatment, and 3) disposal of wastes. Wastes targeted for minimization include radioactive [high-activity, transuranic (TRU), low-activity], radioactive mixed, hazardous (RCRA), and non-hazardous solid wastes. The Site waste minimization program is discussed in further detail in Section 1.3, "Major Operations and Activities."

242-A Evaporator Status

The 242-A Evaporator remains in standby status pending completion of four liquid effluent retention facilities. Planned use of the first of three retention facilities is scheduled for 1993. The PUREX Plant shutdown eliminates the need for one retention facility.

The 242-A Evaporator is used to reduce the volume of liquid wastes that are placed in storage in the double-shell tanks. The retention facilities will be used for the temporary storage of liquid condensate from the 242-A Evaporator until the liquid effluent treatment facility is complete. The treatment facility is being designed and constructed in the 200-East Area to remove listed chemical constituents from the 242-A Evaporator process condensate. The 242-A Evaporator has been upgraded to extend its operational life beyond the year 2000 and is being made ready for a return to service. Readiness activities are expected to be completed by May 7, 1993.

Submarine Reactor Compartments

Eight defueled submarine reactor compartment disposal packages were received and placed in Trench 94 during CY 1992.

The reactor compartment disposal packages are being regulated by Ecology as dangerous waste because of the presence of lead used as shielding and PCBs in the transformers. In December 1989, DOE submitted to the state a draft Part B permit application for low-level waste burial grounds, including Trench 94. DOE is addressing questions and comments from the state, including several related to Trench 94, before submitting a revised permit application.

Hanford Facility Dangerous Waste Permit

EPA and Ecology issued the draft Hanford Facility Dangerous Waste Permit for public comment in January 1992. Extensive consolidated comments by HQ, RL and its contractors, as well as comments from other interested parties, were submitted to EPA and Ecology by mid-March 1992. RL received a letter from Ecology in April 1992 stating that permit issuance would be delayed 2 to 8 months because of the extensive comments received. At this writing, the schedule for permit issuance remains indefinite. Ecology and EPA have indicated that another round of public comment will be needed on the revised draft permit. When the permit is issued and in effect, it will provide the foundation for all future dangerous waste treatment, storage, and/or disposal activities at the Hanford site in accordance with the provisions of the Tri-Party Agreement.

International Environmental Institute

The International Environmental Institute was established by WHC in March 1992 to develop and maintain an environmental resource center for the communication, development, application and commercialization of environmental remediation technologies and experience. The Institute will accomplish this by utilizing the Hanford Site as a unique environmental laboratory to create and nurture partnerships among industry, government, academia, and the public. It is anticipated that agreements, joint programs, and information exchanges will be created to share Hanford's facilities, expertise, and experience with these other sectors. The Institute will act as a window between Hanford and the outside world to facilitate cooperative agreements and to assess existing environmental technologies throughout the world for potential application at the Hanford Site. The overall goal of the Institute is to increase the value of the federal investment in the Hanford cleanup mission through expedited exchange and sharing of technologies, training, and experience.

The International Environmental Institute now employs 240 people. Ongoing activities or projects incorporated into the Institute include WHC Technology Integration and Transfer, Privatization and Commercialization, Hanford Science Center, and Technical Training and Education. In addition to these activities, early efforts toward the new objectives of the Institute have been focused on identifying and assessing needs, opportunities, and benefits; developing strategies and objectives; and creating new processes and mechanisms for working cooperatively with the private sector.

Self-Assessments

Several types of environmental self-assessments were performed at the Hanford Site in 1992. These assessments evaluated compliance with local, state, and federal requirements as well as self-imposed requirements. The major focuses of the assessments were to:

- review the 222-S Analytical Laboratory operations against EPA's test methods (EPA 1982)
- routinely assess permitted activities for compliance with permit requirements
- assess satellite waste accumulation and 90-day waste storage areas for compliance with waste storage requirements
- routinely audit the low-activity waste generators' program for organizational structure, methods used to characterize waste, methods of packaging waste, and methods used to store and accumulate waste
- assess the requirements and implementation of DOE Order 5820.2A, "Radioactive Waste Management."

In the future, the subjects of these self-assessments are expected to be incorporated into and implemented by a comprehensive self-assessment program being developed at the direction of the Secretary of Energy.

2.4 Environmental Occurrences

Onsite and offsite environmental releases of radioactive and nonradioactive materials during 1992 were reported to DOE as specified in DOE Order 5000.3A and to federal and state agencies. The specific agencies notified depended on the type, amount, and location of the individual occurrences. Generally, these materials dispersed naturally, were stabilized in existing waste disposal sites, or were controlled and cleaned up. In some cases an occurrence may be under continuing observation and evaluation. During 1992, all unusual and off-normal occurrences at the Hanford Site were reported to the Hanford Site Occurrence Notification Center. This Center is responsible for maintaining both a computer database and a hardcopy file of event descriptions and corrective actions. Copies of occurrence reports are made available for public review in the RL Public Reading Room located on the Washington State University campus in Richland, Washington.

As defined in DOE Order 5000.3A, emergency occurrences "are the most serious occurrences and require an increased alert status for onsite personnel and, in some specified cases, for offsite authorities." There were no emergency occurrences in 1992.

Unusual occurrences are defined as nonemergency occurrences that may have a "significant impact or potential for impact on safety, environment, and health." There were 127 unusual occurrence reports filed during 1992 for PNL, WHC, and KEH. Several unusual occurrences of environmental significance are summarized below.

Off-normal environmental occurrences are referred to as "abnormal or unplanned events or conditions that adversely affect, potentially affect, or are indicative of degradation in, the safety, environmental or health protection performance or operation of a facility." There were 1,531 off-normal environmental occurrence reports filed at the Hanford Site during 1992, covering everything from battery acid spills and leaks from overheated motor vehicle cooling systems to minor radiation contamination problems. Because of the volume of reported off-normal occurrences and their lack of environmental significance, event summaries are not included here.

Unusual Occurrences

Release of Contaminated Water to the Ground (RL-KEH-1992-0061)

On June 30, 1992, approximately 34,701 L (9,168 gal) of a highly dilute solution of water and calcium hypochlorite were released to the soil in the 200-West Area when a slipjoint failed on a newly installed sanitary pipeline. The release occurred when two 25-cm (10-in.) sections of the pipe separated during a scheduled chlorination test. A similar large release occurred on this same pipeline on July 15, 1992, but the amount of calcium hypochlorite released was less than that required to be reported under CERCLA. Concerns over the potential fouling of the T Plant sanitary water supply affected the use of sanitary water and imposed limitations on facility operations. In the future, inspections of slipjoints shall be increased, and the strength of slipjoints will be enhanced by installing four equally spaced tie rods at the joints.

Lithium Release (RL-WHC-300EM-1992-0044)

During a procedure to remove residual lithium metal from a pipeline and tank in the 324C Building (300 Area), the pipeline over-pressurized, ruptured, and released lithium and lithium compound aerosols to the building. A small amount also escaped the building to the atmosphere. The 324C Building and several adjacent buildings were immediately evacuated. The rupture of the pipeline occurred when the cleaning solution (acetic acid) reacted with the residual lithium in the pipe, creating a gas that over-pressurized the system. As a result of this release, normal operations in part of the 324C Building were delayed for about 3 weeks, and decommissioning of the contaminated piping system was delayed several months. The amount of lithium materials released to the environment was very small; there was no reportable spill.

Waste Tank Leak (RL-WHC-TANKFARM-1992-0073)

Between December 2, 1991, and July 6, 1992, the fluid-level indicator on waste tank 241-T-101 in the 200-West Area operated only sporadically, and no reliable data on liquid levels in the tank could be obtained. Following repair of the gage in July, the liquid level in the tank was found to have dropped 6.6 cm (2.6 in.). The reason for this decrease is unknown but the tank was declared an assumed leaker on October 4, 1992. It is estimated that approximately 28,400 L (7,500 gal) of contaminated fluid leaked to the surrounding soil before October 1992 when the level in the tank seemed to stabilize. Tank 241-T-101 was placed into service in 1944. Records indicate it contains about 132,500 L (35,000 gal) of drainable liquid and 390,000 L (103,000 gal) of sludge. The tank is single shell and constructed of carbon steel; it was not designed to contain wastes for as long as it has. The life of single-shell steel tanks is typically limited by corrosion. The impact of this leak on the environment around the tank cannot be accurately assessed until the character and amount of the leak can be accurately determined. An investigation into the actual cause of the fluid level drop is being conducted, and a detailed action schedule has been published and is updated weekly. The end goal of the schedule is to pump out all of the drainable liquids from the tank. Pumping is expected to commence in 1993.

Discharge to the Columbia River (RL-WHC-NREACTOR -1992-0061)

On August 6, 1992, the monthly NPDES permit limit for the release of total suspended solids was exceeded at Outfall 003 in the 100-K Area. The discharge at this outfall is from the 181-KE inlet screen backwash. The release resulted from the buildup of corrosion products and loose debris in the discharge system. As a result of this accumulation of materials, the discharge has been discontinued and an alternate disposal site is being evaluated.

Oil Spill (RL-WHC-600EM-1992-0011)

More than 380 L (100 gal) of non-PCB oil (39 mg/L) spilled from a transformer to the ground in the 100-B Area on March 17, 1992. The reason for the spill is not known but material failure may have been a causal factor. A cleanup of the contaminated area resulted in the generation of 125 drums of contaminated soil. There was no permanent impact to the environment.

Radiation Leak (RL-WHC-TANKFARM-1992-0074)

A small amount of highly radioactive fluid leaked to the ground from a containment cask on October 1, 1992. The cask, located in the 200-West Area, contained contaminated equipment from waste tank 241-SY-101. The equipment had been "triple rinsed" before containment but the high radiation readings associated with the leakage indicates the equipment was somehow recontaminated. The mechanism for recontamination is not known. The leak occurred because the containment cask did not require a gasket around one of its entry portals (a design flaw in the piston locking dog assembly). The designer assumed that the cask would always be used with the portal in a vertical position. Following this incident, the cask portal design was modified to include a gasket. The contaminated soil has been cleaned up, and there was no permanent impact to the environment.

Waste Oil Contaminated with Lead (RL-WHC-TPlant-1992-0018)

On May 7, 1992, waste oil was spilled at the 2706-T Decontamination Facility in the 200-West Area. The quantity spilled was reported as 52 kg (115 lb) of waste oil. The spill developed from a degraded 55-gal drum leaking onto an asphalt radioactive mixed-waste, less-than-90-day storage pad. The storage pad was cracked in many places, and some of the spilled material may have reached the underlying soil. Proper cleanup actions will consist of removing the contaminated asphalt and taking soil samples to determine if any further remediation is required. Absorbent material was applied to the remaining spill area, and the contaminated mixture was disposed of properly. The content of the drum was identified as 50% viscous yellow oil (which contained 0.5 mg/kg cadmium, 0.8 mg/kg chromium, and 12.8 mg/kg lead) and 50% clear watermiscible liquid. The spill exceeded the CERCLA-reportable quantity of 0.45 kg (1 lb) for unlisted hazardous waste because of the concentration of heavy metals (lead). As a result, notifications were made to the EPA, Ecology, DOH, Oregon State Department of Energy, and the National Response Center. Even though the spill exceeded the 0.45 kg (1 lb) quantity, there was no impact to personnel or the environment.

2.5 Compliance Status Update (January 1 to April 1, 1993)

The following summary supplements Section 2.2, to address compliance with major environmental statutes for the period January 1 to April 1, 1993, per DOE requirements.

Compliance Status

Comprehensive Environmental Response, Compensation, and Liability Act

Expedited Response Actions

Expedited response actions for the following specific waste sites are in progress at the Hanford Site. Status for the period from January 1 through April 1, 1993, is given below:

- Carbon Tetrachloride Vapor Extraction—Vapor extraction from the vadose zone beneath the 200-West Area began in February 1992. One vacuum system is currently operating 24 hours per day at a 14.2-m^3/min (500-cfm) capacity. A second system of this size was operational in February 1993. A third system and upgrades to the two operating systems provided a total of 85 m^3/min (3,000 cfm) round-the-clock vapor extraction program, which became functional March 31, 1993.

- North Slope Disposal Site—The North Slope (Wahluke Slope north of the Columbia River) is located on the northern and eastern borders of the Hanford Site. It was used by the U.S. Army for missile sites and anti-aircraft gun emplacements during the Cold War era. The guns and missiles have been removed, but numerous physical hazards associated with these facilities remain. Early cleanup of the North Slope is desirable because the area is accessible to the public; cleanup would also free 492 km^2 (190 mi^2) of Hanford land for other uses. Field activities to date include soil sampling and geophysical surveys.

- Pickling Acid Cribs—Nitric and hydrofluoric acids were used in the 1940s to clean or "pickle" galvanized pipe before the pipe being used in the construction of the 100 Area reactors. The Pickling Acid Cribs, located south of the White Bluffs townsite, were used to dispose of used acid. No radiological hazards are believed to be associated with this site. Field activities conducted to date include soil sampling, ground-penetrating radar surveillance, and test pit excavations.

- Sodium Dichromate Landfill—During Hanford's early production years, sodium dichromate was added to reactor cooling water to prevent pipe corrosion. Empty chemical drums were placed in a ravine and covered with soil. Construction debris may also have been disposed of at this site. In January 1993, EPA and Ecology recommended excavation and removal of the debris to accomplish a record of decision. Characterization activities include soil sampling and geophysical surveys. Field screening and laboratory analysis have not revealed any contamination. Cleanup and excavation activities were completed on April 13, 1993. Over 4,000 crushed drums were excavated and sent to the Central Landfill.

- Riverland—Riverland is located in the northwest corner of the Hanford Site, west of Highway 240. The site was used to steam-clean and decontaminate railroad cars of grease and low-level radioactivity from 1943 to 1957. The area includes approximately 34 km^2 (13 mi^2) of property and contained two anti-aircraft gun emplacements. The facilities were decommissioned in 1963. Recent site characterization has been accomplished to determine if any residual contamination exists that would conflict with current release criteria.

- 618-11 Burial Grounds—The 618-11 (WYE) Burial Ground is located 12 km (7.5 mi) north of the 300 Area, adjacent to Washington Public Power Supply System WNP-2. Low-level, intermediate, high-level activity, and transuranic wastes from 300 Area research facilities were disposed of into trenches, caissons, and pipe storage units from 1962 to 1967. Field screening and characterization results continue to compare with release criteria.

- N Springs—An engineering study is being conducted and will be completed April 30, 1993.

CERCLA-Reportable Releases

There were three releases under the CERCLA-reportable quantity requirements between January 1 and April 1, 1993. The first spill involved a continuous release of carbon tetrachloride during the solvent extraction process at the Plutonium Reclamation Facility. The second spill involved a small amount of antifreeze (ethylene glycol) being released to an asphalt roadway in the 100-H Area. The third spill involved a small amount of highly concentrated PCB-contaminated oil being released in the 100-D Area. The PCB level for this spill was below the CERCLA-reportable quantity, but was required to be reported per 40 CFR 761.125(c)(1)(i). Absorbent material was applied to the first and second spills, and the contaminated mixtures were disposed of according to the proper regulations. Appropriate notifications were made to the National Response Center, Ecology, and EPA in accordance with CERCLA. There was no impact to personnel or the environment.

Emergency Planning and Community Right-To-Know Act

There were no new compliance issues identified regarding the Emergency Planning and Community Right-To-Know Act during the period from January 1 through April 1, 1993.

Resource Conservation and Recovery Act

Washington State Department of Ecology

On January 15, 1993, DOE and WHC received a compliance letter from Ecology, identifying violations and other waste storage issues at tank 241-SY-101. The violations noted include exceeding the waste accumulation limit of 120 days and compliance problems associated with generator waste storage, pursuant to WAC 173-303-200 and WAC 173-303-630. DOE has issued a formal response. No additional actions were necessary.

Hanford Part B Permit

The draft permit application was issued for public comment on January 15, 1992. Comments by Ecology were received. Responses to Ecology's comments, as well as pertinent changes, were submitted to HQ for final review. Comments from HQ have not been received. When the Part B permit is finally issued, the Hanford Site Facility Permit will provide the foundation for all future RCRA permitting at Hanford in accordance with provisions of the Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement).

Ground-Water Monitoring

Four wells were constructed for projects associated with the 200 Area Effluent Treatment Disposal Facility. Pursuant to WAC 173-160, a regulatory variance on well 299-W18-32 in the low-level burial grounds was issued by Ecology for noncompliance with the construction standards.

Clean Air Act

Compliance with the Revised 40 CFR 61 Emission Measurement Requirements

On February 3, 1993, the DOE and the Hanford Site contractors received a Compliance Order from the EPA, pursuant to Sections 113 and 114 of the Clean Air Act. This Compliance Order requires DOE to comply with the radionuclide NESHAP by evaluating radionuclide emission points at the Hanford Site and performing continuous emission measurements, as specified by 40 CFR 61.93. In addition, EPA has required that DOE prepare a written compliance plan by April 30, 1993, to address the requirements of the Compliance Order. The compliance plan must provide schedules for implementation and monthly reporting of work completed and work planned for the following month. EPA expects to use this schedule as the basis for a Federal Facility Compliance Agreement to be developed with DOE. This agreement will formalize the schedule of emissions assessment and any measurement compliance actions determined necessary.

Washington State Department of Health

On February 2, 1993, the DOH issued a notice of violation for radioactive airborne emission issues related to the proposed fuel encapsulation activities at the 100-KE Fuel Storage Basins. The notice stated that DOE and WHC have initiated work that directly supports fuel encapsulation, without the DOH's approval, pursuant to WAC 246-247. The notice formally directed DOE and WHC to stop all work at the 100-KE basins immediately. DOE has formally responded to the notice and has initiated a notice of construction. Formal discussions have begun with the DOH. Final resolution is pending.

Prevention of Significant Deterioration

Under the PSD program within the Clean Air Act, the PUREX Plant and UO_3 Plant nitrogen oxide emissions are permitted. Emissions from the PUREX Plant essentially ceased with the cessation of all cladding removal and fuel dissolution in 1989. The UO_3 Plant did not operate during 1991 or 1992; therefore, emissions were negligible. Emissions are expected during the upcoming UO_3 Plant stabilization campaign (mid-April 1993), which will consist of a preconcentration phase and a calcination phase. The campaign is expected to take approximately 1 month to complete.

Clean Water Act

There were no compliance issues identified with NPDES permitting requirements during the period from January 1 through April 1, 1993.

Safe Drinking Water Act

There were no new compliance issues identified regarding this Act from January 1 through April 1, 1993.

Toxic Substances Control Act

Radioactive waste with greater than or equal to 50 mg/L PCBs is being stored at the Hanford Central Waste Complex. Meetings with the EPA have commenced and negotiations are continuing on a compliance agreement for the storage of radioactive PCB waste, pursuant to 40 CFR 761. This agreement, between RL and the EPA Region 10, is intended to allow the acceptance and storage of radioactive PCB waste at the Hanford Site until an adequate disposal or treatment technology/capacity is available and the accumulation of the stored waste is eliminated.

Federal Insecticide, Fungicide, and Rodenticide Act

There were no new compliance issues identified regarding this Act from January 1 through April 1, 1993.

Endangered Species Act

There were no new compliance issues identified regarding the Endangered Species Act from January 1 through April 1, 1993.

National Historic Preservation Act

There were no new compliance issues identified regarding the National Historic Preservation Act from January 1 through April 1, 1993.

Current Issues and Actions

Liquid Effluent Consent Order

Consent Order DE 91NM-177 was signed December 23, 1991, by RL and Ecology regulating Hanford Site liquid effluent discharges. This consent order contains compliance milestones for Hanford liquid effluent streams designated as Phase I, Phase II, and miscellaneous streams. In accordance with terms of the consent order, sampling and analysis plans have been submitted to Ecology for the two project effluent streams. The UO_3 Plant process condensate to the 216-U-17 Crib, the UO_3 Plant wastewater to the 216-U-14 Ditch, the PFP wastewater, and 400 Area secondary cooling water sampling and analysis plans have been approved by Ecology. In addition, the liquid effluent sampling quality assurance project plan was approved by Ecology.

Hanford Federal Facility Agreement and Consent Order

The following is a summary of the more significant compliance events pursuant to the Tri-Party Agreement:

- Milestone M-14-00, "Complete construction and initiate operations of a low-level mixed waste laboratory," was not completed as originally established. The DOE determined that analytical needs at the Hanford Site would be better satisfied through the use of commercial laboratory facilities. Dispute resolution was entered as provided by the Tri-Party Agreement. A final resolution was reached on January 11, 1993, which included an agreement to use locally provided commercial laboratories, but with penalties imposed for failure to comply with the Tri-Party Agreement.

- Definitive design of the new multifunction waste tank facility was initiated.

- Improved in-tank monitoring, a revised contingency plan for leaks, and all physical preparations for emergency pumping of liquids were implemented for single-shell tank T-101.

- Construction of the Hanford Waste Vitrification Plant Canister Storage Building/Multipurpose Storage Building was initiated.

- A draft RCRA closure plan for the 100-D Pond was completed and submitted to the EPA and Ecology.

- On April 2, 1993, RL invoked dispute resolution for the solid waste designation compliance issue originated by Ecology's Notice of Penalty ($100,000) and compliance order, March 10, 1993. Approximately 2,000 containers of solid waste were an alleged violation of WAC 173-303-170(1)(a) and the implementation of WAC 173-303-070. On March 10, 1993, DOE and WHC received a Notice of Penalty Incurred and Due for failure to designate these solid wastes as dangerous or extremely hazardous to public health and the environment.

Federal Facility Compliance Agreement

The Federal Facility Compliance Agreement establishes that federal facilities do not have sovereign immunity from state enforcement of environmental laws. This agreement includes a 3-year moratorium on enforcement of mixed-waste land disposal restriction requirements. The moratorium requires that DOE facilities which generate or store mixed wastes prepare a mixed-waste treatment plan, except for facilities that are currently covered by a permit, agreement, or order which establishes a schedule for treatment of these wastes. The Hanford Site, through the Tri-Party Agreement, has such an agreement and therefore is not required to submit a site treatment plan. DOE has discussed this issue with Ecology and EPA, requesting their confirmation that a plan is not required. DOE received EPA concurrence with this view on March 18, 1993, and is awaiting a response from Ecology.

Waste Minimization

The EPA Biennial Waste Minimization Report was completed in March 1992. RL issued guidance to create semiannual progress reports in support of implementing the Executive Order 12780, on federal recycling and affirmative procurement programs. The first progress report was completed on December 15, 1992.

Pursuant to WAC 173-307, "Pollution Prevention Planning," a report on hazardous waste generation and hazardous substance use was completed in August 1992. The report was titled *Executive Summary Hanford Site Pollution Prevention Plan* (DOE 1992j). Process waste assessments are continuing in 1993.

Tiger Team Update

In July 1990, the Tiger Team identified 84 findings and observations/best management practices related to environmental issues at the Hanford Site. Progress is being made on the completion of corrective actions relative to the findings and is being carefully tracked. As of March 8, 1993, 23 completed responses were awaiting verification by WHC Quality Assurance.

Hanford Waste Vitrification Plant

The project was initially validated during FY 1987. The detailed plant design was initiated by Fluor Daniel, Inc., in January 1990. The plant preliminary design was completed during 1992 and early 1993. Construction and site preparation, conducted by United Engineers & Constructors-Catalytic, Inc., began in April 1992 and continues. Construction is expected to be completed in June 1998 and operations to begin December 1999. The overall size of the vitrification building is 24,775 m^2 (266,400 ft^2).

Notice of construction for nonradioactive air emissions from the vitrification plant was completed October 1992 and submitted to Ecology for review and comment. The public comment period ended March 5, 1993. Ecology comments are being addressed with approval expected by midyear.

Notice of construction for radioactive air emissions from the vitrification plant also was completed October 1992. The permit application was submitted to DOH and approval is expected early 1993.

Hanford Site Waste Safety Issues

At various times in the past 10 months, surface-level monitoring instrumentation on single-shell tank 241-T-101 has shown unexpected fluctuations in waste surface levels. Extensive investigations have been conducted to determine the cause of the problem. Similar investigations are under way for single-shell tanks 241-SX-103 and 241-SX-105.

Results from core samples taken from double-shell tank 101-SY during 1992 are being analyzed to further understand the complex chemistry of the tank. Work was initiated to develop a mixer pump, which will be installed mid-1993. The mixer pump will support efforts to reduce the amount of gas buildup in the tank.

International Environmental Institute

Consistent with the goal of the Institute to increase the value of the federal investment in the Hanford cleanup mission through expedited exchange and sharing of technologies, the Institute hosted the "Technology Alliances Workshop" at Pasco, Washington, in January 1993. Attended by over 120 representatives from DOE, DOE contractors, and private industry, the focus of the workshop was to discuss new ways to contribute to the economic development of the country by improving the return on investment from the DOE's Environmental Restoration and Waste Management programs and performing Site cleanup activities safer, better, cheaper, and faster.

Recent economic transition activities of the Institute include establishment of the Economic Transition Cabinet with the economic development directors of Washington, Oregon, and Idaho; initiation of the Hanford Environmental Industrial Complex; and work toward redeployment of a 3,000-ton extrusion press to the city of Richland. Work is also under way on the Hanford-Tri-Cities Salmon Rearing Project Cooperative Research and Development Agreement involving WHC, PNL, the Washington State Department of Fisheries, and Tri-Cities Industrial Development Council, for creation of a salmon hatchery on the Site. In addition, the Institute sponsored a 6-week Hanford assignment of Professor Zinfer Ismaguilov from the Institute of Catalysis at Novosibirsk, Russia. Dr. Ismaguilov was here to review the environmental restoration mission of the Site and to identify possible areas for collaboration or application of technologies between the Russian Institute and Hanford.

Russian - U.S. Environmental Restoration Workshop

In April 1993, DOE and other agencies sponsored a 2-week workshop to share experiences with scientists and decisionmakers from institutes associated with nuclear sites in Russia. Representatives from WHC, PNL, and the U.S. Environmental Training Institute coordinated the workshop, which focused on characterization and cleanup strategies for radiologically contaminated sites. A delegation of high-level officials from Russia participated. The first week was held in Washington, D.C., where the Russian scientists were presented with a national perspective on cleanup issues. The second week was held at the Hanford Site. Among the topics discussed were decontamination and decommissioning of nuclear facilities, waste tanks, contaminated soils and ground water, and public involvement, as well as associated environmental technologies.

Effluent Monitoring Information

3.0 Effluent Monitoring Information

Monitoring effluents and solid waste generated by Hanford Site facilities is essential for determining resulting effects to the public, workers at the Site, and the surrounding environment. Hanford Site contractors have programs to measure liquid and airborne effluents and manage solid waste and chemical inventories. Effluents are almost always monitored at the point of release into the environment (facility effluent monitoring). Once in the environment, the effects of effluents on soil, vegetation, and biota near effluent-producing facilities are evaluated (near-facility environmental monitoring). Solid waste and chemical inventories are tracked much in the same manner as effluents. This section summarizes these programs and the data for 1992 collected by them.

3.1 Facility Effluent Monitoring

Effluents (liquid effluents and airborne emissions) that may contain radioactive or hazardous constituents are continually monitored when released at the Hanford Site. Facility operators perform the monitoring mainly through analyzing samples collected near points of release into the environment. Facility effluent monitoring data are evaluated to determine their degree of compliance with applicable federal, state, and local regulations and permits and to assess the effectiveness of treatment and control systems and effluent management practices. Data evaluations are important components in sound environmental management decisions. Major facilities have their own individual effluent monitoring plans, which are part of the comprehensive Site environmental monitoring plan required by DOE (DOE 1991b).

Measuring devices quantify most facility effluent flows, with a smaller number of flows calculated using process information. Liquid and airborne effluents with a potential to contain radioactivity at prescribed threshold levels are monitored for total alpha and total beta activity and, as warranted, specific alpha-, beta-, and gamma-emitting radionuclides. Nonradioactive constituents are also monitored, as applicable.

The majority of radioactive effluents from facilities at the Site are approaching levels practically indistinguishable from the contributions of natural background radioactivity. The new Site mission of environmental restoration rather than nuclear materials production is largely responsible for this favorable trend, which translates to a very small offsite radiation dose effect attributable to Site activities. Consistent with these conditions of diminishing releases, totals of radionuclides in effluents released at the Site in 1992 are not significantly different from totals in 1991. Small quantities of the radionuclides ^{3}H, ^{41}Ar, ^{90}Sr, ^{129}I, ^{212}Pb, ^{238}Pu, $^{239,240}Pu$, and ^{241}Am were present in airborne and liquid discharges during 1992. These monitored releases accounted for most of the offsite dose attributed to Site activities. Figure 3.1 depicts releases over the past 6 years of several long-lived radionuclides. Both radioactive and nonradioactive constituents in effluents were below applicable standards in 1992.

Effluent release data are reported annually to RL and the public. This reporting is required by DOE Orders 5484.1, "Environmental Protection, Safety, and Health Protection Information Reporting Requirements," and 5400.1, "General Environmental Protection Program." In compliance with the NESHAP statutes, a report documenting radioactive airborne effluents at the Hanford Site is submitted each year to EPA by RL. Onsite radioactive liquid and airborne effluent data are also reported annually to the Idaho National Engineering Laboratory via the Effluent Information System/Onsite Discharge Information System (DOE 1987a). Monitoring results on liquid streams regulated by the NPDES permit are reported monthly to EPA. Data on nonradioactive emissions from fossil-fuel boilers are reported annually to the Benton-Franklin-Walla Walla Counties Air Pollution Control Authority.

Airborne Emissions

Radioactive Airborne Emissions

Radioactive airborne emissions may consist of radioactive particles, radioactive noble gases, and volatile forms of radionuclides. Radioactive emissions having the potential of exceeding 1% of the offsite dose standard are continuously monitored.

Monitoring of radioactive emissions consists primarily of analyzing samples continuously collected before the point of discharge. Samples are analyzed for total alpha and total beta activity and selected radionuclides. Selection of the specific radionuclides that will be sampled, analyzed, and reported is based on 1) an evaluation of emissions expected from the known radionuclide inventories in the facility, 2) criteria for sampling given in the contractor environmental compliance manual, and 3) the potential contribution to the offsite dose received by members of the public from radioactive emission constituents. Continuous radiation monitoring systems are used at certain discharge points to the environment when

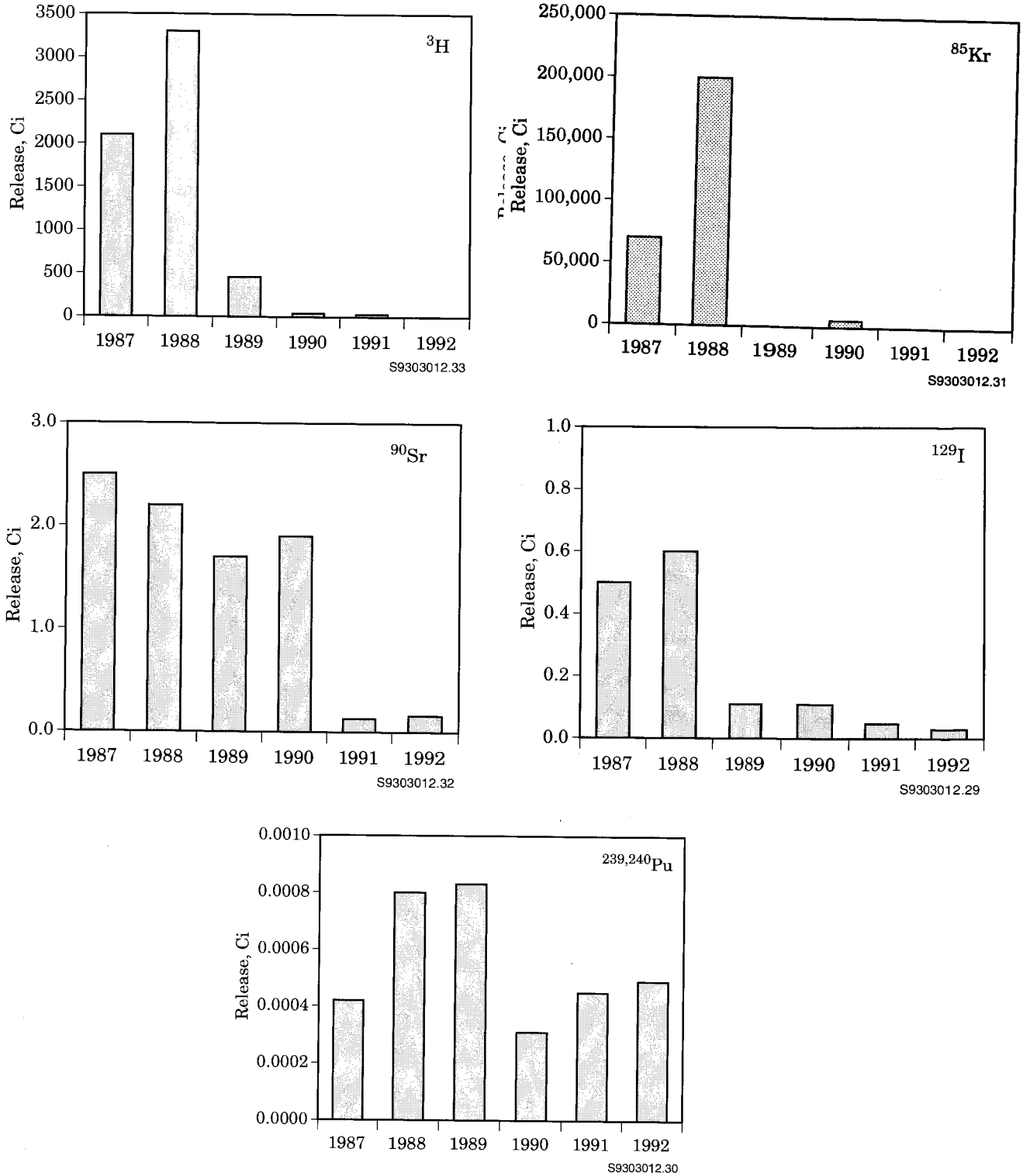


Figure 3.1. Radioactive Emissions to the Atmosphere (Krypton-85, Iodine-129, and Plutonium-239, 240), and Liquid Effluent Releases of Tritium to Ground Disposal Facilities, and Strontium-90 to the Columbia River, 1987 through 1992. Releases of some radionuclides have been very low over the last few years and appear to be zero (no bar) on the graphs.

the potential exists for emissions to exceed normal operating ranges by amounts requiring immediate personnel alert.

Radioactive emission discharge points are located in the 100, 200, 300, 400, and 600 Areas. The sources for these emissions are summarized below:

- In the 100 Areas, emissions originate from the now-shutdown N Reactor, two irradiated-fuel storage basins, and a radiochemistry laboratory. Eight radioactive emission points were active during 1992.

- The 200 Areas contain facilities for nuclear-fuel chemical separations, processing, waste-handling and disposal, and electrical power generation using fossil fuels. Primary sources of radionuclide emissions are the PUREX Plant, the UO_3 Plant, the PFP, T Plant, the 222-S Analytical Laboratory, tank farms for waste storage, underground storage tanks, waste evaporators, and a laundry facility. During 1992, 71 radionuclide and emission points were active in the 200 Areas.

- The 300 Area primarily contains laboratories, research facilities, and a fossil-fuel-powered steam plant. Radioactive emissions arise from research and development and waste-handling activities. Thirty-nine radioactive emission sources were active in the 300 Area during 1992.

- The 400 Area has the FFTF, the Maintenance and Storage Facility, and the Fuels and Materials Examination Facility. Operations and support activities at FFTF and the Maintenance and Storage Facility release small quantities of radioactive emissions. The 400 Area had four active radioactive emission sources during 1992.

- The 600 Area encompasses the remaining portions of the Hanford Site not assigned to other areas. The 600 Area has two minor radioactive air emission points.

A summary of radioactive airborne emissions at the Hanford Site in 1992 is given in Table 3.1.

Nonradioactive Airborne Emissions

Nonradioactive emissions are monitored when they have the potential of exceeding 50% of applicable standards for nonradioactive constituents. Monitoring of nonradioactive air pollutants from power-generating and chemical-processing facilities is conducted when activities at a facility are known to potentially generate the pollutants of interest. Nitrogen oxides, for instance, would be potentially present in emissions from the Uranium-Trioxide (UO_3) Plant should it operate again. Therefore, monitoring for NO_x would be conducted continuously while the plant was operating. This type of monitoring is required by the PSD permit (No. PSD-X80-14). Powerhouse emissions of particulate matter, sulfur oxides, nitrogen oxides, volatile organic compounds, carbon monoxide, and lead are reported in accordance with the air quality standards established by the Tri-Counties (Benton-Franklin-Walla Walla Counties) Air Pollution Control Authority. These emissions are calculated from quantities of fossil fuel consumed, using EPA-approved calculations. Should activities in the 200 Areas generate emissions of ammonia or ammonium hydroxide in excess of a CERCLA-reportable quantity, the release totals are reported annually to EPA. Table 3.2 summarizes emissions of nonradioactive constituents (the 400 and 600 Areas have no nonradioactive emission sources of concern).

Liquid Effluents

Radioactive Liquid Effluents

Effluents that normally or potentially contain low levels of radionuclides are found in the 100, 200, and 300 Areas. These effluents include cooling water, steam condensates, process condensates, laundry wastewater, and wastewater from laboratories and chemical sewers. These wastewater streams are sampled and analyzed for total alpha and total beta activity and selected alpha-, beta-, and gamma-emitting radionuclides. Radioactive liquid effluents classified as high-level wastes are stored in double-shell tanks or monitored interim-storage facilities.

Table 3.1. Radionuclides Discharged to the Atmosphere, 1992

Radionuclide	Half-Life	Release, Ci[a]			
		100 Areas	200 Areas	300 Area	400 Area
^{3}H (as HTO)[b]	12.3 yr			35	
^{3}H (as HT)[c]	12.3 yr			9.5	
^{41}Ar	1.8 h				8.5
^{60}Co	5.3 yr	3.8×10^{-6}			
^{90}Sr[d]	28.8 yr	1.6×10^{-4}	4.4×10^{-4}	5.7×10^{-5}	
^{106}Ru	367 d	3.7×10^{-5}			
^{125}Sb	2.7 yr	1.1×10^{-5}			
^{129}I	1.6×10^{7} yr		3.0×10^{-2}		
^{137}Cs	30 yr	2.6×10^{-4}	2.3×10^{-3}		1.3×10^{-5}
^{147}Pm	2.6 yr		1.7×10^{-4}		
^{154}Eu	16 yr	5.4×10^{-6}			
^{212}Pb	10.6 h		2.7×10^{-3}		
^{220}Rn[e]	55.6 s		34		
^{234}U	2.4×10^{5} yr		5.2×10^{-7}	2.1×10^{-8}	
^{235}U	7×10^{7} yr		1.8×10^{-8}	1.1×10^{-9}	
^{236}U	2.3×10^{7} yr		3.5×10^{-8}		
^{238}U	4.5×10^{9} yr		3.5×10^{-7}	2.0×10^{-8}	
^{238}Pu	87.7 yr	1.3×10^{-6}	1.3×10^{-5}		
$^{239,240}Pu$[f]	2.4×10^{4} yr	8.7×10^{-6}	4.7×10^{-4}	4.3×10^{-6}	2.1×10^{-6}
^{241}Pu	14.4 yr	3.9×10^{-5}	3.4×10^{-3}		
^{241}Am	433 yr	5.1×10^{-6}	2.1×10^{-4}		

(a) 1 Ci = 3.7×10^{10} Bq.
(b) HTO = tritiated water vapor.
(c) HT = elemental tritium.
(d) ^{90}Sr values include total beta activity emitted from facilities at which ^{90}Sr is not directly measured.
(e) ^{220}Rn value is calculated from ^{212}Pb measurements.
(f) $^{239,240}Pu$ values include total alpha activity emitted from facilities at which $^{239,240}Pu$ is not directly measured.

Table 3.2. Nonradioactive Constituents Discharged to the Atmosphere, 1992

Constituent	Release, kg	
	200 Areas	300 Area
Particulate matter	7.0×10^3	3.7×10^4
Nitrogen oxides	1.2×10^5	5.1×10^4
Sulfur oxides	4.2×10^5	2.5×10^5
Carbon monoxide	1.0×10^5	4.6×10^3
Volatile organic compounds	1.5×10^3	2.6×10^3
Ammonia	7.6×10^2	0.0
Lead	2.7×10^2	3.9

A summary of radioactive liquid effluents discharged to ground disposal facilities in 1992 is given in Table 3.3. Table 3.4 summarizes data on radionuclides released in the 100 Areas to the Columbia River. Releases entering the river via ground water are not measured directly but are assessed through river water environmental surveillance (Section 5.3). These measurements are used with the direct effluent measurements to help determine potential public doses.

Nonradioactive Hazardous Constituents in Liquid Effluents

Monitoring for the potential presence of nonradioactive hazardous constituents in liquid effluents is conducted in the 100, 200, 300, and 400 Areas. These effluents are typically discharged to cribs, ponds, ditches, trenches, and the Columbia River (along the 100 Areas). Effluents entering the Columbia River at designated discharge points are sampled and analyzed to determine compliance with the NPDES permit for the Site. Any liquid effluent discharges exceeding a CERCLA-reportable quantity in the 200 Areas are reported annually to EPA. A summary of nonradioactive liquid effluents discharged to ground disposal facilities in the 200, 300, and 400 Areas in 1992 is given in Table 3.5.

Liquid effluents containing nonradioactive hazardous constituents in nonradioactive or otherwise radioactive streams are stored at the 200 Areas in double-shell storage tanks or monitored interim-storage facilities. Activities in the 600 and 1100 Areas generate neither radioactive nor nonradioactive hazardous liquid effluents.

Chemical Releases

Releases of hazardous substances exceeding certain quantities but that are continuous and stable in quantity and rate must be reported as required by Section 103(f)(2) of CERCLA, as amended. In past years, gaseous ammonia has been emitted from the PUREX Plant, 241-AP Tank Farm, and 241-AW Tank Farm and gaseous ammonia and ammonium hydroxide from the 242-A Evaporator. Emissions are monitored for those compounds only when activities at a facility could generate them. Waste ammonia, for instance, was not generated at the PUREX Plant because fuel decladding activities, the only ammonia-generating source there, ceased in March 1990. Also, ammonia-bearing waste was not processed at the 242-A Evaporator; therefore, no waste ammonia was generated. Although the two tank farms continued storing PUREX Plant ammonia-bearing waste, they did not receive any new waste in 1992, resulting in emissions substantially below applicable reportable quantities.

Table 3.3. Radionuclides in Liquid Effluents Discharged to Ground Disposal Facilities, 1992

		Release, Ci[a]	
Radionuclide	Half-Life	200 Areas	300 Area
^{3}H	12.3 yr	2.4	
^{90}Sr	28.8 yr	1.1×10^{-1}	3.7×10^{-2}[b]
^{99}Tc	2.1×10^{5} yr	6.0×10^{-2}	
^{137}Cs	30 yr	3.0×10^{-1}	
Uranium, total	4.5×10^{9} yr	4.6×10^{-3}	
^{238}Pu	87.7 yr	2.2×10^{-3}	
$^{239,240}Pu$	2.4×10^{4} yr	1.4×10^{-2}	1.1×10^{-2}[c]
^{241}Pu	14.4 yr	9.2×10^{-2}	
^{241}Am	433 yr	4.1×10^{-3}	

(a) 1 Ci = 3.7×10^{10} Bq.
(b) Reported as total beta; assumed to be ^{90}Sr for dose calculations.
(c) Reported as total alpha; assumed to be $^{239,240}Pu$ for dose calculations.

Table 3.4. Radionuclides in Liquid Effluents Discharged to the Columbia River from the 100 Areas, 1992

Radionuclide	Half-Life	Release, Ci[a]
^{3}H	12.3 yr	1
^{60}Co	5.3 yr	4.6×10^{-4}
^{90}Sr	28.8 yr	1.6×10^{-1}
^{106}Ru	367 d	8.3×10^{-5}
^{125}Sb	2.7 yr	5.4×10^{-4}
^{137}Cs	30 yr	4.5×10^{-5}
^{238}Pu	87.7 yr	2.9×10^{-6}
$^{239,240}Pu$	2.4×10^{4} yr	1.5×10^{-5}

(a) 1 Ci = 3.7×10^{10} Bq.

Table 3.5. Nonradioactive Liquid Effluents Discharged to Ground Disposal Facilities, 1992

	Release, kg		
Constituent	200 Areas	300 Area	400 Area
Total organic carbon	5.0×10^{3}		
Nitrates	1.4×10^{-3}		5.1×10^{4}
Nitrites		3.3×10^{2}	2.2×10^{1}
Sulfates		1.1×10^{4}	2.9×10^{3}
Fluorine		1.8×10^{2}	3.1×10^{1}
Copper		12	5.5×10^{-1}
Chromium		13	8.4×10^{-1}
Lead		3.5	2.6×10^{-1}
Cadmium		3.2	1.9×10^{-1}
Silver		6.8	
Chlorine		1.1×10^{4}	9.3×10^{3}

3.2 Near-Facility Environmental Monitoring

Several types of environmental media are sampled near nuclear facilities by Westinghouse Hanford Company to monitor the effectiveness of waste management, effluent treatment, and control practices. These media include air, surface water and seeps, surface contamination, soil and vegetation, special sampling (which can include wildlife), and external radiation. The sampling, analysis, and results for 1992 for each of these media are summarized below. Additional information may be found in *Westinghouse Hanford Company Operational Environmental Monitoring Annual Report, Calendar Year 1992* (Schmidt et al. 1993).

Near-Facility Environmental Monitoring at Hanford

Near-facility environmental monitoring is defined principally as routine monitoring near facilities discharging or having discharged radioactive or hazardous contaminants. The monitoring locations are associated mostly with major nuclear facilities, such as the PUREX Plant and N Reactor, and waste disposal facilities, such as burial grounds, tank farms, ponds, cribs, trenches, and ditches.

The purpose of the near-facility environmental monitoring program is to ensure protection of human health and the environment and to determine the status of compliance with local, state, and federal regulations. Much of the program consists of collecting and analyzing environmental samples and methodically surveying areas near facilities releasing effluents and waste streams. The program also evaluates acquired analytical data, determines the effectiveness of facility effluent monitoring and controls, measures the adequacy of containment at waste disposal units, and detects and monitors unusual conditions. The program implements applicable portions of DOE Orders 5400.1, 5484.1, 5400.5, and 5820.2A.

Monitoring activities routinely include sampling and monitoring near-facility ambient air, water from surface-water disposal units, external radiation dose, soil, sediment, vegetation, and animals. Some of the parameters typically monitored are pH, radionuclides, radiation exposure, and hazardous constituents. Samples are collected in known or expected effluent pathways. These pathways generally are downwind of potential or actual airborne releases and downgradient of liquid discharges. The annual routine activities of near-facility monitoring are summarized in Table 3.6, which shows the type, quantity, and location of samples collected. Analytical results for ground-water monitoring wells are summarized in Section 5.8 of this report. A more detailed discussion of results for wells used specifically to monitor operating facilities may be found in *Westinghouse Hanford Company Operational Environmental Monitoring Annual Report, Calendar Year 1992* (Schmidt et al. 1993).

Waste disposal sites and the terrain surrounding them are surveyed to detect and characterize any radioactive surface contamination. The location of these surveys include cribs, trenches, retention basin perimeters, pond perimeters, ditch banks, solid waste disposal sites (for example, burial grounds, trenches), unplanned release sites, tank farm perimeters, stabilized waste disposal sites, roads, and firebreaks in and around the Site operational areas. In 1992, radiological surveys were conducted at 391 sites in the operational areas (100 in 100 Areas; 273 in the 200 and 600 Areas; and 18 in the 300 and 400 Areas) (DOE 1991a).

Air Monitoring

Near-facility air sampling monitors the effectiveness of waste management, and effluent treatment and controls in reducing effluents and emissions; it also monitors diffuse source emissions.

Table 3.6. Near-Facility Routine Environmental Samples and Locations

Samples	Total	100 Areas	200/600 Areas	300/400 Areas
Air	40	4	36	
Surface water	32	22	10	
External radiation	289	213 [(a)]	61	15
Soil	157	32	110	15
Vegetation	95	40	40	15

(a) 41 TLDs and 172 survey points.

Sample Collection and Analysis

Radioactivity in air was sampled by a network of continuously operated samplers at 40 locations near nuclear facilities: 4 located in the 100-N Area, 33 in the 200/600 Areas, and 3 background stations collocated with samplers operated by PNL and the Washington State Department of Health at the Yakima and Wye Barricades and the old Hanford townsite. To avoid duplication of sampling, the near-facility environmental monitoring program used existing PNL air samplers in the 300 and 400 Areas (results reported in Section 5.2, "Air Surveillance"). Air samplers were primarily located at or near (~500 m or 1500 ft) sites and/or facilities having the potential for, or history of, release, with an emphasis on the prevailing downwind directions.

Samples were collected according to a schedule established before the monitoring year. Airborne particles were sampled at each of these stations by drawing air through a glass fiber filter. The filters were collected weekly, field-surveyed for gross radioactivity to detect any unusual trends or off-normal occurrences, held for at least 7 days, and then analyzed for total alpha and beta activity. The 7-day holding period was necessary to allow for the decay of naturally occurring radionuclides that would otherwise obscure detection of longer-lived radionuclides associated with emissions from nuclear facilities. The total radioactivity measurements were used to indicate changes in trends in the near-facility environment.

For most radionuclides, the amount of radioactive material collected on a filter during a 1-week sampling period was too small to be measured accurately. The accuracy of the sample analysis was increased by compositing the samples into a biannual composite for each location. Each biannual composite was then sent to International Technology Corporation to be analyzed for strontium, plutonium, uranium, and gamma-emitting radionuclides.

Radiological Results

Of the radionuclide analyses performed, ^{90}Sr, ^{137}Cs, $^{239,240}Pu$, and uranium were consistently detectable in the 200 Areas; ^{60}Co was also detectable in the 100-N Area. Air concentrations for these radionuclides were elevated near facilities when compared to the concentrations measured offsite. Figure 3.2 shows average values for 1992 and the preceding 5 years compared to the Derived Concentration Guides (DCG) and the background air concentration as measured by PNL. As the data indicate, the concentrations show a large degree of variance. In general, the samples collected from air samplers located on or directly adjacent to waste disposal and other nuclear facilities had significantly higher concentrations than those farther away. The data also show, as expected, that certain radionuclides had higher concentrations within different operational areas. Generally speaking, the predominate radionuclides are activation products/gamma emitters in the 100 Areas and fission products in the 200/600 Areas. A more detailed data summary may be found in the *Westinghouse Hanford Company Operational Environmental Monitoring Annual Report, Calendar Year 1992* (Schmidt et al. 1993).

100-N Area

Analytical results from air samples taken in the 100-N Area were on a downward trend for most radionuclides as a result of facility shutdowns, better effluent controls, and improved waste management practices. These levels were well below the DCG; however, they were above those measured offsite.

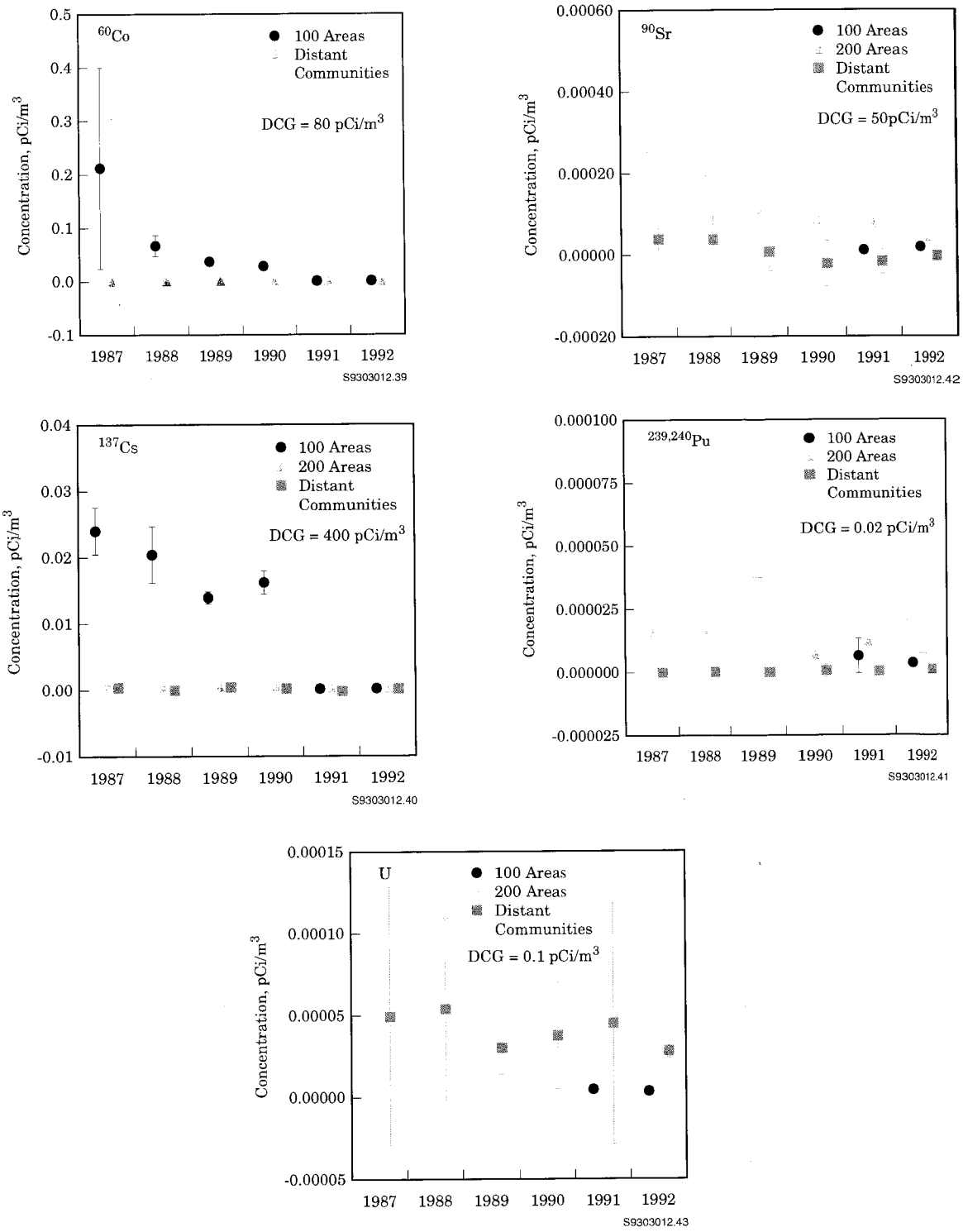


Figure 3.2. Radionuclide Concentrations (±2 SEM) in Near-Facility Air Samples Compared to Background Locations, 1987 Through 1992. As a result of figure scale, some uncertainties (error bars) are concealed by point symbol.

200 Areas

Analytical results from air samples taken in the 200/600 Areas were on a downward trend for most radionuclides as a result of facility shutdowns, better effluent controls, and improved waste management practices. These levels, although well below the DCG, were above those measured offsite and were higher for ^{90}Sr, $^{239,240}Pu$, and uranium when compared to levels in the 100-N Area.

Surface-Water Disposal Units and Seep Monitoring

Surface-water disposal units used by the operating facilities and their seeps are monitored to assess the effectiveness of effluent and contamination controls.

Sample Collection and Analysis

Samples from surface-water disposal units and river shoreline seeps were collected from various locations in the operational areas. A more detailed description of sample locations is given in the *Westinghouse Hanford Company Operational Environmental Monitoring Annual Report, Calendar Year 1992* (Schmidt et al. 1993). Sampling of surface-water disposal units included water, sediment, and aquatic vegetation. Samples taken at river shoreline seeps included water only. The sampling methods are discussed in detail in the WHC manual *Operational Environmental Monitoring* (WHC 1991b). To avoid duplication of sampling, the near-facility environmental monitoring program used PNL surface-water sample data for the 400 Areas (as reported in Section 5.3, "Surface-Water Surveillance").

Radiological analysis of water samples from surface-water disposal units included total alpha, total beta, ^{3}H, $^{239,240}Pu$, and gamma-emitting radionuclides. Alpha and beta measurements provided a general indication of radioactive contamination. Radiological analysis of sediment and aquatic vegetation included ^{90}Sr, $^{239,240}Pu$, uranium, and gamma-emitting radionuclides. Non-radiological analysis performed included pH, temperature, and nitrates. Analytes of interest were selected based on their presence in effluent discharges, and their importance in verifying effluent control and determining compliance with applicable standards. Surface-water disposal units that receive potentially radioactively contaminated effluents are within posted radiological control areas.

Radiological Results

Surface-Water Disposal Units

Radiological analytical results for individual surface-water disposal units are summarized in Table 3.7. In all cases, radionuclide concentrations in surface-water disposal units were less than the applicable DCG and in most cases equal to or less than the analytical detection limit. However, the maximum total beta concentration for one of the samples approached the DCG (using ^{90}Sr DCG of 1,000 pCi/L for comparison). This was a new sample location for the 216-U-14 Ditch in the 200-West Area. The sampling location had been changed as a result of the stabilization (the placement of fill material over contaminated soils) of the original sampling location at the lower portion of the 216-U-14 Ditch in early 1992. This surface-water disposal unit had received radioactively contaminated waste in the past.

Radiological analytical results for aquatic vegetation and sediment samples taken from surface-water disposal units located in the 200/600 Areas are summarized in Tables 3.8 and 3.9, respectively. Although some elevated levels can be seen in both aquatic vegetation and sediment, in all cases the radiological analytical results were well below the standards for radiological control.

A more detailed data summary for samples taken to monitor surface-water disposal units may be found in *Westinghouse Hanford Company Operattional Environmental Monitoring Annual Report, Calendar Year 1992* (Schmidt et al. 1993).

Seeps

Ground-water seeps along the 100-N Area shoreline are sampled annually to verify reported radionuclide releases to the Columbia River from the past operation of the N Reactor. Release reporting utilizes conservatively based radionuclide concentrations, multiplied by the estimated ground-water flow into the river. By characterizing the radionuclide concentrations in the seeps along the shoreline, the results can be compared to the concentrations measured in the effluent monitoring well 199-N-8T.

In 1992, the concentrations detected in the seep samples were highest in those seeps in the area nearest well 199-N-8T, although the seep concentrations were considerably lower than those measured in the well. The

Table 3.7. Radiological Results for Liquid Samples from Surface-Water Disposal Units, 200/600 Areas (pCi/L), 1992

Sample Locations[a]	No. of Samples		Total Alpha	Total Beta	^{3}H	^{90}Sr	^{137}Cs
200-West Area Ditches	21	Mean	5.5	32	450	9.6	43
		Maximum	29	920	450	28	75
200-West Area Ponds	24	Mean	0.29	1.5	600	11	41
		Maximum	0.88	6.2	1,600	78	48
200-East Area Ditches	12	Mean	0.31	5.5	1,200	7.1	42
		Maximum	0.83	40	2,100	10	49
200-East Area Ponds	60	Mean	0.71	3.1	770	10	42
		Maximum	12	21	2,100	64	92
		DCG	30[b]	1,000[c]	2,000,000	1,000	3,000

(a) 200-West Area Ditches: 216-T-4, 216-U-14.
200-West Area Ponds: 216-Z-21 Basin, Powerhouse Pond.
200-East Area Ditches: 216-B-3-3.
200-East Area Ponds: 216-B-3 (East), 216-B-3 (South), 216-B-3 (overflow), 216-B-3 (3rd overflow), Powerhouse Pond.

(b) Using ^{239}Pu DCG for comparison.

(c) Using ^{90}Sr DCG for comparison.

Table 3.8. Radiological Results for Aquatic Vegetation Samples from Surface-Water Disposal Units 200/600 Areas (pCi/g), 1992

Sample Locations[a]	No. of Samples		^{90}Sr	^{137}Cs	$^{239/240}Pu$	U total, g/g
200-West Area Ditches	2	Mean	0.97	<2.9	6.7	5.4×10^{-8}
		Maximum	1.2	<4.9	13	2.4×10^{-7}
200-West Area Ponds	2	Mean	<0.58	<0.83	<0.48	5.4×10^{-8}
		Maximum	<0.69	<0.86	<0.48	8.6×10^{-8}
200-East Area Ditches	1	Mean	1.4	7.8	<0.38	3.6×10^{-8}
		Maximum	1.4	7.8	<0.38	3.6×10^{-8}
200-East Area Ponds	5	Mean	<1.8	<2.8	<0.42	4.5×10^{-8}
		Maximum	5.6	<5.3	<0.46	7.7×10^{-8}

(a) 200-West Area Ditches: 216-T-4, 216-U-14.
200-West Area Ponds: 216-Z-21 Basin, Powerhouse Pond.
200-East Area Ditches: 216-B-3-3.
200-East Area Ponds: 216-B-3 (East), 216-B-3 (South), 216-B-3 (overflow), 216-B-3 (3rd overflow) Powerhouse Pond.

Table 3.9. Radiological Results for Sediment Samples from Surface-Water Disposal Units, 200/600 Areas (pCi/g), 1992

Sample Locations[a]	No. of Samples		^{90}Sr	^{137}Cs	$^{239/240}Pu$	U total, g/g
200-West Area Ditches	2	Mean	0.43	19	0.79	6.1×10^{-6}
		Maximum	0.55	34	1.2	1.2×10^{-5}
200-West Area Ponds	2	Mean	<0.35	<0.14	<0.43	4.7×10^{-7}
		Maximum	<0.58	<0.15	<0.50	6.3×10^{-7}
200-East Area Ditches	1	Mean	1.1	110	14	7.9×10^{-7}
		Maximum	1.1	110	14	7.9×10^{-7}
200-East Area Ponds	5	Mean	0.89	8.1	2.3	8.0×10^{-7}
		Maximum	2.3	16	7.5	1.7×10^{-6}

(a) 200-West Area Ditches: 216-T-4, 216-U-14.
200-West Area Ponds: 216-Z-21 Basin, Powerhouse Pond.
200-East Area Ditches: 216-B-3-3.
200-East Area Ponds: 216-B-3 (East), 216-B-3 (South), 216-B-3 (overflow), 216-B-3 (3rd overflow) Powerhouse Pond.

data from seep sampling are summarized in Table 3.10. A more detailed data summary may be found in *Westinghouse Hanford Company Operational Environmental Monitoring Annual Report, Calendar Year 1992* (Schmidt et al. 1993).

Nonradiological Results for Surface-Water Disposal Units

Nonradiological analytical results for water samples taken from surface-water disposal units located in the 200 and 600 Areas are summarized in Table 3.11. The results for pH were well within the pH of 2.0 and 12.5 standard for liquid effluent discharges based on the discharge limits listed in RCRA. The analytical results for nitrates were all less than the detection limit except for those samples from the 216-T-4 Ditch. The average nitrate result for that location was 2.0 mg/L, which was slightly greater than the analytical detection limit of 1.4 mg/L and is less than the 45-mg/L drinking water standard for public water supplies.

Table 3.10. Concentrations of Radionuclides in 100-N Area Shoreline Seeps, 1992 (results in pCi/L)

Radionuclide	Well 199-N-8T (Mean)	Seeps Maximum	Seeps Mean	DCG[a]
^{3}H	43,000	770	390	2,000,000
^{60}Co	7.8	5.2	1.2	5,000
^{90}Sr	6,500	150	49	1,000

(a) DCG = Derived Concentration Guide (see Appendix C).

Radiological Surveys

Another aspect of the near-facility environmental monitoring program is radiological surveying, which monitors and helps direct the reduction of the radiologically controlled areas on the Hanford Site. There are two type of radiologically controlled areas, which are posted: underground radioactive materials (URMs) and surface contamination areas (SCAs).

URM areas are posted areas with contamination contained below the soil surface. These areas are typically "stabilized" cribs, burial grounds, and covered ponds, trenches, and ditches. Barriers over the contamination sources are used to inhibit radionuclide transport to the surface environs. Waste sites are routinely surveyed (at least annually) to document the current radiological status.

Table 3.11. Nonradiological Results for Liquid Samples from Surface-Water Disposal Units, 1992

	pH				Nitrate (NO_3), mg/L		
Sample Locations[a]	No. of Samples	Mean	Maximum	Minimum	No. of Samples	Mean	Maximum
200-West Area Ditches	86	7.3	9.5	6.5	8	1.7	3.9
200-West Area Ponds	100	8.9	10.3	7.1	8	<1.4	<1.4
200-East Area Ditches	50	8.1	8.7	7.4	4	<1.4	<1.4
200-East Area Ponds	255	8.8	9.7	7.8	20	<1.4	<1.4

(a) 200-West Area Ditches: 216-T-4, 216-U-14.
200-West Area Ponds: 216-Z-21 Basin, Powerhouse Pond.
200-East Area Ditches: 216-B-3-3.
200-East Area Ponds: 216-B-3 (East), 216-B-3 (South), 216-B-3 (overflow), 216-B-3 (3rd overflow) Powerhouse Pond.

SCAs may or may not have been associated with an underground radioactive material structure. A breech in the barrier of URM may have resulted in the growth of contaminated vegetation. Insects or animals might have burrowed into an URM and brought contamination to the surface. Vent pipes or risers from an underground structure could have been a source of speck contamination. Fallout from stacks, or unplanned releases from previously operating facilities, may have caused an area of surface contamination that was not related to a subsurface structure. All types of SCA are susceptible to contamination migration.

There were approximately 1,200 ha (3,000 acres) of posted outdoor SCA and 400 ha (1,000 acres) of posted URM, not including active facilities, at Hanford. The number of SCA acres was three times larger than the URM acres primarily because of the BC Controlled Area located south of the 200-East Area. This area was posted as a Radiologically Controlled Area in 1959 because of widespread speck contamination, and encompassed approximately 1,000 ha (2,500 acres). Table 3.12 contains the acreage for SCA and URM areas showing the net change from 1991 to 1992. Table 3.13 summarizes the number of contaminated acres that changed status in 1992. Twenty acres were reclassified from SCA to URM, and 16 acres were sampled and unconditionally released.

The area of posted surface contamination varied because of an ongoing effort to clean, stabilize, and remediate areas of known contamination while new areas of contamination were being identified. Table 3.13 indicates the changes resulting from stabilization activities during 1992. Newly identified areas may be from contamination migration or the result of an increased effort to investigate outdoor areas for radiological contamination. Vehicles equipped with radiation detection devices and the Ultrasonic Ranging and Data System (USRADS) have identified areas of contamination that were previously undetected.

It was estimated that 80% of the identified outdoor surface contamination would result in an external dose rate of less than 1 mrem/h, although the dose from isolated specks could be considerably higher. Contamination levels of this magnitude would not significantly add to dose rate calculations for the public or employees.

Soil and Vegetation Sampling from Operational Areas

Soil and vegetation samples were collected on or adjacent to waste disposal units and from locations downwind and near or within the boundaries of the operating facilities. Samples are collected to detect potential migration and deposition of facility effluents. Migration can occur as the result of resuspension from radioactively contaminated surface areas, absorption of radionuclides by the roots of vegetation growing on or near underground and surface-water disposal units, or by waste site intrusion by animals. Special samples were

Table 3.12. Outdoor Contamination Status, 1992 (approximate surface area in acres)

Hanford Site Area	Surface Contamination[a]	Net Change[b]	Underground Radioactive Material[c]	Net Change
100 Areas	160	-6	460	5
200 Areas	329	-32	366	17
600 Area	120	0	230	0
BC Control Area	2,500 (RCA)[d]	0	30	0
300 Area	45	0	30	0
Totals	3,154	-38	1,116	22

(a) Includes areas posted as "Surface Contamination Areas" or as "Radiologically Controlled Areas" and areas that had both underground and surface contamination.
(b) - = decreases.
(c) Includes areas with only underground contamination. Does not include areas that had surface as well as underground radioactive material.
(d) Radiologically Controlled Area.

Table 3.13. Zone Status Change by Area, 1992

Location	Zone Change	Acreage
100 Areas	SCA to Released	1
200-East Area	SCA to Released	15
100 Areas	SCA to URM	5
200-East Area	SCA to URM	5
200-West Area	SCA to URM	12

also taken where physical or biological transport problems were identified. The results of sampling effort are discussed below.

Sample Collection and Analysis

The sampling methods and locations used are discussed in detail in the WHC manual *Operational Environmental Monitoring* (WHC 1991b). Radiological analysis of soil and vegetation samples included ^{90}Sr, $^{239,240}Pu$, uranium, and gamma-emitting radionuclides.

Radiological Results

Soil

Of the radionuclide analyses performed, ^{60}Co, ^{90}Sr, ^{137}Cs, $^{239,240}Pu$, and uranium were consistently detectable. Soil concentrations for these radionuclides were elevated near and within facility boundaries when compared to the concentrations measured offsite. Figure 3.3 shows average values for 1992 and the preceding 5 years. As the data indicate, the concentrations show a large degree of variance. In general, the samples collected on or directly adjacent to the waste disposal facilities had significantly higher concentrations than those farther away. The data also show, as expected, that certain radionuclides will have higher concentrations within different operational areas. Generally speaking, the predominate radionuclides are activation products/gamma emitters in the 100 Areas, fission products in the 200/600 Areas, and uranium in the 300 Areas. A more detailed data summary may be found in *Westinghouse Hanford Company Operational Environmental Monitoring Annual Report, Calendar Year 1992* (Schmidt et al. 1993).

100 Areas. Analytical results from soil samples collected in the 100 Areas were on a downward trend, showing effects of the shutdown of the production reactors and the effectiveness of effluent controls that have been implemented in recent years. However, these levels were greater than those measured offsite, and the concentration of ^{60}Co was greater than that measured in the 200/600 and 300/400 Areas. The ^{60}Co in the 100 Areas was the result of past discharges to waste disposal structures, primarily the 1301-N Liquid Waste Disposal Facility. Measures have been taken in recent years to identify and minimize the migration of contamination from these structures.

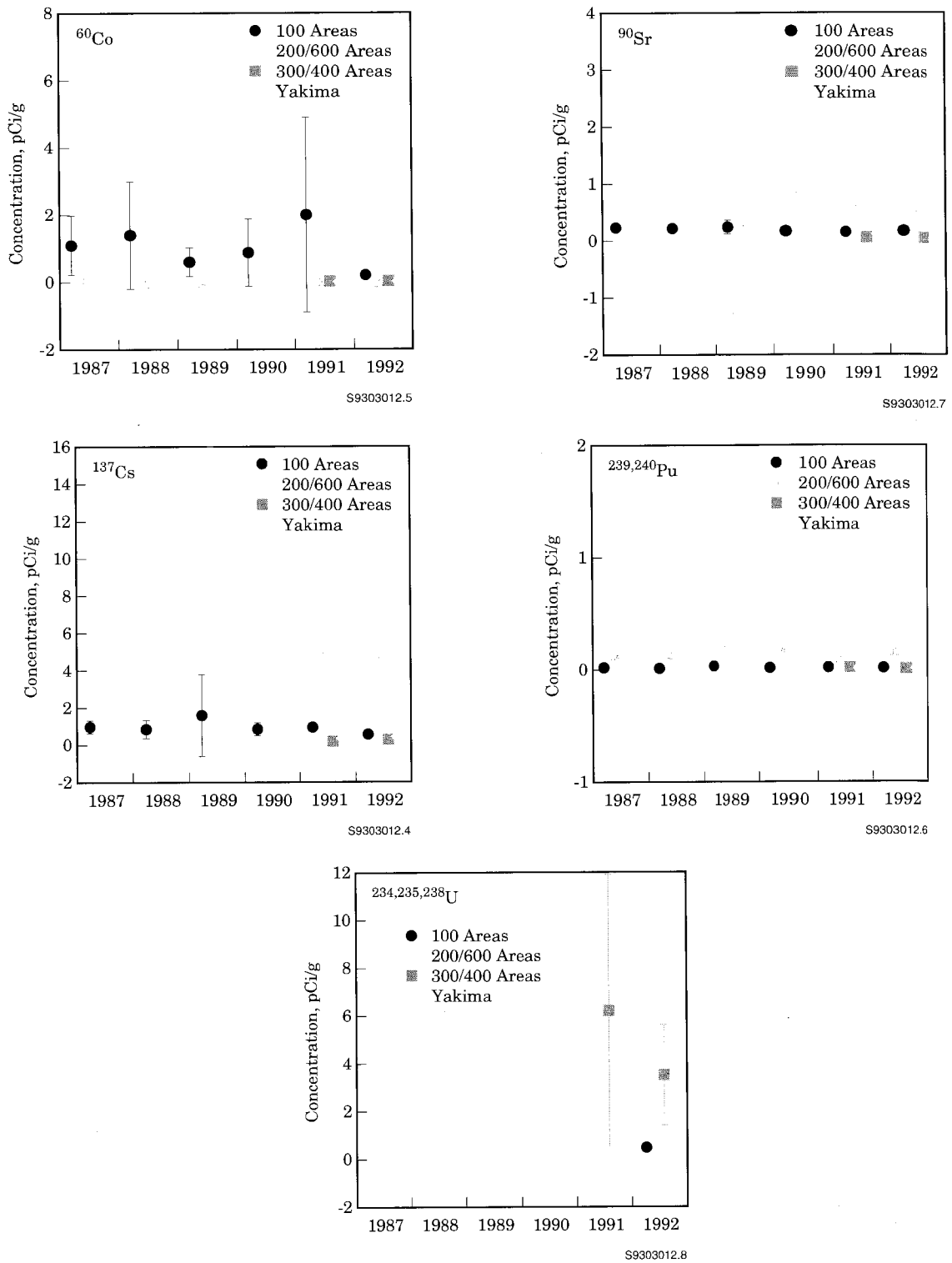


Figure 3.3. Radionuclide Concentrations (±2 SEM) in Near-Facility Soil Samples Compared to Background Concentrations, 1987 Through 1992. As a result of figure scale, some uncertainties (error bars) are concealed by point symbol.

200/600 Areas. Analytical results from soil samples taken in the 200/600 Areas were on a downward trend for most radionuclides as a result of facility shutdowns, better effluent controls, and waste management practices. However, these levels were greater than those measured offsite, and were shown to be higher for ^{90}Sr, ^{137}Cs, and $^{239,240}Pu$ when compared to values from the 100 and 300/400 Areas. Uranium levels were slightly increased over those measured in 1991.

300/400 Areas. This was the second sampling year for the 300/400 Areas near-facility environmental monitoring program. The data for these areas were compared to results for other operational areas and those measured offsite. The levels measured for uranium were higher than those from the 100 and 200/600 Areas. This difference is expected because the uranium is the result of past fuel fabrication operations conducted in the 300 Area.

Vegetation

Of the radionuclide analyses performed, ^{60}Co, ^{90}Sr, ^{137}Cs, $^{239,240}Pu$, and uranium were consistently detectable. Vegetation concentrations for these radionuclides were elevated near and within facility boundaries compared to the concentrations measured offsite. Figure 3.4 shows averages values for 1992 and the preceding 5 years. As the data indicate, the concentrations show a large degree of variance. In general, the samples collected on or directly adjacent to the waste disposal facilities had significantly higher concentrations than those farther away. As with the soil samples, the data show that certain radionuclides will be found in vegetation in higher concentrations within different operational areas. Except for ^{90}Sr (a fission product) detected in vegetation from the N Springs, generally speaking the predominate radionuclides are activation products/gamma emitters in the 100 Areas, fission products in the 200/600 Areas, and uranium in the 300 Areas. A more detailed data summary may be found in *Westinghouse Hanford Company Operational Environmental Monitoring Annual Report, Calendar Year 1992* (Schmidt et al. 1993).

100 Areas. Analytical results from vegetation samples collected in the 100 Areas were all on a downward trend except for those for ^{90}Sr, which increased to the levels seen in 1989. The maximum values were from samples collected from the N Springs area located in the 100-N Area. The reason for this increase may be related to the time of year for sampling, and there were no N Springs vegetation results for 1990 that contributed to the average concentration of ^{90}Sr in the 100 Area vegetation. However, these levels were greater than those measured offsite and were higher for ^{60}Co and ^{90}Sr compared to the 200/600 and 300/400 Areas.

200/600 Areas. Analytical results from vegetation samples taken in the 200/600 Areas were on a downward trend for most radionuclides as a result of facility shutdowns, better effluent controls, and improved waste management practices. Before 1992, these levels were greater than those measured offsite and were higher for ^{137}Cs and $^{239,240}Pu$ compared to the 100 and 300/400 Areas. During 1992, the average concentrations onsite, offsite, and within the various operational areas were similar for these two radionuclides.

300/400 Areas. This was the second sampling year for the 300/400 Areas near-facility environmental monitoring program. Generally, most of the levels in the 300 Area were greater than those measured offsite and were higher for uranium compared to the 100 and 200/600 Areas. This difference is expected because uranium was released during past fuel fabrication operations conducted in the 300 Area. The levels measured in the 400 Area were at or near those measured offsite.

Investigative Sampling

The purpose of investigative sampling was to determine whether effluent controls and waste containment were adequate. An important part of the near-facility program, investigative monitoring was conducted and special samples were taken in the operations areas to confirm the absence of or to detect the presence of radioactive contaminants. This investigative sampling took place near facilities such as storage and disposal sites for at least one of the following reasons:

- because radiological surface surveys had indicated that radioactive contamination was present
- to quantify the radiological condition of a site before facility construction or operation
- to quantify the radiological condition of a site before remediation
- to determine if biotic intrusion (e.g., animal burrows or deep-rooted vegetation) had created a potential for the spread of contaminants

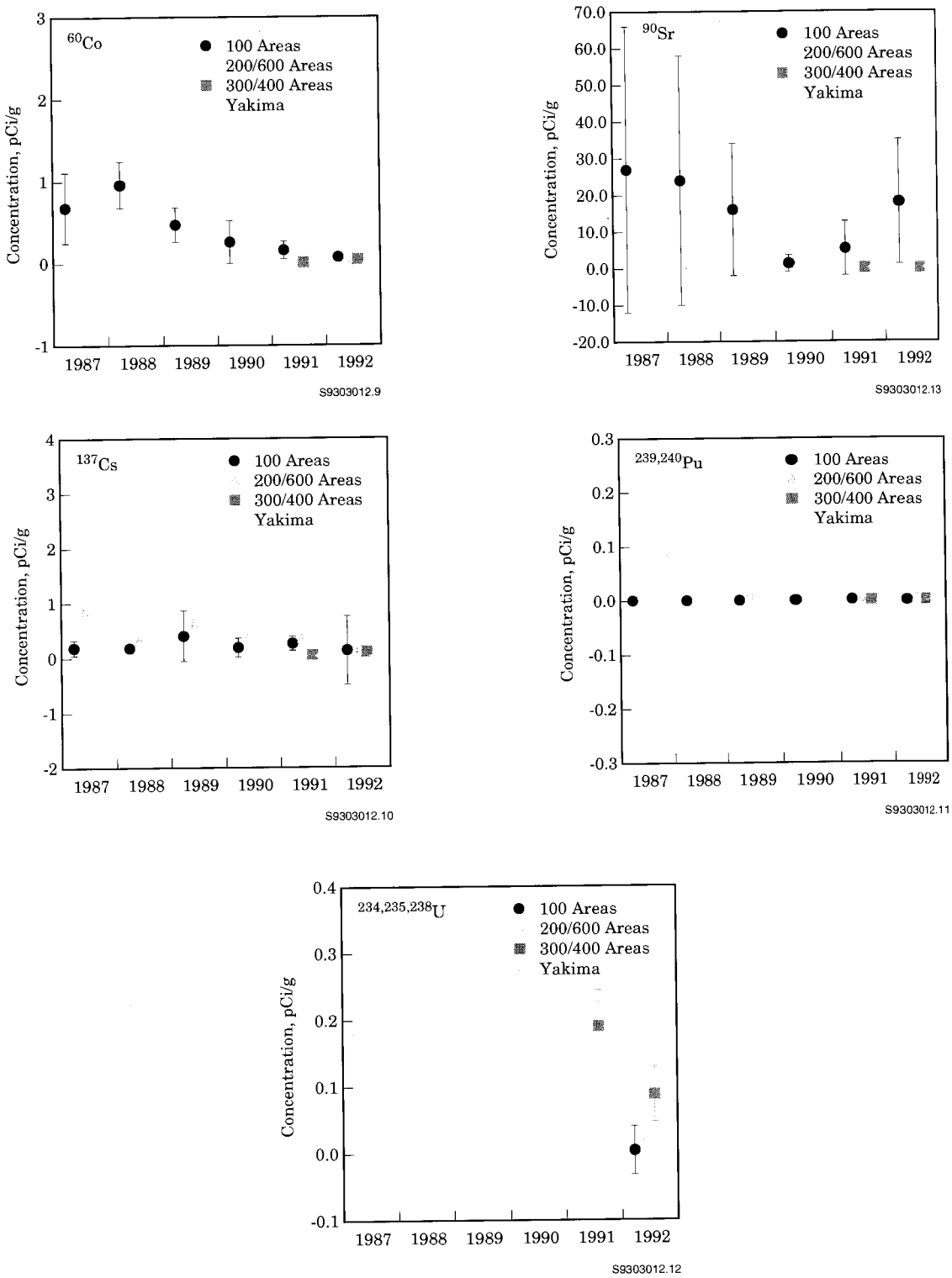


Figure 3.4. Radionuclide Concentrations (±2 SEM) in Near-Facility Vegetation Compared to Background Concentrations, 1987 Through 1992. As a result of figure scale, some uncertainties (error bars) are concealed by point symbol.

- to determine the integrity of waste containment systems.

Because of the diverse operations historically conducted at each of the operating areas (100, 200, and 300 Areas), radionuclide concentrations in samples from the different areas were generally predictable.

Sample Collection and Analysis

Types of investigative samples over the years have included air; water; snow; sediments; soil; vegetation such as grasses, tumbleweeds (also known as Russian thistles), sagebrush, trees, and fruits; and various animals such as spiders, termites, ants, fish, toads, snakes, birds, mice, rabbits, coyotes, and bobcats.

Special samples in 1992 included soil; tumbleweeds; gopher snakes; pigeon feces; cliff swallow nests; house mice; deer mice; a black-tailed jackrabbit; and a Nuttall's cottontail rabbit.

Methods for collecting or otherwise obtaining investigative samples are found in the WHC manual *Operational Environmental Monitoring* (WHC 1991b). Field monitoring results, expressed as counts per minute (cpm), were obtained using a Geiger-Mueller Counter equipped with a P-11 Probe. Laboratory sample analysis results are expressed in pCi/g. Maximum concentrations of radionuclides rather than averages are presented in this subsection.

Results

Special samples were collected where known or suspected radioactive contamination was present. A direct relationship to the general status of the different media within the operating areas to contamination levels reported for special samples cannot be drawn. A more detailed data summary may be found in *Westinghouse Hanford Company Operational Environmental Monitoring Annual Report, Calendar Year 1992* (Schmidt et al. 1993).

Soil

In 1992, 30 investigative soil samples were taken. The radionuclides in maximum concentration were ^{60}Co from D Island near the 100-D Area (11,000,000 pCi/sample); ^{90}Sr (1,000,000 pCi/g) and ^{137}Cs (1,900 pCi/g), both from near 221-B Stack in the 200-East Area; and ^{234}Th (730 pCi/g), ^{234m}Pa (1,100 pCi/g), and ^{235}U (38 pCi/g) from near the 300 Area (Table 3.14). Note that the D Island sample analyses result was for a single speck of contamination (probably about 0.001 g) and if collected as a typical sample (~500 g) the radioactivity concentration would be reduced to several hundred or perhaps thousand picocuries per gram. Further discussion of the shoreline radiological survey may be found in Section 5.7. The number of contamination incidents, the radioactivity levels, and the range of radionuclide concentrations were not unusual. Areas of special soil sampling that were outside radiological control areas and that had levels greater than WHC radiological control limits (WHC 1991a) were posted as surface contamination areas.

Vegetation

There were 13 instances of contaminated vegetation detected in operational areas in 1992 (Table 3.14). Only one sample (i.e., from 100-F Area and reading 1,500 cpm) was analyzed at a laboratory before disposal, and the radionuclides at the maximum concentrations were ^{137}Cs (<0.96 pCi/g) and total uranium (0.04 pCi/g). The remaining 12 instances of contaminated tumbleweeds were found during remedial operations and disposed of so that only field-instrument readings of radioactivity are available. Field-instrument readings ranged from 350 cpm to 40,000 cpm, which are within the ranges reported for the past 3 years. The number of plants found to be contaminated with radioactivity was not unusual. The greatest number of contaminated vegetation (42) submitted for analyses was in 1978. In the 200 Areas before 1980, when vegetation control was limited or nonexistent, contaminated vegetation was counted in acres rather than individual specimens. Vegetation control in 1992, as in 1991, was noticeably more effective than in 1990 and 1989 and hopefully represents a return to an improving trend. An improving trend had been evident from 1981 up to 1989, when resistance to the herbicide in use was first noted. Improved vegetation control was probably the result of improved equipment and use of more effective herbicides.

Wildlife

Animals were collected as a result of an aggressive pest control program designed to limit the exposure and potential contamination of animals to radioactive material. Animals were collected directly from or near facilities to identify problems in preventative measures designed to inhibit animal intrusion. Surveys were

Table 3.14. Special Samples Collected from the Operations Areas, 1992

Sample Type (Number)	Area (Number)	Elevated Radionuclides	Maximum Concentration, pCi/g
Soil (30)	100 (2)	^{60}Co	11,000,000[a]
	200 (26)	^{137}Cs	1,900
		^{90}Sr	1,000,000
	300 (2)	^{234}Th	730
		^{234m}Pa	1,100
		^{235}U	38
Tumbleweed (13)	100 (3)	^{137}Cs	<0.96
		U Total	0.31
	200 (10)	NA[b]	NA
Gopher snake (2)	200 (2)	^{137}Cs	7,900
		^{90}Sr	300
Pigeon feces (1)	200 (1)	^{137}Cs	280
Cliff swallow nest (2)	200 (2)	^{60}Co	74,000
		^{137}Cs	2,300
		^{90}Sr	340
		^{54}Mn	160
		^{154}Eu	470
		^{155}Eu	180
		^{238}Pu	8
		^{239}Pu	47
House mouse (9)	200 (9)	^{137}Cs	1,500
		^{90}Sr	3,100
		$^{239,240}Pu$	<5.0
		U Total	1.3
Deer mouse (10)	100 (2)	^{137}Cs	100
		$^{239,240}Pu$	<1
	200 (6)	^{137}Cs	<25
		$^{239,240}Pu$	<5
	300 (2)	^{60}Co	97
		^{137}Cs	5,500

Table 3.14. Special Samples Collected from the Operations Areas, 1992 (contd)

Sample Type (Number)	Area (Number)	Elevated Radionuclides	Maximum Concentration, pCi/g
Deer mouse (contd)			
		^{90}Sr	63
		$^{106}Ru/Rh$	4,200
		^{125}Sb	1,600
		$^{144}Ce/Pr$	38,000
		^{154}Eu	650
		^{155}Eu	1,700
		^{139}Pu	18
Black-tailed jackrabbit (1)	200 (1)	^{137}Cs	56
		^{90}Sr	1,100
		^{154}Eu	15
		^{239}Pu	19
Nutall's cottontail (1)	200 (1)	$^{234,240}Pu$	5
		U Total	<5

(a) pCi/sample.
(b) NA = not analyzed.

performed after collection to determine if an animal is radioactively contaminated. If an animal was found free of contamination, it would be taken to a suitable habitat area and released. If an animal was contaminated, a decision was made to collect a sample or dispose of the animal. This decision was based on the level of contamination, sampling facility, and frequency of occurrence.

There were 26 special animal or nest samples analyzed in 1992. The radionuclides found at the maximum concentrations were ^{60}Co (74,000 pCi/g), ^{90}Sr (3,100 pCi/g), ^{106}Ru (4,200 pCi/g), ^{137}Cs (7,900 pCi/g), and $^{154,155}Eu$ (1,700 pCi/g) (see Table 3.13). The total number of animals found to be contaminated with radioactivity, the radioactivity levels, and the range of radionuclides concentrations were not unusual; however, the number of incidents decreased slightly compared to 32 in 1991. The greatest number of contaminated animals was found in 1982 (44, mostly pigeons); however, before 1981 fewer representative samples were submitted for radionuclide analyses.

Special Characterization Projects

Special characterization projects were conducted to verify the status of contaminated soil at 216-U-14 Ditch in the 200-West Area before stabilizing the lower end, around B Stack in the 200-East Area, and on D Island in the Columbia River, which was the site of the old liquid effluent outfall from D Reactor. Radionuclides found at the maximum concentrations at these sites were, respectively, ^{137}Cs (1,600 pCi/g); ^{90}Sr (1,000,000 pCi/g) and ^{137}Cs (1,900 pCi/g); and ^{60}Co (11,000,000 pCi/sample). Note that the D Island sample analyses result was for a single speck of contamination (probably about 0.001 g) and if collected as a typical sample (~500 g) the radioactivity concentration would be reduced to several hundred or perhaps thousand picocuries per gram.

External Radiation

External radiation fields were measured near operations facilities and waste handling, storage, and disposal sites to measure, assess, and control the impacts of operations.

Sample Collection and Analysis

Two methods of measurement are employed, one being hand-held μR meters used to survey multiple survey points and the other being thermoluminescent dosimeters (TLD). The measurement methods used for external radiation measurements and sample locations are discussed in detail in the WHC manual *Operational Environmental Monitoring* (WHC 1991b).

Results

Radiation Measurements

Hand-held μR meters were used to survey points near and within three waste disposal locations in the 100-N Area: the N Springs area, 1301-N Liquid Waste Disposal Facility (LWDF), and 1325-N LWDF. These radiation measurements were taken at a height of approximately 1 m (3.28 ft) to assess the effects of changes in operations of these facilities and are not necessarily a true measurement of exposure rate. The hand-held μR meters are known to over-respond to low-energy gamma radiation. The radiation rate measured along the 100-N Area shoreline was still declining in 1992 and is compared to rates during the past 5 years in Figure 3.5. The shift in the dose rate levels show the effects of the decreased discharges to the 1301-N LWDF and the continuing decay of ^{60}Co, the principal residual radionuclide. The radiation measurements taken at the 1301-N LWDF in 1992, as in previous years, continue to show the decay of ^{60}Co (Table 3.15). The radiation measurements taken at the 1325-N LWDF in 1992 and in the previous year were elevated, compared to the earlier years. This increase indicates the effect of decreased discharges of liquid waste to that facility (Table 3.15). The decreased discharges resulted in the loss of the water that normally provided shielding from the gamma-emitting radionuclides contained in the sediments of the LWDF, principally ^{60}Co and ^{137}Cs. A more detailed data summary may be found in *Westinghouse Hanford Company Operational Environmental Monitoring Annual Report, Calendar Year 1992* (Schmidt et al. 1993).

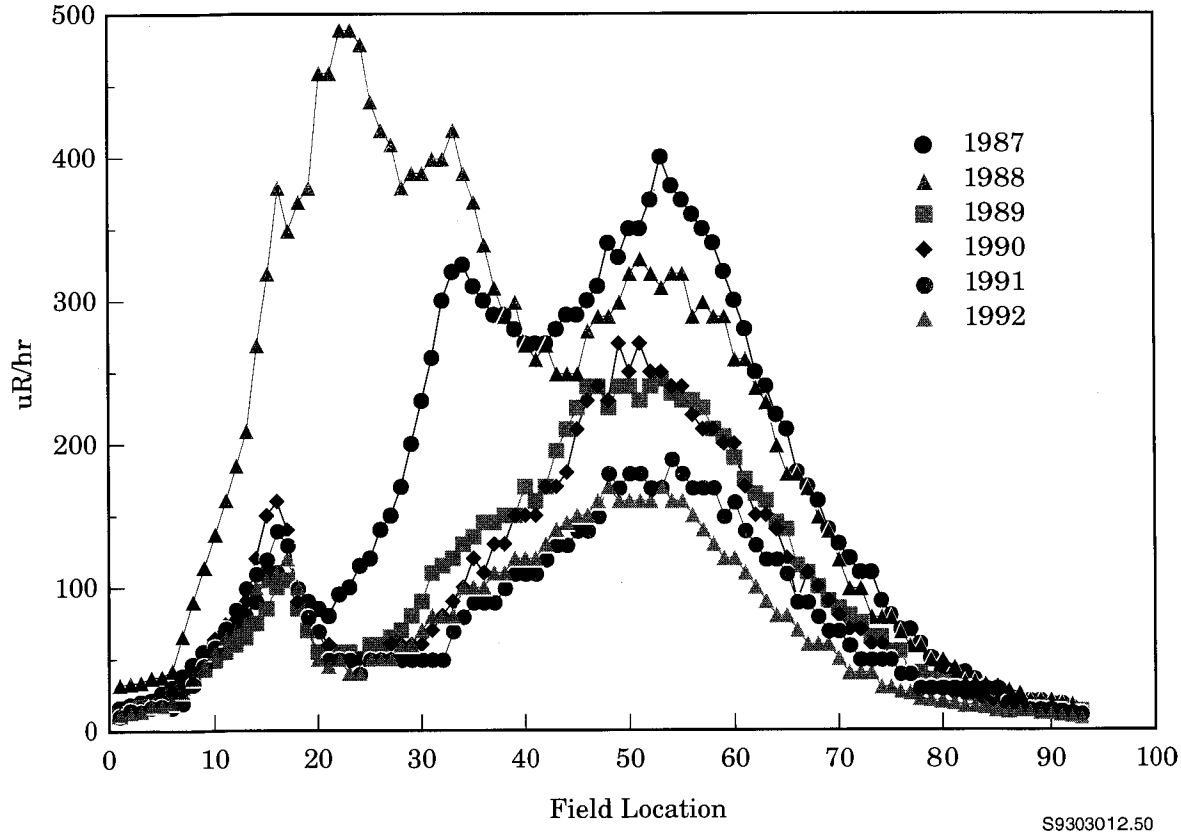
TLDs

100 Areas. All TLDs in the 100 Areas were located in the 100-N Area; results are presented in Table 3.16. The 1992 TLD results indicate that direct radiation levels were highest near facilities that had contained or received liquid effluent from N Reactor. These facilities primarily include the 1325-N LWDF and the 1301-N LWDF. While the results were noticeably higher than those for other 100-N Area TLD locations, the overall results for these two facilities decreased in exposure rate by approximately 5% when compared to 1991.

In 1992, three TLD locations were moved from previously occupied buildings to other locations. Measurements were initiated at two locations between the 1301-N LWDF and the Columbia River shoreline (N Springs). A more detailed data summary may be found in *Westinghouse Hanford Company Operational Environmental Monitoring Annual Report, Calendar Year 1992* (Schmidt et al. 1993).

200/600 Areas. TLD results for 1992 are compared to those of 1991 for the 200/600 Areas in Table 3.16. The highest dose rates were measured near waste-handling facilities such as tank farms. The highest dose rate was measured at the 241-A Tank Farm complex located in the 200-East Area. The average dose rate measured in 1992 by TLDs in the 200/600 Areas was 130 mrem/yr, which was an increase of 8% over the average dose rate of 120 mrem/yr measured in 1991. A more detailed data summary may be found in *Westinghouse Hanford Company Operational Environmental Monitoring Annual Report, Calendar Year 1992* (Schmidt et al. 1993).

300/400 Areas. A comparison of 1992 TLD results to those of 1991 for the 300/400 Areas are presented in Table 3.16. The highest dose rates in the 300 Area were measured near waste-handling facilities such as the 340 Waste Handling Facility. The average dose rate measured in 1992 by TLDs in the 300 Areas was 160 mrem/yr, which was a decrease of 10% of the average dose rate of 180 mrem/yr measured in 1991.



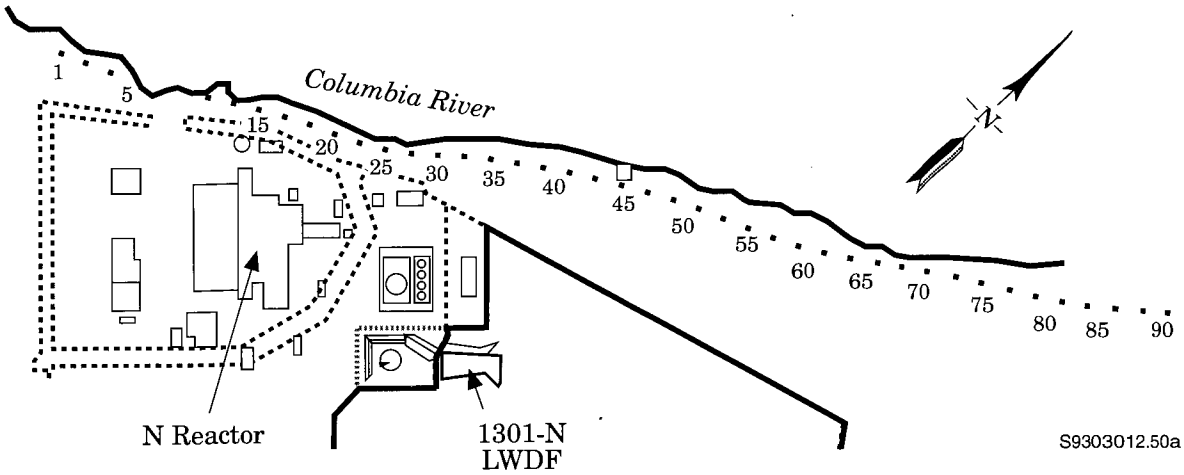


Figure 3.5. Radiation Survey Measurements Along the 100-N Area Shoreline, 1987 Through 1992

Table 3.15. 100-N Liquid Waste Disposal Facilities (LWDF) Direct Radiation Measurements, 1991 and 1992 (μR/h)

LWDF	1991 Average	1992 Average
1301-N	2,100	2,000
1325-N	950	940

The highest dose rates, although not significantly elevated above background, measured in the 400 Area was near the 4718 Building. The average dose rate measured in 1992 by TLDs in the 400 Area was 90 mrem/yr, which was a decrease of 20% of the average dose rate of 110 mrem/yr measured in 1991. A more detailed data summary may be found in *Westinghouse Hanford Company Operational Environmental Monitoring Annual Report, Calendar Year 1992* (Schmidt et al. 1993).

Table 3.16. Thermoluminescent Dosimeter (TLD) Results for Waste-Handling Facilities in the Operating Areas, 1991 and 1992 (mrem/yr, based on 24 h/d)

		1991		1992		
Area	No. of Samples	Maximum	Mean	Maximum	Mean	% Change[a]
100-N	41	14,260	1,210	13,280	1,200	-1
200/600	62	840	120	700	130	8
300	8	720	180	610	160	-10
400	7	190	110	110	90	-20

(a) Numbers indicate a decrease (-) or increase from 1991.

3.3 Solid Waste Management and Chemical Inventories

Solid Waste

Solid waste produced at the Hanford Site is classified as either radioactive, nonradioactive, or mixed waste. Radioactive waste consists of transuranic, high-level, and low-level wastes. Radioactive mixed waste has both radioactive and hazardous nonradioactive components. Nonradioactive waste is composed of hazardous or nondangerous wastes or both. Hazardous waste contains dangerous wastes or extremely hazardous wastes or both, as defined in Ecology's Dangerous Waste Regulations.

Radioactive and mixed waste is currently handled in several ways. High-level waste is stored in double-shell tanks. Low-level waste also is stored in double-shell tanks or on storage pads or is buried, depending on the source, composition, and concentration of the waste. Transuranic waste is stored in vaults or on underground storage pads from which it can be retrieved.

Approximately 200 facilities on the Hanford Site generate dangerous waste. An annual report lists the dangerous wastes and extremely hazardous wastes generated, treated, stored, and disposed of onsite and offsite (DOE 1993a). Dangerous wastes are treated, stored, and prepared for disposal at several Hanford Site facilities. Dangerous wastes generated at the Site are shipped offsite for disposal, destruction, or recycling.

Nondangerous wastes generated at the Hanford Site are buried in the Solid Waste Landfill, located in the 200 Areas. These wastes originate at both process and nonprocess areas at the Site. Examples of these wastes are construction debris, office trash, cafeteria waste, and packaging materials. Other materials and items classified as waste are solidified filter backwash and sludge from the treatment of river water, failed and broken equipment and tools, air filters, uncontaminated used gloves and other clothing, and certain chemical precipitates such as oxalates. Nonradioactive friable asbestos is buried in designated areas at the Solid Waste Landfill. Ash generated at powerhouses in the 200-East and 200-West Areas is buried in designated sites near those powerhouses. Demolition waste from 100 Areas decommissioning projects is buried in situ or in designated sites in the 100 Areas.

A summary of solid waste disposed of at the Hanford Site in 1992 is shown in Table 3.17. Solid waste program activities are regulated by the Toxic Substances Control Act, discussed in Section 2.0, "Environmental Compliance Summary."

Chemical Inventories

Emergency Planning and Community Right-To-Know-Act

Title III of the Superfund Amendments and Reauthorization Act is a free-standing law, called the Emergency Planning and Community Right-To-Know Act. This Act requires that the public be given information about hazardous chemicals in their communities. It also established emergency planning and notification procedures to protect the public in the event of a hazardous chemical release.

Subtitle B contains requirements for reporting information to local communities on hazardous materials existing in or released from a facility near those locales. The Hanford Site was in compliance with the reporting and notification requirements of the Act. The *1992 Hanford Tier-Two Emergency and Hazardous Chemical Inventory* (DOE 1993a) report was issued March 1, 1993, to the State Emergency Response Commission, local county emergency management committees, and the local fire departments. This report contains information on hazardous materials stored across the Hanford Site. Table 3.18 summarizes the information reported, listing the 10 chemicals stored in greatest quantity on the Hanford Site.

Table 3.17. Radioactive Solid Waste Disposal, 1992

Constituent	Units	Low-Level	Low-Level Mixed	Low-Level Plus[a]	Low-Level Mixed Plus[b]	Transuranic	Transuranic Mixed
Uranium	g	9.9×10^{6}	2.9×10^{2}	0.0	0.0	2.6×10^{3}	2.6×10^{6}
Plutonium	g	3.2	4.1×10^{1}	1.6×10^{-4}	2.5×10^{-7}	5.5×10^{2}	3.6×10^{2}
Americium	g	7.3×10^{-1}	1.9×10^{-1}	1.0×10^{-7}	2.2×10^{-10}	1.0×10^{1}	8.8
Thorium	g	8.6×10^{-2}	2.0×10^{-6}	0.0	0.0	1.0×10^{2}	0.0
Strontium	Ci	3.5×10^{3}	2.0×10^{1}	0.0	5.0×10^{-6}	0.0	6.4×10^{1}
Europium	Ci	3.7×10^{3}	2.0×10^{2}	0.0	0.0	7.2×10^{4}	0.0
Cesium	Ci	3.7×10^{3}	3.6×10^{1}	0.0	1.4×10^{-6}	7.2×10^{-2}	2.8
Other fission and activation products	Ci	3.6×10^{1}	3.4	0.0	1.8×10^{9}	3.9×10^{-4}	9.6×10^{-8}

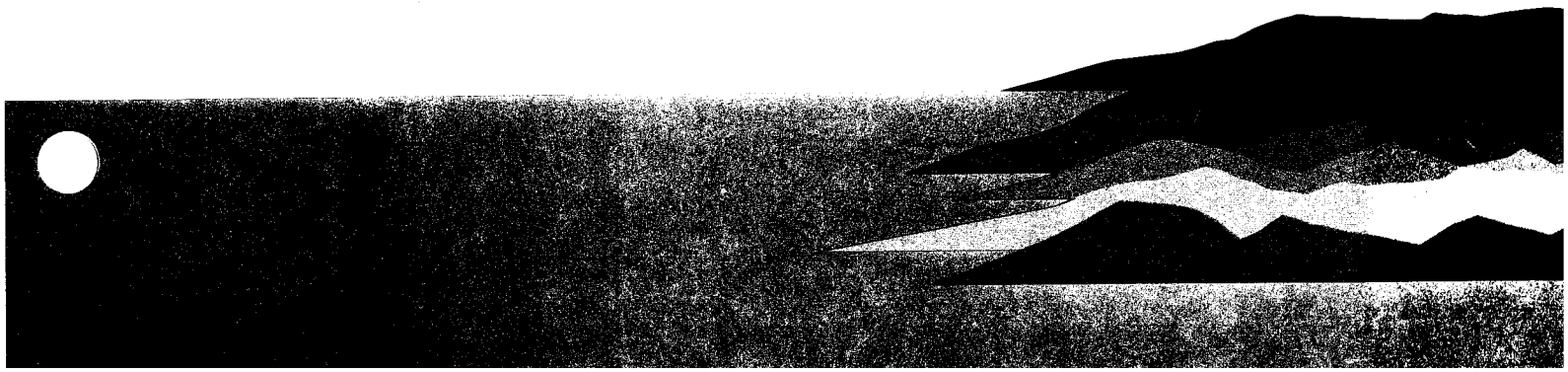
(a) Low-level with polychlorinated biphenyls.
(b) Low-level mixed with polychlorinated biphenyls.

Table 3.18. Hanford Site Tier-Two Emergency and Hazardous Chemical Inventory Average Balance of Ten Chemicals Stored in Greatest Quantity, 1992

Hazardous Material	Average Daily Balance, kg
Coal	7.0×10^{7}
Mineral oil	4.1×10^{6}
Sodium	2.7×10^{6}
Uranium nitrate hexahydrate	1.6×10^{6}
Diesel fuel	1.0×10^{6}
Fuel oil, No. 6	1.0×10^{6}
Nitrogen	7.0×10^{5}
Nitric acid	6.7×10^{5}
Ethylene glycol	6.0×10^{5}
Sodium chloride	5.2×10^{5}

The annual toxic chemical release inventory (DOE 1992i) report is provided to EPA as information only, as directed by HQ. EPA no longer requires this report since the primary mission of the Hanford Site has shifted from production operations to environmental restoration. Available to the public, the report has Site information on toxic chemical releases and transfers, as well as waste management practices.

Environmental Program Information



4.0 Environmental Program Information

It is DOE's policy to conduct its operations in an environmentally responsible manner and comply with applicable environmental standards. At the Hanford Site, a variety of environmental activities are performed to comply with laws and regulations, enhance environmental quality, and monitor the impact of environmental pollutants from Site operations.

Section 2.0 summarized the status of Hanford's compliance with applicable regulations, activities under way to achieve compliance, and programs to manage and improve environmental quality.

This section summarizes significant activities conducted in 1992 to assess the status of wildlife and cultural resources, monitor the meteorology and climatology of the Site, and conduct special environmental programs.

4.1 Climate and Meteorology

Meteorological measurements are conducted to support 1) Hanford Site emergency preparedness and response, 2) atmospheric dispersion calculations, and 3) Hanford Site operations. Support is provided through weather forecasting and the maintenance and distribution of climatological data. Forecasting is provided to help manage weather-dependent operations. Climatological data are provided to help plan weather-dependent activities and are used as a resource to assess the environmental effects of operations.

The Cascade Mountains beyond Yakima to the west greatly influence the climate of the Hanford Site. This range creates a rain shadow effect and also serves as a source of cold air drainage, which has a considerable effect on the wind regime.

The prevailing wind direction on the 200 Area plateau is from the northwest in all months of the year. The secondary wind direction is from the southwest. Summaries of wind direction indicate that winds from the northwest quadrant occur most often during the winter and summer. During the spring and fall, the frequency of southwesterly winds increases, with a corresponding decrease in northwest flow. Monthly average wind speeds are lowest during the winter months, averaging 10 to 11 km/h (6 to 7 mph), and highest during the summer, averaging 14 to 16 km/h (9 to 10 mph). Wind speeds that are well above average are usually associated with southwesterly winds. However, the summertime drainage winds are generally northwesterly and frequently reach 50 km/h (30 mph). These winds are most prevalent over the northern portion of the Site.

Diurnal and monthly averages and extremes of temperature, dew point, and humidity are given by Stone et al. (1983). The record maximum temperature is 46°C (115°F), and the record minimum temperature is -32.8°C (-27°F). For the period 1912 through 1980, the average monthly temperatures ranged from a low of -1.5°C (29.3°F) in January to a high of 24.7°C (76°F) in July. During the winter, the highest monthly average temperature at the Hanford Meteorological Station (HMS) was 6.9°C (44.4°F), and the record lowest was -5.9°C (21.4°F); both occurred during February. During the summer, the record maximum monthly average temperature was 27.9°C (82.2°F) (in July), and the record lowest was 17.2°C (63°F) (in June). The annual average relative humidity at the HMS is 54%. It is highest during the winter months, averaging about 75%, and lowest during the summer, averaging about 35%. Average annual precipitation at the HMS is 16 cm (6.3 in.). Most of the precipitation occurs during the winter, with nearly half of the annual amount occurring in the months of November through February.

Atmospheric dispersion is a function of wind speed, duration and direction, atmospheric stability, and mixing depth. Dispersion conditions are generally good if winds are moderate to strong, the atmosphere is of neutral or unstable stratification, and there is a deep mixing layer. Good dispersion conditions associated with neutral and unstable stratification exist about 57% of the time during the summer. Less favorable dispersion conditions may occur when the wind speed is light and the mixing layer is shallow. These conditions are most common during the winter, when moderately to extremely stable stratification exists about 66% of the time. Occasionally there are extended periods, primarily during winter months, of poor dispersion conditions that are associated with stagnant air in stationary high-pressure systems.

Results of 1992 Monitoring

The weather in 1992 was much warmer and wetter than normal. In fact, 1992 was the warmest year on record and the seventh consecutive year with an above-normal annual average temperature. The average temperature for 1992 was 13.6°C (56.4°F), 1.7°C (3.1°F) above-normal [11.9°C (53.3°F)]. Ten months during 1992 were warmer than normal, with nine months at least 0.6°C (1.1°F) above normal, and five months more than 2.0°C (3.6°F) above normal. Only two months were colder than normal, and both by less than 1.0°C (1.8°F). June (a record warm month) had the largest positive departure, 3.9°C (7.0°F) above normal; while December, at 0.8°C (1.4°F) below normal, had the largest negative departure.

Precipitation for 1992 totaled 20.0 cm (7.9 in.), 126% of normal [15.9 cm (6.3 in.)], with 59.4 cm (23.4 in.) of snow [compared to an annual normal of 35.1 cm (13.8 in.)]. Because 1992 was warmer than normal, with above normal precipitation and no significant cold outbreaks, little adverse impact to either flora or fauna would be anticipated.

The average wind speed for 1992 was 11.0 km/h (6.8 mph), 1.4 km/h (0.9 mph) below normal, and the peak gust for the year was 97 km/h (60 mph) on January 28. Figure 4.1 shows the 1992 wind roses (diagrams showing direction and frequencies of wind) for meteorological monitoring stations on and around the Hanford Site.

Table 4.1 provides monthly climatological data from the Hanford Meteorology Station for 1992.

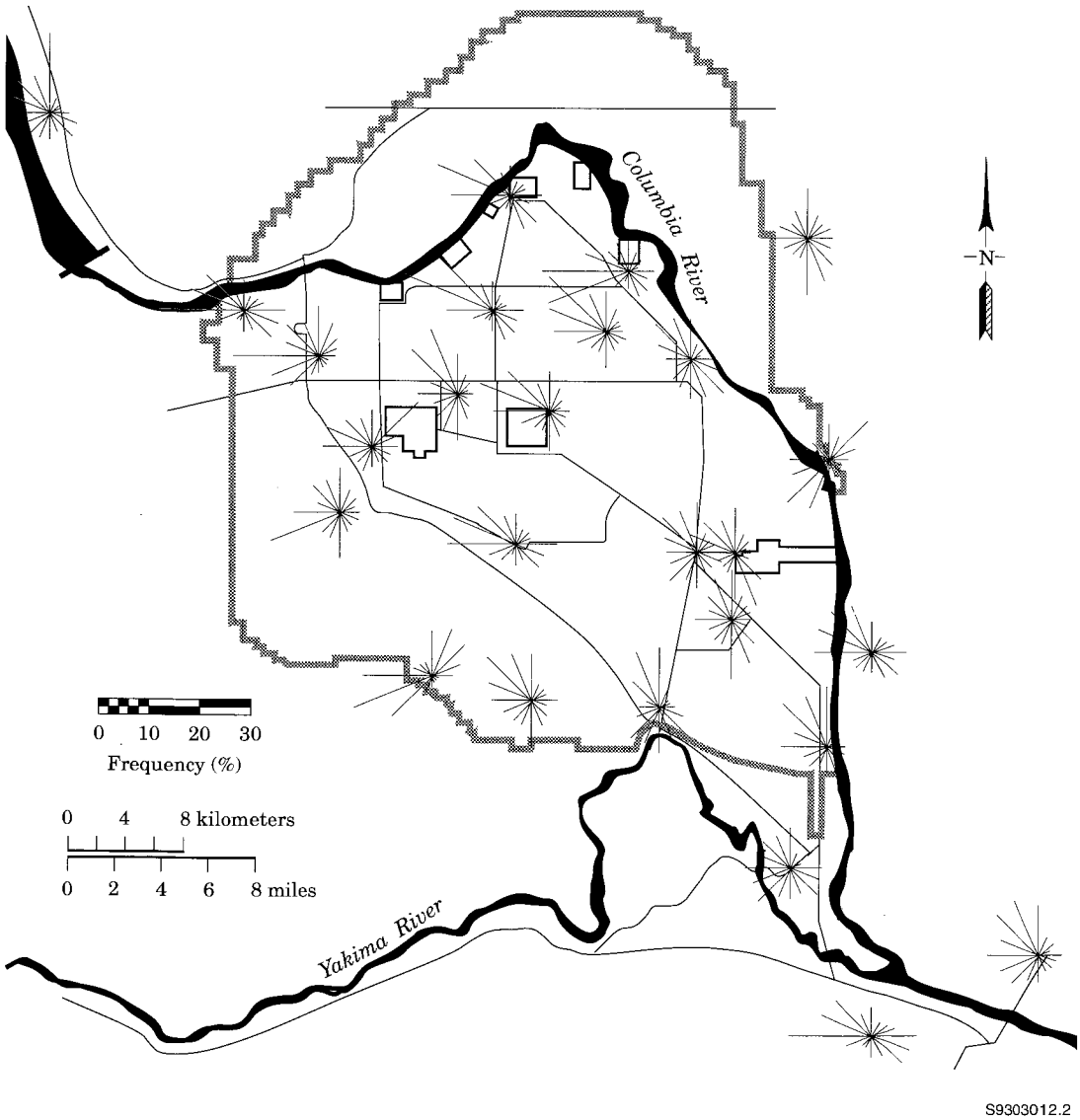


Figure 4.1. Hanford Meteorological Monitoring Network Wind Roses, 1992. Individual lines indicate direction from which wind blows. Length of line is proportional to frequency of occurrence from a particular direction.

Table 4.1. Monthly Climatological Data from the Hanford Meteorology Station, 1992

Hanford Meteorology Station, 25 Miles N.W. of Richland, WA
Latitude 46°34'N, Longitude 119°35'W, Elevation 733 Ft

Month	Temperatures (°C)								Precipitation (cm)				Relative Humidity (%)		50-Ft Wind[a]				
	Averages				Extremes						Snowfall						Peak Gusts		
	Daily Maximum	Daily Minimum	Monthly	Departure[b]	Highest	Date	Lowest	Date	Total	Departure	Total	Departure	Average	Departure	Average Speed (km/h)	Departure	Speed (km/h)	Direction	Date
J	6.5	-0.4	3.1	+3.4	15.6	29	-7.2	8	1.1	-0.9	0.8	-9.1	81.2	+4.8	9.0	-1.4	97	SW	28
F	10.1	1.7	5.9	+2.6	16.7	21	-5.6	5	2.4	+0.8	T[c]	-5.1	82.3	+12.0	8.5	-3.1	72	SW	21
M	18.0	3.7	10.8	+3.3	25.6	31	0.0	19+[d]	0.2	-1.0	0	-0.8	57.9	+2.0	9.8	-3.5	55	WNW	17
A	20.2	6.5	13.3	+1.8	29.4	26	-2.8	8	2.4	+1.3	0	-T	52.4	+5.2	13.2	-1.3	90	SW	17
M	28.4	10.7	19.6	+3.3	36.7	25+	2.8	2	T	-1.3	--[e]	--	32.3	-10.4	13.0	-1.6	74	NW	25
J	32.8	16.9	24.9	+3.9	43.9	23	9.4	14	2.9	+1.9	--	--	36.0	-2.8	13.2	-1.6	95	WSW	28
J	32.6	17.0	24.8	+0.2	41.7	31	12.2	6+	1.0	+0.5	--	--	41.3	+7.8	11.9	-2.2	69	WSW	5
A	33.7	16.2	24.9	+1.0	42.8	14	6.1	24	0.5	-0.2	--	--	34.7	-1.1	11.4	-1.3	60	WNW	7
S	25.9	10.3	18.1	-0.7	32.8	3+	4.4	18+	0.7	-0.1	--	--	45.8	+3.1	12.7	+0.8	68	WSW	26
O	19.9	6.4	13.2	+1.6	30.6	1	-1.1	15	1.5	+0.6	0	-0.2	55.4	+0.2	9.3	-1.1	68	NW	8
N	8.9	1.3	5.1	+0.6	16.7	7	-8.3	26	2.7	+0.4	5.3	+0.8	78.8	+5.4	8.5	-1.8	79	NW	30
D	2.9	-5.1	-1.1	-0.8	11.7	24	-11.1	20+	4.6	+2.0	53.3	+38.9	79.1	-1.2	10.8	+1.3	74	SW	10
(f)						Jun		Dec											Jan
Y	20.0	7.1	13.6	+1.7	43.9	23	-11.1	20+	20.0	+4.2	59.4	+24.4	56.4	+2.1	11.0	-1.4	97	SW	28

(a) Measured on a tower 50 ft above the ground.
(b) Departure columns indicate positive or negative departure of meteorological parameters from 30-year (1961-1990) climatological normals.
(c) Trace.
(d) + after date indicates latest of several occurrences.
(e) -- means no record of any snow fall during these months.
(f) Yearly averages, extremes, and totals.

4.2 Wildlife

The Hanford Site is a relatively large, undisturbed area of shrub-steppe that contains numerous plant and animal species adapted to the region's semi-arid environment. The vegetation mosaic of the Site consists of ten major plant communities: 1) sagebrush/bluebunch wheatgrass, 2) sagebrush/cheatgrass or sagebrush/Sandberg's bluegrass, 3) sagebrush-bitterbrush/cheatgrass, 4) grease wood/cheatgrass-saltgrass, 5) winterfat/Sandberg's bluegrass, 6) thyme buckwheat/Sandberg's bluegrass, 7) cheatgrass-tumble mustard, 8) willow or riparian, 9) spiny hopsage, and 10) sand dunes (Cushing 1992). Nearly 600 species of plants have been identified on the Hanford Site (Sackschewsky et al. 1992). Cheatgrass is the dominant plant on fields that were cultivated 40 years ago.

More than 300 species of terrestrial and aquatic insects, 12 species of reptiles and amphibians, 44 species of fish, 187 species of birds, and 39 species of mammals have been found on the Hanford Site (Cushing 1992). Deer and elk are the major large mammals on the Site; coyotes are plentiful, and the Great Basin pocket mouse is the most abundant mammal. Waterfowl are numerous on the Columbia River, and the bald eagle is a regular winter visitor along the river. Salmon and steelhead are the fish species of most interest.

There are two types of natural aquatic habitats on the Hanford Site; one is the Columbia River, and the other is provided by the small spring-streams and seeps located mainly on the ALE Reserve in the Rattlesnake Hills. These include Rattlesnake Springs, Dry Creek, Snively Springs, and West Lake, a small, natural pond near the 200 Areas. Several artificial water bodies, both ponds and ditches, have been formed as a result of wastewater disposal practices associated with the operation of the reactors and separation facilities; these water bodies form established aquatic ecosystems complete with representative flora and fauna (Emery and McShane 1980).

No plants or mammals on the federal list of Endangered and Threatened Wildlife and Plants (50 CFR 17.11, 17.12) are known to reside fulltime on the Hanford Site. However, four plant species, four mammals, eight birds, and two molluscs occurring on the Hanford Site are currently candidates for formal listing by the federal government and/or Washington State. The federal government lists the peregrine falcon as endangered and the bald eagle and Aleutian Canada goose as threatened. The peregrine falcon and Aleutian Canada goose are migrants through the Hanford Site, and the bald eagle is a common winter resident. Appendix G lists special-status species that could occur on the Hanford Site.

Results for Wildlife Resource Monitoring, 1992

Wildlife populations inhabiting the Hanford Site are monitored to measure the status and condition of the populations and assess effects of Hanford operations. Particular attention is paid to species that are rare, threatened, or endangered nationally or statewide and those species that are of commercial, recreational, or aesthetic importance statewide or locally. These species include the bald eagle, chinook salmon, Canada goose, several species of hawk, Rocky Mountain elk, mule deer, white pelican, and other bird species.

Fluctuations in wildlife and plant species on the Hanford Site appear to be a result of natural ecological factors and management of the Columbia River system. The establishment and management of the Hanford Site has had a net positive effect on wildlife relative to probable alternative uses of the Site.

Bald Eagle

Bald eagles are listed by the U.S. Fish and Wildlife Service as endangered in most states and as threatened in the state of Washington. Historically, bald eagles have wintered along the Hanford Reach of the Columbia River. However, when monitoring began in the early 1960s, numbers were very low (Figure 4.2). Following the passage of the Endangered Species Act in 1973, the number of wintering bald eagles increased. Possible reasons for the observed increase are the added

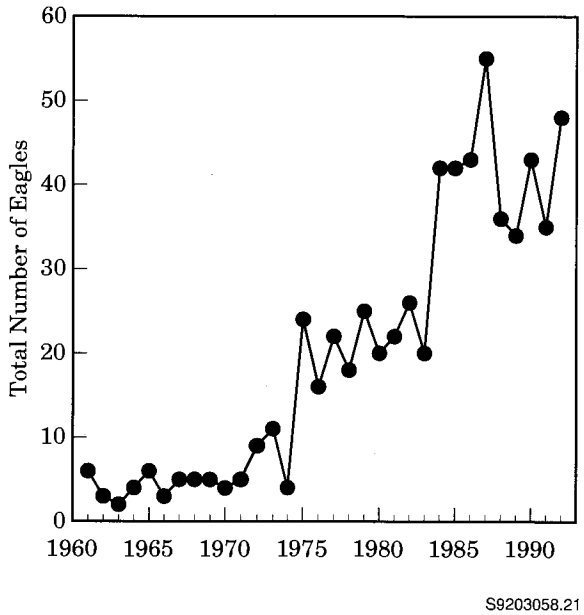


Figure 4.2. Bald Eagles Observed Along the Hanford Reach, Fall and Winter Months, 1962 Through 1992

protection of bald eagles at nesting locations off the Hanford Site and the nationwide elimination of dichlorodiphenyltrichloroethane (DDT) as an agricultural pesticide in 1972. On a local scale, changes in the number of eagles on the Hanford Site generally correspond to changes in the number of salmon carcasses, a major fall and winter food source for eagles. Most of the eagles using the Hanford Reach are concentrated in the section between the abandoned old Hanford townsite and the 100-K Area.

The Hanford Reach is expected to continue providing wintering habitat, as long as the critical resources such as food, perches, and relative freedom from human activities are maintained. Limited nest building by bald eagles has been observed at the Hanford Site in recent years, although none of the attempts have been successful.

Chinook Salmon

Chinook salmon are an important resource to the citizens of the Pacific Northwest. Salmon are caught commercially and for recreation. The commercial and recreational catch is carefully managed to sustain the resource. Today the most important natural spawning area in the mainstream Columbia River for the fall chinook race is found in the free-flowing Hanford Reach. In the early years of the Hanford Site, there were few spawning nests (redds) in the Hanford Reach (Figure 4.3). In the years between 1943 and 1971, a number of dams were constructed on the Columbia River. The reservoirs created behind the dams eliminated most mainstem spawning areas and increased salmon spawning in the Hanford Reach. Fisheries management strategies aimed at maintaining spawning populations in the mainstem Columbia River have also contributed to the observed increases. In recent years, numbers of fall chinook salmon spawning in the Hanford Reach have declined consistent with reduced run sizes returning to the Columbia River. The number of salmon varies each year depending on hatching success, survival of downstream juveniles, and the size of the commercial and recreational catches. The Hanford Reach under existing management practices continues to provide valuable salmon spawning habitat.

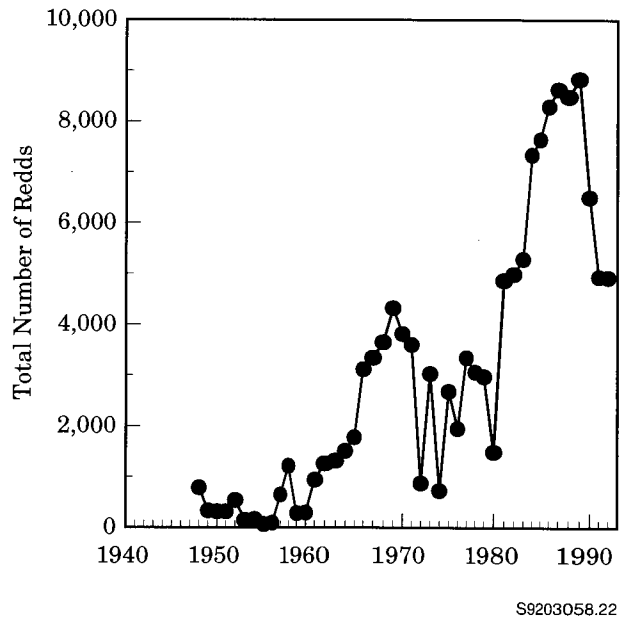


Figure 4.3. Chinook Salmon Spawning Redds in the Hanford Reach, 1948 Through 1992

Canada Goose

Nesting Canada geese are valuable recreational and aesthetic resources along the Snake and Columbia rivers in eastern Washington. Goose nesting surveys began in the 1950s to monitor changes in response to reactor operations (Figure 4.4). The gradual decline observed in the late 1960s and early 1970s is attributed to persistent

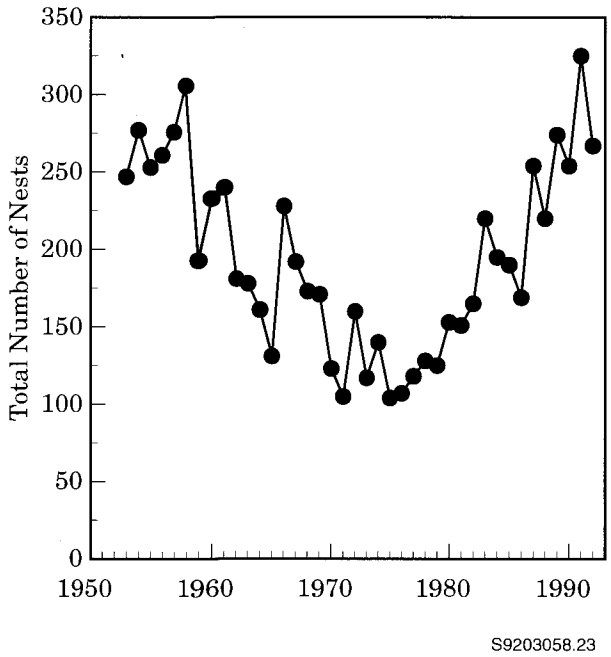


Figure 4.4. Canada Goose Nests on Islands in the Hanford Reach, 1952 Through 1992

coyote predation, mostly on the Columbia River islands upstream from the old Hanford townsite. Since the 1970s, the center of the nesting population has shifted from upstream to downstream islands near Richland, which in recent years have been relatively free from coyote predation. The recent peak in Canada goose nests eclipsed the previous record from the late 1950s.

Canada goose populations are successful on the Hanford Reach because the islands are restricted from human uses during the nesting period and because shoreline habitats provide adequate food and cover for broods (Eberhardt et al. 1989).

Hawks

The undeveloped land of the semi-arid areas of the Hanford Site provides nest sites and food for three species of migratory buteo hawks: Swainson's, red-tailed, and ferruginous. Under natural conditions, these hawks nest in trees, on cliffs, or on the ground. Powerline towers and poles also can serve as nest sites. The ferruginous hawk is a U.S. Fish and Wildlife Service candidate species for listing as threatened and/or endangered. In recent years, the number of ferruginous hawks nesting on the Hanford Site has increased (Figure 4.5). Hawks raised on the Hanford Site die during offsite migration and while wintering on ranges far from the Hanford Site. The Site continues to provide hawk nesting habitats administratively protected from human intrusions, as well as providing suitable foraging areas. The sharp declines in red-tailed and Swainson's hawk nests in the late 1980s are probably not a result of Hanford Site activities because the number of nests for the very sensitive ferruginous hawk did not decline (Figure 4.5). Decreases in nesting red-tailed and Swainson's hawks were probably related to impacts that occurred during their migration and/or while they were on their wintering grounds.

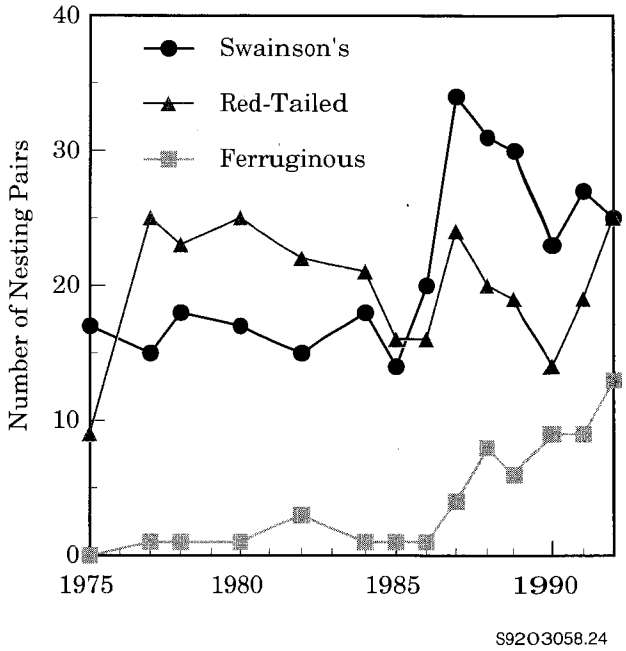


Figure 4.5. Red-Tailed, Swainson's, and Ferruginous Hawks on the Hanford Site, 1975 Through 1992

Rocky Mountain Elk

Rocky Mountain elk did not inhabit the Hanford Site when it was established in 1943. Elk appeared on the ALE Reserve in the winter of 1972. A few animals stayed and reproduced. The greatest number of elk recorded was 190, before the 1992 offsite hunting season (Figure 4.6). With a regulated hunting season on private

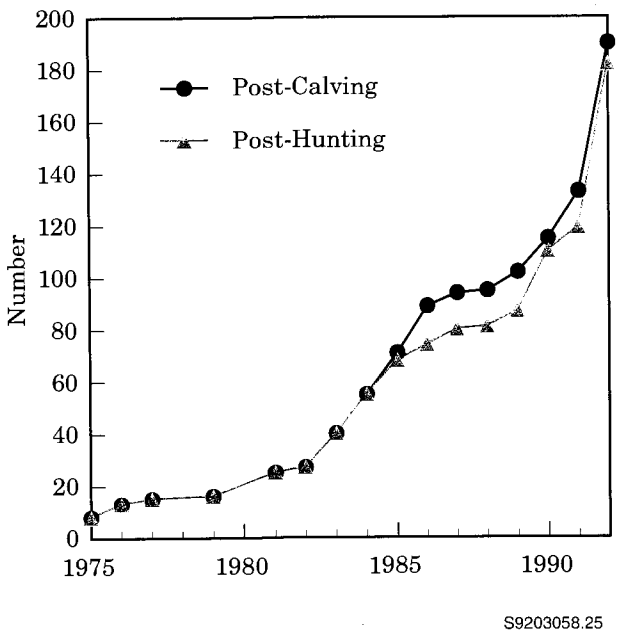


Figure 4.6. Elk on the Hanford Site Counted by Aerial Surveillance During the Post-Calving Period: August Through September; and the Post-Hunting Period: December Through January, 1975 Through 1992

lands adjoining the ALE Reserve, the elk population appeared to be holding at less than 100 animals until the spring of 1990. However, comparatively few elk were killed during the past three offsite hunting seasons, and the herd has expanded to its current population of 182 animals.

Elk are successful on the ALE Reserve because of 1) available forage without competition from domestic livestock; 2) unrestricted access to drinking water at springs located on the ALE Reserve; 3) relatively mild winters; 4) ability to accommodate extreme summer temperatures, even in the absence of shade; and 5) absence of hunting on the Site.

Mule Deer

Mule deer are a common resident of the Hanford Site and are important because of the recreational (offsite hunting) and aesthetic values they provide. Because mule deer have been protected from hunting on the Hanford Site for approximately 50 years, the herd has developed a number of unique population characteristics that are in contrast to most other herds in the semiarid region of the Northwest. These characteristics include a large proportion of old-age animals and large-antlered males. This herd provides a unique opportunity for comparison to other more heavily harvested herds in this region.

Because of the unique nature of the herd and high degree of public interest, a study was initiated in 1990 to 1) obtain estimates of the number of deer on the Hanford Site, 2) determine the extent and frequency of offsite movements by Hanford Site deer, and 3) evaluate the level of ^{90}Sr in deer from the 100 Areas (see Section 5.5, "Wildlife Surveillance").

Thirty-six mule deer were captured and fitted with ear tags and/or radio collars in 1990 between the old Hanford townsite and the N Reactor. Frequent offsite movements were made by these deer during the year, and one animal was killed by a hunter during one of these movements. In general, the mule deer population on the Hanford Site appears to be healthy. The numbers of deer on the Hanford Site do not appear to have changed dramatically over the last few decades, and many very old (>5 years) animals are present.

White Pelican

Historically, the white pelican has visited the Hanford Reach of the Columbia River in small numbers each winter. This large, fish-eating bird has only recently been listed by the Washington State Department of Wildlife as endangered. Therefore, they have not been monitored as extensively as bald eagles. Many of the features of the Hanford Reach that make it attractive to wintering bald eagles also make it attractive to white pelicans.

Shrub-Steppe Birds of Special Concern

The Washington Department of Wildlife has listed several shrub-steppe birds as species of special concern because their populations have been diminished by massive losses of native shrub-steppe habitat as a result of expanding agriculture and urbanization. The Hanford Site contains large contiguous areas of relatively undisturbed shrub-steppe habitat that provides nesting habitat for these birds. To determine the spatial distribution and relative abundance of species of special concern (sage

sparrows, sage thrashers, loggerhead shrikes, and long-billed curlews), two transects have been monitored on the Hanford Site over the past 5 years using U.S. Fish and Wildlife Service procedures. These transects cross a variety of habitats including relatively undisturbed shrub-steppe, recently burned shrub-steppe, and agricultural fields that were abandoned in the early 1940s and are now dominated by cheatgrass.

The only shrub-steppe species of special concern that nested in the abandoned fields was the long-billed curlew. The sage thrasher was seldom seen along either transect route, which is in agreement with other studies of shrub-steppe birds that indicate that sage thrashers are not abundant in low-elevation shrub-steppe habitats. Sage sparrows were most common in places that supported stands of sagebrush which had escaped burning by recent wildfires. Loggerhead shrikes were less plentiful than sage sparrows and occurred in places that supported either sagebrush or bitterbrush shrubs.

The lower elevations of the Hanford Site provide habitat suitable for viable populations of long-billed curlews, sage sparrows, and loggerhead shrikes but not sage thrashers. The long-billed curlew nests on the ground and is not dependent on desert shrubs for nest placement. However, sage sparrows and loggerhead shrikes place their nests in the branches of desert shrubs; thus, the loss of sagebrush and bitterbrush shrubs through burning is detrimental to these species.

Special Plants and Invertebrate Animals

The Washington Natural Heritage Program (1990) has identified three species of vascular plants that could be jeopardized by construction and/or cleanup activities performed on the Hanford Site. These species are Columbia yellowcress, Columbia milk vetch, and Hoover's desert parsley. Columbia yellowcress is listed as an endangered taxon in Washington State. It occurs along the shoreline of the Columbia River on the Hanford Site. Columbia milk vetch is listed as a threatened taxon and occurs on dry land of the Hanford Site upstream from the Vernita Bridge. Hoover's desert parsley, also listed as a threatened taxon, occurs on talus slopes of the Hanford Site in the same general area as Columbia milk vetch.

The U.S. Fish and Wildlife Service lists the Columbia pebblesnail and shortface limpet as candidate species for protection as threatened or endangered species. Both inhabit the Hanford Reach of the Columbia River and appear to have been widespread historically in the mainstem Columbia River Basin before the installation of dams. Both species are now apparently reduced within the Columbia Basin to isolated populations that are separated by large areas of unsuitable habitat.

Only two sizable populations of Columbia pebblesnail remain: those in the Methow and Okanogan rivers of north central Washington. Neither of these larger populations are protected. Smaller populations survive in the Hanford Reach and elsewhere. Because of the lack of habitat protection and the substantial reduction in the species' historical range, the Columbia pebblesnail will probably be listed federally as endangered.

Currently, large populations of shortface limpets persist in four streams: the Deschutes River, Oregon; the Hanford Reach of the Columbia River, Washington; Hells Canyon, Idaho and Oregon; and the Okanogan River, Washington. Smaller populations exist elsewhere. While substantial range reduction has occurred in this species, and the large populations are not protected, the shortface limpet will probably be listed federally as threatened.

4.3 Other Environmental Studies and Programs

Besides the meteorological and wildlife resource monitoring on the Hanford Site, other studies and programs investigate environmental issues. These studies and programs include the Hanford Cultural Resources Laboratory, Hanford Environmental Dose Reconstruction Project, Community-Operated Environmental Surveillance Program, and others.

Hanford Cultural Resources Laboratory

The Hanford Cultural Resources Laboratory (HCRL) was established by RL in 1987 as part of PNL. The HCRL provides support for managing the archaeological, historical, and cultural resources of the Hanford Site in a manner consistent with the National Historic Preservation Act, the Native American Graves Protection and Repatriation Act, the Archaeological Resources Protection Act, and the American Indian Religious Freedom Act.

Pursuant to Section 106 of National Historic Preservation Act, cultural resource reviews are conducted before each proposed ground-disturbing or building alteration/ demolition project on the Hanford Site. During the FY 1992, Hanford contractors requested 286 such reviews, 29 of which required archaeological surveys. The surveys covered a total of 2,539 ha (6,276 acres) and resulted in discovery of 10 prehistoric archaeological sites, 63 historic archaeological sites, 4 archaeological sites with historic and prehistoric components, and 2 sites of undetermined cultural affiliation.

The archaeological site monitoring program, devised to comply with Section 110 of the National Historic Preservation Act, is designed to determine the current condition of cultural resources, and thus to determine whether cultural resource management and protection policies are effective. Results of monitoring are used in planning cultural resource site management and protection. Following procedures established in the *Hanford Cultural Resources Management Plan* (Chatters 1989), staff monitored the condition of 39 sites. The conclusions from this year's monitoring are very similar to those of previous years. Natural erosive processes are the most significant factors impacting the majority of sites and could be reduced by revegetation. Sites outside the security fence continue to receive the heaviest impacts from looters and vandalism. A more recently recognized impact on sites inside and outside the security perimeter is wind erosion enhanced by off-road vehicle use.

Activities for the cultural resources education program included presenting lectures to groups of all ages and developing a series of displays to be used in Hanford Site facilities for worker education. Lectures were presented to groups ranging from primary school rockhounds to civic groups. Work on a video about the cultural resources program continued throughout the year.

The archaeological survey of areas of the Hanford Site that are not targeted for development is a requirement of Section 110 of the National Historic Preservation Act and of 1988 amendments to Archaeological Resources Protection Act. The Hanford Cultural Resources Management Plan specifies that a 10% stratified random sample of Hanford Site lands will be surveyed to refine an existing model of archaeological site distributions. One sample plot covering 0.04 ha (0.1 acre) was surveyed in 1992. No archaeological sites were recorded.

Research activities were conducted when possible as part of compliance work. The emphasis was on fish exploitation and reconstruction of paleostream conditions.

Hanford Environmental Dose Reconstruction Project

In 1987, after receiving a recommendation by the Hanford Health Effects Review Panel the previous year, DOE directed PNL to begin the Hanford Environmental Dose Reconstruction (HEDR) Project. (The Hanford Health Effects Review Panel had been formed to consider the potential health implications of historic Hanford Site releases of radioactive materials.) The objective of the HEDR Project is to develop estimates of the radiation doses that people may have received from past Hanford operations. An independent Technical Steering Panel was selected by the Vice Presidents for Research at major universities of Washington and Oregon to direct the work of the project. The 18-member panel consists of experts in various technical fields relevant to HEDR Project work and representatives from the states of Washington, Oregon, and Idaho; Native American tribes; and the public. In 1991, responsibility for managing the HEDR Project transferred to the U.S. Department of Health and Human Services through the Centers for Disease Control and Prevention. The Technical Steering Panel continues its role as the technical director of the work.

In 1990, scientists completed the first phase of the HEDR Project, which was to determine whether enough information of sufficient quality existed to develop and demonstrate a dose-estimating method. The product of this phase was a set of more than 20 documents that describe:

- the preliminary information found or reconstructed
- preliminary dose-estimating models and computer codes
- preliminary estimates of dose and their uncertainties for representative individuals who may have lived near the Hanford Site during early years of operations.

Work since 1990 has concentrated on improving the tools and data to be used in dose calculations. Technical work for 1992 consisted of restructuring models to enhance their capabilities, developing detailed estimates of releases of radioactive materials, and identifying, acquiring, and evaluating additional information needed to produce estimates. This information is being developed for the 194,000 km^2 (75,000-mi^2) study area highlighted in Figure 4.7, for major exposure pathways, and for the full history of the Hanford Site—1944 through 1991.

In addition to work being performed at PNL, eight northwest Native American tribes are conducting research to support dose estimates for their tribal members.

The key deliverables of the project are the tools for the estimation of doses to real individuals currently being interviewed by staff from the Fred Hutchinson Cancer Research Center under a separate contract with the Centers for Disease Control and Prevention. The actual life histories of these individuals will be used to produce accurate dose estimates.

Community-Operated Environmental Surveillance Program

A Community-Operated Environmental Surveillance (COES) Program was initiated in 1990 to increase the public's involvement in and awareness of Hanford's surveillance program. It is hoped that this program will increase public understanding of surveillance results, provide a mechanism for the public to raise Hanford-related environmental surveillance issues, and provide an educational resource for local schools.

Three community-operated environmental surveillance stations began operation in March 1991. These stations are located downwind of the Hanford Site at Basin City Elementary School in Basin City, Edwin Markham Elementary School in north Franklin County, and Leslie Groves Park in Richland (see Figure 5.2). Local residents have access to the monitoring stations to observe the instruments and results.

Two teachers from nearby schools have been trained to manage and operate each community-operated station. One teacher functions as station manager, and the other acts as a backup or alternate manager. The teachers' current responsibilities include collecting a variety of air samples, preparing samples and collection records for

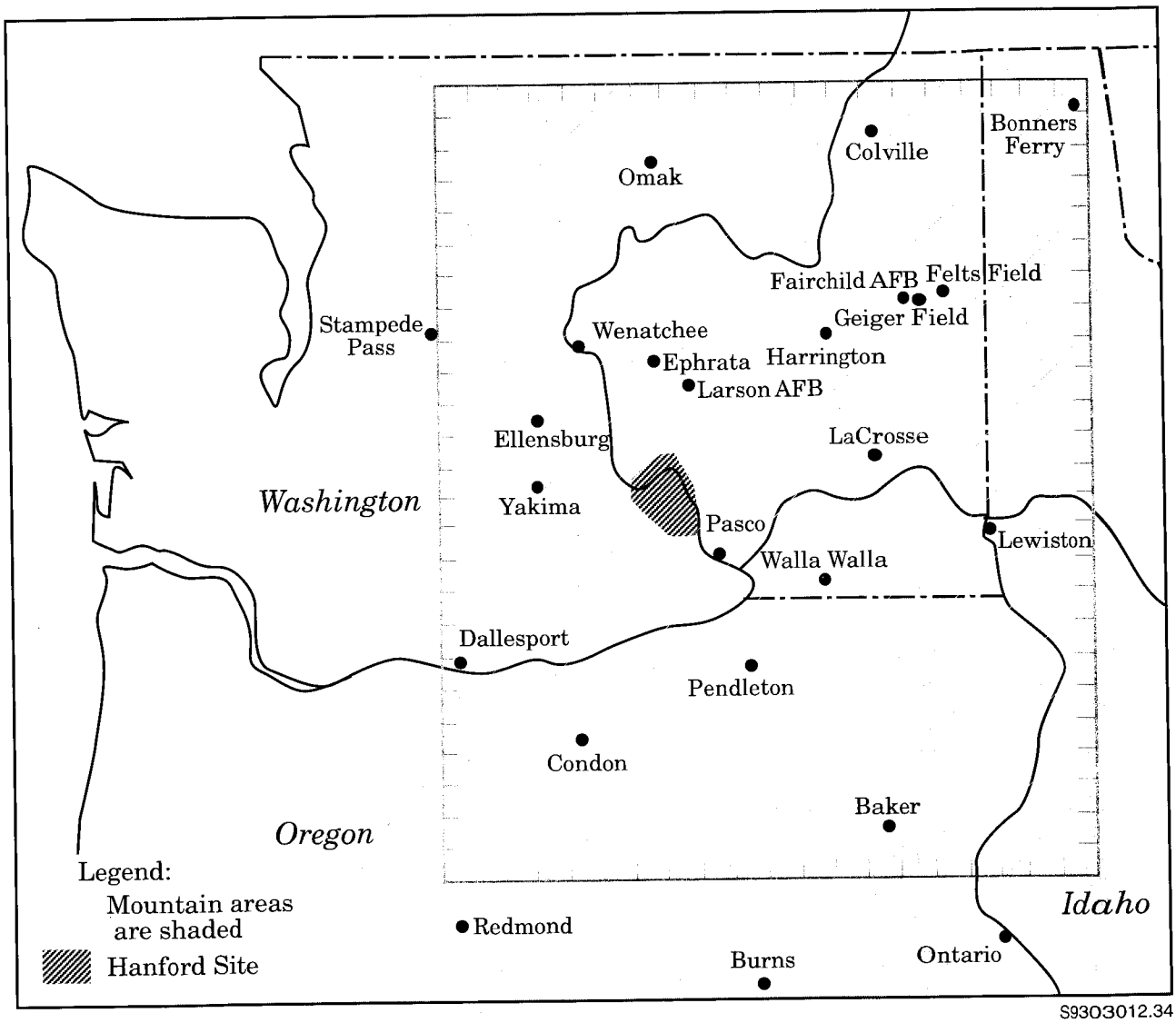


Figure 4.7. Area Considered in Estimating Doses from Past Hanford Operations in the Hanford Environmental Dose Reconstruction Project

submission to a radioanalytical laboratory, monitoring the performance of station equipment, performing minor station maintenance, and participating in scheduled training. The managers also serve as public spokespersons for the COES Program and function as points of contact for local citizens. PNL scientists work closely with the station managers to maintain the equipment and coordinate sampling and analytical efforts with other Hanford environmental surveillance activities.

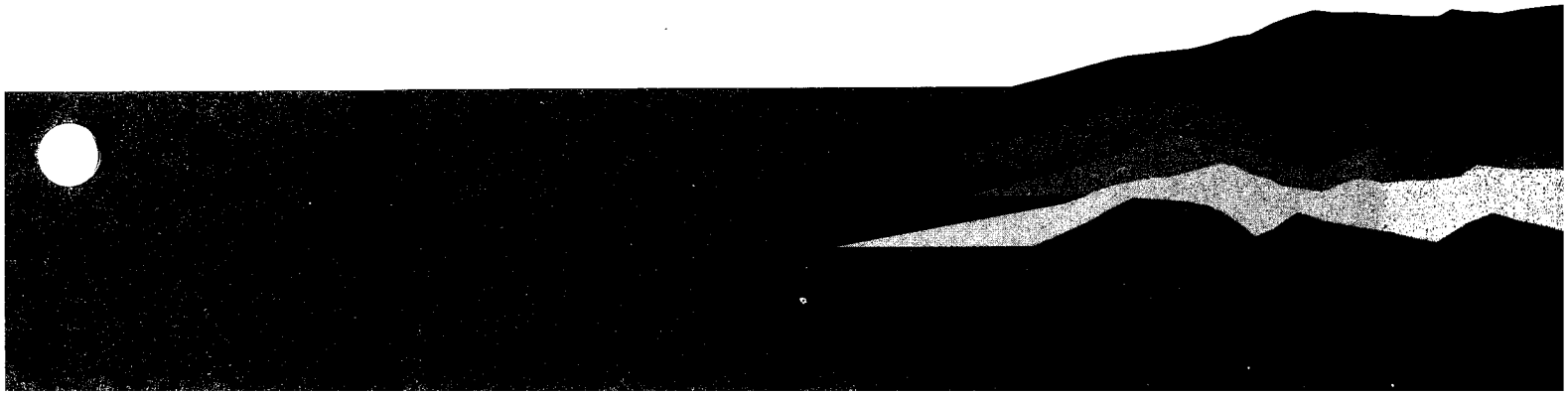
Results from these stations are discussed in Sections 5.2, "Air Surveillance," and 5.7, "External Radiation Surveillance."

Other Environmental Activities

Other significant environmental activities during 1992 included compilation of a Hanford Site land use planning initiative, the continuation of a National Park Service study to consider environmental protection alternatives for the Hanford Reach, and environmental reviews under the National Environmental Policy Act. Each of these activities is summarized in Section 2.0, "Environmental Compliance Summary."

A tribal educational outreach program was established in 1991 to monitor water quality and fish health in the lower and mid-Columbia River. The program was established to address concerns about the effects of past and present operations at the Hanford Site on water quality and the health of salmon and fish consumers. During the summer of 1992, a Yakima Indian Nation college student contacted tribal fishers and fish buyers along the Columbia River between McNary and Bonneville dams in search of salmon that appeared to be diseased or contaminated. Over 80,000 salmonids were caught during the study, and 4 fish were reported as suspect and examined. None of the fish was found to be contaminated or diseased. Lesions observed on the fish that were suspected as signs of disease were determined by the U.S. Fish and Wildlife Service to be abrasions caused by gill nets.

Environmental Surveillance Information



5.0 Environmental Surveillance Information

Environmental monitoring of the Hanford Site consists of effluent monitoring and environmental surveillance. Section 3.0 describes the Site effluent monitoring program. Section 5.0 describes the results of the surface and ground-water surveillance programs for 1992. Quality assurance and control for monitoring programs are discussed in Section 7.0.

In many places, the uncertainty of a result is reported in the units of the measurement or as a percentage. When attempting to measure extremely small quantities, uncertainties become large. Statistically, there is a high probability (95%) that the actual result is within the uncertainty range. When the uncertainty is equal to (100%) or larger than the result, the actual value may be zero. The Helpful Information section at the beginning of this document is provided for the reader desiring further explanation of the notation, units, and type of information being reported.

The environmental surveillance data presented in the following sections are summaries prepared to describe the range of conditions observed during the year in different locations. Additional data can be found in Appendix A, and detailed results by specific sampling location are contained in a data volume, *Hanford Site Environmental Data 1992—Surface and Columbia River* (Bisping and Woodruff 1993).

5.1 Environmental Surveillance at Hanford

Environmental surveillance of the Hanford Site and surrounding region is conducted to demonstrate compliance with environmental regulations, confirm adherence to DOE environmental protection policies, support DOE environmental management decisions, and provide information to the public. Surveillance is conducted as an independent program under DOE Orders 5400.1, "General Environmental Protection Program," and 5400.5, "Radiation Protection of the Public and Environment," and the guidance in *Hanford Site Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE 1991a). The scope, objectives, criteria, design, and description of the program are summarized below and provided in detail in the *Hanford Site Environmental Monitoring Plan* (DOE 1991b).

Scope

Environmental surveillance encompasses sampling and analysis for potential radiological and chemical contaminants on and off the Hanford Site. Emphasis is placed on surveillance of those pathways and radionuclides, or chemicals, constituting the greatest potential risk to humans. The program has always been focused on radionuclides and nonradiological water quality parameters. In the last few years, however, surveillance for hazardous chemicals has been initiated. The environmental surveillance program focuses on routine operational activities conducted by DOE contractors on the Hanford Site; however, the program is also responsive to unplanned releases and releases from non-DOE operations on and near the Site. Surveillance results are provided annually through this report series. In addition, unusual results or trends are reported to DOE and the appropriate facility managers when they occur. Whereas effluent and near-facility environmental monitoring is conducted by the facility operating contractor, environmental surveillance is conducted under an independent program that reports directly to the DOE Quality, Safety, and Health Programs Division.

Objectives

Key surveillance objectives in 1992 included:

- verifying compliance with DOE and EPA radiological dose standards for public protection
- independently assessing the adequacy of facility pollution controls
- assessing the environmental and public health impacts of Hanford operations
- identifying and quantifying potential environmental quality problems
- providing information to DOE for environmental management of the Site, and for the public and regulatory agencies.

Criteria

The criteria for environmental surveillance are derived from DOE Order 5400.1, guidance published for DOE sites (DOE 1991a), and the above-stated objectives. These criteria, pathway analyses to determine the radionuclides and media contributing to the dose to humans, and local needs and interests have been used in establishing the surveillance program. Experience gained from environmental surveillance activities and studies conducted at the Hanford Site for more than 45 years have provided valuable technical background for planning and data interpretation.

Surveillance Design

Environmental surveillance at Hanford is designed to meet the previously listed objectives, considering the environmental characteristics of the Site and the potential

and actual releases from Site activities. The main focus is on determining environmental impacts and compliance with public health standards, as well as environmental standards or protection guides, rather than on detailed radiological and chemical characterization.

The primary pathways for movement of radioactive materials and chemicals from the Site to the public are the atmosphere, surface water, and ground water. Figure 5.1 illustrates these potential primary routes and the possible exposure pathways to humans. The significance of each pathway is determined from measurements and calculations that estimate the amount of radioactive material transported along each pathway and by comparing the concentrations or dose to environmental and public health protection standards or guides. Pathways are also evaluated based on prior studies and observations of radionuclide and chemical movement through the environment and food chains. Calculations based on effluent data show the expected concentrations off the Hanford Site to be low for all radionuclides and generally below the level that can be detected by monitoring technology. To ensure that radiological analyses of samples are sufficiently sensitive, minimum detectable concentrations of

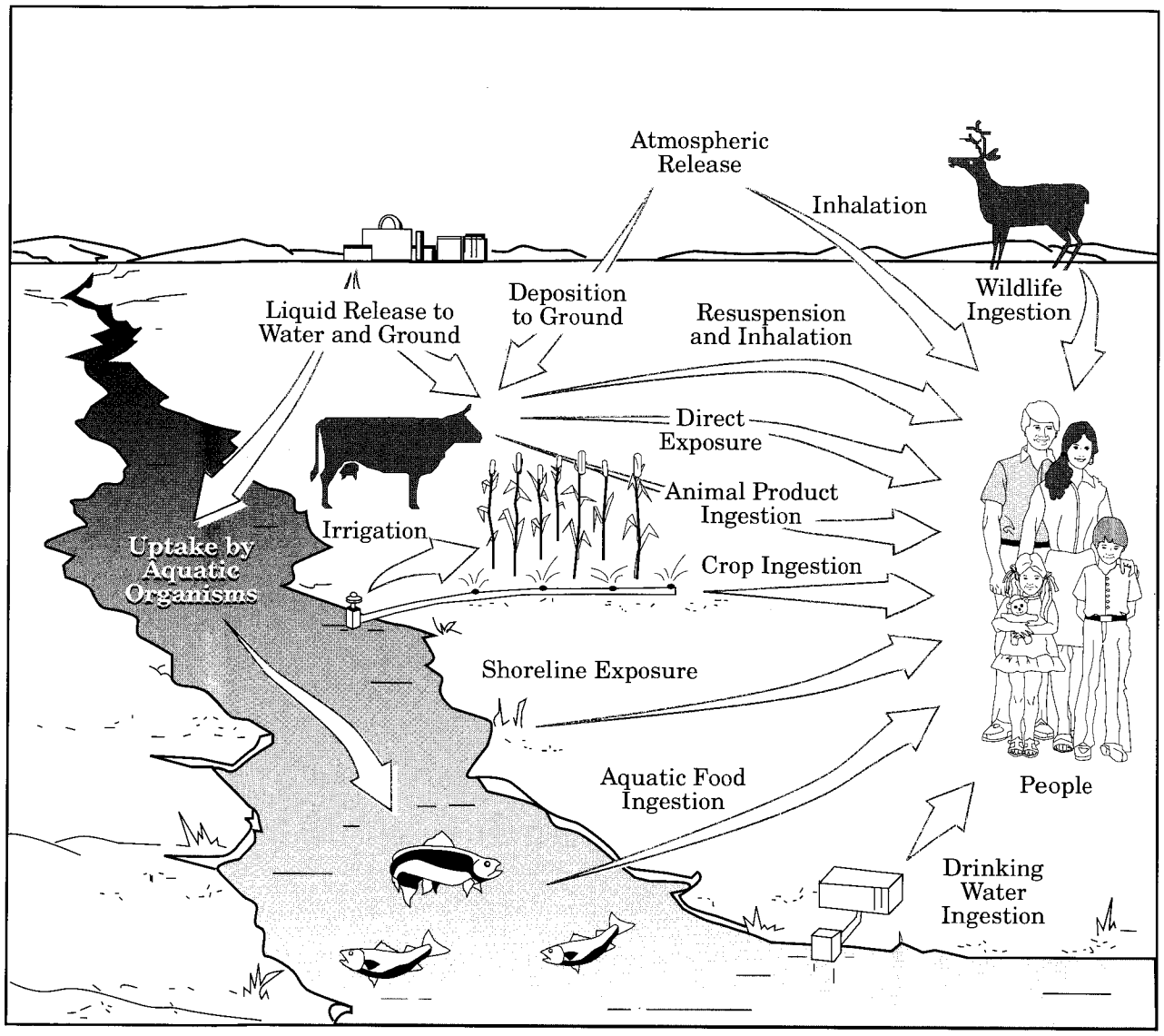


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Figure 5.1. Primary Exposure Pathways

key radionuclides in air, water, and food are established at levels well below the levels that correspond to the standards.

Environmental and food-chain pathways are monitored near the facilities releasing effluents and at offsite receptor locations. The surveillance design at Hanford uses a stratified sampling approach to monitor these pathways. Samples are collected and radiation is measured in three general surveillance zones that extend from onsite operational areas to the offsite environs.

The first zone extends from near the operational areas to the Site perimeter. The environmental concentrations of releases from facilities and fugitive sources (those released from other than monitored sources such as contaminated soils) will generally be the highest, and therefore most easily detected, in this zone. The second surveillance zone consists of a series of perimeter sampling stations positioned near or just inside the Site boundary. Data from these stations document or represent conditions at the nearest points at which members of the public reside or could reside. Exposures at these locations are typically the maximum that any member of the public could receive. The third surveillance zone consists of nearby and distant community locations within an 80-km (50-mi) radius of the Site. Surveillance is conducted in communities to provide measurements at those locations where the most people are potentially exposed and to provide assurance to the communities that levels are well below standards established to protect public health.

Background concentrations are measured at distant locations and compared with onsite, perimeter, and community locations as an indicator of the effects of Hanford operations. Background locations are locations that are essentially unaffected by Hanford operations, that is locations which can be used to measure ambient environmental levels of chemicals and radionuclides.

To the extent possible, radiation dose assessments should be based on direct measurements of radiation dose rates and radionuclide concentrations in environmental media. The amounts of most radioactive materials released from Hanford operations in recent years have generally been too small to be measured directly once dispersed in the offsite environment. For the measurable radionuclides, it is often not possible to distinguish levels resulting from worldwide fallout and natural sources from those associated from Hanford releases. There, offsite doses were estimated using the following methods:

- Doses from measured effluents were estimated by applying environmental transport and dose calculation models to measured effluent monitoring data and selected environmental measurements.

- Doses from fugitive air emissions (for example, contaminated soils) were estimated from measured airborne concentrations at Site perimeter locations.

- Doses from fugitive liquid releases (for example, ground water seeping into the Columbia River) were estimated based on differences in measured concentrations upstream and downstream from the Hanford Site.

Program Description

In the first zone, between the operational areas and the Site perimeter, air monitoring stations were located around each operational area (see Figure 5.2) because air transport is a potential key pathway for movement of radioactive materials off the Site. Surface-water impoundments, potentially accessible to wildlife, and drinking water sources were also sampled (see Figure 5.8). Ground water was sampled from wells located near operating areas and along potential transport pathways (see Figures 5.49 through 5.53). In addition to air and water surveillance, samples of soil, native vegetation, and wildlife were collected (see Figures 5.30 and 5.32). Direct radiation dose rates were also measured (Figures 5.42 through 5.44), and selected onsite roads and rails were surveyed (Figure 5.46).

In the second or perimeter zone, air monitoring stations, radiation measurement locations and ground-water surveillance wells were located near or just inside the Site boundary. Both hazardous chemical and radiological contaminants are measured in ground-water samples. Agriculture is an important industry near the Site; therefore, milk, crops, soil, and native vegetation are monitored (see Figures 5.25 and 5.32) to detect any influence from Hanford on locally produced food and farm products. The Columbia River is included in the second zone. River water is monitored upstream from the Site at Priest Rapids Dam and downstream at Richland, Washington, where it is used for public drinking water. Water pumped from the Columbia River for irrigation is also monitored.

Surveillance in the third zone, consisting of nearby and distant communities, includes air, soil, water supplies, vegetation, and food products sampling, and direct radiation dose rate measurements. Table 5.1 summarizes the geographic distribution of measurement locations.

Surveillance is conducted under established quality assurance plans (see Section 7.0, "Quality Assurance") and written procedures (PNL 1992, 1993). Sample scheduling, accountability, data storage, and data screening were managed and controlled by computerized systems. Laboratory analyses of samples for radioactivity and chemicals were conducted principally by International Technology Corporation and the Pacific Northwest Laboratory, both in Richland, Washington. Selected river water quality and chemistry analyses, and temperature and flow measurements were performed by the U.S. Geological Survey, Denver, Colorado.

Table 5.1. Environmental Surveillance Sample Types and Measurement Locations, 1992

		Sample Locations							
							Columbia River		
	Total Number	Onsite[a]	Site Perimeter[b]	Nearby Communities[c]	Distant Communities[c]	COES Stations[c,d]	Upstream[c]	Hanford Reach[b]	Downstream[c]
Air	45	23	13	4	2	3			
Ground water[e]	436	436							
Springs	3								3
Columbia River	4						2	1	1
Irrigation water	1		1						
Drinking water	13	8	5[f]						
Columbia River sediments	6						1	3	2
Ponds	3	3							
Foodstuffs	11		5	5	1				
Wildlife	9	9							
Soil and vegetation	16	4	8		4				
TLDs[g]	74	28	37[h]	4	2	3			
Railroad/roadway surveys	15	14	1						
Shoreline surveys	16		16						

(a) Surveillance Zone 1.
(b) Surveillance Zone 2.
(c) Surveillance Zone 3.
(d) COES = community-operated environmental surveillance.
(e) Approximately 720 wells were sampled for all ground-water monitoring programs onsite.
(f) Includes four offsite water supplies.
(g) TLDs = thermoluminescent dosimeters.
(h) Includes locations in and along the Columbia River.

5.2 Air Surveillance

Atmospheric releases from Hanford to the surrounding region are a potential source of human exposure. For that reason both radioactive and nonradioactive materials in air are monitored at a number of locations. The potential influence of Hanford emissions on local radionuclide concentrations was evaluated by comparing concentrations measured at distant locations within the region to concentrations measured at the Site perimeter. This section discusses sample collection, analytical methods, and the results of the air surveillance program. Detailed analytical results are reported by Bisping and Woodruff (1993).

Sample Collection and Analysis

Airborne radionuclides were sampled by a network of 42 continuously operating samplers: 23 on the Hanford Site, 13 near the Site perimeter, 4 in nearby communities, and 2 in distant communities. Samples were also collected at three COES stations that were managed and operated by local school teachers (Figure 5.2 and Table 5.2). Air samplers on the Hanford Site were located primarily around major operational areas to maximize the ability to detect contaminants resulting from Site operations. Perimeter samplers were located around the Site, with emphasis on the prevailing downwind directions to the south and east of the Site. Continuous samplers located in Benton City, Richland, Kennewick, Mattawa, and Pasco provided concentrations at the nearest population centers. Samplers at the distant communities of Sunnyside and Yakima provided data from communities essentially unaffected by Site operations.

Samples were collected according to a schedule established before the monitoring year (Bisping 1992). Air sampling locations are listed in Table 5.2, with specific analyses for each location. Airborne particles were sampled at each of these locations by continuously drawing air through a glass fiber filter. The filters were collected every 2 weeks, field surveyed for total radioactivity to detect any unusual occurrences, held for at least 7 days at the analytical laboratory, and then analyzed for total beta radioactivity. The holding period was necessary to allow for the decay of short-lived, naturally occurring radionuclides (e.g., radon gas decay products) that would otherwise obscure detection of longer-lived radionuclides potentially present from Hanford emissions. Field measurements of radioactivity in samples are used to monitor changes in environmental conditions that could warrant attention before the more detailed and sensitive laboratory analyses are completed. In addition, filters from most locations were also analyzed for total alpha radioactivity.

For most radionuclides, the amount of radioactive material collected on the filter during the 2-week period was too small to be readily measured. The sensitivity and accuracy of sample analysis was increased by combining biweekly samples for nearby locations (or in some cases a single location) into quarterly composite samples. The quarterly composite samples were then combined to form annual composite samples (Table 5.2). Most quarterly composite samples were analyzed for numerous specific gamma-emitting radionuclides (Appendix F). Annual composites were analyzed for strontium and plutonium (DOE 1991b), and selected annual composites were also analyzed for uranium isotopes.

Gaseous ^{131}I as sampled at selected locations by drawing air through a cartridge containing chemically treated activated charcoal. These cartridges were located downstream of a particle filter and were exchanged biweekly or monthly. Sampling on the Hanford Site was performed near operational areas to maximize the potential for detecting releases and at locations of potential public exposure. Monthly ^{131}I samples were collected but were not routinely analyzed; these samples were collected to provide additional data in the event of an unusual release. Iodine-129 was sampled using a similar technique as ^{131}I; however, a special low-background petroleum charcoal cartridge was used for increased sensitivity. Samples were collected monthly and combined to form quarterly composite samples for each location.

Atmospheric water vapor was collected for ^{3}H analysis by continuously passing air through cartridges containing

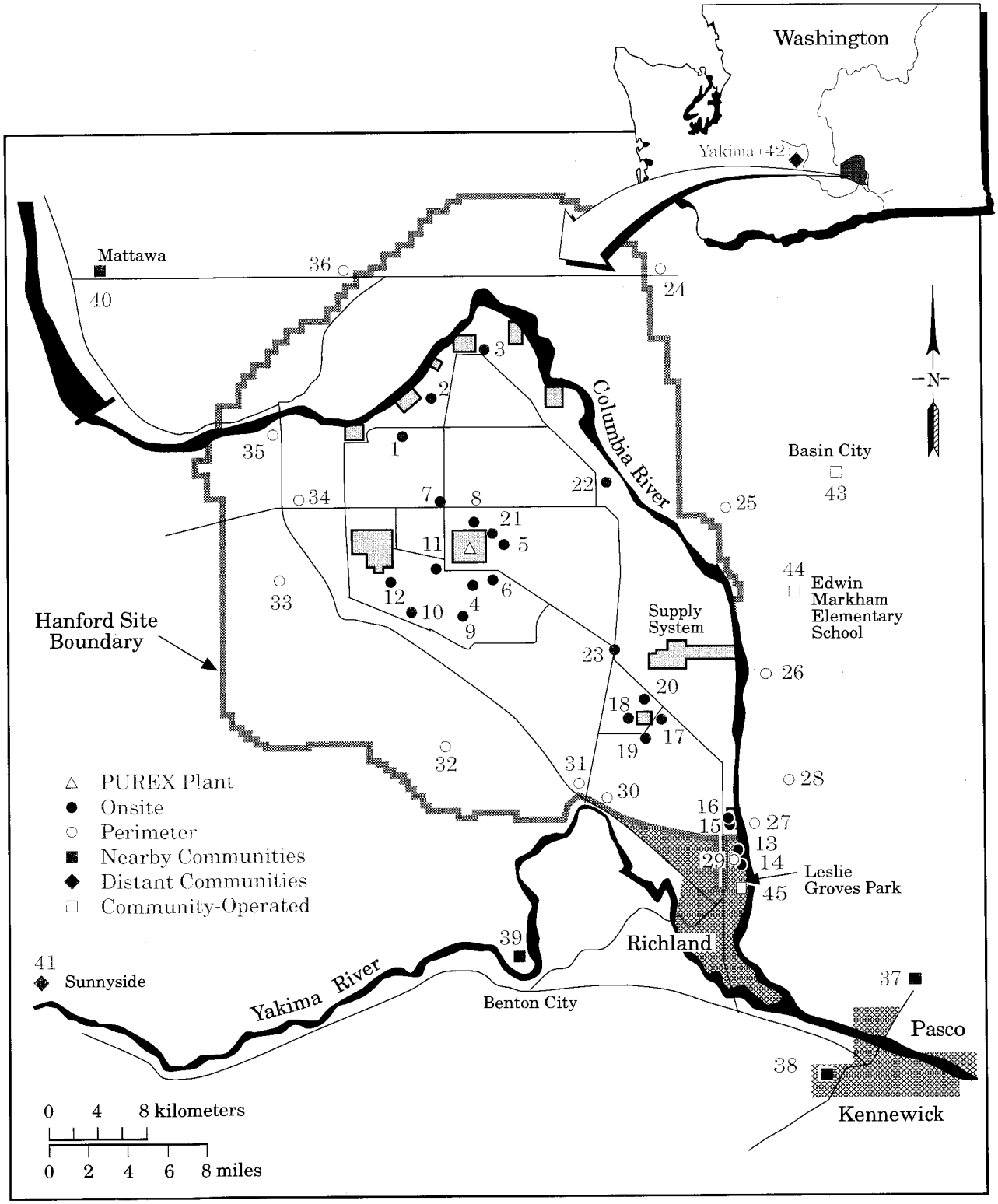

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Figure 5.2. Air Sampling Locations, 1992 (see Table 5.2 for location key)

Table 5.2. Air Sampling Locations, Sample Composite Groups, and Analyses, 1992

Map[a] Location	Sampling Location	Analyses[b]	Composite Group	Analyses[c]
Onsite				
1	100-K	Beta, alpha, ^{3}H	100 Areas	Gamma, Sr, Pu
2	100-N	Beta, alpha		
3	100-D	Beta, alpha		
4	S of 200-East	Beta, alpha	200-East	Gamma, Sr, Pu, U
5	E of 200-East	Beta, alpha		
6	200-East SE	Beta, alpha, ^{3}H, ^{129}I		
7	Rt. 11A, Mi. 9	NRA[d]		
8	N of 200-East	NRA		
9	SW of B/C Cribs	Beta, alpha	200-West, South, and East	Gamma, Sr, Pu, U
10	Army Loop Camp	Beta, alpha		
11	GTE Building	Beta, alpha, ^{3}H		
12	200-West SE	Beta, alpha, VOC, PCB	200-West	Gamma, Sr, Pu, U
13	300 Water intake	Beta	300 Area	Gamma, Sr, Pu, U
14	300-South Gate	Beta, alpha, ^{3}H		
15	300 NE	Beta, alpha, ^{3}H, ^{131}I, VOC, PCB	300 NE	Gamma, Sr, Pu, U
16	300 Trench	Beta, alpha, ^{3}H		
17	400-East	Beta, alpha, ^{3}H, ^{131}I	400 Area	Gamma, Sr, Pu
18	400-West	Beta, alpha (^{131}I NRA)		
19	400-South	Beta, alpha (^{131}I NRA)		
20	400-North	Beta, alpha (^{131}I NRA)		
21	B Pond	Beta, alpha	B Pond	Gamma, Sr, Pu,U
22	Hanford Townsite	NRA		
23	Wye Barricade	^{131}I (beta and alpha NRA)		
Perimeter				
24	Berg Ranch	NRA		
25	Ringold Met. Tower	Beta, alpha, ^{3}H, ^{129}I, ^{131}I	Ringold Met. Tower	Gamma, Sr, Pu
26	W End of Fir Road	Beta, alpha	W End of Fir Road	Gamma, Sr, U
27	Byers Landing	Beta, alpha, ^{3}H, ^{129}I, ^{131}I	Southeast Perimeter	Gamma, Sr, Pu, U
28	Pettett Farm or Dogwood Met. Tower[e]	Beta, alpha, ^{3}H		
29	Battelle Complex	NRA		
30	Horn Rapids Road Substation	Beta, alpha	Prosser Barricade	Gamma, Sr, Pu, U
31	Prosser Barricade	Beta, alpha, ^{3}H, ^{131}I		
32	ALE Field Lab	NRA		

Table 5.2. Air Sampling Locations, Sample Composite Groups, and Analyses, 1992 (contd)

Map[a] Location	Sampling Location	Analyses[b]	Composite Group	Analyses[c]
Perimeter				
33	Rattlesnake Springs	Beta, alpha, VOC, PCB (collected for composite only)	West Perimeter	Gamma, Sr, Pu
34	Yakima Barricade			
35	Vernita Bridge	Beta	Northwest Perimeter	Gamma, Sr, Pu
36	Wahluke Slope	Beta, alpha, ^{3}H		
Nearby Communities				
37	Pasco	Beta	Tri-Cities	Gamma, Sr, Pu
38	Kennewick	Beta, alpha		
39	Benton City	NRA		
40	Mattawa	NRA		
Distant Communities				
41	Sunnyside	Beta, alpha, ^{3}H, ^{131}I	Sunnyside	Gamma, Sr, Pu,U
42	Yakima	Beta, alpha, ^{3}H, ^{129}I, ^{131}I	Yakima	Gamma, Sr, Pu,U
Community-Operated Stations				
43	Basin City	Beta, alpha, ^{3}H, ^{131}I	Basin City Elem. School	Gamma, Sr, Pu,U
44	North Franklin County	Beta, alpha, ^{3}H, ^{131}I	Edwin Markham Elem. School	Gamma, Sr, Pu, U
45	Richland	Beta, alpha, ^{3}H, ^{131}I	Leslie Groves Park	Gamma, Sr, Pu, U

(a) See Figure 5.2.
(b) Beta, alpha, and ^{131}I samples are collected biweekly (every 2-weeks), ^{3}H samples are collected monthly, and ^{129}I samples are collected monthly and combined into a quarterly composite sample for each location (see Sample Collection and Analysis in this section).
(c) Gamma scans are performed on quarterly composite samples; Sr, Pu, and U analyses are performed on annual composite samples (see Sample Collection and Analysis in this section).
(d) NRA = not routinely analyzed.
(e) The Pettett Farm air sampler was moved to the Dogwood Meteorology Tower (near corner of Dogwood Rd. and Cottonwood Dr.) on July 17, 1992.

silica gel, which were exchanged every 4 weeks. The trapped water was removed from the silica gel and analyzed.

A detailed description of all radiological sampling and analytical techniques is provided in the *Hanford Site Environmental Monitoring Plan* (DOE 1991b). Air monitoring was discontinued at several locations in 1992 to reflect the substantial decrease in Hanford Site air emissions following the 1990 reduction in PUREX Plant operations. Air sampling was discontinued at Connell, Eltopia, Othello, Moses Lake, and one location in Richland. In addition, air samples were collected but not routinely analyzed at the following locations: ALE field laboratory; Benton City; Battelle complex; Berg Ranch; old Hanford townsite; Mattawa; north of the 200-East Area; Route 11A, Mile 9; and Wye Barricade. Samples from these locations were stored in an archive facility in the event that later analysis would be required.

Air samples were also collected at three COES stations located at Basin City Elementary School in Basin City, Edwin Markham Elementary School in North Franklin

County, and Leslie Groves Park in Richland (see Figure 5.2 and Table 5.2). These samples were collected by local teachers using the same equipment, procedures, and analytical laboratory as the Hanford Surface Environmental Surveillance Program. This work was part of a DOE-sponsored program to improve public awareness of Hanford environmental monitoring programs and the effects of Site operations.

Nonradiological air samples for volatile organic compounds (VOCs) and PCBs were collected downwind of the 300 Area Process Trenches (Table 5.2, location #15), at the southeast corner of the 200-West Area (Table 5.2, location #12), and at a background location near Rattlesnake Springs (Figure 5.2, near location #33). Air samples for VOCs were collected using EPA Method TO-2 (EPA 1988), which uses low-volume air samplers with adsorbent (carbon molecular sieve) traps. Air samples were analyzed by Air Toxics, Inc. (Rancho Cordova, California), using EPA Method TO-2 (EPA 1988). Air samples for PCB analysis were collected using EPA Method TO-4 (EPA 1988), utilizing high-volume air samplers equipped with glass fiber filters and (polyurethane foam) adsorbent traps. Air samples were analyzed for PCBs by General Physics, Inc. (Gaithersburg, Maryland), using a combination of EPA TO-4 (sample media preparation and analytical extraction) and EPA SWA-846 Method 8080 (EPA 1986a) for analysis. Both VOC and PCB samples were collected using primary and secondary adsorbent traps; the secondary trap was used to monitor vapor penetration (breakthrough) through the primary trap.

Results

Radiological Results

Radiological air sampling results for onsite, Site perimeter, nearby communities, distant communities, and COES stations for total beta, total alpha, and specific radionuclides are summarized in Table 5.3. Numerous specific radionuclides (Appendix F) were analyzed in the quarterly composite gamma scan analyses (DOE 1991b), but none of Hanford origin were detected consistently.

Total beta concentrations in air for 1992, as shown in Figure 5.3, peaked during the winter, repeating a pattern of natural annual radioactivity fluctuations (Eisenbud 1987). As shown in Table 5.3, the average total beta and total alpha concentrations were about the same onsite as at the Site perimeter and in nearby and distant communities, indicating that the observed levels were predominantly a result of natural sources and worldwide fallout. No differences were observed between average Site perimeter and distant locations for either total beta or total alpha concentrations.

All ^{90}Sr results for air samples collected at the Site perimeter, community-operated surveillance stations, and nearby and distant communities were below detectable concentrations (8 aCi/m^3) for 1992. (Because of extremely low concentrations, results for some radionuclides are reported in aCi/m^3 rather than pCi/m^3; one aCi/m^3 = 0.000001 pCi/m^3.) Strontium-90 was reported above detectable levels for 5 of 8 samples collected on the Hanford Site with a maximum concentration of 18 aCi/m^3 reported at B Pond. However, this maximum value is only 0.000036% of the DCG of 50,000,000 aCi/m^3. The *Hanford Site Environmental Report for Calendar Year 1991* (Woodruff et al. 1992) reported anomalously high results for most ^{90}Sr air concentrations for the fourth quarter of 1991 as well as for all annual composites for 1991. All 1991 ^{90}Sr air concentrations were reported by Bisping and Woodruff (1992). Further review of the unusual 1991 results included an inspection of the laboratory and additional data review; however, no apparent cause of the elevated results was discovered.

Quarterly air sampling for ^{129}I began in July 1984. Iodine-129 was sampled downwind of the PUREX Plant (200-East SE location), at two downwind perimeter locations, and at a distant community location (Yakima) in 1992. Concentrations at the Site perimeter in 1992 were higher than those observed at Yakima (Figure 5.4), and the difference was statistically significant (one-tailed t-test, 5% significance level). The average onsite and Site perimeter concentrations decreased in 1989 in response to reduced PUREX Plant operations and have remained at similar levels from 1990 to 1992. Onsite air concentrations of ^{129}I were influenced by minor emissions (0.3 Ci, Table 3.1) from the PUREX Plant, storage of dissolved fuel rod solutions, and possible releases from waste storage tanks and cribs. The annual average ^{129}I concentration at the downwind perimeter in 1992 (1.4 aCi/m^3 ±33%) was 0.000002% of the DCG of 70,000,000 aCi/m^3 (70 pCi/m^3).

Tritium results from January to May 1992 were elevated (48 of 84 samples were ≥10 pCi/m^3) and variable for most air sampling locations (Figure 5.5). The average tritium sample results from distant locations (Yakima

Table 5.3. Airborne Radionuclide Concentrations in the Hanford Environs, 1992 Compared to Values from the Previous 5 Years

Radionuclide	Composite Group[a]	1992 No. of Samples	1992 Maximum[b] pCi/m³	1992 Average[c] pCi/m³	1987-1991 No. of Samples	1987-1991 Maximum[b] pCi/m³	1987-1991 Average[c] pCi/m³	1992 Concentration Guide[d] pCi/m³
^{3}H	Onsite	35	770 ± 6.0	130 ± 69%	355	71 ± 2.3	2.2[e] ± 2.9%	100,000
Jan-May 1992[f]	Perimeter	24	1600 ± 9.4	190 ± 160%	464	12 ± 1.3	1.4[e] ± 9.3%	
	Distant Communities	10	350 ± 3.7	71 ± 81%	123	9.0 ± 0.45	1.2[e] ± 18%	
	COES[g] Stations	15	1200 ± 7.7	200 ± 150%	24	10 ± 1.3	2.4 ± 50%	
^{3}H	Onsite	60	28 ± 1.1	2.4 ± 0.96%	355	71 ± 2.3	2.2[e] ± 2.9%	100,000
June-Dec 1992	Perimeter	40	330 ± 5.0	1.5[h] ± 1.1%	464	12 ± 1.3	1.4[e] ± 9.3%	
	Distant Communities	16	380 ± 5.4	1.4[i] ± 1.1%	123	9.0 ± 0.45	1.2[e] ± 18%	
	COES Stations	23	14 ± 2.1	1.7 ± 1.2%	24	10 ± 1.3	2.4 ± 50%	
Total Beta	Onsite	495	0.11 ± 0.00035	0.020 ± 5.8%	2598	0.13 ± 0.0036	0.021 ± 2.4%	
	Perimeter	234	0.15 ± 0.00039	0.020 ± 9.0%	1747	0.11 ± 0.0040	0.020 ± 3.0%	
	Nearby Communities	54	0.10 ± 0.00033	0.024 ± 22%	1125	0.088 ± 0.0041	0.020 ± 3.7%	
	Distant Communities	54	0.12 ± 0.00038	0.021 ± 25%	701	0.077 ± 0.0030	0.019 ± 4.3%	
	COES Stations	80	0.057 ± 0.00034	0.019 ± 11%	62	0.043 ± 0.0018	0.016 ± 14%	
			aCi/m³	aCi/m³		aCi/m³	aCi/m³	aCi/m³
^{90}Sr	Onsite	8	18 ± 7.9	8.1 ± 50%	153	4,200 ± 140	80 ± 89%	50,000,000
	Perimeter	6	3.0 ± 5.3	0.98 ± 140%	106	2,300 ± 43	110 ± 68%	
	Nearby Communities	1	2.8 ± 5.2	2.8 ± 190%	85	6,300 ± 110	130 ± 120%	
	Distant Communities	2	-1.9 ± 4.9	-2.7 ± 56%	71	150 ± 79	18 ± 49%	
	COES Stations	3	0.13 ± 5.7	-0.087 ± 28%	9	64 ± 36	2.2 ± 1,000%	
^{106}Ru	Onsite	31	1,900 ± 1,500	-470 ± 104%	390	14,000 ± 9,400	3.4 ± 130,000%	30,000,000
	Perimeter	23	1,900 ± 1,800	-62 ± 720%	298	14,000 ± 8,000	52 ± 1,200%	
	Nearby Communities	3	-450 ± 2,600	-1400 ± 108%	245	12,000 ± 7,500	-460 ± 170%	
	Distant Communities	8	630 ± 2,200	-410 ± 160%	200	20,000 ± 16,000	180 ± 490%	
	COES Stations	12	1,700 ± 2,600	150 ± 370%	9	2,400 ± 3,400	-66 ± 1,500%	
^{129}I	Onsite	4	74 ± 7.2	50 ± 35%	20	710 ± 54	180 ± 46%	70,000,000
	Perimeter	8	2.2 ± 0.15	1.4 ± 33%	40	18 ± 2.7	4.9 ± 27%	
	Distant Communities	4	0.13 ± 0.013	0.092 ± 32%	21	0.97 ± 0.22	0.31 ± 35%	
^{131}I	Onsite	79	4,400 ± 5,100	-5.7 ± 6,800%	667	7,900 ± 7,900	51 ± 340%	400,000,000
	Perimeter	78	8,100 ± 5,500	-390 ± 130%	533	13,000 ± 11,000	-130 ± 190%	
	Distant Communities	53	2,000 ± 1,900	-20 ± 1,200%	215	6,300 ± 6,300	-130 ± 250%	
	COES Stations	80	3,600 ± 3,100	-190 ± 170%	62	28,000 ± 19,000	1,100 ± 110%	

Table 5.3. Airborne Radionuclide Concentrations in the Hanford Environs, 1992 Compared to Values from the Previous 5 Years (contd)

Radionuclide	Composite Group[a]	1992 No. of Samples	1992 Maximum[b] aCi/m³	1992 Average[c] aCi/m³	1987-1991 No. of Samples	1987-1991 Maximum[b] aCi/m³	1987-1991 Average[c] aCi/m³	1992 Concentration Guide[a] aCi/m³
^{137}Cs	Onsite	31	350 ± 250	75 ± 71%	390	1,200 ± 870	52 ± 89%	400,000,000
	Perimeter	23	260 ± 180	84 ± 58%	298	1,600 ± 1,400	27 ± 240%	
	Nearby Communities	3	160 ± 230	36 ± 400%	245	2,000 ± 950	78 ± 100%	
	Distant Communities	8	240 ± 220	100 ± 89%	200	2,200 ± 1,100	94 ± 94%	
	COES Stations	12	390 ± 270	74 ± 110%	9	130 ± 240	26 ± 230%	
U(total)[j]	Onsite	6	61 ± 3.9	37 ± 28%	115	6,200 ± 73	230 ± 55%	100,000
	Perimeter	3	58 ± 4.0	44 ± 34%	39	490 ± 31	88 ± 30%	
	Distant Communities	2	60 ± 3.5	44 ± 73%	41	250 ± 20	56 ± 23%	
	COES Stations	3	62 ± 5.0	44 ± 44%	9	87 ± 16	58 ± 19%	
^{238}Pu	Onsite	8	0.86 ± 0.53	0.21 ± 100%	153	2.7 ± 0.020	0.26 ± 42%	300,000
	Perimeter	5	0.29 ± 0.36	0.11 ± 100%	106	3.0 ± 0.025	0.087 ± 150%	
	Nearby Communities	1	0.30 ± 0.42	0.30 ± 160%	85	1.2 ± 0.015	-0.077 ± 120%	
	Distant Communities	2	0.27 ± 0.45	0.17 ± 120%	71	5.3 ± 0.030	0.25 ± 110%	
	COES Stations	3	0.17 ± 0.33	0.082 ± 110%	9	1.8 ± 0.016	0.46 ± 84%	
$^{239,240}Pu$	Onsite	8	7.7 ± 1.6	3.3 ± 41%	153	86 ± 11	1.8 ± 65%	20,000
	Perimeter	5	2.3 ± 0.89	1.2 ± 48%	106	3.2 ± 2.3	0.43 ± 35%	
	Nearby Communities	1	1.0 ± 0.71	1.0 ± 71%	85	2.2 ± 1.5	0.36 ± 42%	
	Distant Communities	2	3.9 ± 1.2	2.4 ± 120%	71	2.8 ± 2.4	0.24 ± 78%	
	COES Stations	3	1.7 ± 0.65	1.5 ± 15%	9	3.3 ± 1.5	1.1 ± 74%	
Total Alpha	Onsite	469	8,700 ± 1,200	620 ± 11%	2,196	56,000 ± 2,600	1,300 ± 11%	
	Perimeter	208	6,800 ± 1,200	660 ± 19%	1,248	32,000 ± 2,300	1,200 ± 11%	
	Nearby Communities	27	1,600 ± 510	660 ± 19%	225	16,000 ± 1,500	1,200 ± 20%	
	Distant Communities	54	8,300 ± 1,100	850 ± 48%	285	22,000 ± 1,600	1,200 ± 24%	
	COES Stations	80	4,800 ± 760	600 ± 23%	62	3,800 ± 1,100	560 ± 65%	

(a) Onsite, Site perimeter, nearby communities, and distant sampling locations are identified in Figure 5.1 and Table 5.2.
(b) Maximum single sample results ±2 sigma counting errors. The use of negative concentration values is explained in the section, "Helpful Information."
(c) Averages of all samples ±2 times the percent standard error of the calculated mean (SEM).
(d) From DOE Derived Concentration Guide (see Appendix C).
(e) Average of annual means.
(f) The Jan - May 1992 results are suspect and are likely at the result of laboratory contamination.
(g) COES = community-operated environmental surveillance (station). Stations are identified in Figure 5.1 and Table 5.2.
(h) Two values at the Prosser Barricade were excluded from the average (280 and 330 pCi/m³).
(i) One value at Sunnyside was excluded from the average (350 pCi/m³).
(j) Summation of ^{234}U, ^{235}U, and ^{238}U.

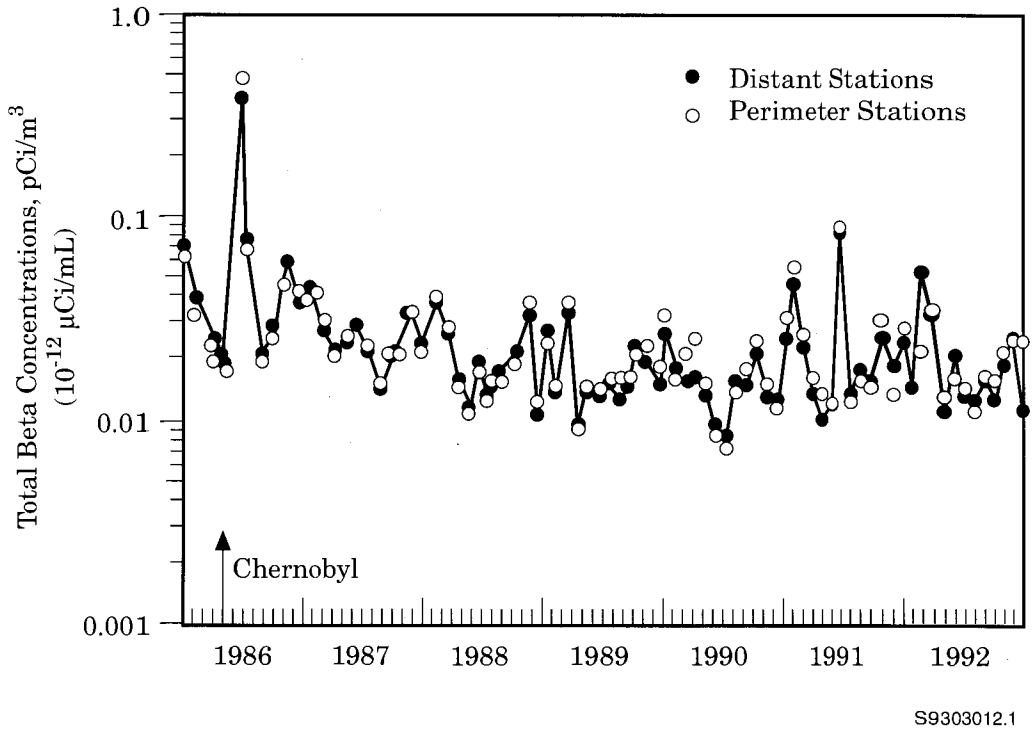

Figure 5.3. Monthly Average Total Beta Radioactivity in Airborne Particulate Samples, 1986 Through 1992

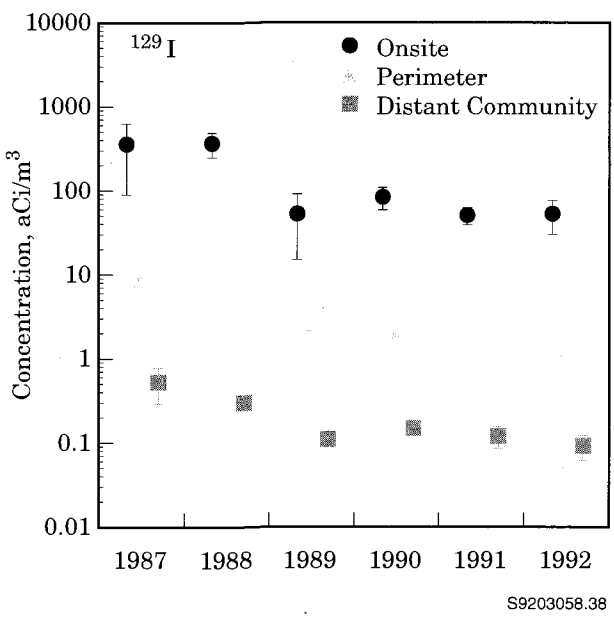

Figure 5.4. Annual Concentrations (±2 SEM) of Iodine-129 (^{129}I) in Air near the Hanford Site, 1987 Through 1992. As a result of figure scale, some uncertainties (error bars) are concealed by point symbol.

and Sunnyside) during this period, were 71 pCi/m^3; typical background levels are less than 5 pCi/m^3. Results for samples from perimeter locations and COES stations were also elevated during this period, with mean concentrations of 190 pCi/m^3 and 200 pCi/m^3, respectively. Given the elevated concentrations reported for samples from the distant locations during this period, these results are suspect and are probably caused by an error or sample contamination during the analytical process; however, no evidence of error or contamination was discovered during an inspection of services at the analytical laboratory. The highest tritium concentration reported for all of 1992 was 1,600 pCi/m^3 at Byers Landing (April); however, even this suspect value was only 1.6% of the DCG of 100,000 pCi/m^3. Reported Hanford Site annual atmospheric releases of tritium for 1992 totaled 44.5 Ci (HT + HTO) (see Table 3.1, Section 3.1, "Effluent Monitoring"), which was a reduction from the 1991 annual release of 85 Ci (HT + HTO).

Tritium concentrations returned to more typical levels for samples collected from June to December 1992, with only 6 of 139 samples reporting concentrations

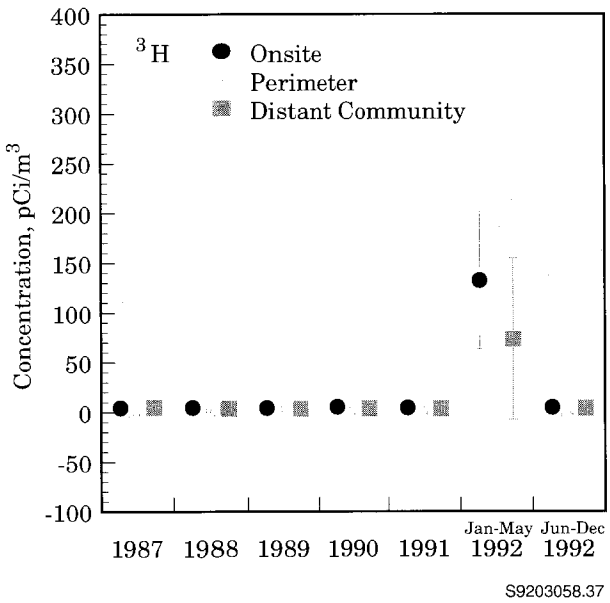

Figure 5.5. Annual Average Concentrations (±2 SEM) of Tritium (^3H) in Air near the Hanford Site, 1987 Through 1992. As a result of figure scale, some uncertainties (error bars) are concealed by point symbol. January through May 1992 results are suspect and may be the result of laboratory contamination. The June through December averages were calculated excluding one value (380 pCi/m^3 at Sunnyside) for the distant locations and two values (280 and 330 pCi/m^3 at the Prosser Barricade) for the perimeter locations.

≥10 pCi/m^3. Tritium concentrations at perimeter stations and distant locations (Yakima and Sunnyside) were similar during this period, with average values of 1.5 pCi/m^3 and 1.4 pCi/m^3, respectively [one value of 380 pCi/m^3 at Sunnyside and two values of 280 and 330 pCi/m^3 at a perimeter location (Prosser Barricade) were excluded from the calculations]. Given the limitations described in the preceding paragraph, the annual average concentration of tritium at the perimeter locations (were 0.2% of the DCG (100,000 pCi/m^3) for January through May 1992 and 0.002% for June through December 1992.

Air concentrations of ^{238}Pu were below detectable concentrations (0.5 aCi/m^3) for all offsite samples collected for 1992 (Table 5.3). The maximum Hanford Site ^{238}Pu concentration was 0.86 aCi/m^3, which is 0.003% of the DCG of 30,000 aCi/m^3. The 1992 average $^{239,240}Pu$ concentrations for Hanford Site and offsite air samples are shown in Table 5.3 and Figure 5.6. The 1992 Site perimeter annual $^{239,240}Pu$ concentration was 1.2 aCi/m^3±48%, which is 0.006% of the DCG of 20,000 aCi/m^3. The maximum Hanford Site $^{239,240}Pu$ concentration was measured at the 200-West Area (7.7 aCi/m^3 or 0.04% of the DCG). The average $^{239,240}Pu$

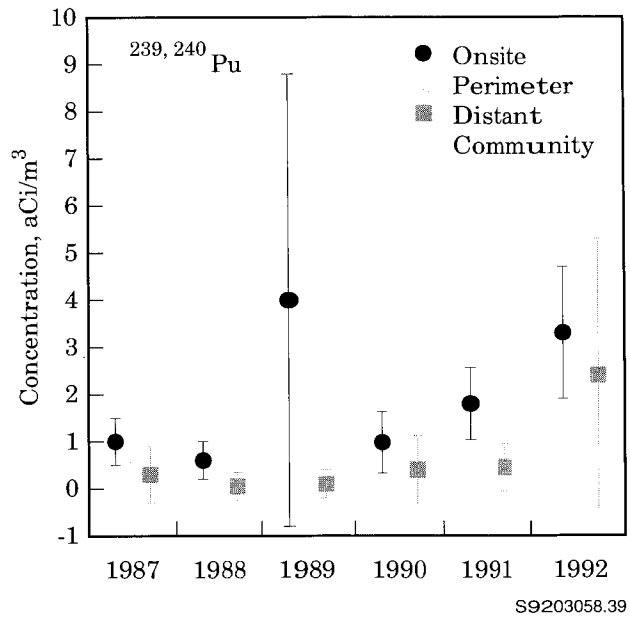

Figure 5.6. Annual Average Concentrations (±2 SEM) of Plutonium-239,240 ($^{239,240}Pu$) in Air at the Hanford Environs, 1987 Through 1992

concentrations onsite showed a possible increasing trend from 1990 to 1992; however, the number of locations sampled was reduced and the sample compositing process was changed from quarterly in 1990 to annual composites in 1992. This trend was influenced by both the elevated concentrations reported at the 200-West Area and the varying number of samples collected onsite. The 1992 air concentration of $^{239,240}Pu$ measured at the 200-West Area was within the range of values reported since the station was established in 1989. For all other individual onsite location, no apparent increasing trend was observed.

Uranium concentrations (^{234}U, ^{235}U, and ^{238}U) in airborne particulate matter in 1992 were similar at the Site perimeter and at distant communities (Table 5.3 and Figure 5.7). The maximum onsite air concentration was at the 300 Area, 61 aCi/m^3±3.9%, which is 0.06% of the

Table 5.4. Average Concentrations of Selected Volatile Organic Compounds in Air on the Hanford Site, 1992 (ng/L ± 2 standard deviation)

Compound	300 Area (4 samples)	200-West Area (3 samples)	Rattlesnake Springs (4 samples)	MACAC[a]	AALG[b]
dichlorodifluoromethane[c]	3.6 ± 5.6	4.8 ± 6.0	2.3 ± 4.0	4950	NA[d]
trichlorofluoromethane	0.52 ± 0.98	0.36 ± 1.0	0.28 ± 0.19	5600[e]	NA
dichloromethane	0.058 ± 0.068	0.013[f] ± 0.0018	0.0077[g] ± 0.0048	1,800	0.1
trichloromethane	0.020[h] ± 0.018	0.098[i] ± 0.030	<0.0075[i] ± 0.0052	9.78	0.022
trichlorotrifluoroethane[j]	0.38 ± 0.30	0.30[i] ± 0.96	0.19 ± 0.20	NA	NA
1,1,1, - trichloroethane	0.70 ± 0.54	0.37 ± 0.50	0.42 ± 0.28	1,900	36,400
benzene	0.40 ± 0.36	0.11 ± 0.18	0.15 ± 0.22	5	0.096
carbon tetrachloride	0.30 ± 0.36	0.28 ± 0.32	0.37 ± 0.30	12.6	0.053
cis-1,3-dichloropropene	0.033[h] ± 0.046	<0.014[k] ± 0.0022	<0.0075[k] ± 0.0052	5	NA
trans-1,3-dichloropropene	0.015[h] ± 0.0058	<0.014[k] ± 0.0022	<0.0075[k] ± 0.0052	5	NA
toluene	0.74 ± 1.1	0.24 ± 0.30	0.22 ± 0.26	375	1400
m,p-xylene	0.42 ± 0.50	0.056 ± 0.066	0.014 ± 0.017	435	57
o-xylene	0.13 ± 0.16	0.033[i] ± 0.042	0.014[g] ± 0.015	435	290

(a) MACAC = maximum allowable concentrations of air contaminants; time-weighted average (TWA) (8-hr day, 40-hr work week); from 29 CFR 1910, January 1989.
(b) AALG = ambient air level goal (Calabrese and Kenyon 1991).
(c) Breakthrough occurred during sample collection; the results should be considered as a lower limits only.
(d) NA = not available.
(e) Short-term exposure limit (no TWA available)
(f) Below detection limit for 2 of 3 samples.
(g) Below detection limit for 3 of 4 samples.
(h) Below detection limit for 2 of 4 samples.
(i) Below detection limit for 1 of 3 samples.
(j) Below detection limit for all samples.
(k) 1,1,2-trichloro-1,2,2-trifluorethane.

DCG of 100,000 aCi/m^3. The 1992 annual average concentration for the Site perimeter was 44 aCi/m^3±34%, which was 0.04% of the DCG.

Ruthenium-106 and ^{137}Cs associated with airborne particulate matter, and ^{131}I collected on charcoal cartridges, were routinely monitored through gamma scan analyses. Results were generally below detectable concentrations both on and off the Hanford Site. The results obtained for 1992 samples are included in Table 5.3. Even the maximum individual measurements for these radionuclides were less than 0.006% of their DCG.

Nonradiological Results

Twenty-one air samples were collected for PCB analysis on the Hanford Site during 1992. All results were below

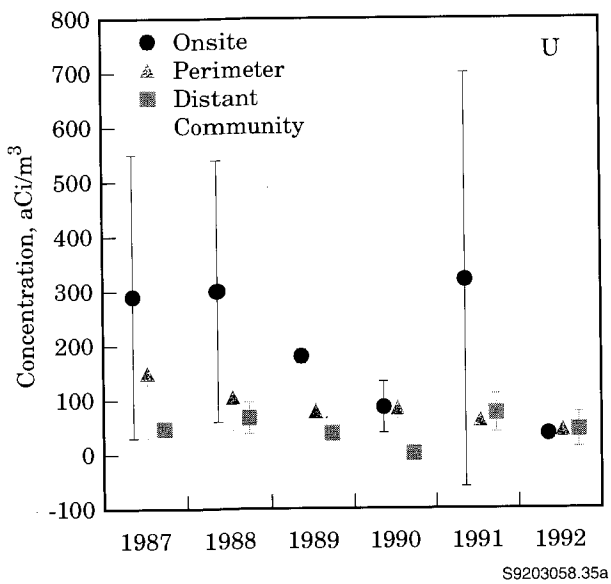

Figure 5.7. Annual Average Concentrations (±2 SEM) of Uranium (^{234}U,^{235}U,^{238}U) in Air at the Hanford Environs, 1987 Through 1992. As a result of figure scale, some uncertainties (error bars) are concealed by point symbols.

the detection limit of ≤100 ng/sample component for each PCB mixture. PCBs were reported as the following Aroclor mixtures: Aroclor 1016 (A-1016), A-1221, A-1232, A-1242, A-1248, A-1254, and A-1260. Air volumes collected ranged from 680 to 726 m^3, which yields air concentrations of ≤0.27 to ≤0.29 ng/m^3, using a detection limit of ≤200 ng/sample (≤100 ng on filter + ≤100 ng on adsorbent). U.S. Environmental Protection Agency Method TO-4 specifies a general detection limit of 1 ng/m^3; therefore the data exceed the required sensitivity by a factor of approximately three.

Eleven air samples were collected for VOC analysis on the Hanford Site during 1992. The samples were analyzed for halogenated alkanes and alkenes, benzene, and alkylbenzenes. These compounds are widely used by modern society and are ubiquitous environmental contaminants. The results are given in Table 5.4, along with ambient air level goals (AALG) and occupational maximum allowable concentrations of air contaminants (MACAC). All measured VOC concentrations were well below MACAC values. The AALG are nonregulatory, nonbinding limits that were developed by Calabrese and Kenyon (1991) for use as health-based guidelines for risk assessments and are somewhat analogous to the EPA's maximum contaminant level goals for water. The AALG values are used as a comparative tool in this report because no regulatory standards for ambient air concentrations have been established for these compounds.

Compounds that routinely approached or exceeded the AALG values were trichloromethane (chloroform), benzene, and carbon tetrachloride. Benzene concentrations at the 300 Area were elevated relative to those at the background site at Rattlesnake Springs; however, the 300 Area concentrations may be influenced by sources both on the Site and in the nearby communities. Carbon tetrachloride and chloroform were used for past Site operations and are routinely detected in ground-water monitoring wells in the 200-West Area (see Section 5.8). However, there was no apparent difference between air concentrations of carbon tetrachloride measured onsite and at the background location. Chloroform concentrations in air were elevated relative to those at the background site for both the 200-West and 300 Area locations; however, this compound was below the detection limit for 43% of the air samples collected onsite. Dichlorodifluoromethane (Freon 12) was the only compound with measured concentrations greater than 1 ng/L; however, these values must be taken only as lower limits because of vapor penetration (breakthrough) to the secondary adsorbent trap. Dichlorodifluoromethane was the only VOC to show substantial breakthrough at the air volumes sampled.

5.3 Surface-Water Surveillance

Surface water on and near the Hanford Site is monitored to determine the potential effects of Hanford operations. Surface water at Hanford includes the Columbia River, riverbank springs, ponds located on the Hanford Site, and offsite water systems directly east of and across the Columbia River from the Hanford Site. In addition, Columbia River sediments are included in this discussion. Tables 5.5 and 5.6 summarize the sample locations, sample type, frequency, and analyses included in the surface-water surveillance activities during 1992. Sample locations are shown in Figure 5.8 as well. This section describes the surveillance effort and summarizes the results for these aquatic environments. Detailed analytical results are reported by Bisping and Woodruff (1993).

Columbia River Water

The Columbia River, second largest river in North America, is the dominant surface-water body on the Site. The river is used as a source of drinking water at onsite facilities and communities located downstream from the Hanford Site. In addition, the river near the Hanford Site is used for a variety of recreational activities, including hunting, fishing, boating, water skiing, and swimming. Water from the Columbia River downstream from the Site is also used extensively for crop irrigation.

Originating in the mountains of eastern British Columbia, Canada, the Columbia River drains a total area of approximately 70,800 km^2 (27,300 mi^2) en route to the Pacific Ocean. Flow of the Columbia River is regulated by 11 dams within the United States, 7 upstream and 4 downstream from the Site. Priest Rapids is the nearest dam upstream from the Site, and McNary is the nearest dam downstream. The Hanford Reach of the Columbia River extends from Priest Rapids Dam to the head of Lake Wallula (created by McNary Dam), near Richland. This Reach is the last stretch of the Columbia River in the United States above Bonneville Dam that remains unimpounded. The width of the river varies from approximately 300 m (984 ft) to 1,000 m (3,281 ft) within the Hanford Site. The Hanford Reach is currently under consideration for designation as a National Wild and Scenic River as a result of congressional action in 1988 (see Section 2.3).

Pollutants, both radiological and nonradiological, are known to enter the river along the Hanford Site. In addition to direct discharges of liquid effluents from Hanford facilities, contaminants in ground water from past discharges to the ground are known to seep into the river (Dirkes 1990; DOE 1992a; McCormack and Carlile 1984; Peterson 1992). Effluents from each direct discharge point are routinely monitored and reported by the responsible operating contractor; they are summarized in "Facility Effluent Monitoring," Section 3.1. Direct discharges are identified and regulated for nonradiological constituents under the NPDES. The NPDES-permitted discharges at Hanford and the regulated parameters are listed in Table C.7, Appendix C.

The State of Washington has classified the stretch of the Columbia River from Grand Coulee Dam to the Washington-Oregon border, which includes the Hanford Reach, as Class A, Excellent (Ecology 1992). Water quality criteria and water use guidelines have been established in conjunction with this designation (Table C.1, Appendix C). The State of Washington and EPA drinking water standards (DWSs) used in evaluating radionuclide concentrations in Columbia River water are provided in Table C.2, Appendix C.

Sample Collection and Analysis

Samples of Columbia River water were collected throughout 1992 at the locations shown in Figure 5.8. Samples were collected upstream from Hanford facilities at Priest Rapids Dam and near the Vernita Bridge to provide background data from locations unaffected by Site operations. Samples were collected from the 300 Area water intake and the Richland Pumphouse to identify any increase in contaminant concentrations at these locations attributable to Hanford operations. The Richland Pumphouse is the first downstream point of

Table 5.5. Surface-Water Surveillance, 1992

Location	Sample Type	Frequency[a]	Analyses
Columbia River - Radiological			
Priest Rapids Dam and Richland	Cumulative (collected weekly)	M Comp[b]	Alpha, beta, lo ^{3}H,[c] gamma scan, ^{90}Sr, ^{99}Tc, U[d]
Priest Rapids Dam, Richland, and 300 Area Water Intake	Particulate (filter)	M Q Comp	Gamma scan Pu[e]
Priest Rapids Dam, Richland, and 300 Area Water Intake	Soluble (resin)	M Q Comp	Gamma scan ^{129}I, Pu[e]
Vernita Bridge and Richland	Grab (transects)	Q	lo ^{3}H, ^{90}Sr, U[d]
Columbia River - Nonradiological			
Vernita and Richland	Grab	Q[f]	WQ-NASQAN, temperature, dissolved oxygen, turbidity, pH, fecal coliforms, suspended solids, dissolved solids, conductivity, hardness as $CaCO_3$, P, Cr, N-Kjeldahl, DOC, Fe, NH_3
Vernita and Richland	Grab (transects)	Q	ICP metals, anions, volatile organic
Vernita and Richland	Thermograph	Continuous	Temperature
Onsite Ponds			
West Lake	Grab	Q	Alpha, beta, ^{3}H, ^{90}Sr, U,[d] gamma scan
B Pond	Grab	M	Alpha, beta, ^{3}H, ^{90}Sr, gamma scan
FFTF Pond	Grab	Q	Alpha, beta, ^{3}H, ^{90}Sr, gamma scan
Offsite Water			
Ringold Hatchery, Mathews Corner, White Bluffs shallow, White Bluffs deep, and Alexander Farm	Grab	A	Alpha, beta, ^{3}H, U,[d] gamma scan, ^{129}I
Riverview Canal	Grab	3[g]	Alpha, beta, ^{3}H, ^{90}Sr, U,[d] gamma scan
Riverbank Springs			
100-N, old Hanford townsite, and 300 Area	Grab	A	Alpha, beta, ^{3}H, ^{90}Sr, ^{99}Tc, gamma scan, U[d]

(a) A = annually; M = monthly; Q = quarterly; Comp = composite.
(b) M Comp is collected weekly and composited for monthly analysis.
(c) lo ^{3}H = low-level tritium analysis.
(d) Isotopic uranium.
(e) Isotopic plutonium.
(f) Numerous water quality analyses are performed by the U.S. Geological Survey (USGS) in conjunction with the National Stream Quality Accounting Network (NASQAN) Program. Thermograph stations are operated and maintained by the USGS.
(g) Three samples during irrigation season.

Table 5.6. Sediment Surveillance, 1992

Location[a]	Frequency	Analyses
McNary Dam		
Oregon shore	A	Gamma scan, ^{90}Sr, U[b], Pu[c], DOH[d]
1/3 from Oregon shore	A	Gamma scan, ^{90}Sr, U[b], Pu[c], DOH[d]
2/3 from Oregon shore	A	Gamma scan, ^{90}Sr, U[b], Pu[c], DOH[d]
Washington shore	A	Gamma scan, ^{90}Sr, U[b], Pu[c], DOH[d]
Priest Rapids Dam		
Grant County shore	A	Gamma scan, ^{90}Sr, U[b], Pu[c], DOH[d]
1/3 from Grant County shore	A	Gamma scan, ^{90}Sr, U[b], Pu[c], DOH[d]
2/3 from Grant County shore	A	Gamma scan, ^{90}Sr, U[b], Pu[c], DOH[d]
Yakima County shore	A	Gamma scan, ^{90}Sr, U[b], Pu[c], DOH[d]
White Bluffs Slough	A	Gamma scan, ^{90}Sr, U[b], Pu[c]
100-F Slough	A	Gamma scan, ^{90}Sr, U[b], Pu[c]
Hanford Slough	A	Gamma scan, ^{90}Sr, U[b], Pu[c]
Richland	A	Gamma scan, ^{90}Sr, U[b], Pu[c]

(a) See Figure 5.8.
(b) Includes ^{235}U and ^{238}U analyzed by low-energy photon analysis.
(c) Isotopic plutonium.
(d) Duplicate samples sent to the Washington State Department of Health.

river water withdrawal for a public drinking water supply. The river sampling locations and the methods used for sample collection are discussed in detail in the *Hanford Site Environmental Monitoring Plan* (DOE 1991b). In addition to the routine fixed-location monitoring stations described in the environmental monitoring plan, routine sampling was performed along cross sections established at Vernita Bridge and the Richland Pumphouse. The transect sampling was initiated as a result of findings of a special study conducted during 1987 and 1988 (Dirkes 1993). The cross sections were sampled quarterly during 1992.

Radiological analyses of water samples included total alpha, total beta, gamma scan, ^{3}H, ^{90}Sr, ^{99}Tc, ^{129}I, ^{238}Pu, ^{239,240}Pu, and isotopic uranium (^{234}U, ^{235}U, and ^{238}U). Alpha and beta measurements provided a general indication of the radioactive contamination. Gamma scans provided the ability to detect numerous specific radionuclides (Appendix F). Specific radiochemical analyses and, in some cases, special sampling techniques were used to determine the concentrations of ^{3}H, ^{90}Sr, ^{99}Tc, ^{129}I, ^{234}U, ^{235}U, ^{238}U, ^{238}Pu, and ^{239,240}Pu in river water during the year. Radionuclides of interest were selected based on their presence in effluent discharges or ground water near the river, and their importance in determining water quality, verifying effluent control and effluent monitoring systems, and determining compliance with applicable standards. Columbia River water samples collected along cross sections established near the Vernita Bridge and the Richland Pumphouse were also analyzed for metals, anions, and volatile organic compounds during 1992. Chemical constituents of interest were determined from reviews of existing surface- and ground-water data and various Remedial Investigation/ Feasibility Study work plans as well as preliminary risk assessments conducted by the Surface Environmental Surveillance Project (Dirkes et al. 1993; DOE 1992b; Evans et al. 1992).

In addition to monitoring conducted by PNL, non-radiological water quality measurements were also taken by the U.S. Geological Survey (USGS) at Vernita Bridge and Richland (USGS 1988). During 1992, the USGS samples were collected along cross sections every 2 months at Vernita Bridge and quarterly at Richland.

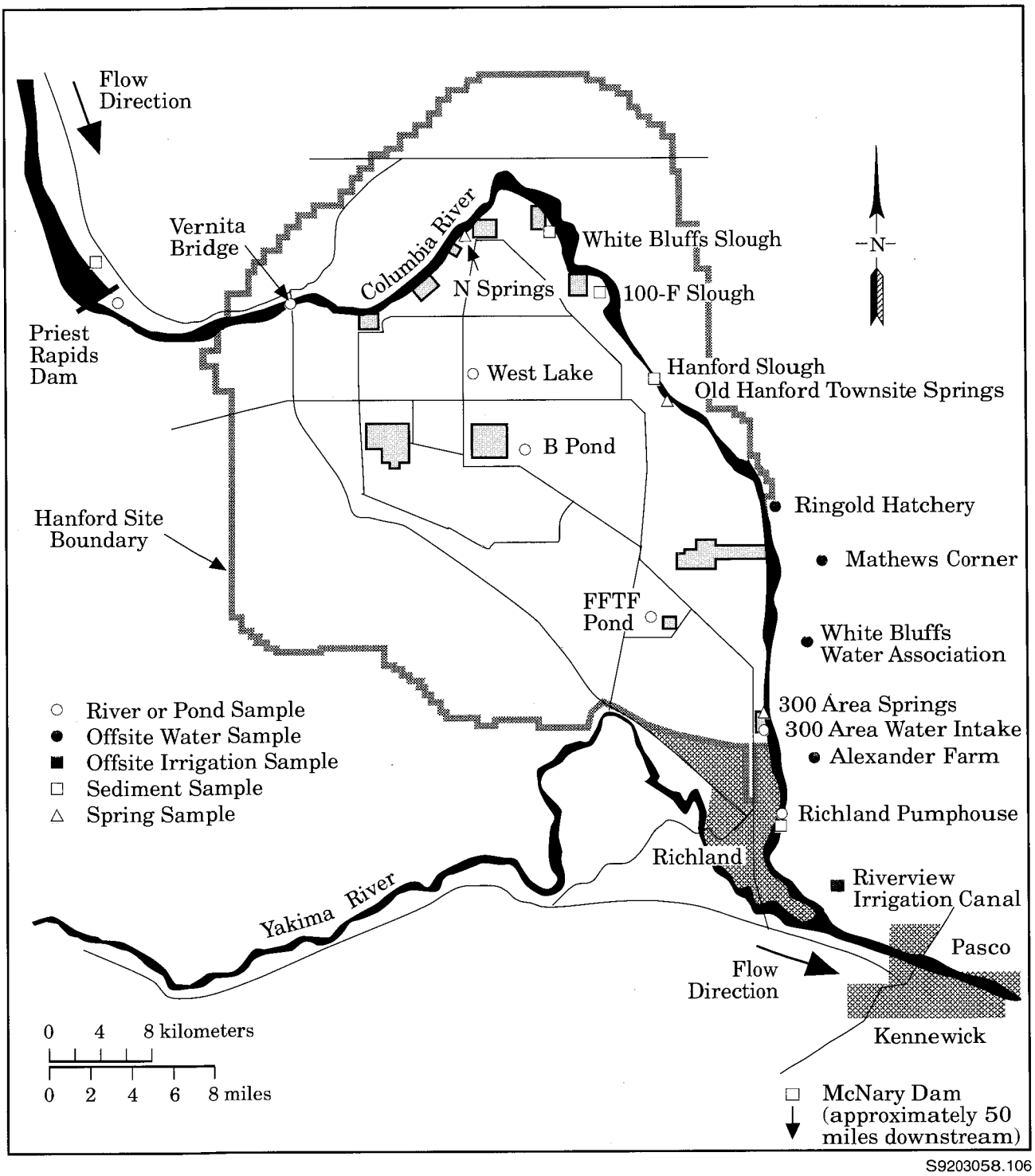

Figure 5.8. Water and Sediment Sampling Locations, 1992

Numerous physical, biological, and chemical constituents were analyzed for at the USGS laboratory in Denver, Colorado. Results of the USGS monitoring activities are documented in Bisping and Woodruff (1993). In addition to sampling, the USGS provided continuous river temperature monitoring, both upstream from the Site near Priest Rapids Dam and at Richland, and provided flow rate measurements at Priest Rapids Dam.

Radiological Results for River Water

Results of the radiological analyses of Columbia River water samples collected at Priest Rapids Dam, the 300 Area, and the Richland Pumphouse during 1992 are reported by Bisping and Woodruff (1993) and summarized in Tables A.1 through A.3, Appendix A. The data summaries also include the maximum individual result observed during the previous 5 years and the mean of all sample results for 1987 through 1991. Significant results are discussed and illustrated in the following paragraphs, with comparisons to previous years provided. Levels throughout the year were extremely low. Radionuclides consistently detected in river water during 1992 were ^{3}H, ^{90}Sr, ^{129}I, ^{234}U, and ^{238}U. In addition, ^{99}Tc, ^{235}U, and $^{239,240}Pu$, while not detected all of the time, were detected in 50% or more of the samples analyzed during the year. Tritium and ^{90}Sr exist in worldwide fallout, as well as in effluents from Hanford facilities. Uranium, as well as ^{3}H, occurs naturally in the environment in addition to being present in Hanford effluents.

Total alpha and total beta measurements are useful indicators of the general radiological quality of the river and provide an early indication of changes in the levels of radioactive contamination because results are obtained quickly. The 1992 average alpha and beta concentrations in Columbia River water at Priest Rapids Dam, the 300 Area, and the Richland Pumphouse were approximately 5% or less of the applicable DWS of 15 and 50 pCi/L, respectively. Figures 5.9 and 5.10 illustrate the annual average total alpha and total beta concentrations, respectively, at Priest Rapids Dam and the Richland Pumphouse during the past 6 years. The 1992 alpha concentrations were similar to those previously reported. Total beta concentrations during 1992 were also similar to those observed during recent years. Statistical analyses (paired sample comparison and t-test of differences, Snedecor and Cochran 1980) of alpha and beta concentrations at Priest Rapids Dam and the Richland Pumphouse indicated the differences were not significant (5% significance level).

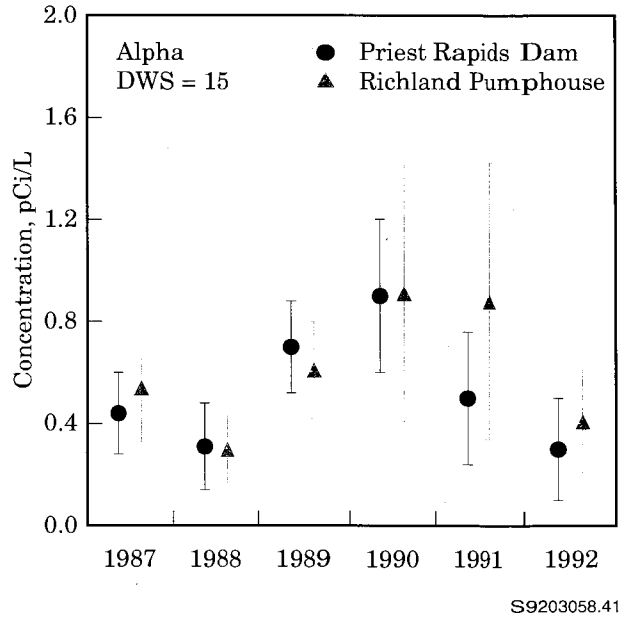

Figure 5.9. Annual Average Total Alpha Concentrations (±2 SEM) in Columbia River Water, 1987 Through 1992

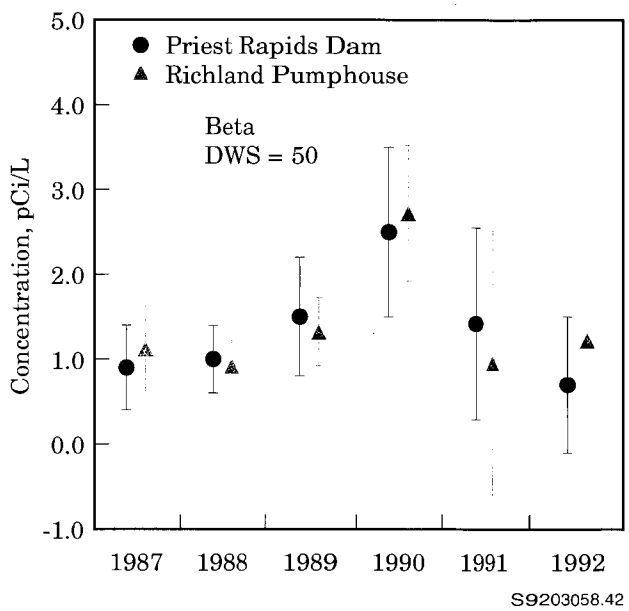

Figure 5.10. Annual Average Total Beta Concentrations (±2 SEM) in Columbia River Water, 1987 Through 1992

Annual average ^3H concentrations at Priest Rapids Dam and the Richland Pumphouse during 1992 were 50 pCi/L ±24% and 101 pCi/L ±18%, respectively. Figure 5.11 compares the annual average ^3H concentrations at Priest Rapids Dam and the Richland Pumphouse from 1987 through 1992. The general decline in ^3H concentrations in river water noted in recent years remains evident. Tritium concentrations are decreasing more rapidly than expected solely as a result of radioactive decay (12-year half-life). Studies conducted following the U.S. Pacific nuclear weapons tests indicated that the effective residence time of ^3H deposited on the North American continent is approximately 5.7 years (NCRP 1979). The difference between the ^3H concentrations at Priest Rapids Dam and the Richland Pumphouse was significant (paired sample comparison, t-test of differences, 5% significance level). Sources of ^3H entering the river were effluent releases from the 100-N Area and ground-water seepage into the river along the Site (see "Facility Effluent Monitoring," Section 3.1, and "Ground-Water Protection and Monitoring Program," Section 5.8). Tritium concentrations measured at the Richland Pumphouse, while representative of the water consumed by users of the city of Richland drinking water, tend to overestimate the average concentrations of ^3H in the river (Dirkes 1993). This bias is attributable to the contaminated 200 Area ground-water plume entering the river at the 300 Area, relatively close to the Richland sample intake; this plume is not completely mixed within the river at the Richland Pumphouse. Sampling along a cross section at the Richland Pumphouse during 1992 confirmed this concentration gradient in the river under certain flow conditions and is discussed in subsequent sections of this report. The degree of overestimation is highly variable and appears to be related to the flowrate of the river just before and during sample collection. All ^3H concentrations were less than 1% of the State of Washington and EPA DWS of 20,000 pCi/L.

Annual average ^{90}Sr concentrations at Priest Rapids Dam and the Richland Pumphouse during 1992 were 0.09 pCi/L±11% and 0.09 pCi/L±11%, respectively. Figure 5.12 shows the annual average ^{90}Sr concentrations at these locations from 1987 through 1992. Concentrations observed in 1992 were similar to those seen in recent years. The difference between the ^{90}Sr concentrations throughout the year at these locations was not significant (at the 5% significance level). The primary source of ^{90}Sr attributable to Hanford entering the Columbia River has been the 100-N Area liquid waste disposal facilities, which are known to discharge to the river via ground-water seepage. Strontium-90 concentrations in Columbia River water during 1992 remained below the State of Washington and EPA DWS of 8 pCi/L (approximately 1%).

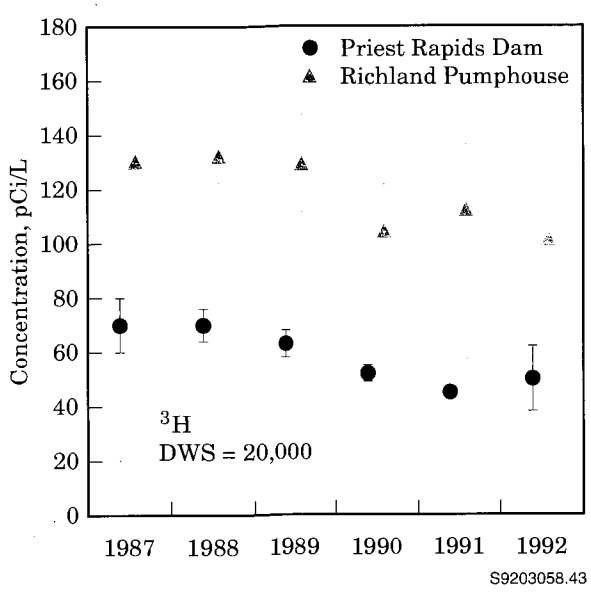

Figure 5.11. Annual Average Tritium (^3H) Concentrations (±2 SEM) in Columbia River Water, 1987 Through 1992. As a result of figure scale, some uncertainties (error bars) are concealed by point symbol.

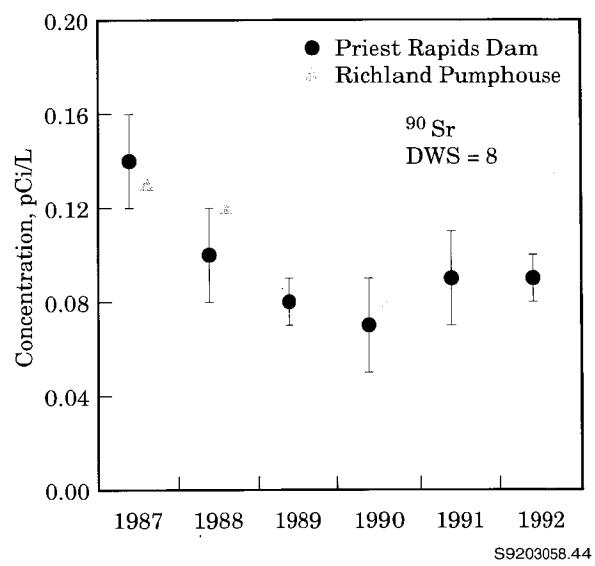

Figure 5.12. Annual Average Strontium-90 (^{90}Sr) Concentrations (±2 SEM) in Columbia River Water, 1987 Through 1992

Annual average uranium concentrations in river water during 1992 were slightly higher at the 300 Area and the Richland Pumphouse than at Priest Rapids Dam; 0.63 pCi/L±17%, 0.51 pCi/L±12%, and 0.42 pCi/L±7%, respectively. Annual average uranium concentrations at the Richland Pumphouse and Priest Rapids Dam for 1987 through 1992 are shown in Figure 5.13. Uranium concentrations were slightly elevated at the Richland Pumphouse. Differences during the year were statistically significant (5% significance level). Although there is no direct discharge of uranium to the river, uranium is present in the ground water beneath the 300 Area as a result of past operations (see "Ground-Water Protection and Monitoring Program," Section 5.8) and has been detected at elevated levels in riverbank springs in this area (see Riverbank Springs in this section). Uranium, naturally occurring, is also known to be entering the river across from Hanford via seepage from the extensive irrigation practices east of the river and via irrigation canal outfalls (Dirkes 1990). There is currently no DWS directly applicable to uranium. However, uranium concentrations in the river during 1992 were below those that would result in doses exceeding the State of Washington and EPA DWS of 4 mrem/year, which is applicable to anthropogenic radionuclides.

Technetium-99 concentrations less than the analytical detection level were found in about 50% of the samples submitted during 1992. The 1992 average ^{99}Tc concentrations at the Richland Pumphouse and Priest Rapids Dam were 0.21 pCi/L±114% and 0.10 pCi/L±120%, respectively. The uncertainties associated with these results (±2 SEM) were greater than the concentrations. Differences in individual samples during the year were not statistically significant (5% significance level). The presence of ^{99}Tc in the river at these locations, if real, is attributable to the discharge of the 200 Area ground-water plume, contaminated with ^{3}H, ^{99}Tc, and ^{129}I, near the sample locations. The concentrations of ^{99}Tc at all locations during 1992 were less than one-tenth of 1% of the DWS of 900 pCi/L.

Continuous filter/resin samples collected during 1990, 1991, and 1992 were submitted for ^{129}I analysis during 1992 following a 2-year delay that resulted from limitations in the availability and capability of analytical resources. Iodine-129 results, which were not available for the 1990 and 1991 Hanford Site Environmental Reports are provided in this report. The concentrations of ^{129}I during 1990, 1991, and 1992 were extremely low and similar to previous years. Figure 5.14 presents the annual average ^{129}I concentrations for Priest Rapids Dam and the Richland Pumphouse for the years 1987 through 1992

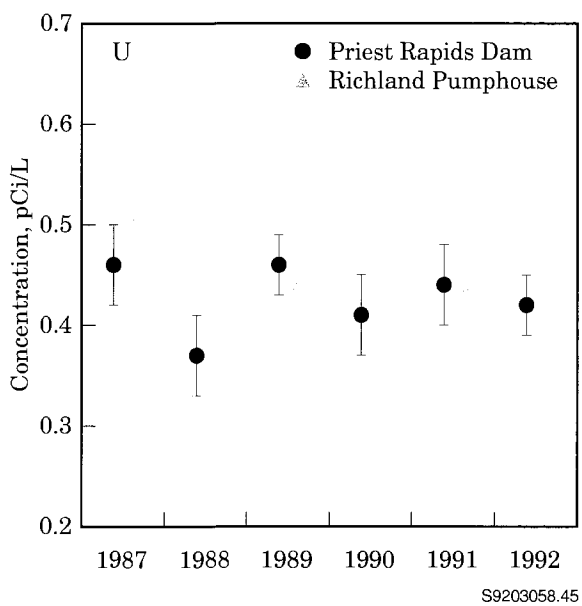

Figure 5.13. Annual Average Uranium Concentrations (±2 SEM) in Columbia River Water, 1987 Through 1992

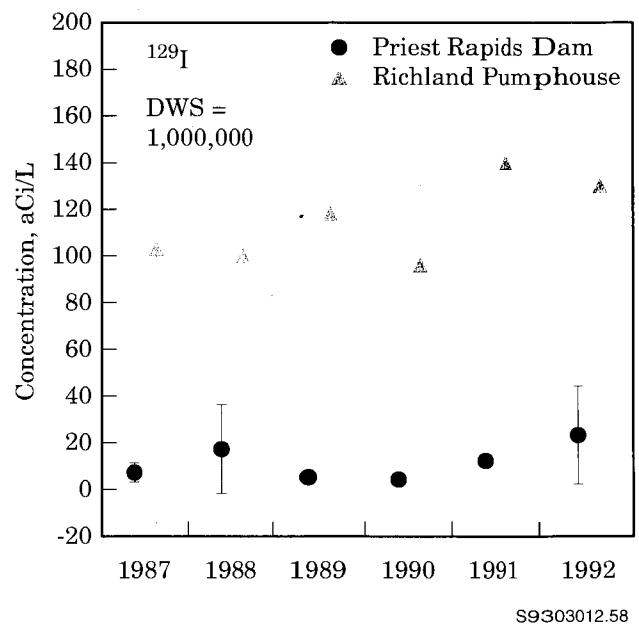

Figure 5.14. Annual Average Iodine-129 (^{129}I) Concentrations (±2 SEM) in Columbia River Water, 1987 Through 1992. As a result of figure scale, some uncertainties (error bars) are concealed by point symbol.

(note the aCi/L units). As has been the case in previous years, the concentrations of ^{129}I at the Richland Pumphouse (96 aCi/m^3±35% to 140 aCi/L±14%) were higher than at Priest Rapids Dam (4 aCi/m^3±25% to 23 aCi/L±91%). The ^{129}I concentrations at the 300 Area (140 aCi/m^3±78% to 170 aCi/L±47%) were similar to that observed at the Richland Pumphouse. The differences between ^{129}I concentrations at Priest Rapids Dam and the Richland Pumphouse were found to be statistically significant (5% significance level), as has been the case over the years. The presence of ^{129}I at elevated levels at the 300 Area and the Richland Pumphouse is attributable to the flow of contaminated ground water from the unconfined aquifer into the river. All ^{129}I sample results were less than one-tenth of 1% of the DWS of 1 pCi/L (1,000,000 aCi/L).

The concentrations of $^{239,240}Pu$, also obtained from the filter/resin samples discussed above, were greater than the detection level approximately 50% of the time at all locations. Priest Rapids Dam $^{239,240}Pu$ concentrations were not statistically different from those observed at the Richland Pumphouse during 1992 (5% significance level).

During 1992, ^{60}Co, ^{106}Ru, ^{131}I, ^{134}Cs, ^{137}Cs, and ^{238}Pu were not consistently found in measurable quantities in Columbia River at Priest Rapids Dam, the 300 Area water intake, or the Richland Pumphouse. The approximate minimum detectable concentrations for ^{60}Co, ^{106}Ru, ^{131}I, ^{134}Cs, ^{137}Cs, and ^{238}Pu during 1992 were 1.5, 10.0, 1.0, 1.5, 1.5, and 0.00001 pCi/L, respectively.

Radiological results of samples collected along cross sections established at Vernita Bridge and the Richland Pumphouse during 1992 are presented in Table A.4, Appendix A. The average concentrations of ^{90}Sr and uranium found during cross-sectional sampling were similar to those obtained from the routine automatic composite samplers used at similar locations. Consistent with studies conducted during 1988 (Dirkes 1993), the average concentrations of ^{3}H measured along the cross section at the Richland Pumphouse were less than those measured using the single-point sample located near the western shoreline of the river at the Richland Pumphouse. The data indicate a ^{3}H concentration gradient across the river at the Richland Pumphouse. It has been concluded that contaminants in the 200 Area ground-water plume entering the river at the 300 Area are not completely mixed at the Richland Pumphouse, consistent with past dispersion studies (Backman 1962; Dirkes 1993). As was observed with the composite sampling system results, the concentrations of radionuclides measured along the cross sections were well below state and federal DWSs.

Nonradiological Results for River Water

Nonradiological water quality data were compiled by PNL and the USGS during 1992. A number of the parameters measured have no regulatory limits. These parameters are, however, useful as indicators of water quality and/or are indicative of Hanford-origin contaminants. Specific water quality measurement results are reported by Bisping and Woodruff (1993). In 1992, USGS results were comparable to results from recent years. Applicable standards for Class A-designated water were met. There was no indication during 1992 of any deterioration of the water quality along this stretch of the Columbia River resulting from Hanford operations. Potential sources of pollutants not associated with Hanford include irrigation return water and seepage associated with extensive irrigation north and east of the Columbia River.

Figure 5.15 shows Vernita Bridge and Richland results for the period 1987 through 1992 for several water quality parameters with respect to the applicable standards. Table A.5, Appendix A, summarizes the results obtained through the USGS national water quality network. The pH measurements upstream and downstream from the Site were in close agreement and were within the acceptable range for Class A waters. Turbidity, fecal coliform, and dissolved oxygen concentrations during 1992 were in compliance with Class A requirements at both locations as well.

Results of sampling conducted by PNL along cross sections of the Columbia River at Vernita Bridge and the Richland Pumphouse are provided by Bisping and Woodruff (1993) and discussed in detail by Dirkes et al. (1993). Volatile organic compounds were not routinely detected during 1992 at either Vernita Bridge or the Richland Pumphouse. Several metals were detected both upstream and downstream from the Hanford Site at levels comparable to those reported by the USGS as part of their ongoing national water quality monitoring network. Similarly, some anions were detected upstream and downstream from the Site at levels consistent with

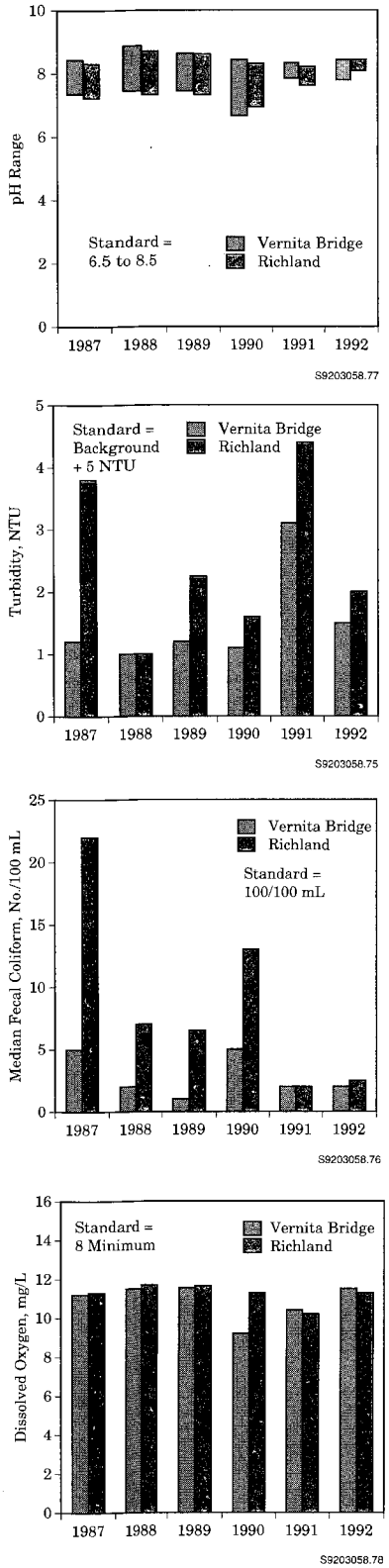

Figure 5.15. Columbia River Water Quality Measurements, 1987 Through 1992

those reported by the USGS. There was no measurable difference between the concentrations of metals or anions detected in the river water along the cross sections upstream from the Site at Vernita Bridge and downstream from the Site at the Richland Pumphouse, indicating no apparent impact from operations at Hanford.

The annual average flow rate of the Columbia River was 2,860 m^3/s (101,000 cfs) during 1992, slightly lower than recent years. The monthly average flow rates at Priest Rapids Dam are shown in Figure 5.16. The peak monthly average flow occurred during June, 4,190 m^3/s (148,000 cfs), and the lowest average monthly flow occurred during October, 2,040 m^3/s (72,000 cfs). Daily average flow rates varied from 1,190 to 5,260 m^3/s (42,100 to 186,000 cfs) during 1992.

Average monthly Columbia River water temperatures at Priest Rapids Dam and the Richland Pumphouse are shown in Figure 5.17. The major source of heat to the Columbia River in the Hanford Reach is solar radiation (Dauble et al. 1987). River temperatures and the differences between temperatures at Priest Rapids Dam and the Richland Pumphouse during 1992, in the absence of reactor operations, were similar to those in the past (Price 1986). Monthly average temperatures were slightly higher at the Richland Pumphouse than at Priest Rapids Dam from February through August and December 1992. Cooler monthly average temperatures were observed at the Richland Pumphouse during January and November. Monthly average temperatures were the same during September and October. Temperatures along the Hanford Reach were in compliance with applicable state Class A water quality requirements during the year.

Columbia River Sediment

Sample Collection and Analysis

Annual samples of Columbia River sediment were collected during 1992 at locations shown in Figure 5.8 and summarized in Table 5.6. Samples were collected upstream from the Hanford Site behind Priest Rapids Dam, downstream from the Site at Richland, and approximately 50 miles downstream from the Site at McNary Dam. Samples were also collected along the Hanford Reach from sloughs at White Bluffs, 100-F Area, and the old Hanford townsite. Samples were obtained from approximately 15 cm (6 in.) of the top sediment material

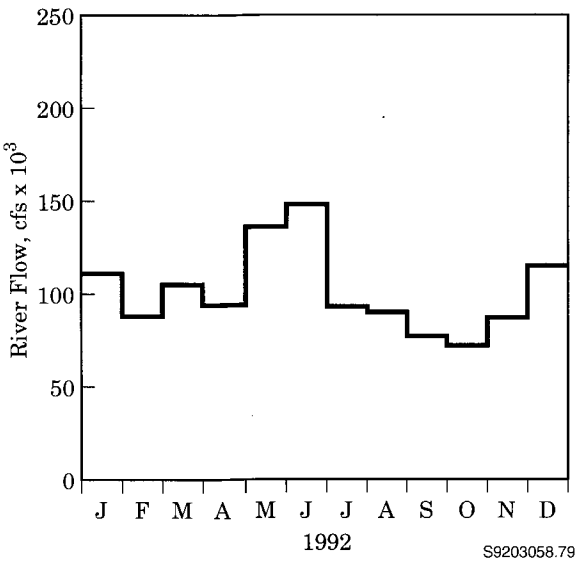

Figure 5.16. Monthly Average Columbia River Flow Rates During 1992 (measured at Priest Rapids Dam)

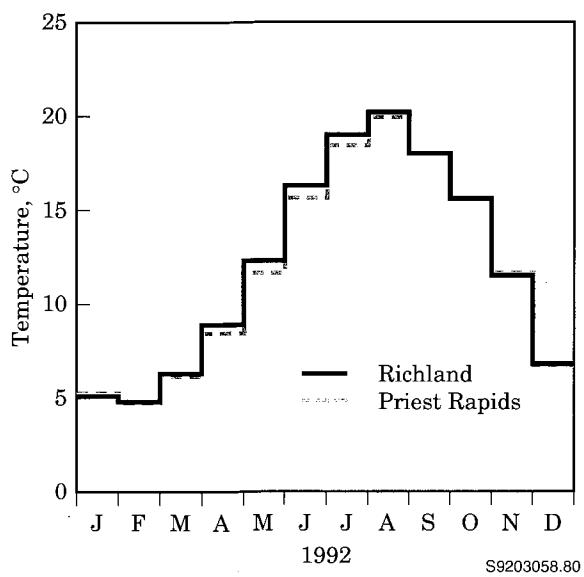

Figure 5.17. Monthly Average Columbia River Water Temperatures During 1992

using a dredge sampler. Analyses of the sediment samples include gamma scans (see Appendix F), ^{90}Sr, ^{235}U, ^{238}U, ^{238}Pu, and $^{239,240}Pu$.

Radiological Results for Sediments

Surface sediments in the Columbia River are known to contain low levels of radionuclides of Hanford origin and from nuclear weapons testing fallout (Beasley et al. 1981; Robertson and Fix 1977; Woodruff et al. 1992). Analytical results for surface sediment samples collected during 1992 are summarized in Table A.6, Appendix A, and presented in detail by Bisping and Woodruff (1993). Table A.6, Appendix A, also includes summary data for the years 1988 through 1991.

In general, the level of radioactivity in surface sediments behind McNary Dam was slightly higher than that behind Priest Rapids Dam during 1992. Radionuclide concentrations in sediments collected from the sloughs along the Hanford Reach and at Richland were generally comparable to those observed upstream from Hanford at Priest Rapids Dam. The exception to this is uranium, which was present in sediments collected at Richland at levels comparable to those at McNary Dam.

Figure 5.18 shows the concentrations of selected radionuclides in Columbia River sediment at Priest Rapids Dam and McNary Dam for 1989 through 1992. The concentrations of radionuclides measured during 1992 were similar to those seen in sediment samples collected during the previous 4 years. The concentrations of ^{60}Co during 1992, which were less than the detection level (0.05 pCi/g) in sediments behind Priest Rapids Dam, were highest in sediments collected from McNary pool. The levels of ^{60}Co in surface sediments behind McNary Dam have been relatively stable over the past 5 years. The average concentrations of ^{60}Co, ^{90}Sr, and ^{238}U were higher in sediments collected at McNary Dam than in those collected from Priest Rapids Dam during 1992. Concentrations of ^{137}Cs, ^{238}Pu, and $^{239,240}Pu$ were similar at the two locations.

Riverbank Springs

The seepage of ground water into the Columbia River has been known to occur for many years. Riverbank spring discharges were documented along the Hanford

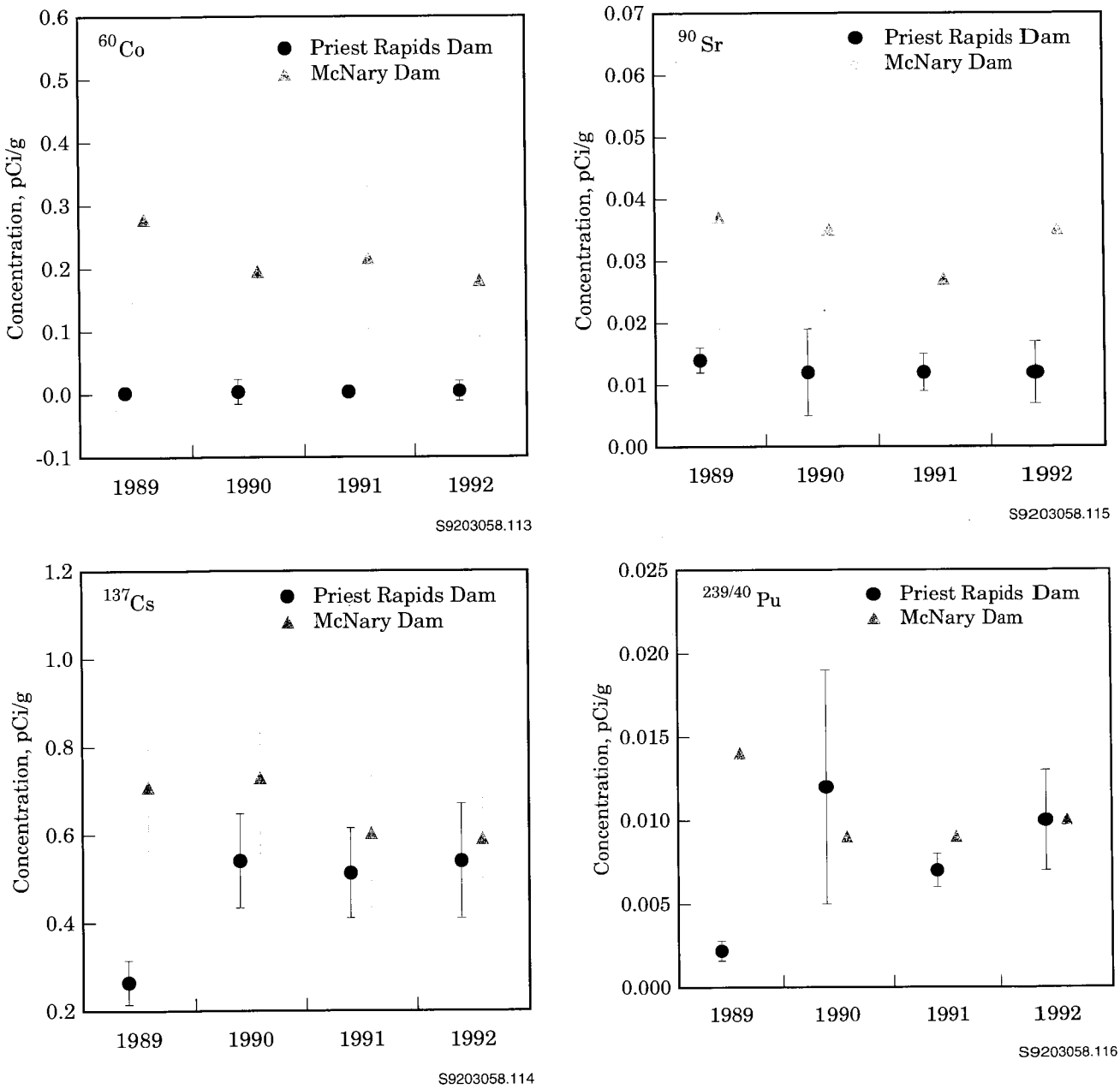

Figure 5.18. Radionuclide Concentrations (±2 SEM) in Columbia River Sediments at Priest Rapids Dam and McNary Dam, 1989 Through 1992. As a result of figure scale, some uncertainties (error bars) are concealed by point symbol.

Reach long before the startup of Hanford operations (Jenkins 1922). These relatively small springs flow intermittently, apparently influenced primarily by changes in river level. Hanford-origin contaminants associated with these ground-water discharges have been documented to enter the river along the Hanford Reach (Dirkes 1990; DOE 1992c; McCormack and Carlile 1984; Peterson and Johnson 1992).

Sample Collection and Analysis

Samples of ground-water seepage were collected during 1992 at the locations identified in Figure 5.8. Sample collection methods are described in the *Hanford Site Environmental Monitoring Plan* (DOE 1991b). The analyses, limited to radiological constituents in 1992, were selected based on findings of previous riverbank spring investigations and reviews of contaminant concentrations observed in nearby ground-water monitoring wells. At a minimum, riverbank spring samples collected during 1992 were analyzed for total alpha, total beta, gamma scan, and ^{3}H. Uranium, ^{90}Sr, ^{99}Tc, and ^{129}I analyses were included for those locations where these constituents are known to exist in the local ground water as a result of past operations at Hanford.

Results

Hanford-origin contaminants were detected in spring water entering the Columbia River along the Hanford Site during 1992. The types and concentrations of contaminants in the spring water, reported by Bisping and Woodruff (1993), were similar to those known to exist in the ground water near the river as a result of past operations at Hanford. The location and extent of the contaminated discharges agreed with recent riverbank spring investigations, ground-water monitoring results, ground-water model predictions, and results of seep sampling conducted by others (DOE 1992c; Peterson and Johnson 1992).

Radionuclide concentrations were less than DOE DCGs (see Appendix C), with the exception of ^{90}Sr near the 100-N Area. Tritium, while less than the DCG, was detected at concentrations greater than the EPA DWS in several springs. All other radionuclide concentrations were less than DWSs.

Figure 5.19 provides selected radionuclide concentrations measured in the N Spring monitoring well (199-N-46) during December 1992. Tritium concentrations continued to decline during 1992. Evident in the figure is the significant increase in the concentrations of total beta and ^{90}Sr. The total beta concentration was nearly 2 times greater than what has been reported since 1986. The concentration of ^{90}Sr was also significantly higher (approximately 1.5 times) than what has been measured during the previous 6 years. The sample results were rechecked, and reserve sample aliquots were reanalyzed by the analytical laboratory without identifying any

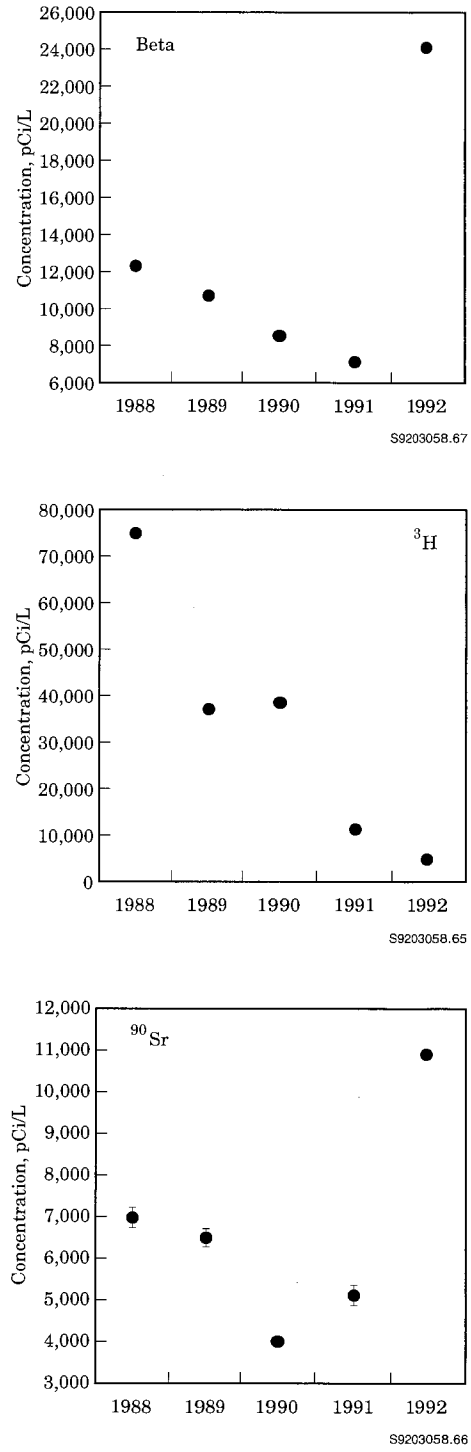

Figure 5.19. Radionuclide Concentrations (±2 SEM) in N Springs, 1988 Through 1992. As a result of figure scale, some uncertainties (error bars) are concealed by point symbol.

discrepancies. Sample results from the December 1992 sample are not consistent with near-facility environmental monitoring results (Section 3.2 and Schmidt et al. 1993). Well 199-N-46 (cassion) replaced well 199-N-8T as the effluent monitoring well to avoid the need for purge water disposal. Well 199-N-46 is not purged before sampling. It is unclear at this printing whether this may influence results obtained from this sample location.

Concentrations of radionuclides of concern in the riverbank springs near the old Hanford townsite for the years 1988 through 1992 are provided in Figure 5.20. The levels of contaminants observed in this seep in recent years have been relatively consistent and comparable to those known to exist in the ground water near the river at this location as a result of past operations. Concentrations of ^{3}H during 1992 were elevated with respect to 1990 and 1991 concentrations; however, it was within the range seen during the past 5 years and similar to local ground-water levels. The concentration of ^{99}Tc during 1992, 116±1 pCi/L, was similar to those reported during past studies and indicative of ground-water concentrations (Dirkes 1990; Woodruff et al. 1992). The ^{129}I concentration, 0.22±0.01 pCi/L, was also similar to nearby ground-water concentrations during 1992.

Figure 5.21 shows the concentrations of constituents of concern in the 300 Area riverbank springs from 1988 through 1992. Notable increases in the total alpha, total beta, ^{3}H, and uranium concentrations during 1992 are apparent. Special arrangements to control the river water level during the 1992 riverbank spring sampling activities at the 300 Area maximized the contribution of ground water in the springs and minimized the bank-storage effect. As expected, the sample results were higher than recent years, indicating the impact of sampling methodology. The contaminant concentrations were similar to those observed in the nearby ground water (see Section 5.8 for results). Tritium is attributable primarily to the expansion of the contaminated ground-water plume emanating from the 200 Areas. This plume has expanded into the 300 Area during recent years (Dirkes 1993). The concentration of uranium in the spring water during 1992 was within the range observed in the ground water beneath the 300 Area (Section 5.8). The elevated alpha and beta concentrations are likely associated with the uranium present in the spring water.

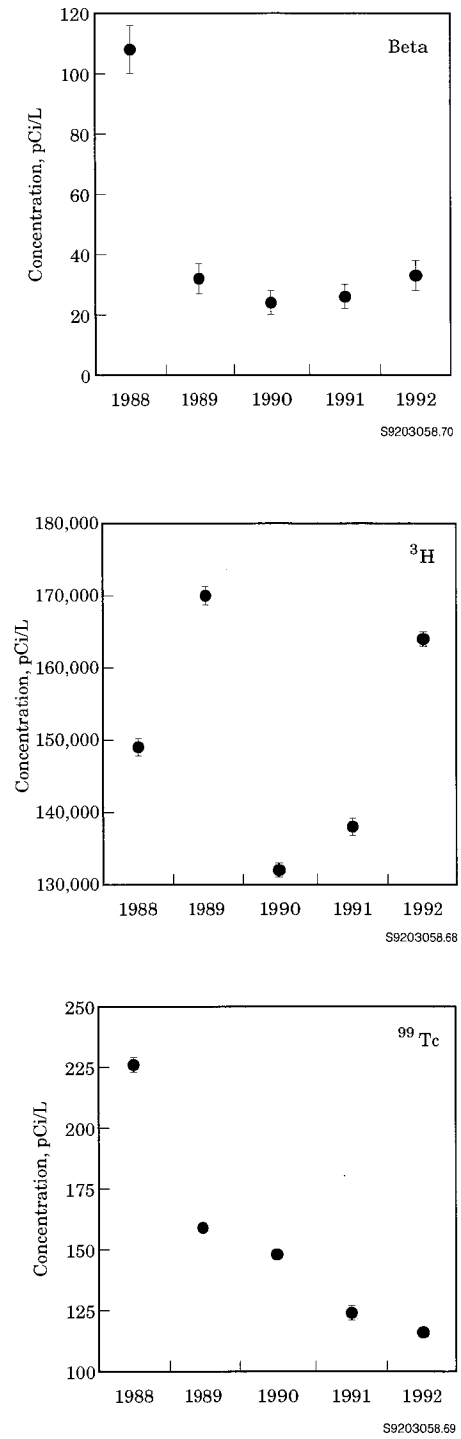

Figure 5.20. Radionuclide Concentrations (±2 SEM) in Riverbank Springs near the Old Hanford Townsite, 1988 Through 1992. As a result of figure scale, some uncertainties (error bars) are concealed by point symbol.

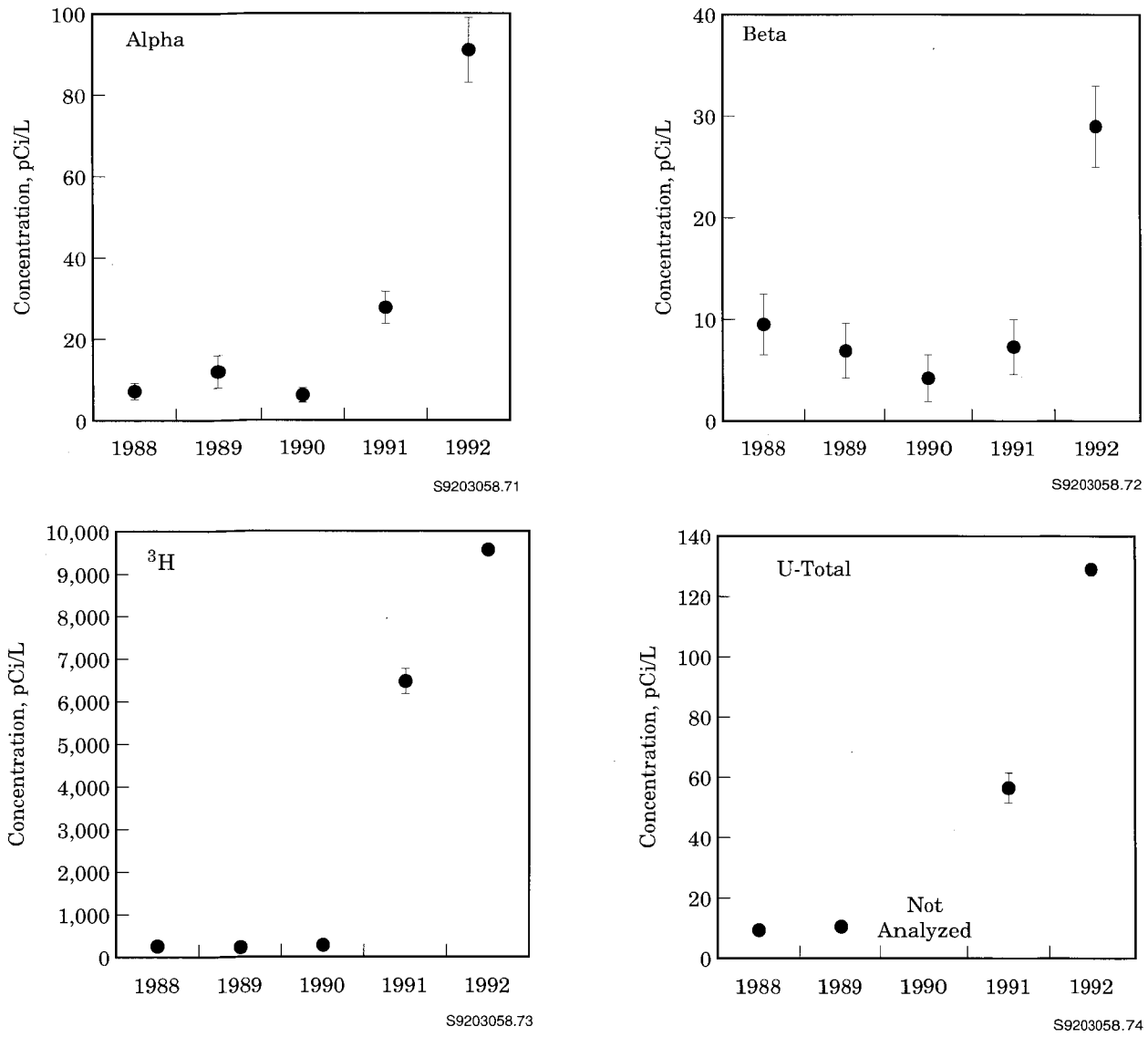

Figure 5.21. Constituents of Concern in 300 Area Riverbank Springs, 1988 to 1992. Concentrations are ±2 SEM. As a result of figure scale, some uncertainties (error bars) are concealed by point symbol.

Onsite Ponds

Three onsite ponds (see Figure 5.8) located near operational areas were sampled periodically during 1992. B Pond, located near the 200-East Area, was excavated in the mid-1950s for disposal of process cooling water and other liquid wastes occasionally containing low levels of radionuclides. West Lake, located north of the 200-East Area, is recharged from ground water (Gephart et al. 1976). West Lake has not received direct effluent discharges from Site facilities. The FFTF Pond, located near the 400 Area, was excavated in 1978 for the disposal of cooling and sanitary water from various facilities in the 400 Area.

Westinghouse Hanford Company is responsible for monitoring effluents discharged to the ponds and for operational surveillance of the ponds (Manley and Diediker 1992). Although the ponds were inaccessible to the public and did not constitute a direct offsite environmental impact during 1992, they were accessible to migratory waterfowl, creating a potential biological

pathway for the dispersion of contaminants (see "Wildlife Surveillance," Section 5.5). Periodic sampling of the ponds also provided an independent check on effluent control and monitoring systems.

Sample Collection and Analysis

During 1992, grab samples were collected quarterly from the FFTF Pond and West Lake. Monthly samples were collected from B Pond. Unfiltered aliquots of all samples were analyzed for total alpha and total beta activities, gamma-emitting radionuclides, and ^{3}H. Samples from B Pond were also analyzed for ^{90}Sr and ^{99}Tc. West Lake samples were analyzed for ^{90}Sr, ^{234}U, ^{235}U, and ^{238}U in addition to those constituents listed above.

Results

Analytical results from pond samples collected during 1992 are listed by Bisping and Woodruff (1993). Maximum, minimum, and average concentration values are provided for various radionuclides in each pond. In all cases, radionuclide concentrations in onsite pond water were less than applicable DCGs. Further discussion of individual constituents and comparisons with results obtained during previous years are provided below.

Annual average radionuclide concentrations in B Pond for the years 1987 through 1992 are shown in Figure 5.22. Total alpha and beta concentrations during the year were within the range observed during the previous 5 years and, as in past years, near the analytical detection limit. Concentrations of ^{90}Sr were comparable to those observed during the previous 5 years. Tritium concentrations in B Pond remained in the range observed during recent years. Cesium-137 concentrations were generally less than the detection level, approximately 1.5 pCi/L, during 1992 and were similar to recent years.

Figure 5.23 shows the annual average total beta and ^{3}H concentrations in FFTF Pond during the years 1987 through 1992. As in the past, total alpha, ^{22}Na, and ^{90}Sr concentrations were less than the detection levels (1.5, 6.0, 0.06 pCi/L, respectively) during the year. Total beta concentrations in FFTF Pond water during 1992 were slightly higher than those reported during 1991, similar to those observed from 1987 through 1990. The concentrations of ^{3}H were comparable to those measured in FFTF Pond in the past. The ^{3}H concentrations observed in FFTF Pond are indicative of the levels of ^{3}H known to exist in the ground water beneath the 400 Area, from which the 400 Area obtains its water (Woodruff et al. 1992).

The 1987 through 1992 annual average contaminant concentrations in West Lake are shown in Figure 5.24. Average total alpha and total beta concentrations during 1992 were similar to those observed in the past. Total alpha and total beta concentrations in West Lake, which is recharged from ground water (Gephart et al. 1976), continued to be higher than the alpha and beta levels found in the other onsite ponds. These elevated levels are believed to result from high concentrations of naturally occurring uranium (Poston et al. 1991; Speer et al. 1976). Annual average uranium concentrations were similar to those reported during 1991 and substantiate the elevated total alpha and total beta measurements. Strontium-90 concentrations during 1992 were similar to those observed during the previous 5 years, well within the range observed in the ground water near this pond. West Lake ^{3}H concentrations were similar to those observed during the mid-1980s. Gamma-emitting radionuclides remained less than the analytical detection levels (approximately 1 pCi/L for ^{60}Co and ^{137}Cs).

Offsite Water

Water samples were collected from four water systems directly east of and across the Columbia River from the Hanford Site during 1992. Samples were also collected from an irrigation canal that obtains water from the Columbia River downstream from Hanford. As a result of public concerns about the potential for Hanford-associated contaminants being present in offsite water, sampling was conducted to document the levels of radionuclides in the water used by the public. Consumption of food irrigated with Columbia River water downstream from the Site has been identified as one of the primary pathways contributing to the potential dose to the hypothetical maximally exposed individual (Jaquish and Mitchell 1988).

Sample Collection, Analysis, and Results

Grab samples were collected once from four offsite domestic water supplies during 1992 (see Figure 5.8). Analyses of these samples included total alpha, total

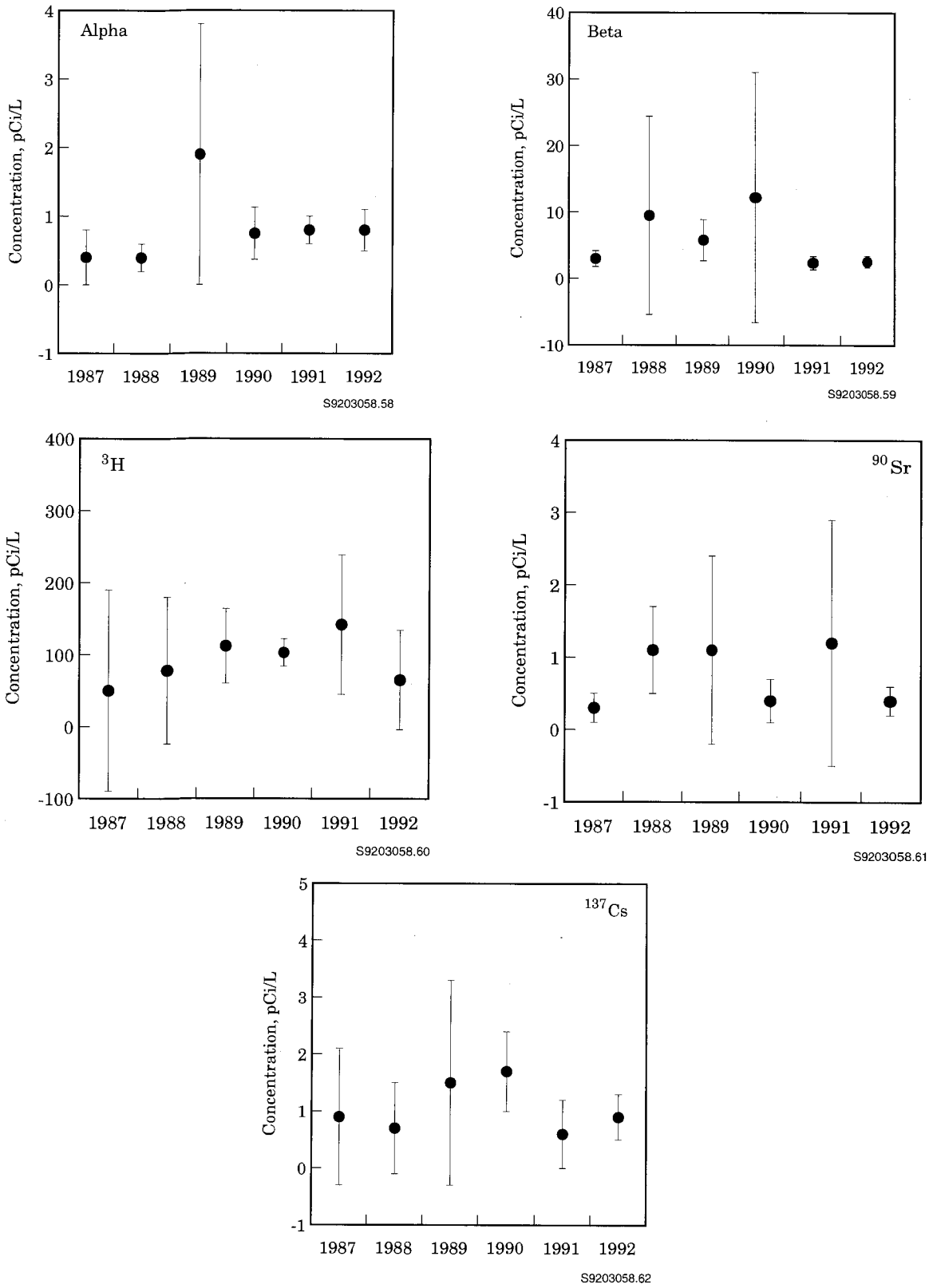

Figure 5.22. Annual Average Radionuclide Concentrations (±2 SEM) in B Pond, 1987 Through 1992

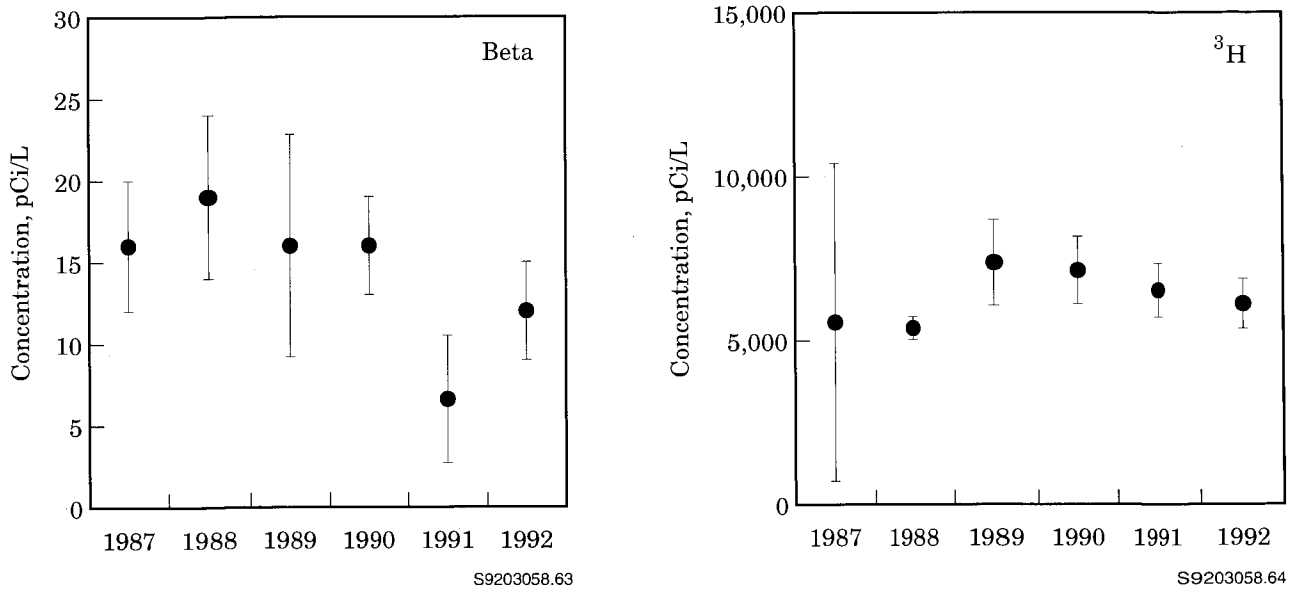

Figure 5.23. Average Total Beta and Tritium (^{3}H) Concentrations (±2 SEM) in FFTF Pond, 1987 Through 1992

beta, gamma scan, ^{3}H, ^{129}I, ^{234}U, ^{235}U, and ^{238}U. Results are presented by Bisping and Woodruff (1993). Alpha and beta concentrations are attributable to natural uranium concentrations in the ground water of this area. The concentrations observed in the offsite water supplies were comparable to those reported by the State of Washington and not attributable to Hanford operations (WDSHS 1987). Iodine-129 concentrations were within the range previously reported in offsite water (Woodruff et al. 1992). Annual average radionuclide concentrations in offsite water during 1992 were within applicable DWSs.

Water in the Riverview irrigation canal was sampled three times in 1992 during the irrigation season. These samples were analyzed for total alpha, total beta, gamma emitters, ^{90}Sr, ^{234}U, ^{235}U, and ^{238}U. Results are presented by Bisping and Woodruff (1993). Radionuclide concentrations were found in the Riverview irrigation water during 1992 at the same levels observed in the Columbia River. Strontium-90 was the radionuclide of most concern because it has been identified as one of the primary contributors to the calculated hypothetical dose to the public via the water pathway (Jaquish and Bryce 1989). The average concentration of ^{90}Sr in the irrigation water during 1992, 0.08±0.004 pCi/L, was similar to that reported for the Columbia River at Priest Rapids Dam and the Richland Pumphouse (see Columbia River Water subsection).

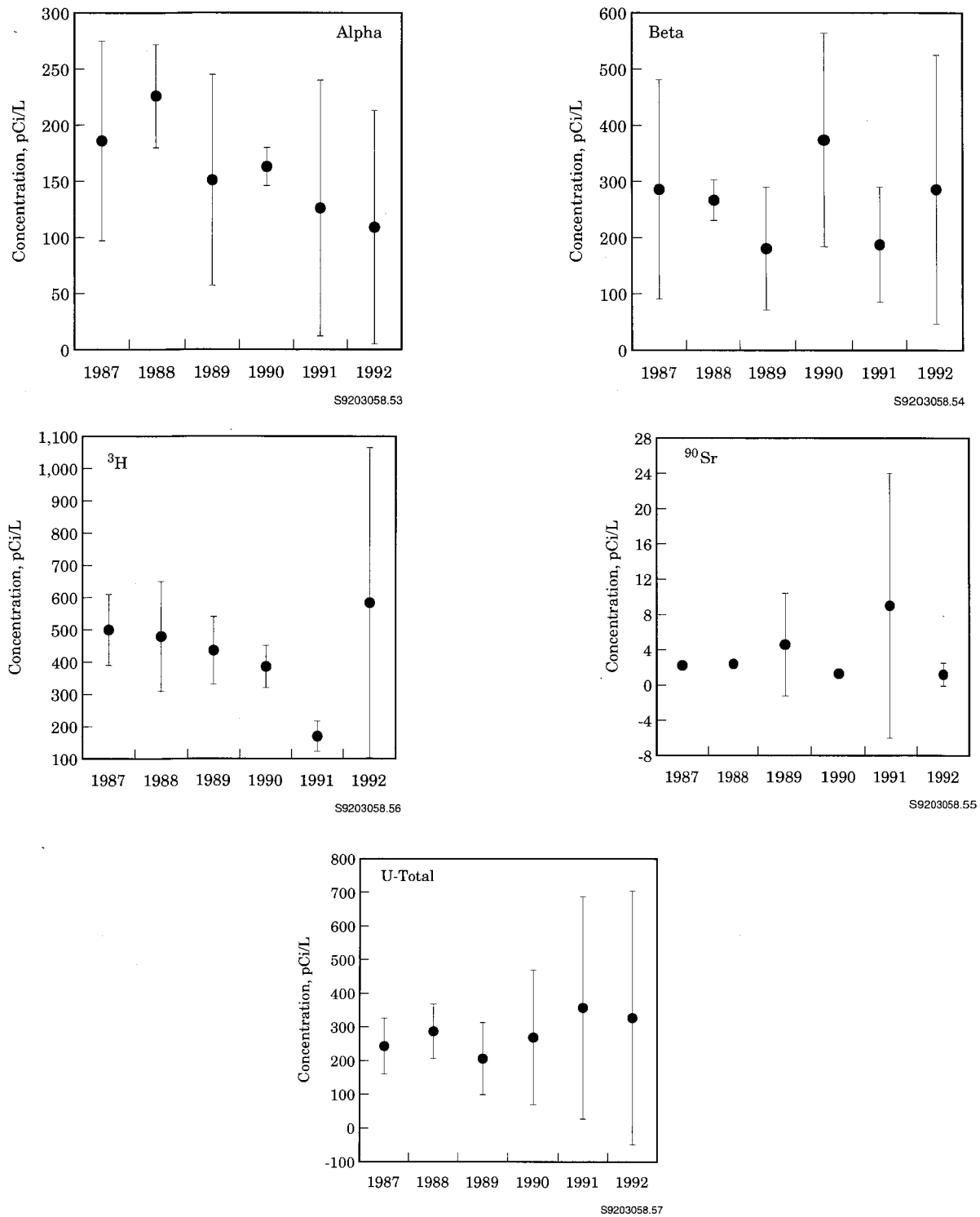

Figure 5.24. Annual Average Radionuclide Concentrations (±2 SEM) in West Lake, 1987 Through 1992. As a result of figure scale, some uncertainties (error bars) are concealed by point symbol.

5.4 Food and Farm Product Surveillance

Alfalfa and a number of foodstuffs, including milk, vegetables, fruits, wine, wheat, beef, chickens, and eggs, were collected at several locations surrounding the Hanford Site (Figure 5.25). Samples were collected primarily from locations in the prevailing downwind directions (south and east of the Site) where airborne effluents from Hanford could be expected to be deposited. Samples were also collected in generally upwind directions somewhat distant from the Site to provide information on background radioactivity. This section describes samples collected, radiological analyses performed, and summary results for 1992. Detailed analytical results are available in Bisping and Woodruff (1993), some of which has been summarized in Appendix A. The potential dose to members of the public from the consumption of local food and farm products is addressed in Section 6.0, "Potential Radiation Doses from 1992 Hanford Operations." Results for liquids are reported in pCi/L of liquid product or distillate from fruits. Plant material results are reported in pCi/g dry weight and animal products in pCi/g wet weight. Many samples had concentrations that were less than detectable.

By comparing several downwind locations to generally upwind or distant locations (Figure 5.25), the sampling approach addresses the potential influence of Hanford Site releases. Specific details of the sampling design including sampling locations and radionuclides analyzed are reported in Bisping (1992) and DOE (1991b) and have been summarized in Table 5.7. Gamma scans (see Appendix F) and ^{90}Sr analyses were routinely performed for nearly all products. Selected farm products were specifically analyzed for additional radionuclides including ^{3}H, ^{99}Tc, ^{129}I, ^{131}I, uranium, and plutonium. Additionally, a special study was conducted to evaluate ^{90}Sr levels in alfalfa.

Milk

Sample Collection and Analysis

Samples of raw, whole milk were collected from East Wahluke and Sagemoor area dairy farms near the Site perimeter in the prevailingly downwind direction to evaluate possible Hanford impacts (Figure 5.25). Milk samples were also collected from a Sunnyside dairy to indicate the general background concentrations of radionuclides. Samples were routinely collected every other week throughout the year from the Sagemoor area and monthly from the other areas.

Tritium analyses were conducted on one sample either monthly or quarterly, ^{90}Sr analyses were conducted quarterly and ^{129}I analyses were conducted on two semi-annual composite samples. Gamma scans of milk were performed on samples from each location at frequencies varying from biweekly to quarterly.

Results

Iodine-129 contributed about 30% of the dose to the maximally exposed individual (MEI) through the consumption of food products (see Section 6.0). Iodine-129 was identified by high-resolution mass spectroscopy in all six milk samples tested. In recent years, the levels of ^{129}I in milk collected from Sagemoor and East Wahluke (downwind locations) have persisted at levels 2 to 4 times greater than levels measured in Sunnyside (Figure 5.26); however, concentrations were low (Table 5.8).

About 11% of the 35 milk samples collected and analyzed for ^{137}Cs in 1992 contained detectable concentrations (>4.00 pCi/L), and no other gamma emitters were consistently detectable (Appendix A, Table A.7). However, 88% of all milk samples analyzed for ^{90}Sr in 1992 contained measurable levels with no apparent differences between upwind and downwind locations (Table 5.8). Both ^{90}Sr and ^{137}Cs are expected to some degree in milk samples because of the presence of these radionuclides in worldwide fallout and movement through the air-pasture-cow-milk food chain. Figure 5.27 shows the 6-year record for ^{90}Sr in milk samples from all sampling areas. Concentrations of ^{90}Sr have remained relatively constant over the past 6 years. Tritium was measured in about 14% of the 22 samples analyzed, with maximum concentrations near a detection limit of 280 pCi/L. There was no apparent difference between results upwind and downwind of the Site (Table 5.8).

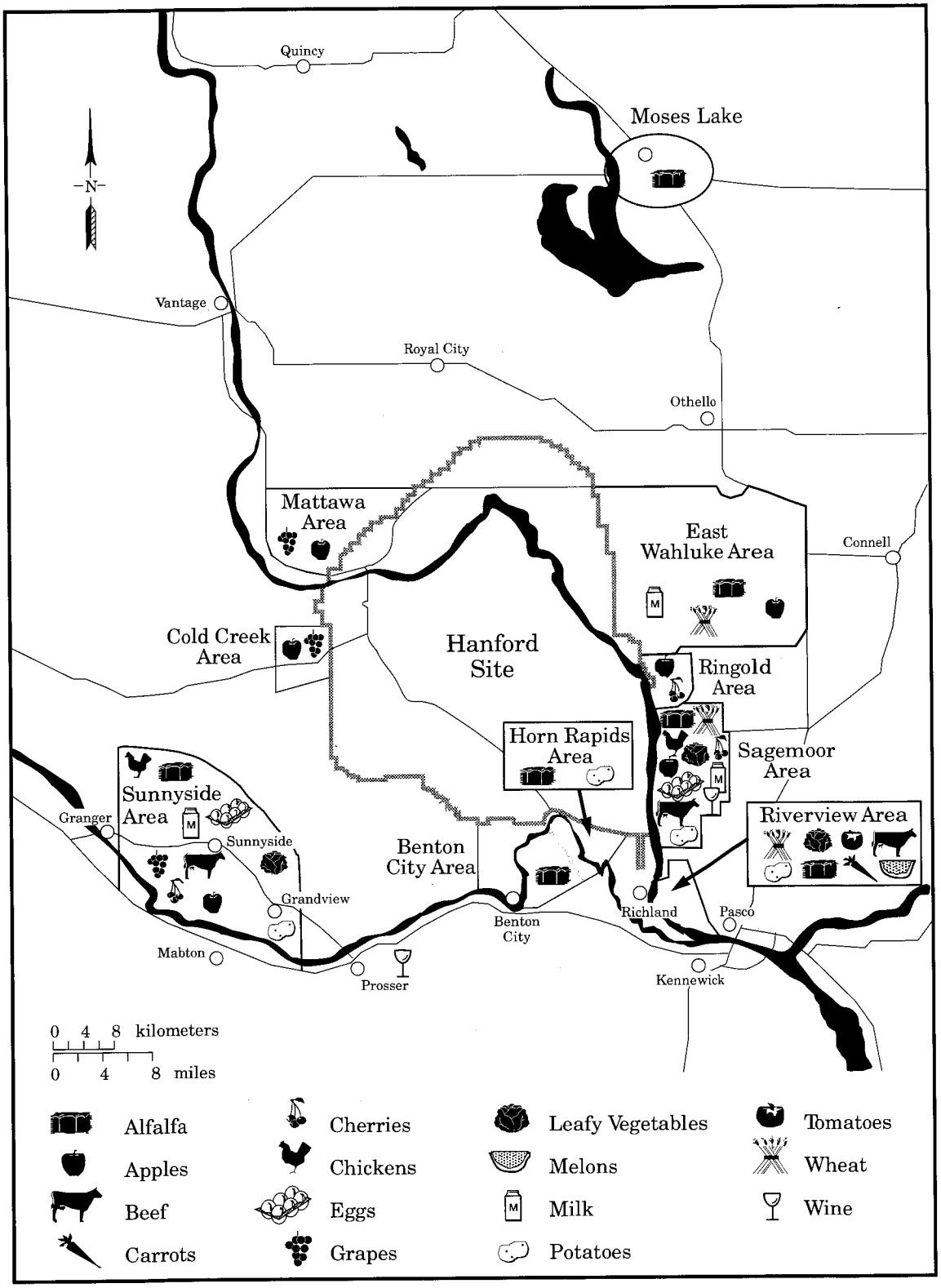

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Figure 5.25. Food and Farm Product Sampling Locations, 1992

Table 5.7. Numbers of Locations, Sampling Frequency, and Analyses Performed for Routinely Sampled Food and Farm Products, 1992[a]

Media	Number of Locations		Sampling	Number of Locations Analyzed						
	Upwind	Downwind	Frequency[b]	^{3}H	Gamma	^{90}Sr	^{99}Tc	$^{129,131}I$[c]	U	Pu
Milk	1	2	B,M,Q, or SA	3	3	3	0	3	0	0
Eggs, meat and poultry	1	2	SA or A	0	3	3	0	0	0	0
Vegetables	1	3	A	0	5	5	4	2	2	2
Fruit	3	4	A	4	4	4	0	2	0	3
Wheat and alfalfa	2	5	A	0	3	3	0	0	0	2
Wine	2	2	A	4	4	0	0	0	0	0

(a) Media may include multiple varieties for each category. Not all analytes were assayed at all locations or for each variety of media.
(b) M = monthly; Q = quarterly; SA = semiannually; A = annually; B = biweekly.
(c) ^{131}I was only measured in milk.

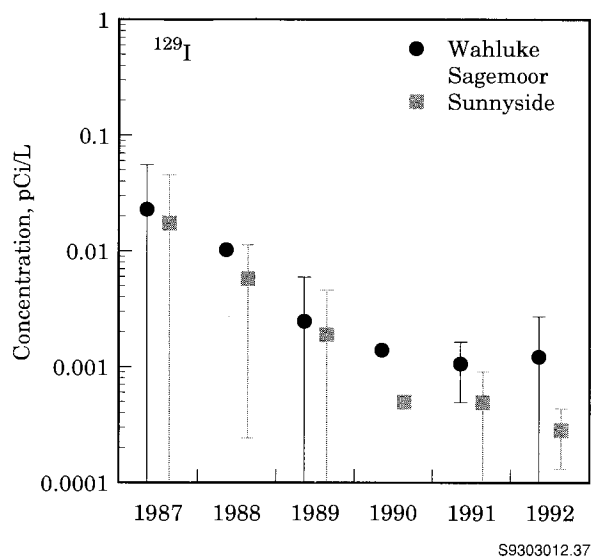

Figure 5.26. Average Iodine-129 (^{129}I) Concentrations (±2 SEM) in Milk, 1987 Through 1992. As a result of figure scale, some uncertainties (error bars) are concealed by point symbol. Uncertainties for some annual averages for Sunnyside samples were less than zero and cannot be shown on a log-scaled figure.

Thirty-four milk samples were collected and analyzed for ^{131}I during 1992. No atmospheric releases of ^{131}I from Hanford were reported for 1992 (see Table 3.1), and ^{131}I was not detected in any milk sample.

Vegetables

Sample Collection and Analysis

Samples of leafy vegetables (cabbage, broccoli leaves, beet tops, or turnip greens), tomatoes, carrots, and potatoes were obtained during the summer from gardens and farms located within the sampling areas (see Figure 5.25). Leafy vegetables are sampled because of the potential deposition of airborne contaminants. At some locations they may also receive deposition from overhead irrigation. Three replicate samples of each vegetable were collected at each sampling location. If analysis of one of the replicates showed detectable levels of radionuclides, the remaining two replicates were also analyzed. All vegetable samples were analyzed for ^{90}Sr and gamma-emitting radionuclides; in addition, potatoes from selected locations were analyzed for $^{239,240}Pu$ and uranium isotopes. Samples were collected from the

Table 5.8. Radionuclide Concentrations in Milk, 1992 Compared to Values from the Previous 5 Years (pCi/L)

Location		1992[a] Maximum[b]	Mean[c]	No. Less Than Detection[d]
^{3}H				
Downwind	Wahluke Area	210 ± 100%	91 ± 120%	3 of 4
	Sagemoor	300 ± 80%	200 ± 20%	7 of 14
Upwind	Sunnyside	170 ± 120%	60 ± 190%	4 of 4
^{90}Sr				
Downwind	Wahluke Area	0.62 ± 60%	0.52 ± 20%	2 of 4
	Sagemoor	0.53 ± 70%	0.39 ± 50%	1 of 4
Upwind	Sunnyside	0.62 ± 80%	0.54 ± 20%	1 of 4
^{129}I				
Downwind	Wahluke Area	0.0019 ± 9%	0.0012 ± 120%	0 of 2
	Sagemoor	0.0015 ± 9%	0.0012 ± 50%	0 of 2
Upwind	Sunnyside	0.00035 ± 9%	0.00028 ± 50%	0 of 2

Location		1987-1991[a] Maximum[b]	Mean[c]	No. Less Than Detection[d]
^{3}H				
Downwind	Wahluke Area	300 ± 70%	80 ± 30%	50 of 55
	Sagemoor	330 ± 70%	100 ± 20%	57 of 63
Upwind	Sunnyside	310 ± 70%	60 ± 50%	53 of 55
^{90}Sr				
Downwind	Wahluke Area	1.8 ± 60%	0.80 ± 20%	2 of 20
	Sagemoor	1.3 ± 50%	0.80 ± 20%	0 of 20
Upwind	Sunnyside	3.2 ± 60%	0.73 ± 40%	3 of 20
^{129}I				
Downwind	Wahluke Area	0.038 ± 10%	0.0081 ± 100%	0 of 9
	Sagemoor	0.017 ± 10%	0.0081 ± 50%	0 of 9
Upwind	Sunnyside	0.031 ± 10%	0.0056 ± 120%	0 of 9

(a) Results have shown a decreasing trend over the period of 1987 to 1992.
(b) Maximum ±2 sigma analytical propagated error, expressed as a percentage.
(c) Mean ±2 standard error of the calculated mean, expressed as a percentage.
(d) Number of samples less than detection out of number of samples analyzed. Means are based on all samples collected.

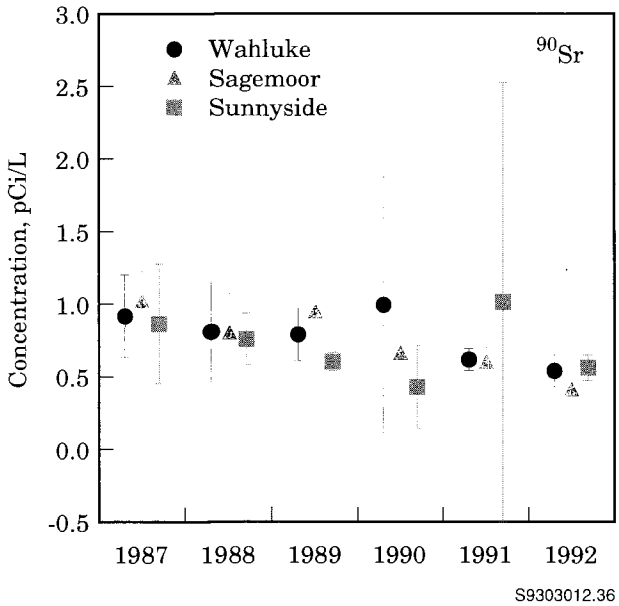

Figure 5.27. Strontium-90 (^{90}Sr) Concentrations (±2 SEM) in Milk, 1987 Through 1992. As a result of figure scale, some uncertainties (error bars) are concealed by point symbol.

Riverview and Horn Rapids areas to assess potential contamination from the irrigation of crops at those locations. Irrigation water for Horn Rapids and Riverview is withdrawn from the Columbia River downstream from Hanford.

Results

Strontium-90 was identified in most leafy vegetable samples but with no apparent difference between distant and nearby locations, indicating that Hanford was not a significant source (Appendix A, Table A.8). The concentrations were variable and near detection (~0.005 pCi/g) in 1992 and similar to those in previous years (Figure 5.28). Cesium-137 was found in leafy vegetables collected from Sagemoor (0.013±0.007 pCi/g), and no other gamma emitters were consistently detectable.

Potatoes from the Horn Rapids and Sunnyside areas had two detectable radiation measurements in 1992: 0.005±80% pCi ^{137}Cs/g from Sunnyside and 0.007±60% pCi ^{90}Sr/g from Horn Rapids. No other gamma emitters, ^{99}Tc, or isotopes of plutonium or uranium were detected in potatoes. Carrots from Riverview had an average concentration of 0.007±90% pCi ^{90}Sr/g (Appendix A, Table A.9).

Leafy vegetables from Sunnyside and Sagemoor had measurable quantities of ^{90}Sr (Appendix A, Table A.9); however, there were no apparent differences between upwind and downwind locations (Figure 5.28).

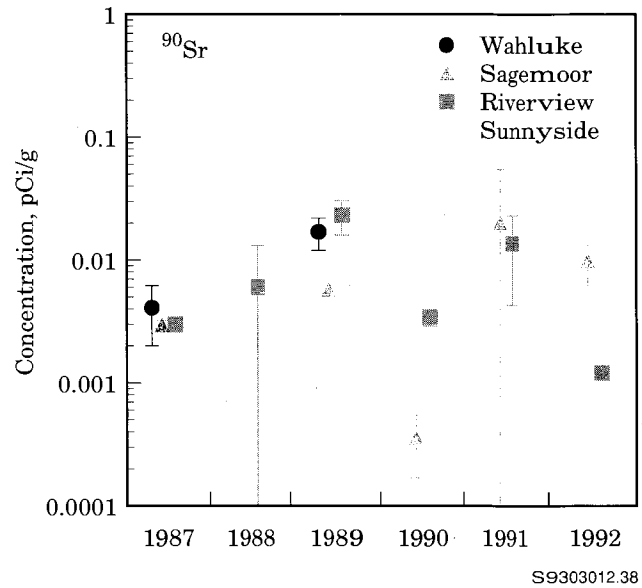

Figure 5.28. Annual Average Strontium-90 (^{90}Sr) Concentrations (±2 SEM) in Leafy Vegetables, 1987 Through 1992. As a result of figure scale, some uncertainties (error bars) are concealed by point symbol.

Fruit

Sample Collection and Analysis

Samples of apples, cherries, grapes, and melons were collected in triplicate during harvest from the areas shown in Figure 5.25 (not all types were collected in each area). The edible portions were analyzed for ^{3}H, ^{90}Sr, gamma emitters and, for selected samples, ^{129}I and $^{239,240}Pu$. Tritium was analyzed in the distillate collected from fruit samples.

Results

Measurable levels of radioactivity were not detected in apples, cherries, concord grapes, or melons collected in 1992 from either upwind or downwind locations. Minimum levels of detection were 300 pCi/L plant

distillate (^{3}H), 0.005 pCi/g dry ^{90}Sr, 1 pCi/g dry ^{129}I, 0.02 pCi/g dry ^{137}Cs, and 0.0006 pCi/g dry $^{239,240}Pu$.

Wine

Sample Collection and Analysis

Locally produced red and white wines (1992 vintage grapes) were analyzed for ^{3}H and gamma-emitting radionuclides. The wines were made from grapes grown at individual vineyards in the Sagemoor Area downwind of the Site and in the Yakima Valley near Prosser upwind of the Site. Three samples of each wine were obtained from each area.

Results

The results for ^{3}H in wine indicate no difference between locations (Table 5.9). The concentrations of ^{3}H were close to the analytical detection limit of 300 pCi/L. The ^{137}Cs results do not indicate an accumulation of this radionuclide in wine (Bisping and Woodruff 1993). Collectively, these results do not indicate an impact of Hanford operations on wine. While there is no ^{3}H standard for wine; the standard for drinking water is 20,000 pCi/L.

Wheat and Alfalfa

Sample Collection and Analysis

Samples of ripened wheat and mature alfalfa were collected from the areas shown in Figure 5.25. Three replicate samples of wheat and alfalfa were collected at each location and analyzed for ^{90}Sr and gamma emitters. Wheat from the Sagemoor area was also analyzed for $^{239,240}Pu$. A special study was conducted in 1992 to examine ^{90}Sr in alfalfa.

Table 5.9. Tritium (^{3}H) Concentrations in Wine, 1992 Compared to Values from the Previous 5 Years (pCi/L)

		1992		
Type of Wine	Location	Maximum[a]	Mean[b]	No. Less Than Detection[c]
White Wine	Columbia Basin	570 ± 40%	380 ± 30%	1 of 6
	Yakima Valley	550 ± 40%	350 ± 30%	0 of 6
Red Wine	Columbia Basin	790 ± 30%	410 ± 40%	0 of 6
	Yakima Valley	650 ± 40%	460 ± 50%	1 of 6
		1987-1991		
	Location	Maximum[a]	Mean[b]	No. Less Than Detection[c]
White Wine	Columbia Basin	930 ± 30%	370 ± 40%	4 of 12
	Yakima Valley	820 ± 40%	260 ± 50%	9 of 14
Red Wine	Columbia Basin	600 ± 50%	320 ± 30%	2 of 11
	Yakima Valley	500 ± 40%	240 ± 50%	4 of 9

(a) Maximum ± analytical propagated error, expressed as a percentage.
(b) Mean ±2 standard error of the calculated mean, expressed as a percentage.
(c) Number of samples less than detection out of number of samples analyzed.

Results

Gamma emitters, ^{238}Pu, and $^{239,240}Pu$ were not detected (<0.0006 pCi/g) in any wheat samples. There was one positive ^{137}Cs measurement (in 18 samples) in Sagemoor alfalfa (0.02±80% pCi/g). Strontium-90 levels in alfalfa continued to show a slight difference between alfalfa irrigated with Columbia River water withdrawn downstream from Hanford relative to other locations (Riverview and Horn Rapids). Sunnyside and Benton City use water from the Yakima River, and Moses Lake, Wahluke, North Riverview, and Sagemoor use irrigation water originating in Lake Roosevelt behind Grand Coulee Dam. The concentrations of ^{90}Sr in alfalfa from Benton City samples in 1992 were greater than levels reported at Riverview, but less than concentrations at Horn Rapids (Table 5.10). All other locations routinely sampled in 1992 had concentrations of ^{90}Sr lower than Riverview and Horn Rapids. Analysis of the data based on whether the alfalfa was irrigated with Columbia River water withdrawn downstream from the Hanford Site compared to other irrigation sources indicated that the Columbia River water irrigated samples had significantly elevated levels of ^{90}Sr (as has been observed since 1988, see Figure 5.29 and Appendix A, Table A.10). Analysis of Columbia River water at Priest Rapids Dam and the Richland Pumphouse, however, indicated no measurable difference between ^{90}Sr concentrations in the water. While the differences in ^{90}Sr in alfalfa at these locations appears significant, the actual concentrations at all locations are low and do not present a significant hazard to humans or livestock.

Table 5.10. Strontium-90 (^{90}Sr) in Alfalfa Samples, 1992

Location	Concentration[a]	No. of Samples	Irrigation Water Source
Benton City	0.12 ± 0.07	3	Yakima River
Horn Rapids	0.20 ± 0.06	2	Columbia River
Moses Lake	0.05 ± 0.002	3	Roosevelt Lake[b]
North Riverview	0.03 ± 0.03	3	Roosevelt Lake[b]
Riverview	0.11 ± 0.02	3	Columbia River
Sagemoor	0.06 ± 0.02	6	Roosevelt Lake[b]
Sunnyside	0.07 ± 0.06	3	Yakima River
Wahluke	0.05 ± 0.04	3	Roosevelt Lake[b]

(a) Concentrations are mean ±2 SEM.
(b) Columbia Basin Irrigation Project water.

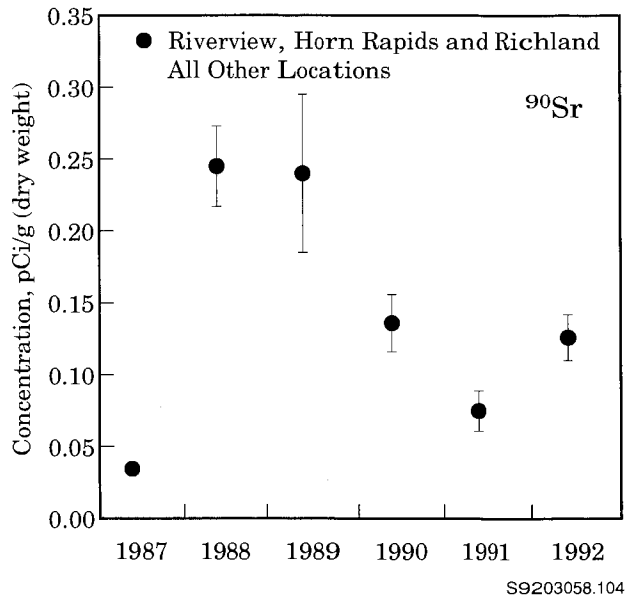

Figure 5.29. Strontium-90 (^{90}Sr) Concentrations in (±2 SEM) Alfalfa Routinely Collected at Riverview and Richland (irrigated with Columbia River water) and All Other Sampling Locations, 1987 Through 1992. As a result of figure scale, some uncertainties (error bars) are concealed by point symbol.

Beef, Chickens, and Eggs

Sample Collection and Analysis

Samples of locally produced beef, poultry, and eggs are collected twice annually from the areas adjacent to the Hanford Site (Figure 5.25).

Results

Beef collected from Riverview and Sunnyside had measurable concentrations of ^{137}Cs, 0.005±80% and 0.008±60% pCi/g, respectively. No measurable concentrations of any radionuclide were found in chicken or egg samples. Similarly, ^{90}Sr concentrations were less than detection (0.005 pCi/g) in all three products. There was no apparent effect from Hanford operations on radionuclide levels in beef, poultry, or eggs.

5.5 Wildlife Surveillance

A number of fish and wildlife species inhabit the Columbia River and Hanford Site. Wildlife have access to several areas that contain some radioactive contamination, and fish can be exposed to contamination in spring water entering the river along the shoreline. It is important, therefore, to monitor fish and wildlife. Fish and some wildlife species exposed to Hanford effluents may be harvested, and potentially contribute to the dose to people. Detection of radioactivity in fish and wildlife may indicate that wildlife are entering restricted areas or that radioactivity is migrating out of restricted areas. Consequently, many of the collection sites are located adjacent to restricted areas (Figure 5.30). Samples are collected once annually during the hunting or fishing season for selected species.

When radioactivity is found in fish or wildlife, it is important to estimate what part of that radioactivity originated at Hanford. A number of background samples of fish and wildlife have been collected from distant locations and analyzed in 1992. Radionuclide concentrations in all background samples for each species routinely sampled onsite are reported below.

Strontium-90 and ^{137}Cs have been the most importantand frequently reported radionuclides in fish and wildlife. However, a much larger number of radionuclides (see Appendix F) are analyzed, but are not reported unless detected. Cesium is particularly important because it is chemically similar to potassium and accumulates in the muscle tissue of fish and wildlife. Strontium is chemically similar to calcium; consequently, it accumulates in hard tissues high in calcium like bone, antlers, and egg shells. Plutonium was monitored in liver because it accumulates in that organ and is therefore a sensitive indicator of exposure. A listing of the media sampled, number of sampling locations, and radionuclides analyzed is shown in Table 5.11. The locations of wildlife sample collections are indicated in Figure 5.30. Concentrations of radioactivity in fish and wildlife are reported in units of pCi/g wet weight ± the analytical propagated error expressed as a percent. Average concentrations are expressed in pCi/g wet weight ±2 SEM. Additional data covering 1987 to 1992 may be found in Appendix A. None of the radionuclides measured in fish would result in a significant dose if consumed by humans. This is reflected in the dose estimates (Section 6.0) for the MEI, which indicates that consumption of Columbia River fish contributed only 9% of the 0.02-mrem MEI dose, with the primary contributors being ^{90}Sr and ^{137}Cs.

Fish

Bass, carp, and whitefish were collected from the Hanford Reach in 1992. In general, radionuclides were not consistently detected in fish flesh. Results for radionuclides known to enter the Columbia River are discussed below. The 1992 results were compared to background samples collected in 1990 and 1991 from areas distant from Hanford Site. Results from all 1992 samples are listed by Bisping and Woodruff (1993).

Bass

Sample Collection and Analysis

Bass were collected from near the 100-F Slough because it is downstream of N Springs and is a natural place where bass congregate in the spring for breeding. Five bass were collected in May 1992 from the 100-F Slough. Fillets were analyzed for gamma-emitting radionuclides and ^{90}Sr. Carcasses were analyzed for ^{90}Sr only. Background samples of bass were collected from a pond near Sunnyside, Washington, and analyzed in 1991.

Results

One of five bass samples collected at the 100-F Slough contained 0.05 (± 60%) pCi ^{137}Cs/g muscle (Table 5.12). Neither ^{60}Co (< 0.004 pCi/g) nor ^{90}Sr (< 0.002 pCi/g) was detected in 100-F Slough bass muscle. Bass carcasses contained 0.022 (± 40%) pCi ^{90}Sr/g. This mean concentration exceeded the mean concentrations reported in background bass samples collected in 1991 from a Sunnyside pond of 0.007 (± 50%) pCi/g.

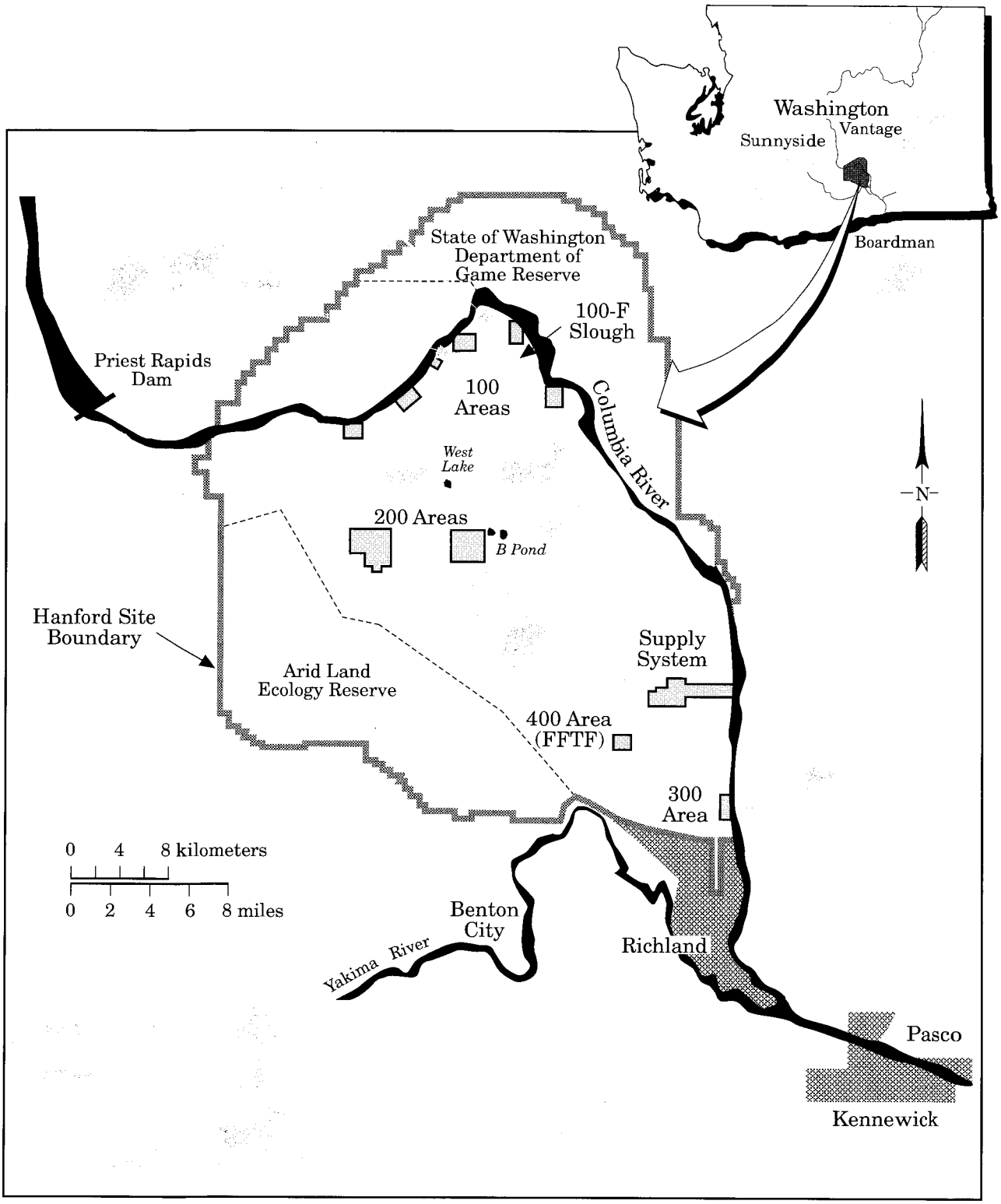

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Figure 5.30. Fish and Wildlife Sampling Locations, 1992

Table 5.11. Locations, Species, and Radionuclides Sampled for Fish and Wildlife, 1992

Media	Number of Species	Onsite Locations	Number of Locations				
			Gamma	^{90}Sr[a]	^{99}Tc	U	Pu[b]
Fish	3	1 to 3	3	3	1	1	0
Ducks	1[c]	3	2	3	1	0	0
Upland gamebirds	1[d]	1	1	0	0	0	0
Mule deer	1	3	3	2	0	0	3
Jack rabbits and cottontails	2	3	3	3	0	0	3

(a) Analyzed in bone and some muscle samples.
(b) Analyzed in liver only.
(c) Usually mallards; a teal was sampled at West Lake in 1992.
(d) Usually pheasants.

Table 5.12. Summary of Cesium-137 (^{137}Cs) in Bass Muscle and Strontium-90 (^{90}Sr) in Bass Carcass (pCi/g wet), 1992 Compared to Values from the Previous 5 Years

Location	1992			1987-1991		
	Maximum[a]	Mean[b]	No. Less Than Detection[c]	Maximum[a]	Mean[b]	No. Less Than Detection[c]
^{137}Cs in Muscle						
100-F Slough	0.05 ± 60%	0.02 ± 110%	4 of 5	0.09 ± 50%	0.04 ± 30%	5 of 20
Sunnyside[d]				0.08 ± 90%	0.01 ± 160%	19 of 20
^{90}Sr in Carcass						
100-F Slough	0.030 ± 30%	0.022 ± 40%	0 of 5	0.066 ± 50%	0.040 ± 20%	0 of 20
Sunnyside[d]				0.032 ± 30%	0.007 ± 50%	2 of 20

(a) Maximum is the concentration in pCi/g ±2 sigma analytical propagated error as a percentage.
(b) Mean is pCi/g ±2 standard error as a percentage.
(c) Number of samples less than detection out of number of samples analyzed.
(d) Collected in 1991.

Carp

Sample Collection and Analysis

Carp are collected from the 100-N Area because of the proximity of the N Springs and the release of ^{90}Sr to the river. Carp are also collected near the 300 Area because of the potential contribution of uranium and the potential releases of ^{90}Sr and gamma-emitting radionuclides from ground-water seeps along the river shoreline at the 300 Area and upstream. Carp have been sampled in the past when inadvertently collected; however, they were added to the routine schedule in 1990 because of potential consumption by specific ethnic groups in the area. Background samples of carp were collected from the Columbia River near Vantage, Washington, in 1990 and 1991.

Results

A single carp was collected at the 100-N Area; the muscle contained 0.01 (± 90%) pCi ^{137}Cs/g (see Appendix A, Table A.11) and 0.01 (± 60%) pCi ^{60}Co/g. The carcass contained 0.011 (± 70%) pCi ^{90}Sr/g; however, ^{90}Sr was not detected in muscle (<0.005 pCi/g). Near the 300 Area, two of five carp collected had measurable levels of ^{137}Cs in muscle [maximum 0.02 (± 100%) pCi/g]. In comparison, 6 of 13 carp collected in 1990 and 1991 at Vantage had measurable concentrations of ^{137}Cs, with a maximum concentration of 0.01 (± 60%) pCi/g.

Uranium was not found in carp muscle samples (<0.02 pCi/g) collected from the 300 Area. Strontium-90 was detected in all carp carcasses collected from the 300 Area [0.025 (± 50%) pCi/g]. Background carp carcass samples collected from Vantage in 1990 and 1991 contained greater levels of ^{90}Sr than the carp sampled from the 300 Area over the past 2 years. The range of concentrations measured using Vantage samples are indicators of background concentrations, while the concentrations from samples from the 100-N Area indicate exposure to elevated ^{90}Sr in the river.

Whitefish

Sample Collection and Analysis

Whitefish were collected because historically they have been the sportfish that accumulated the highest levels of radioactivity. Whitefish are currently collected from the 100-N Area and the 300 Area. Whitefish muscle was analyzed for gamma-emitting radionuclides, ^{90}Sr, uranium isotopes, and ^{99}Tc.

Results

Six of nine whitefish collected near the 100-N Area had measurable levels of ^{137}Cs in muscle [the mean concentration was 0.04 (± 70%) ^{137}pCi/g]. Muscle from whitefish collected near the 300 Area had a maximum concentration of 0.03 (± 60%) pCi/g (see Appendix A, Table A.12). Neither ^{60}Co (<0.02 pCi/g), nor ^{238}U (<0.0008 pCi/g) was detected in whitefish muscle. One of ten whitefish muscle samples had measurable levels of ^{99}Tc [1.9 (± .30%) pCi/g].

Average concentrations of ^{90}Sr in whitefish carcasses ranged from 0.013 (± 40%) pCi/g at the 100-N Area to 0.025 (± 50%) pCi/g at the 300 Area. Mean results for background whitefish carcasses collected in 1990 from the Kettle River were 0.035 (± 20%) pCi ^{90}Sr/g. The higher concentrations of ^{90}Sr measured in Kettle River whitefish carcasses may indicate exposure to elevated environmental ^{90}Sr resulting from weapons testing fallout.

Waterfowl

Sample Collection and Analysis

Duck sampling at B Pond was modified in 1992 to segregate the ducks into two distinct populations. Mallard ducks were collected in August to represent resident ducks, and in November to represent a population influenced by northern migrants.

Results

Cesium-137 was detected in all muscle sampled from ducks at B Pond; however, the mean concentration in the August sampling was 0.89 (± 40%) pCi/g compared to 0.18 (± 60%) pCi/g in the November sample (Figure 5.31). The higher concentration of ^{137}Cs in the August duck population reflects the long-term, chronic exposure of the resident waterfowl compared to the transient exposure of the migrants. A single green-wing teal collected from West Lake had measurable levels of ^{137}Cs (0.060 ± 70% pCi/g, Table 5.13) and ^{90}Sr (0.003 ± 90% pCi/g) that were very close to detection. For comparison, ducks

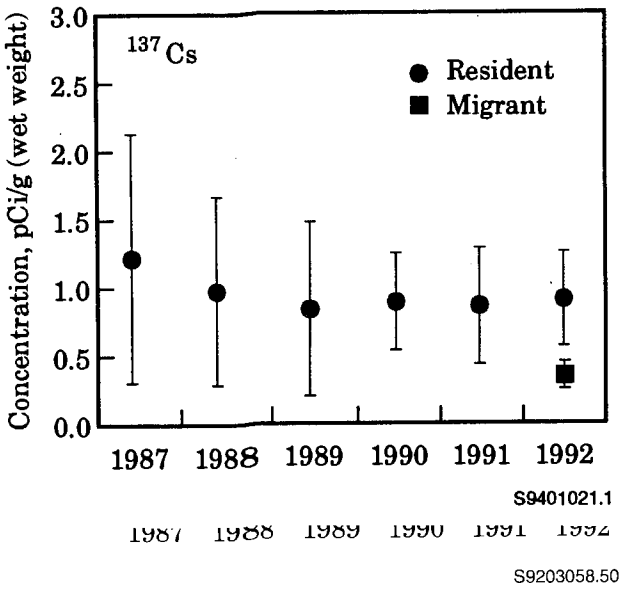

Figure 5.31. Concentrations (±2 SEM) of Cesium-137 (^{137}Cs) in Duck Muscle Samples from B Pond, 1987 Through 1992

collected from Vantage in November of 1990 contained a maximum concentration of 0.03 (±40%) pCi ^{137}Cs/g muscle and 0.41 (± 30%) pCi ^{90}Sr/g bone.

Goose Egg Shells

Sample Collection and Analysis

Because ^{90}Sr behaves similarly to calcium in the environment, goose egg shells have been monitored in the past for ^{90}Sr as an indicator of migration of ^{90}Sr in the environment (Rickard and Price 1990). Goose egg shells collected from several islands in the Hanford Reach near the 100-D to 100-F Areas in 1991 and 1992 were analyzed for ^{90}Sr and compared to 1987 and 1988 data to measure any trends over time.

Results

Concentrations of ^{90}Sr in goose egg shells collected in 1992 (Table 5.14) were significantly lower than samples collected in 1987; however, results were variable and

Table 5.13. Summary of Cesium-137 (^{137}Cs) in Duck Muscle, 1992 Compared to Values from the Previous 5 Years

	1992			1987-1991		
Location	Maximum[a]	Mean[b]	No. Less Than Detection[c]	Maximum[a]	Mean[b]	No. Less Than Detection[c]
B Pond	1.32 ± 10%	0.54 ± 50%	0 of 10	4.1 ± 10%	0.86 ± 30%	11 of 63
100-N Area	---[d]	---	---	0.03 ± 80%	0.008 ± 120%	11 of 12
West Lake	0.06 ± 70%		0 of 1	1.4 ± 10%	0.31 ± 100%	4 of 9
Vantage[e]	---	---	---	0.03 ± 40%	0.004 ± 160%	7 of 9

(a) Maximum is the concentration in pCi/g ±2 sigma analytical propagated error as a percentage.
(b) Mean is pCi/g ±2 standard error as a percentage.
(c) Number of samples less than detection out of number of samples analyzed.
(d) None collected.
(e) Collected in 1990.

Table 5.14. Concentrations of Strontium-90 (^{90}Sr) in Goose Egg Shells, 1987, 1988, 1991, and 1992

Year[a]	Concentration[b]	No. of Samples
1987	1.26 ± 0.22%	15
1988	0.84 ± 0.15%	51
1991	1.01 ± 0.34%	17
1992	0.61 ± 0.27%	11

(a) 1987, 1988, and 1991 results do not differ significantly. 1988, 1991, and 1992 results also do not differ significantly.
(b) Concentrations are means ±2 SEM expressed as a percentage.

there were no other significant differences between collection years. The concentrations of ^{90}Sr in egg shells do not represent a pathway to humans.

Gamebirds

Sample Collection and Analysis

Pheasants were collected from the 100-D to 100-F Areas on the Hanford Site. This population of game birds has the potential to migrate across the river or move on to islands where they may be hunted. Breast muscle was analyzed for gamma-emitting radionuclides.

Results

Breast muscle was analyzed for ^{60}Co and ^{137}Cs. Three of four pheasants collected in 1992 had detectable levels of ^{137}Cs that ranged from 0.02 (± 0.50%) to 0.04 (±40%) pCi/g (Table 5.15). Cobalt-60 was not detected (<0.02 pCi/g) in muscle.

A population of pheasants from Sunnyside was sampled in 1990 and analyzed in 1992 to determine background concentrations of ^{60}Co and ^{137}Cs in muscle samples. Neither ^{60}Co [≤ 0.016 (± 130%) pCi/g] nor ^{137}Cs [≤ 0.007 (± 180%) pCi/g] were measured in the 10 muscle samples submitted for analysis (Table 5.15). Lack of measurable concentrations of radionuclides in pheasant muscle indicate a low potential contribution to human dose from consumption.

Rabbits

Sample Collection and Analysis

Muscle, bone, and liver samples were taken from cottontail rabbits collected at the 100-N Area, and from jackrabbits collected from the 200-East and 200-West Areas. Rabbits cannot be hunted for human consumption on the Hanford Site, and they cannot cross the Columbia River to where they could be hunted. However, rabbits are good indicators of potential exposure to contamination because of their burrowing behavior and ability to enter fenced restricted areas. Background rabbit samples of both species were collected at Boardman, Oregon, in 1990. Muscle, bone, and liver were analyzed in 1992 for gamma-emitting radionuclides, ^{90}Sr, ^{238}Pu, and $^{239,240}Pu$, respectively.

Results

Cesium-137 was measured in muscle from four of eight jackrabbits collected from the 200 Areas (Table 5.16); however, the concentrations were comparable to concentrations found in background samples collected from Boardman, Oregon. Rabbits collected from the 200 Areas had elevated concentrations of ^{90}Sr in bone compared to rabbits from the 100-N Area and Boardman (Table 5.17). Plutonium-238 was not detected in any liver samples collected in 1992; however, $^{239,240}Pu$ was measured in half of the jackrabbit liver samples analyzed in 1992 (see Appendix A, Table A.13). The maximum concentration of 0.0008 (± 60%) pCi/g is consistent with prior measurements. Usually, plutonium isotopes are not detected in rabbit liver tissue; however, more data are needed to verify whether these data indicate a trend.

Deer

Sample Collection and Analysis

Samples were taken from deer that were killed in road accidents or selectively hunted. All deer muscle samples were analyzed for gamma-emitting radionuclides, including ^{60}Co and ^{137}Cs. Background bone samples and samples collected from the 100-N Area were analyzed for ^{90}Sr. Five antler samples collected during a wildlife survey were also analyzed for ^{90}Sr to check for probable environmental exposure to ^{90}Sr. Plutonium-238 and

Table 5.15. Summary of Cesium-137 (^{137}Cs) in Upland Gamebird Muscle (pCi/g wet), 1992 Compared to Values from the Previous 5 Years

	1992			1987-1991		
Location	Maximum[a]	Mean[b]	No. Less Than Detection[c]	Maximum[a]	Mean[b]	No. Less Than Detection[c]
100-D to 100-F Areas	0.04 ± 40%	0.02 ± 60%	1 of 4	0.02 ± 60%	0.007 ± 80%	20 of 31
100-N Area	---[d]	---	---	2.0 ± 2%		1 of 1
Yakima County[e]				0.007 ± 180%	0.001 ± 680%	10 of 10

(a) Maximum is the concentration in pCi/g ± 2 sigma total error as a percentage.
(b) Mean is pCi/g ± 2 standard error as a percentage of all samples analyzed including less-than-detection values.
(c) Number of samples less than detection out of number of samples analyzed.
(d) None collected.
(e) Collected in 1990.

Table 5.16. Summary of Cesium-137 (^{137}Cs) in Rabbit Muscle (pCi/g wet), 1992 Compared to Values from the Previous 5 Years

	1992			1987-1991		
Location/Species	Maximum[a]	Mean[b]	No. Less Than Detection[c]	Maximum[a]	Mean[b]	No. Less Than Detection[c]
200-East Area/ jackrabbit	0.022 ± 50%	0.008 ± 130%	3 of 4	0.25 ± 20%	0.04 ± 90%	7 of 13
200-West Area/ jackrabbit	0.014 ± 70%	0.011 ± 40%	1 of 4	0.15 ± 20%	0.03 ± 110%	7 of 9
100-N Area/ cottontail	0.032 ± 130%	-0.001 ± 2,000%	4 of 4	0.15 ± 30%	0.03 ± 100%	10 of 15
Boardman[d]/						
jackrabbit				0.03 ± 70%	0.005 ± 200%	9 of 10
cottontail				0.03 ± 130%	0.006 ± 150%	10 of 10

(a) Maximum is the concentration in pCi/g ±2 sigma analytical propagated error as a percentage.
(b) Mean is pCi/g ±2 standard error as a percentage.
(c) Number of samples less than detection out of number of samples analyzed.
(d) Collected in 1990.

Table 5.17. Summary of Strontium-90 (^{90}Sr) in Rabbit Bone (pCi/g wet), 1992 Compared to Values from the Previous 5 Years

	1992			1987-1991		
Location/Species	Maximum[a]	Mean[b]	No. Less Than Detection[c]	Maximum[a]	Mean[b]	No. Less Than Detection[c]
200-East Area/ jackrabbit	18.0 ± 1%	7.9 ± 90%	0 of 4	49 ± 20%	11 ± 70%	0 of 13
200-West Area/ jackrabbit	14.8 ± 20%	4.1 ± 170%	0 of 4	140 ± 20%	21 ± 150%	0 of 9
100-N Area/ cottontail	0.41 ± 20%	0.24 ± 40%	0 of 4	460 ± 20%	98 ± 70%	0 of 15
Boardman[d]/						
jackrabbit				0.91 ± 10%	0.47 ± 20%	0 of 10
cottontail				0.36 ± 20%	0.27 ± 10%	0 of 10

(a) Maximum is the concentration in pCi/g ±2 sigma analytical propagated error as a percentage.
(b) Mean is pCi/g ±2 standard error as a percentage.
(c) Number of samples less than detection out of number of samples analyzed.
(d) Collected in 1990.

$^{239,240}Pu$ were analyzed in liver samples from all deer sampled in 1992. While deer hunting is not allowed onsite, deer can leave the Site, and a small number of deer potentially from Hanford are harvested annually from Columbia River islands and Grant, Benton, and Franklin counties. Background deer samples were donated by a hunter who collected them in Stevens County, located about 210 km (131 mi) northeast of the Hanford Site.

Results

Generally, ^{60}Co and other gamma-emitting radionuclides were not detectable in deer muscle; the maximum concentration was 0.01 (± 90%) pCi/g. However, three of nine deer sampled at Hanford had positive measurements of ^{137}Cs (Bisping and Woodruff 1993). These measurements ranged from 0.006 (± 50%) pCi ^{137}Cs/g to 0.017 (± 40%) pCi ^{137}Cs/g. The background deer samples from Stevens County contained 0.33 (± 10%) and 0.52 (± 10%) pCi ^{137}Cs/g. These background deer samples contain about ten times higher concentrations of ^{137}Cs because the Stevens County area historically received more precipitation and thus received more deposition of fallout from atmospheric weapons testing than the arid Hanford Site.

A positive relationship between elevated levels of ^{137}Cs in Hanford workers has been established with the consumption of wild game taken from other areas that received relatively higher levels of fallout (MacLellan et al. 1993). In this study, Hanford workers who had elevated whole-body measurements consumed large amounts of deer or elk meat from animals that had accumulated elevated levels of fallout ^{137}Cs in their natural habitat. The annual effective dose to the hunters was about 2.5 mrem.

In 1992, the three deer sampled from the 100-N Area had measurable amounts of ^{90}Sr in bone (range 1.4 to 20.8 pCi/g) that exceeded the levels measured in background deer (maximum value of 0.81 pCi/g). Concentrations of ^{90}Sr in antlers from Hanford deer ranged from 0.34 (± 30%) to 0.54 (± 10%) pCi/g antler. These concentrations of ^{90}Sr are comparable to levels in deer bone from background samples from Stevens County

(see Appendix A, Table A.14) and rabbit bone samples collected from Boardman, Oregon (Table 5.17). Even though one deer antler was found close to the 100-N Area, the relatively low ^{90}Sr concentrations may indicate that the deer had not been exposed to elevated levels of ^{90}Sr in their habitat. Analysis of antlers is a non-destructive method of monitoring deer populations.

In 1992, no plutonium was detected in any deer liver sample (<0.0005 pCi/g).

5.6 Soil and Vegetation Surveillance

Surface soil samples were collected from nine locations during the summer of 1992, three on and six off the Hanford Site. The offsite samples were collected at four perimeter and two distant locations. Perennial vegetation was collected at seven locations including two distant, one onsite, and four perimeter locations. The purpose of this sampling was to detect any buildup of radionuclides from deposition of airborne effluents released from Hanford facilities, compare current data with previous years data to determine obvious long-term trends, and add to the information concerning radionuclide concentrations for soil and vegetation both on and off the Hanford Site.

Radiological contributions from Hanford operations were assessed by comparing results from samples taken: 1) onsite with those collected offsite and 2) around the Site perimeter with those collected at distant locations. Results in 1992 were also compared to results obtained in previous years.

A special study was completed in 1992 to analyze shoreline vegetation sampled from areas where elevated radionuclide concentrations were found in ground water seeping into the Columbia River.

Sample Collection and Analysis

Soil and vegetation samples were collected at the locations shown in Figure 5.32 and summarized in Table 5.18. Onsite sampling was concentrated around the 100-N Area, where previous studies have documented the existence of elevated concentrations of some radionuclides (Dirkes 1990). Two-thirds of the offsite samples were collected at downwind locations near the Site boundary, where the maximum effects from releases would be expected to be found. The other one-third of the offsite samples were collected at relatively distant and upwind locations, where buildup of Hanford's radioactive emissions should be minimal. These upwind and distant locations were used to establish background radionuclide concentration levels for 1992. The area southeast of the Site is generally considered to be downwind and the area north to northwest of Hanford is considered upwind.

Soil samples were composites of five soil cores 2.54 cm deep by 10 cm diameter (1 in. by 4 in.) taken from the same general location. Perennial vegetation samples consisted of new growth from predominant shrub-steppe species (e.g., rabbitbrush and sagebrush), collected in the same vicinity as the soil samples. Sample aliquots were analyzed for gamma-emitting radionuclides (Appendix F), ^{90}Sr, ^{238}U, and ^{239,240}Pu.

A shoreline vegetation study was started in 1990 by sampling shoreline vegetation in areas reported to have radiological contamination in ground-water seeps. Areas of particular interest included the 100-N Area, the old Hanford townsite, and the 300 Area springs (Dirkes 1990). A contaminated ground-water plume originating in the 200 Areas extends from the old Hanford townsite to the 300 Area (Dirkes 1990; Woodruff et al. 1991; Woodruff et al. 1992). In 1992, additional samples were collected at the same locations and at a background location upstream from the Vernita Bridge.

Results for Soil

Of the soil analyses performed, the only consistently detectable radionuclides were ^{40}K, ^{90}Sr, ^{137}Cs, ^{238}U, and ^{239,240}Pu. Potassium-40 is a naturally occurring radionuclide with a half-life longer than one billion years, and is not of Hanford origin. Strontium-90 and ^{137}Cs are both fission products and have half-lives of 27.7 and 30 yr, respectively (USDHEW 1970); these radionuclides may be of Hanford origin or from global atmospheric fallout. Uranium-238 is a primordial radionuclide having a half-life of 4.51 billion years and is naturally found in soils off the Hanford Site. However, ^{238}U as well as ^{234}U and ^{235}U have been released during past Hanford operations. Plutonium isotopes in soils near the Hanford Site may be from historical Hanford operations or may be the result of global atmospheric fallout.

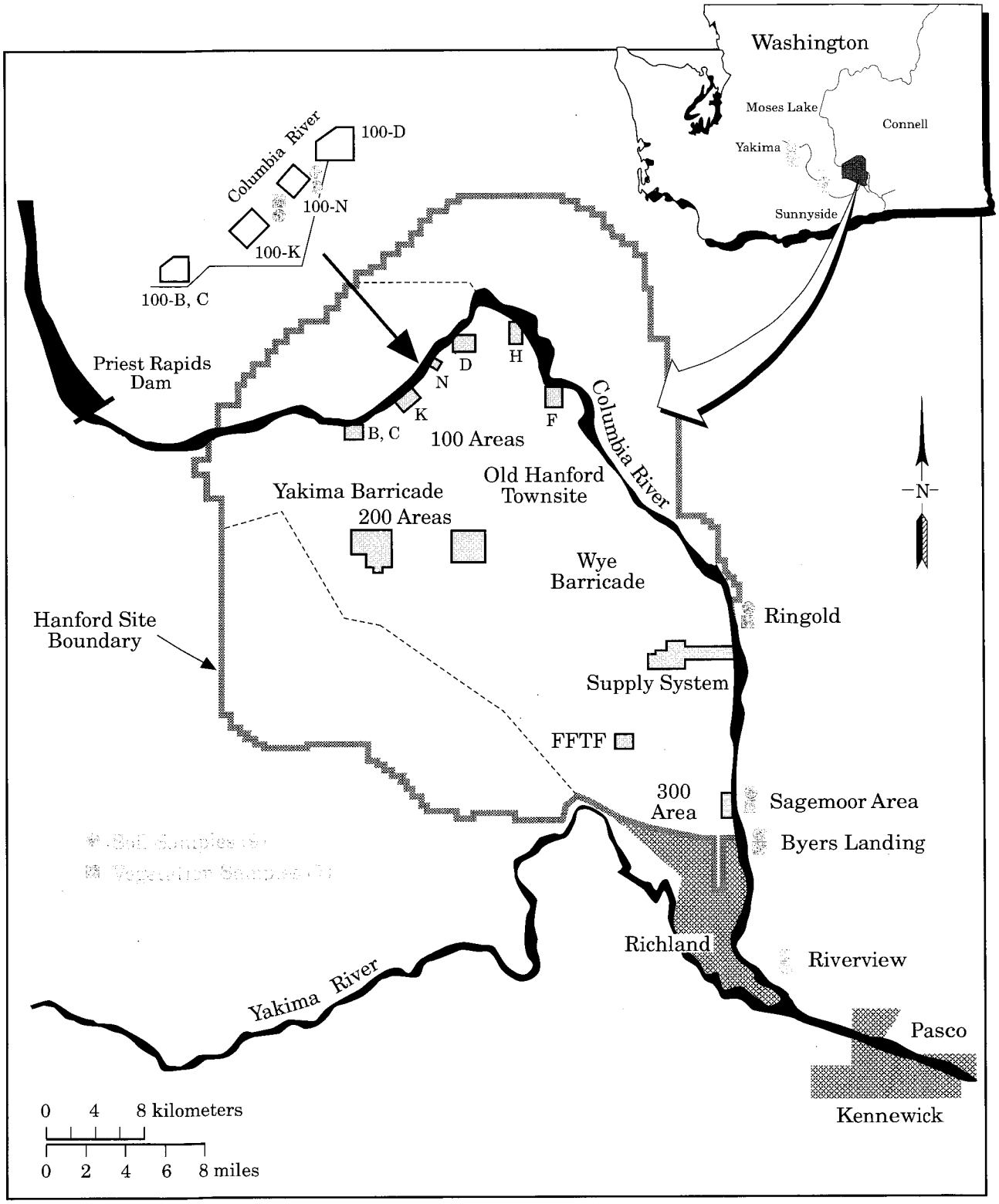

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Figure 5.32. Soil and Vegetation Sampling Locations, 1992

Table 5.18. Soil and Vegetation Samples, 1992

General Location		No. of Samples	Frequency[a]	Analytes
Soil				
Onsite	100-N Area	3	A	^{90}Sr, gamma scan, U, Pu
Offsite[b]	Near	4	A to 3 yr	^{90}Sr, ^{241}Am, gamma scan, U, Pu
	Distant	2	A or 5 yr	^{90}Sr, ^{241}Am, gamma scan, U, Pu
Vegetation				
Onsite	100-N Area	1	A	^{90}Sr, gamma scan, U, Pu
Offsite[b]	Near	4	A to 3 yr	^{90}Sr, gamma scan, U, Pu
	Distant	2	A or 5 yr	^{90}Sr, gamma scan, U, Pu

(a) A = annually.
3 yr = once every 3 years.
5 yr = once every 5 years.
(b) Near = locations at the Site perimeter.
Distant = Yakima and Sunnyside (see Figure 5.32).

Radionuclide concentrations in soil are reported in Table 5.19 and Appendix A, Tables A.15 through A.18, and are shown in Figures 5.33 and 5.34. Nonparametric statistical analyses of the analytical results indicated no significant differences between the distant upwind and the perimeter downwind locations for ^{90}Sr, ^{137}Cs, ^{238}U, and ^{239,240}Pu concentrations (p values were 0.133, 0.467, 0.733, and 0.200, respectively). A p value represents the likelihood that data sets being compared are the same. A p value greater than or equal to 0.1 indicates the data sets are similar, and a p value less than 0.1 indicates they are not similar. Likewise, there were no statistical differences between the onsite and the combined offsite radionuclide concentrations for ^{90}Sr, ^{137}Cs, and ^{239,240}Pu (p values were 0.952, 0.655, and 0.714, respectively). A statistical difference was found when comparing onsite and combined offsite ^{238}U values, p = 0.012, with the onsite data having a higher range of values. This means that the ^{238}U concentrations measured in soil from around the 100-N Area were significantly different (and higher) than concentrations measured in offsite soil samples.

Results for Vegetation

Activity concentrations of the three most consistently detected radionuclides found in vegetation during 1992, ^{7}Be, ^{40}K, and ^{90}Sr, are presented in Table 5.20. Beryllium-7 and ^{40}K are naturally occurring radionuclides and are not of Hanford origin. Strontium-90 is a fission product and may be of Hanford origin or from global fallout. Historically, other radionuclides of interest have been uranium, ^{137}Cs, and ^{239,240}Pu; however, in 1992, these radionuclides were only sporadically detected (Table 5.21). Uranium-238 was only seen in one sample collected at Yakima (5.07±2.57 fCi/g ^{238}U); ^{137}Cs and ^{239,240}Pu were only detected in a sample collected at Sagemoor, a downwind location (13.1±11.5 fCi/g and 27.7±15.8 fCi/g, respectively). A fCi (1 x 10^{-15} Ci) is 2.22 radioactive disintegrations every 1,000 minutes. The remaining samples had errors associated with the analyses such that the 95% confidence interval encompassed zero (i.e., not 95% confident that the true radionuclide concentration was above zero). Table 5.21 summarizes data collected in 1992 and 5-yr averages for ^{90}Sr, ^{137}Cs, ^{238}U, and ^{239,240}Pu.

Table 5.19. Radionuclide Concentrations in Soil Samples Collected on and off the Hanford Site, 1992 Compared to Values from the Previous 5 Years (units are pCi/g dry weight)

		1992			1987-1991		
Location	Radio-nuclide	No. of Samples	Maximum[a]	Mean[b]	No. of Samples	Maximum[c]	Mean[d]
Onsite	^{90}Sr	3	0.24 ± 5%	0.12 ± 103%	60	2.7 ± 3%	0.24 ± 35%
	^{137}Cs	3	1.0 ± 4%	0.73 ± 54%	60	26 ± 1%	1.9 ± 60%
	$^{238}U_{LEPS}$ [e]	3	1.3 ± 30%	1.2 ± 14%	43	3.3 ± 14%	0.77 ± 18%
	$^{239/240}Pu$	3	0.020 ± 9%	0.013 ± 73%	60	0.71 ± 1%	0.063 ± 66%
Perimeter	^{90}Sr	4	0.15 ± 6%	0.11 ± 37%	48	0.40 ± 6%	0.13 ± 18%
	^{137}Cs	4	0.95 ± 8%	0.60 ± 59%	48	1.8 ± 3%	0.58 ± 22%
	$^{238}U_{LEPS}$	3	0.91 ± 25%	0.72 ± 26%	37	1.8 ± 22%	0.76 ± 13%
	$^{239/240}Pu$	4	0.021 ± 8%	0.013 ± 68%	33	0.029 ± 11%	0.0072 ± 34%
						0.033 ± 7%	0.011 ± 21%
Distant	^{90}Sr	2	0.045 ± 11%	0.042 ± 17%	33	0.35 ± 4%	0.10 ± 28%
	^{137}Cs	2	0.45 ± 6%	0.43 ± 6%	33	1.2 ± 5%	0.39 ± 29%
	$^{238}U_{LEPS}$	2	0.84 ± 34%	0.76 ± 22%	24	1.7 ± 5%	0.75 ± 21%
	$^{239/240}Pu$	2	0.0078 ± 14%	0.0077 ± 1%	33	0.029 ± 11%	0.0072 ± 34%

(a) Maximum value ±2 sigma counting error expressed as a percentage of the maximum value.
(b) Mean value ±2 SEM expressed as a percentage of the mean value.
(c) Maximum value in previous 5 years ±2 SEM expressed as a percentage of the maximum value.
(d) Five-year mean value ±2 SEM expressed as a percentage of the mean value.
(e) $^{238}U_{LEPS}$ is a method of analyzing for ^{238}U by detecting low-energy photons.

Based on these results (Figure 5.35) and the associated statistical analyses, no accumulation of radionuclides from deposition of airborne effluents was detected.

Shoreline Vegetation Special Study

Columbia River shoreline vegetation samples were collected in 1990 through 1992. Vegetation from the 100-N Area, the old Hanford townsite, and the 300 Area contained elevated levels of radionuclides. Tritium was elevated above background in all areas (Figure 5.36); ^{60}Co and ^{90}Sr were found in highest concentrations in vegetation from the 100-N Area (Figures 5.37 and 5.38). The concentrations of ^{137}Cs were greater than background in only the 100-N Area (Figure 5.39). Uranium and plutonium were just above background in all three areas (Figures 5.40 and 5.41). The maximum concentrations of ^{60}Co, ^{137}Cs, ^{238}Pu, and $^{239,240}Pu$ were similar to or less than those at the background location; however, there were instances of plutonium in shoreline vegetation that appeared to be slightly elevated above the background location. The committed effective dose equivalent was estimated based on consumption of a kilogram of plants containing the highest concentrations found in the edible portions of vegetation. The highest dose was three orders of magnitude less than the 100-mrem dose limit for the public set by the DOE.

As part of the shoreline vegetation study, samples of milfoil (a submerged aquatic plant) were also collected in 1992 from the Columbia River at the 300 Area, the 100-N Area, and upstream from the Vernita Bridge (upstream from the Site). Results showed higher concentrations of uranium isotopes at the 300 Area. The isotopic ratios of ^{235}U:^{238}U suggest that the source of uranium around the 300 Area is enriched with ^{235}U.

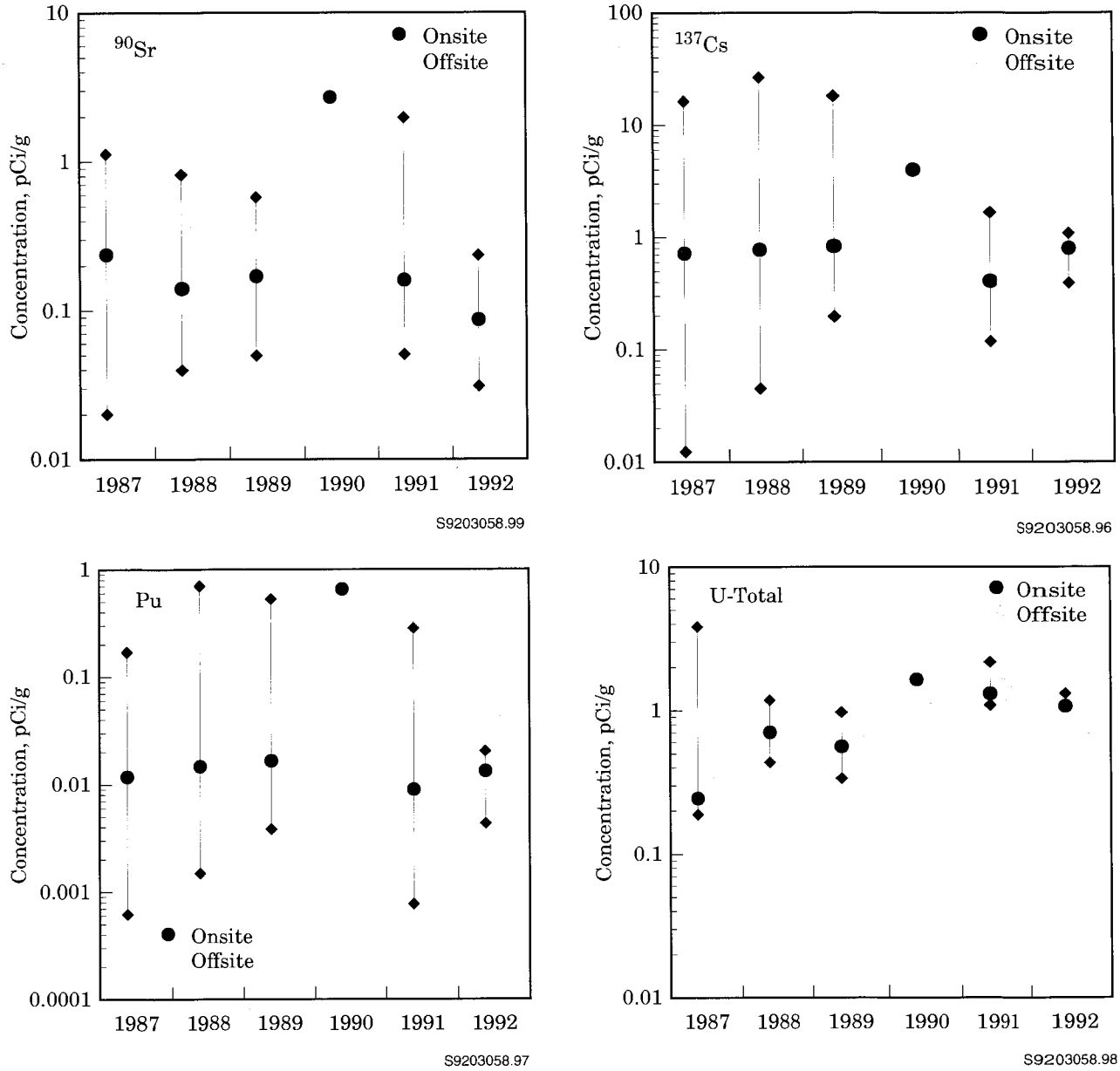

Figure 5.33. Selected Radionuclide Maximum, Median, and Minimum Concentrations in Soil, 1987 Through 1992. Units are pCi/g (dry weight). For the U-total graph, samples from 1987 were analyzed by U_{NAT}; 1988, 1989, and 1992 by U_{LEPS}; onsite 1990 by U_{iso} and offsite by U_{NAT}; and 1991 by U_{iso}.

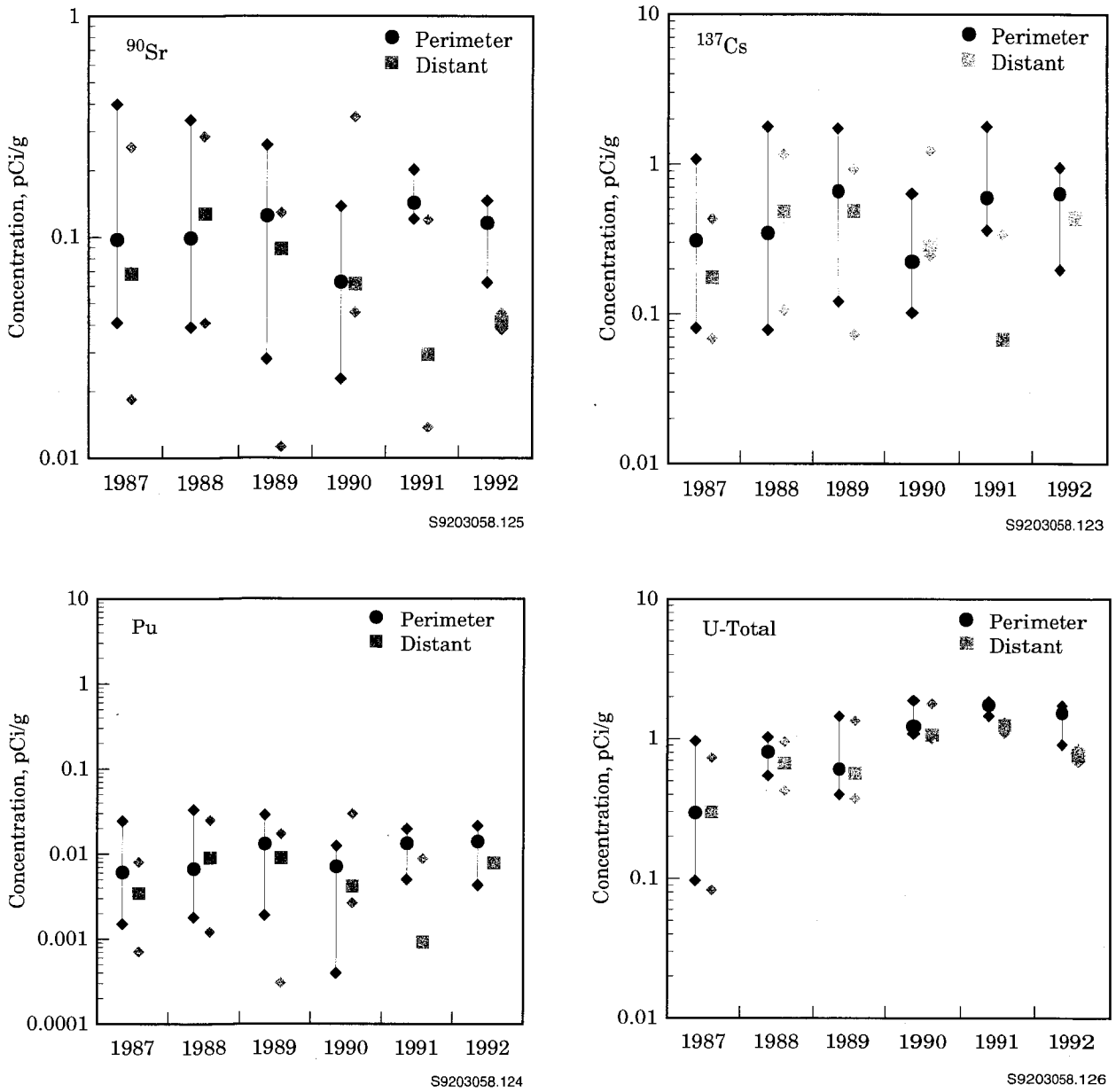

Figure 5.34. Selected Radionuclide Maximum, Median, and Minimum Concentrations in Soil at Perimeter and Distant Locations, 1987 Through 1992. Units are pCi/g (dry weight). As a result of figure scale, some values overlap.

Table 5.20. Concentrations of Three Radionuclides Consistently Found in Vegetation, 1992 (units are pCi/g dry weight)[a]

Sampling Location	^{7}Be	^{40}K	^{90}Sr
N Springs	7.0 ± 0.39	16 ± 0.88	0.015 ± 0.0039
Yakima	1.7 ± 0.32	17 ± 0.99	0.0026 ± 0.0025
Sunnyside	2.9 ± 0.29	13 ± 0.83	0.0144 ± 0.0041
Ringold	2.7 ± 0.27	17 ± 0.78	0.0021 ± 0.0033
Byers Landing	3.8 ± 0.41	19 ± 1.2	0.0028 ± 0.0026
Sagemoor	4.6 ± 0.27	15 ± 0.67	0.015 ± 0.0046
Riverview	4.4 ± 0.31	14 ± 0.68	0.0181 ± 0.0053

(a) Reported are individual results ± 2 sigma counting error.

Table 5.21. Radionuclide Concentrations in Vegetation Samples on and off the Hanford Site, 1992 Compared to Values from the Previous 5 Years (units are pCi/g dry weight)

		1992			1987-1991		
Location	Radio-nuclide	No. of Samples	Maximum[a]	Mean[b]	No. of Samples	Maximum[c]	Mean[d]
Onsite	^{90}Sr	1	0.015 ± 26%	0.015	57	0.41 ± 5%	0.089 ± 24%
	^{137}Cs	1	0.0059 ± 388%	0.0059	57	0.32 ± 8%	0.053 ± 35%
	U_{NAT}[e]	1	-0.0044	-0.0044	56	0.036	0.012 ± 18%
	U-iso[f]	0			1	0.0062 ± 24%	0.0062
	$^{239/240}Pu$	1	0.000064 ± 156%	0.000064	57	0.041 ± 6%	0.0016 ± 95%
Perimeter	^{90}Sr	4	0.018 ± 29%	0.0095 ± 87%	53	0.36 ± 4%	0.059 ± 28%
	^{137}Cs	4	0.013 ± 88%	-0.0006 ± 1730%	53	0.11 ± 24%	0.018 ± 32%
	U_{NAT}	4	<0.0049	-0.0029 ± 221%	53	0.06	0.018 ± 19%
	$^{239/240}Pu$	4	0.00028 ± 57%	0.00013 ± 78%	53	0.00075 ± 42%	0.00019 ± 22%
Distant	^{90}Sr	2	0.014 ± 28%	0.0085 ± 139%	26	0.74 ± 3%	0.064 ± 85%
	^{137}Cs	2	0.0051 ± 364%	-0.0013 ± 962%	26	0.079 ± 29%	0.017 ± 40%
	U_{NAT}	1	-0.0017	0.0017	24	0.47	0.05 ± 81%
	U-iso	1	0.0077 ± 47%	0.0077	2	0.15 ± 8%	0.079 ± 188%
	$^{239/240}Pu$	2	0.00010 ± 111%	0.000103 ± 3%	26	0.0013 ± 28%	0.00029 ± 43%

(a) Maximum value ±2 sigma counting error expressed as a percentage of the maximum value.
(b) Mean value ±2 SEM expressed as a percentage of the mean value.
(c) Maximum value in previous 5 years ±2 standard deviations expressed as a percentage of the maximum value.
(d) Five-year mean value ±2 SEM expressed as a percentage of the mean.
(e) U_{NAT} is a chemical analysis and does not have counting error.
(f) U-iso is a sum of isotopic results.

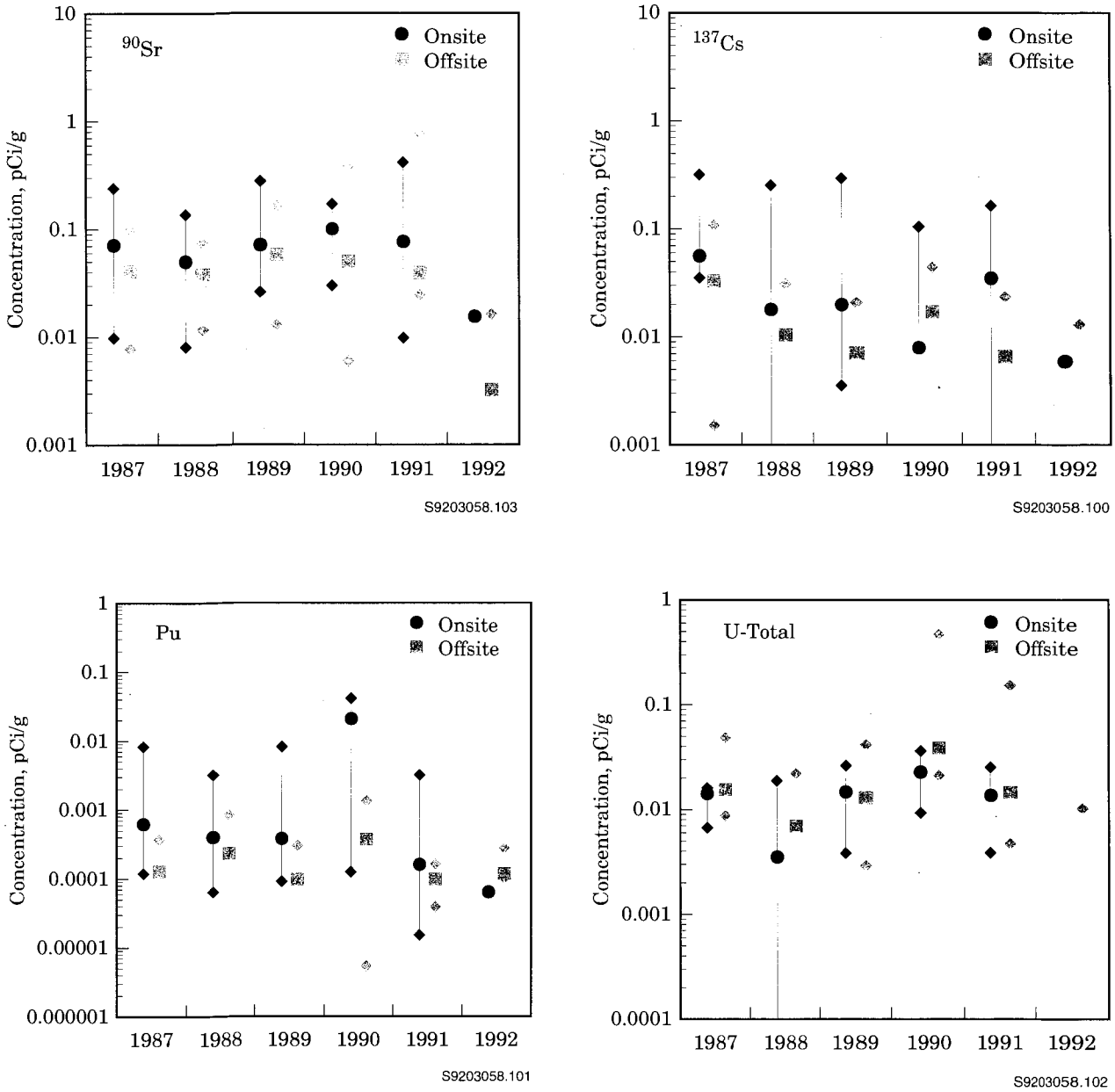

Figure 5.35. Selected Radionuclide Maximum, Median, and Minimum Concentrations in Vegetation, 1987 Through 1992. Units are pCi/g (dry weight). As a result of figure scale, some values overlap.

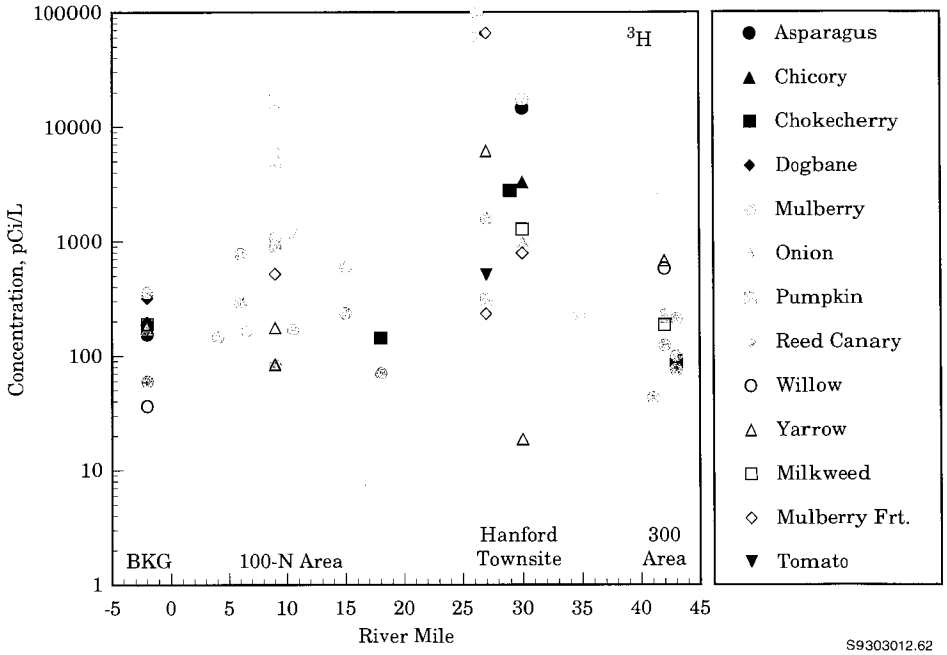

Figure 5.36. Tritium (^{3}H) Concentrations in Columbia River Shoreline Vegetation for Individual Samples Collected from 1990 Through 1992. Pumpkin and tomatoes had been planted along the shoreline at the old Hanford townsite and are not normal shoreline vegetation.

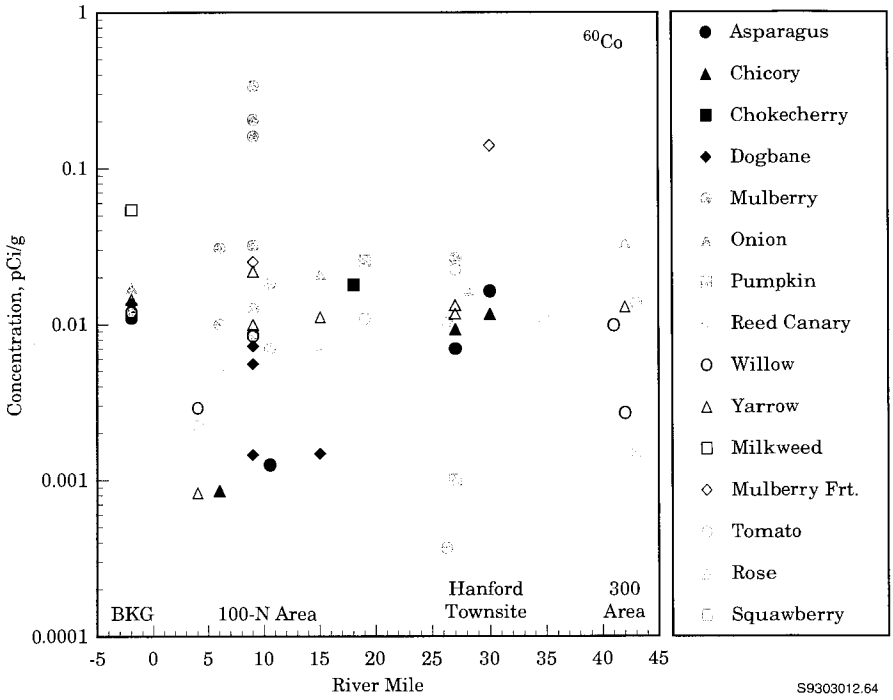

Figure 5.37. Cobalt-60 (^{60}Co) Concentrations in Columbia River Shoreline Vegetation for Individual Samples Collected from 1990 Through 1992. Pumpkin and tomatoes had been planted along the shoreline at the old Hanford townsite and are not normal shoreline vegetation.

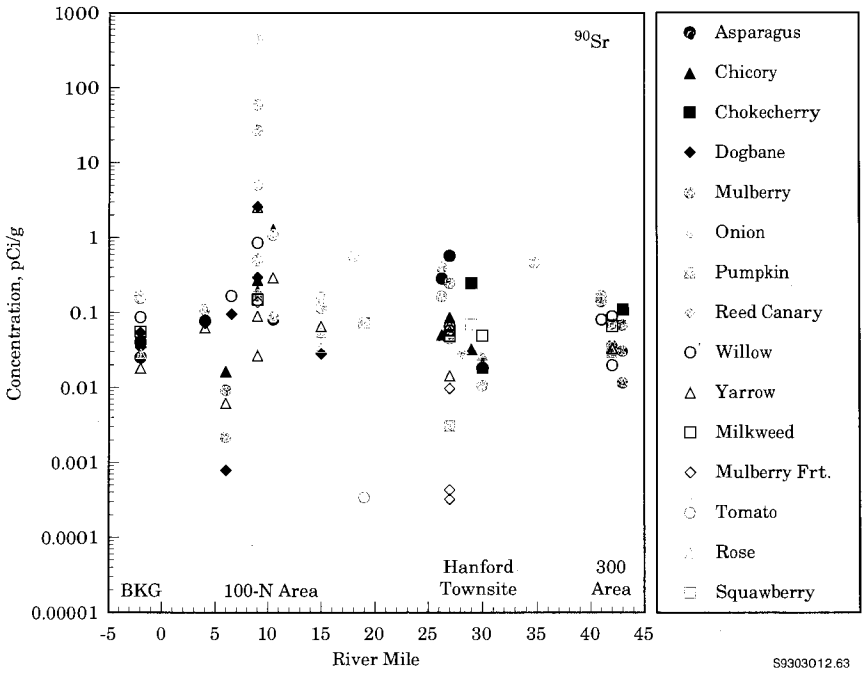

Figure 5.38. Strontium-90 (^{90}Sr) Concentrations in Columbia River Shoreline Vegetation for Individual Samples Collected from 1990 Through 1992. Pumpkin and tomatoes had been planted along the shoreline at the old Hanford townsite and are not normal shoreline vegetation.

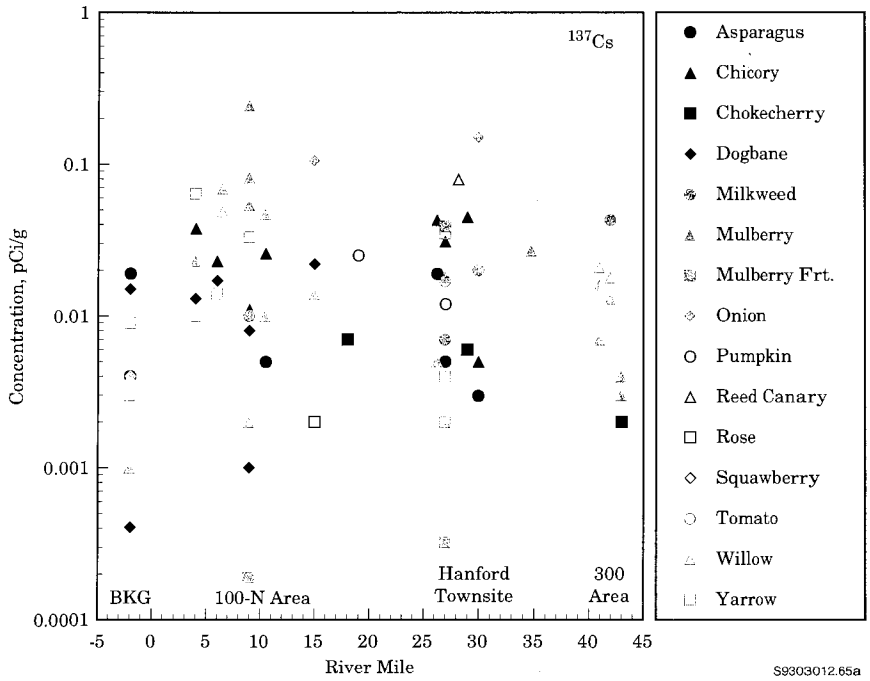

Figure 5.39. Cesium-137 (^{137}Cs) Concentrations in Columbia River Shoreline Vegetation for Individual Samples Collected from 1990 Through 1992. Pumpkin and tomatoes had been planted along the shoreline at the old Hanford townsite and are not normal shoreline vegetation.

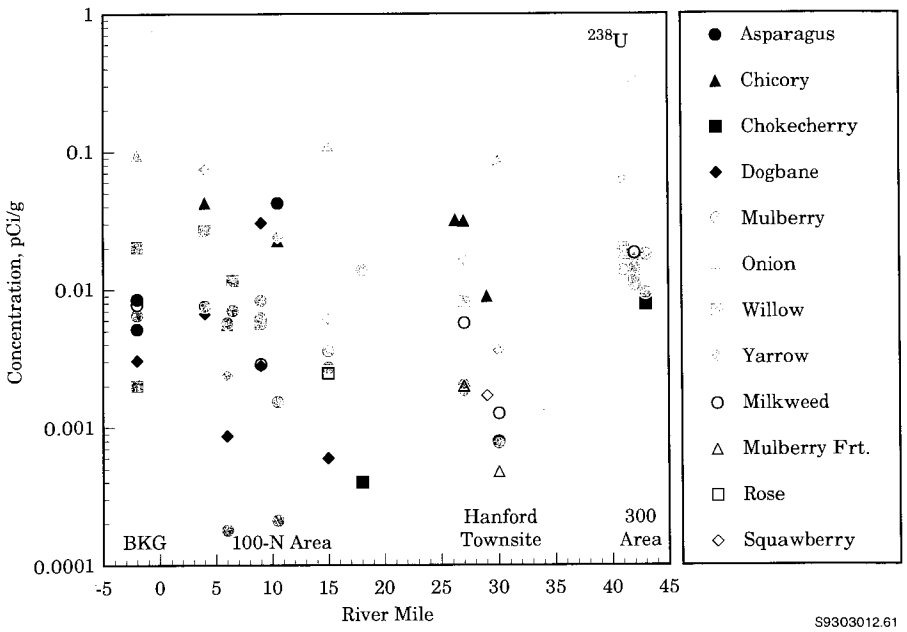

Figure 5.40. Uranium Concentrations in Columbia River Shoreline Vegetation for Individual Samples Collected from 1990 Through 1992

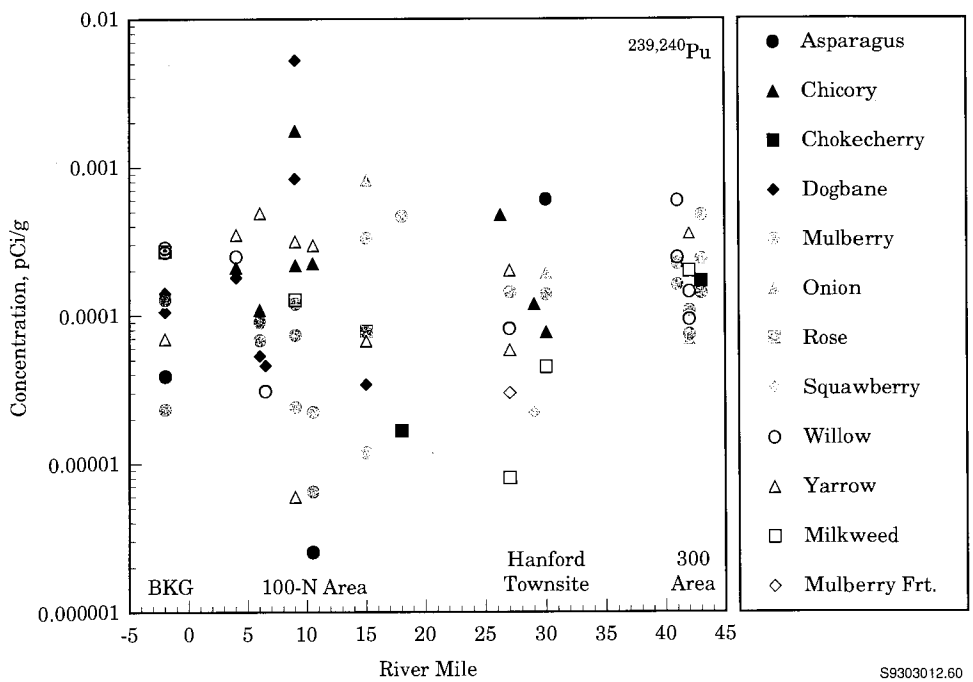

Figure 5.41. Plutonium ($^{239,240}Pu$) Concentrations in Columbia River Shoreline Vegetation for Individual Samples Collected from 1990 Through 1992

5.7 External Radiation Surveillance

External radiation is definedd as radiation originating from a source outside the body (Appendix B). External radiation fields consist of a natural component and an artificial or human-made component. The natural component can be divided into: 1) cosmic radiation, 2) primordial radionuclides in the earth's crust (primarily ^{40}K, ^{232}Th, and ^{238}U), and 3) an airborne component, primarily radon. The human-made component may be divided into medical x rays, nuclear power, nuclear research, nuclear waste management, and consumer products. Environmental radiation fields may be influenced by the presence of artificially produced radionuclides deposited as fallout from past atmospheric testing of nuclear weapons or those produced and released to the environment during the making or use of nuclear fuel. The interaction of radiation with matter results in energy being deposited in that material. The concept of energy deposited in a mass of material is called radiation absorbed dose. A special unit called the rad was introduced for this concept in the early 1950s, and more recently, an International System (SI) unit called the gray (Gy) has been defined.

External radiation exposure rates were measured at locations on and off the Hanford Site using TLDs. External radiation and contamination surveys were also performed at locations on and around the Hanford Site. This section describes how external radiation was measured, how the surveys were performed, and the results of these measurements.

External Radiation Measurements

Thermoluminescence, TL, or light output exhibited by TLDs is proportional to the amount of radiation exposure, X, which is measured in units of roentgen (R). The exposure is multiplied by a factor of 0.98, to convert to a dose (D) in rad to soft tissue (USDHEW 1970). This conversion factor relating R to rad is, however, assumed to be unity throughout this report for consistency with past reports. This dose is further modified by a quality factor, Q = 1 for beta and gamma radiation, and the product of all other modifying factors (N). N is assumed to be 1 to obtain dose equivalence (H), measured in rem.

$$D\ (rad) = X\ (R) * 1.0$$
$$H\ (rem) = D * N * Q$$

To convert to SI units of Gy and Sv, divide rad and rem by 100, respectively.

An environmental TLD comprises three plastic cards that each hold four LiF (TLD 700) chips and one CaF_2:Dy (TLD 200) chip. The TLD is positioned 1 m (3.3 ft) above the ground at various locations both on and off the Hanford Site. The TLDs are collected and read quarterly, except for those at the 100-N Area shoreline, which are processed monthly. The 12 TLD 700 chips at each location are used to determine the average environmental dose at that location and that quantity is divided by the length of time the TLD was in the field to determine the average environmental dose rate. The three TLD 200 chips are included to permit dose determination in the event of a radiological emergency.

The TLDs are positioned at numerous locations onsite (Figure 5.42), around the Site perimeter, in nearby and distant communities, at COES stations (Figure 5.43), and along the Hanford Reach of the Columbia River (Figure 5.44). All community and most of the onsite and perimeter locations are collocated with air monitoring stations. These locations were selected based on historical determinations of the highest potentials for public exposures (access areas, downwind population centers) from past and current Hanford operations.

Dose rates were also measured at three COES stations located at Edwin Markham Elementary School, Basin City Elementary School, and Leslie Groves Park. Each COES station is managed by local school teachers and measures dose rates using both TLDs and portable survey instruments.

Twenty-five locations have been established on the Columbia River shoreline from upstream from the 100-B

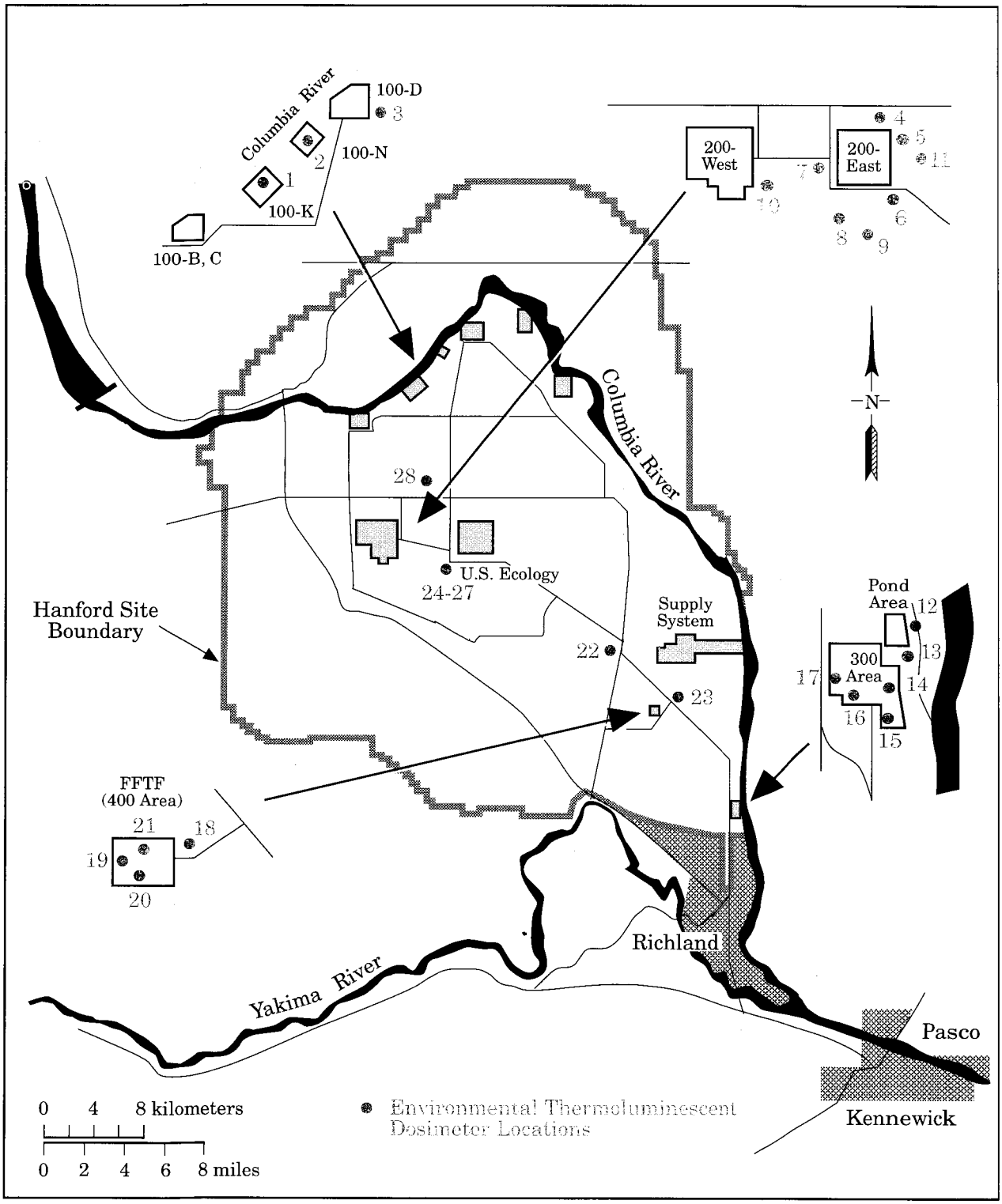

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Figure 5.42. Thermoluminescent Dosimeter (TLD) Locations and Station Numbers on the Hanford Site, 1992

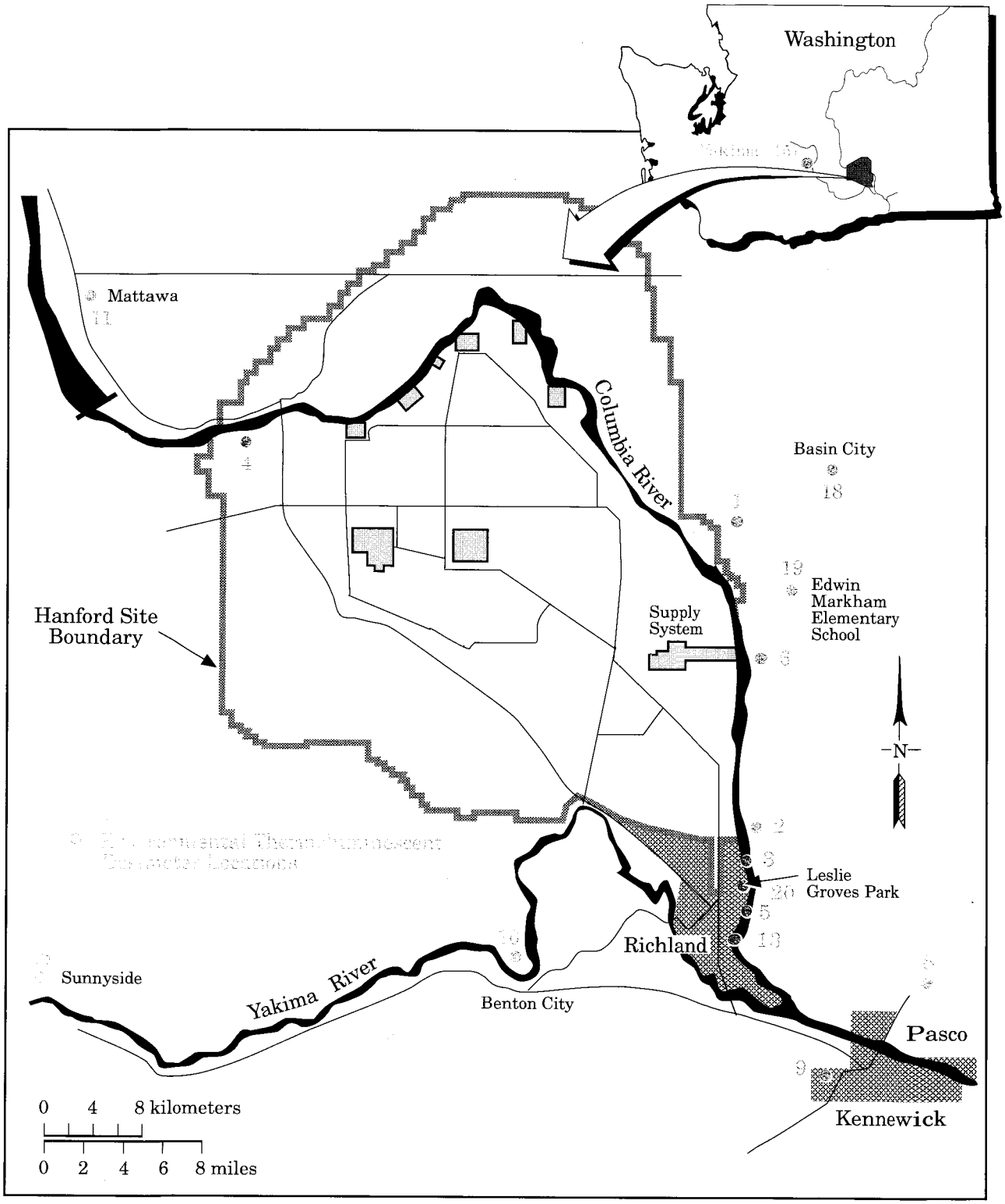

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Figure 5.43. Thermoluminescent Dosimeter (TLD) Measurement Locations and Station Numbers for Perimeter and Community Sites, 1992

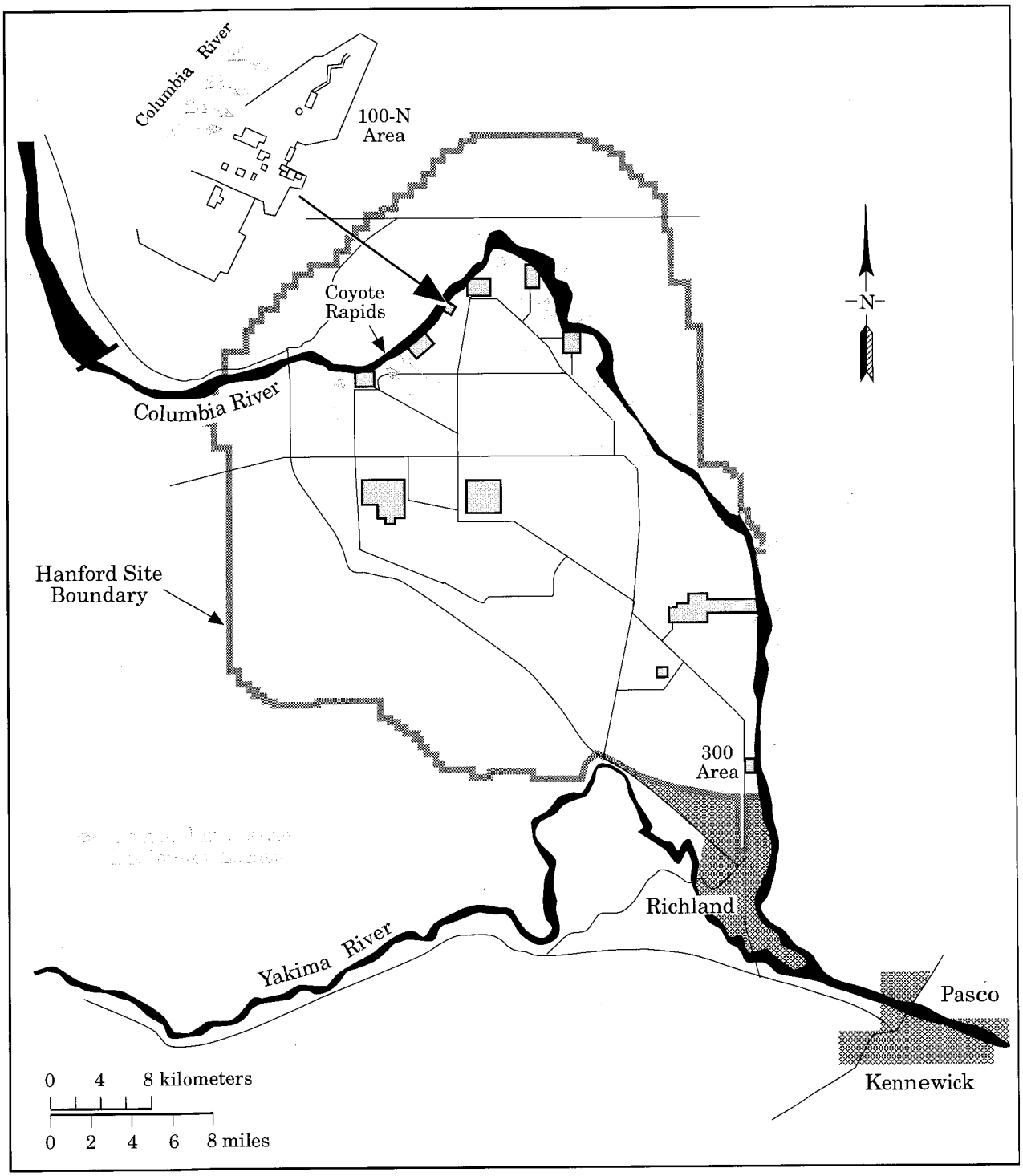

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Figure 5.44. Thermoluminescent Dosimeter (TLD) Locations and Station Numbers on the Hanford Reach of the Columbia River, 1992

Area to just upstream from the 300 Area. The general public has access to some of these locations. Historically, dose rates measured along the shoreline have been higher than typical background rates. Sula (1980) attributed these rates to ^{60}Co and ^{154}Eu in shoreline sediments as a result of liquid releases during past reactor operations in the 100 Areas. Two locations, Coyote Rapids and Richland Pumphouse, had TLDs submerged in the Columbia River. These two locations were discontinued after the second quarter of 1992, because submerged TLD readings were less than terrestrial background readings and radionuclide concentrations in the Columbia River have decreased to levels such that no difference was seen between the upstream (Coyote Rapids) and downstream (Richland Pumphouse) TLD readings.

External Radiation Results

Perimeter and offsite locations, primarily downwind of the Site and near population centers, were monitored with TLDs. TLD exposures have been converted to dose equivalent rates by the process described above. Table 5.22 shows average dose rates for perimeter and offsite locations. Quarterly exposure rates were averaged by map location, ranked within the location classification, and then converted to dose equivalents per year.

Perimeter dose rates for 1992 were similar to those observed in 1991, but on average all offsite dose rates increased slightly. Variations in natural background radiation can occur as a result of changes in annual cosmic radiation (up to 10%) and terrestrial radiation (15 to 25%, NCRP 1987). Other factors possibly affecting annual dose rates reported here may include variations in the sensitivity of individual TLDs zero dose readings, fading, random errors in the readout equipment or procedures (Rathbun 1989), and changes in TLD station locations.

The background external radiation dose rate was 93 mrem/yr ± 6% as compared to the perimeter average of 102 mrem/yr ± 6%. This slight difference in average dose rates may be due to natural geographic variations in terrestrial radiation [many of the perimeter locations are rich in ^{40}K and thorium isotopes (Rathbun 1989)] and variations resulting from human activity. The 1992 average ^{40}K concentration in soil at perimeter locations (19 pCi/g) is higher than the average ^{40}K concentration in soil at distant locations (13 pCi/g). Although this difference in ^{40}K concentrations does not account for a 9-mrem/yr difference in exposure rates, other radionuclides were found in higher soil concentrations at the Site perimeter than at distant community locations (see Section 5.6). Human activities affecting the average dose rates may include landscape changes such as buildings and other construction, which may shield a portion of the terrestrial component. Figure 5.45 graphically displays a comparison between, and trends of, perimeter and distant TLD locations during 1987 through 1992. Year-to-year variability is obvious for reasons stated above, and 10% variability is not unlikely (NCRP 1987).

Table 5.22. Dose Rates Measured by Thermoluminescent Dosimeters (TLDs) at Perimeter and Community Locations, 1992 Compared to Values from the Previous 5 Years

		Dose Rate, mrem/yr					
		1992			1987-1991		
Location	Map Location[a]	No. of Samples	Maximum	Mean	No. of Samples	Maximum	Mean
Perimeter	1 - 6	6	111 ± 5%	102 ± 6%	153	168 ± 18%	89 ± 3%
Nearby community	7 - 10	4	96 ± 10%	93 ± 4%	170	112 ± 15%	79 ± 3%
Distant community	11 - 12	2	96 ± 7%	93 ± 6%	93	107 ± 20%	77 ± 4%
COES stations	13 - 15	3	103 ± 69%	93 ± 12%	10	89 ± 9%	79 ± 7%

(a) See Figure 5.43.

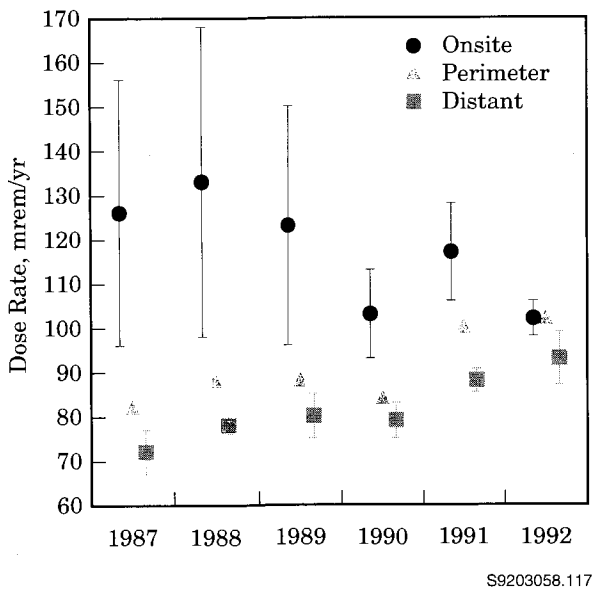

Figure 5.45. Annual Average Dose Rates, 1987 Through 1992

Figure 5.44 shows locations of TLDs positioned along the Columbia River shoreline, and Table 5.23 shows the average measured dose rates for shoreline locations. Dose rates were highest near the 100-N Area shoreline, two to three times higher than typical shoreline dose rates. The higher rates measured in the 100-N Area are attributed to past waste management practices in that area. The public does not have open access to the 100-N Area shoreline, but does have access to the adjacent water body. The dose implications at this location are discussed in Section 6.0.

Figure 5.42 displays the 28 onsite locations where TLDs were placed in 1992. Table 5.24 summarizes the results of 1992 measurements, which are divided by operational area. All areas had higher average dose rates than background. The highest average dose rate was seen in the 600 Area and is due to the waste-handling activities at U.S. Ecology, a non-DOE facility.

Radiation Survey Results

Onsite roads and railways, the Columbia River shoreline, and perimeter locations were routinely surveyed using portable radiation detectors in 1992. The frequency of surveys on specific roads and railroads was determined by their use and the potential for contamination. These routes and frequencies were reported by Bisping (1992).

Railroads and roads were surveyed using mobile scintillation detectors. The detector consisted of four sodium iodide detectors mounted on the rear bumper of a four-wheel-drive truck. The detectors were mounted 0.46 m (1.5 ft) above the ground. Output from the detectors and the associated electronics was recorded on strip charts for review and documentation after surveys were complete. In 1992, road and railroad surveys revealed no areas of detectable contamination. Routes are shown in Figure 5.46.

Hand-held survey instruments were used to perform radiation surveys at many of the Columbia River shoreline TLD locations. These surveys provide a coarse screening for elevated radiation fields. The shoreline surveys showed that radiation levels at some locations were comparable to levels measured at those locations in previous years. The highest levels were recorded on the 100-N Area shoreline and ranged from 10 to 100 mrem/hr using a Bicron Micro Rem meter. Results for radiation surveys are not tabulated by Bisping and Woodruff (1993), but are in the Surface Environmental Surveillance Project files at PNL.

Table 5.23. Dose Rates Measured Along the Hanford Reach of the Columbia River, 1992 Compared to Values from the Previous 5 Years

		Dose Rate,[a] mrem/yr				
		1992			1987-1991	
Location[b]	Map Location[c]	Maximum	Mean[d]	No. of Samples	Maximum	Mean
Typical shoreline area	1 - 21	141 ± 8%	108 ± 5%	20	132 ± 59%	100 ± 7%
100-N shoreline[e]	22 - 25	324 ± 8%	239 ± 20%	4	333 ± 8%	250 ± 30%
All shoreline		324 ± 8%	130 ± 16%	24	333 ± 8%	165 ± 9%
Immersed in Columbia River[f]		69 ± 2%	61 ± 29%	2	53 ± 60%	51 ± 16%

(a) Quarterly integrated readings in mR/d were converted to annual dose equivalent rates (mrem/yr).
(b) All locations are shown in Figure 5.44.
(c) Locations are identified in Figure 5.44.
(d) Means ±2 SEM computed using station averages.
(e) Monthly integrated exposure readings in mR/d converted to annual dose equivalent rates in mrem/yr.
(f) Immersion points at Richland Pumphouse and Coyote Rapids. Measurement discontinued after second quarter 1992.

Table 5.24. Dose Rates for Thermoluminescent Dosimeter (TLDs) Locations on the Hanford Site, 1992 Compared to Values from the Previous 5 Years

		Dose Rate,[a] mrem/yr				
		1992			1987-1991	
Location	Map Location[b]	Maximum	Mean[c]	No. of Samples	Maximum	Mean
100 Areas	1 - 3	104 ± 11%	95 ± 10%	39	96 ± 9%	90 ± 6%
200 Areas	4 - 11	109 ± 3%	101 ± 4%	84	96 ± 10%	88 ± 3%
300 Area	12 - 17	108 ± 6%	98 ± 6%	53	94 ± 9%	89 ± 4%
400 Area	18 - 21	107 ± 5%	97 ± 7%	43	90 ± 11%	85 ± 5%
600 Area	22 - 28	183 ± 9%	113 ± 22%	130	135 ± 9%	102 ± 5%

(a) Quarterly integrated readings in mrem were converted to annual dose equivalent rates.
(b) Locations are identified in Figure 5.42.
(c) Means ±2 SEM computed using station averages.

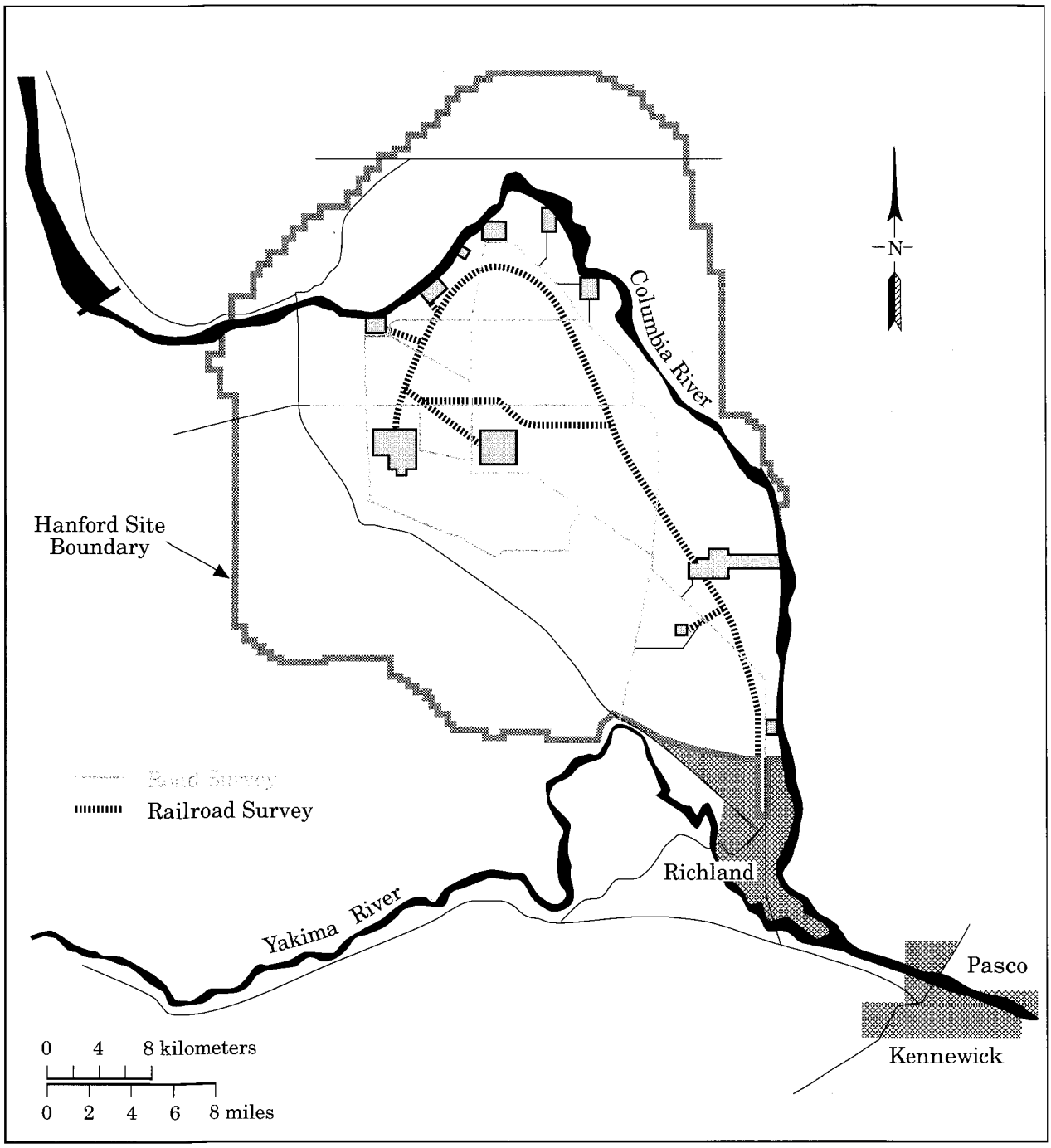

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Figure 5.46. Road and Railroad Survey Routes, 1992

5.8 Ground-Water Protection and Monitoring Program

The strategy for protecting ground water at the Hanford Site is presented in the *Hanford Site Ground-Water Protection Management Program* (DOE 1989c). Two of the key elements of this strategy are to 1) protect the unconfined aquifer from further contamination, and 2) conduct a monitoring program to provide an early warning when contamination of ground water does occur. The monitoring program at Hanford has also been designed to allow an assessment of the distribution and movement of existing ground-water contamination. The geology and hydrology of the Hanford Site controls, to a large extent, the movement of contaminants.

Geology

The Hanford Site lies within the Pasco Basin, one of many topographic and structural basins within the Columbia Plateau. Principal geologic units beneath the Hanford Site include, in ascending order, the Columbia River Basalt Group, the Ringold Formation, and a series of deposits informally referred to as the Hanford formation. These units are covered locally by a few meters or less of recent alluvial or windblown deposits. Older geologic units have been deformed into a series of roughly east-west trending folds. The stratigraphic and structural relationships between these units are displayed in Figure 5.47.

The Columbia River Basalt Group is composed of numerous basaltic lava flows. River and lake sediments of the Ringold Formation contain a wide range of sediment types, with beds ranging from weakly cemented coarse sandy gravel to compacted silt and clay. Within the Pasco Basin, the Hanford formation consists of mostly coarse gravel and sand that overlie the eroded surface of the Ringold Formation, but in places the Hanford formation directly overlies basalt. Near the 200-West Area, the Ringold and Hanford formations are separated by a well-developed buried soil (Plio-Pleistocene unit) and fine-grained wind deposits (early "Palouse" soil) (Last et al. 1989). More detailed descriptions of Hanford Site geology are provided in Myers and Price (1979), DOE (1988c), and Lindsey et al. (1992).

Ground-Water Hydrology

Both confined and unconfined aquifers are present beneath the Hanford Site. The confined aquifers, where ground water is under pressure greater than that of the atmosphere, are found primarily within the Columbia River basalts. In general, the unconfined or water-table aquifer is located in the Ringold Formation and glacio-fluvial sediments, as well as some more recent alluvial sediments in areas adjacent to the Columbia River. This relatively shallow aquifer has been affected by waste-water disposal at Hanford (Thorne and Chamness 1992), and therefore, is the most thoroughly monitored aquifer beneath the Site.

The unconfined aquifer is bounded below by either the basalt surface or, in places, the relatively impervious clays and silts of the Ringold Formation. The water table defines the upper boundary of the unconfined aquifer. Laterally, the unconfined aquifer is bounded by the basalt ridges that surround the basin and by the Yakima and Columbia rivers. The basalt ridges have a low permeability and act as a barrier to lateral flow of ground water (Gephart et al. 1979) where they rise above the water table. The saturated thickness of the unconfined aquifer is greater than 61 m (200 ft) in some areas of the Hanford Site and pinches out along the flanks of the basalt ridges. Depth from the ground surface to the water table ranges from less than 0.3 m (1 ft) at the Columbia River to more than 106 m (348 ft) in the center of the Site. Elevation of the water table in meters above mean sea level for the Hanford Site and adjacent portions of Franklin County is shown in Figure 5.48.

Recharge to the unconfined aquifer originates from several sources (Graham et al. 1981). Natural recharge

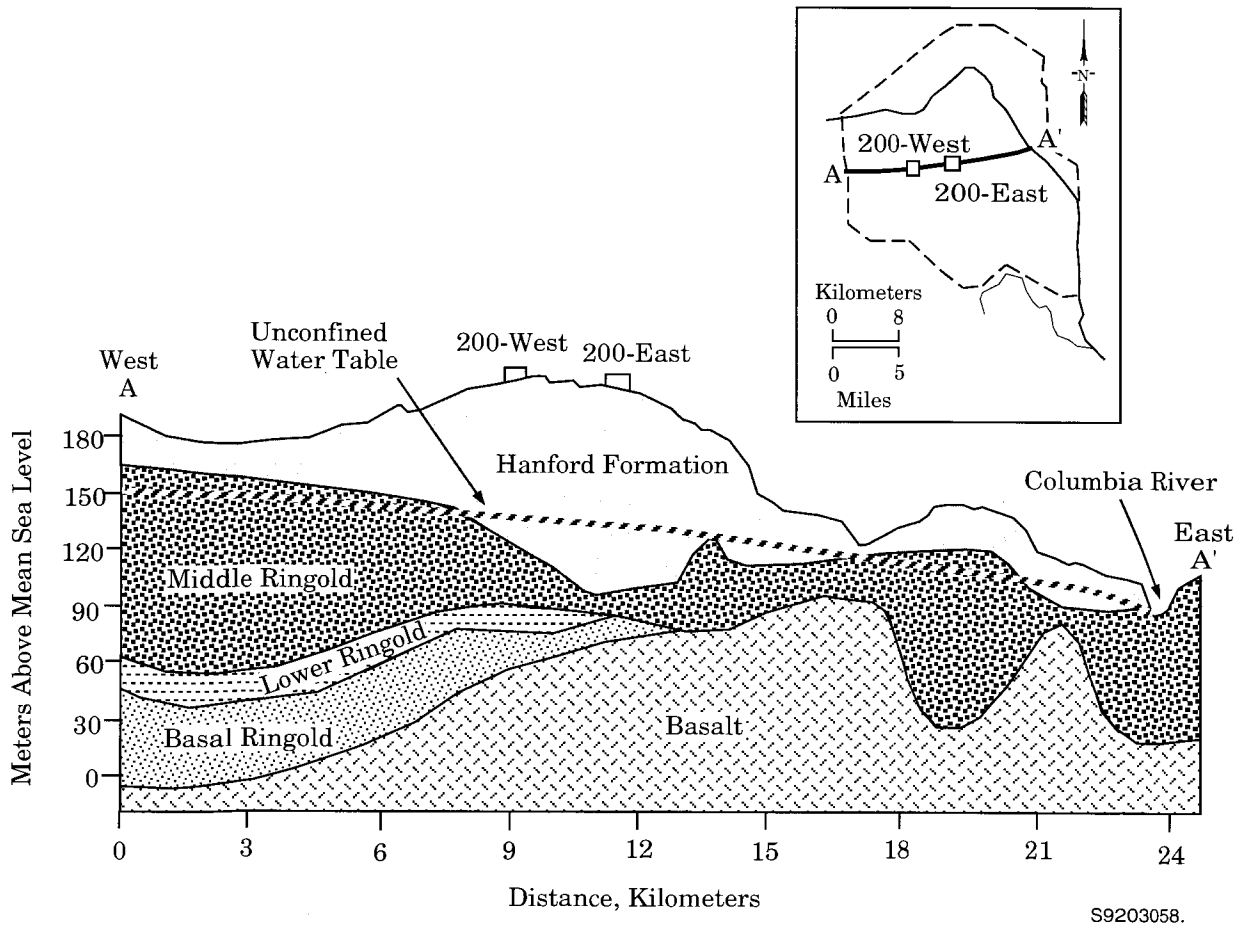

Figure 5.47. Geologic Cross Section of the Hanford Site (modified from Tallman et al. 1979)

occurs from precipitation at higher elevations and runoff from intermittent streams, such as Cold Creek and Dry Creek on the western margin of the Site. The unconfined aquifer is recharged by the Yakima River as it flows along the southwest boundary of the Hanford Site. The Columbia River recharges the unconfined aquifer during high stages when river water is transferred to the aquifer along the river bank. The unconfined aquifer receives little, if any, recharge from precipitation directly on vegetated areas of the Hanford Site because of a high rate of evapotranspiration from native soil and vegetation. However, studies described by Gee et al. (1992) suggest that precipitation may contribute recharge to the ground water in areas where soils are course textured and bare of vegetation.

Large-scale artificial recharge occurs from offsite agricultural irrigation and liquid-waste disposal in the operating areas. Recharge from irrigation in the Cold Creek Valley enters the Hanford Site as ground-water flow across the western boundary. Recharge to ground water across the Columbia River from the Hanford Site is primarily from irrigation and irrigation canal leakage. As indicated in Figure 5.48, the water-table elevation in this area is from 100 to 150 m (328 to 492 ft) higher than the water-table elevation on the Hanford Site.

The operational discharge of water has created ground-water mounds near each of the major wastewater disposal facilities in the 200 Areas. These mounds have altered the aquifer's local flow pattern, which is generally from the recharge areas in the west to the discharge areas (primarily the Columbia River) in the east. Water levels in the unconfined aquifer have changed continually during Site operations because of variations in the volume of waste water discharged. Consequently, the

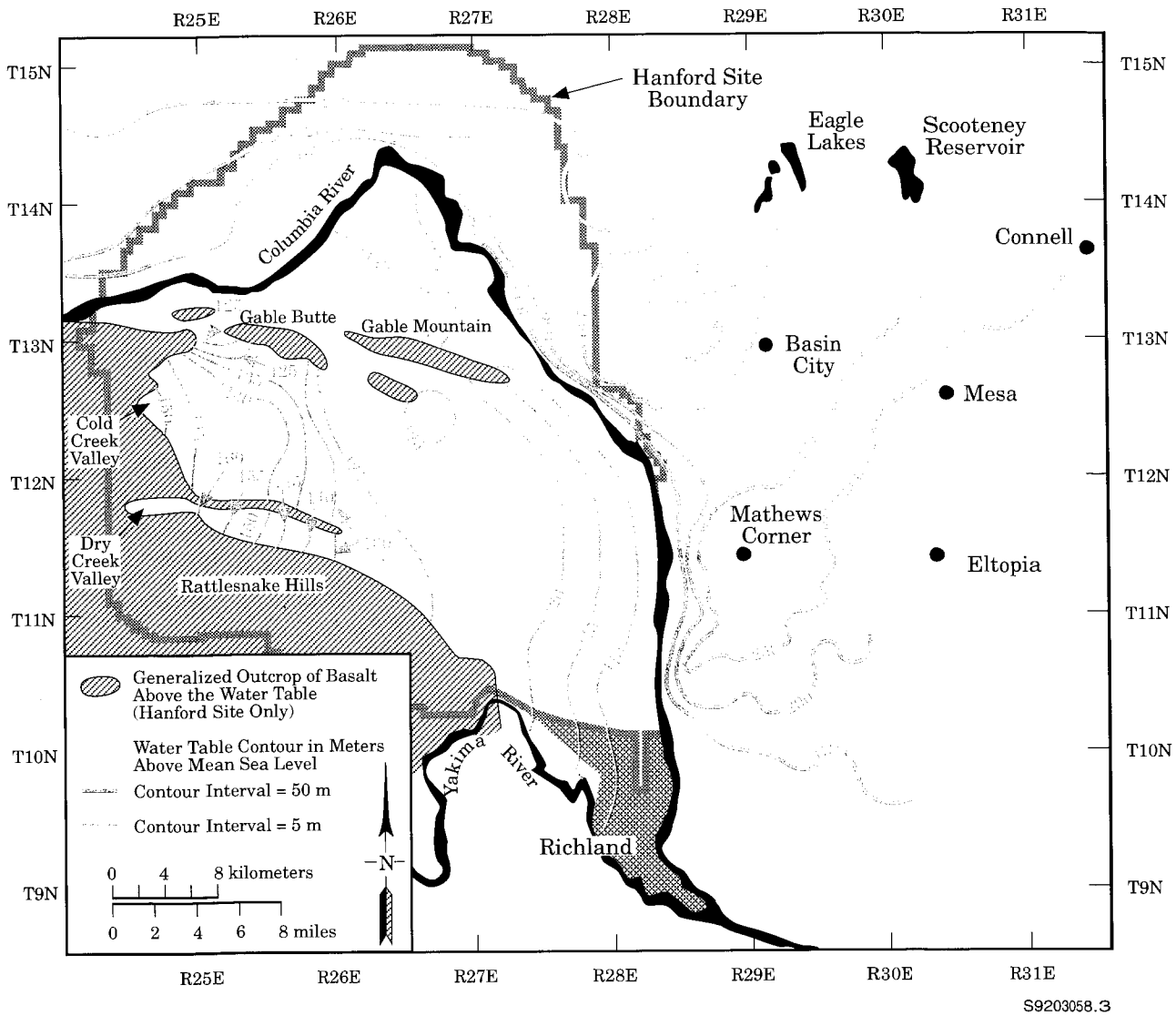

Figure 5.48. Water-Table Elevations for the Unconfined Aquifer at Hanford, June 1992

movement of ground water and its associated constituents has also changed with time.

Ground-water mounding also occurs in the 100 and 300 Areas. Ground-water mounding in these areas is not as significant as in the 200 Areas because of differences in discharge volumes and subsurface geology. In the 100 and 300 Areas, water levels are also greatly influenced by river stage.

As significant quantities of liquid effluents are discharged to the ground at Hanford facilities, these effluents percolate downward through the unsaturated zone to the water table. Adsorption onto soil particles, chemical precipitation, and ion exchange attenuate or delay the movement of some radionuclides, such as ^{90}Sr, ^{137}Cs, and $^{239,240}Pu$. These constituents move through the soil column at varying rates and eventually enter the ground water. Other ions, such as nitrate, and radionuclides,

such as ^{3}H, ^{99}Tc, and ^{129}I, are not as readily retained by the soil and move downgradient in the same direction as, and at a rate nearly equal to, the flow of ground water. When the liquid effluents reach the ground water, their concentrations are reduced by dilution. As these constituents move with the ground water, radionuclide and chemical concentrations are further reduced by spreading (dispersion), and radionuclide concentrations are reduced by radioactive decay.

Ground-Water Protection

The effort to protect ground-water quality is being implemented through programs to minimize wastes being discharged to the soil column and through site remediation activities being carried out in accordance with an agreement between the Washington State Department of Ecology (Ecology), DOE, and EPA. This agreement, called the Tri-Party Agreement, provides a framework for remediation of the Hanford Site over a 30-year period. A summary of accomplishments in waste minimization and site remediation is presented in Section 2.0, "Environmental Compliance and Cleanup."

In 1987 Congress directed DOE to prepare a *Plan and Schedule to Discontinue Disposal of Liquids Into the Soil Column at the Hanford Site* (DOE 1987c). That document presents an implementation plan for providing alternative treatment and disposal of contaminated effluent discharged to the soil on the Hanford Site. The 33 major waste streams that have been identified will be addressed in two phases. Phase I projects are considered higher priority, and cessation or alternative treatment and disposal systems will be implemented by 1995 for those streams. Phase II streams will be dealt with after completion of Phase I projects.

Ground-Water Monitoring

Ground-water monitoring at the Hanford Site is an integral part of the *Hanford Site Ground-Water Protection Management Program* (DOE 1989c). The program includes monitoring at active waste disposal facilities to comply with the RCRA (e.g., DOE 1992a), operational monitoring in and adjacent to reactor and chemical processing facilities, and environmental surveillance. Monitoring is also carried out during cleanup investigations under the Superfund (CERCLA) programs (e.g., DOE 1992f). The RCRA and operational monitoring are managed by the Site operating contractor. CERCLA characterizations are managed by the operating contractor and the U.S. Army Corps of Engineers. Additional details on RCRA compliant monitoring are presented in Section 2.0, "Environmental Compliance and Cleanup." The Environmental Surveillance Program assesses the impact of Hanford operations on ground water, both onsite and offsite, independently of the operating contractors' programs.

Sample Collection and Analysis

Ground-water samples were collected as part of the Hanford Ground-Water Environmental Surveillance Program and other monitoring programs. The Ground-Water Environmental Surveillance Program utilizes the data from other programs to provide as complete an interpretation as possible. Wells monitored by the various programs in 1992 are shown in Figures 5.49 through 5.52. Ground-water monitoring was conducted at the facilities shown in Figure 5.53 to comply with RCRA.

Ground-water samples were collected from approximately 720 wells for the monitoring programs during 1992. The monitoring frequency for the wells was selected based on regulatory requirements, proximity to waste sources, and the characteristics of the ground-water flow system at the sampled location. One hundred and ninety-nine of the wells were sampled once, 163 were sampled twice, 202 were sampled approximately quarterly, and 156 wells were sampled more frequently during the year.

Although the programs are managed by different organizations, a common database is used to store ground-water data so that each monitoring program has access to data collected by other programs. Samples for the environmental surveillance, RCRA, and operational programs are collected by sampling teams following a single set of procedures. Ground-water samples were analyzed by a combination of subcontractor and in-house laboratories.

Most ground-water monitoring wells on the Site are 10 to 20 cm in diameter and are constructed of steel or stainless-steel casing. Monitoring wells for the unconfined aquifer are constructed with well screens or perforated casing generally in the upper 3 to 6 m of the aquifer. This construction allows sample collection near the top of the aquifer, where maximum concentrations for radionuclides tend to be found. Wells monitoring the

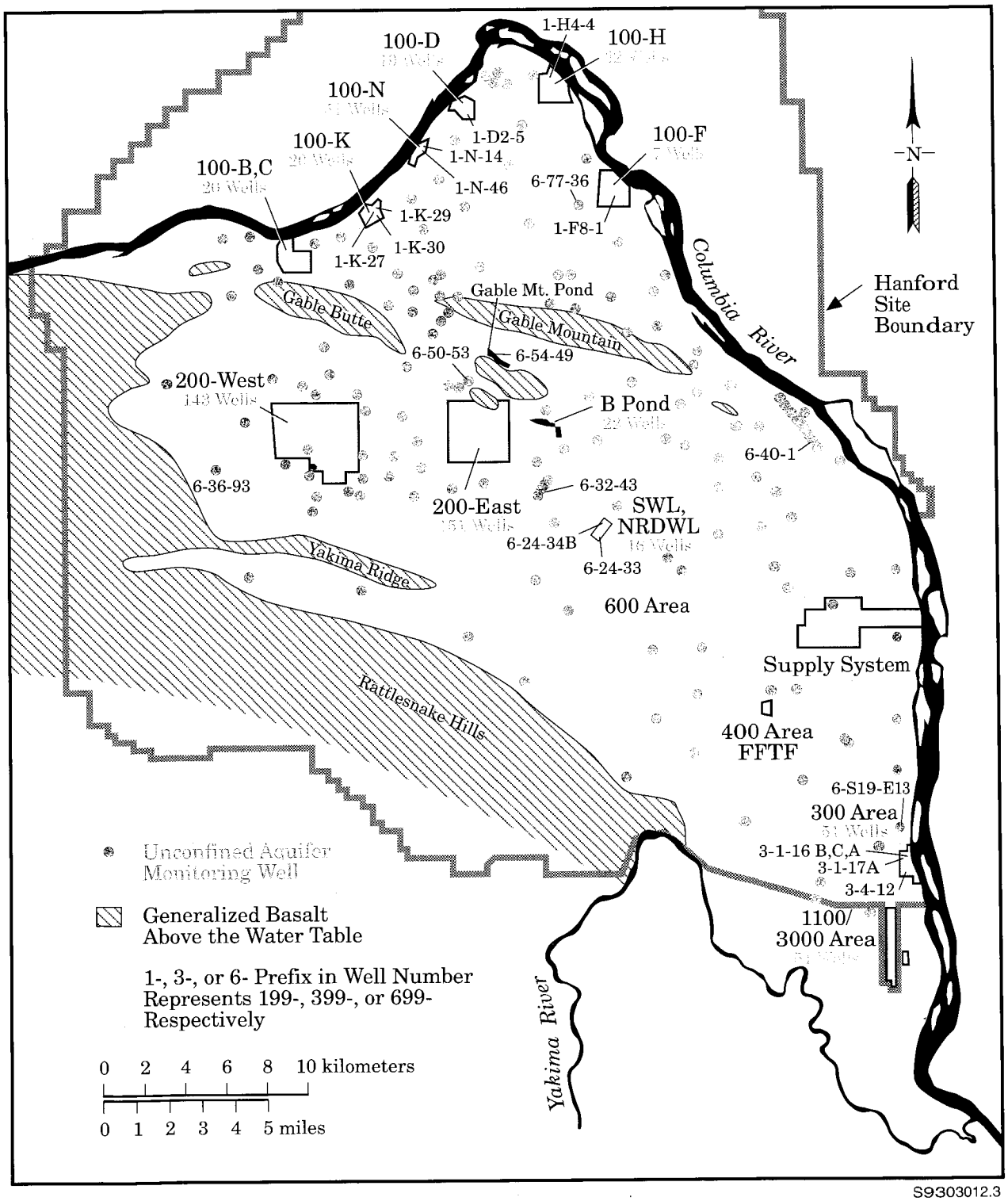

Figure 5.49. Hanford Site Unconfined Aquifer Monitoring Well Locations, 1992. Numbered well locations are discussed in the text.

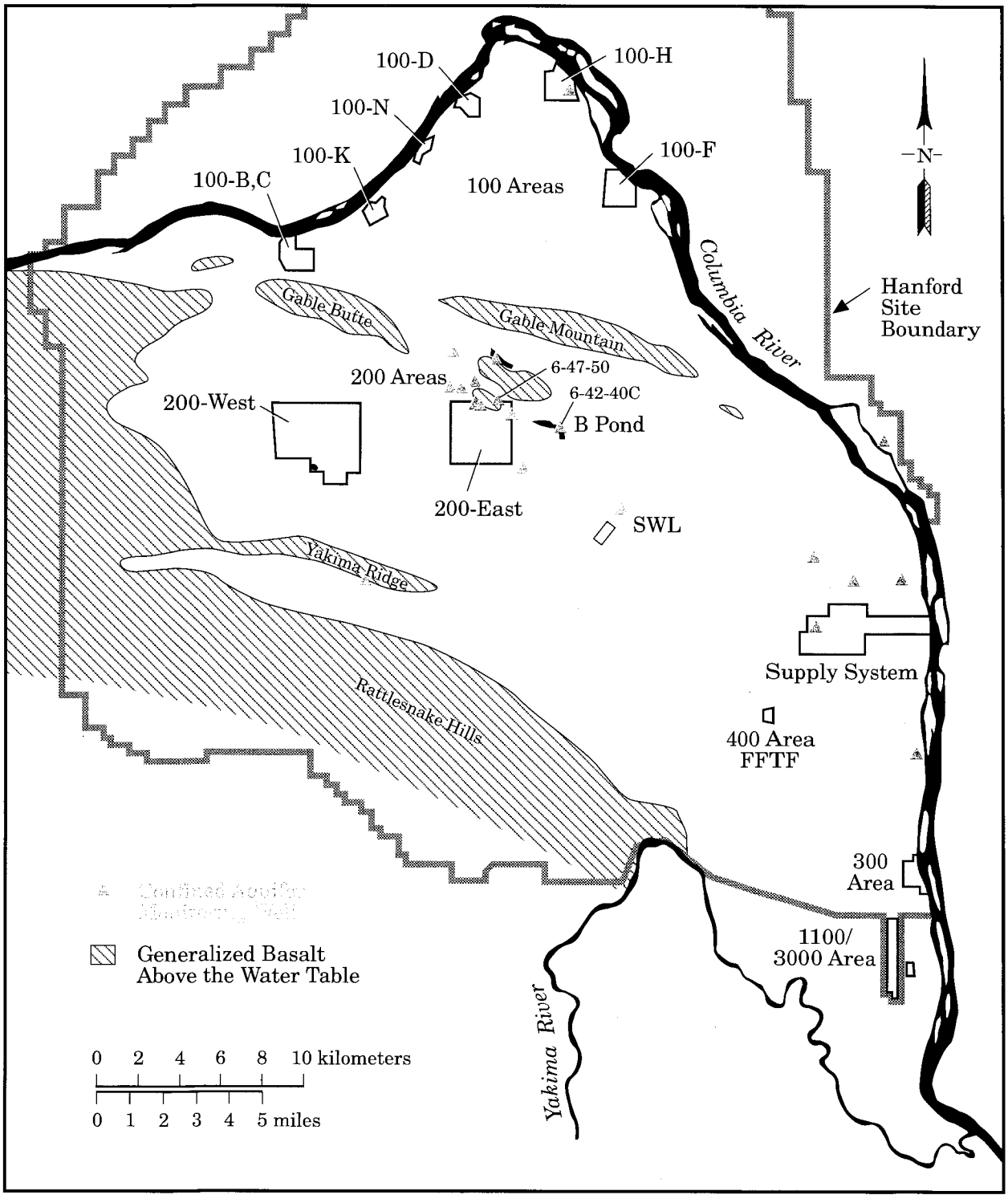

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Figure 5.50. Hanford Site Confined Aquifer Monitoring Well Locations, 1992. Numbered well locations are discussed in the text.

Figure removed as per DOE guidance.

Figure 5.51. Monitoring Well Locations in the 200-East Area, 1992. Numbered well locations are discussed in the text.

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Figure 5.52. Monitoring Well Locations in the 200-West Area, 1992. Numbered well locations are discussed in the text.

Figure removed as per DOE guidance.

Figure 5.53. Locations of RCRA Ground-Water Monitoring Projects and Landmarks on the Hanford Site

confined aquifer have screens, perforated casing, or an open hole within the monitored aquifer. Wells drilled before 1985 were generally constructed with carbon steel casing. Wells recently constructed for RCRA monitoring projects and CERCLA characterizations have been constructed with stainless-steel casing.

Samples were collected for all programs following documented sampling procedures (PNL 1993; WHC 1991b) based on EPA guidelines (EPA 1986c). Analytical techniques used are described in the *Hanford Site Environmental Monitoring Plan* (DOE 1991b) and CERCLA work plans. The species analyzed for are listed in Table 5.25.

Each analysis of a ground-water sample provides information on the composition of ground water at one time at one location in the aquifer. Uncertainty in the analysis results from a number of sources. Some of the sources of uncertainty are discussed below. Several techniques are used in this discussion to interpret the sample results given these uncertainties and are also discussed.

Table 5.25. Radionuclides and Chemicals Analyzed for in Ground Water

Radiological Parameters	Chemical Parameters
^{3}H	pH (field and laboratory)
^{60}Co	Conductance (field)
^{90}Sr	Alkalinity
^{99}Tc	Total carbon
^{103}Ru	Total organiccarbon
^{106}Ru	Total organic halogens
^{125}Sb	B, Be, Na, Mg, Al, K, Co, Si
^{129}I	Ca, V, Cr, Mn, Fe, Ni
^{131}I	Cu, Zn, Sr, Ag, Cd, Sb, Ba
^{137}Cs	F^-, Cl^-, NO_3^-, PO_4^{-3}, SO_4^{-2}, NO_2^-, Br^-
^{241}Am	CN^-
Total Alpha	NH_3^-
Total Beta	Volatile organic constituents
Plutonium Isotopes	Semivolatile organic constituents
Uranium Isotopes	PCBs
Uranium (total)	Pesticides/herbicides
	Biological oxygen demand/chemical oxygen demand
	Dissolved oxygen

Sampling techniques are designed to provide a sample that is reasonably representative of the aquifer concentration when the sample is taken. However, there are limitations in our ability to collect representative samples or even to define precisely what volume of aquifer is represented in the sample. Proper well construction, well purging, sample preservation, and, in some instances, filtering are used to help ensure consistent and representative samples. Careful sample labeling protocols, chain-of-custody documentation, and bottle preparation avoid many gross errors in sample results. Duplicate samples and field blanks help assess the sampling procedure.

Uncertainties are inherent in laboratory analysis of samples. Gross errors can be introduced in the laboratory or at other stages in the sampling. Gross errors include transcription errors, calculation errors, mislabeling results, or other errors that result from not following established procedures. Often, these gross errors can be recognized because unreasonably high or unreasonably low values result. Data review procedures are used to investigate and correct gross errors. Even if the source of a possible gross error cannot be identified, a flag is entered into the database indicating the review has occurred and the datum may be suspect.

Random errors are unavoidably introduced in the analytical procedures. Usually there are insufficient replicate analyses to assess the overall random error. Instruments for analysis of radioactive constituents count the number of radioactive decay products at a detector, and background counts are subtracted out. The nature of radioactive decay and the instrument design result in a random counting error, which is reported with the analytical result. Generally, sample results less than the counting error indicate the constituent was not detected. The background subtraction may result in the reporting of results that are less than zero. Although this is physically impossible, the negative values may be of use for some statistical analyses.

Systematic errors may result from instrument calibration, standard or sample preparation, chemical interferences in analytical techniques, as well as sampling methodology and sample handling. Sample and laboratory protocols have been designed to minimize systematic errors. The laboratories used by the ground-water surveillance and other programs participate in interlaboratory comparisons in which many laboratories analyze blind samples prepared by the EPA. The laboratories used have compared favorably with other laboratories, indicating the level of systematic error from many sources is acceptable.

The chemical composition of ground water may fluctuate from differences in the contaminant source, recharge, or the flow-field. The range of this concentration fluctuation can be estimated by taking many samples, but there is a limit to the number that can be practically taken. Comparison of results through time help interpret this natural variability.

When more than one sample was collected from a well during 1992, the variability of the data can be indicated by the average (mean) value and the standard error of the calculated mean. Ground-water concentrations typically change very slowly with time, so the fact that the samples are not always collected at the same time is not a major problem.

Overall sample uncertainty may be factored into data evaluation by considering the concentration trend in a given well over time. This often helps identify gross errors, and overall long-term trends can be distinguished from short-term variability. The interpretation of concentration trends depends on an understanding of chemical properties as well as site hydrogeology. The trend analysis in turn aids in refining the conceptual model of the chemical transport.

Plume maps presented in this section are diagrammatic representations of the interpretation of Site ground-water chemistry. Although analytical data are only available at specific points where wells were sampled, contours are drawn to join the approximate locations of equal chemical concentration or radionuclide activity. The contour maps are somewhat simplified representations of plume geometry because of map scale, the lack of detailed information, and the fact that plume depth and thickness cannot be fully represented on a two-dimensional map. Plume maps are a powerful tool because knowledge of concentrations in surrounding wells, knowledge of ground-water flow, site geology, and other available information may be factored into the preparation. This minimizes the impact of uncertainty or error in any particular sample.

Radiological Analysis

Most ground-water samples collected onsite in 1992 were analyzed for ^{3}H. Selected samples were subjected to more extensive radiological analysis by alpha-, beta-, and gamma-counting techniques, in many cases accompanied by selective radiochemical separations. These techniques allow the analysis of individual radionuclides. Uranium analyses were performed by a laser fluorescence method or by alpha counting. Results from the former method are reported in µg/L; results for the latter are reported in pCi/L. A list of radionuclides analyzed is presented in Table 5.25. The radiological monitoring network for most areas on the Hanford Site is shown in Figures 5.49 and 5.50. Figures 5.51 and 5.52 show monitoring wells in the 200-East and 200-West Areas, respectively. Figure 5.53 shows RCRA ground-water monitoring projects throughout the Hanford Site.

Chemical Analysis

Nitrate analyses were typically performed on samples collected during 1992 because of the extensive areas with elevated nitrate concentrations originating from on- and offsite sources. Selected monitoring wells were used for additional chemical surveillance. Chemical sampling wells were chosen by considering the results of previous chemical analyses and the proximity to known active and inactive chemical disposal sites. Table 5.26 lists major contaminants found in each area. The list of chemicals analyzed is presented in Table 5.25, including most parameters investigated onsite. Several of these parameters are seldom analyzed currently because sufficient characterization has been obtained by past analyses.

Results

Ground-water monitoring information obtained for the RCRA monitoring program is reported by DOE (DOE 1993b) and for drinking water supplies on the Hanford Site by Hanford Environmental Health Foundation (e.g., Thurman 1992). Onsite drinking water supply wells at the FFTF are discussed in Section 6.0, "Potential Radiation Doses from 1992 Hanford Operations." Information gathered in support of the CERCLA program are reported in Remedial Investigation reports (e.g., DOE 1992f). Sitewide ground-water monitoring results for

Table 5.26. Major Chemical and Radiological Ground-Water Contaminants and Their Link to Site Operations

Facilities Type	Area	Constituents
Reactor Operations	100	tritium, ^{60}Co, ^{90}Sr, Cr^{+6}, SO_4
Irradiated Fuel Processing	200	tritium, ^{137}Cs, ^{90}Sr, ^{129}I, ^{99}Tc, NO_3^-, Cr^{+6}, CN^-, F^- U, Pu
Plutonium Purification	200	Pu, ^{241}Am, NO_3, CCl_4, $CHCl_3$
Fuel Fabrication	300	U, ^{99}Tc, Cr^{+6}, Trichloroethylene, Cu

the year are in the Ground-Water Environmental Surveillance Programs annual report (e.g., Evans et al. 1992) and listed in a complementary volume to this report. Highlights of those results are discussed below.

One way to assess the impact of radionuclides and chemicals in ground-water is to compare the concentrations to EPA's DWS and DOE's DCGs (Tables C.2, C.3, and C.6, Appendix C). Specific drinking water standards have only been proposed for a few radiological constituents at the time this report was prepared. Drinking water standards have been calculated for other radionuclides by considering the half-life of the isotope, the energy and nature of the radioactive decay for that isotope, and physiological factors such as the buildup of the isotope in particular organs. Drinking water standards are more restrictive than the DCG because the DWS are based on an annual dose to the affected organ of 4 mrem/yr and the DCG are based on an effective dose equivalent of 100 mrem/yr (see Appendix C "Applicable Standards and Permits and Environmental Compliance Documentation"). The DCGs are available only for radionuclides. Derived Concentration Guides are presented in DOE Order 5400.5.

Radiological Monitoring Results for the Unconfined Aquifer

Radionuclides analyzed for in ground water are listed in Table 5.25. Ruthenium-103, ^{106}Ru, and ^{131}I have relatively short half-lives and historically have been detected near operating reactors or liquid waste disposal facilities near active fuel reprocessing facilities. These radionuclides have not been observed in concentrations above the DWS, and in general, have not been detected since soon after the shutdown of N Reactor and the PUREX Plant. The detection limit for ^{106}Ru by gamma-scan is higher than the DWS but the half-life of only 1 year indicates that it decays rapidly to concentrations less than the DWS. Gross (total) alpha and beta are used as indicators of radionuclide distribution and are not discussed in detail because the radionuclides contributing to these measurements are discussed. The distribution of ^{3}H, ^{60}Co, ^{90}Sr, ^{99}Tc, ^{125}Sb, ^{129}I, ^{137}Cs, uranium, and plutonium, will be discussed in the following sections. The type of operation resulting in the release of these radionuclides to the ground water are listed in Table 5.26. The table also lists the locations where these operations were performed.

Tritium. Tritium is present in many waste streams discharged to the soil column and is the most mobile radionuclide onsite. As a result, ^{3}H reflects the extent of contamination in the ground water from Site operations and is the radionuclide most frequently monitored at the Hanford Site. Figure 5.54 shows the 1992 distribution of ^{3}H in the unconfined aquifer resulting from over 47 years of Site operations. Contours of ^{3}H concentrations were based on the analysis of ground-water samples collected from monitoring wells.

Extensive ^{3}H plumes are associated with past activities at the 100-N, 200-East, and 200-West Areas. The ^{3}H plume from the 200-East Area affects ground water in the 400 Area. Tritium concentrations greater than the 20,000 pCi/L DWS were also detected in the 100-D and 100-K Areas.

Tritium concentrations greater than the DWS were only detected in one well (199-D2-5) in the 100-D Area.

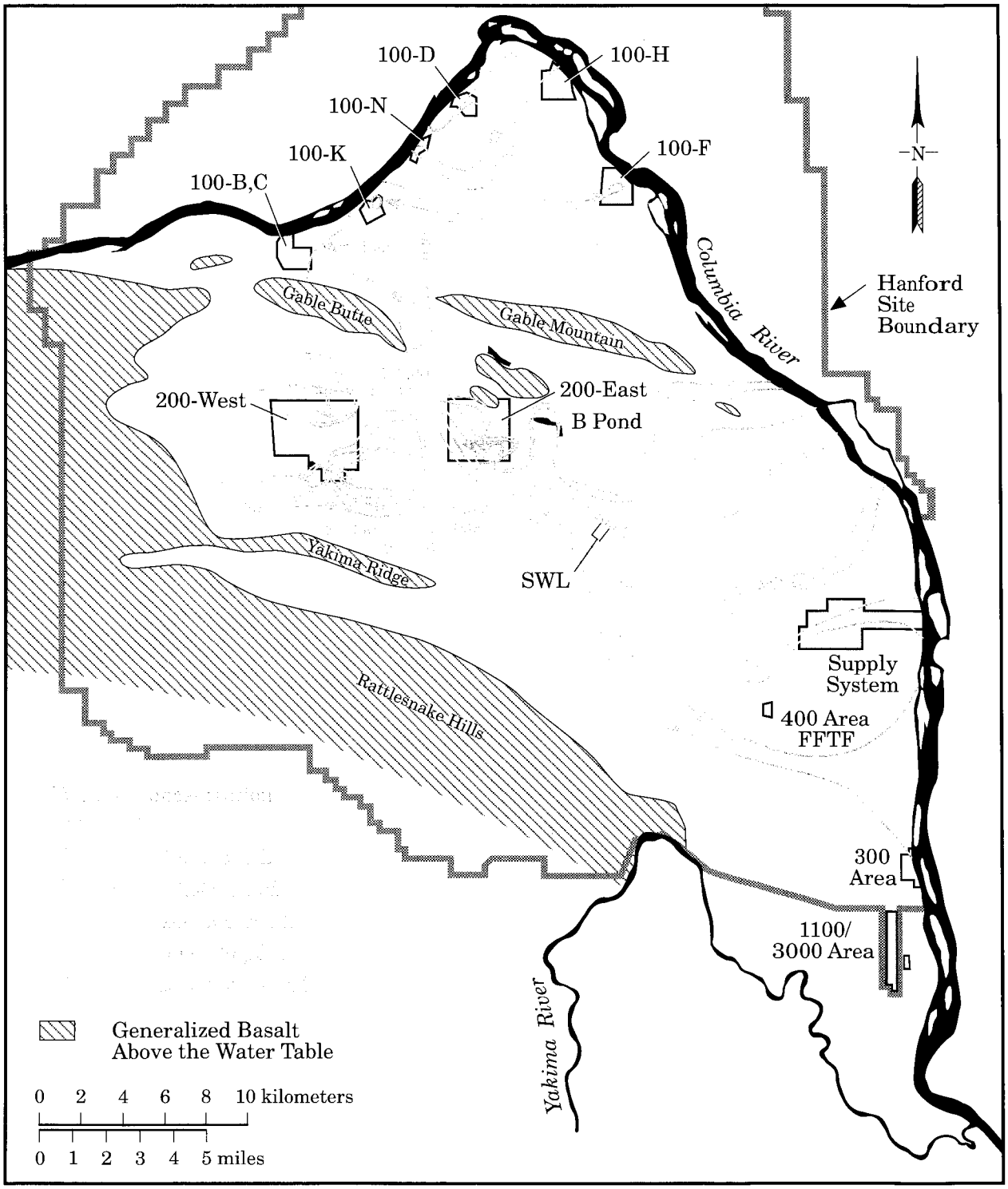

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Figure 5.54. Tritium (^3H) Concentrations in the Unconfined Aquifer, 1992

Tritium levels of 39,700 pCi/L were detected. This was slightly higher than concentrations detected in previous years.

The 100-K Area well, 199-K-30, continued to contain the highest ^3H concentration within the 100 Areas with a maximum concentration of 1,690,000 pCi/L. This concentration was considerably higher than that detected in 1989 and 1990, when the maximum concentration was 882,000 pCi/L. Concentrations in this well fluctuate; the previous high was in late 1987. Thus, the long-term trends are difficult to predict. Concentrations in well 199-K-27 also generally stayed above the DWS but remained well below the high of 179,000 pCi/L observed in 1989.

Concentrations greater than the 2,000,000-pCi/L DCG were detected in four wells in the 200-East Area. The highest ^3H concentrations in the 200-East Area continued to be in wells near cribs that have received effluent from the PUREX Plant. Tritium concentrations greater than the DCG were present in wells near the 216-A-10 and 216-A-36B cribs. Two wells monitoring downgradient of the 216-A-10 crib were above the DCG in 1992. The ^3H concentrations in well 299-E17-1 continued a generally decreasing trend but remained above the DCG in 1992. Concentrations in well 299-E17-20 also continued a generally decreasing trend in ^3H concentrations and dropped slightly below the DCG in December 1992.

Well 299-E17-9, monitoring the 216-A-36B Crib, continued to have the highest detected ^3H concentrations in the 200-East Area. Tritium levels detected in this well in 1992 ranged from 3,660,000 to 4,080,000 pCi/L. Well 299-E17-14, which also monitors the 216-A-36B Crib, was slightly above the DCG in May 1992 but dropped to 1,890,000 pCi/L in December 1992.

The ground-water ^3H concentrations measured in well 299-E25-19, near the 216-A37-1 Crib, dropped below the DCG in late 1991 and in 1992. Tritium concentrations exceeding the DWS continued to occur in many wells affected by cribs near the PUREX Plant.

The movement of the widespread ^3H plume (see Figure 5.54) extending from the southeastern portion of the 200-East Area to the Columbia River was consistent with patterns noted earlier (Evans et al. 1992; Woodruff et al. 1992). Separate ^3H pulses associated with the two episodes of PUREX operations can be distinguished in the plume. The 200,000- to 2,000,000-pCi/L lobe east of the 200-East Area near the Columbia River is a result of discharges to ground water during the operation of the PUREX Plant from 1956 to 1972. Following an 11-year shutdown, plant operation began again in 1983 and ceased in December 1988. Elevated ^3H concentrations measured in several wells (e.g., wells 699-32-43 and 699-24-33) downgradient from the 200-East Area represent the formation of a second pulse of ^3H moving away from PUREX waste disposal facilities. Large-scale movement of the leading edge of this plume is best observed in well 699-24-33, Figure 5.55, which shows arrival of the plume in early 1987 following the passage of the plume from the earlier campaign. The first plume had reached much higher levels in the mid-1960s. By contrast, a trend plot of the ^3H concentrations in well 699-40-1 located near the shore of the Columbia River (Figure 5.56) shows the arrival in the early 1970s of the plume from the first campaign and no indication that the second plume has yet arrived.

The eastern portion of the ^3H plume continues to move to the east-southeast and discharge into the Columbia River. Figure 5.57 shows the trend of ^3H concentrations in well 699-S19-E13, located just north of the 300 Area. In recent years, this well has shown a steady increase in ^3H, having reached a new maximum value of 11,600 pCi/L in November 1992. The plume is not expected to move farther south than the 300 Area because of the influence of the Yakima River and recharge at the North Richland Wellfield on ground-water flow in this area. The Yakima River is at a higher elevation than the ground water in this area, which is in turn at a higher elevation than the Columbia River (Newcomer et al. 1991). As a result, ground water flows from west to east, limiting the extent of southward movement of the contaminant plume. Recharge ponds at the North Richland Wellfield supply infiltration of Columbia River water to the ground water. The amount of recharge water exceeds the amount pumped at the wellfield, resulting in ground-water flow away from the wellfield. This further ensures that the Site ground water will not reach the wellfield.

The configuration of the western portion of the ^3H plume closely matches previous predictions of the direction of contaminant movement from the 200-East Area (Freshley and Graham 1988). Movement is forced to the south by the spreading ground-water mound beneath B Pond. This mound is spreading as a result of increased discharge of steam condensate and process cooling water to B Pond since 1984 when Gable Mountain Pond was deactivated. Flow to the southeast also appears to be

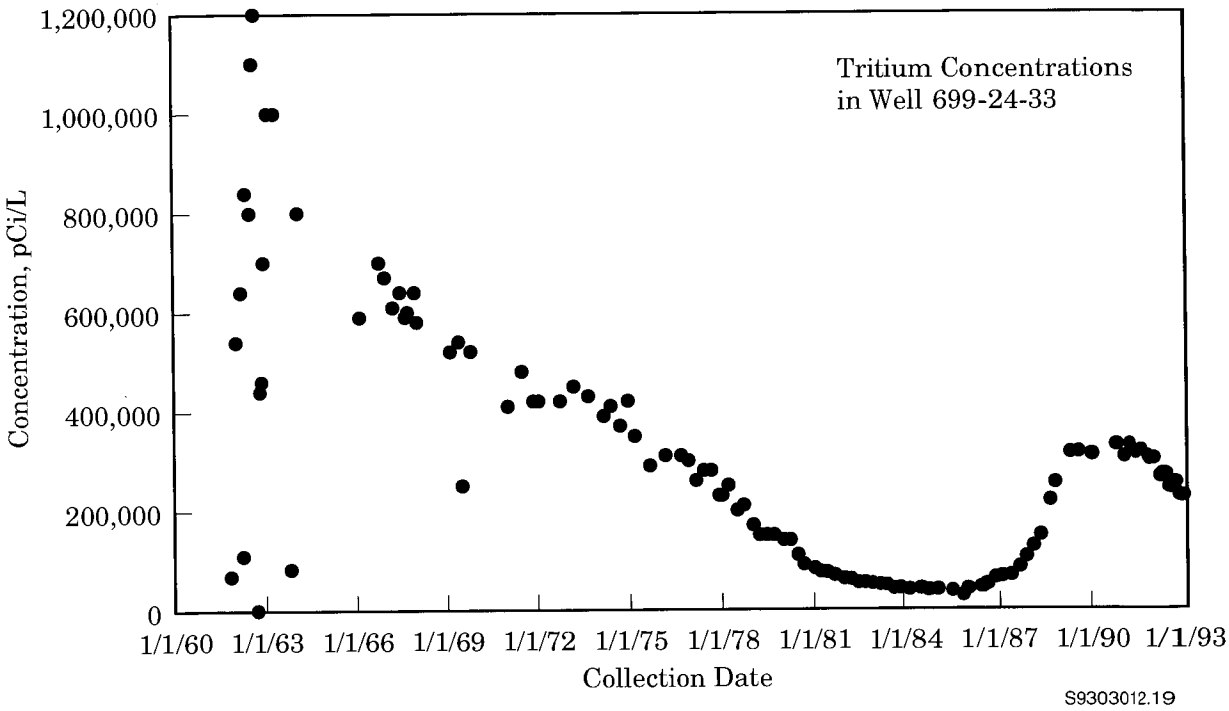

Figure 5.55. Tritium (^3H) Concentrations in Well 699-24-33, 1962 Through 1992

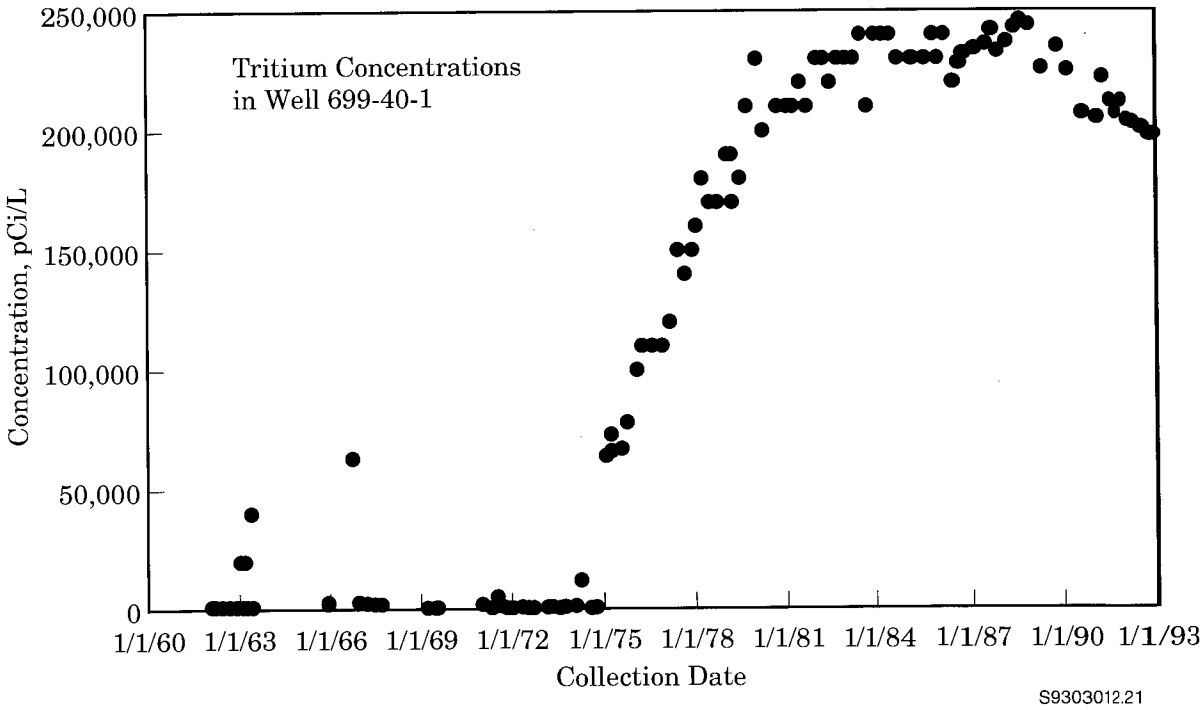

Figure 5.56. Tritium (^3H) Concentrations in Well 699-40-1, 1962 Through 1992

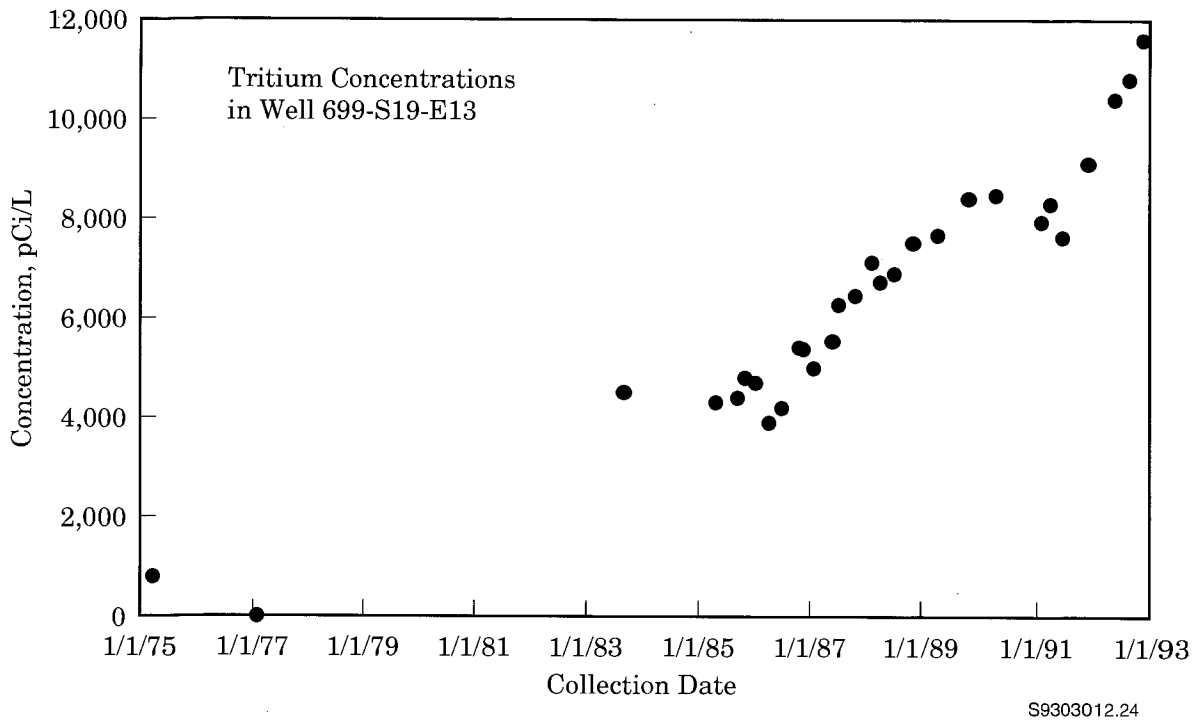

Figure 5.57. Tritium (^3H) Concentrations in Well 699-S19-E13, 1975 Through 1992

promoted by a zone of high permeability sediments stretching from the 200-East Area toward the 400 Area (Jacobson and Freshley 1990).

The movement of ^3H plumes in the 200-West Area was also consistent with previous observations. The plume extending from near the Reduction Oxidation (REDOX) Plant in the southern part of the 200-West Area continued to move slowly to the east and north. Only one well in the 200-West Area (299-W22-9) continued to show ^3H levels in excess of the DCG during 1992; however, that well contained up to 4,450,000 pCi/L, the highest ^3H levels of any ground-water monitoring wells on the Site. The ^3H concentrations detected in well 299-W22-9 have decreased steadily since 1977 (Figure 5.58).

Movement of the REDOX Plant ^3H plume is expected to be slow because of the low permeability of the sediments in this area and the declining flow from the ground-water mound beneath the nearby U Pond since the pond's deactivation. Tritium concentrations in individual wells are affected by the original source concentration, radioactive decay during the travel time to the well, and dispersion or dilution of the plume.

Cobalt-60. All ^{60}Co concentrations were consistently near or below the detection limit (20 pCi/L) for wells monitored in 1992 except for two wells. The first well, 299-E17-16, is in the area south of the PUREX Plant in the 200-East Area. Results for ^{60}Co analyses from this well in 1992 ranged from 38 to 92.8 pCi/L, which remain below the DWS of 100 pCi/L. Transport of ^{60}Co in this area is very slow, as indicated by the limited extent of ^{60}Co detected in this highly monitored area. The second well with detectable ^{60}Co is well 699-50-53, which is located in a region north of the 200 Areas affected by waste disposal in the BY Cribs (Figure 5.59). The concentrations of ^{60}Co in this well in 1992 were up to 332 pCi/L, which is lower than the 1991 maximum of 449 pCi/L. Cobalt-60 in this area appears to be highly mobile, probably because of the presence of a soluble cobalt-cyanide (or ferrocyanide) complex associated with the plume originating in the BY Cribs.

Strontium-90. Concentrations of ^{90}Sr were above the 8 pCi/L DWS in wells in the 100-B, 100-D, 100-F, 100-H, 100-N, 200-East, and 600 Areas. Concentrations of ^{90}Sr were greater than the 1,000-pCi/L DCG in the

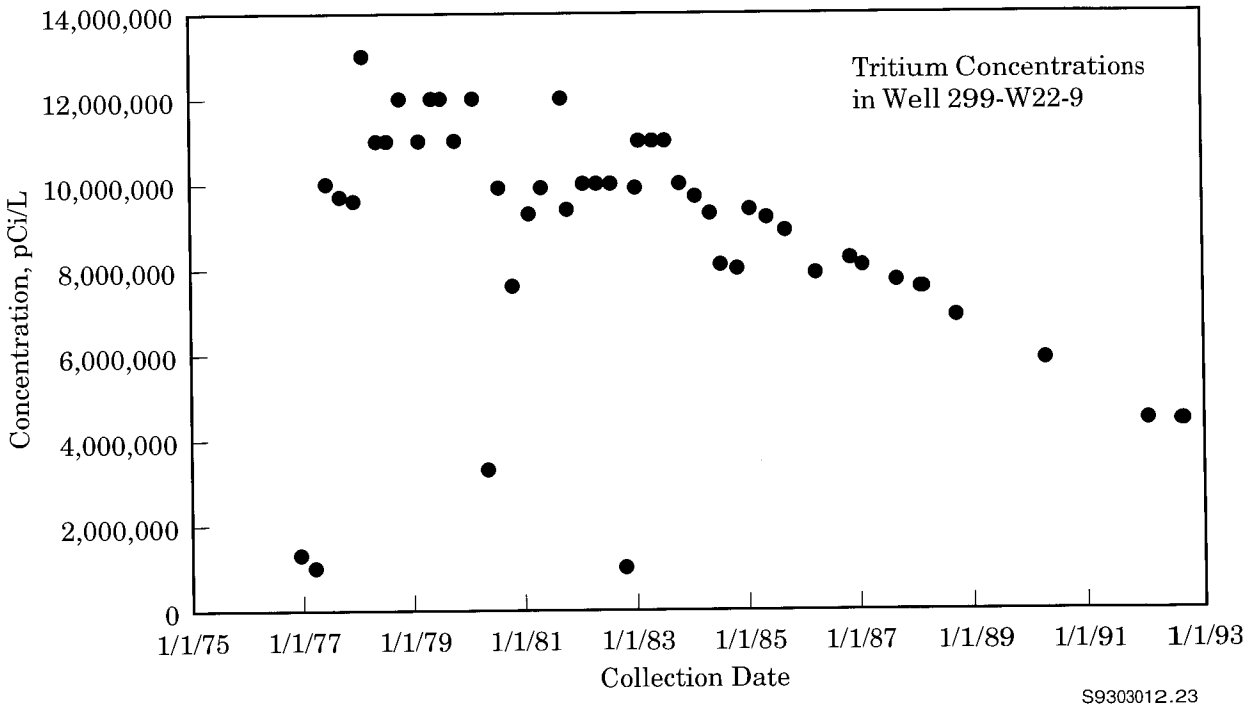

Figure 5.58. Tritium (^3H) Concentrations in Well 299-W22-9, 1976 Through 1992

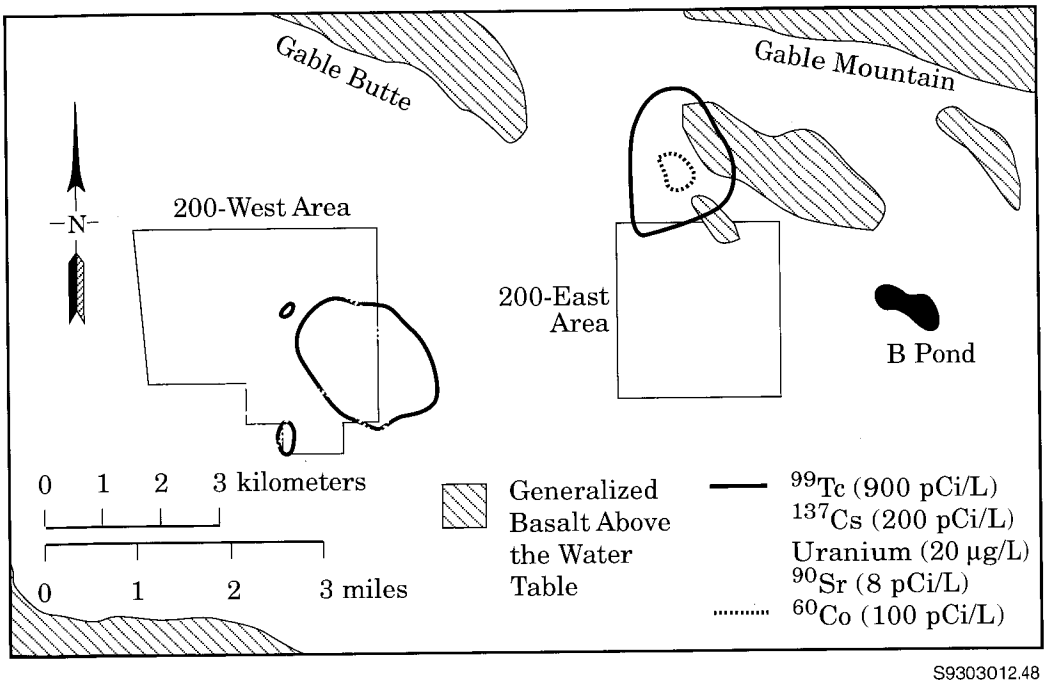

Figure 5.59. Distribution of Selected Radionuclides Greater Than the Drinking Water Standard near the 200 Areas, 1992. Drinking water standard for each constituent is shown in parantheses.

100-N and 200-East Areas. Areas with ^{90}Sr above the DWS are shown in Figures 5.59 and 5.60.

Strontium-90 was detected in concentrations up to 6,550 pCi/L in the 100-N Area in 1992 (well 199-N-46). This well is located between the 1301-N LWDF and the Columbia River. Strontium-90 discharges to the Columbia River in the 100-N Area through springs along the shoreline, which are sampled as part of the surface water surveillance and near-facility environmental monitoring programs. The ^{90}Sr plume's spread northward in the 1980s is illustrated by the trend data from well 199-N-14 (Figure 5.61). The ^{90}Sr concentrations in this well have remained approximately level since 1989. Wells farther northeast do not show detectable ^{90}Sr. The steady levels indicate the plume is not spreading at any discernible rate at this time.

Concentrations of ^{90}Sr in the 200-East Area ranged up to 7,660 pCi/L in well 299-E28-23 near the 216-B-5 Reverse Injection Well. It was not possible in 1992 to sample several of the wells in this vicinity that have been historically high in ^{90}Sr because of restrictions on access to radiation protection zones.

Concentrations of ^{90}Sr above the DWS but less than the DCG have historically been detected in several wells in the Gable Mountain Pond area. Strontium-90 contamination in that area resulted from the accidental discharge of radioactive waste to Gable Mountain Pond during its early use. Strontium-90 has since migrated through the sedimentary column to the ground water, which is relatively close to the surface at that location. Initial breakthrough occurred in 1980 in some areas. The depth to bedrock is also small in the Gable Mountain Pond area, and ^{90}Sr has been detected in wells completed in the top-of-basalt interval. Monitoring well 699-54-49 was the only well in this area sampled in 1992 with ^{90}Sr concentrations greater than the DWS. The concentrations in the October 1992 sample from well 699-54-49 were 43.9 pCi/L.

Technetium-99. Concentrations of ^{99}Tc greater than the 900-pCi/L DWS were detected in wells in the 200-East and 200-West Areas. Concentrations greater than the DWS also extended to portions of the 600 Area east of the 200-West Area and north of the 200-East Area. These locations are identified on Figure 5.59. Technetium-99 greater than the DWS has not been detected in

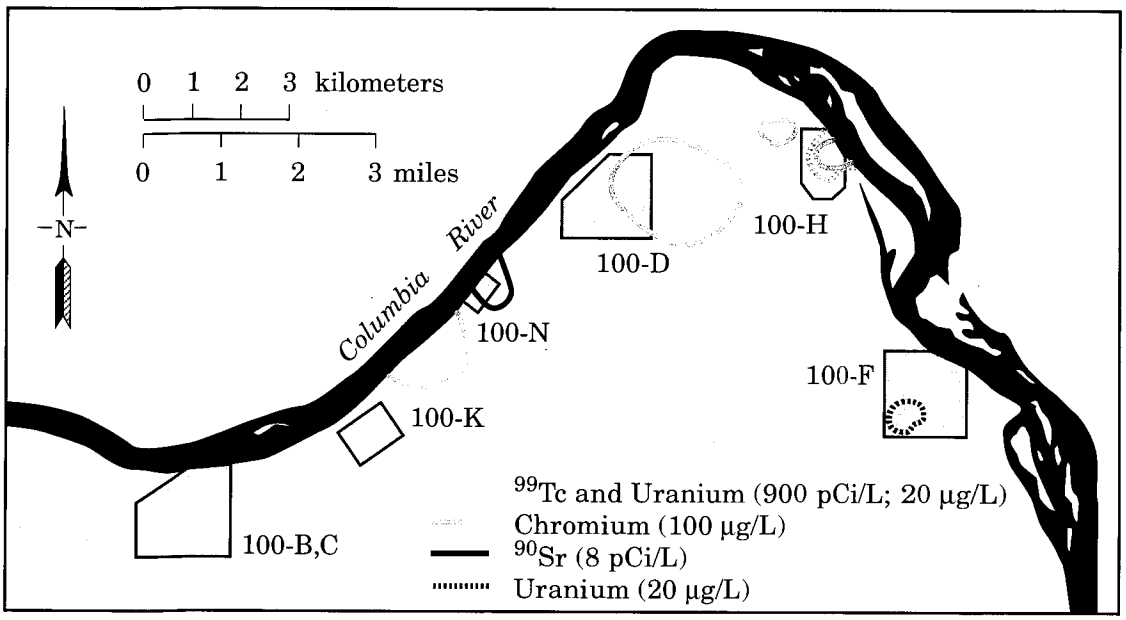

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Figure 5.60. Distribution of Selected Contaminants Greater Than the Drinking Water Standard near the 100 Areas, 1992. Drinking water standard for each constituent is shown is parentheses.

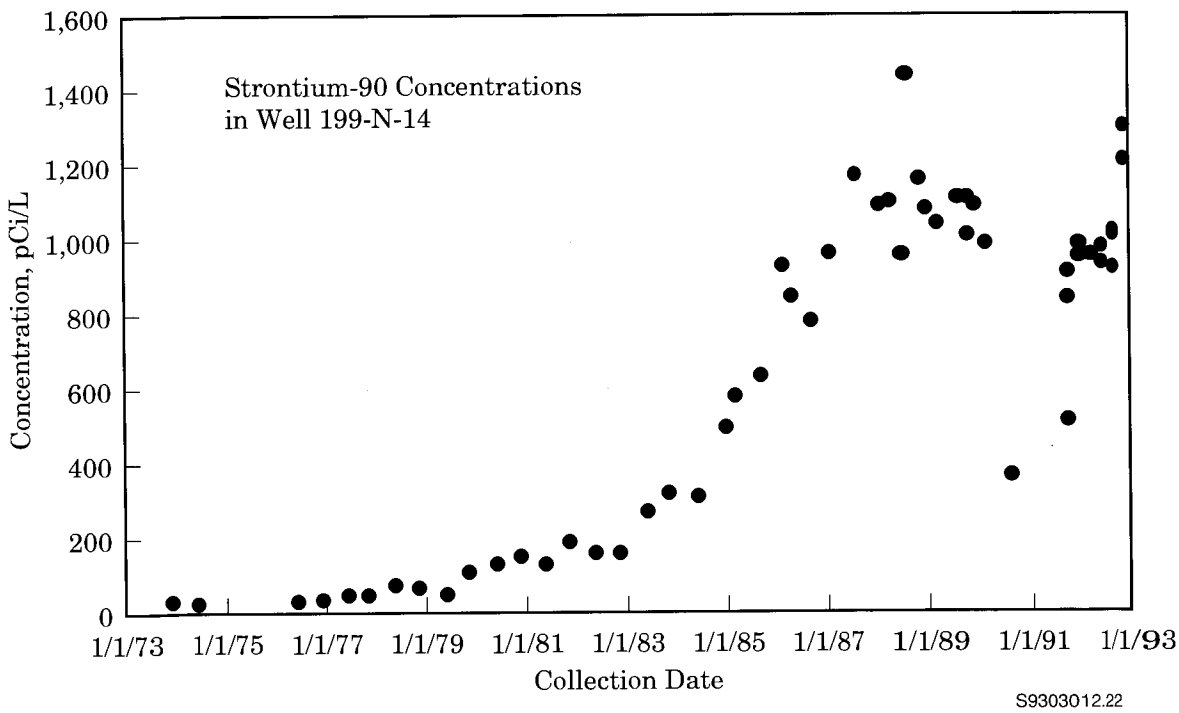

Figure 5.61. Strontium-90 (^{90}Sr) Concentrations in Well 199-N-14, 1973 Through 1992

the 100-H Area since 1990. Technetium is transported in ground water as a negatively charged (anionic) species that is highly mobile.

Antimony-125. Antimony-125 has been measured in the past in a few wells in the 100-N and 100-K Areas. Concentrations measured in samples from these two areas have been as high as 305 pCi/L near the 1325-N LWDF in 1987. The DWS for ^{125}Sb for is 300 pCi/L, and the DCG is 60,000 pCi/L. Antimony-125 was not detected at levels above the DWS in 1992. Antimony-125 has a relatively short half-life (2.7 yr) and its lack of detection in recent years is attributable to radioactive decay.

Iodine-129. The presence of ^{129}I in ground water is significant, because of its relatively low DWS (1 pCi/L), its potential for accumulation in the environment as a result of long-term releases from nuclear fuel reprocessing facilities (Soldat 1976), and its relatively long half-life (16 million years). At Hanford, the main contributor of ^{129}I to ground water has been liquid discharges to cribs in the 200 Areas. Assay of that isotope by high-sensitivity, direct-counting methods requires long counting times with correspondingly low analytical throughput. The highest concentrations observed onsite are downgradient from the PUREX and REDOX plants, in the 200-East and 200-West Areas, respectively. No ^{129}I samples were above the DCG of 500 pCi/L.

The highest ^{129}I concentrations in the 200-East Area are in the northwest near the 216-BY Cribs and in the southeast near the PUREX Plant. The maximum concentration of ^{129}I detected in 1992 in the 200-East Area was 16 pCi/L in well 299-E17-20. This well is located south of the PUREX Plant. The ^{129}I plume from the PUREX area extends southeast into the 600 Area and appears coincident with the ^{3}H and nitrate plumes. The more limited extent of the ^{129}I plume shown in Figure 5.62 results from the lower initial concentrations of ^{129}I than the initial concentrations of ^{3}H and nitrate. The ^{129}I plume likely had the same sources as the ^{3}H and nitrate. Iodine-129 has nearly the same high mobility in ground water as ^{3}H and nitrate.

The highest ^{129}I concentration observed in 1992 in Hanford ground water were 52.9 pCi/L found in well 299-W14-12. The ^{129}I plume from the 200-West Area extends into the 600 Area to the east, and is essentially coincident with the ^{3}H and nitrate plumes.

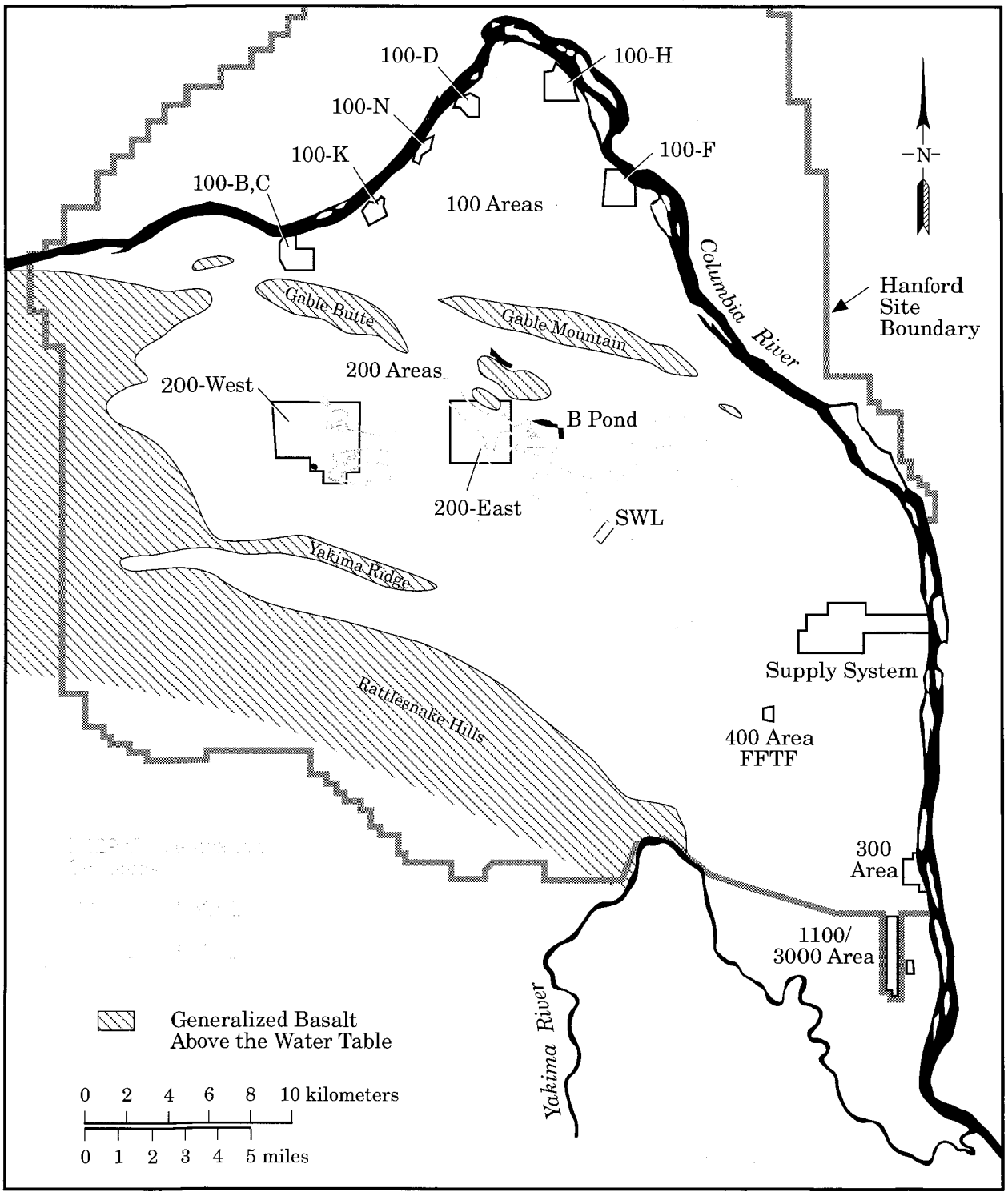

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Figure 5.62. Distribution of Iodine-129 (^{129}I) in the Unconfined Aquifer, 1992

Cesium-137. Concentrations of ^{137}Cs were below the contractual detection limit (20 pCi/L) except in one well, 299-E28-23, located near the 216-B-5 Reverse Injection Well (Figure 5.51). The 1992 sample from well 299-E28-23 contained 1,860 pCi/L of ^{137}Cs. The 216-B-5 Reverse Injection Well received an estimated 27.5 Ci of ^{137}Cs (decayed through December 31, 1992) during its use for waste disposal from 1945 to 1947 (Stenner et al. 1988). The DWS for ^{137}Cs is 200 pCi/L, and the DCG is 3,000 pCi/L. The area with ^{137}Cs above the DWS, based on 1992 and past results, is depicted in Figure 5.59. Most of the wells located near the 216-B-5 Reverse Injection Well were not sampled in 1992 because of restrictions on entry to radiation protection zones. Cesium-137 is restricted to the immediate vicinity of the reverse well by its extremely low mobility in ground water.

Uranium. The EPA has proposed a DWS of 20 µg/L for uranium. This is in contrast to other radionuclides where the standards are given in pCi/L. The reasons for the difference are that uranium is often analyzed by a fluorescence method which is calibrated in µg/L and that there is evidence that uranium ingestion may cause kidney damage, which is better assessed as a chemical hazard rather than a radiological hazard. However, uranium may be analyzed by an alpha-counting method and has an associated risk through its radioactivity so it is important to be able to convert between ground-water concentrations expressed in µg/L and those expressed in pCi/L. The conversion factor depends on the proportions of ^{234}U, ^{235}U, and ^{238}U in the ground water. The EPA considers the DWS of 20 µg/L to be equivalent to a standard of 30 pCi/L, based on a series of ground-water analyses throughout the United States (EPA 1986c). However, site-specific data for Hanford indicate that the proportion of the different uranium isotopes in ground water is nearly identical to the average proportion in natural rock. In this case, the uranium activity in pCi/L should be multiplied by 1.49 to convert to the concentration in µg/L. This gives a proposed DWS equivalent of 13.4 pCi/L. The site-specific conversion factor provides a more stringent standard for activity data and will be used in the discussion below.

Uranium has been detected at concentrations greater than the proposed DWS in the 100-F, 100-H, 200-East, 200-West, and 300 Areas. The highest concentrations detected onsite in 1992 were in the 200-West Area near the 216-U-1 and 216-U-2 cribs.

In 1992, uranium was detected at concentrations greater than the proposed DWS at one location in the 100-F Area, well 199-F8-1. The uranium concentration in this well is generally decreasing with time, from a maximum of 616 µg/L in 1988 to the 1992 value of 40.3 µg/L.

Uranium was detected at concentrations greater than the DWS in four wells in the 100-H Area. The maximum concentrations detected there in 1992 were 69.9 µg/L in well 199-H4-4.

A few wells in the 200-East Area contained uranium at concentrations greater than the proposed DWS for at least one sampling event. The highest concentration detected in the 200-East Area was 33.8 µg/L in well 299-E28-23. The concentration in this well has remained relatively steady since 1981. Well 299-E32-5 was the only 200-East Area well with more than one 1992 sample greater than the DWS. It had three quarterly samples in the 21- to 22-µg/L range. The uranium levels in this and several other 200-East Area wells appear to be decreasing to levels around or just below the proposed DWS.

The highest uranium levels in Hanford ground water occurred near U Plant in 200-West Area in wells adjacent to the inactive 216-U-1 and 216-U-2 cribs (Figure 5.62). Uranium concentrations in these wells have been decreasing over the last 5 years following remediation activities associated with those cribs. A trend plot of uranium concentrations in samples from well 299-W19-18, immediately downgradient from the cribs, is shown in Figure 5.63. The uranium levels in this well continue to decrease slowly but remain greater than the proposed DWS. The maximum concentrations detected in this area were 4,090 µg/L in one sample from well 299-W19-29; however, results from that well have been erratic since 1991 and further data are needed to interpret the trends.

A plume of uranium exists in the unconfined aquifer beneath the 300 Area in the vicinity of uranium fuel fabrication facilities and inactive waste sites known to have received uranium waste. The extent of the plume is limited to an area downgradient from active and inactive LWDFs. An Expedited Response Action performed on the 300 Area Process Trenches in mid-1991 was aimed at reducing the uranium source in that area. Use of the trenches for disposal of cooling water was resumed following completion of the remedial action, although

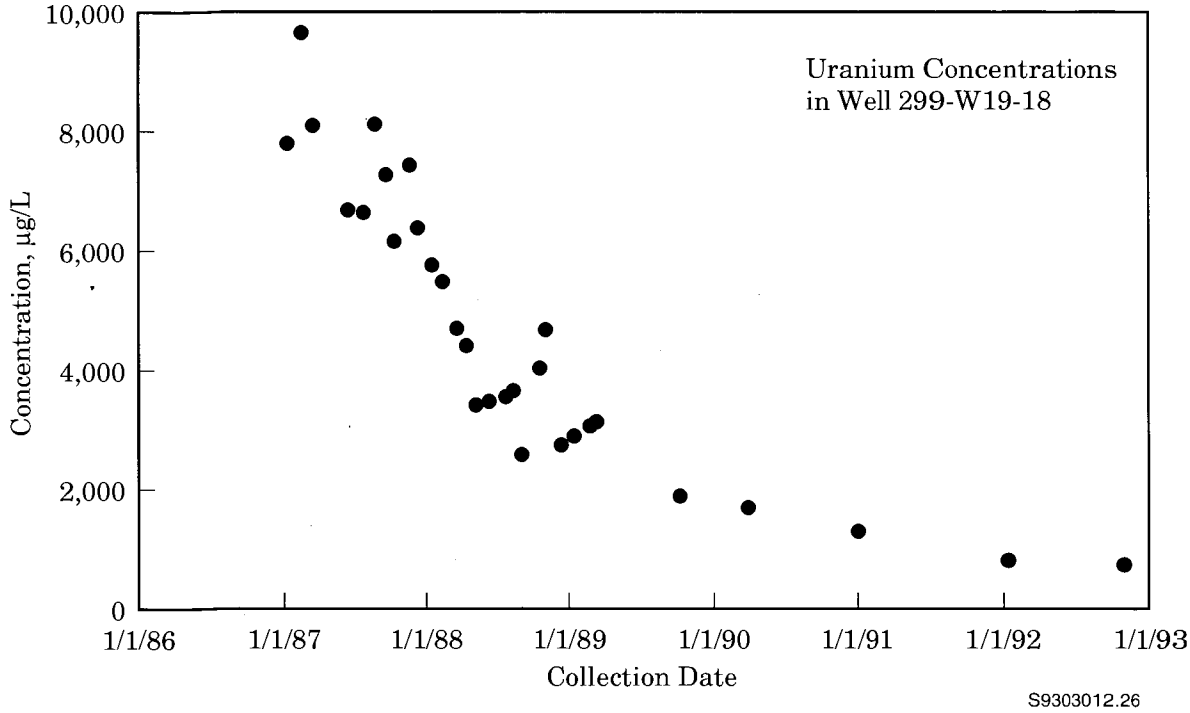

Figure 5.63. Uranium Concentrations in Well 299-W19-18, 1987 Through 1992

current discharge to the trenches is much lower than in the past. Uranium levels in well 399-1-17A appear to have been reduced following that action; levels apparently stabilized about a factor of 10 below the maximum values seen in 1990. However, results for 13 of the 52 samples collected in 1992 remained greater than the proposed DWS. A trend plot showing the uranium concentrations in that well is shown in Figure 5.64. Well 399-1-17A is located near the 300 Area Process Trenches. That well has shown cyclic variations in the uranium level in the past. Monitoring will continue to confirm the apparent improvement in uranium levels resulting from the remediation and flow reduction.

Plutonium. Concentrations of plutonium were below the detection limit in all wells sampled in 1992 except for one 200-East Area and one 200-West Area well.

Ground water sampled at 200-East Area well 299-E28-23, which is located near the 216-B-5 Reverse Injection Well, ranged from 24.2 to 33.0 pCi/L of ^{239,240}Pu in 1992. This is comparable to 1990 levels. Plutonium-238 was also detected in well 299-E28-23 but at considerably lower levels ranging from 0.09 to 0.15 pCi/L. The 216-B-5 Reverse Injection Well received an estimated 244 Ci of ^{239,240}Pu during its operation from 1945 to 1947 (Stenner et al. 1988). The DCG of 300 pCi/L for ^{239}Pu was reduced to 30 pCi/L effective February 1990. There is no explicit DWS for ^{239}Pu; however, the gross alpha DWS of 15 pCi/L would be applicable at a minimum. Alternately, if the DCG (which is based on a 100-mrem dose standard) is converted to the 4-mrem dose equivalent used for the DWS, 1.2 pCi/L would be the relevant guideline. Plutonium is generally considered to bind strongly to sediments and thus has limited mobility in the aquifer.

The April 1992 sample from 200-West Area well 299-W23-13, an upgradient well for the S-SX single-shell tanks, was reported to contain 0.26 pCi/L of ^{239,240}Pu. This low-concentration sample is the only 200-West Area sample in which plutonium was detected, and plutonium was not detected in the other three quarterly samples. Plutonium-239, 240 was detected in 1990 and 1991 in a 200-West Area well, 299-W15-8, which monitors the 216-Z-9 Crib. The 216-Z-9 Crib received a large burden of plutonium and americium from Z Plant liquid effluent streams. Well 299-W15-8 was not sampled in 1992 because there was insufficient water in the well to collect a sample.

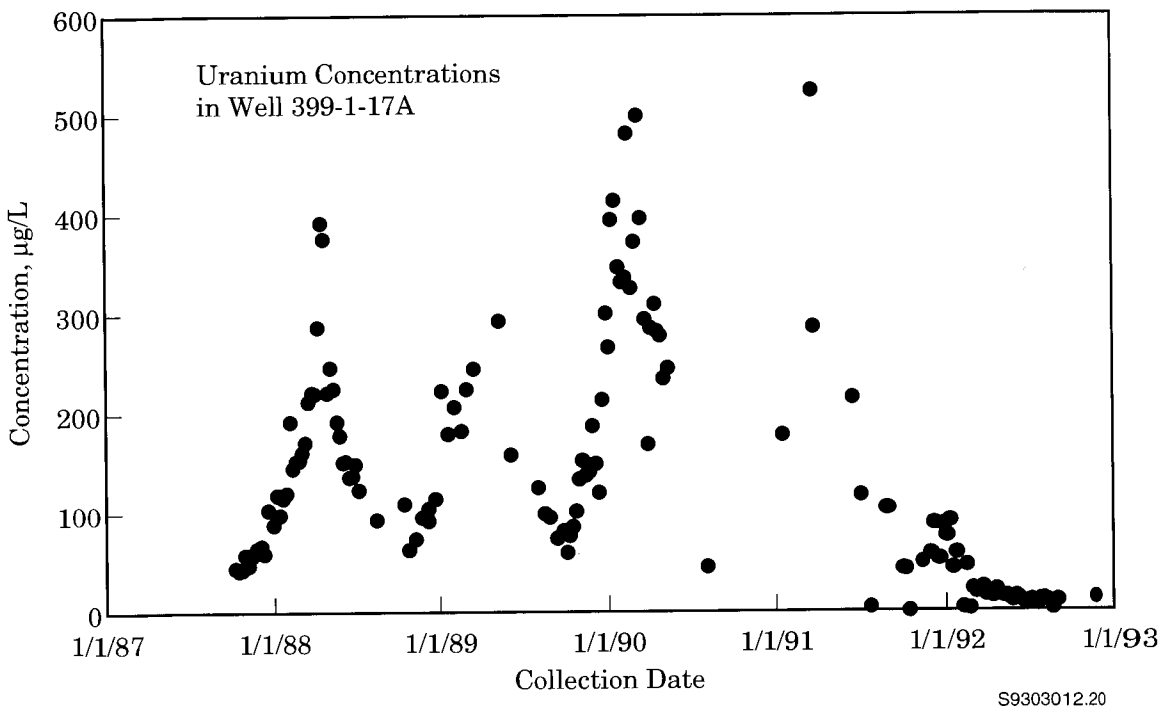

Figure 5.64. Uranium Concentrations in Well 399-1-17A, 1987 Through 1992

Chemical Monitoring Results for the Unconfined Aquifer

Chemical analyses performed on ground-water samples by various monitoring programs at Hanford have identified eight hazardous chemicals occurring in ground water at concentrations greater than existing or proposed federal drinking water standards. These are nitrate, cyanide, fluoride, chromium, carbon tetrachloride, chloroform, trichloroethylene, and tetrachloroethylene.

A number of the constituents measured such as conductance, total carbon, total organic carbon, and total organic halogens are used as indicators of contamination. These will not be discussed in detail in this report because the specific contaminant contributing to these parameters will be discussed. Other chemicals listed in Table 5.25 are indicators of the natural chemical composition of ground water and in general are not contaminants from operations at Hanford. These include alkalinity, pH, sodium, magnesium, potassium, aluminum, silica, calcium, manganese, and iron. Chloride and sulfate are both naturally occurring and site-related constituents. There is no primary DWS for chloride or sulfate (the secondary standard for each is 250,000 µg/L and is based on aesthetic rather than health considerations) so they will not be discussed in detail. The analytical technique used to determine the concentration of metals in ground water provides results for a number of constituents that are rarely observed above background concentrations such as vanadium, nickel, copper, zinc, strontium, silver, cadmium, antimony, barium, beryllium, and boron.

The following subsections present additional information on the eight chemical constituents occurring in ground water at concentrations above existing or proposed DWS.

Nitrate. Most ground-water samples collected in 1992 were analyzed for nitrate. Nitrate was measured at concentrations greater than the DWS (45 mg/L as NO_3 ion) in wells in all operational areas except the 100-B and 400 Areas.

Although nitrate is associated primarily with process condensate liquid wastes, other liquids discharged to ground also contained nitrate. Nitrate contamination in the unconfined aquifer reflects the extensive use of nitric

acid in decontamination and chemical reprocessing operations. Nitrate, like ^{3}H, can be used to define the extent of contamination because nitrate is present in many waste streams and is mobile in ground water. However, additional offsite sources of nitrate are located to the west and southwest. The distribution of nitrate on the Hanford Site is shown in Figure 5.65. The nitrate distribution shown in Figure 5.65 is similar to previous evaluations.

The highest nitrate concentrations in the 200-East Area continued to be found near LWDFs that received effluent from PUREX operations. Nitrate concentrations in wells near the 216-A-10 and 216-A-36B Cribs have generally tended to decrease in the past few years but remained above the DWS even though these facilities were removed from service in 1987.

The configuration of the nitrate plume emanating from the 200-East Area shows the influence of two periods of PUREX operation and recent changes in the operation of B Pond. The location of B Pond is shown in Figure 5.49. Increases in the volume of low-nitrate process cooling water discharged to B Pond apparently result in an expanding area of "clean" ground water to the east and south of B Pond (see Figure 5.65). The nitrate ground-water plume related to PUREX operations discharges to the Columbia River along a stretch from east of Gable Mountain to the northern portion of the 300 Area. Further spread of the nitrate plume south of the 300 Area is restricted by ground-water flow from the Yakima River east- and northeastward to the Columbia River. Further consideration of the influence of ground-water flow in this area is discussed above with regard to the ^{3}H plume.

Nitrate concentrations greater than the DWS were widespread in ground water beneath the 200-West Area. Highest concentrations were centered in three locations: 1) wells near U Plant, 2) wells in the north-central part of the 200-West Area, and 3) wells near the 216-S-25 Crib. The highest nitrate concentrations across the Site continued to be found in wells east of U Plant near the 216-U-17 Crib. The presence of nitrate in wells near this crib was observed before February 1988 when the crib went into operation. The source of nitrate is believed to be wastes disposed of in the 216-U-1 and 216-U-2 Cribs. These cribs received over 1 million kg of nitrate during their operation from 1951 to 1967 (Stenner et al. 1988). Nitrate concentrations in wells located near the 216-U-1 and 216-U-2 Cribs west of U Plant continued to decrease, with concentrations in several of the wells dropping below the DWS. For example, the nitrate concentrations in well 299-W19-18 located near U Plant have decreased to less than the DWS as shown in Figure 5.66.

Several wells in the northwestern part of the 200-West Area continued to contain nitrate at concentrations greater than the DWS. These wells are located near several inactive LWDFs that received waste from early T Plant operations. Maximum concentrations in these wells in 1992 ranged up to 650,000 µg/L in well 299-W15-4, similar to that observed in recent years.

Although most nitrate observed onsite is the result of Hanford operations, elevated nitrate concentrations in wells in the western part of the Site appear to be the result of increasing agricultural activity in Cold Creek Valley, west of Hanford. There is no known source of nitrate in that area associated with Site operations, and wells located between well 699-36-93 and Hanford waste disposal facilities show no evidence of plume passage. Nitrate levels have fluctuated considerably in wells in the western part of the Site over the past 30 years and again appear to be increasing, particularly in well 699-36-93. Nitrate levels have been at or greater than the DWS in that well since 1985.

Nitrate concentrations near the city of Richland and in the 1100 Area, 3000 Area, and adjacent parts of the 600 Area are also apparently affected by offsite nitrate sources. These sources may include agriculture, food processing, urban horticulture, and nuclear fuel processing at commercial offsite facilities.

Cyanide. In past monitoring activities, cyanide was detected in samples collected from wells in and directly north of the 200-East Area. The cyanide source is believed to be wastes containing ferrocyanide disposed of in the 216-BY Cribs. Samples taken from the 200-East Area in 1992 had a maximum cyanide concentration of 130 µg/L in one sample from well 299-E33-41, which is in the 241-B Tank Farm area, southeast of the BY Cribs. Other samples from this well do not confirm the presence of cyanide. Well 699-50-53, north of the BY Cribs, continued to contain detectable cyanide (110 µg/L in 1992) but at concentrations considerably lower than in previous years. Wells containing cyanide often contain concentrations of several radionuclides, including ^{60}Co. Although ^{60}Co is normally immobile in the subsurface, it appears to be chemically complexed and mobilized by cyanide or ferrocyanide. A chemical speciation study

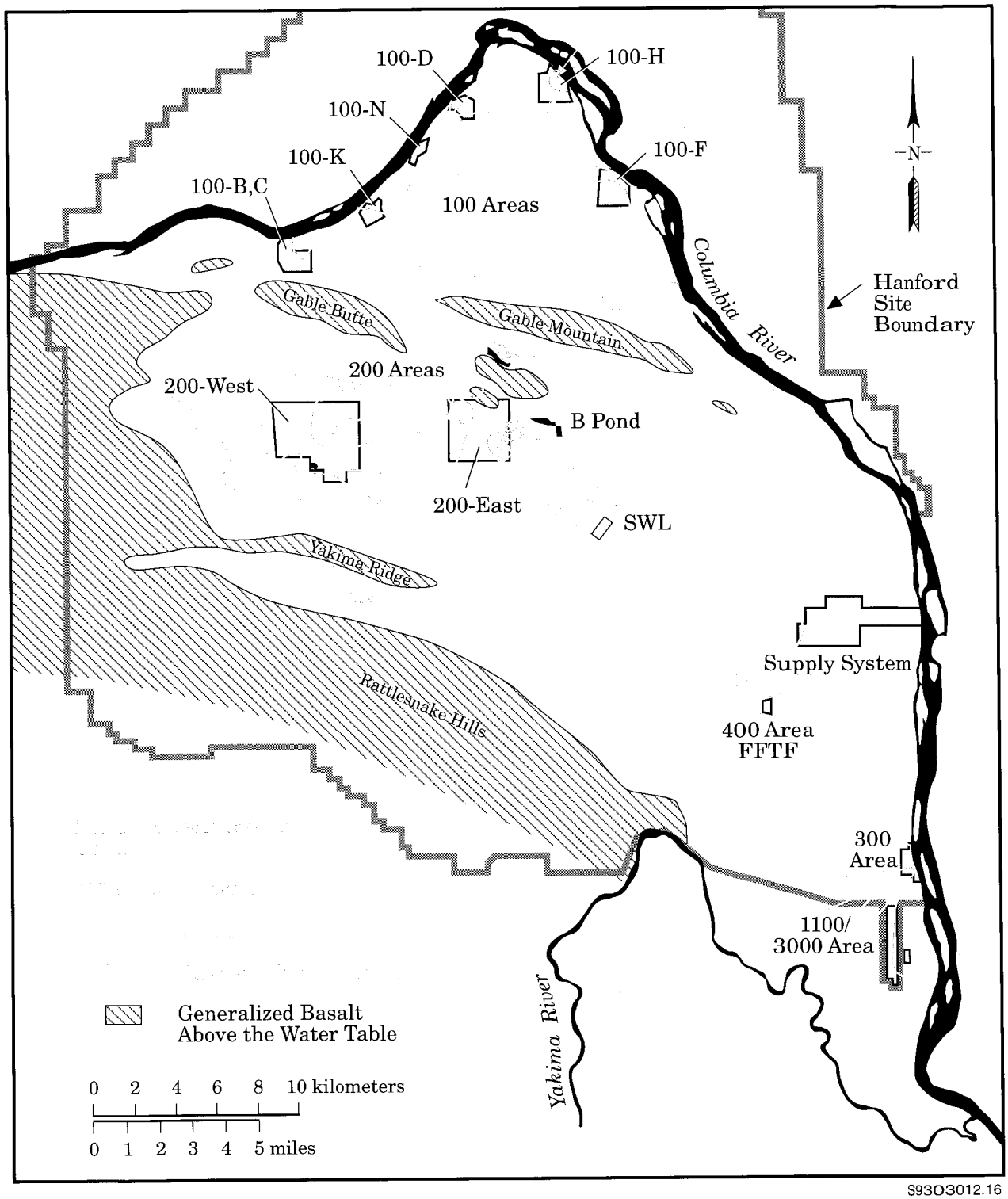

Figure 5.65. Distribution of Nitrate (NO_3^-) in the Unconfined Aquifer, 1992

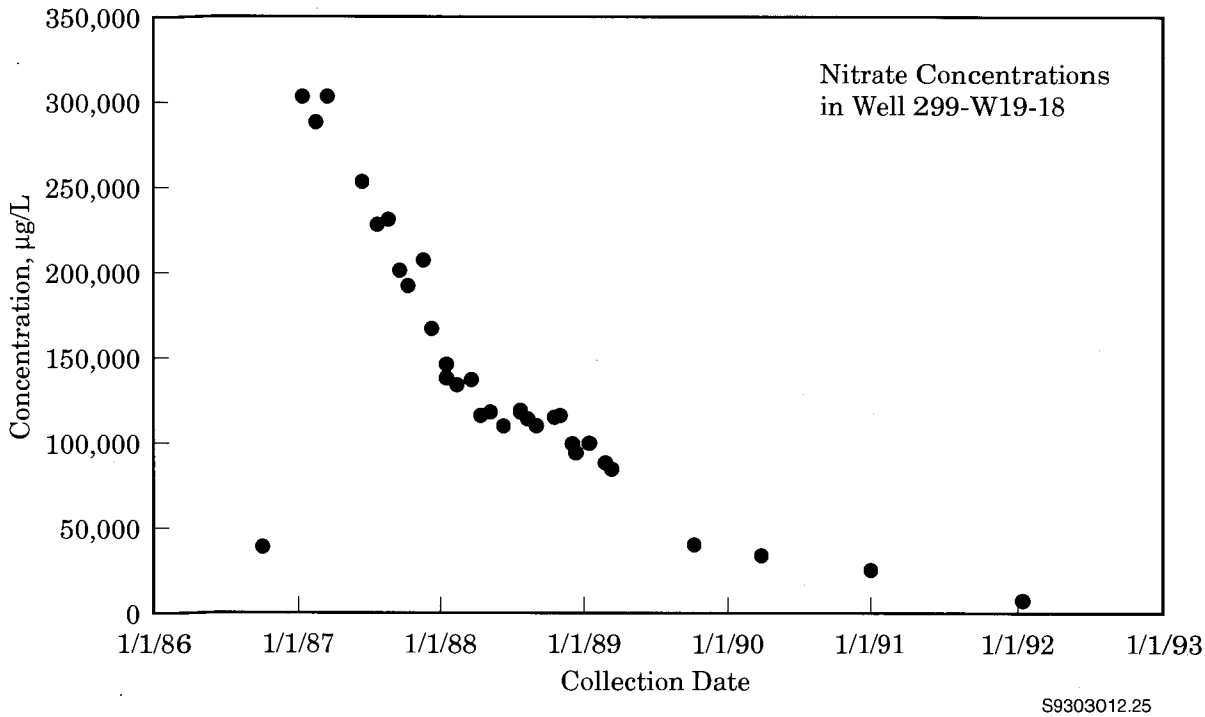

Figure 5.66. Nitrate (NO_3^-) Concentrations in Well 299-W19-18, 1986 Through 1992

performed in 1988 indicated that approximately one-third of the cyanide is present as free cyanide and the rest may be present as ferrocyanide (Evans et al. 1989a, 1989b).

Cyanide forms two distinct plumes in the 200-West Area; the highest level reported in 1992 was 70 µg/L in wells 299-W14-2 and 299-W18-5. No formal DWS has been established for cyanide. A standard of 200 µg/L has been proposed by the EPA.

Fluoride. Fluoride currently has a primary DWS of 4.0 mg/L and a secondary standard of 2.0 mg/L. Secondary standards are based primarily on aesthetic considerations and are not federally enforceable rules, although the State of Washington claims the right to require corrective action from drinking water suppliers if secondary standards are exceeded. Both standards will be used in the discussion below; however, it should be remembered that only the primary standard is based on health considerations and that the DWS are only an indication of the degree of contamination because the area of elevated fluoride is far from any drinking water supply. Fluoride was detected at levels greater than the primary DWS in the 200-West Area and greater than the secondary standard in the 200-East and 200-West Areas.

Fluoride concentrations greater than the 2.0-mg/L secondary standard occurred in one 200-East Area well, 299-E28-24, near the 216-B-5 Reverse Injection Well. The maximum concentration detected in this well in 1992 was 2.7 mg/L.

A few wells in the 200-West Area near T Plant had fluoride concentrations greater than the secondary standard in 1992, although only two wells were greater than the primary DWS. A 200-West Area well (299-W10-15) showed a fluoride concentration of up to 5.0 mg/L in 1992. Well 299-15-4 showed the maximum fluoride onsite with a concentration of 7.2 mg/L. A map depicting the area of fluoride concentrations greater than the secondary standard in the 200-West Area is shown in Figure 5.67. Aluminum fluoride nitrate use in the 200-West Area processes is the probable source of the fluoride plume.

Chromium. Both filtered and unfiltered samples were collected for chromium and other metals from many of the wells onsite. Unfiltered samples may contain metals present as particulate matter, while filtered samples are representative of the more mobile dissolved metals. Filtered samples may also contain some colloidal particles fine enough to pass through the filter. Drinking water

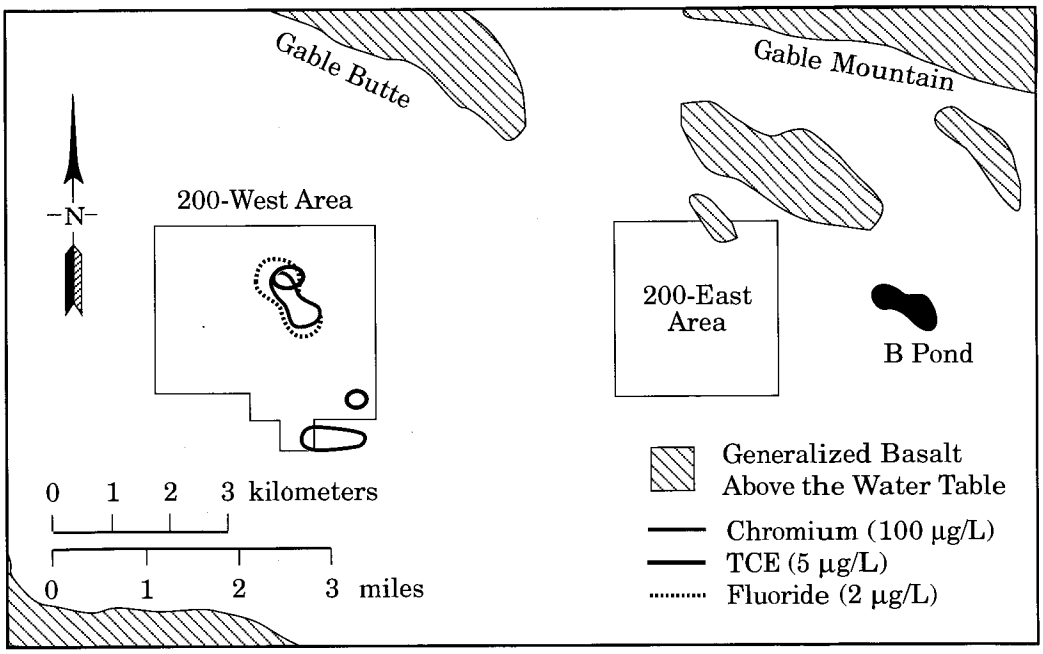

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Figure 5.67. Distribution of Selected Hazardous Chemicals Greater Than the Drinking Water Standard near the 200 Areas, 1992. Drinking water standard for each constituent is shown in parentheses.

standards are based on unfiltered concentrations; however, differences in well construction and pumping between monitoring wells and water-supply wells make it difficult to predict potential drinking water concentrations from monitoring well data. Comparison of filtered to unfiltered samples provides a greater understanding of the transport of chromium onsite.

Chromium has been detected in ground water from wells in each of the 100 Areas. However, concentrations in the 100-B/C Area were less than the federal DWS of 100 µg/L (the Washington State MCL is 50 µg/L) with the exception of one anomalous value from a triplicate of analyses. The chromium distribution in the 100 Areas is shown in Figure 5.60.

High chromium concentrations were detected at similar levels in both filtered and unfiltered samples from the 100-D Area. This indicates that the chromium concentrations are representative of the mobile concentrations in the ground water.

Relatively few chromium analyses are available from the 100-F Area in 1992. Of these, only one filtered sample had detectable chromium and this was less than the DWS.

Many samples from the 100-H Area contained chromium at levels greater than the DWS. Chromium was often present at similar levels in both filtered and unfiltered samples. Potential chromium sources in the 100-H Area include disposal of sodium dichromate near the reactor building and to the 107-H Liquid Waste Disposal Trench, and chromium in acid wastes stored in the 183-H Solar Evaporation Basins (Peterson and Connelly 1992). Chromium was also detected in parts of the 600 Area adjacent to the 100-H Area.

Chromium is found in both filtered and unfiltered samples from the 100-K Area at levels greater than the DWS. In contrast, at the 100-N Area, only three samples from 1992 contained chromium at concentrations greater than the DWS. All three of these samples were unfiltered and other filtered and unfiltered samples from the same wells contained chromium at levels less than the DWS. Thus, the high concentrations at the 100-N Area may result from greater amounts of particulate matter in the samples.

Chromium at concentrations greater than the DWS in the 200-East Area is found only in unfiltered samples with the exception of samples from well 299-E24-19. The

widespread presence of chromium associated with particulate matter in the 200-East Area may be related to the stainless-steel well construction. Chromium is a component of stainless steel, and it is not clear that the sample concentrations are representative of the ground water. Well 299-E24-19 has recently developed chromium concentrations of up to 3,000 µg/L in unfiltered and 1,800 µg/L in filtered samples. These concentrations are possibly related to well corrosion because nickel (another stainless-steel component) concentrations are also increasing. Some of the chromium and nickel may be associated with ultra-fine or colloidal particles that pass through the 0.45-µm filters used in ground-water sampling.

Chromium contamination has been found at several locations in the 200-West Area. Chromium in the 200-West Area is found in both filtered and unfiltered samples, although the filtered concentrations tend to be somewhat lower in many instances. A map showing the distribution of chromium contamination in the 200-West Area is shown in Figure 5.67.

Chromium has been detected at concentrations greater than the DWS in a few unfiltered samples from the 300 Area. The concentrations in filtered samples remain less than the DWS and the detected values in the unfiltered samples are erratic. This difference suggests that the high chromium concentrations found in these monitoring wells represent particulate matter which may be related to well construction and are affected by the well purging procedures, the time between samples, or other effects that do not reflect the general ground-water quality.

Chromium greater than the DWS has also been detected in 600 Area RCRA monitoring wells near the Solid Waste Landfill and B Pond. Chromium in filtered samples, however, remained below the DWS. In the B Pond area, high chromium was found in wells monitoring the top of the unconfined aquifer and what is referred to as the semi-confined aquifer. It appears that the stainless-steel well casings or well screens may be contributing particulate chromium to the unfiltered samples.

Carbon Tetrachloride and Chloroform. Carbon tetrachloride contamination was found in the unconfined aquifer beneath much of the 200-West Area. The contamination is believed to be from waste disposal operations associated with Z Plant before 1973. A concentration of 8,100 µg/L was found in a well near Z Plant first monitored in October 1988 (well 299-W15-16). Carbon tetrachloride concentrations in well 299-W15-16 were somewhat lower in 1992, reaching a maximum of 6,700 µg/L. Numerous other wells in the area had carbon tetrachloride levels ranging from 1,000 to 5,000 µg/L. The distribution of carbon tetrachloride in the 200-West Area greater than the DWS is shown in Figure 5.68.

The carbon tetrachloride distribution in the 200-West Area ground water has remained relatively stable since the presence of the contaminant plume was first noted in 1987. The only discernible exception is the western or southwestern edge of the plume, which has shown considerable movement over the past 4 to 5 years. Figure 5.68 shows the trends in carbon tetrachloride concentrations with time for five wells located at the east, west, north, and south boundaries of the plume. Well 699-39-79 shows a major increase during 1987 and 1988, indicating arrival of the bulk of the plume at that time. Since 1988 the concentration in well 699-39-79 has remained relatively constant. The other three locations show less change although there is a distinct increase in concentration in wells located to the southeast of the plume center.

The spreading of the 200-West Area carbon tetrachloride plume to the west is counter to the ground-water flow direction. Changes in ground-water flow since decommissioning U Pond may influence the exact plume configuration and the concentrations at particular locations. Another potential influence is the continued spreading of carbon tetrachloride above the water table, in either the liquid or vapor phase. Free phase liquid carbon tetrachloride above and possibly below the water table provides a continuing source of contamination. Thus, the carbon tetrachloride plume is expected to expand slowly until remedial measures are implemented.

The DWS for carbon tetrachloride is 5 µg/L. In addition to carbon tetrachloride, significant amounts of other chlorinated hydrocarbon solvents were found in 200-West Area ground water, including trichloroethylene and chloroform. A chloroform concentration of 1,540 µg/L was measured in well 299-W15-8 in May 1990. The chloroform plume appears to be associated with but not exactly coincident with the carbon tetrachloride plume. The DWS for chloroform is 100 µg/L (total trihalomethanes), 20 times higher than that for carbon tetrachloride. The location of the chloroform plume is shown on Figure 5.69.

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Figure 5.68. Distribution of Carbon Tetrachloride (CCl_4) in the 200-West Area, 1992

Trichloroethylene. Trichloroethylene has a DWS of 5 µg/L. Trichloroethylene has been detected in wells in the 100-B/C, 100-F, 100-K, 200-West, 300 Areas, and the Solid Waste Landfill, part of the 600 Area.

Trichloroethylene has been detected in 1992 at levels less than the DWS in 100-B/C Area wells and at levels greater than the DWS in one 100-F Area and several 100-K Area wells. In addition, trichloroethylene was found at levels up to 29 µg/L in well 699-77-36, east of the 100-F Area.

Trichloroethylene was detected in 1992 at levels greater than the DWS in the 200-West Area in two locations. The first location is to the west of T Plant, and concentrations up to 34 µg/L were detected in 1992. The second location is near U Plant, where up to 6.2 µg/L, just greater than the DWS, were detected in well 299-W19-29. Several wells with trichloroethylene in 1991 samples were not sampled in 1992. These include wells in the vicinity of the REDOX Plant. The maximum level found in 1991 in a well near REDOX Plant (299-W22-20) was 34 µg/L.

Trichloroethylene and cis-1,2-dichloroethylene were found in wells monitoring the lower portion of the unconfined aquifer near the North Process Pond in the northern half of the 300 Area. Cis-1,2-dichloroethylene is a product of trichloroethylene biodegradation. Maximum concentrations in 1992 were 16 µg/L trichloroethylene and 120 µg/L cis-1,2-dichloroethylene in well 399-1-16B. Similar levels were found in nearby well 399-1-16C, which monitors the upper portion of the confined aquifer. These may be related to leakage from the unconfined aquifer from well construction. Monitoring well 399-1-16C apparently does not have an adequate seal between the confined aquifer and the aquifer above, so the chemical concentrations are not believed to be representative of the confined aquifer. Evidence for the poor seal includes a reversal in relative water levels between 399-1-16B and 399-1-16C shortly after completion of the wells. This suggests that water was being drawn down to 399-1-16C from above. The water levels have recently changed back indicating that the leakage may no longer be taking place. The water levels and chemistry continue to be monitored to determine if remediation of well 399-1-16C is needed. Trichloroethylene has only recently been observed in well 399-1-16A, which monitors the upper portion of the unconfined aquifer. The trichloroethylene concentration of 2.0 µg/L found in well 399-1-16A in 1992 remains less than the DWS. Trichloroethylene greater than the DWS was also detected in well 399-4-12, in the southern 300 Area. Past samples from other wells in this part of the 300 Area have had trichloroethylene concentrations greater than the DWS.

Several wells at the Solid Waste Landfill contained trichloroethylene close to but slightly less than the DWS. Solid Waste Landfill wells had shown trichloroethylene concentrations greater than the DWS in previous years. These wells also continued to show levels of tetrachloroethylene just greater than the 5-µg/L DWS. The source of the trichloroethylene in this area is apparently disposal of waste from vehicle maintenance operations in the mid-1980s through 1987.

Tetrachloroethylene. Tetrachloroethylene, also referred to as perchloroethylene, is found at levels greater than the DWS in a number of areas of the Site including the 200-West Area, the 300 Area, and the southern portion of the 600 Area. A number of samples from wells in the 1100 and 3000 Areas contained low concentrations of tetrachloroethylene. The only area where tetrachloroethylene was detected at concentrations greater than the DWS is the Solid Waste Landfill, where the concentrations reached a maximum of 6.6 µg/L in well 699-24-34B. Tetrachloroethylene was apparently used as a degreasing solvent.

Radiological and Chemical Monitoring Results for the Confined Aquifer

The uppermost (Rattlesnake Ridge) confined aquifer was monitored to determine the extent of ground-water interaction between the confined and unconfined aquifers. Intercommunication between aquifers has been previously identified by Gephart et al. (1979) and Graham et al. (1984). Ground-water samples from selected confined aquifer wells have been analyzed for a variety of radionuclides and hazardous chemicals. In most cases, no indication of contamination was observed. Detection of radionuclides in well 299-E33-12 is attributed to contamination by high-salt waste that migrated by density flow into the borehole when it was open to both the unconfined and the confined aquifer during drilling (Graham et al. 1984). The 1992 sample from well 299-E33-12 contained 561 pCi/L of ^{3}H.

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Figure 5.69. Distribution of Chloroform in the Unconfined Aquifer near the 200-West Area, 1992

Intercommunication between the Rattlesnake Ridge confined aquifer and the unconfined aquifer north of the 200-East Area was indicated by nitrate concentrations in well 699-47-50, which were 8,800 µg/L in 1992. This well is located near an erosional window (an area where the confining layer is absent) in the confining basalt flow (Graham et al. 1984). Elevated levels of ^{3}H have also been measured in ground water from the Rattlesnake Ridge interbed in well 699-42-40C. This well contained a maximum of 7,830 pCi/L of ^{3}H in samples collected in 1992. Elevated levels of ^{129}I (0.15 pCi/L) have previously been observed in the same well.

Potential Radiation Doses from 1992 Hanford Operations

6.0 Potential Radiation Doses from 1992 Hanford Operations

Present and past operations at Hanford have resulted in the release of radionuclides into the surrounding environment. Members of the public are potentially exposed to low levels of radiation from these effluents through a variety of pathways. The potential radiation doses[a] to the public in 1992 from Hanford operations were calculated for the hypothetical MEI and for the general public residing within 80 km (50 mi) of the Hanford Site. These doses were calculated from effluent releases reported by the operating contractors, and radionuclide measurements in environmental media, using Version 1.485 of the GENII code (Napier et al. 1988a, 1988b, 1988c) and Hanford Site-specific parameters.

The potential dose to the MEI in 1992 from Hanford operations was 0.02 mrem (2×10^{-4} mSv), the same as reported for 1991. The potential dose to the local population of 380,000 persons (Beck et al. 1991) from 1992 operations was 0.8 person-rem (0.008 person-Sv), compared to 0.9 person-rem (0.009 person-Sv) reported for 1991. The 1992 average dose to the population was 0.002 mrem (2×10^{-5} mSv) per person. The current DOE radiation limit for an individual member of the public is 100 mrem/yr (1 mSv/yr), and the national average dose from natural sources is 300 mrem/yr (3 mSv/yr). The MEI potentially received 0.02% of the DOE dose limit and 0.007% of the natural background average dose. The average individual potentially received 0.002% of the standard and 0.0007% of the 300 mrem/yr received from typical natural sources.

During 1992, radionuclides reached the environment in gaseous and liquid effluents from present and past Hanford operations. Gaseous effluents were released from operating stacks and ventilation exhausts. Liquid effluents were released from operating wastewater treatment facilities and in seepage of contaminated ground water into the Columbia River. These radioactive materials were then transported throughout the environment by wind and the Columbia River. Eventually, animals and people can be exposed to these radionuclides through external exposure, and inhalation and ingestion of contaminated air and foodstuffs. Because of the many variables involved in the transport of the radionuclides in the environment and differing living habits of people, the assumptions used to describe the exposure scenarios are conservative (in other words, the doses are likely to be overestimated).

Potential radiation doses to the public from these releases were evaluated in detail to determine compliance with pertinent regulations and limits. The potential radiological impacts of 1992 Hanford operations were assessed in terms of the following:

- dose to a hypothetical MEI at an offsite location
- maximum dose rate from external radiation at a publicly accessible location on or within the Site boundary
- dose to an avid sportsman
- dose to the population residing within 80 km (50 mi) of the operating areas
- absorbed dose rate (rad/d) potentially received by animals associated with contaminant releases to the Columbia River.

During 1992, the various unusual environmental occurrences listed in Section 2.4, "Environmental Occurrences," involved potential uncontrolled releases of radionuclides into the environment. However, no additional dose to the public resulted from such occurrences.

(a) Unless stated otherwise the term "dose" in this chapter is the "effective dose equivalent" (see Glossary).

To the extent possible, radiation dose assessments should be based on direct measurements of radiation dose rates and radionuclide concentrations in the surrounding environment. The amounts of most radioactive materials released during 1992 were generally too small to be measured directly once they were dispersed in the offsite environment. For many of the measurable radionuclides, it was difficult to identify the contributions from Hanford sources in the presence of those contributed from worldwide fallout and from naturally occurring uranium and its decay products. Therefore, in nearly all instances, potential offsite doses were estimated using environmental pathway models that calculate concentrations of radioactive materials in the environment from effluent releases reported by the operating contractors.

As in the past, the differences in measured concentrations of certain radionuclides in samples of Columbia River water collected upstream and downstream of the Hanford Reach were used to estimate the doses to the public from these radionuclides entering the river with riverbank seepage of ground water. During 1992, ^{3}H, ^{99}Tc, ^{129}I and isotopes of uranium were found at greater concentrations than predicted from direct discharge from the 100 and 300 Areas.

Although the uncertainty associated with the radiation dose calculations has not been quantified, whenever Hanford-specific data were not available for parameter values (for example, vegetation uptake and consumption factors) conservative values were selected from the literature for use in environmental transport models. Thus, doses calculated using models should be viewed as maximum estimates of potential doses resulting from Hanford operations.

Maximally Exposed Individual Dose

The MEI is a hypothetical person who lives at a location and has a postulated lifestyle such that it is unlikely that other members of the public would receive higher doses. This individual's characteristics were chosen to maximize the combined doses from all realistic environmental pathways of exposure to radionuclides in Hanford effluents. In reality, such a combination of maximized parameters is unlikely to apply to any single individual.

The location selected for the MEI can vary from year to year depending on the relative importance of the several sources of radioactive effluents released to the air and to the Columbia River from Hanford facilities.

Historically, two separate locations in the Hanford environs have been identified as potential sites for the MEI: the Ringold area 26 km (16 mi) east of the 200 Areas separation facilities, and the Riverview irrigation district across the river from Richland (Figure 6.1). The principal differences between the two MEI locations are that Ringold is closer than Riverview to the Hanford facilities which had been the major contributors of airborne effluents, but the MEI at Ringold does not drink water derived from the Columbia River. The MEI at Riverview, although farther from the Hanford sources of airborne radionuclides, can be exposed to the one additional pathway of consumption of drinking water derived from the Columbia River.

In recent years, the calculated doses to an MEI at the two locations have been very nearly the same. For the 1990 calendar year, the dose calculated for the MEI at Ringold was about 5% higher than that calculated for the MEI at Riverview. For the 1991 calendar year, the situation was reversed (i.e., the calculated dose to the MEI at Riverview was 5% higher than that calculated for the MEI at Ringold). The change resulted from the continued reduction of the quantity of radionuclides released to the atmosphere from Hanford facilities. For the 1992 calendar year the MEI for air pathways only was located at Ringold, while the MEI for all pathways combined was at Riverview.

The following exposure pathways were included in the calculation of doses potentially received by the MEI at Riverview for 1992: inhalation of and submersion in air downwind of the Site, consumption of foods contaminated by radionuclides deposited on the ground from airborne materials and by irrigation with water from the Columbia River, direct exposure to radionuclides deposited on the ground, consumption of drinking water derived from the Columbia River, consumption of fish taken from the Columbia River, and external radiation during recreation activities on the Columbia River and its shoreline. The MEI for 1992 was postulated to be an individual who:

- was a resident of the Riverview area

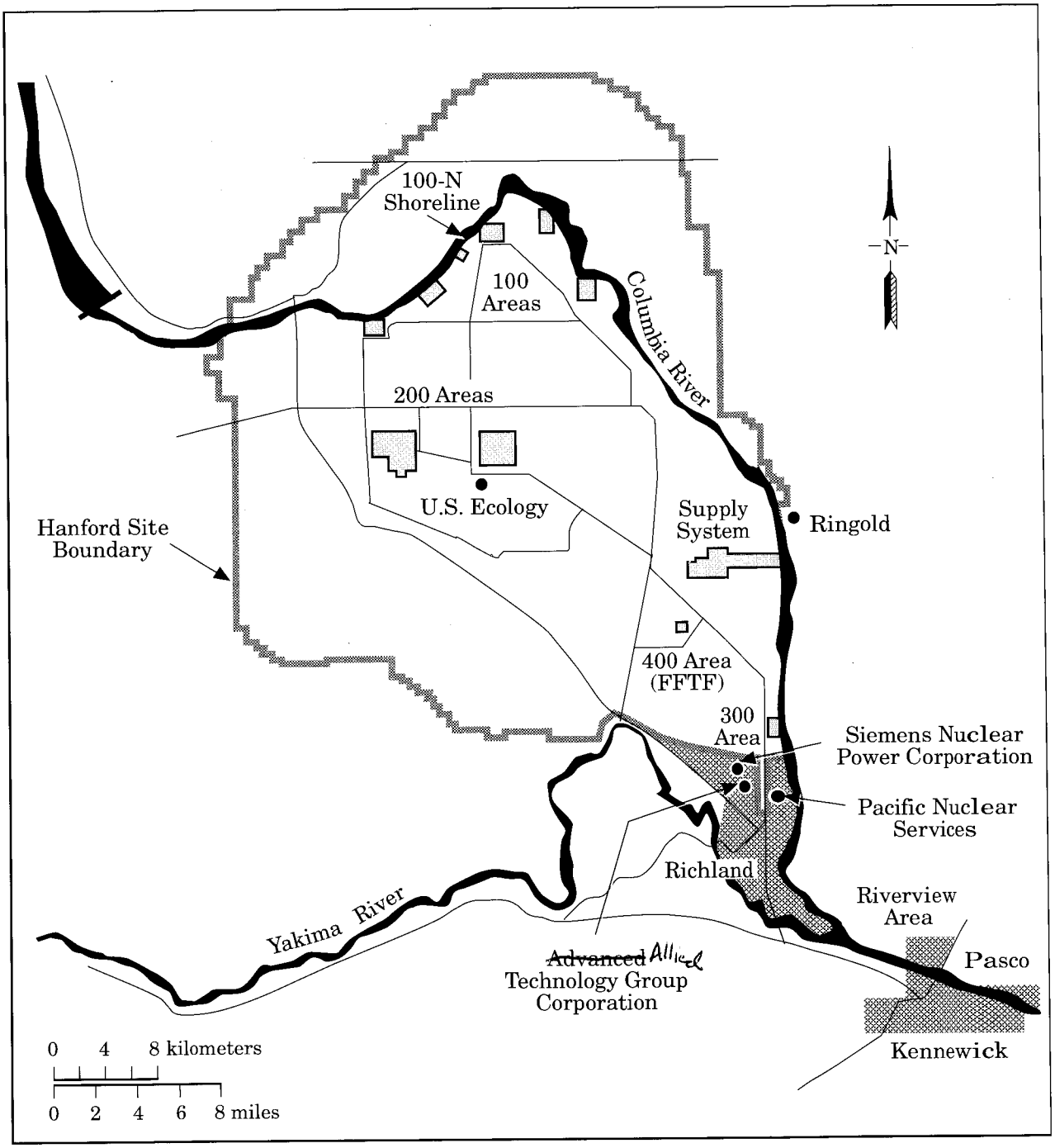

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Figure 6.1. Locations Important to Dose Calculations

- consumed homegrown foodstuffs irrigated with Columbia River water
- used the Columbia River extensively for boating, swimming, and fishing, and consumed the fish caught
- drank water that was derived from the Columbia River via the Pasco municipal water system.

Doses to the MEI were calculated using the effluent data in Section 3.1, Tables 3.1, 3.3, and 3.4, and measured quantities of radionuclides assumed to be present in the Columbia River from riverbank springs as input to the GENII code. The calculated doses for the MEI are summarized in Table 6.1. These values include the potential doses received from exposure to liquid and airborne effluents during 1992, as well as the future dose from radionuclides that were deposited in the body during 1992 via inhalation and ingestion. As releases from facilities and the doses from these sources decrease, the contribution of diffuse sources, such as wind-blown contaminated soil, becomes relatively more significant. A preliminary upper estimate of the dose from diffuse sources is discussed in a following subsection (Comparison with Clean Air Act Standards). This contribution is not included in the MEI dose. Site-specific parameters for food pathways, diet, and recreational activity used for the dose calculations are contained in Appendix D.

The total potential dose to the hypothetical MEI in 1992 was calculated to be 0.02 mrem (2×10^{-4} mSv) the same as calculated for in 1991. The primary pathways contributing to this dose as determined by the computer calculations were:

- consumption of food irrigated with Columbia River water containing radionuclides (principally ^{3}H and ^{99}Tc) (40%)

Table 6.1. Doses to the Hypothetical Maximally Exposed Individual from Hanford Operations, 1992

		Operating Area Contribution Doses, mrem[a,b]				
Effluent	Pathway	100 Areas	200 Areas	300 Area	400 Area	Pathway Total
Air	External[c]	4×10^{-8}	5×10^{-6}	3×10^{-9}	2×10^{-5}	3×10^{-5}
	Inhalation	6×10^{-6}	7×10^{-4}	1×10^{-4}	7×10^{-6}	9×10^{-4}
	Foods[d]	6×10^{-7}	0.003	7×10^{-4}	2×10^{-7}	0.004
Water	Recreation[e]	2×10^{-6}	1×10^{-4}	3×10^{-7}	---[f]	1×10^{-4}
	Foods[g]	5×10^{-4}	0.01	1×10^{-4}	---	0.01
	Fish[h]	4×10^{-4}	0.005	2×10^{-4}	---	0.006
	Drinking water	3×10^{-5}	0.004	1×10^{-5}	---	0.004
	Total	0.001	0.02	0.001	0.00003	0.02

(a) To convert these dose values to mSv, divide them by 100.
(b) Values rounded after adding.
(c) Includes air submersion and exposure to ground-deposited radionuclides.
(d) Includes consumption of all foodstuffs contaminated via deposition from the air.
(e) External exposure during river recreation plus inadvertent ingestion of water while swimming.
(f) There are no releases to the river from the 400 Area.
(g) Includes consumption of all foodstuffs contaminated via irrigation water and external exposure to ground contaminated via irrigation.
(h) Consumption of fish taken from the Columbia River.

- consumption of fish containing radionuclides (principally ^{3}H, ^{99}Tc, and isotopes of uranium) from the Columbia River (23%).
- consumption of food containing radionuclides (primarily ^{129}I) deposited from the air (20%)
- consumption of drinking water containing radionuclides (primarily ^{3}H, ^{99}Tc, and isotopes of uranium) from the Columbia River (14%).

The dose limit for any member of the public from all routine DOE operations is 100 mrem/yr (1 mSv/yr). The dose calculated for the MEI was 0.02% of the DOE limit.

The doses from Hanford operations for the MEI for 1988 through 1992 are illustrated in Figure 6.2. During each year the doses were estimated using methods and computer codes that were state-of-the-art at the time. Doses were estimated for the location determined to potentially result in the highest dose to the MEI. Soldat (1989) presents a comparison of the calculated doses for the 5-year period 1983 through 1987. In recent years, the differences in doses calculated for the MEI at the two locations, Ringold and Riverview, have become very small.

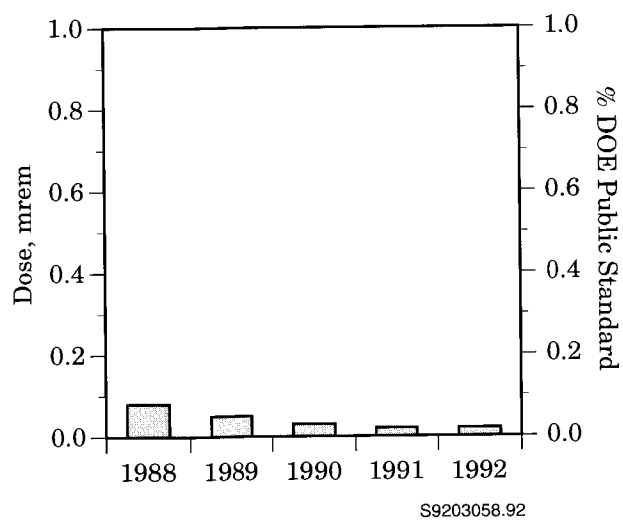

Figure 6.2. Calculated Effective Dose Equivalent to the Hypothetical Maximally Exposed Individual, 1988 Through 1992

Special Case Exposure Scenarios

While characteristics that define the standard and historical MEI are selected to define a high exposure scenario that is unlikely to occur, they do not necessarily represent the highest conceivable dose scenario that could occur. Low probability exposure scenarios exist that could conceivably result in somewhat higher doses. Two potential scenarios include an individual who could spend time at the Site boundary location with the maximum external radiation dose rate, and a sportsman who might obtain contaminated wildlife that migrated from the Site. These special cases are discussed below, as well as the potential dose from consumption of drinking water at the FFTF Visitors Center.

Maximum "Boundary" Dose Rate

The "boundary" dose rate is the external radiation dose rate measured at publicly accessible locations on or near the Site. The "boundary" dose rate was determined from radiation exposure measurements using radiation dosimeters (TLDs) at locations of expected elevated dose rates onsite and at representative locations offsite. These "boundary" dose rates should not be used to calculate annual doses to the general public because no one can actually reside at any of these "boundary" locations. However, these rates can be used to determine the dose to a specific individual who might spend some time at that location.

"Boundary" external radiation dose rates were measured in the vicinity of the 100-N, 300, and 400 (FFTF) Areas, as described in Section 5.7, "External Radiation Surveillance." The 200 Areas results were not used because these locations are not accessible to the general public. Radiation measurements made at the 100-N Area shoreline (Figure 6.1) were consistently above background level and represent the highest measured "boundary" dose rate. The Columbia River provides public access to an area within a few hundred meters of the N Reactor and supporting facilities.

The annual average dose rate at the location with the highest exposure rate along the 100-N shoreline during 1992 was 0.03 mrem/h (3×10^{-4} mSv/h), or about

0.02 mrem/h (2 x 10^{-4} mSv/h) above the average background dose rate of 0.01 mrem/h (1 x 10^{-4} mSv/h) normally observed at offsite shoreline locations. Therefore, for every hour someone spent at the 100-N Area shoreline, the external radiation dose received from Hanford operations would be about 0.02 mrem (2 x 10^{-4} mSv). This dose would be in addition to the annual dose calculated for the MEI at Riverview. In practice, the public can approach the shoreline by boat, but they are legally restricted from stepping onto the shoreline.

The FFTF Visitors Center, located southeast of the FFTF Reactor building (Figure 6.1), provides public access to the 400 Area. Dose rates measured at this location during 1992 were essentially equal to normal background radiation levels in the vicinity of Hanford [0.01 mrem/h (1 x 10^{-4} mSv/h)].

Sportsman Dose

Wildlife have access to areas of the Site that contain contamination and could thereby become contaminated. The potential also exists for contaminated wildlife to move offsite. For this reason, sampling is conducted onsite to estimate maximum contamination that might exist in animals hunted offsite. This is a unique and relatively low probability scenario that is not included in the MEI calculation.

Listed below are examples of the estimated radiation doses that could have resulted if wildlife, containing the maximum concentrations measured in onsite wildlife in 1992, migrated offsite, were hunted, and were consumed. These are very low doses, and qualitative observations suggest that the significance of this pathway is further reduced because of the relatively low migration offsite and the inaccessibility of onsite wildlife to hunters. Not all of the maximum values were observed in the same animal of each species sampled. However, the maximum values were compounded to arrive at an upper limit to the potential concentrations. These doses would be in addition to the MEI dose.

- The dose from eating 1 kg[(a)] of meat containing the maximum concentration of ^{137}Cs measured in a deer collected onsite is estimated to be 1 x 10^{-3} mrem (1 x 10^{-5} mSv).
- The dose from eating 1 kg of meat containing the maximum concentration of ^{137}Cs measured in any duck collected onsite is estimated to be 0.07 mrem (7 x 10^{-4} mSv).
- The dose from eating 1 kg of meat containing the maximum concentration of ^{137}Cs measured in a pheasant collected onsite is estimated to be 2 x 10^{-3} mrem (2 x 10^{-5} mSv).

The methodology for calculating doses from consumption of wildlife are addressed in more detail in a recent report (Soldat et al. 1990).

FFTF Visitors Center Drinking Water

During 1992, ground water was used as a drinking water source at the FFTF Visitors Center (Figure 6.1). This water is sampled and analyzed throughout the year in accordance with applicable drinking water regulations. Radionuclide concentrations during 1991 were well below applicable drinking water standards, but concentrations of ^{3}H and ^{129}I were detected at levels above typical background values. Based on these measurements, the potential dose received by a member of the public from drinking 1 L ($\approx$1 qt) of drinking water during a visit to the FFTF Visitors Center was calculated to be 5 x 10^{-4} mrem (5 x 10^{-6} mSv). The maximum organ dose (thyroid) was also calculated to be 5 x 10^{-4} mrem (5 x 10^{-6} mSv). These doses are very small percentages of the DOE limit of 4 mrem EDE (0.04 mSv).

Comparison with Clean Air Act Standards

Limits for radiation dose to the public from airborne emissions at DOE facilities are provided in 40 CFR 61, Subpart H, of the Clean Air Act Amendments. The regulation specifies that no member of the public shall receive more than 10 mrem/yr (0.1 mSv/yr) from exposure to airborne radionuclide effluents released at DOE facilities. It also requires that each DOE facility submit an annual report that supplies information about atmospheric emissions for the preceding year and their potential offsite impacts. The following summarizes information that is provided in more detail in the 1992 air emissions report (Diediker et al. 1993).

(a) 1 kg = 2.2 lb.

The 1992 air emissions from monitored Hanford facilities resulted in a potential dose to an MEI at Ringold of 0.004 mrem (4×10^{-5} mSv), which is 0.04% of the limit. Therefore, the estimated annual dose from monitored stack releases at the Hanford Site during 1992 was well below the Clean Air Act standard. The Clean Air Act requires the use of CAP-88 or other EPA models to demonstrate compliance with the standard, and the assumptions embodied in these codes differ slightly from standard assumptions used at the Hanford Site for reporting to DOE via this document. Nevertheless, the results of calculations performed with CAP-88 for air emissions from Hanford facilities agree well with those calculated using the GENII code (0.005 mrem or 5×10^{-5} mSv).

The 1990 amendments to the Clean Air Act (40 CFR 61, Subpart H) also require DOE facilities to estimate the dose to a member of the public for radionuclides released from diffuse and unmonitored sources as well as from monitored point sources. The EPA has not specified or approved methods for estimating emissions from diffuse sources, and standardization is difficult because of the wide variety of such sources at DOE sites. Estimates of potential diffuse source emissions at the Hanford Site have been developed using environmental surveillance measurements of airborne radionuclides at the Site perimeter. The information reported below is based on environmental data from 1991 and 1992 because results from 1991 sampling were not available until late 1992, and it was not possible to include them in the previous report.

Using the 1991 air sample data, the hypothetical dose from diffuse and unmonitored sources at eight individual perimeter monitoring stations was estimated to range from 0.011 to 0.064 mrem/yr (1.1×10^{-4} to 6.4×10^{-4} mSv/yr). The dose to the MEI at Ringold was 0.035 mrem/yr (3.5×10^{-4} mSv/yr), which is somewhat greater than the estimated dose at this location from stack emissions during 1991 (0.007 mrem or 7×10^{-5} mSv). Based on these results, the combined dose from stack emissions and diffuse and unmonitored sources during 1991 was substantially below the EPA standard.

Air sampling data from 1992 yielded somewhat higher dose estimates for the diffuse and unmonitored sources, in part because of suspected cross-contamination of ^{3}H air samples in the analytical laboratory (see Section 5.2, "Air Surveillance"). Elevated ^{3}H concentrations were found sporadically throughout the year, but were most common during the first 5 months. Samples from both perimeter and distant community stations were affected; however not all were elevated to the same degree. When all ^{3}H sample data are included, the estimated dose from diffuse and unmonitored sources at six individual perimeter monitoring stations ranged from 0.09 to 0.18 mrem/yr (9.0×10^{-4} to 1.8×10^{-3} mSv/yr). The dose to the MEI at Ringold was 0.09 mrem/yr (9.0×10^{-4} mSv/yr), which, as in 1991, was greater than the estimated dose at that location from stack emissions during 1992 (0.004 mrem or 4×10^{-5} mSv). If the ^{3}H data are excluded entirely, the dose at all locations from the remaining radionuclides amounts to less than 0.01 mrem/yr (1×10^{-4} mSv). Based on these results, the combined dose from stack emissions and diffuse and unmonitored sources during 1992 was also much less than the EPA standard.

Population Dose

Pathways of exposure to the population from releases of radionuclides to the atmosphere include inhalation, air submersion, and consumption of contaminated food. Pathways of exposure associated with Hanford-generated radionuclides present in the Columbia River include consumption of drinking water, fish, and irrigated foods, and external exposure during aquatic recreation. The regional population dose from 1992 Hanford operations was estimated by calculating the radiation dose to the population residing within an 80-km (50-mi) radius of the onsite operating areas. Results of the dose calculations are shown in Table 6.2. Food pathway, dietary, residency, and recreational activity assumptions for these calculations are given in Appendix D.

The potential dose calculated for the population was 0.8 person-rem (0.008 person-Sv) in 1992, compared to 0.9 person-rem (0.009 person-Sv) in 1991. The 80-km (50-mi) population doses attributed to Hanford operations from 1988 through 1992 are compared in Figure 6.3.

Primary pathways contributing to the 1992 dose to the population were:

- consumption of foodstuffs contaminated with radionuclides (principally ^{129}I) released with gaseous effluents primarily from the PUREX Plant stack (57% of the total dose)
- consumption of drinking water contaminated with radionuclides (principally ^{3}H) released to the Columbia River at Hanford (21%)

Table 6.2. Population Doses from Hanford Operations, 1992

Effluent	Pathway	Operating Area Contribution Doses, person-rem[a,b] 100 Areas	200 Areas	300 Area	400 Area	Pathway Total
Air	External[c]	0.00001	0.0006	0.0000002	0.003	0.003
	Inhalation	0.003	0.1	0.01	0.001	0.1
	Foods[d]	0.0002	0.4	0.04	0.00002	0.4
Water	Recreation[e]	0.00001	0.0005	0.000002	---[f]	0.0005
	Foods[g]	0.0006	0.01	0.0001	---	0.01
	Fish[h]	0.0002	0.002	0.00006	---	0.002
	Drinking Water	0.001	0.2	0.0004	---	0.2
	Total	0.005	0.7	0.05	0.004	0.8

(a) To convert these dose values to person-Sv, divide them by 100.
(b) Values rounded after adding.
(c) Includes air submersion and exposure to ground-deposited radionuclides.
(d) Includes consumption of all foodstuffs contaminated via deposition from the air.
(e) External exposure during river recreation plus inadvertent ingestion of water while swimming.
(f) There are no releases to the river from the 400 Area.
(g) Includes consumption of all foodstuffs contaminated via irrigation water and external exposure to ground contaminated via irrigation.
(h) Consumption of fish taken from the Columbia River.

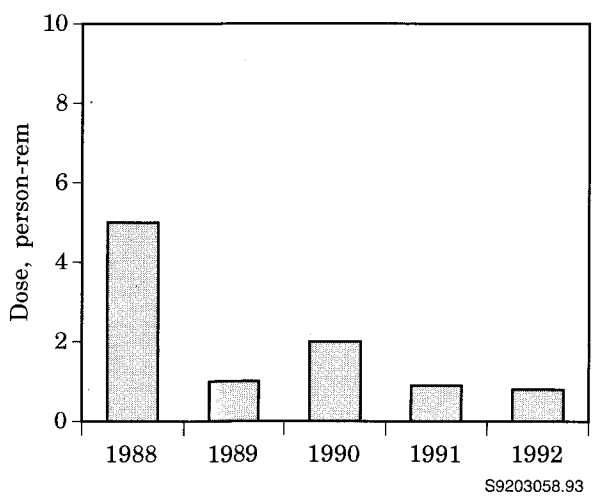

Figure 6.3. Calculated Effective Dose Equivalent to the Population Within 80 km (50 mi) of the Hanford Site, 1988 Through 1992

- inhalation of radionuclides (principally $^{239,240}Pu$ and ^{241}Am) that were released to the air from the PUREX Plant stack (19%).

The average per capita dose from 1992 Hanford operations, based on a population of 380,000 within 80 km (50 mi), was 0.002 mrem (2×10^{-5} mSv). This dose estimate may be compared with doses from other routinely encountered sources of radiation, such as natural terrestrial and cosmic background radiation, medical treatment and x rays, natural radionuclides in the body, and inhalation of naturally occurring radon. The national average radiation doses from these other sources are illustrated in Figure 6.4. The estimated per capita dose to individual members of the public from Hanford sources is a small fraction (approximately 0.0007%) of the annual per capita dose (300 mrem) from natural background sources.

The doses to the MEI and to the 80-km (50-mi) population from Hanford effluents are compared to appropriate standards and natural background radiation in Table 6.3.

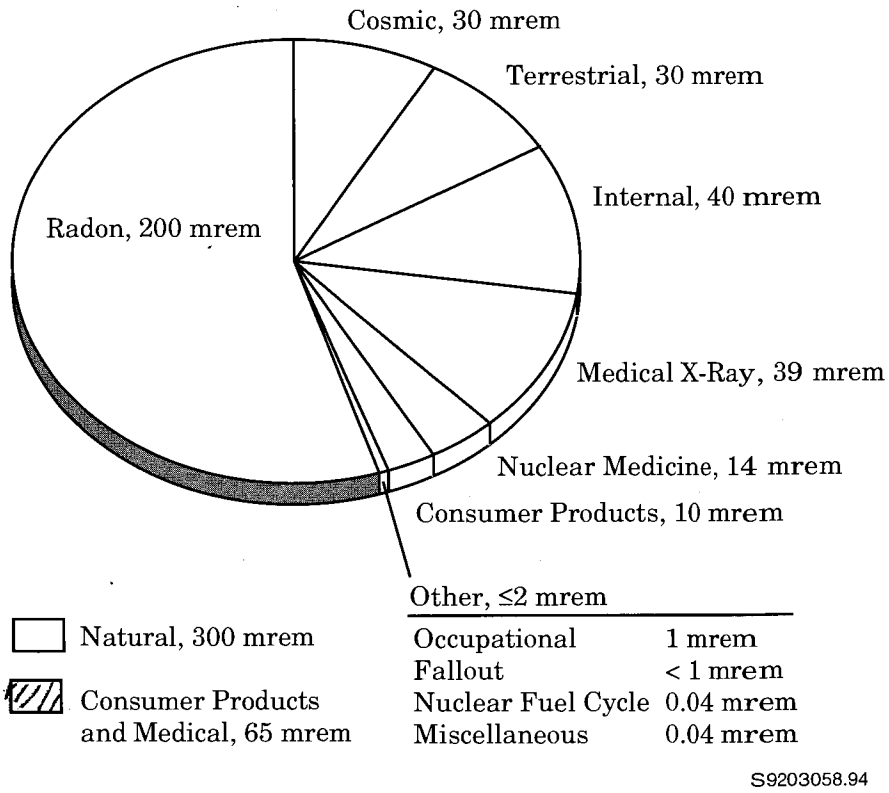

Figure 6.4. National Annual Average Radiation Doses from Various Sources (mrem) (NCRP 1987)

Table 6.3. Summary of Doses to the Public in the Vicinity of Hanford from Various Sources, 1992

Source	Maximum Individual, mrem[a]	80-km Population, person-rem[a]
All Hanford effluents[b]	0.02	0.8
DOE limit	100	---
Percent of DOE limit	0.02%	---
Background radiation	300	110,000
Hanford doses percent of background	0.007%	0.0007%
Doses from gaseous effluents[c]	0.004	---
EPA air standard	10	---
Percent of EPA standard	0.04%	---

(a) To convert the dose values to mSv or person-Sv, divide them by 100.
(b) Calculated with the GENII code (Napier et al. 1988a, 1988b, 1988c).
(c) Calculated with the EPA CAP-88 code.

This table shows that the calculated doses from Hanford operations in 1992 are a small percentage of the standards and of natural background.

Doses from Other Than DOE Sources

DOE maintains an awareness of other artificial sources of radiation (other than DOE artificial sources), which if combined with the DOE sources might have the potential to exceed a dose contribution to any member of the public of 10 mrem (0.1 mSv). Various non-DOE industrial sources of public radiation exposure exist at or near Hanford. These include the low-activity commercial radioactive waste burial ground at Hanford operated by U.S. Ecology, the nuclear generating station at Hanford operated by Washington Public Power Supply System (Supply System), the nuclear fuel production plant operated by Siemens Nuclear Power Corporation, the commercial low-activity radioactive waste compacting facility operated by Allied Technology Group Corporation, and a commercial decontamination facility operated by Pacific Nuclear Services (Figure 6.1). With information gathered from the mentioned companies, it was conservatively determined that the total 1992 individual dose from their combined activities is on the order of 0.05 mrem (0.0005 mSv). Therefore, the combined dose from Hanford area non-DOE and DOE sources to a member of the public for 1992 was well below any regulatory dose limit.

Hanford Public Radiation Dose in Perspective

Several scientific studies (NRC 1980, 1990; UNSCEAR 1988) have been performed to estimate the potential risk of developing detrimental health effects from exposure to low levels of radiation. These studies have provided vital information to those government and scientific organizations that recommend radiation dose limits and standards for public and occupational safety.

Although increased incidence of health effects from low doses of radiation has not actually been confirmed by the scientific community, most scientists accept the conservative hypothesis that low-level doses increase the probability that these effects will occur. Regulatory agencies conservatively (cautiously) assume that the probability of health effects at low doses (down to zero) is proportional to the probability of health effects that have been observed historically at much higher doses (atomic bomb victims, radium dial painters, etc.). Therefore, using conservative assumptions, one can infer that even the natural background radiation (which is many hundreds of times greater than radiation from Hanford releases) increases each person's probability or chance of developing a detrimental health effect.

Scientists do not agree about how to translate the available data on health effects into the numerical probability (risk) of detrimental effects from low-level radiation doses. Some scientific studies have even indicated that low-level radiation doses may be beneficial (HPS 1987). Because the rate of cancer and hereditary diseases in the general population may be caused by a multitude of sources (e.g., genetic defects, sunlight, chemicals, and background radiation), some scientists doubt that the risk from low-level radiation exposure will ever be determined accurately. The EPA has used a probability value of approximately 4 per 10 million (4×10^{-7}) for the risk of developing a fatal cancer after receiving a dose of 1 mrem (0.01 mSv) in developing Clean Air Act regulations (EPA 1989). Recent data (NRC 1990) support the reduction of this risk value, possibly to zero, for certain types of radiation when the dose is spread over an extended time.

Government agencies are trying to determine what level of risk is safe for members of the public exposed to pollutants from industrial activities (for example, DOE facilities, nuclear power plants, chemical plants, and hazardous waste sites). All of these industrial activities are considered beneficial to people in some way, such as providing electricity, national defense, waste disposal, and consumer products. These government agencies have a complex task in establishing environmental regulations that control levels of risk to the public without unnecessarily reducing the needed productivity of the industry.

The public is subjected to some incremental risks from exposure to industrial pollutants (radiological and nonradiological). These risks can be kept in perspective by comparing them to the increased risks involved in other typical activities. For instance, two added risks that an individual receives from flying on an airline are the risks of added radiation dose (stronger cosmic radiation field at higher altitude) and the possibility of being in an aircraft accident. Table 6.4 compares the

Table 6.4. Estimated Risk from Various Activities and Exposures[a]

Activity or Exposure Per Year	Risk of Fatality
Riding or driving in a passenger vehicle (300 miles)	2×10^{-6}[b]
Home accidents	100×10^{-6}[b]
Drinking 1 can of beer or 4 ounces of wine per day (liver cancer/cirrhosis)	10×10^{-6}
Pleasure boating (accidents)	6×10^{-6}[b]
Firearms, sporting (accidents)	10×10^{-6}[b]
Smoking 1 pack of cigarettes per day (lung/heart/other diseases)	3600×10^{-6}
Eating 4 tablespoons of peanut butter per day (liver cancer)	8×10^{-6}
Eating 90 pounds of charcoal-broiled steaks (gastrointestinal-tract cancer)	1×10^{-6}
Drinking chlorinated tap water (trace chloroform—cancer)	3×10^{-6}
Taking contraceptive pills (side effects)	20×10^{-6}
Flying as an airline passenger (cross country roundtrip—accidents)	8×10^{-6}[b]
Flying as an airline passenger (cross country roundtrip—radiation)	0 to 5×10^{-6}
Natural background radiation dose (300 mrem, 3 mSv)	0 to 120×10^{-6}
Dose of 1 mrem (0.01 mSv)	0 to 0.4×10^{-6}
Dose to the maximally exposed individual living near Hanford in 1992 (0.02 mrem, 0.0002 mSv)	0 to 0.008×10^{-6}

(a) These values are generally accepted approximations with varying levels of uncertainty; there can be significant variation as a result of differences in individual lifestyle and biological factors (Ames et al. 1987; Atallah 1980; Dinman 1980; Wilson and Crouch 1987; Travis and Hester 1990).

(b) Real actuarial values. Other values are predicted from statistical models. For radiation dose, the values are reported in a possible range from the least conservative (0) to the currently, accepted most conservative value.

estimated risks from various radiation doses to the risks of some activities encountered in everyday life.

Another way of looking at the risk of detrimental health effects from Hanford radioactive releases is illustrated in Table 6.5. Listed are some activities considered approximately equal in risk to the hypothetical risk from the potential radiation dose received by the MEI from Hanford releases in 1992.

Dose Rates to Animals

Conservative (upper) estimates have been made of the potential radiation dose to "native aquatic animal organisms," in accordance with a DOE Order 5400.5 interim requirement for management and control of liquid discharges. Potential radiation dose rates during 1992 were calculated for several possible exposure modes, including exposure to water entering the Columbia River from springs near the 100-N Area, and internally deposited radionuclides measured in samples of fish and waterfowl collected from the Columbia River and in samples of waterfowl and terrestrial animals collected onsite.

Because the volumetric flow of the springs at the 100-N Area is so low, no aquatic animal can live directly in this seep water. Exposure to the radionuclides from the springs cannot occur until the seep water has been noticeably diluted in the Columbia River. The unlikely assumption was made that a few aquatic animals might be exposed to the spring water after dilution at only 10 to 1 by the river. Radiation doses were calculated for several different types of aquatic animals, using highly conservative assumptions and the computer code

Table 6.5. Activities Comparable in Risk to That from the 0.02-mrem Dose Calculated for the 1992 Maximally Exposed Individual

Driving or riding in a car 2 km (1.2 mi)
Smoking 1/60 of a cigarette
Flying 5 km (3.1 mi) on a commercial airline
Eating 1 1/3 tablespoons of peanut butter
Eating one 0.3-kg (12-ounce) charcoal-broiled steak
Drinking about 1.9 L (2 quarts) of chlorinated tap water
Being exposed to natural background radiation for about 40 minutes in a typical terrestrial location
Drinking about one-third of a can of beer or one-fourth a glass of wine per week for a year

CR1TR2 (Baker and Soldat 1992). The animal receiving the highest potential dose was calculated to be a duck consuming aquatic plants. However, a duck would have to spend 50% of its time in the one-tenth spring water consuming only plants growing there to receive a radiation dose of 1 rad/d. Thus, it is highly unlikely that any native aquatic animal organism actually received a dose as high as the 1 rad/d-limit given in DOE Order 5400.5.

Doses were also estimated for clams, fish, and waterfowl exposed to Columbia River water containing a mixture of all the radionuclides reaching the Columbia River from Hanford sources during 1992. The highest potential dose was for a plant-eating duck, 2×10^{-5} rad/d.

Dose estimates based on the maximum concentrations of ^{137}Cs measured in muscle of animals collected onsite ranged from 5×10^{-7} rad/d for carp and rabbit to 3×10^{-5} rad/d for the maximum duck. Doses to the bone of these animals were calculated from measured values of ^{90}Sr. The dose estimates ranged from 1×10^{-5} rad/d for the fish to 6×10^{-3} rad/d for rabbit and deer.

Quality Assurance

7.0 Quality Assurance

Quality assurance (QA) and quality control (QC) practices encompass all aspects of Hanford Site environmental monitoring and surveillance programs. Samples are analyzed according to documented standard analytical procedures. Analytical data quality is verified by a continuing program of internal laboratory QC, participation in interlaboratory cross-checks, replicate sampling and analysis, submittal of blind standard samples and blanks, and splitting samples with other laboratories.

QC for ground-water environmental surveillance also includes procedures for 1) documenting instrument calibrations and procedures used in the field and laboratory, 2) scheduling maintenance of wells to ensure structural integrity, 3) inspecting wells using downhole video cameras and other devices, and 4) using dedicated sampling pumps to avoid cross-contamination.

This section discusses specific measures taken to ensure quality in project management, sample collection, and analytical results.

Environmental Surveillance

Comprehensive QA programs, including various QC practices, are maintained to ensure the quality of data collected through the surveillance programs. QA plans are maintained for all surveillance activities, defining the appropriate controls and documentation required to meet the guidance of the American Society of Mechanical Engineers (ASME) NQA-1 QA program document (U.S. nuclear industry's standard, ASTM 1989) and DOE Orders.

Project Management Quality Assurance

Site surveillance and related programs, such as processing of TLDs and dose calculations, are subject to an overall QA program. This program implements the requirements of RL Order RL 5700.1A, "Quality Assurance," and is based on ASME NQA-1, *Quality Assurance Program Requirements for Nuclear Facilities* (ASME 1989). The program is defined in a QA manual (PNL 1991). The manual provides guidance for implementation by addressing 18 QA elements. These are:

1. Organization
2. Quality Assurance Program
3. Design Control
4. Procurement Document Control
5. Instructions, Procedures, and Drawings
6. Document Control
7. Control of Purchased Items and Services
8. Identification and Control of Items
9. Control of Processes
10. Inspection
11. Test Control
12. Control of Measuring and Test Equipment
13. Handling, Storage, and Shipping
14. Inspection, Test, and Operating Status
15. Control of Nonconforming Items
16. Corrective Action
17. Quality Assurance Records
18. Audits.

The environmental surveillance projects have current QA plans that describe the specific QA elements that apply to each project. These plans are approved by a QA organization that conducts surveillances and audits to verify compliance with the plans. Work performed through contracts, such as sample analysis, must meet the same QA requirements. Audits of potential equipment and services suppliers are conducted before awarding contracts for services or approving purchase requisitions having significant impact on a project's quality.

Sample Collection Quality Control

Environmental surveillance samples were collected by staff trained to conduct sampling according to approved and documented procedures. Continuity of all sampling location identities is maintained through documentation.

Samples for ground-water hazardous chemical monitoring are sealed with evidence tape to prevent tampering and transported to the laboratory in accordance with the chain-of-custody procedures required by the EPA for RCRA monitoring programs.

Analytical Results Quality Control

Routine radiochemical analyses for environmental surveillance samples are performed by International Technology Corporation's (IT) Richland laboratory. Analytical quality at the laboratory is evaluated in a number of ways. IT's Richland laboratory participates in the DOE's Quality Assessment Program and the EPA's Laboratory Intercomparison Studies. PNL conducts an additional QC program. IT's Richland laboratory also maintains an internal QC program, which PNL audits and reviews. Other audits and comparisons are conducted on specific types of samples. A final QC check of data is performed by a computerized screening of results against project-specific criteria. Anomalous results are reported, and discrepancies resolved and documented. Additional information on these efforts is provided in the following subsections.

U.S. Department of Energy and U.S. Environmental Protection Agency Comparison Studies

IT's Richland laboratory participated in the DOE's Quality Assessment Program and EPA's Laboratory Intercomparison Studies Program. These programs provide standard samples of various environmental media (water, milk, air filters, soil, and foodstuffs) containing specific amounts of one or more radionuclides that are unknown by the participating laboratory. After sample analyses, the results were forwarded to DOE and EPA for comparison with known values and results from other laboratories. Both EPA and DOE have established criteria for evaluating the accuracy of results (Jarvis and Siu 1981; Sanderson 1985). Summaries of the 1992 results for the programs are provided in Tables 7.1 and 7.2. Approximately 93% of the results during the year were within the typically used "3-sigma control limits" (±3 standard errors of the mean). This level of performance was determined to be acceptable and was among the best of participating radiochemistry laboratories.

Pacific Northwest Laboratory Evaluations

In addition to DOE and EPA interlaboratory QC programs, a QC program is maintained by PNL to evaluate analytical contractor precision and accuracy and to conduct special intercomparisons. This program includes the use of blind samples and replicate samples. Blind standard QC samples and blanks are prepared and submitted to check the accuracy and precision of IT's analyses. The methods used to determine accuracy and precision acceptability were taken from the EPA and DOE (Jarvis and Siu 1981; Sanderson 1985). In 1992, blind and blank samples were submitted in air filters, soil, water, and wine. Overall, IT reported that 75% of requested QC analytes were within control limits (Table 7.3). This program identified a potential problem in the gamma spectroscopy software, which has been corrected. The deficiency involved short-lived radionuclides that are not normally found in environmental media currently submitted for analysis.

PNL also participates in a Quality Assurance Task Force (QATF), a program conducted by the Washington State Department of Social and Health Services. Two environmental media samples and an EPA reference water sample were analyzed in triplicate by up to six other participating laboratories in the Pacific Northwest (Table 7.4). The IT results submitted by PNL compared favorably with those of other participating laboratories for ^{3}H, ^{40}K and ^{137}Cs. Strontium-90 results were lower than expected for the EPA reference water and the Bull Run Lake sediment.

Laboratory Internal Quality Control Programs

IT's Richland laboratory is required to maintain an internal QC program, and PNL audited and reviewed their compliance with this program. The internal QC program involves routine calibrations of counting instruments, yield determinations of radiochemical procedures, frequent radiation check source and background counts, replicate and spiked samples analyses, maintenance of control charts to indicate analytical deficiencies, and analyses of reagents to ensure purity of processing chemicals. Available calibration standards traceable to the National Institute of Standards and Technology were used for radiochemical calibrations.

Table 7.1. International Technology Corporation Performances on DOE Quality Assessment Program Samples, 1992

Sample Media	Radionuclides	Number of Results Reported	Number Within Control Limits[a]
Air filters	^{7}Be, ^{54}Mn, ^{57}Co, ^{60}Co, ^{134}Cs, ^{137}Cs, ^{144}Ce	7	6
Soil	^{40}K, ^{90}Sr, ^{137}Cs, ^{238}Pu, $^{239,240}Pu$, ^{241}Am, U (mass)	7	5
Vegetation	^{40}K, ^{137}Cs	2	2
Water	^{54}Mn, ^{60}Co, ^{90}Sr, ^{134}Cs, ^{137}Cs, ^{144}Ce, ^{238}Pu, ^{241}Am, U (mass)	10	9

(a) Control limits are from Sanderson (1985).

Table 7.2. International Technology Corporation Performances on EPA Intercomparison Program Samples, 1992

Sample Media	Radionuclides	Number of Results Reported	Number Within Control Limits[a]
Water	Total alpha, total beta, ^{65}Zn, ^{60}Co, ^{106}Ru, ^{131}I, ^{133}Ba, ^{134}Cs, ^{137}Cs	33	33
Water	^{226}Ra, ^{228}Ra, U (mass), $^{239,240}Pu$	11	11
Water	^{89}Sr, ^{90}Sr	6	6
Water	^{3}H	2	2
Milk	^{89}Sr, ^{90}Sr, ^{131}I, ^{137}Cs	8	5
Air filters	Total alpha, total beta ^{90}Sr, ^{137}Cs	12	12

(a) Control limits are from Jarvis and Siu (1981).

Table 7.3. International Technology Corporation Performances on PNL Quality Control Samples, 1992

Sample Media	Radionuclides	Number of Results Reported	Number Within Control Limits[a]
Air filters	^{54}Mn, ^{57}Co, ^{60}Co, ^{137}Cs, ^{144}Ce, ^{234}U, ^{238}U, $^{239,240}Pu$	24	24
Soil	^{137}Cs, ^{241}Am, ^{238}U, $^{239,240}Pu$	12	12
Water	^{22}Na, ^{54}Mn, ^{57}Co, ^{60}Co, ^{65}Zn, ^{90}Sr, ^{137}Cs, ^{144}Ce, ^{154}Eu	31	17
Wine	^{3}H, ^{54}Mn, ^{134}Cs	18	11

(a) Control limits are from Jarvis and Siu (1981).

Table 7.4. Comparison of Quality Assurance Task Force 1992 Intercomparison Samples. PNL analyses by IT are compared against grand mean (± 2 SEM) of participating laboratories.

		Media			
				EPA Reference Water	
Radionuclide	No. of Samples	Bull Run Lake[a] sediment, pCi/g dry	Ground-water well 199-N-56, pCi/L	pCi/L	Expected Value, pCi/L
^{3}H					
PNL (IT)	3		16,600 ± 350	18,600 ± 180	19,455
Other	15		15,900 ± 850	18,900 ± 910	19,455
^{40}K					
PNL (IT)	3	4.81 ± 0.51			
Other	18	5.06 ± 0.37			
^{60}Co					
PNL (IT)	3		7.2 ± 0.9		
Other	7		2.6 ± 0.4[b]		
^{90}Sr					
PNL (IT)	3	0.30 ± 0.05	230 ± 25	35.6 ± 2.8	48
Other	8 to 11	0.48 ± 0.10	205 ± 45	41.1 ± 6.3	48
^{137}Cs					
PNL (IT)	3	9.05 ± 0.36		23.8 ± 5.5	22
Other	14 to 18	10.3 ± 0.72		23.0 ± 2.3	22

(a) Bull Run Lake is near Portland, Oregon.
(b) Samples were not acidified. Lower value may indicate plating out of ^{60}Co on container walls.

In 1992, the PNL Process Quality Department (PQD) conducted one formal audit and participated in two inspections of IT. These audits and inspections document conformance with contractual requirements of the analytical facility and provide the framework for identifying and resolving potential performance problems. Responses to audit and inspection findings are documented by written communication, or follow-up audits and inspections by project and PQD staff.

Internal laboratory QC program data are summarized by IT in quarterly reports to PNL. These reports indicate that during 1992 approximately 38% of all analyses performed were QC analyses, including blanks, spikes, and duplicates. The results of these analyses and the observations noted in each report were found to indicate an acceptably functioning QC program.

Verification of minimum detectable concentration (MDC) requirements for specific radionuclide-media combinations (for example, ^{90}Sr in air) was initiated with the IT contract. MDC verification is conducted (when requested) for up to five radionuclide-media combinations for analyses performed during the previous month. Equation 37 from Chapter 6 in EPA 520/1-80-012 (EPA 1980a) is used in the MDC calculations, which involves the use of factors such as the average counting efficiencies and background for detection instruments, length of time for background and sample counts, sample volumes, radiochemical yields, and a predesignated uncertainty multiplier. The MDC verification is used to document historical performance to project detection goals. As of this report writing, 12 MDC verification reports had been completed for 59 radionuclide-media combinations, indicating that 42 MDCs had been achieved. Eleven of the seventeen radionuclide-media combinations not meeting MDC requirements involved ^{3}H analysis.

Sample-Specific Audits and Comparisons

Additional audits and comparisons are conducted on several specific types of samples. The State of Washington routinely collected samples of various environmental media and measured external radiation levels at multiple locations during 1992. The results from the state monitoring program were reviewed and indicated good agreement between TLD measurements (approximately 10% variation), total beta measurements in air (approximately 20% variation), and ^{90}Sr measurements in alfalfa (approximately 10% variation).

Quality control for environmental TLDs includes the audit exposures of three environmental TLDs to known values of radiation (between 16 and 29 mR), which are routinely processed quarterly. A summary of 1992 results is shown in Figure 7.1. On average, the TLD measurements were biased 2% lower than the known values. The average percent bias was calculated from

$$\frac{\sum \left[\frac{\text{measured - known value}}{\text{known value}} \times 100\% \right]}{\text{Number of TLDs}}$$

Effluent Monitoring

The WHC facility effluent and near-facility environmental monitoring programs are subject to the QA program defined in *Quality Assurance Manual* (WHC 1989). The PNL effluent monitoring program is subject to the QA program defined in *Quality Assurance Manual* (PNL 1991). These QA programs comply with RL Order 5700.1A, "Quality Assurance," (1989 edition, without addenda) and use ASME NQA-1, *Quality Assurance Program Requirements for Nuclear Facilities* (ASME 1989), as their basis. The program also adheres to the U.S. Environmental Protection Agency (EPA)

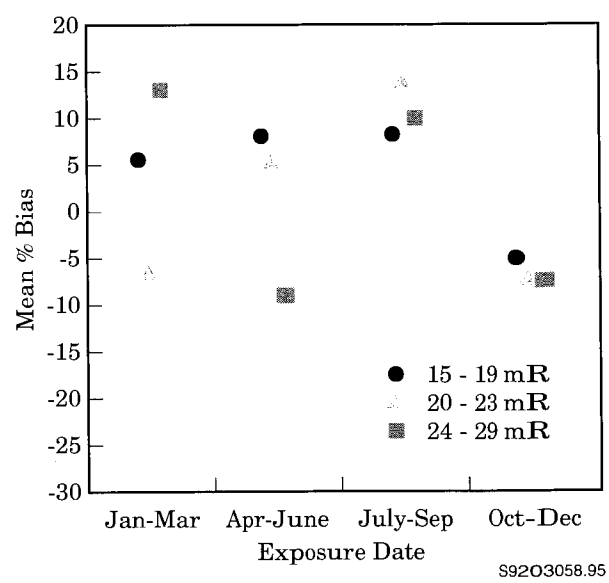

Figure 7.1. Comparison of Thermoluminescent Dosimeter Results with Known Exposures, 1992

guidelines in *Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans* (EPA 1980b) and *Data Quality Objectives for Remedial Response Activities* (EPA 1987).

The facility effluent and near-field environmental monitoring programs each have a QA project plan describing specific QA elements that apply to the program. These plans are approved and monitored by the contractor QA function, which conducts surveillances and audits to verify compliance with the plans. Work performed through contracts, such as sample analysis, must meet the same QA requirements. Audits of potential equipment and service suppliers are conducted by the regulatory support function before awarding contracts for services or approving purchase requisitions having significant impact on a project's quality.

Sample Collection Quality Assurance

Effluent and near-facility operational monitoring samples are collected by staff trained to conduct sampling according to approved and documented procedures. Locations routinely sampled are accurately identified and documented to assure continuity of near-facility sample data for those sites. Sample location descriptions and procedures are in *Operational Environmental Monitoring* (WHC 1991b) for WHC sampling and in controlled procedures for PNL sampling.

Analytical Results Quality Assurance

PNL's effluent samples are analyzed by IT's Richland Laboratory and PNL Radiation Protection Section. The 222-S Analytical Laboratory, located in the 200-West Area of the Site, analyzes most routine WHC effluent samples and many near-facility environmental samples for chemical and radioactive constituents. Low-level radioactive environmental samples taken for the near-facility environmental monitoring program are sent to IT's Richland laboratory for analysis. Samples that have a potential of higher levels of contamination are submitted to the 222-S Analytical Laboratory.

The quality of the analytical data are assured by several means. Counting room instruments, for instance, are kept within calibration limits through daily checks, the results of which are stored in a computer database to efficiently control tracking. Radiochemical standards used in analyses are regularly measured and the results reported and tracked. Formal, written laboratory procedures are used in analyzing samples. Analytical procedural control is ensured through administrative procedures. Chemical technologists at the laboratory qualify to perform analyses through formal classroom and on-the-job training.

For years the 222-S Analytical Laboratory has participated in the EPA Environmental Monitoring and Surveillance Laboratory intercomparison program and the DOE Environmental Measurements Laboratory Quality Assessment Program. Sometimes the concentrations of the standards are less than the established detection limits of the laboratory methods. Performance in these programs provides an analytical baseline to compare with analysis results obtained in the future waste sampling and characterization facility. Analytical summaries of the Laboratory's participation in the two programs are shown in Tables 7.5 and 7.6.

Table 7.5. 222-S Analytical Laboratory Performance on DOE Quality Assessment Program Samples, 1992

Sample Media	Radionuclides	Number of Results Reported	Number Within Control Limits[a]
Air Filters	^{7}Be, ^{54}Mn, ^{60}Co, ^{134}Cs, ^{137}Cs, ^{144}Ce	13	12
Soil	^{40}K, ^{137}Cs	4	3
Vegetation	^{40}K, ^{137}Cs	5	5
Water	^{3}H, ^{54}Mn, ^{60}Co, ^{90}Sr, ^{134}Cs, ^{137}Cs, ^{144}Ce, ^{238}Pu	19	19

(a) Control limits are from Sanderson (1985).

Table 7.6. 222-S Analytical Laboratory Performance on EPA Intercomparison Program Samples, 1992

Sample Media	Radionuclides	Number of Results Reported	Number Within Control Limits[a]
Air filters	Total alpha, total beta, ^{137}Cs	6	3[b]
Alpha, beta, and gamma emitters in water	Total alpha, total beta[c], ^{60}Co, ^{65}Zn, ^{106}Ru, ^{133}Ba, ^{134}Cs, ^{137}Cs	34	26[b]
Water	U (natural), ^{239}Pu	6	4
Tritium in water	^{3}H	3	3

(a) Control limits are from Jarvis and Siu (1981).
(b) The levels of the EPA samples are usually less than 50 pCi/L and the sample size 500 mL, which places them at or below background levels at the 222-S Analytical Laboratory.
(c) Performance differences exist in analyzing beta samples because the instruments at the 222-S Analytical Laboratory are calibrated with a ^{60}Co source but the EPA known values are based on ^{90}Sr calibration.

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8.0 References

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Appendixes

Appendix A

Monitoring Results for 1992

Appendix A

Additional Monitoring Results for 1992

This Appendix contains additional information on 1992 monitoring results, supplementing the data summarized in the main body of the report. More detailed information is available in the accompanying 1993 report by L. E. Bisping and R. K. Woodruff, *Hanford Site Environmental Data for Calendar Year 1992—Surface and Columbia River* (PNL-8683, Pacific Northwest Laboratory, Richland, Washington).

Table A.1. Radionuclide Concentrations Measured in Columbia River Water at Priest Rapids Dam, 1992 Compared to Values from the Previous 5 Years

Radionuclide[b]	1992 No. of Samples	1992 Concentration, pCi/L[a] (10^{-9} µCi/mL) Maximum	1992 Concentration, pCi/L[a] (10^{-9} µCi/mL) Average	1987-1991 No. of Samples	1987-1991 Concentration[a], pCi/L Maximum	1987-1991 Concentration[a], pCi/L Average	Drinking Water Standard[c]
Composite System							
Alpha	12	0.8 ± 0.7	0.3 ± 67%	59	1.7 ± 1.2	0.56 ± 18%	15
Beta	12	3.4 ± 2.2	0.7 ± 114%	59	5.2 ± 2.5	1.5 ± 27%	50
^{3}H	12	114 ± 4	50 ± 24%	59	107 ± 6	61 ± 7%	20,000
^{90}Sr	12	0.13 ± 0.04	0.09 ± 11%	58	0.18 ± 0.08	0.10 ± 10%	8
^{99}Tc	12	0.32 ± 0.11	0.10 ± 120%	34	4.1 ± 1.2	-0.34 ± 191%	900
^{234}U	12	0.27 ± 0.04	0.23 ± 9%	58	0.34 ± 0.08	0.23 ± 4%	---[d]
^{235}U	12	0.02 ± 0.01	0.008 ± 50%	58	0.04 ± 0.02	0.009 ± 22%	---
^{238}U	12	0.24 ± 0.05	0.18 ± 11%	58	0.37 ± 0.06	0.19 ± 5%	---
U-Total	12	0.49 ± 0.07	0.42 ± 7%	58	0.57 ± 0.07	0.43 ± 5%	---
Continuous System							
^{129}I D	4	0.000050 ± 0.000005	0.000023 ± 91%	16	0.000045 ± 0.000005	0.000009 ± 56%	1
$^{239,240}Pu$ P	4	0.00004 ± 0.00002	0.00003 ± 67%	19	0.00010 ± 0.00008	0.00003 ± 33%	---
D	4	0.00063 ± 0.00019	0.00020 ± 145%	19	0.00014 ± 0.00007	0.00005 ± 40%	---

(a) Maximum values are ±2 sigma counting errors. Averages are ±2 times the standard error of the calculated mean, expressed as a percentage.
(b) Radionuclides measured using the continuous system show the particulate (P) and dissolved (D) fractions separately. Other radionuclides are based on samples collected by the composite system (see text).
(c) The drinking water standards are in pCi/L from State of Washington and Environmental Protection Agency (see Table C.2, Appendix C).
(d) Dashes indicate no concentration guides provided in drinking water standard.

Table A.2. Radionuclide Concentrations Measured in Columbia River Water at the 300 Area, 1992 Compared to Values from the Previous 5 Years

Radionuclide[b]	1992 No. of Samples	1992 Concentration, pCi/L[a] (10^{-9} µCi/mL) Maximum	1992 Average	1987-1991 No. of Samples	1987-1991 Concentration[a], pCi/L Maximum	1987-1991 Average	Drinking Water Standard[c]
Composite System							
Total alpha	4	1.1 ± 0.6	0.8 ± 50%	20	1.40 ± 0.95	0.6 ± 17%	15
Total beta	4	1. 5 ± 0.9	1.1 ± 27%	20	2.8 ± 1.5	1.3 ± 31%	50
^{3}H	4	192 ± 4	157 ± 19%	19	20.6 ± 5	148 ± 11%	20,000
^{90}Sr	4	0.11 ± 0.03	0.10 ± 20%	20	0.41 ± 0.34	0.11 ± 36%	8
^{99}Tc	4	0.48 ± 0.16	0.30 ± 50%	12	52 ± 1[d]	4.7 ± 185%	900
^{234}U	4	0.38 ± 0.07	0.34 ± 9%	20	0.44 ± 0.07	0.30 ± 7%	---[e]
^{235}U	4	0.02 ± 0.02	0.02 ± 50%	20	0.04 ± 0.02	0.010 ± 60%	---
^{238}U	4	0.40 ± 0.07	0.28 ± 29%	20	0.30 ± 0.05	0.24 ± 8%	---
U-Total	4	0.79 ± 0.10	0.63 ± 17%	20	0.77 ± 0.09	0.54 ± 7%	---
Continuous System							
^{129}I D	4	0.00027 ± 0.00003	0.00017 ± 47%	16	0.00026 ± 0.00002	0.00013 ± 23%	1
$^{239,240}Pu$ P	4	0.00002 ± 0.00001	0.000017 ± 35%	19	0.0020 ± 0.0001	0.00013 ± 154%	---
D	4	0.00058 ± 0.00026	0.00016 ± 175%	19	0.00011 ± 0.00006	0.00003 ± 33%	---

(a) Maximum values are ±2 sigma counting errors. Averages are ±2 times the standard error of the calculated mean, expressed as a percentage.
(b) Radionuclides measured using the continuous system show the particulate (P) and dissolved (D) fractions separately. Other radionuclides are based on samples collected by the composite system (see text).
(c) The drinking water standards are in pCi/L from State of Washington and Environmental Protection Agency (see Table C.2, Appendix C).
(d) Suspected outlier. Average concentration influenced by this value.
(e) Dashes indicate no concentration guides provided in drinking water standard.

Table A.3. Radionuclide Concentrations Measured in Columbia River Water at the Richland Pumphouse, 1992 Compared to Values from the Previous 5 Years

Radionuclide[b]	1992 No. of Samples	1992 Concentration, pCi/L[a] (10^{-9} µCi/mL) Maximum	1992 Concentration, pCi/L[a] (10^{-9} µCi/mL) Average	1987-1991 No. of Samples	1987-1991 Concentration[a], pCi/L Maximum	1987-1991 Concentration[a], pCi/L Average	Drinking Water Standard[c]
Composite System							
Total alpha	12	1.4 ± 1.0	0.4 ± 50%	59	3.4 ± 1.3	0.62 ± 26%	15
Total beta	12	3.2 ± 2.2	1.2 ± 50%	59	9.2 ± 2.9	1.4 ± 29%	50
^{3}H	12	165 ± 4	101 ± 18%	59	211 ± 5	121 ± 7%	20,000
^{90}Sr	12	0.13 ± 0.04	0.09 ± 11%	58	0.18 ± 0.04	0.10 ± 10%	8
^{99}Tc	12	1.35 ± 0.15	0.21 ± 114%	34	6.5 ± 0.9	0.36 ± 178%	900
^{234}U	12	0.45 ± 0.06	0.28 ± 14%	58	0.45 ± 0.06	0.24 ± 8%	---[d]
^{235}U	12	0.04 ± 0.02	0.010 ± 60%	58	0.04 ± 0.02	0.10 ± 20%	---
^{238}U	12	0.29 ± 0.05	0.22 ± 9%	58	0.36 ± 0.05	0.20 ± 5%	---
U-Total	12	0.78 ± 0.08	0.51 ± 12%	58	0.84 ± 0.08	0.45 ± 7%	---
Continuous System							
^{129}I D	4	0.00017 ± 0.00002	0.00013 ± 31%	16	0.00016 ± 0.00001	0.00011 ± 18%	1
$^{239,240}Pu$ P	4	0.000017 ± 0.000016	0.000012 ± 42%	19	0.00013 ± 0.00006	0.000036 ± 42%	---
D	4	0.00020 ± 0.00012	0.00008 ± 113%	19	0.00215 ± 0.00030[e]	0.00017 ± 135%	---

(a) Maximum values are ±2 sigma counting errors. Averages are ±2 times the standard error of the calculated mean, expressed as a percentage.
(b) Radionuclides measured using the continuous system show the particulate (P) and dissolved (D) fractions separately. Other radionuclides are based on samples collected by the composite system (see text).
(c) The drinking water standards are in pCi/L from State of Washington and Environmental Protection Agency (see Table C.2, Appendix C).
(d) Dashes indicate no concentration guides provided in drinking water standard.
(e) Suspected outlier, currently under investigation. Average concentration influenced by suspected outlier.

Table A.4. Radionuclide Concentrations Measured in Columbia River Water Along Cross Sections Established at the Vernita Bridge and Richland Pumphouse, 1992

Radionuclide	No. of Samples	Concentration,[a] pCi/L Maximum	Minimum	Average
Vernita Bridge				
^{3}H	16	43 ± 6	26 ± 8	37 ± 2
^{90}Sr	16	0.14 ± 0.03	0.05 ± 0.03	0.09 ± 0.01
^{234}U	16	0.30 ± 0.05	0.20 ± 0.05	0.24 ± 0.01
^{235}U	16	0.06 ± 0.06	0.001 ± 0.009	0.012 ± 0.007
^{238}U	16	0.23 ± 0.04	0.04 ± 0.06	0.18 ± 0.02
U-Total	16	0.51 ± 0.07	0.35 ± 0.06	0.43 ± 0.02
Richland Pumphouse				
^{3}H	40	126 ± 4	34 ± 2	50 ± 7
^{90}Sr	40	0.13 ± 0.04	-0.008 ± 0.025	0.082 ± 0.07
^{234}U	40	0.37 ± 0.05	0.19 ± 0.04	0.25 ± 0.01
^{235}U	40	0.03 ± 0.02	-0.001 ± 0.007	0.009 ± 0.002
^{238}U	40	0.34 ± 0.05	0.14 ± 0.03	0.20 ± 0.01
U-Total	40	0.73 ± 0.08	0.35 ± 0.06	0.46 ± 0.02

(a) Maximum and minimum values are ±2 sigma counting errors. Averages are ±2 times the standard error of the calculated mean (2 SEM).

Table A.5. Columbia River Water Quality Data, 1992

		Vernita Bridge (upstream)				Richland Pumphouse (downstream)				
Analysis[a]	Units	No. of Samples	Maximum	Minimum	Annual Average	No. of Samples	Maximum	Minimum	Annual Average	State Standard[b]
Temperature[c]	°C	365	20.4	3.8	11.8	365	21.1	3.9	12.1	20 (maximum)
Dissolved oxygen	mg/L	5	14.0	9.0	11.5	4	13.8	9.5	11.3	8 (minimum)
Turbidity	NTU[d]	5	1.5	0.6	1.0	4	2.0	0.2	1.1	5 + background
pH	pH units	5	8.4	7.8	8.2	4	8.4	8.1	8.2	6.5 - 8.5
Fecal coliform	#/100 mL	5	3	<1	<2[e]	4	3	1	2.5[e]	100
Suspended solids, 105°C	mg/L	5	4	1	2.6	4	4	2	3	---[f]
Dissolved solids, 180°C	mg/L	5	86	81	83	4	84	74	80	---
Specific conductance	µS/cm[g]	5	147	133	140	4	148	133	140	---
Hardness, as $CaCO_3$	mg/L	5	70	59	64	4	69	59	63	---
Phosphorus, total	mg/L	5	0.01	<0.01	<0.01	4	0.06	<0.01	<0.05	---
Chromium, dissolved	µg/L	5	NR[h]	NR	NR	4	2	<1	<1	---
Nitrogen, Kjeldahl	mg/L	5	<0.2	<0.2	<0.2	4	4.0	<0.2	<1.3	---
Total organic carbon	mg/L	5	2.2	1.3	1.6	4	2.2	1.2	1.5	---
Iron, dissolved	µg/L	5	3	<3	<3	4	5	<3	<3.5	---
Ammonia, dissolved	mg/L	5	0.03	0.01	0.02	4	0.03	<0.01	<0.02	---

(a) Provisional data from USGS sampling program, subject to revision.
(b) See Appendix C.
(c) Maximum and minimum represent daily averages.
(d) Nephelometric turbidity units.
(e) Annual median.
(f) Dashes indicate no standard available.
(g) µ Siemens/cm.
(h) NR = not reported.

Table A.6. Radionuclide Concentrations in Columbia River Sediment, 1992 Compared to Values from the Previous 4 Years

Location	Radionuclide	1992 No. of Samples	1992 Concentration, pCi/L[a] Maximum	1992 Concentration, pCi/L[a] Average	1988-1991 No. of Samples	1988-1991 Concentration, pCi/L[a] Maximum	1988-1991 Concentration, pCi/L[a] Average
Priest Rapids Dam	^{60}Co	4	0.02 ± 0.02	0.005 ± 320%	16	0.01 ± 0.02	-0.002 ± 300%
	^{90}Sr	4	0.017 ± 0.005	0.012 ± 42%	16	0.072 ± 0.006	0.016 ± 50%
	^{137}Cs	4	0.69 ± 0.04	0.54 ± 24%	16	0.80 ± 0.07	0.40 ± 20%
	^{238}U[b]	4	0.87 ± 0.22	0.80 ± 8%	18	0.96 ± 0.10	0.83 ± 10%
	^{238}Pu	4	0.0011 ± 0.0007	0.0007 ± 43%	16	0.0005 ± 0.0002	0.0002 ± 50%
	$^{239,240}Pu$	4	0.014 ± 0.002	0.010 ± 30%	16	0.012 ± 0.001	0.005 ± 40%
White Bluffs Slough	^{60}Co	1	0.10 ± 0.02		3[c]	0.07 ± 0.03	0.05 ± 40%
	^{90}Sr	1	0.009 ± 0.004		3	0.013 ± 0.004	0.009 ± 56%
	^{137}Cs	1	0.73 ± 0.04		3	0.57 ± 0.05	0.32 ± 81%
	^{238}U[b]	1	0.53 ± 0.22		3	2.3 ± 0.1	1.3 ± 77%
	^{238}Pu	1	0.0003 ± 0.0002		3	0.0004 ± 0.0002	0.0002 ± 100%
	$^{239,240}Pu$	1	0.004 ± 0.001		3	0.0030 ± 0.0007	0.0016 ± 88%
100-F Slough	^{60}Co	1	0.03 ± 0.02		3[c]	0.06 ± 0.02	0.035 ± 69%
	^{90}Sr	1	0.003 ± 0.003		3	0.005 ± 0.003	0.0045 ± 20%
	^{137}Cs	1	0.76 ± 0.31		3	0.23 ± 0.03	0.15 ± 60%
	^{238}U[b]	1	0.84 ± 0.23		3	1.4 ± 0.1	1.1 ± 45%
	^{238}Pu	1	0.0001 ± 0.0002		3	0.0003 ± 0.0002	0.0001 ± 100%
	$^{239,240}Pu$	1	0.0015 ± 0.0007		3	0.0013 ± 0.0004	0.0009 ± 56%
Hanford Slough	^{60}Co	1	0.03 ± 0.02		3[c]	0.08 ± 0.02	0.04 ± 100%
	^{90}Sr	1	0.007 ± 0.003		3	0.021 ± 0.006	0.011 ± 82%
	^{137}Cs	1	0.11 ± 0.02		3	0.52 ± 0.03	0.27 ± 96%
	^{238}U[b]	1	0.66 ± 0.21		3	2.1 ± 1.3	1.4 ± 50%
	^{238}Pu	1	0.0002 ± 0.0002		3	0.0004 ± 0.0002	0.0002 ± 100%
	$^{239,240}Pu$	1	0.0006 ± 0.0004		3	0.0035 ± 0.0006	0.0025 ± 68%
Richland	^{60}Co	1	0.03 ± 0.02		2[d]	0.08 ± 0.02	0.05 ± 100%
	^{90}Sr	1	0.002 ± 0.002		2	0.003 ± 0.003	0.002 ± 100%
	^{137}Cs	1	0.36 ± 0.04		2	0.41 ± 0.03	0.32 ± 56%
	^{238}U[b]	1	1.2 ± 0.3		2	2.3 ± 1.6	2.0 ± 35%
	^{238}Pu	1	0.0004 ± 0.0005		2	0.00018 ± 0.00016	0.00015 ± 47%
	$^{239,240}Pu$	1	0.002 ± 0.001		2	0.0030 ± 0.0006	0.0021 ± 90%

Table A.6. Radionuclide Concentrations in Columbia River Sediment, 1992 Compared to Values from the Previous 4 Years (contd)

Location	Radionuclide	1992 No. of Samples	1992 Concentration, pCi/L[a] Maximum	1992 Concentration, pCi/L[a] Average	1988-1991 No. of Samples	1988-1991 Concentration, pCi/L[a] Maximum	1988-1991 Concentration, pCi/L[a] Average
McNary Dam	^{60}Co	4	0.27 ± 0.06	0.18 ± 44%	16	0.44 ± 0.04	0.24 ± 21%
	^{90}Sr	4	0.061 ± 0.007	0.035 ± 54%	16	0.064 ± 0.008	0.036 ± 17%
	^{137}Cs	4	0.71 ± 0.04	0.59 ± 15%	16	1.19 ± 0.08	0.68 ± 13%
	^{238}U[b]	4	1.4 ± 0.3	1.3 ± 8%	8	1.2 ± 0.1	1.0 ± 10%
	^{238}Pu	4	0.0008 ± 0.0005	0.0007 ± 14%	16	0.0021 ± 0.0006	0.0007 ± 43%
	$^{239,240}Pu$	4	0.012 ± 0.002	0.010 ± 10%	16	0.022 ± 0.002	0.010 ± 20%

(a) Maximum values are ±2 sigma counting errors. Averages are ±2 times the standard error of the calculated mean, expressed as a percentage.
(b) Uranium-235 was analyzed by low-energy photon spectra method.
(c) Sampling at White Bluffs, 100-F, and Hanford sloughs was initiated in 1989.
(d) Sampling at Richland was initiated in 1990.

Table A.7. Summary of Cesium-137 (^{137}Cs) in Milk, 1992 Compared to Values from the Previous 5 Years (pCi/L)

	1992			19987-1991		
Radionuclide	Maximum[a]	Mean[b]	No. Less Than Detection[c]	Maximum[a]	Mean[b]	No. Less Than Detection[c]
Downwind						
Wahluke Area	2.24 ± 190%	0.32 ± 640%	4 of 4	7.69 ± 100%	0.5 ± 100%	53 of 56
Sagemoor	6.91 ± 60%	1.07 ± 80%	23 of 27	8.55 ± 43%	0.64 ± 60%	116 of 129
Upwind						
Sunnyside	103 ± 300%	-0.93 ± 170%	4 of 4	10.8 ± 40%	1.17 ± 40%	90 of 107

(a) Maximum is ±2 sigma analytical propagated error, expressed as a percentage.
(b) Mean is ±2 SEM, expressed as a percentage.
(c) Number of samples less than detection out of number of samples analyzed.

Table A.8. Strontium-90 (^{90}Sr) in Leafy Vegetables, 1992 Compared to Values from the Previous 5 Years (pCi/dry weight)

	1992			1987-1991		
Radionuclide	Maximum[a]	Mean[b]	No. Less Than Detection[c]	Maximum[a]	Mean[b]	No. Less Than Detection[c]
Downwind						
Wahluke Area	NS[d]	NS	NS	0.021 ± 30%	0.010 ± 60%	3 of 8
Sagemoor	0.011 ± 50%	0.0096 ± 40%	0 of 3	0.053 ± 20%	0.0071 ± 120%	4 of 12
Riverview	0.0012 ± 220%	---	1 of 1	0.0027 ± 30%	0.0096 ± 50%	5 of 15
Upwind						
Sunnyside	0.027 ± 30%	0.024 ± 10%	0 of 3	0.026 ± 30%	0.059 ± 60%	8 of 15

(a) Maximum is ±2 sigma analytical propagated error, expressed as a percentage.
(b) Mean is ±2 SEM, expressed as a percentage.
(c) Number of samples less than detection out of number of samples analyzed.
(d) NS = no sample.

Table A.9. Cobalt-60 (^{60}Co), Strontium-90 (^{90}Sr), and Cesium-137 (^{137}Cs) in Riverview Carrots, 1992 Compared to Values from the Previous 5 Years (pCi/dry weight)

	1992			1987-1991		
Radionuclide	Maximum[a]	Mean[b]	No. Less Than Detection[c]	Maximum[a]	Mean[b]	No. Less Than Detection[c]
^{60}Co	0.0011 ± 70%		0 of 1	0.0069 ± 140%	0.00034 ± 630%	15 of 18
^{90}Sr	0.012 ± 40%	0.0066 ± 90%	1 of 3	0.013 ± 40%	0.0064 ± 30%	3 of 15
^{137}Cs	0.0025 ± 260%		1 of 1	0.0076 ± 70%	0.00071 ± 230%	14 of 15

(a) Maximum is ±2 sigma analytical propagated error, expressed as a percentage.
(b) Mean is ±2 SEM, expressed as a percentage.
(c) Number of samples less than detection out of number of samples analyzed.

Table A.10. Annual Average (±2 SEM) Concentration of Strontium-90 (^{90}Sr) in Alfalfa, 1982 to 1992 (pCi/g dry weight)

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Benton City	0.097 ± 10%	0.052 ± 46%	0.053 ± 38%	0.076 ± 11%	0.209 ± 18%	0.043 ± 37%	0.151 ± 7%	0.150 ± 4%	0.041 ± 10%	NS[a]	0.119 ± 57%
Horn Rapids/Richland	NS	NS	NS	NS	NS	NS	NS	NS	0.116 ± 2%	NS	0.201 ± 30%[b]
Moses Lake	0.032 ± 31%	0.040 ± 35%	0.223 ± 13%	0.191 ± 2%	0.193 ± 29%	0.161 ± 4%	0.202 ± 18%	0.087 ± 44%	0.067 ± 45%	NS	0.051 ± 4%
Riverview	0.090 ± 11%	0.061 ± 16%	0.125 ± 5%	0.111 ± 41%	0.154 ± 45%	0.034 ± 6%	0.245 ± 11%	0.240 ± 23%	0.155 ± 12%	0.075 ± 19%	0.113 ± 28%
North Riverview	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.033 ± 91%
Sagemoor	0.117 ± 32%	0.020 ± 30%	0.135 ± 19%	0.085 ± 12%	0.192 ± 35%	0.112 ± 5%	0.174 ± 25%	0.081 ± 5%	0.036 ± 11%	0.030 ± 7%	0.057 ± 39%[b]
Sunnyside	0.029 ± 14%	0.072 ± 67%	0.091 ± 33%	0.095 ± 25%	0.118 ± 36%	0.071 ± 14%	0.076 ± 8%	0.114 ± 33%	NS	NS	0.068 ± 91%
Wahluke	0.009 ± 67%	0.066 ± 73%	0.062 ± 39%	0.110 ± 13%	0.219 ± 19%	0.023 ± 9%	0.153 ± 8%	0.095 ± 21%	0.036 ± 11%	NS	0.050 ± 80%

(a) NS = no sample.
(b) Mean is for samples collected as part of routine sampling and part of a special study (n=6).

Table A.11. Summary of Strontium-90 (^{90}Sr) in Carp Carcass and Cesium-137 (^{137}Cs) in Carp Muscle, 1992 Compared to Values from 1990 and 1991 (pCi/g wet)

	1992			1990 -1991		
Location	Maximum[a]	Mean[b]	No. Less Than Detection[c]	Maximum[a]	Mean[b]	No. Less Than Detection[c]
^{90}Sr in Carcass						
100-N Area	0.011 ± 70%		0 of 1	0.420 ± 20%	0.11 ± 80%	0 of 10
300 Area	0.046 ± 20%	0.025 ± 50%	0 of 5	0.036 ± 30%	0.019 ± 60%	0 of 5
Vantage[d]				0.110 ± 20%	0.059 ± 20%	0 of 13
^{137}Cs in Muscle						
100-N Area	0.01 ± 90%		0 of 1	0.04 ± 30%	0.02 ± 50%	5 of 10
300 Area	0.02 ± 100%	0.01 ± 50%	3 of 5	<0.01 ± 190%	<0.004 ± 70%	5 of 5
Vantage[d]				0.01 ± 60%	0.007 ± 40%	6 of 13

(a) Maximum is the concentration in pCi/g ±2 sigma analytical propagated error, expressed as a percentage.
(b) Mean is pCi/g ±2 standard error, expressed as a percentage.
(c) Number of samples less than detection out of number of samples analyzed.
(d) Collected in 1990 and 1991.

Table A.12. Concentrations of Strontium-90 (^{90}Sr) in Whitefish Carcass and Cesium-137 (^{137}Cs) in Whitefish Muscle, 1992 Compared to Values from the Previous 5 Years (pCi/g wet weight)

	1992			1987-1991		
Location	Maximum[a]	Mean[b]	No. Samples Less Than Detection[c]	Maximum[a]	Mean[b]	No. Samples Less Than Detection[c]
^{90}Sr in Carcass						
100-N to 100-D Areas	0.032 ± 20%	0.013 ± 40%	0 of 9	0.064 ± 20%	0.019 ± 20%	0 of 36
300 Area	0.046 ± 20%	0.025 ± 50%	0 of 5	0.036 ± 30%	0.019 ± 60%	0 of 5
Kettle River[d]				0.048 ± 40%	0.035 ± 20%	0 of 9
^{137}Cs in Muscle						
100-N to 100-D Areas	0.17 ± 20%	0.04 ± 70%	3 of 9	0.06 ± 60%	0.02 ± 40%	27 of 41
300 Area	0.03 ± 60%	0.01 ± 70%	7 of 10	<0.04 ± 110%	<0.01 ± 90%	0 of 7
Kettle River[d]				0.04 ± 70%	0.003 ± 410%	8 of 9

(a) Maximum is the concentration in pCi/g ±2 sigma total error, expressed as a percentage.
(b) Mean is pCi/g ±2 standard error, expressed as a percentage.
(c) Number of samples less than detection out of number of samples analyzed.
(d) Collected in 1991.

Table A.13. Summary of Plutonium-238 (^{238}Pu) and Plutonium-239,240 ($^{239,240}Pu$) in Rabbit Liver, 1992 Compared to Values from the Previous 5 Years (pCi/g wet weight)

	1992			1987-1991		
Location/Species	Maximum[a]	Mean[b]	No. Less Than Detection[c]	Maximum[a]	Mean[b]	No. Less Than Detection[c]
^{238}Pu						
200-East Area/ jackrabbit	<0.0003 ± 100%	<0.00008 ± 210%	0 of 4	<0.0003 ± 150%	0.00007 ± 90%	13 of 13
200-West Area/ jackrabbit	<0.0003 ± 130%	<0.00007 ± 200%	0 of 4	<0.0005 ± 160%	0.00009 ± 160%	8 of 9
100-N Area/ cottontail	<0.0009 ± 440%	<0.0002 ± 340%	0 of 4	0.99 ± 10%	0.082 ± 60%	12 of 14
Boardman, OR[d]/						
jackrabbit				<0.00006 ± 240%	<-0.000001 ± 4,300%	10 of 10
cottontail				<0.0002 ± 240%	<-0.00001 ± 1,000%	10 of 10
$^{239,240}Pu$						
200-East Area/ jackrabbit	0.0008 ± 60%	0.0005 ± 70%	2 of 4	0.0009 ± 60%	0.0004 ± 60%	8 of 13
200-West Area/ jackrabbit	0.0006 ± 80%	0.0004 ± 60%	2 of 4	0.0073 ± 20%	0.0019 ± 100%	5 of 9
100-N Area/ cottontail	<-0.00003 ± 3,400%	<-0.00003 ± 80%	0 of 4	6.7 ± 10%	0.55 ± 60%	10 of 14
Boardman, OR[d]/						
jackrabbit				<0.0005 ± 370%	<-0.00004 ± 90%	10 of 10
cottontail				<0.0005 ± 240%	<-0.00005 ± 300%	10 of 10

(a) Maximum is the concentration in pCi/g ±2 sigma analytical error, expressed as a percentage.
(b) Mean is pCi/g ±2 standard error, expressed as a percentage.
(c) Number of samples less than detection out of number of samples analyzed.
(d) Collected in 1990.

Table A.14. Summary of Strontium-90 (^{90}Sr) in Deer Bone and Cesium-137 (^{137}Cs) in Deer Muscle, 1992 Compared to Values from the Previous 5 Years (pCi/g wet weight)

	1992			1987-1991		
Location	Maximum[a]	Mean[b]	No. Less Than Detection[c]	Maximum[a]	Mean[b]	No. Less Than Detection[c]
^{90}Sr in Bone						
200 Areas	NS[d]	NS	NS	0.71 ± 30%	0.59 ± 40%	2 of 2
100-N Area	20.8 ± 30%	8.1 ± 20%	0 of 3	58.3 ± 20%	15.3 ± 190%	4 of 4
Stevens County	0.8 ± 20%	0.59 ± 30%	0 of 2	NS	NS	NS
^{137}Cs in Muscle						
200 Areas	0.006 ± 50%	NS	1 of 1	0.006 ± 80%	0.005 ± 40%	1 of 2
100-N Area	0.02 ± 40%	0.004 ± 60%	1 of 3	0.03 ± 30%	0.01 ± 140%	2 of 4
Stevens County	0.52 ± 10%	0.43 ± 40%	0 of 2	NS	NS	NS

(a) Maximum is the concentration in pCi/g ±2 sigma total error, expressed as a percentage.
(b) Mean is pCi/g ±2 standard error, expressed as a percentage.
(c) Number of samples less than detection out of number of samples analyzed.
(d) NS = no sample.

Table A.15. Strontium-90 (^{90}Sr) Concentrations in Soil,[a] 1987 Through 1992

Location	Concentration, pCi/g (dry weight)[b]					
	1987	1988	1989	1990	1991	1992
Onsite						
Above 100-D Pumphouse						0.0866 ± 0.00753
1 Mile NE of 100-N Area		0.11 ± 0.01	0.18 ± 0.01		0.152 ± 0.012	
1 Mile E of 100-N Area	0.31 ± 0.01	0.22 ± 0.01	0.17 ± 0.01		0.16 ± 0.012	
100 Area Fire Station	0.33 ± 0.01	0.28 ± 0.02	0.31 ± 0.01		0.131 ± 0.011	
200-East N Central	1.1 ± 0.1	0.77 ± 0.02	0.58 ± 0.01		0.409 ± 0.0129	
E of 200-East	0.34 ± 0.02	0.57 ± 0.02	0.41 ± 0.02		0.345 ± 0.013	
200-East SE	0.24 ± 0.02	0.59 ± 0.02	0.13 ± 0.01		0.173 ± 0.0142	
SW of BC Cribs	0.02 ± 0.01	0.04 ± 0.01	0.12 ± 0.01		0.102 ± 0.0096	
S of 200-East	0.11 ± 0.01	0.23 ± 0.01	0.28 ± 0.01		0.214 ± 0.013	
E of 200-West	0.38 ± 0.02	0.71 ± 0.27	0.50 ± 0.02	2.70 ± 0.0714	0.374 ± 0.018	
2 Miles S of 200-West		0.14 ± 0.01	0.14 ± 0.01		0.157 ± 0.0118	
NE of Fast Flux Test Facility (FFTF)	0.09 ± 0.01	0.09 ± 0.01	0.05 ± 0.01		0.0959 ± 0.00718	
SE of FFTF		0.07 ± 0.01	0.06 ± 0.01		0.0506 ± 0.00765	
N of 300 Area	0.24 ± 0.01	0.13 ± 0.01	0.15 ± 0.01		0.167 ± 0.00936	
Hanford Townsite	0.29 ± 0.01	0.13 ± 0.01	0.28 ± 0.01		0.0574 ± 0.0062	
Wye Barricade	0.18 ± 0.01	0.14 ± 0.01	0.11 ± 0.01		0.23 ± 0.016	
100-N Spring Shoreline					1.97 ± 0.063	0.235 ± 0.0125
100-N Shore Hanford Generating Plant (HGP)						0.0311 ± 0.00495
Onsite Average	0.31 ± 0.16	0.31 ± 0.13	0.23 ± 0.08	2.70	0.299 ± 0.229	0.118 ± 0.122
Offsite						
Riverview	0.19 ± 0.01	0.23 ± 0.01	0.07 ± 0.01		0.145 ± 0.0117	0.0623 ± 0.00781
Byers Landing	0.08 ± 0.01	0.10 ± 0.01	0.13 ± 0.01	0.122 ± 0.00956	0.121 ± 0.0081	0.146 ± 0.00855
Sagemoor	0.04 ± 0.01	0.20 ± 0.01	0.03 ± 0.01	0.0378 ± 0.00772	0.135 ± 0.00786	0.0851 ± 0.00806
Taylor Flats No. 2	0.10 ± 0.01	0.06 ± 0.01	0.16 ± 0.01	0.0229 ± 0.00488		
W End Fir Road	0.05 ± 0.01	0.08 ± 0.01	0.20 ± 0.01			
Ringold	0.21 ± 0.01	0.26 ± 0.01	0.15 ± 0.01	0.121 ± 0.0121	0.203 ± 0.014	0.132 ± 0.00815
Berg Ranch	0.20 ± 0.01	0.10 ± 0.01	0.09 ± 0.01	0.138 ± 0.012		
Wahluke Slope No. 2[c]	0.07 ± 0.01	0.09 ± 0.01	0.07 ± 0.01	0.0628 ± 0.00766		
Vernita Bridge[c]		0.07 ± 0.01	0.12 ± 0.01			
Yakima Barricade[c]	0.06 ± 0.01	0.07 ± 0.01	0.13 ± 0.01		0.143 ± 0.012	
Rattlesnake Springs	0.12 ± 0.01	0.04 ± 0.01	0.09 ± 0.01			
Arid Lands Ecology (ALE)	0.40 ± 0.03	0.34 ± 0.01	0.26 ± 0.01			
Prosser Barricade[c]		0.11 ± 0.01	0.24 ± 0.01			
S of 300 Area[c]		0.27 ± 0.01	0.30 ± 0.01		0.326 ± 0.0122	
Benton City	0.24 ± 0.01	0.43 ± 0.02	0.17 ± 0.01			

Table A.15. Strontium-90 (^{90}Sr) Concentrations in Soil,[a] 1987 Through 1992 (contd)

Location	pCi/g (dry weight)[b]					
	1987	1988	1989	1990	1991	1992
Sunnyside	0.25 ± 0.02	0.26 ± 0.06	0.13 ± 0.01	0.348 ± 0.0134	0.0293 ± 0.00314	0.0383 ± 0.00466
Walla Walla	0.02 ± 0.01	0.04 ± 0.01	0.01 ± 0.01	0.0455 ± 0.00584		
McNary Dam	0.07 ± 0.06	0.13 ± 0.01	0.09 ± 0.01	0.0789 ± 0.00804		
Moses Lake	0.06 ± 0.02	0.08 ± 0.01	0.05 ± 0.01	0.0612 ± 0.0086	0.0137 ± 0.00429	
Washtucna	0.12 ± 0.12	0.25 ± 0.01	0.12 ± 0.01	0.0496 ± 0.00599		
Connell	0.12 ± 0.11	0.09 ± 0.01	0.14 ± 0.01	0.204 ± 0.0125	0.094 ± 0.0106	
Othello	0.15 ± 0.08	0.04 ± 0.01	0.08 ± 0.01	0.0759 ± 0.0078		
Yakima	0.06 ± 0.04	0.09 ± 0.01	0.10 ± 0.01	0.126 ± 0.00852	0.119 ± 0.0111	0.0452 ± 0.00515
Offsite Average	0.12 ± 0.03	0.16 ± 0.04	0.13 ± 0.03	0.107 ± 0.0454	0.133 ± 0.0555	0.0848 ± 0.0369

(a) Blank field indicates no data.
(b) Individual results are ±2 sigma counting errors. Averages are ±2 times the standard error of the calculated mean.
(c) Perimeter location onsite near Site boundary.

Table A.16. Cesium-137 (^{137}Cs) Concentrations in Soil,[a] 1987 Through 1992

Location	pCi/g (dry weight)[b] 1987	1988	1989	1990	1991	1992
Onsite						
Above 100-D Pumphouse						0.764 ± 0.0346
1 Mile NE of 100-N Area		0.80 ± 0.05	0.96 ± 0.05		0.652 ± 0.044	
1 Mile E of 100-N Area	1.1 ± 0.1	0.74 ± 0.05	0.63 ± 0.05		0.768 ± 0.061	
100 Area Fire Station	1.3 ± 0.1	1.2 ± 0.1	1.1 ± 0.1		0.312 ± 0.042	
200-East N Central	16 ± 0.1	26 ± 0.1	18 ± 0.2		0.295 ± 0.029	
E of 200-East	0.69 ± 0.04	1.8 ± 0.1	2.1 ± 0.1		1.13 ± 0.053	
200-East SE	0.61 ± 0.04	1.6 ± 0.1	0.59 ± 0.04		0.408 ± 0.035	
SW of BC Cribs	0.01 ± 0.02	0.04 ± 0.02	0.52 ± 0.04		0.346 ± 0.032	
S of 200-East	0.13 ± 0.03	0.58 ± 0.04	0.80 ± 0.04		0.357 ± 0.041	
E of 200-West	1.3 ± 0.1	5.4 ± 1.7	3.0 ± 0.1	3.86 ± 0.105	1.6 ± 0.065	
2 Miles S of 200-West		0.49 ± 0.04	0.63 ± 0.04		0.496 ± 0.043	
NE of FFTF	0.33 ± 0.03	0.24 ± 0.03	0.19 ± 0.02		0.387 ± 0.038	
SE of FFTF		0.12 ± 0.02	0.22 ± 0.03		0.142 ± 0.024	
N of 300 Area	1.2 ± 0.1	0.51 ± 0.04	1.2 ± 0.1		0.709 ± 0.043	
Hanford Townsite	1.1 ± 0.1	0.88 ± 0.06	1.2 ± 0.1		0.271 ± 0.028	
Wye Barricade	0.59 ± 0.04	0.56 ± 0.04	0.39 ± 0.04		0.66 ± 0.04	
100-N Spring Shoreline					0.11 ± 0.022	1.04 ± 0.0405
100-N Shore (HGP)						0.37 ± 0.0307
Onsite Average	2.0 ± 2.6	2.9 ± 3.2	2.1 ± 2.3	3.86	0.540 ± 0.192	0.725 ± 0.0337
Offsite						
Riverview	0.86 ± 0.05	1.3 ± 0.1	0.45 ± 0.04		1.78 ± 0.105	0.197 ± 0.039
Byers Landing	0.23 ± 0.03	0.52 ± 0.03	0.68 ± 0.04	0.623 ± 0.0451	0.597 ± 0.038	0.852 ± 0.0377
Sagemoor	0.12 ± 0.02	1.0 ± 0.1	0.12 ± 0.02	0.106 ± 0.0244	0.473 ± 0.036	0.421 ± 0.0611
Taylor Flats No. 2	0.60 ± 0.06	0.39 ± 0.04	0.79 ± 0.06	0.102 ± 0.0206		
W End Fir Road	0.23 ± 0.04	0.28 ± 0.03	1.3 ± 0.1			
Ringold	1.0 ± 0.1	1.8 ± 0.06	1.7 ± 0.1	0.583 ± 0.0422	0.726 ± 0.05	0.947 ± 0.0717
Berg Ranch	0.31 ± 0.04	0.35 ± 0.03	0.53 ± 0.04	0.637 ± 0.0421		
Wahluke Slope No. 2[c]	0.16 ± 0.03	0.22 ± 0.03	0.25 ± 0.03	0.224 ± 0.029		
Vernita Bridge[c]		0.19 ± 0.04	0.66 ± 0.05			
Yakima Barricade[c]	0.08 ± 0.02	0.08 ± 0.02	0.54 ± 0.04		0.362 ± 0.033	
Rattlesnake Springs	0.32 ± 0.04	0.08 ± 0.02	0.46 ± 0.03			
ALE	1.1 ± 0.1	1.0 ± 0.1	0.96 ± 0.06			
Prosser Barricade[c]		0.33 ± 0.03	0.86 ± 0.05			
S of 300 Area[c]		0.77 ± 0.04	1.1 ± 0.1		0.751 ± 0.0514	
Benton City	0.65 ± 0.04	0.91 ± 0.06	0.76 ± 0.05			

Table A.16. Cesium-137 (^{137}Cs) Concentrations in Soil,[a] 1987 Through 1992 (contd)

Location	pCi/g (dry weight)[b]					
	1987	1988	1989	1990	1991	1992
Sunnyside	0.29 ± 0.04	1.0 ± 0.3	0.48 ± 0.04	1.22 ± 0.0641	0.0668 ± 0.0258	0.420 ± 0.0315
Walla Walla	0.07 ± 0.02	0.23 ± 0.03	0.07 ± 0.03	0.333 ± 0.0619		
McNary Dam	0.30 ± 0.47	0.48 ± 0.04	0.54 ± 0.04	0.276 ± 0.0398		
Moses Lake	0.16 ± 0.09	0.38 ± 0.04	0.18 ± 0.03	0.243 ± 0.0346	-0.0017 ± 0.0201	
Washtucna	0.38 ± 0.17	0.97 ± 0.06	0.91 ± 0.05	0.288 ± 0.0497		
Connell	0.35 ± 0.61	0.46 ± 0.04	0.67 ± 0.05	1.19 ± 0.0905	0.334 ± 0.0388	
Othello	0.76 ± 0.42	0.22 ± 0.03	0.54 ± 0.04	0.344 ± 0.0413		
Yakima	0.16 ± 0.06	0.11 ± 0.02	0.56 ± 0.04	0.599 ± 0.0459	0.334 ± 0.0353	0.445 ± 0.0271
Offsite Average	0.38 ± 0.12	0.59 ± 0.18	0.74 ± 0.27	0.483 ± 0.1902	0.542 ± 0.317	0.547 ± 0.2891

(a) Blank field indicates no data.
(b) Individual results are ±2 sigma counting errors. Averages are ±2 times the standard error of the calculated mean.
(c) Perimeter location onsite near Site boundary.

Table A.17. Plutonium-239,240 ($^{239,240}Pu$) Concentrations in Soil,[a] 1987 Through 1992

Location	Concentration, pCi/g (dry weight)[b]					
	1987	1988	1989	1990	1991	1992
Onsite						
Above 100-D Pumphouse						0.0133 ± 0.00128
1 Mile NE of 100-N Area		0.11 ± 0.01	0.017 ± 0.002		0.0129 ± 0.00129	
1 Mile E of 100-N Area	0.023 ± 0.002	0.019 ± 0.002	0.013 ± 0.001		0.0177 ± 0.00197	
100 Area Fire Station	0.017 ± 0.00	0.027 ± 0.002	0.026 ± 0.003		0.00488 ± 0.000934	
200-East N Central	0.031 ± 0.002	0.066 ± 0.03	0.031 ± 0.003		0.017 ± 0.0014	
E of 200-East	0.009 ± 0.001	0.017 ± 0.001	0.018 ± 0.002		0.00895 ± 0.00121	
200-East SE	0.012 ± 0.001	0.036 ± 0.002	0.011 ± 0.001		0.00799 ± 0.00114	
SW of BC Cribs	0.001 ± 0.001	0.001 ± 0.001	0.014 ± 0.001		0.00844 ± 0.00151	
S of 200-East	0.003 ± 0.001	0.013 ± 0.001	0.015 ± 0.002		0.0104 ± 0.00118	
E of 200-West	0.17 ± 0.01	0.67 ± 0.12	0.53 ± 0.01	0.656 ± 0.0125	0.286 ± 0.00546	
2 Miles S of 200-West		0.015 ± 0.001	0.022 ± 0.002		0.0214 ± 0.00289	
NE of FFTF	0.006 ± 0.001	0.005 ± 0.001	0.004 ± 0.001		0.0085 ± 0.00118	
SE of FFTF		0.003 ± 0.001	0.006 ± 0.001		0.00395 ± 0.000731	
N of 300 Area	0.014 ± 0.001	0.011 ± 0.001	0.024 ± 0.002		0.0173 ± 0.00161	
Hanford Townsite	0.019 ± 0.002	0.021 ± 0.002	0.027 ± 0.003		0.00368 ± 0.000846	
Wye Barricade	0.011 ± 0.001	0.008 ± 0.001	0.007 ± 0.001		0.0168 ± 0.00255	
100-N Spring Shoreline					0.000769 ± 0.000774	0.0204 ± 0.00177
100-N Shore (HGP)						0.00434 ± 0.000799
Onsite Average	0.026 ± 0.027	0.10 ± 0.11	0.051 ± 0.069	0.656	0.0279 ± 0.0691	0.0127 ± 0.00805
Offsite						
Riverview	0.015 ± 0.001	0.022 ± 0.002	0.008 ± 0.001		0.0197 ± 0.00212	0.00427 ± 0.000659
Byers Landing	0.003 ± 0.001	0.009 ± 0.001	0.014 ± 0.002	0.00901 ± 0.00139	0.0133 ± 0.00145	0.0204 ± 0.00155
Sagemoor	0.002 ± 0.001	0.020 ± 0.002	0.019 ± 0.001	0.00141 ± 0.000761	0.00936 ± 0.00105	0.00661 ± 0.000801
Taylor Flats No. 2	0.019 ± 0.002	0.004 ± 0.001	0.015 ± 0.001	0.000381 ± 0.000285		
W End Fir Road	0.003 ± 0.001	0.004 ± 0.001	0.028 ± 0.002			
Ringold	0.017 ± 0.002	0.033 ± 0.002	0.029 ± 0.003	0.0112 ± 0.00117	0.0183 ± 0.00214	0.0214 ± 0.00175
Berg Ranch	0.006 ± 0.001	0.008 ± 0.001	0.009 ± 0.002	0.0124 ± 0.00144		
Wahluke Slope No. 2[c]	0.003 ± 0.001	0.007 ± 0.001	0.005 ± 0.001	0.00711 ± 0.00098		
Vernita Bridge[c]		0.003 ± 0.001	0.013 ± 0.002			
Yakima Barricade[c]	0.002 ± 0.001	0.003 ± 0.001	0.011 ± 0.001		0.00502 ± 0.000938	
Rattlesnake Springs	0.006 ± 0.001	0.003 ± 0.001	0.011 ± 0.001			
ALE	0.024 ± 0.002	0.026 ± 0.002	0.021 ± 0.002			
Prosser Barricade[c]		0.006 ± 0.001	0.018 ± 0.002			
S of 300 Area[c]		0.017 ± 0.001	0.025 ± 0.002		0.0201 ± 0.00173	

Table A.17. Plutonium-239,240 ($^{239,240}Pu$) Concentrations in Soil,[a] 1987 Through 1992 (contd)

Location	Concentration, pCi/g (dry weight)[b]					
	1987	1988	1989	1990	1991	1992
Benton City	0.014 ± 0.001	0.014 ± 0.002	0.015 ± 0.001			
Sunnyside	0.006 ± 0.001	0.023 ± 0.006	0.011 ± 0.002	0.0291 ± 0.00327	0.000885 ± 0.000577	0.00766 ± 0.00119
Walla Walla	0.00129 ± 0.002	0.003 ± 0.001	0.001 ± 0.001	0.00306 ± 0.000546		
McNary Dam	0.006 ± 0.008	0.009 ± 0.001	0.009 ± 0.002	0.00607 ± 0.000783		
Moses Lake	0.002 ± 0.001	0.008 ± 0.001	0.002 ± 0.001	0.00412 ± 0.000596	0.0000336 ± 0.000162	
Washtucna	0.006 ± 0.003	0.016 ± 0.001	0.017 ± 0.002	0.0026 ± 0.000573		
Connell	0.007 ± 0.011	0.008 ± 0.001	0.010 ± 0.002	0.0164 ± 0.00127	0.00399 ± 0.000778	
Othello	0.013 ± 0.011	0.004 ± 0.001	0.008 ± 0.002	0.00765 ± 0.000878		
Yakima	0.003 ± 0.003	0.003 ± 0.001	0.010 ± 0.001	0.0106 ± 0.00111	0.00861 ± 0.00153	0.00776 ± 0.00107
Offsite Average	0.011 ± 0.004	0.013 ± 0.003	0.0134 ± 0.00155	0.00865 ± 0.004	0.00993 ± 0.00481	0.0114 ± 0.0075

(a) Blank field indicates no data.
(b) Individual results are ±2 sigma counting errors. Averages are ±2 times the standard error of the calculated mean.
(c) Perimeter location onsite near Site boundary.

Table A.18. Uranium Concentrations in Soil,[a] 1987 Through 1992

Location	Total Uranium,[b] pCi/g (dry weight)[c]			^{238}U,[d] pCi/g (dry weight)[c]		
	1987	1988	1989	1990	1991	1992
Onsite						
Above 100-D Pumphouse						1.31 ± 0.0388
1 Mile NE of 100-N		0.78 ± 0.45	0.35 ± 0.20		1.44 ± 0.159	
1 Mile E of 100-N	0.34 ± 0.10	0.71 ± 0.44	0.67 ± 0.22		1.31 ± 0.137	
100 Area Fire Station	0.35 ± 0.10	0.88 ± 0.30	0.97 ± 0.29		1.2 ± 0.108	
200-East N Central	0.23 ± 0.06	0.64 ± 0.50	0.44 ± 0.26		1.17 ± 0.158	
E of 200-East	0.31 ± 0.09	1.2 ± 0.3	0.40 ± 0.23		1.77 ± 0.29	
200-East SE	0.25 ± 0.07	1.2 ± 0.3	0.91 ± 0.28		1.34 ± 0.132	
SW of BC Cribs	0.19 ± 0.05	0.61 ± 0.48	0.85 ± 0.26		1.2 ± 0.148	
S of 200-East	0.22 ± 0.06	0.66 ± 0.33	0.39 ± 0.23		1.89 ± 0.17	
E of 200-West	0.39 ± 0.11	0.77 ± 0.31	0.97 ± 0.29	1.64 ± 0.156	1.5 ± 0.129	
2 Miles S of 200-West		0.65 ± 0.33	0.39 ± 0.22		1.31 ± 0.124	
NE of FFTF	0.24 ± 0.07	0.54 ± 0.45	0.72 ± 0.29		1.31 ± 0.165	
SE of FFTF		0.76 ± 0.32	0.56 ± 0.17		1.48 ± 0.165	
N of 300 Area	3.8 ± 1.1	0.90 ± 0.47	0.34 ± 0.19		2.17 ± 0.145	
Hanford Townsite	0.42 ± 0.12	0.44 ± 0.46	0.42 ± 0.28		1.66 ± 0.121	
Wye Barricade	0.19 ± 0.05	0.45 ± 0.45	0.66 ± 0.20		1.25 ± 0.0767	
100-N Spring Shoreline					1.09 ± 0.104	1.07 ± 0.344
100-N Shore (HGP)						1.06 ± 0.453
Onsite Average	0.58 ± 0.39	0.74 ± 0.15	0.60 ± 0.12	1.64	1.44 ± 0.147	1.15 ± 0.142
Offsite						
Riverview	0.30 ± 0.08	0.90 ± 0.46	0.58 ± 0.20		1.75 ± 0.124	0.460 ± 0.176
Byers Landing	0.10 ± 0.03	0.90 ± 0.48	0.42 ± 0.23	1.22 ± 0.131	1.46 ± 0.118	0.911 ± 0.224
Sagemoor	0.24 ± 0.07	0.63 ± 0.31	0.75 ± 0.29	1.56 ± 0.137	1.85 ± 0.127	0.742 ± 0.204
Taylor Flats No. 2	0.97 ± 0.27	0.93 ± 0.55	0.87 ± 0.24	1.88 ± 0.113		
W End Fir Road	0.55 ± 0.15	0.86 ± 0.34	0.56 ± 0.21			
Ringold	0.67 ± 0.19	0.83 ± 0.35	0.50 ± 0.19	1.44 ± 0.108	1.75 ± 0.13	0.752 ± 0.36
Berg Ranch	0.38 ± 0.11	0.55 ± 0.46	0.80 ± 0.24	1.23 ± 0.106		
Wahluke Slope No. 2[e]	0.17 ± 0.05	0.68 ± 0.49	1.1 ± 0.3	1.09 ± 0.0945		
Vernita Bridge[e]		0.58 ± 0.32	0.58 ± 0.20			
Yakima Barricade[e]	0.27 ± 0.08	1.0 ± 0.5	0.40 ± 0.19		1.5 ± 0.0811	
Rattlesnake Springs	0.28 ± 0.08	0.78 ± 0.45	0.84 ± 0.25			
ALE	0.45 ± 0.13	0.68 ± 0.36	1.5 ± 0.3			
Prosser Barricade[e]		0.81 ± 0.43	0.61 ± 0.22			
S of 300 Area[e]		0.94 ± 0.33	1.1 ± 0.3		1.56 ± 0.122	
Benton City	0.39 ± 0.11	1.1 ± 0.4	0.45 ± 0.19			

Table A.18. Uranium Concentrations in Soil,[a] 1987 Through 1992 (contd)

Location	Total Uranium,[b] pCi/g (dry weight)[c]			^{238}U,[d] pCi/g (dry weight)[c]		
	1987	1988	1989	1990	1991	1992
Sunnyside	0.29 ± 0.08	0.70 ± 0.39	1.0 ± 0.3	1.17 ± 0.138	1.29 ± 0.108	0.838 ± 0.287
Walla Walla	0.62 ± 0.17	0.66 ± 0.34	1.3 ± 0.3	1.43 ± 0.107		
McNary Dam	0.32 ± 0.09	0.59 ± 0.33	0.56 ± 0.21	1.76 ± 0.118		
Moses Lake	0.19 ± 0.05	0.42 ± 0.29	0.37 ± 0.19	0.99 ± 0.0955	1.23 ± 0.117	
Washtucna	0.24 ± 0.07	0.73 ± 0.39	0.72 ± 0.24	1.05 ± 0.0977		
Connell	0.32 ± 0.09	0.53 ± 0.30	0.69 ± 0.29	1.21 ± 0.113	1.16 ± 0.105	
Othello	0.24 ± 0.06	0.58 ± 0.30	0.64 ± 0.18	1.07 ± 0.101		
Yakima	0.41 ± 0.11	1.0 ± 0.5	0.45 ± 0.22	1.02 ± 0.0922	1.08 ± 0.0978	0.671 ± 0.260
Offsite Average	0.36 ± 0.07	0.75 ± 0.11	0.73 ± 0.13	1.29 ± 0.1498	1.463 ± 0.169	0.729 ± 0.127

(a) Blank field indicates no data.
(b) Total uranium leached from sample; not directly comparable to $^{238}U_{LEPS}$.
(c) Individual results are ±2 sigma counting errors. Averages are ±2 times the standard error of the calculated mean.
(d) Uranium-238 analyzed by low-energy photon spectra (LEPS) method.
(e) Perimeter location onsite near Site boundary.

Appendix B

Glossary

Appendix B

Glossary

activation product - Material made radioactive by exposure to radiation from a source such as a nuclear reactor's neutrons.

air submersion dose - Radiation dose received from external exposure to radioactive materials present in the surrounding atmosphere.

aquifer - Permeable geologic unit that can transmit significant quantities of water.

background radiation - Radiation in the natural environment, including cosmic rays from space and radiation from naturally occurring radioactive elements in the air, in the earth, and in our bodies. In the United States, the average person receives about 300 millirems (mrem) of background radiation per year.

bank storage - Hydrologic term that describes river water that flows into and is retained in permeable stream banks during periods of high river stage. Flow is reversed during periods of low river stage.

becquerel (Bq) - Unit of activity equal to one nuclear transformation per second (1 Bq =1/s). The conventional unit of activity, the curie, is related to the becquerel according to 1 Ci = 3.7×10^{10} Bq.

boundary dose rate - Dose rate measured or calculated at publicly accessible locations on or near the Hanford Site.

composite sample - Sample formed by mixing discrete samples taken at different points in time or from different locations.

confined aquifer - An aquifer bounded above and below by less permeable layers. Ground water in the confined aquifer is under a pressure greater than atmospheric pressure.

continuous sample - Sample formed by the continuous collection of the medium or contaminants within the medium during the entire sample period.

controlled area - An area to which access is controlled to protect individuals from exposure to radiation or radioactive and/or hazardous materials.

cosmic radiation - High-energy subatomic particles and electromagnetic radiation from outer space that bombard the earth. Cosmic radiation is part of natural background radiation.

curie (Ci) - A unit of radioactivity equal to 37 billion (3.7×10^{10}) nuclear transformations per second.

decay - The decrease in the amount of any radioactive material with the passage of time, due to the spontaneous emission from the atomic nuclei of nucleons or either alpha or beta particles, often accompanied by gamma radiation. When a radioactive material decays, the material may be converted to another radioactive species (decay product) or to a nonradioactive material.

Derived Concentration Guides (DCG) - Concentrations of radionuclides in air and water that an individual could continuously consume, inhale or be immersed in at average annual rates, without receiving an effective dose equivalent of greater than 100 mrem/yr.

detection level - Minimum amount of a substance that can be measured with a 99% confidence that the analytical result is greater than zero.

dispersion - Process whereby effluents are spread or mixed as they are transported by ground water or air.

dosimeter - Portable device for measuring the total accumulated exposure or absorbed dose from ionizing radiation fields.

Effective Dose - See "Effective Dose Equivalent" under "Radiation Dose."

effluent - Liquid or gaseous waste streams released from a facility.

effluent monitoring - Sampling or measuring specific liquid or gaseous effluent streams for the presence of pollutants.

exposure - Subjecting a target (usually living tissue) to radiation or chemicals. Also used as a term describing external radiation air ionization (see "Roentgen").

fallout - Radioactive materials that are released into the earth's atmosphere following a nuclear explosion or atmospheric release and that eventually fall to earth.

fission - A nuclear reaction involving the splitting or breaking apart of a nucleus into at least two other nuclei, accompanied with a release of various types of energy. For example, when a heavy atom, such as uranium, is split, large amounts of energy including radiation and neutrons are released along with the new nuclei (which are fission products).

fission products - Elements formed from fissioning. Many fission products are radioactive.

glaciofluvial sediments - Sedimentary deposits consisting of material transported by, suspended in, or laid down by the meltwater streams flowing from melting glacier ice.

grab sample - A sample that is randomly collected or "grabbed" from the collection site.

ground water - Subsurface water that is in the pore spaces of soil and geologic units.

gray (Gy) - Unit of absorbed dose in the International System of Units (SI) equal to 1 joule per kilogram. 1 Gy = 100 rad.

half-life - Length of time in which a radioactive substance will lose one half of its radioactivity by decay. Half-lives range from a fraction of a second to billions of years, and each radionuclide has a unique half-life.

ion exchange - The reversible exchange of one species of ion for a different species of ion within a medium.

irradiation - Exposure to radiation.

isotopes - Different forms of the same chemical element that are distinguished by different numbers of neutrons in the nucleus. A single element may have many isotopes; some may be radioactive and some may be nonradioactive (stable). For example, the three isotopes of hydrogen are protium, deuterium, and tritium.

kurtosis - measure of the degree of peakedness of a data distribution.

maximally exposed individual - A hypothetical member of the public residing near the Hanford Site who, by virtue of location and living habits, could receive the highest possible radiation dose from radioactive effluents released from Hanford.

mean - Average value of a series of measurements.

The mean, X, was computed as:

$$X = \frac{1}{n} \sum_{i=1}^{n} X_i$$

where X_i is the ith measurement and n is the number of measurements.

median - Middle value in a set of results when the data are ranked in increasing or decreasing order.

millirem (mrem) - A unit of radiation dose equivalent that is equal to one one-thousandth (1/1000) of a rem. According to DOE standards, an individual member of the public may receive no more than 100 mrem per year from a site's operation. This limit does not include radiation received for medical treatment or the approximately 300 mrem that people receive annually from natural background radiation.

minimum detectable concentration - Smallest amount or concentration of a radioactive or nonradioactive element that can be reliably detected in a sample.

mode - the value of the piece of data that occurs with the greatest frequency.

noble gas - Any of a group of chemically and biologically inert gases that includes argon, krypton, and xenon. These gases are not retained in the body following inhalation. The principal exposure pathways from radioactive noble gases are direct external dose from the surrounding air (see "Air Submersion Dose").

offsite locations - Sampling and measurement locations outside the Hanford Site boundary.

onsite locations - Sampling and measurement locations within the Hanford Site boundary.

outfall - End of a drain or pipe that carries waste water or other effluents into a ditch, pond, or river.

plume - The cloud of a pollutant in air, surface water, or ground water formed after the pollutant is released from a source.

plutonium - A heavy, radioactive, anthropogenic metallic element consisting of several isotopes. One important isotope is ^{239}Pu, which is produced by the irradiation of ^{238}U. Routine analysis cannot distinguish between the ^{239}Pu and ^{240}Pu isotopes; hence, the term ^{239,240}Pu as used in this report is symbolic of the presence of one or both of these isotopes in the analytical results.

radiation - The energy emitted in the form of rays or particles, such as those thrown off by transforming (disintegrating) atoms. For this report, radiation refers to ionizing types of radiation; not radiowaves, microwaves, radiant light, or other types of nonionizing radiation. The ionizing rays or particles typically consist of alpha, beta, or gamma radiation.

- **alpha radiation** - Least penetrating type of radiation. Alpha radiation can be stopped by a sheet of paper or the outer dead layer of skin, and can cause biological damage only if sufficient quantities are emitted inside the body.

- **beta radiation** - One form of radiation emitted from a nucleus during radioactive decay. Beta radiation can be stopped by an inch of wood or a thin sheet of aluminum, and may cause biological damage if a sufficient amount is internal, or occasionally external, to the body.

- **external radiation** - Radiation originating from a source outside the body.

- **gamma radiation** - Form of electromagnetic, high-energy radiation emitted from a nucleus. Gamma rays are essentially the same as x rays. They require heavy shielding, such as concrete or steel, to be stopped, and may cause biological damage when originating internally or externally to the body in sufficient amounts.

- **internal radiation** - Radiation originating from a source within the body as a result of the inhalation, ingestion, skin absorption, or implantation of natural or anthropogenic radionuclides in body tissues (e.g., uranium dust in the lungs, radioiodine in the thyroid).

radiation dose - For the purpose of this report, radiation doses are defined as follows:

- **absorbed dose** - Amount of energy deposited by radiation in a given amount of material. Absorbed dose is measured in units of "rads" or "grays."

- **collective effective dose equivalent** - Sum of the effective dose equivalents for individuals composing a defined population. The units for this are "person-rem" or "person-sievert."

- **committed dose equivalent** - Total dose equivalent accumulated in an organ or tissue in the 50 years following a single intake of radioactive materials into the body.

- **dose equivalent** - Product of the absorbed dose, the quality factor, and any other modifying factors. The dose equivalent is a quantity for comparing the biological effectiveness of different kinds of radiation on a common scale. The unit of dose equivalent is the rem. A millirem is one one-thousandth of a rem.

- **effective dose equivalent** - A value used for estimating the total risk of potential health effects from radiation exposure. This estimate is the sum of the committed effective dose equivalent (see above) from internal deposition of radionuclides in the body and the effective dose equivalent from external radiation received during a year.

radioactivity - Property possessed by some isotopes of elements of emitting radiation (such as alpha, beta, or gamma rays) spontaneously in their decay process to stable element isotopes.

radioisotope - Radioactive isotope of a specified element. Carbon-14 is a radioisotope of carbon. Tritium is a radioisotope of hydrogen.

- **long-lived radioisotope** - A radionuclide that decays at such a slow rate that a quantity will exist for an extended period (typically many years).

- **short-lived radioisotope** - A radionuclide that decays so rapidly that a given quantity is transformed almost completely into decay products within a short period (typically less than a few months).

radionuclide - Radioactive atomic species or isotope of an element. There are several hundred known radionuclides, both anthropogenic and naturally occurring. Radionuclide and radioisotope are terms that are sometimes used interchangeably, although they are theoretically different terms.

rem - Acronym for roentgen equivalent man; a unit of dose equivalent that indicates the potential for impact on human cells.

risk - The probability that a detrimental health effect will occur.

roentgen - Unit of x ray or gamma radiation exposure in air, typically used for describing external radiation levels. An exposure of 1 roentgen (R) is approximately equal to a 1-rem dose to human tissue.

sievert (Sv) - Unit of dose equivalent in the International System of Units (SI) equal to 100 rem.

skewness - measure of the lack of symetry in a frequency distribution.

spent fuel - Nuclear fuel that has been exposed in a nuclear reactor; this fuel contains uranium, activation products, fission products, and plutonium.

standard deviation - An indication of the dispersion or variability of a set of results around their average.

standard error of the mean - An indication of the dispersion or variability of an estimated mean from the average of other estimates of the same mean.
The standard error of X was computed as

$$SE = \sqrt{\frac{S^2}{n}}$$

where S^2, the variance of the n measurements, was computed as

$$S_M^2 = \frac{1}{n-1} \sum_{i=1}^{n} (X_i - X)^2$$

This estimator, S^2, includes the variance among the samples and the counting variance. The estimated S^2 may occassionally be less than the average counting variance.

taxon - A group of organisms constituting one of the categories or formal units in taxonomic classification (i.e., kingdom, phylum, class, order, family, genus, or species) and characterized by common characteristics in varying degrees of distinction.

thermoluminescent dosimeter (TLD) - A material that, after being exposed to beta and/or gamma radiation, emits light when processed and heated. The amount of light emitted is proportional to the amount of radiation (dose) to which the TLD has been exposed.

unconfined aquifer - An aquifer containing ground water that is not confined above by relatively impermeable rocks. The pressure at the top of the unconfined aquifer is equal to that of the atmosphere. At Hanford, the unconfined aquifer is the uppermost aquifer and is most susceptible to contamination from Site operations.

uncontrolled area - Area on or near a nuclear facility to which public access is not restricted.

vadose zone - underground area from the surface to the top of the water table or aquifer.

water table - Theoretical surface represented by the elevation of water surfaces in wells penetrating only a short distance into the unconfined aquifer.

whole-body dose - Radiation dose that involves exposure of the entire body. Whole-body dose typically refers to external radiation exposure.

wind rose - Star-shaped diagram showing how often winds of various speeds blow from different directions,

Appendix C

Applicable Standards and Permits

Appendix C

Applicable Standards and Permits

Operations at the Hanford Site must conform to a variety of governmental standards and permits designed to ensure the biological and physical quality of the environment for either public health, ecological, or aesthetic considerations. The primary environmental quality standards and permits applicable to Hanford operations in 1992 are listed in the following tables. The State of Washington has promulgated water quality standards for the Columbia River, Washington Administrative Code (WAC), 173-201. The Hanford Reach of the Columbia River has been designated 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 C.1. Drinking water standards promulgated by the U.S. Environmental Protection Agency (EPA) in 40 Code of Federal Regulations (CFR) 141 are summarized in Tables C.2 and C.3. Tri-Counties Air Pollution Control Authority air quality standards are shown in Table C.4. Applicable radiation standards pursuant to the Clean Air Act for sources of radionuclide emissions to the air, 40 CFR 61, are summarized in Table C.5. Environmental radiation protection standards are published in U.S. Department of Energy (DOE) Order 5400.5, "Radiation Protection of the Public and the Environment." This DOE order establishes new limits for public radiation dose and gives guidance for keeping radiation exposures to members of the public as low as reasonably achievable (ALARA). These standards are based on guidelines recommended by authoritative organizations, such as the International Commission on Radiological Protection and the National Council on Radiation Protection and Measurements. The DOE has initiated a policy for creating and implementing public radiation protection standards that are generally consistent with the standards used by the U.S. Nuclear Regulatory Commission (NRC) in regulating and licensing non-DOE nuclear facilities (i.e., nuclear power plants). Table C.5 shows the radiation standards from DOE Order 5400.5. These standards govern allowable public exposures to ionizing radiation from DOE operations.

In Order 5400.5, the DOE established Derived Concentration Guides (DCGs) that reflect the concentrations of individual nuclides in water or air that would result in an effective dose equivalent of 100 mrem per year caused by ingestion of water or inhalation of air at average annual intake rates. Table C.6 lists selected DCGs of particular interest at the Hanford Site. The DCGs are useful reference values but do not generally represent concentrations in the environment that ensure compliance with either the DOE, the Clean Air Act, or drinking water dose standards.

Permits required for regulated releases to water and air have been issued by the EPA under the National Pollutant Discharge Elimination System (NPDES) of the Clean Water Act and the Prevention of Significant Deterioration (PSD) requirements of the Clean Air Act. Also, under authority granted by the Clean Air Act, the Washington State Department of Health has issued a permit for Hanford radioactive air emissions. Permits for collecting wildlife for environmental sampling are issued by the Washington State Department of Wildlife and the U.S. Fish and Wildlife Service. Current permits are listed in Table C.7.

Table C.1. Washington State Water Quality Standards for the Hanford Reach of the Columbia River

Parameter	Permissible Levels
Fecal coliform	1) ≤100 organisms/100 mL 2) ≤10% of samples may exceed 200 organisms/100 mL
Dissolved oxygen	>8 mg/L
Temperature	1) ≤20°C (68°F) due to human activities 2) When natural conditions exceed 20°C, no temperature increase in receiving water of greater than 0.3°C allowed; nor shall increases at any time exceed 34/(T+9), where T = highest existing temperature in °C outside of dilution zone.
pH	1) 6.5 to 8.5 range 2) <0.5 unit induced variation
Turbidity	≤5 NTU[(a)] over background turbidity
Toxic, radioactive, or deleterious materials	Concentrations shall be below those of public health significance, or which cause acute or chronic toxic conditions to the aquatic biota, or which may adversely affect any water use.
Aesthetic value	Shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste.

(a) NTU = nephelometric turbidity units.

Table C.2. Selected Radiological Drinking Water Standards: U.S. Environmental Protection Agency, National Primary Drinking Water Regulations (40 CFR 141); and State of Washington, Rules and Regulations of the State Board of Health Regarding Public Water Systems (WAC 248-54)

Contaminant	Limit
Total alpha (excluding uranium)	15 pCi/L
Combined ^{226}Ra and ^{228}Ra	5 pCi/L
Radium-226 (State of Washington only)	3 pCi/L
Beta and gamma radioactivity from anthropogenic radionuclides	Annual average concentration shall not produce an annual dose from anthropogenic radionuclides equivalent to the total body or any internal organ dose greater than 4 mrem/yr. If two or more radionuclides are present, the sum of their annual dose equivalents shall not exceed 4 mrem/yr. Compliance may be assumed if annual average concentrations of total beta, ^{3}H, and ^{90}Sr are less than 50, 20,000, and 8 pCi/L, respectively.

The following list provides the annual average concentrations for anthropogenic radionuclides of interest. These radionuclides are assumed to yield an annual dose of 4 mrem to the indicated organ. Data are taken from the National Interim Primary Drinking Water Regulations, Table IV-2A (EPA 1976).

Radionuclide	Critical Organ	Concentration, pCi/L
^{3}H	Whole body	20,000
^{14}C	Fatty tissue	2,000
^{60}Co	GI (LLI)[a]	100
^{89}Sr	Bone	20
^{89}Sr	Bone marrow	80
^{90}Sr	Bone marrow	8
^{95}Zr	GI (LLI)	200
^{95}Nb	GI (LLI)	300
^{99}Tc	GI (LLI)	900
^{103}Ru	GI (LLI)	200
^{106}Ru	GI (LLI)	30
^{125}Sb	GI (LLI)	300
^{129}I	Thyroid	1
^{131}I	Thyroid	3
^{134}Cs	GI (S)[b]	20,000
^{137}Cs	Whole body	200

(a) Gastrointestinal tract (lower large intestine).
(b) Stomach.

Table C.3. Selected Chemical Drinking Water Standards: U.S. Environmental Protection Agency, National Primary Drinking Water Regulations (40 CFR 141); and State of Washington, Public Water Supplies (WAC 248-54)

Chemical Constituent	Concentration
As	50 µg/L
Ba	1 mg/L
CCl_4	5 µg/L
Cd	10 µg/L
Cr	50 µg/L
Cu	1 mg/L
F^-	2 mg/L
Hg	2 µg/L
NO_3^-	45 mg/L
Pb	50 µg/L
Se	10 µg/L

Table C.4. Benton-Franklin-Walla Walla Counties (Tri-Counties) Air Pollution Control Authority Ambient Air Quality Standards[a]

Parameter	Type of Standard[b]	Sampling Period	Permissible Level
NO_2	Secondary and primary	Annual average	100 µg/m^3

(a) Benton-Franklin-Walla Walla Counties Air Pollution Control Authority (1980).
(b) Primary standards for ambient air quality define levels of air quality to protect the public health. Secondary standards define levels of air quality to protect the public welfare from any known or anticipated adverse effects of a pollutant.

Table C.5. Radiation Standards (Dose Limits[a]) for Protection of the Public from All Routine DOE Activities

All Pathways [limits from DOE Order 5400.5]

The effective dose equivalent for any member of the public from all routine DOE activities[b] shall not exceed the values given below.

	Effective Dose Equivalent[c]	
	mrem/yr	mSv/yr
Routine Public Dose	100	1
Potential Authorized Temporary Public Dose[d]	500	5

Dose to Native Aquatic Animal Organisms from Liquid Discharges [interim limits from DOE Order 5400.5]

Radioactive material in liquid wastes discharged to natural waterways shall not cause an absorbed dose[e] to native aquatic animal organisms that exceeds 1 rad per day (10 mGy per day).

Drinking Water Pathway Only [limits from 40 CFR 141 and DOE Order 5400.5]

Radionuclide concentrations in DOE-operated public drinking water supplies shall not cause persons consuming the water to receive an effective dose equivalent greater than 4 mrem (0.04 mSv) in a year. DOE activities shall not cause private or public drinking water systems downstream of the facility discharge to exceed the radiological drinking water limits in 40 CFR 141 (Table B.2).

Air Pathways Only [limits from 40 CFR 61]

	Effective Dose Equivalent[c]	
	mrem/yr	mSv/yr
Public Dose Limit at Location of Maximum Annual Air Concentration as a Consequence of Routine DOE Activities[b]	10	0.1

(a) Radiation doses received from natural background, residual weapons testing and nuclear accident fallout, and medical consumer product exposures are excluded from the implementation of these dose limits.
(b) "Routine DOE activities" implies normal, planned activities and does not include actual or potential accidental or unplanned releases.
(c) Effective dose equivalent is expressed in rem (or millirem) with the corresponding value in sievert (or millisievert) in parentheses.
(d) Authorized temporary annual dose limits may be greater than 100 mrem/yr (but cannot exceed 500 mrem/yr) if unusual circumstances exist that make avoidance of doses greater than 100 mrem to the public impracticable. The RL is required to request and receive specific authorization from DOE-HQ for an increase from the routine public dose limit to a temporary annual dose limit.
(e) Absorbed dose is expressed in rad (or millirad) with the corresponding value in gray (or milligray) in parentheses.

Table C.6. Selected Derived Concentration Guides[a,b,c]

Radionuclide	Water, pCi/L (10^{-9} µCi/mL)	Air, pCi/m^3 (10^{-12} µCi/mL)
^{3}H	2,000,000	100,000
^{14}C	70,000	500,000
^{51}Cr	1,000,000	60,000
^{54}Mn	50,000	2,000
^{60}Co	5,000	80
^{65}Zn	9,000	600
^{85}Kr	NS[d]	3,000,000
^{90}Sr	1,000	50
^{99}Tc	100,000	2,000
^{103}Ru	50,000	2,000
^{106}Ru	6,000	30
^{125}Sb	60,000	1,000
^{129}I	500	70
^{131}I	3,000	400
^{137}Cs	3,000	400
^{144}Ce	7,000	30
^{234}U	500	0.09
^{235}U	600	0.1
^{238}U	600	0.1
^{238}Pu	40	0.03
^{239}Pu	30	0.02
^{240}Pu	30	0.02

(a) Concentration of a specific radionuclide in water or air that could be continuously consumed or inhaled at average annual rates and not exceed an effective dose equivalent of 100 mrem/yr. An exception is the limit for ^{85}Kr, which is based on the skin dose limit of 5 rem from immersion in a plume.

(b) Values in this table represent the lowest, most conservative derived concentration guides considered potentially applicable to Hanford operations, and may be adjusted upward (larger) if accurate solubility information is available.

(c) From DOE Order 5400.5.

(d) NS = No standard.

Table C.7. Environmental Permits

Clean Water Act Permit
NPDES Permit No. WA-000374-3, issued to the DOE, Richland Operations Office (RL) by Region 10 of the EPA, covers nonradioactive discharges to the Columbia River from eight outfalls. The following are measurements required for NPDES-permitted discharges at Hanford:

	Location		
Measurement	100-K Area (2 discharges)	100-N Area (5 discharges)	300 Area (1 discharge)
Flow rate	X	X	X
Suspended solids	X	X	X
Temperature	X	X	---[a]
pH	X	X	X
Chlorine	X	X	---
Oil and grease	---	X	---
Heat discharged	---	X	---
Settleable solids	---	---	X
Iron	---	X	---
Ammonia	---	X	---
Chromium	---	X	---

(a) Dashed line indicates no measurement required.

Clean Air Act Permits
PSD Permit No. PSD-X80-14, issued to RL by Region 10 of the EPA, covers emission of NO_x to the atmosphere from the Plutonium Uranium Extraction (PUREX) Plant and the Uranium Trioxide (UO_3) Plant. No expiration date.

Radioactive Air Emission Permit No. FF-01, issued to RL by the DOH under authority granted by the Clean Air Act, covers operations on the Hanford Site having a potential to emit radioactive airborne effluents. Initially issued August 15, 1991, the permit is for a 2-year period.

Wildlife Sampling Permits
Scientific Study or Collection Permit No. 036, issued by Washington State Department of Wildlife to Pacific Northwest Laboratory (PNL) for 1992, covers the collection of wildlife, including gamefish, for environmental monitoring purposes. Renewed annually.

Scientific Collection Permit No. 92-36, issued by Washington State Department of Fisheries to PNL for 1992, covers the collection of food fish and shellfish for environmental monitoring purposes. Renewed annually.

Federal Fish and Wildlife Permit No. 671877, issued by the U.S. Fish and Wildlife Service to PNL, covers the collection of migratory wildlife. Renewed annually (new rule).

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

State of Washington
Department of Ecology
Olympia, WA 98504

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

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

References

40 CFR 61. U.S. Government Printing Office, "National Emissions Standard for Hazardous Air Pollutants; Standards for Radionuclides." *Code of Federal Regulations.*

40 CFR 141. U.S. Government Printing Office, "National Primary Drinking Water Regulations." *Code of Federal Regulations.*

Benton-Franklin-Walla Walla Counties (Tri-Counties) Air Pollution Control Authority. 1980. *General Regulation 80-7.* Air Pollution Control Authority, Richland, Washington.

Clean Air Act. Public Law 88-206, as amended, 42 USC 7401 et seq.

Clean Water Act. Public Law 95-217, December 27, 1977, 91 Stat. 1566 and Public Law 96-148.

DOE Order 5400.5. 1990. "Radiation Protection of the Public and the Environment."

U.S. Environmental Protection Agency (EPA). 1976. *National Interim Primary Drinking Water Regulations.* EPA-570/9-76-003, Office of Water Supply, Washington, D.C.

Washington Administrative Code (WAC) 173-201, Water Quality Standards for Waters of the State of Washington, Washington State Department of Ecology.

Washington Administrative Code (WAC) 248-54, Public Water Supplies, Washington State Department of Social and Health Services. 1983.

Appendix D

Dose Calculations

Appendix D

Dose Calculations

The radiation dose that the public could have potentially received in 1992 from Hanford operations was calculated in terms of the "effective dose equivalent." These dose quantities are given in units of millirem (mrem) [millisievert (mSv)][a] for individuals and in units of person-rem (person-Sv) for the collective dose received by the total population within an 80-km (50 mi) radius of the Site. These quantities provide a way to express the radiation dose, regardless of the type or source of radiation or the means by which it is delivered. The values given in this report may be compared to standards for radiation protection (Table C.5, Appendix C). This appendix describes how the doses in this report were calculated.

Radionuclide release rates from Hanford Site activities are usually too low to be measured in offsite air, drinking water, and food crops. Therefore, in most cases, the dose calculations were based on measurements made at the point of release (stacks and effluent streams), and environmental concentrations were estimated from these effluent measurements by environmental transport models.

The transport of radionuclides from the environment to the body is predicted by empirical models of exposure pathways. These pathways account for inhalation or ingestion of radionuclides present in air, water, and foods. Radionuclides taken into the body may be distributed among different organs and retained for various times. In addition, long-lived radionuclides deposited on the ground become possible sources for long-term external exposure and uptake by agricultural products. Dietary and exposure parameters were applied to calculate radionuclide intakes and radiation doses to the public. Standardized computer programs were used to perform the calculations. These programs contain internally consistent mathematical models that use site-specific dispersion and uptake parameters. These programs are incorporated in a master code, GENII (Napier et al. 1988a, 1988b, 1988c), which employs the dosimetry methodology described in International Commission on Radiological Protection (ICRP) Reports (1979a, 1979b, 1980, 1981a, 1981b, 1982a, 1982b, 1988). The assumptions and input data used in these calculations are described below.

Types of Dose Calculations Performed

Calculations of radiation doses to the public from radionuclides released into the environment are performed to demonstrate compliance with applicable standards and regulations.

The U.S. Department of Energy (DOE) requires that estimates of radiation exposure to the general public be in terms of the "effective dose equivalent." The effective dose equivalent is representative of the total risk of potential health effects from radiation exposure. The adoption and use of the effective dose equivalent was previously recommended by the ICRP (1977). In addition to implementing the effective dose equivalent requirement for offsite population dose calculations, the DOE has also adopted the biokinetic models and metabolic parameters for radionuclides given by the ICRP in 1977 for estimating radiation dose. As in the past, when concentrations of radionuclides in the environment are too low to measure, then DOE specifies that the doses are to be calculated from effluent data using environmental transport and dosimetry models.

(a) 1 rem (0.01 Sv) = 1000 mrem (10 mSv).

The calculation of the effective dose equivalent takes into account the long-term (50-year) internal exposure from radionuclides taken into the body during the current year. The effective dose equivalent is the sum of individual committed (50-year) organ doses multiplied by weighting factors that represent the proportion of the total health-effect risk that each organ would receive from uniform irradiation of the whole body. Internal organs may also be irradiated from external sources of radiation. The external exposure received during the current year is added to the committed internal dose to obtain the total effective dose equivalent. In this report, the effective dose equivalent is expressed in rem (or millirem), with the corresponding value in sievert (or millisievert) in parentheses. The numerous transfer factors used for pathway and dose calculations have been documented in GENII (Napier et al. 1988a, 1988b, 1988c).

The following types of radiation doses were estimated:

1. **"Boundary" Dose Rate (mrem/h and mrem/yr).** The external radiation dose rates during the year in areas accessible by the general public were determined from measurements obtained in proximity to operating facilities.

2. **"Maximally Exposed Individual" Dose (mrem).** The maximally exposed individual is a hypothetical member of the public who lives at a location and has a postulated lifestyle such that it is unlikely that other members of the public would receive higher doses. All potentially significant exposure pathways to this hypothetical individual were considered, including the following:

- inhalation of airborne radionuclides
- submersion in airborne radionuclides
- ingestion of foodstuffs contaminated by radionuclides deposited on vegetation and the ground by both airborne deposition and irrigation water drawn from the Columbia River downstream of the N Reactor
- exposure to ground contaminated by both airborne deposition and irrigation water
- consumption of sanitary water derived from the Columbia River
- ingestion of fish taken from the Columbia River
- recreation along the Columbia River, including boating, swimming, and shoreline activities.

3. **80-km Population Doses (person-rem).** Regulatory limits have not been established for population doses. However, evaluation of the collective population doses to all residents within an 80-km (50-mi) radius of Hanford Site operations is required by DOE Order 5400.5. The 80-km (50-mi) population dose represents the summed products of the individual doses for the number of individuals involved for all potential exposure pathways.

The pathways assigned the maximally exposed individual were assumed to be applicable to the offsite population. Consideration was given, however, to the fraction of the offsite population actually affected by each pathway. The exposure pathways for the population are as follows:

- **Drinking Water.** The cities of Richland and Pasco obtain their municipal water directly, and Kennewick indirectly, from the Columbia River downstream from the Hanford Site. A total population of approximately 70,000 in the three cities drinks water derived from the Columbia River.
- **Irrigated Food.** Columbia River water is withdrawn for irrigation of small vegetable gardens and farms in the Riverview district of Pasco in Franklin County. Enough food is grown in this district to feed an estimated 2,000 people. Commercial crops are also irrigated by Columbia River water in the Horn Rapids area of Benton County.
- **River Recreation**. These activities include swimming, boating, and shoreline recreation. An estimated 125,000 people who reside within 80 km (50 mi) of the Hanford Site are assumed to be affected by these pathways.

- **Fish Consumption**. Population doses from the consumption of fish obtained locally from the Columbia River were calculated from an estimated total annual catch of 15,000 kg/yr (without reference to a specified human group of consumers).

Data

The data that are needed to perform dose calculations based on measured effluent releases include information on initial transport through the atmosphere or river, transfer or accumulation in terrestrial and aquatic pathways, and public exposure. By comparison, radiation dose calculations based on measured concentrations of radionuclides in food require data describing only dietary and recreational activities and exposure times. These data are discussed in the following sections.

Population Distribution and Atmospheric Dispersion

Geographic distributions of the population residing within an 80-km (50-mi) radius of the four Hanford Site operating areas are shown in the *Hanford Site Environmental Data for Calendar Year 1992—Surface and Columbia River* (Bisping and Woodruff 1993). These distributions are based on 1990 Bureau of Census data (Beck et al. 1991). These data influence the population dose by providing estimates of the number of people exposed to radioactive material releases and their proximity to the points of release.

Atmospheric dispersion data are also shown in the *Hanford Site Environmental Data for Calendar Year 1992—Surface and Columbia River* (Bisping and Woodruff 1993). These data describe the transport and dilution of airborne radioactive material, which influences the amounts of radionuclides being transported through the air to specific locations.

Terrestrial and Aquatic Pathways

Important parameters affecting the movement of radionuclides within potential exposure pathways, such as irrigation rates, growing periods, and holdup periods, are listed in Table D.1. Certain parameters are specific to either the lifestyles of "maximally exposed" or "average" individuals.

Public Exposure

The potential offsite radiation dose is related to the extent of external exposure to or intake of radionuclides that are released from Hanford Site operations. Tables D.2 through D.4 give the parameters describing the diet, residency, and river recreation assumed for "maximally exposed" and "average" individuals.

Dose Calculation Documentation

The Hanford Dose Overview Panel has the responsibility for defining standard, documented computer codes and input parameters to be used for radiation dose calculations for the public in the vicinity of the Hanford Site. Only those procedures, models, and parameters defined by the Hanford Dose Overview Panel were used to calculate the radiation doses. The calculations were then reviewed by the Dose Overview Panel. Summaries of dose calculation documentation for this report are shown in Tables D.5 through D.9 and *Hanford Site Environmental Data for Calendar Year 1992—Surface and Columbia River* (Bisping and Woodruff 1993).

Table D.1. Food Pathway Parameters Used in Dose Calculations,1992

	Holdup, days [a]		Growing		Irrigation
	Maximally Exposed Individual	Average Individual	Period, days	Yield, kg/m^2	Rate, $L/m^2/month$
Leafy vegetables	1	14	90	1.5	150
Other vegetables	5	14	90	4	170
Fruit	5	14	90	2	150
Cereal	180	180	90	0.8	0
Eggs	1	18	90	0.8	0
Milk	1	4			
Hay	(100)[b]	(100)	45	2	200
Pasture	(0)	(0)	30	1.5	200
Red meat	15	34			
Hay	(100)	(100)	45	2	200
Grain	(180)	(180)	90	0.8	0
Poultry	1	34	90	0.8	0
Fish	1	1	---	---	---
Drinking water	1	1	---	---	---

(a) Holdup is the time between harvest and consumption.
(b) Values in ( ) are the holdup in days between harvest and consumption by farm animals.

Table D.2. Dietary Parameters Used in Dose Calculations, 1992

	Consumption, kg/yr	
	Maximally Exposed Individual	Average Individual
Leafy vegetables	30	15
Other vegetables	220	140
Fruit	330	64
Grain	80	72
Eggs	30	20
Milk[a]	270	230
Red meat	80	70
Poultry	18	8.5
Fish	40	--[b]
Drinking water[a]	730	440

(a) Units L/yr.
(b) Average individual consumption not identified; radiation doses were calculated based on estimated total annual catch of 15,000 kg.

Table D.3. Residency Parameters Used in Dose Calculations, 1992

Parameter	Exposure, h/yr: Maximally Exposed Individual	Exposure, h/yr: Average Individual
Ground contamination	4,383	2,920
Air submersion	8,766	8,766
Inhalation[a]	8,766	8,766

(a) Inhalation rates: Adult 270 cm^3/s.

Table D.4. Recreational Parameters Used in Dose Calculations, 1992

Parameter	Exposure, h/yr[a]: Maximally Exposed Individual	Exposure, h/yr[a]: Average Individual
Shoreline	500	17
Boating	100	5
Swimming	100	10

(a) Assumed river water travel times from 100-N to the point of aquatic recreation were 8 h for the maximally exposed individual and 13 h for the average individual. Correspondingly lesser times were used for other locations.

Table D.5. Documentation of 100-N Area Airborne Release Dose Calculations, 1992

Facility name	100-N Area
Releases	See Table 3.1
Meteorological conditions	1992 annual average, calculated from data collected at the 100-N Area and the Hanford Meteorology Station from January 1992 through December 1992, using the computer code HANCHI [see Table D-5, Bisping and Woodruff (1993)].
$\overline{X}/Q'$	Maximally exposed individual, 3.9×10^{-9} s/m³ at 53 km SSE, 80-km population, 1.8×10^{-3} person-s/m³
Release height	89-m effective stack height
Population distribution	375,000 ~~(see Table D-1, Bisping and Woodruff (1993))~~
Computer code	GENII, Version 1.485, 12-3-90
Doses calculated	Chronic, 1-year exposure, 50-year committed internal dose equivalent, and annual effective dose equivalent to individual and population
Pathways considered	External exposure to plume and ground deposits Inhalation Ingestion of locally produced foods
Files addressed	Radionuclide Library, Rev. 7-1-92 Food Transfer Library, Rev. 8-29-88 External Dose Factor Library, Rev. 5-9-88 Internal Dose Factor Library, Rev. 12-3-90

Table D.6. Documentation of 100-N Area Liquid Release Dose Calculations, 1992

Facility name	100-N Area
Releases	See Table 3.4
Mean river flow	101,000 cfs (2,860 m^3/s)
Shore-width factor	0.2
Population distribution	70,000 for drinking water pathway 125,000 for aquatic recreation 2,000 for consumption of irrigated foodstuffs 15,000 kg/yr total harvest of Columbia River fish
Computer code	GENII, Version 1.485, 12-3-90
Doses calculated	Chronic, 1-year exposure, 50-year committed internal dose equivalent, and annual effective dose equivalent to individual and population
Pathways considered	External exposure to irrigated soil, to river water, and to shoreline sediments Ingestion of drinking water, aquatic foods, and irrigated farm products
Files addressed	Radionuclide Library, Rev. 7-1-92 Food Transfer Library, Rev. 8-29-88 External Dose Factor Library, Rev. 5-9-88 Internal Dose Factor Library, Rev. 12-3-90 Bioaccumulation Factor Library, Rev. 10-26-92

Table D.7. Documentation of 200 Area Airborne Release Dose Calculations, 1992

Facility name	200 Areas
Releases	See Table 3.1
Meteorological conditions	1992 annual average, calculated from data collected at the Hanford Meteorology Station from January 1992 through December 1992, using the computer code HANCHI [see Table D-6, Bisping and Woodruff (1993)]
$\overline{X}/Q'$	Maximally exposed individual, 1.1 x 10^{-8} s/m 3 at 43 km SE; 80-km population, 1.7 x 10^{-3} person-s/m^3
Release height	89-m effective stack height
Population distribution	376,000 [~~see Table D-2, Bisping and Woodruff (1993)]~~
Computer code	GENII, Version 1.485, 12-3-90
Doses calculated	Chronic, 1-year exposure, 50-year committed internal dose equivalent, and annual effective ~~(whole-body)~~ dose equivalent to individual and population
Pathways considered	External exposure to plume and ground deposits Inhalation Ingestion of locally produced foods
Files addressed	Radionuclide Library, Rev. 7-1-92 Food Transfer Library, Rev. 8-29-88 External Dose Factor Library, Rev. 5-9-88 Internal Dose Factor Library, Rev. 12-3-90

Table D.8. Documentation of 300 Area Airborne Release Dose Calculations, 1992

Facility name	300 Areas
Releases	See Table 3.1
Meteorological conditions	1992 annual average, calculated from data collected at the 300 Area and the Meteorology Station from January 1992 through December 1992, using the computer code HANCHI [see Table D-7, Bisping and Woodruff (1993)]
$\overline{X}/Q'$	Maximally exposed individual, 8.9×10^{-8} at 13 km SSE; 80-km population, 8.0×10^{-3} person-s/m^3 s/m³
Release height	10 m
Population distribution	282,000 ~~[see Table D-3, Bisping and Woodruff (1993)]~~
Computer code	GENII, Version 1.485, 12-3-90
Doses calculated	Chronic, 1-year exposure, 50-year committed internal dose equivalent, and annual effective ~~(whole-body)~~ dose equivalent to individual and population
Pathways considered	External exposure to plume and ground deposits Inhalation Ingestion of locally produced foods
Files addressed	Radionuclide Library, Rev 7-1-92 Food Transfer Library, Rev. 8-29-88 External Dose Factor Library, Rev. 5-9-88 Internal Dose Factor Library, Rev. 12-3-90

Table D.9. Documentation of 400 Area Airborne Release Dose Calculations, 1992

Facility name	300 Areas
Releases	See Table 3.1
Meteorological conditions	1992 annual average, calculated from data collected at the 400 Area and the Meteorology Station from January 1992 through December 1992, using the computer code HANCHI [see Table D-8, Bisping and Woodruff (1993)]
$\overline{X}/Q'$	Maximally exposed individual, 4.2×10^{-8} s/m3 at 22 km SSE; 80-km population, 5.6×10^{-3} person-s/m^3
Release height	10 m
Population distribution	283,000 ~~[see Table D-4, Bisping and Woodruff (1993)]~~
Computer code	GENII, Version 1.485, 12-3-90
Doses calculated	Chronic, 1-year exposure, 50-year committed internal dose equivalent, and annual effective ~~(whole-body)~~ dose equivalent to individual and population
Pathways considered	External exposure to plume and ground deposits Inhalation Ingestion of locally produced foods
Files addressed	Radionuclide Library, Rev 7-1-92 Food Transfer Library, Rev. 8-29-88 External Dose Factor Library, Rev. 5-9-88 Internal Dose Factor Library, Rev. 12-3-90

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Appendix E

RCRA and CERCLA Monitoring Documents

Appendix E

RCRA and CERCLA Monitoring Documents

The following lists Resource Conservation and Recovery Act (RCRA) ground-water monitoring publications for 1992:

- U.S. Department of Energy (DOE). 1992. *Quarterly Report of RCRA Groundwater Monitoring Data for January 1, 1992 Through March 31, 1992.* DOE/RL 92-26-1, U.S. Department of Energy, Richland, Washington.

- U.S. Department of Energy (DOE). 1992. *Quarterly Report of RCRA Groundwater Monitoring Data for April 1, 1992 Through June 30, 1992.* DOE/RL 92-26-2, U.S. Department of Energy, Richland, Washington.

- U.S. Department of Energy (DOE). 1992. *Quarterly Report of RCRA Groundwater Monitoring Data for July 1, 1992 Through September 30, 1992.* DOE/RL 92-26-3, U.S. Department of Energy, Richland, Washington.

Below is the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) ground-water monitoring publication for 1992:

- Westinghouse Hanford Company (WHC). 1992. *Groundwater Data Quality Report for the 1100-EM-1 Operable Unit for First and Second Quarter 1992.* WHC-MR-0296, Westinghouse Hanford Company, Richland, Washington.

The annual and fourth quarter RCRA/CERCLA documents are currently being prepared and will not be published until midyear 1993. There were no reports on the 100 and 200 Area operable units during 1992.

Appendix F

Radionuclides Detected by Gamma Spectroscopy

Appendix F

Radionuclides Detected by Gamma Spectroscopy (Gamma Scan)

One of the more common forms of radiation is gamma radiation. Gamma radiation is emitted by many radionuclides. Gamma spectroscopy, sometimes called a gamma scan, is used in the environmental surveillance program to detect the presence of the radionuclides shown in Table F.1. These radionuclides may be natural or result from Hanford activities. They include activation products formed by the absorption of a neutron by a stable element and fission products that occur following fission (splitting) of nuclear fuel radionuclides like ^{235}U or ^{239}Pu. These radionuclides may not be discussed in the main body of this report if they are below detection levels.

Table F.1. Radionuclides Analyzed by Gamma-Spectroscopy

Radionuclide	Symbol	Source
Beryllium-7	^{7}Be	Natural
Sodium-22	^{22}Na	Activation product
Sodium-24	^{24}Na	Activation product
Potassium-40	^{40}K	Natural
Manganese-54	^{54}Mn	Activation product
Cobalt-58	^{58}Co	Activation product
Cobalt-60	^{60}Co	Activation product
Iron-59	^{59}Fe	Activation product
Zinc-65	^{65}Zn	Activation product
Zirconium/Niobium-95	$^{95}Zr/Nb$	Activation product and fission product
Molybdenum-99	^{99}Mo	Activation product and fission product
Ruthenium-103	^{103}Ru	Activation product and fission product
Ruthenium-106	^{106}Ru	Fission product
Antimony-125	^{125}Sb	Activation product
Iodine-131	^{131}I	Fission product
Cesium-134	^{134}Cs	Activation product
Cesium-137	^{137}Cs	Fission product
Barium/Lanthanum-140	$^{140}Ba/La$	Fission product
Cerium-141	^{141}Ce	Activation product and fission product
Cerium/Praseodymium-144	$^{144}Ce/Pr$	Fission product
Europium-152	^{152}Eu	Activation product
Europium-154	^{154}Eu	Activation product
Europium-155	^{155}Eu	Activation product

Appendix G

Threatened and Endangered Species

Appendix G

Threatened and Endangered Species

Threatened and endangered plants and animals identified on the Hanford Site, as listed by the federal government [50 Code of Federal Regulations (CFR) 17] and Washington State (Washington Natural Heritage Program 1990), are shown in Table G.1. No plants or mammals on the federal list are known to occur on the Hanford Site. Several species of plants and animals, however, are under consideration for formal listing by the federal government and Washington State (Table G.2). One species, eatonella (*eatonella nivea*) is listed by the State as threatened. However, it has not been sighted on Hanford. It is known to exist near the Site and occupies habitats similar to those found at Hanford. Surveys have not been completed for this species. Washington State plant species of concern are listed in Table G.3.

Table G.1. Threatened (T) and Endangered (E) Species

Common Name	Scientific Name	Federal	State
Plants			
Columbia milk-vetch	*Astragalus columbianus*		T
Columbia yellowcress	*Rorippa columbiae*		E
Hoover's desert parsley	*Lomatium tuberosum*		T
Northern wormwood	*Artemisia campestris borealis var. wormskioldii*		E
Birds			
Aleutian Canada goose	*Branta canadensis leucopareia*	E	E
Peregrine falcon	*Falco peregrinus*	E	E
Bald eagle	*Haliaeetus leucocephalus*	T	T
White pelican	*Pelecanus erythrorhychos*		E
Sandhill crane	*Grus canadensis*		E
Ferruginous hawk	*Buteo regalis*		T
Mammals			
Pygmy rabbit	*Brachylagus idahoensis*		T

Table G.2. Candidate Species

Common Name	Scientific Name	Federal	State
Molluscs			
Shortfaced lanx	*Fisherola (= Lanx) nuttalli*		X
Columbia pebblesnail	*Fluminicola (= Lithoglyphus) columbiana*	X	X
Birds			
Common loon	*Gavia immer*		X
Swainson's hawk	*Buteo swainsoni*		X
Ferruginous hawk	*Buteo regalis*	X	
Western sage grouse	*Centrocercus urophasianus phaios*	X	X
Sage sparrow	*Amphispiza belli*		X
Burrowing owl	*Athene cunicularia*		X
Loggerhead shrike	*Lanius ludovicianus*	X	X
Northern goshawk	*Accipter gentilis*	X	X
Black tern	*Chlidonias miger*	X	
Mammals			
Merriam's shrew	*Sorex merriami*		X
Townsend's big-eared bat	*Plecotus townsendii*		X
Pygmy rabbit	*Brachylagus idahoensis*	X	X
Plants			
Columbia milk-vetch	*Astragalus columbianus*	X	
Columbia yellowcress	*Rorippa columbiae*	X	
Hoover's desert parsley	*Lomatium tuberosum*	X	
Northern wormwood	*Artemisia campestris borealis* var. *wormskioldii*	X	

Table G.3. Washington State Plant Species of Concern Occurring on the Hanford Site

Common Name	Scientific Name	Status[a]
Dense sedge	*Carex densa*	S
Gray cryptantha	*Cryptantha leucophaea*	S
Bristly cyptantha	*Cryptantha interrupta*	S
Shining flatsedge	*Cyperus rivularis*	S
Piper's daisy	*Erigeron piperianus*	S
Southern mudwort	*Limosella acaulis*	S
False-pimpernel	*Lindernia anagallidea*	S
Dwarf evening primrose	*Oenothera pygmaea*	S
Tooth-sepal dodder	*Cuscuta denticulata*	M1
Thompson's sandwort	*Arenaria franklinii v. thompsonii*	M2
Robinson's onion	*Allium robinsonii*	M3
Squill onion	*Allium syscillioides*	M3
Columbia River mugwort	*Artemisia lindleyana*	M3
Stalked-pod milkvetch	*Astragalus sclerocarpus*	M3
Medic milkvetch	*Astragalus speirocarpus*	M3
Crouching milkvetch	*Astragalus succumbens*	M3
Rosy balsamroot	*Balsamorhiza rosea*	M3
Palouse thistle	*Cirsium brevifolium*	M3
Smooth cliffbrake	*Pellaea glabella*	M3
Fuzzy-tongue penstemon	*Penstemon eriantherus*	M3

The following species may inhabit the Hanford Site, but have not been recently collected, and the known collections are questionable in terms of location and/or identification.

Palouse milkvetch	*Astragalus arrectus*	S
Few-flowered blue-eyed Mary	*Collinsia sparsiflora*	S
Coyote tobacco	*Nicotiana attenuata*	S

(a) Abbreviations: S = Sensitive; taxa vulnerable or declining, and could become endangered or threatened without active management or removal of threats; M1 = Monitor Group 1, taxa for which there are insufficient data to support listing as threatened, endangered, or sensitive; M2 = Monitor Group 2, taxa with unresolved taxonomic questions; M3 = Monitor Group 3, taxa that are more abundant and/or less threatened than previously assumed.

References

50 CFR 17, U.S. Fish and Wildlife Service, Department of Interior, "Endangered and Threatened Wildlife and Plants." *Code of Federal Regulations.*

Washington Natural Heritage Program. 1990. *Endangered, Threatened, and Sensitive Vascular Plants of Washington.* Department of Natural Resources, Olympia, Washington.

1992 Distribution

	No. of Copies
Hanford Site Contractors	
Pacific Northwest Laboratory (PNL)	226
Westinghouse Hanford Company (WHC)	111
Hanford Environmental Health Foundation (HEHF)	3
Kaiser Engineers Hanford (KEH)	1
DOE, EPA, State and Federal Agencies, Other DOE Sites, Other Companies, or Nuclear Facilities	
DOE Richland Operations Office (RL)	41
DOE Headquarters (DOE-HQ)	30
Environmental Protection Agency (EPA)	8
Washington State Agencies	19
Oregon State Agencies	7
Other DOE Sites and Federal Agencies, Other Companies or Nuclear Facilities	73
Libraries, Universities, and Schools	13
Public and Elected Officials	25
Professional Organizations, Public Interest Groups, and Native American Officials	44
Farmers Contributing Samples for Analyses	29
Owners and/or Administrators of Islands in the Hanford Reach of the Columbia River (Excluding DOE)	7
Community-Operated Environmental Surveillance Station Managers	5
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