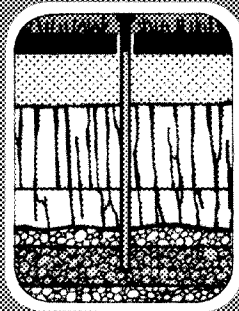
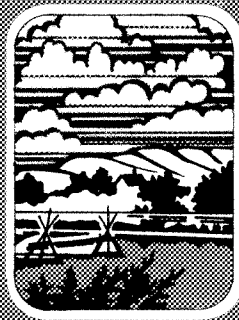


File Copy R. H. H. H.

PNL-7930  
UC-602

# Hanford Site Environmental Report for Calendar Year 1990

## Environmental Excellence



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

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



PNL-7930

## DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor Battelle Memorial Institute, nor any of their employees, makes **any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights.** Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or Battelle Memorial Institute. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

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

Printed in the United States of America

Available to DOE and DOE contractors from the  
Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831;  
prices available from (615) 576-8401. FTS 626-8401.

Available to the public from the National Technical Information Service,  
U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161.



This document is printed on recycled paper.

PNL-7930  
UC-602

## **Hanford Site Environmental Report for Calendar Year 1990**

### **Scientific Editors**

R. K. Woodruff  
R. W. Hanf

### **Technical Editors**

M. G. Hefty  
R. E. Lundgren

December 20, 1991

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

Pacific Northwest Laboratory  
Richland, Washington 99352





# Preface

The U.S. Department of Energy (DOE) Order 5400.1, "General Environmental Protection Program," establishes the requirement for environmental protection programs to ensure that DOE operations are in compliance with applicable federal, state, and local environmental laws and regulations, executive orders, and department policies. The DOE Richland Field Office (RL) has established a plan for implementing this order, *United States Department of Energy-Richland Operations Office Environmental Protection Implementation Plan* (Brich and Paasch 1990); this plan is updated annually.

The *Hanford Site Environmental Report* is prepared annually pursuant to DOE Order 5400.1 for the purpose of presenting summary environmental data that characterize Hanford Site environmental management performance and that 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 order reporting requirements and guidelines, it is also intended to meet the needs of the public. The Summary has been written minimizing the use 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 Technical Support Division as an activity of the Hanford Environmental Surveillance and Oversight Program, Pacific Northwest Laboratory, Office of Hanford 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 Technical Support Division, P.O. Box 550, Richland, Washington 99352, or to Pacific Northwest Laboratory, Office of Hanford Environment, P.O. Box 999, Richland, Washington 99352.



# 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). However, the report is also intended to meet the needs of the public. This summary has been written with a minimum of technical terminology. The section entitled Helpful Information can also aid in reading and interpreting the body of the report.

This report is prepared for the DOE Richland Field Office, Technical Support Division, as an activity of the Hanford Environmental Surveillance and Oversight Program, Pacific Northwest Laboratory, Office of Hanford Environment. Inquiries regarding this report may be directed to the U.S. Department of Energy, Richland Field Office, Technical Support Division, P.O. Box 550, Richland, Washington 99352, or Pacific Northwest Laboratory, Office of Hanford Environment, P.O. Box 999, Richland, Washington 99352.

The following sections:

- describe the Hanford Site and its new mission
- summarize the status in 1990 of compliance with environmental regulations
- describe the environmental programs at the Hanford Site
- present information on environmental surveillance and the ground-water protection and monitoring program
- discuss activities to ensure quality.

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

## The Hanford Site and Its Mission

The Hanford Site in southcentral Washington State is about 1,450 km<sup>2</sup> (about 560 mi<sup>2</sup>) of semi-arid shrub-steppe located just north of the confluence of the Snake and Yakima rivers. 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)
- 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 other operational areas.

The Hanford Site was acquired by the federal government in 1943 and was dedicated for more than 20 years primarily to the production of plutonium for national defense and the management of the resulting wastes. In the following years, missions were diversified to include research and development in the areas of energy, waste management, and environmental restoration.

## Summary

The DOE is ending the production of nuclear materials at Hanford for weapons. The new mission being implemented by the DOE Richland Field 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 defense activities) in the 200-East and 200-West Areas and storing used fuel in the 100-K Area.

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. The environmental restoration program was established to clean up about 1,100 inactive waste sites.

Research and technology development activities are also conducted on the Hanford Site in the 200 and 300 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
- Boeing Computer Services Richland (subcontractor to Westinghouse Hanford Company).

Non-DOE operations and activities included 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 by U.S. Ecology (near the 200 Areas). Advanced Nuclear Fuels Corporation (now Siemens Nuclear Power Corporation) operated a commercial nuclear fuel fabrication facility, and Allied Technology Group Corporation operated a low-level radioactive waste decontamination, supercompaction, and packaging-for-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 1990.

A key element in Hanford's compliance program is the Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement). The Tri-Party Agreement establishes schedules for achieving compliance with requirements for managing hazardous and mixed wastes and provides the framework for the cleanup of Hanford over the next 30 years. The Tri-Party Agreement is an agreement among the U.S. Environmental Protection Agency (EPA), Washington State Department of Ecology (WDOE), 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 the Resource Conservation and Recovery Act (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 extended it to 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 studies (RI/FS) process at some operable units on the Hanford Site. All milestones related to the RI/FS process established for 1990 were achieved, and Hanford was in compliance with these CERCLA/SARA requirements.

Under Section 103(a), the Emergency Release Notification provision of CERCLA, releases exceeding reportable quantity limits for regulated chemicals were appropriately reported.

#### **Superfund Amendments and Reauthorization Act, Title III**

Title III of SARA is a free-standing law, called the Emergency Planning and Community Right-to-Know Act of 1986. The purpose of Title III is to provide the public with information about hazardous chemicals in their community and

establish emergency planning and notification procedures to protect the public in the event of a release.

During 1990, the Hanford Site was in compliance with the reporting and notification requirements contained in Title III.

#### **Resource Conservation and Recovery Act**

The RCRA establishes regulatory standards for the generation, transportation, storage, treatment, and disposal of hazardous waste. The WDOE has been authorized by the EPA to implement these regulatory standards in Washington State. The WDOE also implements the state's regulations, which are often more stringent.

At the Hanford Site, 61 treatment, storage, and disposal (TSD) units have been identified that must be permitted or closed in accordance with RCRA and Washington regulations. The TSD units are being operated under the interim status compliance requirements of the state's regulations. Approximately one-half of the units will be closed; applications for operating under a RCRA Part B permit will be made for the other units, which will continue to operate.

Subtitle I of RCRA deals with regulation of underground storage tank systems. The EPA has promulgated regulations that impose technical standards for tank performance and management, including standards governing the cleanup and closure of leaking tanks.

During 1990, five underground petroleum-product storage tanks located in the 100-N Area were removed from the ground and disposed of. Throughout the Hanford Site, nine other petroleum tanks and two pressurized piping systems were inspected and tested. Two petroleum storage tanks, one at the 100-N Area and the other at the 200-East Area, were reported as each having a leak near the top of the tank.

Another issue for 1990 was the methods for handling and disposing of potentially contaminated purgewater. (Ground-water monitoring wells on

## Summary

the Hanford Site are purged before sampling.) On August 9, 1990, the Tri-Party Agreement Project Managers for DOE, EPA, and WDOE signed the "Strategy for Handling and Disposing of Purgewater at the Hanford Site, Washington." The strategy includes containing the purgewater in retention tanks and sampling for contaminants before it is returned to the soil.

Under provisions of RCRA, new management strategies and new technologies must be developed to reduce the volume and toxicity of waste generated. Numerous waste minimization techniques are being implemented across the Site.

A number of major nationwide regulatory conflicts and issues have been identified in complying with RCRA requirements. The RL has notified regulators of the compliance issues considered unresolved and of national significance. The WDOE has not formally responded. The EPA is addressing these issues on the national level.

### 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, WDOE, 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 Plutonium Uranium Extraction (PUREX) and Uranium Oxide (UO<sub>3</sub>) plants.

The DOH, Division of Radiation Protection, has promulgated regulatory controls for radioactive air emissions under Section 116 of the Clean Air Act. Washington State regulations (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. These stacks are included in the DOH permit (No. FF-01) to RL for the Hanford Site.

New Clean Air Act requirements for radioactive air emissions were issued December 15, 1989, under 40 CFR 61, Subpart H. Emissions from the Hanford Site are well within the new EPA offsite emissions standard of 10 mrem/yr [effective dose equivalent (see Glossary)]. However, Hanford Site sources do not yet meet the new procedural requirements for flow measurement, emissions measurement, quality assurance, and sampling documentation. The RL sent a formal request for a 2-year extension of the Subpart H requirements to EPA Region 10 on May 14, 1990.

The EPA has retained authority for regulating certain hazardous pollutants under different standards, called the National Emission Standards for Hazardous Air Pollutants (NESHAP), per 40 CFR 61. Pursuant to the NESHAP program within the Clean Air Act, EPA has developed regulations specifically addressing asbestos emissions. These regulations apply at Hanford in building demolition/disposal and waste disposal operations.

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 been delegated to enforce the EPA asbestos regulations under NESHAP. The Site remains in compliance with the regulations.

During 1990, Hanford Site air emissions remained below all regulatory limits concerning radioactive and other regulated pollutants.

### Clean Water Act

The Clean Water Act applies to all nonradioactive 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 three reportable releases in 1990. The first occurred when the free available chlorine discharge limit was exceeded in April 1990 at a 100 Area outfall. The 300 Area reported that the settleable solids discharge limit was exceeded in May 1990. On June 20, 1990, an aluminum sulfate spill resulted in a discharge that exceeded the pH limit for a 100 Area outfall. Nonetheless, during 1990, the Hanford Site was in substantive compliance with the discharge limits.

### **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. During 1990, sanitary water was supplied on the Hanford Site by 15 individual drinking water systems. With one exception, all water systems were in compliance with the requirements of the applicable regulations. The one exception concerns the requirement for the correct number of certified operators.

### **Toxic Substances Control Act**

The application of Toxic Substances Control Act requirements to Hanford essentially involves regulation of PCBs. The Hanford Site is currently in compliance with regulations for nonradioactive PCBs. For radioactive PCBs, effective treatment and disposal technologies have not been developed. These wastes are being stored with EPA approval, pending development of treatment and disposal technologies.

### **Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)**

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. The FIFRA and the Revised Code of Washington 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 3.3, "Environmental Studies and Programs." Hanford activities complied with the Endangered Species Act in 1990.

### **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 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 3.3, "Environmental Studies and Programs." In 1990, Hanford operations complied with these Acts.

### **National Environmental Policy Act (NEPA)**

The 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:

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

## Summary

- *Office of Environmental Restoration and Waste Management Programmatic Environmental Impact Statement*
- *Hanford Remedial Action Environmental Impact Statement*
- *Irradiated Fuel Environmental Impact Statement*
- *Waste Tank Safety Supplemental Environmental Impact Statement*
- *Single-Shell Tank Closure Supplemental Environmental Impact Statement*
- *New Production Reactor Environmental Impact Statement*
- Leaking Pipe (WHC-UO-90-33-SWM-03)
- Gasoline Leak (WHC-90-0337-100N)
- Missing Ethylene Glycol (PNL-90-06)
- Unauthorized Disposal of Liquid Hazardous Waste (PNL-90-04)
- Waste Container Failure (Kaiser 90-001)
- Radionuclide Release (WHC-UO-90-031-B Plant-02)
- Contamination Control Loss in the 200-West Area (WHC-UO-90-007-SWM-1).

## Environmental Occurrences

Onsite and offsite environmental occurrences (spills, leaks, etc.) of radioactive and nonradioactive effluent materials during 1990 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 at the Federal Building, Richland, Washington. There were no Emergency Occurrence Reports on file in the reading room for 1990. A large number of off-normal environmental occurrence reports were filed at Hanford during 1990, covering everything from spills of automotive battery acid to leaks from overheated motor vehicle cooling systems. Because of the volume of reported off-normal occurrences, event summaries are not included here.

The 1990 unusual occurrences with the most potential for environmental impact and their occurrence numbers are:

- Aluminum Sulfate Spill (WHC-UO-90-027-100N-01)
- Apparent Tank Leak (WHC-UO-90-23-TF-05)
- Chlorine Discharge to the Columbia River (WHC-UO-90-028-100N-02)

## Environmental Programs

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

### Environmental Restoration

The environmental restoration program has been established, as mandated by Congress in 1988, to clean up inactive waste sites, and decontaminate and decommission surplus facilities. Two major programs will implement these actions:

- environmental restoration remedial action program
- Hanford surplus facilities program.

The environmental restoration remedial action program was established to comply with regulations for characterization and cleaning up of inactive waste sites. The program specifically includes identification and characterization of inactive sites, cleanup design and action, and post-closure activities of inactive radioactive, chemically hazardous, and mixed waste sites. A number of operable units (clusters of waste sites) have been created. The operable units in the 1100 Area have been given high priority because of their proximity to drinking water sources for the city of Richland. The environmental



restoration remedial action program will also support development of optimal waste retrieval and in-place disposal technologies for the several types of wastes currently stored in single-shell tanks.

Many DOE-owned facilities at the Hanford Site that were formerly used for nuclear materials production have been retired from service and declared surplus. The Hanford surplus facilities program manages these facilities for DOE. The program provides for surveillance and maintenance, as well as eventual decommissioning, of these facilities.

The activities currently under way include cleaning up the 183-H Solar Evaporation Basins, decommissioning of the 201-C Strontium Semi-works, decommissioning of several 100 Areas ancillary facilities, and preparing the final EIS *Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington*.

### 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. An important component is to minimize the generation of waste. The Site contractors have integrated waste minimization and pollution prevention awareness programs into a single, coordinated initiative. Waste minimization is being accomplished primarily by source reduction and recycling techniques.

A major strategy for Hanford's waste management is to discontinue discharges of liquid contaminated 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 Tri-Party Agreement Action Plan.

The major effort for cleanup of the Hanford Site will be the disposal of the stored wastes resulting from past production operations. The strategies for handling and disposing of these wastes, as

well as newly generated wastes, were established through the National Environmental Policy Act (NEPA) 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*.

### Technology Development

The Office of Technology Development was formed to consolidate and provide centralized management and oversight for research, development, demonstration, testing, and evaluation activities, and support to DOE Headquarters (HQ, in Washington, D.C.) Offices of Environmental Restoration and Waste Management, Waste Operations, Defense Programs, Nuclear Energy, and Energy Research. The technology development activities seek to coordinate new and more effective technologies to solve environmental restoration and waste management problems.

During 1990, two integrated demonstrations were assigned to Hanford contractors for lead coordination: 1) for underground storage tank stabilization and remediation, and closure of high-priority single-shell tank RCRA sites and 2) to provide solutions for the expedited response action to remediate the carbon tetrachloride plume in the 200-West Area.

### Environmental Studies

Studies were conducted to monitor rare, threatened, or endangered species; species of wildlife and fish that are valued as commercial, recreational, or aesthetic resources; and those species that can be used as biological indicators of the presence of toxic and hazardous materials in the environment. In addition, the Cultural Resources Project manages the archaeological, historical, and cultural resources of the Hanford Site in a manner consistent with the National Historic Preservation Act, the Archaeological Resources Protection Act, and the American Indian Religious Freedom Act. A meteorology program was also maintained to document meteorological conditions at Hanford for emergency response purposes and use in dose calculations.

## Summary

The Hanford Environmental Dose Reconstruction (HEDR) Project was initiated in 1988 to develop estimates of the radiation doses people could have received from past operations at Hanford. In 1990 scientists completed the first phase of the project. The objectives of this phase were to 1) determine whether enough historical information could be found or reconstructed to be used for dose estimation, and 2) develop and test conceptual and computational models for calculating credible dose estimates.

## Environmental Monitoring Information

Environmental monitoring of the Hanford Site consists of 1) effluent monitoring and 2) environmental surveillance. Effluent monitoring is performed as appropriate by the Site facility operators at the facility or at the point of release to the environment. 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 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 describe the effluent monitoring and environmental surveillance conducted in 1990 and the results. During 1990 the contract for the analysis of environmental monitoring samples was terminated (see Section 2.3). The delays associated with replacement of the contract resulted in some samples not being analyzed, and in a few cases there appeared to be differences in the results from the two contractors. These cases are discussed in the body of the report.

### Effluent Monitoring

The facility operators quantify and document the amounts of radioactive and nonradioactive liquids, gases, and solids released to, or disposed of

in, the environment from their operations. These efforts determine the degree of compliance with applicable federal, state, and local regulations and permits. Major facilities have facility effluent monitoring plans that are part of the Site environmental monitoring plan required by DOE orders. Monitoring data are also used in pollution abatement programs that assess the effectiveness of effluent treatment and control.

Radioactive and nonradioactive releases to the air are monitored through a combination of stack measurements and calculations based on process data. Radioactive effluents include volatile forms of radionuclides, noble gases, and radioactive particles. Effluent streams that have a potential to release 10% of discharge limits are monitored. Stacks are monitored for total alpha and total beta activity and for specific radionuclides potentially emitted from the facility. Nonradioactive effluents are monitored in effluent streams that have a potential for emitting 50% of applicable standards. Monitoring focuses on nitrogen oxides, particulate matter, sulfur oxides, carbon monoxide, hydrocarbons, and ammonia. Air emission points were located in the 100, 200, 300, 400, 600, and 1100 Areas.

The total amount of activity released to air in 1990 decreased significantly from that released in 1989. However, releases of  $^{129}\text{I}$ , the primary contributor to the potential air pathway dose to the hypothetical maximally exposed individual, did not change. Nonradioactive discharges to air continued to be within permitted limits.

Liquid effluents are discharged onsite to cribs, ponds, ditches, trenches, and french drains. Effluents are discharged directly to the Columbia River from the 100 and 300 Areas, and to the City of Richland treatment facility from the 1100 Areas. Where the potential exists for regulated materials to be transported, samples are collected to ensure that the effluents do not exceed existing standards. Radioactive liquid discharges to the ground were significantly reduced in 1990 because of the closure of the PUREX Plant, as were nonradioactive discharges, with the exception of total organic carbon and nitrates in the 200 Areas. Radioactive discharges to the Columbia River in the 100 Area showed increases in some radionuclides and decreases in others.

Discharges to the river from ground-water infiltration along the Hanford Reach were estimated as lower than in 1989 based on the absence of any detection of  $^{99}\text{Tc}$ .

### Air Surveillance

Transport of atmospheric releases of radioactive and nonradioactive materials from Hanford to the surrounding region represents a direct pathway for human exposure. Radioactive materials in air were sampled continuously onsite, at the Site perimeter, and in nearby and distant communities at 53 locations. 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. Nitrogen dioxide ( $\text{NO}_2$ ) was sampled at three locations onsite. Several radionuclides released at Hanford are also found worldwide from two other sources: those radionuclides that are naturally occurring and those resulting from the fallout from nuclear weapons testing. The influence of Hanford emissions on local radionuclide levels was indicated by the difference between concentrations measured at a distant upwind location within the region and concentrations measured close to the Site.

In 1990,  $^3\text{H}$ ,  $^{129}\text{I}$ , uranium, gross alpha, and gross beta concentrations were greater at the downwind Site perimeter than at a distant upwind location. The differences in  $^3\text{H}$  and  $^{129}\text{I}$  were likely due to Site operations. The differences in gross alpha, gross beta, and uranium were predominantly due to the effects of natural geographic variations. The air pathway resulted in a potential dose to the maximally exposed individual that was 0.09% of the Clean Air Act standard. Annual average  $\text{NO}_2$  concentrations at all sampling locations were less than 12% of federal and Washington State ambient air quality standards.

### Surface-Water Surveillance

The Columbia River was one of the primary environmental exposure pathways to the public during 1990 as a result of operations at the Hanford

Site. Radiological and nonradiological 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. Non-radiological water quality constituents measured in Columbia River water during 1990 were also in compliance with applicable standards.

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 1990 were similar to those observed during past years. In all cases, radionuclide concentrations in the onsite pond water were below the DOE Derived Concentration Guides (DCG).

Samples of Columbia River surface sediments were collected from behind McNary and Priest Rapids dams and from three shoreline sloughs along the Hanford Reach of the Columbia River during 1990. Because of the termination of the analytical contract during the year, sediment sample results were not available for inclusion in this report. Previous sampling has shown that slightly elevated levels of some radionuclides exist in surface sediments behind McNary Dam as a result of Hanford operations.

Offsite water, used for irrigation and/or drinking water, was sampled to determine radionuclide concentrations in water used by the nearby public. Elevated gross alpha and gross beta concentrations, attributed to naturally occurring uranium, were observed at some locations. Average radionuclide concentrations in offsite water during 1990 were within applicable drinking water limits.

## Summary

### 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 during 1990. Samples were collected primarily from locations in the prevailing downwind directions (to the 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 levels of radioactivity that could be attributed to worldwide fallout. Foodstuffs were also collected from the Riverview area where crops were irrigated with water pumped from the Columbia River downstream of the Site. Alfalfa and foodstuff samples were analyzed for one or more of the following radionuclides:  $^3\text{H}$ ,  $^{90}\text{Sr}$ ,  $^{129}\text{I}$ ,  $^{131}\text{I}$ ,  $^{137}\text{Cs}$ , and  $^{239,240}\text{Pu}$ .

In many samples, the concentrations of specific radionuclides were below detection limits. However, low levels of  $^3\text{H}$ ,  $^{90}\text{Sr}$ ,  $^{129}\text{I}$ , and  $^{137}\text{Cs}$  were found in a number of foodstuff samples collected during 1990. Generally, concentrations of  $^{90}\text{Sr}$  and  $^{137}\text{Cs}$  in samples collected near the Hanford Site were similar to those in samples collected away from the Site. However,  $^{90}\text{Sr}$  was found at higher concentrations in alfalfa irrigated with Columbia River water, and concentrations of  $^{129}\text{I}$  appeared to be higher in milk sampled from locations close to the Hanford Site perimeter. Levels of  $^3\text{H}$  in wine indicated an apparent increase in concentration that will require further sampling and analysis to clarify. The potential offsite radiation dose from consumption of foodstuffs grown in the vicinity of the Hanford Site was a very small fraction of the public dose standard as determined by the reported measurements and pathway modeling (as discussed in "Potential Radiation Doses from 1990 Hanford Operations," Section 4.8).

### Wildlife Surveillance

The Hanford Site serves as a refuge for a variety of wildlife, such as waterfowl, rabbits, and deer. Wildlife have access to several areas near facilities that contain low levels of radionuclides attributable to Site operations (for example,

waste-water ponds) and serve as biological indicators of environmental contamination. Sampling was performed in areas where the potential exists for wildlife to ingest radionuclides from sources of surface contamination. The number of animals that visited these areas was small compared to the total wildlife population in the region. In addition, fish were collected from the Hanford Reach of the Columbia River. Analyses provided an indication of the radionuclide concentrations in local sport fish and were used to evaluate the potential dose to humans from this pathway.

Analytical results for wildlife, clam, and fish samples collected during 1990 were similar to those from recent years. The potential dose to a person who consumed wildlife containing even the maximum radionuclide concentrations measured in wildlife on the Site in 1990 was far below applicable standards for radiation dose. While most samples were collected as scheduled, only selected samples were analyzed because of the interruption in analytical services in June 1990.

### Soil and Vegetation Surveillance

Because of the loss of analytical support in June 1990 and limited capability to perform soil analyses at the interim analytical facility, only a small subset of the soil and vegetation samples collected and archived in 1990 were selected for analysis and reporting. No samples of soil or natural vegetation from onsite locations were analyzed. Samples were analyzed from three offsite soil locations and six vegetation locations east of Hanford. The purpose of sampling was to detect the possible accumulation of radionuclides from the deposition of airborne effluents released from Hanford facilities. Samples were collected at nonagricultural, relatively undisturbed sites so that natural deposition and accumulation would be represented.

Results in 1990 remained low and did not indicate trends or increases in the concentrations of radionuclides in the offsite environment that could be attributed to Hanford operations with the exception of increasing uranium concentrations. Uranium concentrations, however, remained very low and near natural soil concentrations.

## External Radiation Surveillance

Dose rates from external radiation were measured at a number of locations in 1990 using thermoluminescent dosimeters (TLDs). Artificial and naturally occurring external radiation sources (cosmic radiation and radionuclides in the air and ground), as well as worldwide fallout, all contributed to the dose rates measured. Results from both onsite and offsite TLDs were similar to results for the previous 5 years. Some onsite dose rates near waste storage and handling facilities were elevated above natural background rates, but these were in agreement with historical values. Any observed differences at specific locations can be attributed to variability in naturally occurring dose rates from year to year and expected measurement variability at low dose rates. These observations indicate no increase from the typical historical external radiation levels for all TLD locations.

Various routine external radiation and contamination surveys were performed at numerous locations on the Hanford Site. Selected onsite roads, railroads, waste disposal sites (located outside of operating areas), locations on the Columbia River shoreline, and areas of the Site perimeter were surveyed for elevated radiation levels. In addition, a report from the Remote Sensing Laboratory on a 1988 external radiation survey performed over the Hanford Site and surrounding area with aerial radiological equipment indicated no increase in areas with elevated external radiation levels since the last (1978) aerial study. In general, the report showed a decrease in levels historically attributed to past Hanford activities, mainly because of radioactive decay of the artificial radionuclide sources in the environment and, to some extent, the changing operational activities at the Site.

## Potential Radiation Doses from 1990 Hanford Operations

Potential radiation doses were calculated for the hypothetical maximally exposed individual (MEI) and the general public residing within 80 km of the Hanford Site. These calculations included the potential impact of radionuclides in the environment of Hanford from 1990 operations and of

those reaching the Columbia River from past operations.

The potential radiation dose to the MEI from Hanford operations in 1990 was 0.03 mrem (0.0003 mSv). The current DOE limit for an individual member of the public is 100 mrem/yr (1 mSv/yr), and the national average radiation dose from natural sources is 300 mrem/yr (3 mSv/yr). The dose that the MEI potentially received was 0.03% of the limit and 0.01% of the national average dose from natural sources.

The potential radiation dose from 1990 operations to the local population of 340,000 persons was 2 person-rem (0.02 person-Sv). The average dose to this population was potentially 0.006 mrem (0.00006 mSv) per person. This average dose is 0.006% of the limit and 0.002% of that from natural sources.

## Ground-Water Protection and Monitoring Program

Radiological and chemical constituents in ground water were monitored during 1990 throughout the Hanford Site in support of the overall objectives described in "Environmental Program Information," Section 3.0. 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 the Resource Conservation and Recovery Act, additional monitoring was conducted to assess the impact that specific facilities have had on ground-water quality (DOE 1991). During 1990, 623 Hanford Site wells were sampled to satisfy ground-water monitoring needs. As discussed in Section 4.3, four additional wells located across the Columbia River and east of the Hanford Site were sampled to determine whether Hanford operations had affected water quality off the Hanford Site.

Analytical results for samples were compared with EPA Drinking Water Standards (DWS) (Tables B.2 and B.3, Appendix B) and DOE's Derived Concentration Guides (DCG) (Table B.6,

## Summary

Appendix B). 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 4.8. 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 gross alpha, gross beta,  $^3\text{H}$ ,  $^{60}\text{Co}$ ,  $^{90}\text{Sr}$ ,  $^{99}\text{Tc}$ ,  $^{129}\text{I}$ , and  $^{137}\text{Cs}$  concentrations in wells in or near operating areas were at levels above the DWS. Concentrations of uranium in the 200-West Area were above the DCG. Concentrations of  $^3\text{H}$  in the 200 Areas and  $^{90}\text{Sr}$  in the 100-N and 200-East Areas were also above 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 ground water near operating 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 above the DWS at the 100-D, 100-H, and 100-K Areas, and in the surrounding areas. Chromium concentrations above 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, 200-West, and 300 Areas. Trichloroethylene levels in wells near the Solid Waste Landfill (outside the 200-East Area) have dropped to slightly below the DWS, while tetrachloroethylene levels in those wells remain just above the DWS. Sampling at monitoring wells near Richland water supply wells showed that concentrations of regulated

groundwater constituents in this area were below the DWS and, in general, below detection levels.

A comprehensive review of all ground-water monitoring work on the Site is published annually (for example, Evans et al. 1990). Before 1989, these reports contained complete listings of all radiological and chemical data collected during the reporting periods. Since 1989, complete listings can be found in a companion volume to this report (for example, Bryce and Gorst 1990).

## Quality Assurance

A comprehensive quality assurance (QA) program, which included various quality control (QC) practices and methods to verify data, was maintained to ensure data quality. The QA program is implemented through QA plans designed to meet the 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 surveillance activities, and conformance is verified by independent auditors. Quality control methods include 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 90% of the results were within the control limits, a result that ranked very favorably among participating laboratories.

# Acknowledgments

The production of the *Hanford Site Environmental Report* requires the knowledge, skills, information, and cooperation of many people and several organizations. The contributions and cooperation, often under demanding time constraints, of the following individuals are gratefully acknowledged. The lead authors are listed with the sections they were responsible for producing. (The authors are from the Pacific Northwest Laboratory unless otherwise indicated.)

Section	Lead Authors
Helpful Information	R. W. Hanf
1.0 Introduction	R. K. Woodruff
1.1 Site Mission	R. K. Woodruff
1.2 Major Operations and Activities	R. K. Woodruff
1.3 Site Environment	C. E. Cushing
2.0 Environmental Compliance Summary	R. A. Paasch, Westinghouse
3.0 Environmental Program Information	R. K. Woodruff
3.1 Environmental Restoration, Waste Management, and Technology Development	R. A. Paasch, Westinghouse
3.2 Environmental Monitoring at Hanford	R. K. Woodruff
Effluent Monitoring	M. J. Brown, Westinghouse
Environmental Surveillance	R. K. Woodruff
3.3 Environmental Studies and Programs	R. K. Woodruff
Wildlife Resources	W. H. Rickard
Cultural Resources	J. C. Chatters
Meteorology and Climatology of the Hanford Area	D. J. Hoitink
Hanford Environmental Dose Reconstruction Project	D. B. Shipler
Community-Operated Environmental Surveillance Stations	R. G. Schreckhise
Other Environmental Activities	R. K. Woodruff
4.0 Environmental Monitoring Information	R. K. Woodruff
4.1 Effluent Monitoring	L. P. Diediker, Westinghouse
4.2 Air Surveillance	G. W. Patton
4.3 Surface-Water Surveillance	R. L. Dirkes
4.4 Food and Farm Product Surveillance	T. M. Poston
4.5 Wildlife Surveillance	T. M. Poston
4.6 Soil and Vegetation Surveillance	T. M. Poston
4.7 External Radiation Surveillance	W. R. James
4.8 Potential Radiation Doses from 1990 Hanford Operations	J. K. Soldat
5.0 Ground-Water Protection and Monitoring Program	R. W. Bryce and J. C. Evans
6.0 Quality Assurance	W. R. James
7.0 References	Staff
Appendix A - Glossary	Staff
Appendix B - Applicable Standards and Permits	Staff
Appendix C - Dose Calculations	J. K. Soldat

The programs described in this report were managed by the Office of Hanford Environment under the direction of R.E. Jaquish. Valuable text processing support was provided by L. M. Andor, D. J. Kennedy, C. L. Ouren, and K. J. Webb. Finally, the authors appreciate the reviews by R. F. Brich, R. D. Hildebrand, and T. P. Pietrok of the U.S. Department of Energy Richland Field Office, and T. A. Ikenberry, G.L. Harvey, E. B. Moore, F. A. Spane, Jr., and L. K. Grove, Pacific Northwest Laboratory.





# Contents

<b>Preface</b> .....	iii
<b>Summary</b> .....	v
The Hanford Site and its Mission .....	v
Compliance with Environmental Regulations .....	vi
Environmental Programs .....	x
Environmental Monitoring Information .....	xii
Ground-Water Protection and Monitoring Program .....	xv
Quality Assurance .....	xvi
<b>Acknowledgments</b> .....	xvii
<b>Helpful Information</b> .....	xxxi
Scientific Notation .....	xxxi
Metric Units .....	xxxi
Radioactivity Units .....	xxxi
Radiation Dose Units .....	xxxii
Understanding the Data Tables .....	xxxii
Understanding Graphical Information .....	xxxiii
Greater Than (>) or Less Than (<) Symbols .....	xxxiv
Radionuclide Nomenclature .....	xxxv
Elemental and Chemical Constituent Nomenclature .....	xxxvi
Conversion Table .....	xxxvi
Acronyms and Abbreviations .....	xxxvii
<b>1.0 Introduction</b> .....	1
<b>1.1 Site Mission</b> .....	3
<b>1.2 Major Operations and Activities</b> .....	5
Waste Management .....	5
Site Restoration .....	5
Corrective Activities .....	7
Research and Technology Development .....	7
Site Management .....	7
<b>1.3 Site Environment</b> .....	9
Demographics and Land Use .....	9
Climate and Meteorology .....	10
Geology .....	10
Ground-Water Hydrology .....	11
Surface-Water Hydrology .....	14
Ecology .....	14
Archaeology and Cultural Resources .....	15

<b>2.0 Environmental Compliance Summary .....</b>	<b>17</b>
<b>2.1 Overseeing Hanford's Environmental Compliance and Cleanup .....</b>	<b>19</b>
Environmental Regulations and Standards .....	19
The Regulating Agencies .....	20
The Tri-Party Agreement .....	20
Washington State's Other Roles at Hanford .....	21
Oregon's Role at Hanford .....	21
Role of Indian Nations at Hanford .....	21
Public Participation .....	22
<b>2.2 Compliance Status .....</b>	<b>23</b>
Comprehensive Environmental Response, Compensation, and Liability Act .....	23
Superfund Amendments and Reauthorization Act, Title III .....	24
Resource Conservation and Recovery Act .....	25
Clean Air Act .....	27
Clean Water Act .....	27
Safe Drinking Water Act .....	27
Toxic Substances Control Act .....	27
Federal Insecticide, Fungicide, and Rodenticide Act .....	28
Endangered Species Act .....	28
National Historic Preservation Act, Archaeological Resources Protection Act, and American Indian Religious Freedom Act .....	28
National Environmental Policy Act .....	28
<b>2.3 Current Issues and Actions .....</b>	<b>31</b>
Tri-Party Agreement .....	31
Hanford Future Site Use/Cleanup Strategy .....	32
The Columbia River's Hanford Reach .....	32
U.S. Testing Company Contract Termination .....	32
Environmental Litigation .....	33
Tiger Team Assessment .....	33
Plutonium Uranium Extraction Plant Status .....	34
Plutonium Finishing Plant Restart .....	34
Hanford Waste Vitrification Plant Construction Delay .....	35
Waste Tank Safety Issues .....	35
Waste Minimization Program Status .....	35
Wahluke Slope Waste Sites .....	35
<b>2.4 Environmental Occurrences .....</b>	<b>39</b>
Unusual Occurrences .....	39
<b>3.0 Environmental Program Information .....</b>	<b>43</b>
<b>3.1 Environmental Restoration, Waste Management and Technology     Development .....</b>	<b>45</b>

Environmental Restoration .....	45
Waste Management .....	46
Technology Development .....	47
<b>3.2 Environmental Monitoring at Hanford .....</b>	<b>49</b>
Effluent Monitoring .....	49
Environmental Surveillance .....	50
<b>3.3 Environmental Studies and Programs .....</b>	<b>55</b>
Wildlife Resources .....	55
Cultural Resources .....	58
Meteorology and Climatology of the Hanford Area .....	58
Hanford Environmental Dose Reconstruction Project .....	59
Community-Operated Environmental Surveillance Stations .....	62
Other Environmental Activities .....	62
<b>4.0 Environmental Monitoring Information .....</b>	<b>63</b>
<b>4.1 Effluent Monitoring .....</b>	<b>65</b>
Air Emissions .....	65
Liquid Effluents .....	66
Solid Waste .....	66
<b>4.2 Air Surveillance .....</b>	<b>73</b>
Sample Collection and Analysis .....	73
Results .....	78
<b>4.3 Surface-Water Surveillance .....</b>	<b>85</b>
Columbia River .....	85
Riverbank Springs .....	91
Onsite Ponds .....	92
Offsite Water .....	95
<b>4.4 Food and Farm Product Surveillance .....</b>	<b>97</b>
Milk .....	97
Vegetables .....	99
Fruit .....	101
Wine .....	101
Wheat and Alfalfa .....	101
Beef, Chickens, and Eggs .....	102
<b>4.5 Wildlife Surveillance .....</b>	<b>103</b>
Deer .....	103
Fish .....	103
Clams .....	103

## Contents

Waterfowl .....	105
Rabbits .....	105
<b>4.6 Soil and Vegetation Surveillance .....</b>	<b>109</b>
Sample Collection and Analysis .....	109
Soil Results .....	109
Vegetation Results .....	109
<b>4.7 External Radiation Surveillance .....</b>	<b>115</b>
External Radiation Measurements .....	115
External Radiation Results .....	115
Radiation Surveys .....	118
<b>4.8 Potential Radiation Doses from 1990 Hanford Operations .....</b>	<b>125</b>
Maximally Exposed Individual Dose .....	126
Special Case Exposure Scenarios .....	128
Comparison with Clean Air Act Standards .....	130
Population Dose .....	130
Doses from Other Than DOE Sources .....	131
Hanford Public Radiation Dose in Perspective .....	133
Absorbed Dose Rates to Native Aquatic Animal Organisms .....	134
<b>5.0 Ground-Water Protection and Monitoring Program .....</b>	<b>135</b>
Sample Collection and Analysis .....	135
Results .....	136
<b>6.0 Quality Assurance .....</b>	<b>159</b>
Project Management Quality Assurance .....	159
Sample Collection Quality Assurance .....	160
Surface and Ground-Water Analytical Results Quality Assurance .....	160
<b>7.0 References .....</b>	<b>165</b>
U.S. Department of Energy Orders .....	174
<b>Appendix A - Glossary .....</b>	<b>A.1</b>
<b>Appendix B - Applicable Standards and Permits .....</b>	<b>B.1</b>
<b>Appendix C - Dose Calculations .....</b>	<b>C.1</b>

# Figures

H.1 Data Plotted Using a Linear Scale .....	xxxii
H.2 Data Plotted Using a Logarithmic Scale .....	xxxiv
H.3 Data With Error Bars Plotted Using a Linear Scale .....	xxxiv
1.1 DOE's Hanford Site .....	6
1.2 Geologic Cross Section of the Site .....	11
1.3 Water-Table Elevations at Hanford, June 1990 .....	13
3.1 Primary Exposure Pathways .....	53
3.2 Bald Eagles Observed Along the Hanford Reach, Fall and Winter Months .....	55
3.3 Chinook Salmon Spawning Redds in the Hanford Reach .....	55
3.4 Canada Goose Nests on Islands in the Hanford Reach .....	56
3.5 Red-Tailed, Swainson's, and Ferruginous Hawks on the Hanford Site .....	56
3.6 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 .....	57
3.7 Hanford Telemetry Network Wind Roses, 1990 .....	60
4.1 Air Sampling Locations, 1990 .....	74
4.2 Nitrogen Dioxide Sampling Locations, 1990 .....	77
4.3 Monthly Average Gross Beta Radioactivity in Airborne Particulate Samples, 1980 Through 1990 .....	81
4.4 Annual Average Air Concentrations of Krypton-85 in Air at Selected Locations, 1985 Through 1990 .....	81
4.5 Annual Average Concentrations of Strontium-90 in Air at the Hanford Environs Compared to Other U.S. Locations, 1985 Through 1990 .....	82
4.6 Annual Average Concentrations of Iodine-129 in Air at the Hanford Environs, 1985 Through 1990 .....	82
4.7 Annual Average Concentrations of Tritium in Air at the Hanford Environs, 1985 Through 1990 .....	83

## Contents

4.8 Annual Average Concentrations of Plutonium-239,240 in Air at Northwest and Hanford Environs, 1985 Through 1990 .....	83
4.9 Annual Average Concentrations of Uranium in Air at Northwest and Hanford Environs, 1985 Through 1990 .....	84
4.10 Onsite and Offsite Water and Sediment Sampling Locations, 1990 .....	86
4.11 Annual Average Gross Alpha Concentrations in Columbia River Water, 1985 Through 1990 .....	88
4.12 Annual Average Gross Beta Concentrations in Columbia River Water, 1985 Through 1990 .....	88
4.13 Annual Average Tritium Concentrations in Columbia River Water, 1985 Through 1990 .....	88
4.14 Annual Average Strontium-90 Concentrations in Columbia River Water, 1985 Through 1990 .....	89
4.15 Annual Average Uranium Concentrations in Columbia River Water, 1985 Through 1990 .....	89
4.16 Columbia River Water Quality Measurements, 1985 Through 1990 .....	90
4.17 Monthly Average Flow Rates of the Columbia River During 1990 .....	91
4.18 Monthly Average Temperatures in Columbia River Water During 1990 .....	91
4.19 Annual Average Radionuclide Concentrations in B Pond, 1985 Through 1990 .....	93
4.20 Average Gross Beta and Tritium Concentrations in FFTF Pond, 1990 .....	94
4.21 Annual Average Radionuclide Concentrations in West Lake, 1985 Through 1990 .....	95
4.22 Food and Farm Product Sampling Locations, 1990 .....	98
4.23 Annual Average Cesium-137 and Strontium-90 Concentrations in Milk for All Sampling Locations, 1986 Through 1990 .....	100
4.24 Annual Average Cesium-137 and Strontium-90 Concentrations in Leafy Vegetables for All Sampling Locations, 1986 Through 1990 .....	100
4.25 Strontium-90 Concentrations in Alfalfa Collected at Riverview and Richland and All Other Sampling Locations, 1986 Through 1990 .....	102
4.26 Annual Average Cesium-137 and Strontium-90 Concentrations in Beef for All Sampling Locations, 1986 Through 1990 .....	102
4.27 Wildlife Sampling Locations, 1990 .....	104

4.28 Mean Concentrations of Cesium-137 in Deer Muscle, 1986 Through 1990 .....	105
4.29 Mean Combined Concentrations of Cobalt-60 and Cesium-137 in Muscle from Whitefish and Bass Samples Collected Above Vernita Bridge and Near the 100-D Area, 1986 Through 1990 .....	105
4.30 Mean Concentrations of Strontium-90 in Fish Carcasses Collected from the Columbia River, 1990 .....	106
4.31 Mean Concentrations of Cesium-137 in Mallard Ducks from B Pond, 1986 Through 1990 .....	107
4.32 Median Concentrations of Strontium-90 in Bone and Cesium-137 in Muscle of Rabbits Collected from the 100-N Area, 1986 Through 1990 .....	107
4.33 Soil and Vegetation Sampling Locations, 1990 .....	110
4.34 Combined Onsite and Offsite Measurements of Strontium-90, Cesium-137, Plutonium-239,240, and Uranium in Soil, 1985 Through 1990 .....	112
4.35 Median Strontium-90, Cesium-137, Plutonium-239,240, and Uranium Concentrations Measured in Vegetation at Onsite and Offsite Locations, 1985 Through 1990 .....	112
4.36 External Radiation Measurement Locations, 1990 .....	116
4.37 Annual Average Dose Rates at Perimeter and Distant Locations, 1985 Through 1990 .....	117
4.38 Thermoluminescent Dosimeter Locations on the Hanford Reach of the Columbia River, 1990 .....	119
4.39 Onsite External Radiation Measurement Locations, 1990 .....	121
4.40 Road and Railroad Survey Routes, 1990 .....	123
4.41 Calculated Effective Dose Equivalent to the Hypothetical Maximally Exposed Individual, 1986 Through 1990 .....	128
4.42 Calculated Effective Dose Equivalent to the Population Within 80 km of Hanford, 1986 Through 1990 .....	131
4.43 Annual Radiation Doses from Various Sources .....	132
5.1 Hanford Site Unconfined Aquifer Monitoring Well Locations, 1990 .....	138
5.2 Hanford Site Confined Aquifer Monitoring Well Locations, 1990 .....	139
5.3 200-East Area Monitoring Well Locations, 1990 .....	140
5.4 200-West Area Monitoring Well Locations, 1990 .....	141

## Contents

5.5	Tritium Concentrations in the Hanford Site Unconfined Aquifer, 1990 .....	143
5.6	Tritium Concentrations in 100-K Area Wells .....	144
5.7	Tritium Concentrations in Well 699-24-33.....	145
5.8	Tritium Concentrations in Well 699-40-1 .....	145
5.9	Tritium Concentrations in Well 699-S19-E13 .....	146
5.10	Strontium-90 Concentrations in 100-N Area Ground-Water Wells Between 1301-N LWDF and the Shoreline of the Columbia River .....	147
5.11	Uranium Concentrations in Wells on the West Side of the 100-F Area .....	149
5.12	Uranium Concentrations Near the South End of the 300 Area Process Trenches .....	150
5.13	Uranium Ground-Water Plume in the 300 Area .....	151
5.14	Plutonium Isotope Concentrations in Wells Located Close to the 216-B-5 Reverse Injection Well in the 200-East Area .....	152
5.15	Nitrate Concentrations in the Hanford Site Unconfined Aquifer, 1990 .....	153
5.16	Nitrate Concentrations in Ground-Water Wells Located Near the Western Margin of the Hanford Site Downslope from Yakima Ridge .....	154
5.17	Chromium Concentrations in Well 199-D5-12 .....	155
5.18	Carbon Tetrachloride Ground-Water Plume in the 200-West Area .....	155
5.19	Carbon Tetrachloride Concentrations in Monitoring Wells Located Near the Margins of the Z Plant Ground-Water Plume .....	158
5.20	Carbon Tetrachloride Concentrations in Monitoring Wells Located Near the Center of the Z Plant Ground-Water Plume.....	158
6.1	Comparison of Thermoluminescent Dosimeter Results With Known Exposures .....	163



# Tables

H.1 Names and Symbols for Units of Measure .....	xxx
H.2 Units of Radioactivity .....	xxxii
H.3 Units of Radiation Dose .....	xxxii
3.1 Near-Facility Routine Environmental Samples and Locations .....	51
3.2 Routine Environmental Sample Types and Measurement Locations, 1990 .....	54
3.3 Monthly Climatological Data from the Hanford Meteorology Station, 1990 .....	61
4.1 Radionuclides Discharged to the Atmosphere, 1990 .....	67
4.2 Nonradioactive Constituents Discharged to the Atmosphere, 1990 .....	68
4.3 Radionuclides in Liquid Effluents Discharged to Ground Disposal Facilities, 1990 .....	68
4.4 Nonradioactive Constituents in Liquids Discharged to Ground Disposal Facilities, 1990 .....	69
4.5 Radionuclides in Liquid Effluents Discharged to the Columbia River from the 100 Areas, 1990 .....	69
4.6 Radioactive Solid Waste Disposal at Hanford, 1990 .....	70
4.7 Hanford Tier-Two Emergency and Hazardous Chemical Inventory Average Balances of Chemicals Stored in Greatest Quantities on the Site .....	71
4.8 Air Sampling Locations and Sample Composite Groups .....	75
4.9 Ambient Nitrogen Dioxide Concentrations in the Hanford Environs, 1990 .....	78
4.10 Airborne Radionuclide Concentrations in the Hanford Environs, 1990 .....	79
4.11 Radionuclide Concentrations in Milk Samples, 1990 .....	99
4.12 Cobalt-60, Strontium-90, and Cesium-137 Concentrations in Freshwater Clams Collected from the Columbia River Near the 100-N and 300 Areas, 1990 .....	106
4.13 Radionuclide Concentrations in Soil Collected from Perimeter Locations East of the Hanford Site .....	111
4.14 Radionuclide Concentrations in Vegetation Collected from Perimeter Locations East of the Hanford Site and Sunnyside .....	113
4.15 Average Dose Rates for External Radiation at Perimeter and Community Locations, 1990 .....	117

## Contents

4.16	Locations and Average Dose Rates for External Radiation Along the Hanford Reach of the Columbia River, 1990 .....	120
4.17	Onsite External Penetrating Dose Measurements, 1990 .....	122
4.18	Doses to the Hypothetical Maximally Exposed Individual from 1990 Hanford Operations .....	127
4.19	Population Doses from 1990 Hanford Operations .....	130
4.20	Summary of Doses to the Public in the Vicinity of Hanford from Various Sources, 1990 .....	132
4.21	Estimated Risk from Various Activities and Exposures .....	134
4.22	Activities Comparable in Risk to that from the 0.03 mrem Dose Calculated for the 1990 Maximally Exposed Individual .....	136
5.1	Facility-Specific Monitoring Projects .....	136
5.2	Radiological and Chemical Constituents Analyzed for in the Hanford Ground-Water Environmental Surveillance Program .....	137
5.3	Major Chemical and Radiological Ground-Water Contaminants and Their Link to Site Operations .....	142
6.1	United States Testing Company, Inc. and International Technology Corporation Performances on DOE Quality Assessment Program Samples in 1990 and 1991 .....	161
6.2	United States Testing Company, Inc. and International Technology Corporation Performances on EPA Intercomparison Program Samples in 1990 and 1991 .....	162
B.1	Washington State Water Quality Standards for the Hanford Reach of the Columbia River .....	B.2
B.2	Radiological Drinking Water Standards: U.S. Environmental Protection Agency, National Primary Drinking Water Regulations; and State of Washington, Rules and Regulations of the State Board of Health Regarding Public Water Systems .....	B.3
B.3	Chemical Drinking Water Standards: U.S. Environmental Protection Agency, National Primary Drinking Water Regulations; and State of Washington, Public Water Supplies .....	B.4
B.4	Benton-Franklin-Walla Walla Counties Air Pollution Control Authority Ambient Air Quality Standards .....	B.4
B.5	Radiation Standards for Protection of the Public from All Routine DOE Activities .....	B.5
B.6	Derived Concentration Guides .....	B.6
B.7	Environmental Permits .....	B.7

C.1 Food Pathway Parameters Used in 1990 Dose Calculations .....	C.4
C.2 Dietary Parameters Used in 1990 Dose Calculations .....	C.4
C.3 Residency Parameters Used in 1990 Dose Calculations .....	C.5
C.4 Recreational Parameters Used in 1990 Dose Calculations .....	C.5



## Helpful Information



41  
76



# Helpful Information

The following information is provided to assist the reader in understanding the report. Definitions of technical terms can be found in Appendix A, "Glossary."

## Scientific Notation

Scientific notation is used in this report to express very large or very small numbers without using a long line of zeros. For example, the number 1 billion could be written as 1,000,000,000 or using scientific notation as  $1 \times 10^9$ . 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  $2.0 \times 10^3$ , 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  $2.0 \times 10^{-5}$ , 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 and the impact these levels have on people living within a defined area. 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

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

Length	
Symbol	Name
km	kilometer ( $10^3$ m)
m	meter
cm	centimeter ( $10^{-2}$ m)
mm	millimeter ( $10^{-3}$ m)
$\mu$ m	micrometer ( $10^{-6}$ m)

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

Area	
Symbol	Name
ha	hectare ( $10,000$ m <sup>2</sup> )

Volume	
Symbol	Name
cm <sup>3</sup>	cubic centimeter
L	liter
mL	milliliter ( $10^{-3}$ L)
m <sup>3</sup>	cubic meter
ppmv	parts per million volume
cfs	cubic feet per second

Mass	
Symbol	Name
g	gram
kg	kilogram ( $10^3$ g)
$\mu$ g	microgram ( $10^{-6}$ g)
ng	nanogram ( $10^{-9}$ g)
t	metric ton (or tonne; $10^3$ kg)

**Table H.2. Units of Radioactivity**

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

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 written with two different sets of units. One set of units is always 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  $3.7 \times 10^{10}$ . 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 of exposure to natural background radiation (see "Hanford Environmental Radiation Public Dose in Perspective" in Section 4.8 for a more in-depth discussion of risk comparisons). For those readers interested in converting the most commonly used dose term in this report, the

**Table H.3. Units of Radiation Dose**

Radiation Dose	
Symbol	Name
rem	rem
mrem	millirem ( $10^{-3}$ rem)
Sv	sievert
mSv	millisievert ( $10^{-3}$ Sv)
$\mu$ Sv	microsievert ( $10^{-6}$ Sv)

millirem, to the SI equivalent, the sievert, 1 sievert is equal to  $1.0 \times 10^5$  millirem.

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

General information on radiation and radiation dose, Hanford's Environmental Monitoring Program, Hanford's Cultural Resource Program, and Hanford's wildlife has been compiled in informational pamphlets that can be obtained, free, by writing to Dr. Robert H. Gray, Manager, Hanford Environmental Surveillance and Oversight, 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 (e.g., 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 ( $\pm$ ) value (sometimes expressed as a percentage of the related concentration value), which is the uncertainty term known as a two-sigma counting error. Because measuring a radionuclide requires a



process of counting random radioactive emissions from a sample, the two-sigma counting error gives information on what the measurement might be if the same sample were counted again under identical conditions. The two-sigma 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 two-sigma counting error and the reported value plus the two-sigma counting error. Values in the tables that are less than the two-sigma 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 two-sigma counting errors, reported means ( $\bar{X}$ ) are accompanied by two standard errors of the calculated mean (SEM). In this report, SEM is expressed as a percentage of the mean concentration value. If the data fluctuate randomly, then the SEM is a measure of the uncertainty in the estimated mean of the data due to this randomness. If trends or periodic (e.g., seasonal) fluctuations are present, then the SEM is primarily a measure of the variability in the trends and fluctuations about the mean of the data, rather than a measure of the uncertainty of the estimated mean due to random fluctuations in the data.

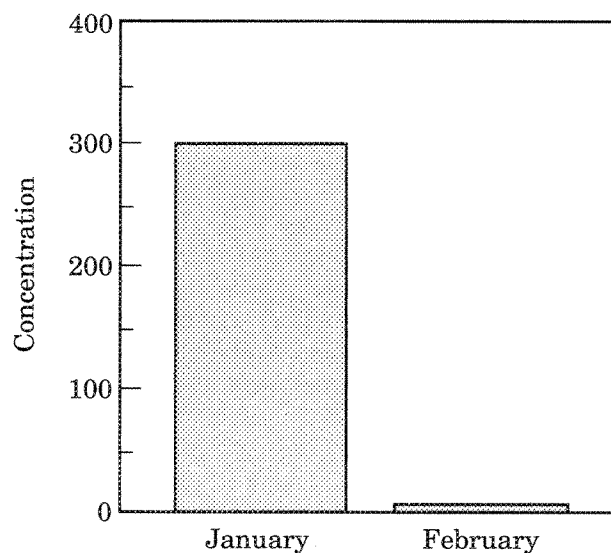
## Understanding Graphical Information

Graphical data presentations are 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) and concentration units being used.

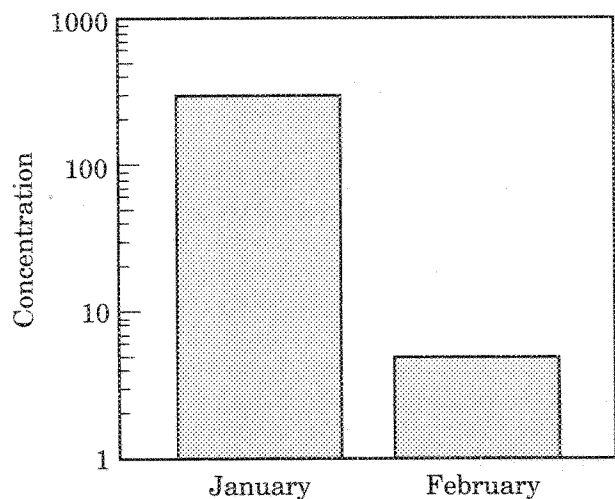
Some of the data graphed in this report are plotted using logarithmic (or compressed) scales. Logarithmic scales are useful when plotting two or more numbers that vary greatly in size. For example, a sample with a concentration of 5 g/L would get lost at the bottom of the graph if plotted on a linear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

Many of the mean values graphed in this report have vertical lines (bars) extending above and below the data point. These bars (called error bars), which are usually capped at both ends with a short horizontal line, indicate the amount of uncertainty in the reported result. The error bars in this report represent a 95% chance that the result is between the upper and lower ends of the error bar, and a 5% chance that the actual result is either lower or higher than the error



S9105027.1n

**Figure H.1. Data Plotted Using a Linear Scale**

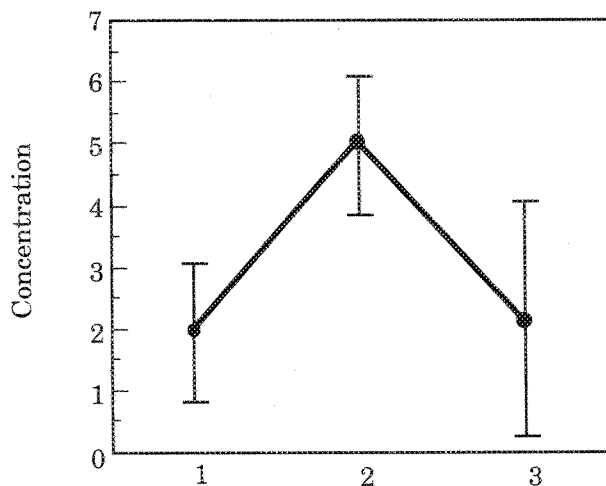


S9105027.2n

**Figure H.2. Data Plotted Using a Logarithmic Scale**

bar.<sup>(a)</sup> For example, in Figure H.3, the first plotted value has a result of  $2.0 \pm 1.1$ , 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 graph. These bars indicate whether one value is statistically similar to or different from another value. If the error bars (or range of values) of two or more values overlap, as is the case with values 1 and 3 and values 2 and 3, the values are considered to be similar, statistically. If the error bars do not overlap (values 1 and 2), the values are considered to be statistically different. Values that appear to be very different visually (values 2 and 3) may actually be quite similar when compared statistically.

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



S9105027.3n

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

## 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 ( $\leq$  or  $\geq$ ), this indicates that the actual value is either less-than-or-equal-to or greater-than-or-equal-to the number given, respectively.

## Radionuclide Nomenclature

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

## Elemental and Chemical Constituent Nomenclature

Constituent	Symbol	Constituent	Symbol
aluminum	Al	iron	Fe
ammonia	NH <sub>3</sub>	lead	Pb
ammonium	NH <sub>4</sub> <sup>+</sup>	magnesium	Mg
antimony	Sb	manganese	Mn
arsenic	As	mercury	Hg
barium	Ba	nickel	Ni
beryllium	Be	nitrate	NO <sub>3</sub> <sup>-</sup>
bicarbonate	HCO <sub>3</sub> <sup>-</sup>	nitrogen	N
boron	B	nitrogen dioxide	NO <sub>2</sub>
cadmium	Cd	phosphate	PO <sub>4</sub> <sup>3-</sup>
calcium	Ca	phosphorus	P
carbon	C	potassium	K
carbonate	CO <sub>3</sub> <sup>2-</sup>	selenium	Se
carbon tetrachloride	CCl <sub>4</sub>	silver	Ag
chloride	Cl <sup>-</sup>	sodium	Na
chromium (species)	Cr <sup>6+</sup>	strontium	Sr
chromium (total)	Cr	sulfate	SO <sub>4</sub> <sup>2-</sup>
copper	Cu	vanadium	V
fluoride	F <sup>-</sup>	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 <sup>2</sup>	0.093	m <sup>2</sup>	m <sup>2</sup>	10.76	ft <sup>2</sup>
acres	0.405	ha	ha	2.47	acres
mi <sup>2</sup>	2.59	km <sup>2</sup>	km <sup>2</sup>	0.386	mi <sup>2</sup>
ft <sup>3</sup>	0.028	m <sup>3</sup>	m <sup>3</sup>	35.7	ft <sup>3</sup>
dpm	0.450	pCi	pCi	2.22	dpm
nCi	0.001	pCi	pCi	1000	nCi
pCi/L	10 <sup>-9</sup>	μCi/mL	μCi/mL	10 <sup>9</sup>	pCi/L
pCi/m <sup>3</sup>	10 <sup>-12</sup>	Ci/m <sup>3</sup>	Ci/m <sup>3</sup>	10 <sup>12</sup>	pCi/m <sup>3</sup>
pCi/m <sup>3</sup>	10 <sup>-15</sup>	mCi/cm <sup>3</sup>	mCi/cm <sup>3</sup>	10 <sup>15</sup>	pCi/m <sup>3</sup>
mCi/km <sup>2</sup>	1.0	nCi/m <sup>2</sup>	nCi/m <sup>2</sup>	1.0	mCi/km <sup>2</sup>
becquerel	3.7 x 10 <sup>-10</sup>	curie	curie	3.7 x 10 <sup>10</sup>	becquerel
gray	100	rad	rad	0.01	gray
sievert	100	rem	rem	0.01	sievert
ppb	0.001	ppm	ppm	1000	ppb
ppm	1.0	mg/L	mg/L	1.0	ppm
°F	(F° - 32) ÷ 9/5	°C	°C	(C° x 9/5) + 32	°F

## Acronyms and Abbreviations

<b>ALARA</b>	as low as reasonably achievable	<b>EPA</b>	U.S. Environmental Protection Agency
<b>ALE</b>	Arid Lands Ecology (Reserve)	<b>ERDA</b>	U.S. Energy Research and Development Administration
<b>ANSI</b>	American National Standards Institute	<b>ES&amp;H</b>	environment, safety, and health
<b>ASME</b>	American Society of Mechanical Engineers	<b>FDA</b>	U.S. Food and Drug Administration
<b>ASTM</b>	American Society for Testing and Materials	<b>FEMP</b>	Facility Effluent Monitoring Plan
<b>CEDE</b>	committed effective dose equivalent	<b>FFTF</b>	Fast Flux Test Facility
<b>CERCLA</b>	Comprehensive Environmental Response, Compensation, and Liability Act	<b>FIFRA</b>	Federal Insecticide, Fungicide, and Rodenticide Act
<b>CFR</b>	Code of Federal Regulations	<b>FR</b>	Federal Register
<b>DCE</b>	dichloroethylene	<b>FY</b>	fiscal year
<b>DCG</b>	Derived Concentration Guide	<b>HCRL</b>	Hanford Cultural Resources Laboratory
<b>DOE</b>	U.S. Department of Energy	<b>HEDR</b>	Hanford Environmental Dose Reconstruction Project
<b>DOE-HQ</b>	U.S. Department of Energy-Headquarters	<b>HMS</b>	Hanford Meteorological Station
<b>DOH</b>	State of Washington Department of Health	<b>ICRP</b>	International Commission on Radiological Protection
<b>DOT</b>	U.S. Department of Transportation	<b>ISV</b>	in situ vitrification
<b>DWS</b>	drinking water standards	<b>IT</b>	International Technology Co. Inc.
<b>EDE</b>	effective dose equivalent	<b>LWDF</b>	Liquid Waste Disposal Facility
<b>EIS</b>	environmental impact statement	<b>MCL</b>	maximum contaminant level
<b>EIS-ODIS</b>	Effluent Information System/Onsite Discharge Information System	<b>MDA</b>	minimum detectable activity
<b>EML</b>	Environmental Measurements Laboratory	<b>MDC</b>	minimum detectable concentration
		<b>MEI</b>	maximally exposed individual

## Helpful Information

<b>NCRP</b>	National Council on Radiation Protection and Measurements	<b>RI/FS</b>	remedial investigation/feasibility study
<b>NEPA</b>	National Environmental Policy Act	<b>RL</b>	U.S. Department of Energy Richland Field Office
<b>NESHAP</b>	National Emission Standards for Hazardous Air Pollutants	<b>SARA</b>	Superfund Amendments and Reauthorization Act
<b>NPDES</b>	National Pollutant Discharge Elimination System	<b>SE</b>	standard error
<b>NPR</b>	New Production Reactor	<b>SEM</b>	standard error of the mean
<b>NRC</b>	U.S. Nuclear Regulatory Commission	<b>SEN</b>	Secretary of Energy Notice
<b>NS</b>	no standard	<b>SI</b>	International System of Units
<b>NTU</b>	nephelometric turbidity unit	<b>TCE</b>	trichloroethylene
<b>PCB</b>	polychlorinated biphenyl	<b>TLD</b>	thermoluminescent dosimeter
<b>PFP</b>	Plutonium Finishing Plant	<b>TOX</b>	total organic halogens
<b>PNL</b>	Pacific Northwest Laboratory	<b>TRU</b>	transuranic
<b>PSD</b>	prevention of significant deterioration	<b>TSD</b>	treatment, storage, and disposal
<b>PUREX</b>	Plutonium Uranium Extraction (Plant)	<b>UO<sub>3</sub> Plant</b>	Uranium Oxide Plant
<b>QA</b>	quality assurance	<b>USC</b>	United States Code
<b>QC</b>	quality control	<b>USGS</b>	U.S. Geological Survey
<b>RCRA</b>	Resource Conservation and Recovery Act	<b>UST</b>	U.S. Testing Company, Inc.
<b>RCW</b>	Revised Code of Washington	<b>VOA</b>	volatile organic analyses
<b>REDOX</b>	Reduction Oxidation (Plant)	<b>WAC</b>	Washington Administrative Code
		<b>WDOE</b>	State of Washington Department of Ecology

## Introduction





# 1.0 Introduction

The purpose of this report is to present summary 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 changing 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 the National Technical Information Center, Springfield, Virginia 22161 and libraries. Descriptions of analytical and sampling methods, formerly part of this report, will be contained in the Hanford Site Environmental Monitoring Plan to be completed in November 1991. Readers less familiar with the concepts, terminology, and units used in the report may find the preceding Helpful Information section useful.



## 1.1 Site Mission

The Hanford Site was acquired by the federal government in 1943. For more than 20 years, Hanford Site facilities were dedicated primarily to the production of plutonium for national defense and management of the resulting wastes. In following 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, mixed, hazardous, or sanitary wastes from current operations
- Environmental Restoration of approximately 1100 inactive radioactive, mixed, and hazardous 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; and education outreach programs.

DOE has set the goal of cleaning up Hanford's waste sites and bringing its facilities into compliance with all local, state, and federal environmental laws by 2018.



## 1.2 Major Operations and Activities

The primary DOE operations and activities on the Hanford Site in 1990 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 overall program plan is discussed in Section 3.0, "Environmental Program Information."

### Waste Management

Current waste-management activities at the Site primarily included the management of high- and low-level defense wastes in the 200-East and 200-West Areas (Figure 1.1) and the storage of spent defense fuel in the 100-K Area. Key waste-management facilities include the waste storage tanks, 100-K Fuel Storage Basins, Plutonium Uranium Extraction (PUREX) Plant, Plutonium Finishing Plant (PFP), B Plant, and 242-A Evaporator.

Waste-management activities involving single-shell and double-shell tanks currently include ensuring safe storage of wastes through surveillance and monitoring of the tanks and upgrading monitoring instrumentation. Studies are also being conducted to address the risks of chemical explosions in some tanks.

The 100-KE and 100-KW Fuel Storage Basins are currently being used to store N Reactor spent fuel. In October 1990, DOE announced an environmental impact statement would be prepared to evaluate options for disposition of the remaining fuel.

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. PUREX did not operate in 1990 after the stabilization run

and is currently in standby status awaiting determination of the option for disposition of the remaining N Reactor fuel.

The PFP was used to convert liquid plutonium from the PUREX Plant to plutonium oxide or metal. The PFP has not produced a product since 1987. The plant also processes and stabilizes scrap plutonium materials; operations for this purpose will resume in 1991.

B Plant was being upgraded in 1990 to operate as a pretreatment facility to separate high- and low-activity fractions of stored tank wastes. The cost effectiveness of upgrading the facility to meet current safety and environmental requirements is being investigated to determine whether the plant will operate in the future.

The 242-A Evaporator is used to treat dilute waste from double-shell waste tanks. It did not operate in 1990.

### Site Restoration

Site 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 surplus facilities, and has begun to clean up and dispose of more than 100 facilities. Decontamination and decommissioning activities in 1990 included completion of the liquid waste solidification at the 183-H Solar Evaporation Basins. In addition, design work was completed to remove backfill from the 100-F and 100-H Fuel Storage Basins.

The environmental restoration remedial action program was established to clean up about 1100 inactive waste sites. During 1990, remedial investigations were completed for a group of sites just north of Richland. These investigations included soil sampling, geophysical investigations, and radiological surveys. Wells for water sampling

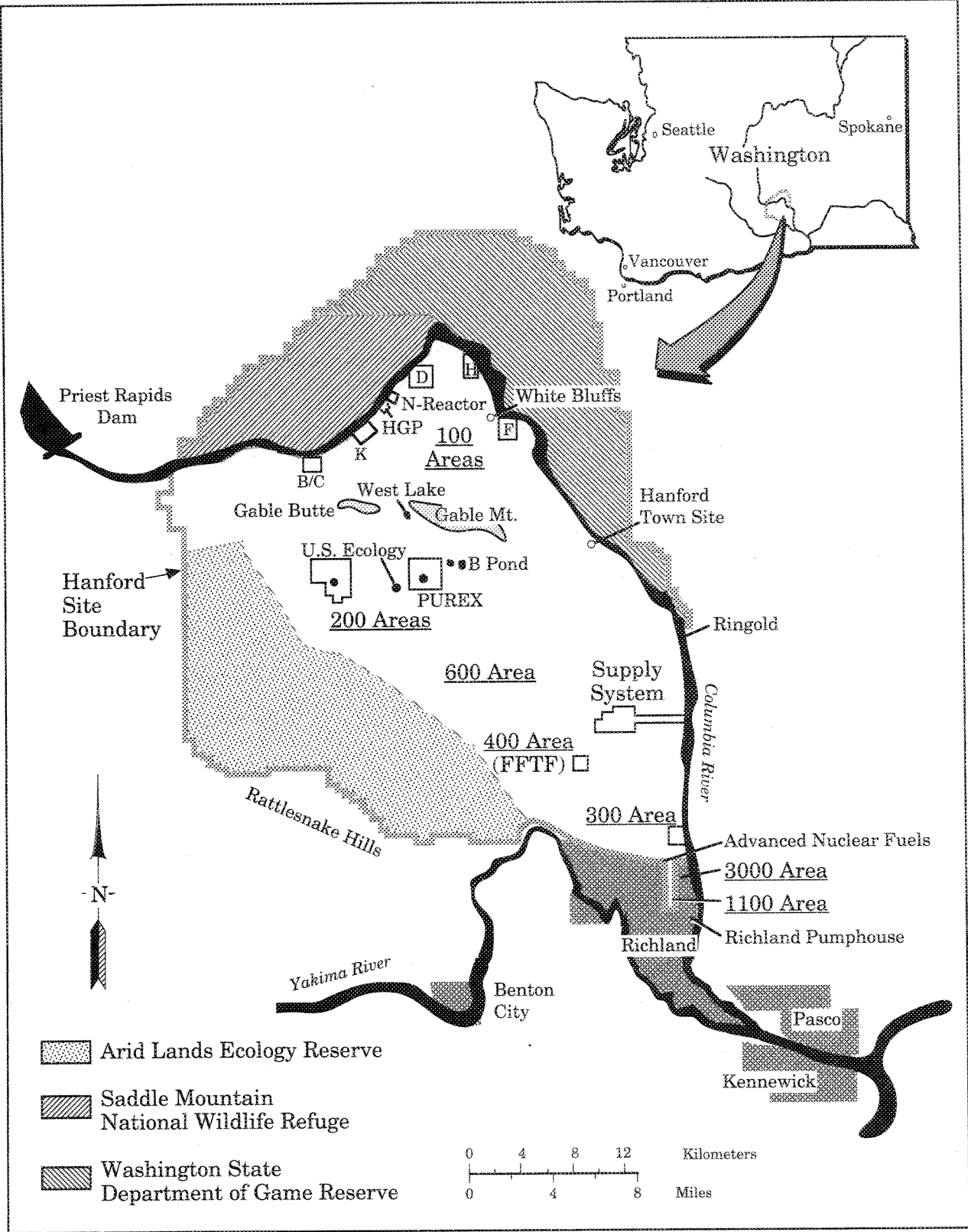


Figure 1.1. DOE's Hanford Site

S9111080.2

were drilled at many waste sites, and cleanup was expedited at three sites to stop or prevent the spread of contamination.

## 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 1990 are addressed in Section 2.0, "Environmental Compliance Summary."

## Research and Technology Development

Research and technology development activities on the Hanford Site are a relatively minor contributor to Site releases. Most of these activities are located in the 200, 300, 400, and 3000 Areas, and releases occur primarily from the operation of research laboratories and pilot facilities. Many of these activities are intended to improve the techniques and reduce the costs of waste management, environmental protection, and Site restoration.

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  $6.1 \times 10^8$  L (160 million gallons) of mixed waste are planned to be processed between 1992 and 2014. In 1990, facility systems were being upgraded and dry material formulations redesigned based on the results of pilot tests completed in 1989. Construction was initiated on four new vaults with completion scheduled for 1991 and 1992.

The Fast Flux Test Facility (FFTF) continued operations in 1990 conducting irradiation experiments. While continued operation was in question during the year, Congress has authorized \$84 million for operation in fiscal year (FY) 1992.

The in situ vitrification (ISV) process is a technology for remediating contaminated soils. In the process, organic materials are destroyed by extreme heat and inorganic materials are immobilized for geologic periods in a highly durable glass and crystalline block.

During 1990 several tests were conducted to provide information on ISV operation with numerous contaminants. One large test conducted in March resulted in about 900 tons of soil contaminated with hazardous and radioactive materials being immobilized at the 216-B-12 crib in the 200-East Area.

## Site Management

Hanford Site operations and activities are managed by DOE Richland Field Office (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 responsibilities of these contractors include the following:

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

## Major Operations and Activities

- 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.
- Boeing Computer Services Richland, a subcontractor to Westinghouse Hanford Company, provides Site computer operations and support services.

Non-DOE operations and activities on the Hanford Site included commercial power production by the Washington Public Power Supply System WNP-2 reactor and commercial low-level radioactive waste burial by U.S. Ecology. Advanced Nuclear Fuels Corporation (now Siemens Nuclear Power Corporation) operated a commercial nuclear fuel fabrication facility, and Allied Technology Group Corporation operated a low-level radioactive waste decontamination, supercompaction, and packaging disposal facility immediately adjacent to the southern boundary of the Site.



## 1.3 Site Environment

The Hanford Site lies within the semiarid Pasco Basin of the Columbia Plateau in southeastern Washington State (see Figure 1.1). The Site occupies an area of about 1450 km<sup>2</sup> (approximately 560 mi<sup>2</sup>) 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 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 below the city of Richland. Adjoining lands to the west, north, and east are principally range and agricultural land. The cities of Richland, Kennewick, and Pasco (Tri-Cities) constitute the nearest population center and are located southeast of the Hanford Site.

### Demographics and Land Use

Estimates by Washington State's Office of Financial Management, dated April 1990, place the population totals of Benton and Franklin counties at 110,000 and 34,600, respectively. The 1990 estimates for the Tri-Cities populations are Richland, 30,250; Kennewick, 37,910; and Pasco, 17,820. The populations of Benton City, Prosser, and West Richland totaled 9,615 in 1990. The population of Benton and Franklin counties is young with 48% of the total population under the age of 30, compared to 44% of the total state population. The examination of age groups in 5-year increments reveals that the largest age group in Benton and Franklin counties ranges from 0 to 4 years old, representing almost 10% of the total biconty population; the largest group in the state ranges from 30 to 34 years, which represents about 10% of the total state population.

The Hanford Site lands embrace several DOE operational areas. The major areas are as follows:

- The entire Hanford Site has been designated a National Environmental Research Park.
- The 100 Areas, bordering on the right bank (south shore) of the Columbia River, are the sites of the eight retired plutonium production reactors and the N Reactor, which is currently in dry standby. The 100 Areas occupy about 11 km<sup>2</sup> (4 mi<sup>2</sup>).
- The 200-West and 200-East Areas are located on a plateau about 8 and 11 km (5 and 7 mi), respectively, from 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<sup>2</sup> (6 mi<sup>2</sup>).
- 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<sup>2</sup> (0.6 mi<sup>2</sup>).
- The 400 Area is about 8 km (5 mi) northwest of the 300 Area and is the site of the FFTF, used in the testing of breeder reactor systems. Also included in this area is the Fuels and Material Examination Facility.
- The 600 Area includes all of the Hanford Site not occupied by the 100, 200, 300, 400, 1100, or 3000 Areas.

Several areas of the Site, totaling 665 km<sup>2</sup> (257 mi<sup>2</sup>), have been designated as the Arid Lands Ecology (ALE) Reserve, the U.S. Fish and Wildlife Service Saddle Mountain Wildlife Refuge, and the Washington State Department of Game Reserve area (DOE 1986).

Land use in surrounding environs includes urban and industrial development, irrigated and dry-land farming, and grazing. In 1985, wheat represented the largest single crop in terms of area

planted in Benton and Franklin counties, with 116,000 ha. Corn, alfalfa, hay, barley, and grapes are other major crops in Benton and Franklin 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 (1990), where more detailed information can be found.

## Climate and Meteorology

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 directions on the 200 Area plateau is from the northwest (Figure 1.1) 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 mi/h), and highest during the summer, averaging 14 to 16 km/h (9 to 10 mi/h). 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 mi/h). 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 of wind, 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 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.

## 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 1.2.

The Columbia River Basalt Group is composed of numerous basaltic lava flows. River and lake sediments of the Ringold Formation contain a

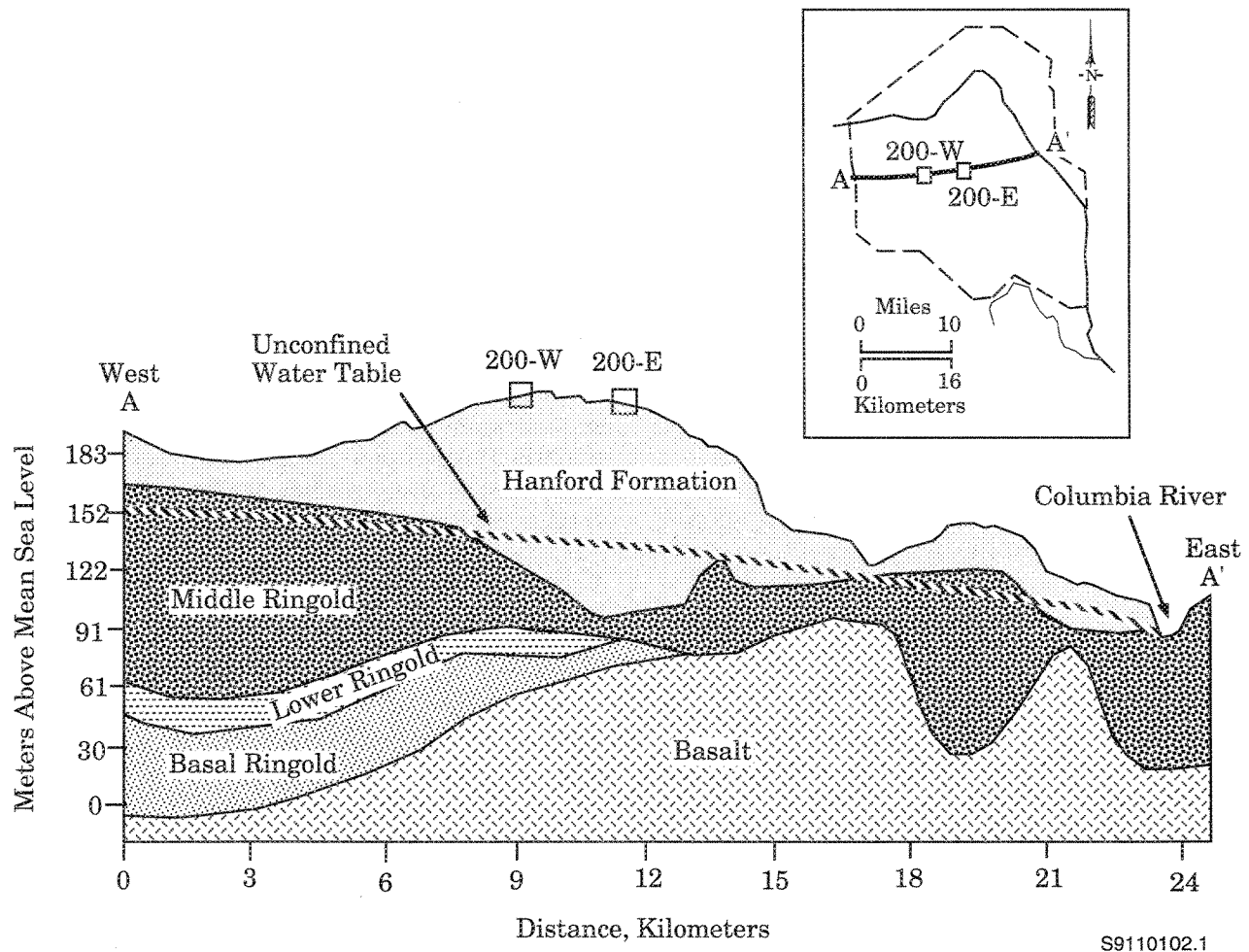


Figure 1.2. Geologic Cross Section of the Site (modified from Tallman et al. 1979)

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). Hajek (1966) lists and describes 15 different soil types on the Site, varying from sand to silty and sandy loam.

## 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 glaciofluvial sediments, as well as some more recent alluvial sediments in areas adjacent to the Columbia River (Gephart et al. 1979). This relatively shallow aquifer has been affected by waste-water disposal at Hanford (Graham et al. 1981). Therefore, the unconfined aquifer 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 1.3.

Recharge to the unconfined aquifer originates from several sources (Graham et al. 1981). Natural recharge 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 Yakima River recharges the unconfined aquifer 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 Routson and Johnson (1990) state that the measured recharge rate in the 200 Areas is  $0 \pm 0.2$  cm/yr.

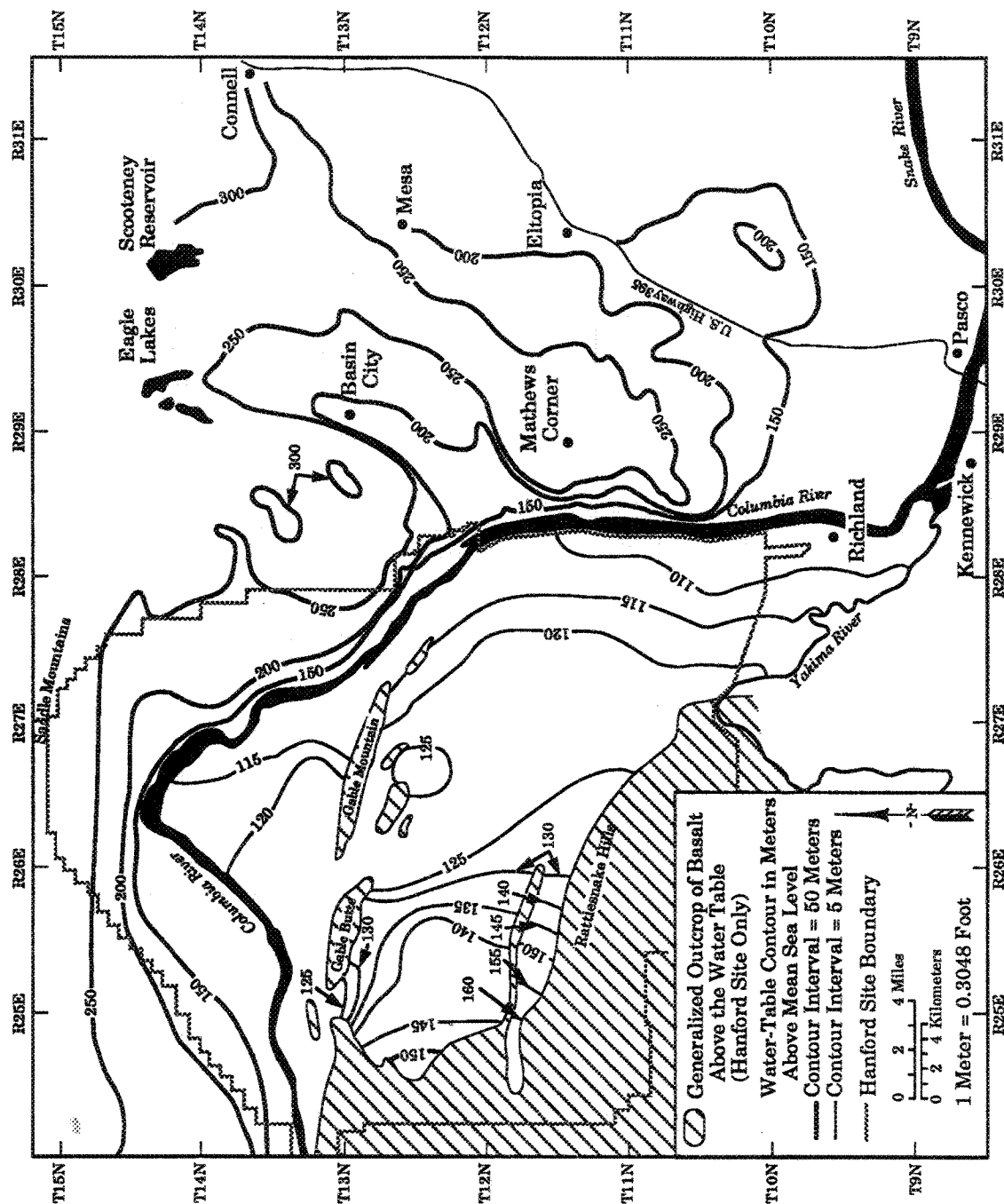
Large-scale artificial recharge occurs from offsite agricultural irrigation and liquid-waste disposal in the operating areas. Recharge from irrigation in the Cold Creek Valley enters the Hanford Site as ground-water flow across the western boundary. Recharge to ground water across the Columbia River from the Hanford Site is primarily from irrigation and irrigation canal leakage. As indicated in Figure 1.3, 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 waste-water 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 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. As effluents move through the unsaturated zone, adsorption onto soil particles, chemical precipitation, and ion exchange attenuate or delay the movement of some radionuclides, such as  $^{90}\text{Sr}$ ,  $^{137}\text{Cs}$ , and  $^{239,240}\text{Pu}$ . Other ions, such as nitrate ( $\text{NO}_3^-$ ), and radionuclides, such as  $^3\text{H}$ ,  $^{99}\text{Tc}$ , and  $^{129}\text{I}$ , are not as readily retained by the soil. These constituents move through the soil column at varying rates and eventually enter the ground water. Subsequently, the more soluble constituents 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.



S9104047.1n

Figure 1.3. Water-Table Elevations for the Unconfined Aquifer at Hanford, June 1990

## Surface-Water Hydrology

The Columbia River is the dominant surface-water body on the Site. The Columbia, which originates in the mountains of eastern British Columbia, Canada, drains a total area of approximately 70,800 km<sup>2</sup> (27,300 mi<sup>2</sup>) enroute to the Pacific Ocean. Flow of the Columbia River is regulated by 11 dams within the United States, 7 upstream and 4 downstream of the Site. Priest Rapids is the nearest dam upstream of 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.

Flows in the Hanford Reach fluctuate significantly because of the relatively small storage capacities and the operational practices at upstream dams. Flow rate of the Columbia River through the Site is regulated primarily by Priest Rapids Dam. Typical daily flows range from 1,000 m<sup>3</sup>/s (35,310 cfs) to 7,000 m<sup>3</sup>/s (247,170 cfs), with peak spring runoff flows of up to 12,600 m<sup>3</sup>/s (444,906 cfs). The minimum regulated flow is 1,000 m<sup>3</sup>/s. Typical annual average flows at Priest Rapids Dam are 2,800 m<sup>3</sup>/s (99,000 cfs) to 3,400 m<sup>3</sup>/s (120,000 cfs). Monthly mean flows typically peak from April through June and are lowest from September through October.

The temperature of the Columbia River varies seasonally. Minimum temperatures are observed during January and February, and maximum temperatures typically occur during August and September. Mean monthly temperatures for the river range from approximately 3°C (37°F) to about 20°C (68°F) during a year. Solar radiation, water storage management practices at upstream dams, and water flow rate dictate, to a large extent, the thermal characteristics of the Columbia River along the Hanford Reach.

The Columbia River has been developed extensively for hydroelectric power, flood control, navigation, irrigation, and municipal and industrial

water supplies. In addition, the Hanford Reach is used for a variety of recreational activities, including fishing, hunting, boating, water skiing, and swimming. The State of Washington has classified the stretch of the Columbia River from the Washington-Oregon border to Grand Coulee Dam (which includes the Hanford Reach) as Class A (Excellent) and has established water quality criteria and water use guidelines for this class designation.

## Ecology

The Hanford Site is a relatively large, undisturbed area of shrub-steppe that contains numerous plant and animal species adapted to the region's semiarid environment. The vegetation mosaic of the Site consists of eight major kinds of plant communities: 1) sagebrush/bluebunch wheatgrass, 2) sagebrush/cheatgrass or sagebrush/Sandberg's bluegrass, 3) sagebrush-bitterbrush/cheatgrass, 4) greasewood/cheatgrass-saltgrass, 5) winterfat/Sandberg's bluegrass, 6) thyme buckwheat/Sandberg's bluegrass, 7) cheatgrass-tumble mustard, and 8) willow. More than 240 species of plants have been identified on the Hanford Site (ERDA 1975), and cheatgrass is the dominant plant on fields that were cultivated 40 years ago.

More than 300 species of terrestrial and aquatic insects, 16 species of reptiles and amphibians, 44 species of fish, 125 species of birds, and about 30 species of mammals have been found on the Hanford Site. 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 trout 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 waste-water 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 (DOI 1986; 50 CFR 17.11, 17.12) are known to reside on the Hanford Site. However, several species of vascular plants are under consideration for formal listing by the federal government and Washington State. The federal government lists the peregrine falcon (Falco peregrinus) as endangered and the bald eagle (Haliaeetus leucocephalus) as threatened. The peregrine

falcon is a casual migrant through the Hanford Site, and the bald eagle is a common winter resident. Plants under consideration include Columbia milk vetch (Astragalus columbianus) and yellowcress (Rorippa columbiae).

## Archaeology and Cultural Resources

The Hanford Site is rich in cultural resources. It contains numerous, well-preserved archaeological sites representing the prehistoric and historical periods and is still thought of as a homeland by many Indian people (Chatters 1989).





## 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 unusual occurrences.



## 2.1 Overseeing Hanford's Environmental Compliance and Cleanup

Many entities have a role in the Hanford Site's new mission of waste management and environmental restoration: the regulatory agencies, environmental groups, the community, the affected Indian nations, as well as individual citizens. This section describes the roles of the principal agencies, other organizations, and the public in the Hanford Site's environmental compliance and cleanup.

### Environmental Regulations and Standards

The DOE Order 5400.1, "General Environmental Protection Program," prescribes the environmental standards and regulations applicable at DOE operations. 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 DOE has developed guidance for protecting the environment from its operations. This guidance is contained in DOE directives, called orders, and in Secretary of Energy Notices (SENs). Orders and SENs have been developed to implement several of the key environmental regulations.

Over the last several decades, a compendium of laws has evolved that primarily address environmental protection. The federal statutes that resulted in the most significant environmental protection regulations and standards follow:

- The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 (commonly referred to as "Superfund") requires the identification, characterization, and cleanup of inactive hazardous waste sites by responsible parties.
- The Superfund Amendments and Reauthorization Act (SARA) of 1986 provided significant revisions to CERCLA and requirements for emergency planning and notification.
- The Resource Conservation and Recovery Act (RCRA) authorizes the U.S. Environmental Protection Agency (EPA) to regulate hazardous and solid wastes; the Hazardous and Solid Waste Amendments of 1984 added waste minimization requirements and a national land disposal ban program.
- The Clean Air Act provides requirements to protect and enhance the quality of the nation's air to promote public health and welfare.
- The Clean Water Act provides requirements to restore and maintain the chemical, physical, and biological integrity of the nation's waters.
- The Safe Drinking Water Act authorizes EPA to promulgate regulations under two specific programs: the first protects the nation's public drinking water supplies; the second protects subsurface waters.
- The Toxic Substances Control Act provides requirements to safely regulate the manufacture, processing, distribution in commerce, use, or disposal of chemical substances and mixtures that may present an unreasonable risk to either the public health or the environment.
- The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) authorizes EPA to promulgate regulations governing the use and disposal of pesticides.
- The Endangered Species Act of 1973 establishes a program for the conservation of endangered species and their ecosystems.
- The National Historic Preservation Act of 1966, the Archaeological Resources Protection Act of 1979, and the American Indian

Religious Freedom Act of 1978 establish the policy of the U.S. Government to protect and preserve archaeological, historical, and cultural resources.

- The National Environmental Policy Act (NEPA) of 1969 establishes broad national policy for protection of environmental quality and provides the means (which includes public participation) for implementing that policy.

## The Regulating Agencies

Several federal, state, and local government agencies are responsible for enforcing and overseeing environmental regulations at the Hanford Site. The DOE, through its directives to field offices and compliance audits, initiates and assesses actions for conforming to environmental requirements. Other responsible agencies are the EPA, the Washington State Department of Ecology (WDOE), the State of Washington Department of Health (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 EPA is the principal federal environmental legislation regulator in Washington State. The EPA develops, promulgates, 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 states when the state's program meets or exceeds the EPA's requirements. For example, EPA has delegated enforcement authority to WDOE for air-pollution control and RCRA hazardous-waste management. In other instances, the states are given regulatory authority directly by the statute. For example, DOH has authority, from the Clean Air Act, over radionuclide emissions to the atmosphere at Hanford. Where regulatory authority is not delegated or instituted by the state, such as for CERCLA, EPA Region 10 is responsible for reviewing and evaluating compliance with EPA regulations as they pertain to the Hanford Site.

## The Tri-Party Agreement

The signing in 1989 of the Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) was a hallmark for a coordinated direction of Hanford's environmental compliance and cleanup. The Tri-Party Agreement establishes schedules for achieving compliance with requirements for hazardous and mixed waste management and provides the framework for the cleanup of Hanford over the next 30 years.

The Tri-Party Agreement is an agreement among the EPA, WDOE, and DOE for achieving compliance with 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.

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 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 Department of Community Development ensures communities are prepared for emergencies. It conducts emergency planning training.
  - The Utilities and Transportation Commission inspects highway route-controlled quantity shipments leaving Washington State and routed through Oregon.
  - The Nuclear Waste Advisory Council, a Washington State citizen's panel, advises WDOE on the public's concerns about Hanford issues. The principal issues are public involvement and waste transportation.

The Action Plan implements the Legal Agreement by defining how the parties will work together, describing the processes and procedures to be followed, defining the units to be addressed, and 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.

## **Washington State's Other Roles at Hanford**

The WDOE has played a significant role at Hanford; however, the following state agencies also have an environmental role at the Hanford Site:

- The Governor's Office communicates with DOE on policy, funding, and Congressional affairs. The Governor's Office also is involved in the Western Governors' Association cooperative agreement for activities relating to transuranic (TRU) waste shipments to the Waste Isolation Pilot Plant in New Mexico.
- The DOH administers parts of the Clean Air Act and Safe Drinking Water Act. It regulates the Hanford Site for radioactive air releases, monitors Hanford's drinking water systems, and oversees Hanford's environmental surveillance program. The DOH is also involved in radiation safety issues and emergency preparedness and response.

## **Oregon's Role at Hanford**

Oregon does not have a direct regulatory role at the Hanford Site. However, the DOE recognizes that Oregon has an interest in Hanford's cleanup because of its location downstream on the Columbia River and because of the potential for shipping radioactive wastes from the Hanford Site through Oregon. Therefore, 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 takes the lead in the state's involvement at Hanford. The Department is performing a 4-year research program to determine the effects of radioactive waste activities at the Hanford Site on the environment and on the health of the people of Oregon. Information is provided to the public and key leaders on proposed cleanup, transport, and disposal activities and costs.

## **Role of Indian Nations at Hanford**

The Hanford Site is on land ceded in treaties in 1855 with the Yakima Indian Nation and the Confederated Tribes of the Umatilla Indian Reservation. The Confederated Tribes include the Umatilla, Cayuse, and Walla Walla. The Nez Perce Tribe ceded lands east of the Site and used to hunt and fish in the Hanford Site area.

The tribes retain rights and privileges in the ceded areas. The most important right is the right to take fish at usual and accustomed places.

In addition to the treaties of 1855, the following laws protect Indian rights and culture at the Hanford Site: the American Indian Religious Freedom Act, the Archaeological Resources Protection Act, the Archaeological and Historic Preservation Act, and the American Antiquities Act. The RL program to implement the protections provided by these laws is described in Section 3.3, "Environmental Studies and Programs."

The RL is providing a grant to the Yakima Indian Nation to ensure their involvement in the Environmental Restoration and Waste Management Five-Year Plan activities for cleanup of the Hanford Site (DOE 1989d). A similar grant is being discussed with members of the Confederated Tribes of the Umatilla Indian Reservation and being considered for the Nez Perce Tribe. Members of the Confederated Tribes are also involved in discussions for a grant to address their concerns about transporting wastes to the Waste Isolation Pilot Plant.

## Public Participation

Individual citizens of Washington and neighboring states may participate in determining how Hanford's 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, WDOE, and EPA Region 10 with public comment and was jointly approved in 1990.

Quarterly information meetings are held in the Tri-Cities and one other Northwest city to update the public on Tri-Party Agreement activities. Meeting dates are announced approximately 3 weeks in advance through the quarterly Hanford Update newsletter, which is mailed to about 2,300 people. The meetings also are announced in news releases and paid newspaper advertisements. Before each meeting, outreach efforts are conducted to ensure the press is aware of the issues to be discussed. Additionally, each meeting is preceded by notices to elected officials, community leaders, special interest groups, and the press.

The public can go to four repositories for up-to-date information on Hanford's cleanup efforts. These repositories are maintained at:

- RL Public Reading Room, Federal Building, Richland, Washington
- University of Washington Library, Seattle, Washington
- Crosby Library at Gonzaga University, Spokane, Washington
- Portland State University Library, Portland, Oregon.

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



## 2.2 Compliance Status

This section summarizes the activities conducted to ensure the Hanford Site is in compliance with the environmental protection regulations. These regulations include the principal federal environmental protection statutes, as well as related Washington State and local regulations.

Environmental permits required under the environmental protection regulations are discussed under the applicable statute. Appendix B lists environmental permits currently issued for the Hanford Site.

### **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 legislation also created a claims procedure for parties who have cleaned up sites or spent money to restore natural resources. The SARA broadened CERCLA and extended it to federal facilities.

The law 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: preliminary assessments, remedial investigation/feasibility studies (RI/FS), and remedial action(s). The EPA has established procedures to conduct the three-tiered assessment. The Hanford Site must comply with EPA procedures.

The preliminary assessments conducted for the Hanford Site revealed that there are approximately 1100 known individual waste sites where hazardous substances may have been disposed of in an environmentally unsound manner. These 1100 sites have been grouped into 78 operable units, which have been further grouped into four aggregate areas using identifiable geographic boundaries on the Hanford Site. The four aggregate areas have been placed on the 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 currently under investigation is a result of Tri-Party Agreement negotiations. All milestones related to the RI/FS process established for 1990 were achieved (this takes into consideration several milestones delayed through the change request process), and the Hanford Site was in compliance with these CERCLA/SARA requirements.

On October 18, 1990, Secretary of Energy Watkins proposed three accelerated cleanup actions. These actions would be completed as expedited response actions (i.e., a way to hasten cleanup at sites to prevent further spread of contamination). The three actions would 1) remove drums thought to contain hexone contaminated with uranium from a burial ground in the 300 Area, 2) remove carbon tetrachloride from the vadose zone of two ground disposal sites in the 200-West Area, and 3) remove contaminated sediments from the bottom of 300 Area process trenches. All of these expedited response actions were initiated in 1990.

Under Section 103(a), the Emergency Release Notification provision of CERCLA, releases exceeding reportable quantity limits for regulated chemicals were appropriately reported.

### **Superfund Amendments and Reauthorization Act of 1986, Title III**

Title III of SARA is a free-standing law, called the Emergency Planning and Community Right-to-Know Act of 1986. The purpose of Title III is to provide the public with information about hazardous chemicals in the community and to establish emergency planning and notification procedures to protect the public in the event of a release. The law calls for creation of State Emergency Response Commissions to guide planning for chemical emergencies. The state commissions have created Local Emergency Planning Committees to ensure community participation and planning.

During 1990, field representatives throughout the Hanford Site participated in annual training and recertification on the regulatory requirements of the SARA Title III community right-to-know reporting and on supplying information to the newly developed Hazardous Material Inventory Database.

The 1989 Hanford Tier-Two Emergency and Hazardous Chemical Inventory (DOE 1990a) was issued March 1, 1990, to the State Emergency Response Commission, local county emergency management committees, and the local fire department. This report, required under SARA, contains information on hazardous material in storage across the Hanford Site. The 1989 Hanford Toxic Chemical Release Inventory (DOE 1990b) was issued to EPA and WDOE July 1, 1990. This report, also required under SARA, contains data on toxic releases and transfers, as well as waste management practices, to provide the public with information about toxics that may affect health or the environment.

During 1990, the Hanford Site was in compliance with the reporting and notification requirements contained in the SARA, Title III Emergency Planning and Community Right-to-Know Act of 1986.

## **Resource Conservation and Recovery Act**

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

The Hanford Site has identified 61 treatment, storage, and disposal (TSD) units that must be permitted or closed in accordance with RCRA and WAC 173-303. Some of the TSD units contain

numerous individual components (e.g., the single-shell tank TSD unit includes 149 separate tanks). The TSD units are being operated under interim status compliance requirements of the state's regulations. Approximately one-half of the units will be closed; applications for operating under the RCRA Part B permit will be made for the other units, which will continue to operate.

The Hanford Site has been assigned a single dangerous waste permit by WDOE. This permit identification number (WA7890009867) encompasses all TSD units on the Hanford Site. Because all TSD units cannot be permitted simultaneously, WDOE will issue the initial permit for less than the entire facility, probably in early 1992. Each operating unit will be added as a major modification to the permit as documentation is completed in accordance with the Tri-Party Agreement Action Plan schedule.

Environmental self-assessments have been conducted at all TSD facilities containing significant environmental effluents and for all dangerous and mixed-waste management facilities. Where potential deficiencies were noted, corrective actions were identified. These assessments were submitted to EPA and WDOE along with schedules for completion of the action items. These action items are the subject of a Tri-Party Agreement milestone.

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 promulgated 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 TSD facilities. The EPA has authorized the WDOE to implement the underground storage tank rules.

During 1990, five underground petroleum-product storage tanks located in the 100-N Area were removed from the ground and disposed of. Throughout the Site, nine other tanks and two pressurized piping systems were inspected and tested for integrity. Two tanks, one at the 100-N

Area and the other at the 200-East Area, were reported as having a leak near the top of the tank.

On December 10, 1990, WDOE serve RL with a Notice of Noncompliance regarding the return of 68 problem drums from the Central Waste Complex to the generator, the 183-H Solar Evaporation Basins. Return of the drums to the generator was considered to be a violation by WDOE. The WDOE did not take any formal action but requested that the 68 drums be repackaged and returned to the Central Waste Complex and the remaining 1,600 problem drums be repackaged or overpacked without being returned to the 183-H basins.

The methods for handling and disposing of potentially contaminated purgewater, from the purging of ground-water monitoring wells, was a major issue in 1990. On August 9, 1990, the Tri-Party Agreement Project Managers for DOE, EPA, and WDOE signed the "Strategy for Handling and Disposing of Purgewater at the Hanford Site, Washington." Final agreement on compliance issues associated with the sitewide collection, storage, future treatment, and disposal of purgewater took approximately 15 months of meetings and negotiations by RL with WDOE and EPA Region 10. The agreement specified that RL would fully implement the purgewater management strategy on or before October 1, 1990, which was done. The strategy includes containing the purgewater in retention tanks and sampling for contaminants to ensure releasability. The purgewater management strategy will be added as an Amendment to the Tri-Party Agreement.

Under provisions of RCRA, new management strategies and new technologies must be developed to reduce the volume and toxicity of waste generated various waste minimization techniques are being implemented across the Site (see Section 3.1, "Environmental Restoration, Waste Management, and Technology Development"). For 1990, the use of source reduction techniques reduced hazardous waste by 82,000 kg (181,000 lb), radioactive mixed waste by 4,000 kg (8,800 lb), low-level waste by 37,000 kg (81,500 lb), and TRU waste by 800 kg (1,760 lb). Recycling initiatives prevented 70,000 kg (154,000 lb) of materials from becoming waste. Also in 1990, the use of a combination of source reduction and recycling techniques resulted in the reduction of 3,000 kg

(6,615 lb) of hazardous waste and 247,000 kg (545,000 lb) of radioactive mixed waste.

A number of major nationwide regulatory conflicts and issues have been identified in complying with RCRA requirements. Examples of these conflicts and issues include:

- the issue of the differences that exist between RCRA requirements associated with the management of mixed waste and as-low-as-reasonably-achievable requirements promulgated under the Atomic Energy Act
- the issue of whether the nonradioactive portion of special nuclear material scrap would be managed as RCRA-regulated waste
- the issue of whether radioactively contaminated lead, stored for future use, should be RCRA-regulated
- the issue that strict adherence to some RCRA technical standards is not achievable in the near future because of hazards of radioactivity associated with certain mixed wastes.

The DOE has formed a task force with representatives from Hanford and other DOE sites to develop or clarify an interpretation on these issues. After DOE's understanding of these issues is clarified internally, DOE intends to initiate discussions with EPA and/or the U.S. Nuclear Regulatory Commission (NRC) on certain issues, as appropriate.

The RL has notified regulators of the compliance issues considered unresolved and of national significance. The WDOE has not formally responded. The EPA is addressing these issues on the national level.

## 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, WDOE, DOH, and local air authorities.

For clean air areas such as the Hanford Site, 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 WDOE for regulation under the PSD program.

The Hanford Site operates under a PSD permit (No. PSD-X80-14) issued by the EPA in 1980. The permit sets specific limits for emissions of nitrogen oxides from the Plutonium Uranium Extraction (PUREX) and Uranium Oxide (UO<sub>3</sub>) plants. Significant increases in emissions from the Hanford Site of any pollutant regulated by the Clean Air Act also require agency review of potential impacts to regional air quality and any additional limits that may be necessary in the PSD permit. To date, no additional limits have been added.

The DOH, Division of Radiation Protection, has promulgated regulatory controls for radioactive air emissions under Section 116 of the Clean Air Act. The WAC 246-247 requires registration of all radioactive air emission point sources with the DOH.

All significant Hanford Site stacks emitting radiation have been registered with the division in accordance with applicable regulations. These stacks are included in the DOH permit (No. FF-01) to RL for the Hanford Site. A total of about 130 stacks are registered and are operated under the permit. Washington State law requires an annual report of emissions from each stack and the resulting offsite dose impact. This report was submitted in 1990 for calendar year 1989.

New Clean Air Act requirements for radioactive air emissions were issued December 15, 1989, under 40 CFR 61, Subpart H. Emissions from the Hanford Site are well within the new EPA offsite emissions standard of 10 mrem/yr (effective dose equivalent). However, because of the new requirements for flow measurement, emissions measurement, quality assurance, and sampling documentation, all Hanford Site sources do not yet meet the new procedural requirements.

These reporting and monitoring requirements demand significant additional effort. The RL sent a formal request for a 2-year extension of the

Subpart H requirements to EPA Region 10 on May 14, 1990. During this extension period, an evaluation will determine the need for any additional continuous sampling equipment and other actions to meet EPA criteria.

Hanford Site contractors are preparing Facility Effluent Monitoring Plans (FEMPs) specific to various facilities across the Site. The FEMPs will be used to help demonstrate compliance with that part of 40 CFR 61 dealing with atmospheric emissions. The preparation of all required FEMPs is expected to be complete in late 1991. (When completed, the full set of FEMPs will be incorporated into a site-wide Environmental Monitoring Plan covering effluent monitoring and environmental surveillance.)

The EPA has retained authority for regulating certain hazardous pollutants under different standards, called the National Emission Standards for Hazardous Air Pollutants (NESHAP), per 40 CFR 61. These standards are designed to protect the public from significantly dangerous pollutants (arsenic, asbestos, beryllium, mercury, radionuclides, and vinyl chloride). Pursuant to the NESHAP program within the Clean Air Act, EPA has promulgated regulations specifically addressing asbestos emissions. These regulations apply at Hanford in building demolition/disposal and waste disposal operations. Approximately 1,400 facilities on the Hanford Site have asbestos-containing material. During 1990, 610 m<sup>3</sup> (800 yd<sup>3</sup>) of asbestos were removed and disposed of in the Hanford Central Landfill in accordance with applicable regulations.

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 been delegated to enforce the EPA asbestos regulations under NESHAP. The Site remains in compliance with the regulations.

During 1990, Hanford Site air emissions remained below all regulatory limits concerning radioactive and other regulated pollutants. Routine reporting of air emissions was provided to each air quality agency, in compliance with requirements.

## Clean Water Act

The Clean Water Act applies to all nonradioactive discharges to navigable surface waters. 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 permit holder is RL. The permit was issued in 1981 and is being renegotiated with EPA.

The NPDES permit (No. WA-000374-3) specifies discharge points (called outfalls, of which there are eight), effluent limitations, and monitoring requirements. Above-limit conditions are detected by a routine sampling and analysis program for each of the eight discharges. Sample analysis requirements may include temperature, flow, pH, free available chlorine, total suspended solids, oil and grease, iron, ammonia, and chromium. Sampling activities for each outfall are summarized and reported to EPA each month.

There were three reportable release occurrences in 1990. The first was an exceedance of the free available chlorine discharge limit in April 1990 at a 100 Area outfall. The 300 Area reported an exceedance of the settleable solids discharge limit in May 1990. On June 20, 1990, an aluminum sulfate spill resulted in a discharge that exceeded the pH limit for a 100 Area outfall. Nonetheless, during 1990, the Hanford Site was in substantive compliance with the discharge limits.

## 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.

During 1990, sanitary water was supplied on the Hanford Site by 15 individual drinking water systems. Fourteen are operated by RL contractors; the other is the city of Richland municipal system, which provides water to the 700, 1100, and 3000 Areas. Ten of the systems use Columbia River water as a raw water source, four systems use ground water, and one system uses a combination of the two.

The water supplies are monitored for the contaminants indicated in the rules and regulations of the DOH regarding public water systems. In 1990, with one exception, all water systems were in compliance with the requirements of the applicable regulations. The one exception concerns the requirement for the correct number of certified operators. An agreement with the DOH allows for use of noncertified operators as long as they are under constant supervision of certified operators.

## Toxic Substances Control Act

Congress and EPA have determined that several chemicals pose an unacceptable risk to human health and the environment, and the EPA has regulated these chemicals under the Toxic Substances Control Act. In 1978, EPA instituted regulatory controls over the manufacture, use, and disposal of polychlorinated biphenyls (PCBs) and banned aerosol uses of chlorofluorocarbons.

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

Various concentrations of PCBs are found in electrical equipment throughout the Site. All transformers have been characterized, and all large capacitors containing PCBs have been identified. Many PCB-containing (>500 ppm) transformers and large capacitors have been replaced or retrofitted, and a risk assessment has been completed for all remaining transformers to aid in removal of the PCBs.

Defueled and decommissioned submarine reactor compartments shipped by the Department of the Navy to Hanford for burial were found to contain PCB-contaminated sound-dampening material and electrical wiring. The Navy is removing most of the contaminated material from those already at Hanford and from newly decommissioned compartments. However, sufficient residual PCBs

remain to cause the Hanford Site disposal trench to be regulated under Toxic Substance Control Act chemical waste landfill requirements. Waivers from chemical waste landfill requirements for PCBs in the compartments are required, or it will be necessary to reconstruct the disposal trench to meet technical requirements. A Compliance Agreement between EPA and DOE forms the basis for compliance with these requirements and establishes the process by which a Toxic Substance Control Act permit will be issued.

The Hanford Site is currently in compliance with regulations for nonradioactive PCBs. For radioactive PCBs, effective treatment and disposal technologies have not been developed. These wastes are being stored with EPA approval pending development of treatment and disposal technologies.

## **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. The FIFRA requires EPA to consider economic, social, and environmental costs and benefits when making decisions on allowing and controlling use of insecticides, fungicides, and rodenticides (collectively called pesticides).

Where benefits of use outweigh risks, EPA can lessen the risk by limiting the amount of pesticide applied and/or limiting frequency or location of application. The EPA pesticide program licenses the use of chemicals, many of which are potentially hazardous to people or the environment. The EPA also restricts the use of licensed chemicals to specially trained and certified applicators.

The WDOE administers the FIFRA certification and storage requirements under authority granted by EPA. The FIFRA and the Revised Code of Washington 17.21, "Washington Pesticide Application Act," as implemented by WAC 16-228, General Pesticides Regulations, apply to storage

and use of pesticides. At Hanford, pesticides are applied by personnel licensed by the WDOE 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 3.3, "Environmental Studies and Programs."

## **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 the National Historic Preservation Act and the Archaeological Resources Protection Act. Compliance with the applicable regulations is accomplished through an active monitoring program that includes 1) review of all proposed land-disturbing projects to assess potential impacts on cultural resources and 2) periodic inspections of known archaeological and historical sites to determine their condition and the effects of land management policies on the sites. The 1990 program activities are described in Section 3.3, "Environmental Studies and Programs."

## **National Environmental Policy Act**

The NEPA provides the basic national charter for the protection of the environment. The NEPA establishes environmental policy to prevent or



eliminate damage to the environment and to enrich our understanding of ecological systems and natural resources. In addition, NEPA sets goals and provides means for carrying out the environmental policy.

The NEPA requires that major federal projects with significant impacts are 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. The NEPA documents are prepared and reviewed in accordance with the Council on Environmental Quality regulations in 40 CFR 1500 to 1508, DOE guidance published in the Federal Register (52 FR 47662, December 15, 1987), and SEN-15-90, "National Environmental Policy Act."

The SEN-15-90, issued in February 1990, directs the field offices to conduct early and adequate NEPA planning, and to designate an official to have overall NEPA compliance responsibilities. It also terminated the use of Memorandum to File exclusion assessments for activities and projects after September 30, 1990. The RL has complied with these, as well as other, requirements of the notice.

Several related programmatic and site-specific EISs are in process or in the planning and scoping stages. These are summarized below.

### **Draft 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, is eligible for listing as a National Historic Monument.

The draft EIS (DOE 1989c) 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

being prepared. Completion of responses to comments and publication of the final EIS for decommissioning the reactors is expected for 1991.

### **Office of Environmental Restoration and Waste Management Programmatic Environmental Impact Statement**

This EIS will evaluate the potential environmental impacts of DOE's national environmental restoration and waste management program. It will include actions for remediation, compliance with RCRA and CERCLA, restoration, waste management, and repositories.

The Notice of Intent was published in the Federal Register in October 1990. Scoping hearings were held in key cities near DOE waste sites in December 1990. For the Hanford Site, hearings were held in Seattle, Richland, and Spokane, Washington, and Portland, Oregon.

### **Hanford Remedial Action Environmental Impact Statement**

This proposed EIS would assess the potential impacts of remediation alternatives at the Hanford Site. This EIS would support the Office of Environmental Restoration and Waste Management Programmatic EIS. While the Hanford Defense Waste EIS (DOE 1987a) covered disposal of single- and double-shell tank waste and TRU waste, this EIS is being considered to address the conduct of Hanford's other remedial actions. This EIS would place major emphasis on cumulative impacts and would be examined every 5 years to ensure it sufficiently documents impacts from actual remediation activities. Specific NEPA documentation will still be prepared as needed. The scope of this proposed EIS is being determined. The scope will include the development of a future Site use/cleanup strategy for the Hanford Site (see Section 2.3, "Current Issues and Actions").

### **Irradiated Fuel Environmental Impact Statement**

This proposed EIS will assess the potential environmental consequences of alternatives for

disposition of the inventory of irradiated fuel stored at Hanford. This inventory includes approximately 2,100 metric tons ( $4.63 \times 10^6$  lb) of N Reactor fuel, 16 metric tons (35,000 lb) of Shippingport reactor fuel, and 10 metric tons (22,000 lb) of FFTF fuel. A small amount of irradiated fuel from the other Hanford production reactors and some miscellaneous fuel pieces and experimental fuel assemblies are also stored at Hanford.

The DOE announced this EIS in mid-October 1990, and RL began to work on a Notice of Intent in December 1990. The Notice of Intent is expected to be published in 1991.

### **Waste Tank Safety Supplemental Environmental Impact Statement**

The DOE announced a supplement to the Hanford Defense Waste EIS (DOE 1987a) would be prepared to address waste tank safety issues. This announcement followed the October 1990 General Accounting Office audit of the single-shell tank program. By the end of 1990, the total scope of the EIS had not been determined.

### **Single-Shell Tank Closure Supplemental Environmental Impact Statement**

This planned supplement to the Hanford Defense Waste EIS will evaluate options for disposing of single-shell tank wastes. In the Record of

Decision for the Hanford Defense Waste 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 developed for disposing of the wastes. Because of Tri-Party Agreement milestones, this supplemental EIS's schedule is proposed for acceleration.

### **New Production Reactor Environmental Impact Statement**

The RL contractors are assisting Argonne National Laboratory in the preparation of the draft EIS for the siting, construction, and operation of a New Production Reactor (NPR) to produce  $^3\text{H}$ . The draft will compare potential environmental and socioeconomic impacts from the siting of an NPR to the Hanford Site, Idaho National Engineering Laboratory, and the Savannah River Plant. The technologies proposed for  $^3\text{H}$  production are the Light Water Reactor, Modular High-Temperature Gas-Cooled Reactor, and Heavy Water Reactor. The sites will be evaluated regarding each of the three technologies. At Hanford, the Light Water Reactor would be the 63% completed WNP-1. The fuel/tritium target fabrication and  $^3\text{H}$  processing would be housed in the existing Fuels and Material Examination Facility in the 400 Area. The draft EIS will be issued and public hearings will be held in the spring of 1991. The Record of Decision on the selected site and technology is scheduled to be announced on or before December 31, 1991.



## 2.3 Current Issues and Actions

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

### Tri-Party Agreement

Forty-five of 49 milestones scheduled for 1990 were completed, although some were delayed as approved through the change request process. Included in these completed milestones were the following activities:

- Submitted two RCRA Part B permit applications and six closure plans for Hanford TSD facilities.
- Submitted six CERCLA RI/FS or RCRA facility investigation/corrective measures study work plans for inactive waste sites.
- Stabilized four single-shell waste storage tanks.
- Completed design of an expanded laboratory for low-level radioactive mixed waste sample analysis.
- Installed 22 RCRA ground-water monitoring wells.

At the end of 1990, 75 Tri-Party Agreement milestones (for 1989 and 1990) had been completed on or ahead of schedule. However, four milestones were not met, and schedule extensions were being processed.

The DOE submitted change packages to WDOE for Tri-Party Agreement milestones for an

exemption to T Plant treatment-by-generator; for single-shell tank ground-water monitoring wells, to reduce the number of wells to be installed in calendar year 1990 from the planned 11 to 6; and for the installation of 30 ground-water monitoring wells Sitewide and 11 at the single-shell tanks in calendar year 1990. This latter change package seeks to reduce the number of wells to be installed from 30 to 22 and 11 to 3, respectively.

The Tri-Party Agreement was amended in 1990. The most significant changes was the addition of compliance agreements for extended storage of land-disposal-restricted waste and compliance schedules for dangerous waste tanks. Late in the year, DOE notified EPA and WDOE that some other milestone schedules will also need to be revised in upcoming months because of technical and budget issues. Foremost of these is the 2-year delay in start of construction of the Hanford Waste Vitrification Plant.

During the development of the Tri-Party Agreement, public comments were received regarding reduction of the discharge of liquid effluents into the soil column at the Hanford Site. To address these comments, the Agreement participants committed to document the discharge history, characterize the liquid discharge, and assess the potential for and extent of contamination in soils and ground water.

The Liquid Effluent Study (DOE 1990e) was completed and transmitted to WDOE and EPA Region 10 in the third quarter of 1990. This study provides summary descriptions, characterization sampling data, proposed designations of those effluent streams that go to the soil column, accompanying ground-water flow descriptions, and an assessment of potential contaminant migration. Stream-specific reports are included for all major liquid effluent streams on the Hanford Site. The WDOE and EPA Region 10 are reviewing the liquid effluent study documents and are expected to provide comments early in 1991.

## **Hanford Future Site Use/ Cleanup Strategy**

The DOE; other federal, state, local, and tribal government officials; and members of the public recognize the need for a Hanford future Site use/cleanup strategy. These organizations have initiated an effort to develop a strategy that will be a source of guidance for the environmental restoration efforts ongoing at the Site. Currently, the guidance is based on environmental regulations and on technical judgment. This guidance is incomplete. Not all circumstances and substances encountered during cleanup are covered by regulations, nor does technology currently exist to respond to all regulations or handle all contaminants. Another key item that is missing is a clearly defined goal for cleanup stated in terms clearly understood by everyone who has an interest in cleanup. This goal is essential to establishing the direction of Hanford's cleanup.

The question "how clean is clean" for a given site can really be answered only when it is known what the land at that site might be used for after cleanup is complete. For example, more of the contaminants may need to be removed from a site to protect public health if that site is to be used for agricultural purposes than if it is to be used for industrial development. Conversely, it may not be a prudent use of resources to restore a part of the site to pristine conditions if a hazardous-waste landfill will eventually be located adjacent to it.

The development of this strategy will occur as part of the Hanford Remedial Action EIS. The purpose of the Hanford Remedial Action EIS is to address the complex issues associated with cleanup of about 1100 waste sites at the Hanford Site. The development of the future Site use/cleanup strategy as part of this EIS will provide the framework for many cleanup decisions related to future development of the Site, placement of facilities, and determination of uses.

## **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 in 1988 for a comprehensive study of the Hanford Reach. The Secretary of Interior, in consultation with the Secretary of Energy, will 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 section in the National Wild and Scenic Rivers system. The inventory and evaluation were completed in April 1990. The Department of Interior is to present its study and an EIS to Congress by November 1991, 3 years from the date the law was passed.

The law states that for 8 years, no federal agency may build any dams, navigation, or channelization projects. It also requires all other activities, to the extent practicable, be planned and implemented to minimize adverse impacts on the river's resources.

Analysis of the alternatives began in May 1990. Options range from designating the Reach a National Natural Landmark or a National River 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 questions to be determined. For example, if the Hanford Reach were declared a National Natural Landmark, no government agencies would regulate the area or acquire the land. If it were 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 plans to announce its preferred alternative in a draft EIS in the spring of 1991. A public comment period will follow. Public hearings are planned but a schedule is not yet available. The final report, due to Congress in November 1991, will present the study team's final recommendation.

## **U.S. Testing Company Contract Termination**

On June 1, 1990, the Pacific Northwest Laboratory (PNL) terminated, for default, its

subcontract with the United States Testing Company, Inc. (UST), for analytical laboratory services. This company performed radiological and chemical analyses of environmental and other samples collected from the Hanford Site and vicinity. Contract termination followed an evaluation of UST conducted by PNL.

The termination resulted because UST performed dioxin and petroleum hydrocarbon tests at its Hoboken, New Jersey, facility, without having the required approvals in place. Hanford Site analyses have been performed at UST in Richland. Quality control checks of data generated by UST's Richland laboratory had been performed routinely by PNL. The company was also required by contract to participate in inter-laboratory comparison programs conducted by the EPA and DOE's Environmental Measurements Laboratory. The results of these programs, as well as analytical results from split samples with the states of Oregon and Washington, were within the range of normal variability.

Termination of the subcontract significantly impacted environmental surveillance and monitoring analysis capability at the Hanford Site. Until new permanent arrangements can be made for providing analytical services to the Hanford Site, PNL is attempting to make interim arrangements with other laboratories for sample analyses.

## Environmental Litigation

Currently, six "downwinder" lawsuits that have been filed against past and present Hanford Site operating contractors. One has been brought by the survivors of an individual who lived in the Pasco area in the early 1950s. Five of the actions are class actions filed between August and November 1990 alleging personal injury, diminution in property values, and other claims resulting from releases of radioactive material to the air, ground, and water. At least one of the lawsuits also indicates it will seek injunctive relief for unspecified violations of various environmental statutes and implementing regulations.

## Tiger Team Assessment

On June 27, 1989, Secretary of Energy James D. Watkins announced a 10-point Initiative to strengthen safety, environmental protection, and waste management activities at DOE's production, research, and testing facilities. The Initiative is part of the Secretary's overall plan to ensure full accountability in the areas of environment, safety, and health (ES&H), and ensure that all DOE facilities achieve and maintain full compliance with applicable federal and state environmental, safety, and health requirements.

Tiger Team Assessments, one of the 10 points in the Initiative, are one of Secretary Watkins' highest priorities for DOE. The assessments include, but are not limited to, the following ES&H areas:

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

Before the Tiger Team Assessment RL and its contractors completed a self-assessment on the status of Hanford Site contractor compliance activities in three major performance disciplines. The Hanford Tiger Team began evaluating Site operations in May 1990. During the Tiger Team review, environmental compliance findings were compared with environmental findings listed in the self-assessment. It was determined that approximately 50% of the findings identified by the Tiger Team were also documented in the Hanford Site self-assessment report.

The Tiger Team presented its findings to RL and state officials on July 18, 1990. The team's report listed 371 separate findings and 4 special issues; no findings were characterized as representing an imminent danger. The documentation of the results of the assessment are published in *Tiger Team Assessment of the Hanford Site* (DOE 1990g). A copy of this document is available at the RL Public Reading Room.

There were 84 findings related to environmental issues. The team chose the following six findings to summarize their nature and scope:

- Long-term storage of radioactive and mixed wastes at the Hanford tank farms and at the low-level burial grounds presents a potential for release to the environment.
- Clear definition of roles and responsibilities are lacking for management and quality assurance of activities under the Tri-Party Agreement, as is independent verification of Tri-Party Agreement Past Practice Cost Projection Model.
- Current and past waste disposal practices at Hanford have contaminated the ground water onsite and potentially offsite, and Hanford has not adequately defined the vertical and horizontal ground-water flow regimes.
- Sitewide radiological monitoring programs, including radioactive air emissions stack monitoring, need improvements.
- Radioactively contaminated surface soil areas are expanding at a rate greater than the stabilization and cleanup rates.
- Environmental quality assurance and quality control programs are currently inadequate.

A Hanford Site team is preparing a corrective action plan to respond to the Tiger Team's findings. Corrective actions will require additional resources to respond to the findings while maintaining the current commitments to the Tri-Party Agreement and other activities.

## Plutonium Uranium Extraction Plant Status

The DOE announced in October 1990 that weapons-grade plutonium from the remaining N Reactor fuel was not needed and that an EIS would be prepared for disposition of the remaining irradiated fuel. Therefore, the PUREX Plant would not immediately be used to process the fuel. At the end of FY 1990, a standby plan for the PUREX Plant was to be implemented over the following 6 to 8 months. These planned actions would reduce activities to minimum surveillance, maintenance of essential equipment (primarily ventilation systems), and engineering support of longer-range planning and documentation upgrades.

It is anticipated that no decision on further operation of the PUREX Plant will be made for as long as 3 years (until the EIS is complete).

## Plutonium Finishing Plant Restart

Reactivation of two process areas in the Plutonium Finishing Plant (PFP) will stabilize materials held in the facility. This materials stabilization campaign is in response to RL direction from DOE-Headquarters (DOE-HQ) to operate 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.

Operation of the Plutonium Reclamation Facility, one of two "active" process facilities and the first step in the stabilization process, could be resumed following completion of the Readiness Review process. Residual "in-process" chemically active recyclable liquids, sludges, fluoride powder, and rags containing plutonium will be processed to produce plutonium nitrate solutions. These plutonium nitrate solutions will then be processed through the other process facility, the Remote Mechanical C Line, to an oxide form. Plutonium oxide is a stable form suitable for extended storage. Reactivation of this latter facility is

scheduled for early in 1992. Operations beyond this materials stabilization campaign will be dependent on the conclusions from appropriate NEPA assessment.

Resolution of the issues regarding the use of 216-Z-20 Crib for PFP liquid effluents and the reduction of waste-water flow to the crib is under discussion and negotiation with WDOE and the EPA.

## Hanford Waste Vitrification Plant Construction Delay

The Hanford Waste Vitrification Plant will be constructed to treat much of the waste currently stored in double-shell tanks. The high-activity fraction resulting from pretreatment of the stored waste would be immobilized into borosilicate glass and stored until a repository is ready to receive this waste.

The RL advised WDOE in December 1990 of technical and programmatic concerns that may delay the start of plant construction. To address these technical and programmatic concerns, RL has initiated two parallel activities. The first activity is a systems engineering risk assessment to evaluate the technical, safety, and regulatory uncertainties in the Hanford Waste Vitrification Program. The second activity is to perform a range of engineering studies to provide a detailed technical analysis of selected elements of the program.

## Waste Tank Safety Issues

Several waste tank safety issues identified in 1990 have potential impact 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 supplement to the Hanford Defense Waste EIS will be prepared to address the new information concerning the safety questions for the Hanford

waste tanks. However, empirical and analytical data to support the supplemental EIS will not be available until many of the waste tank safety issues are resolved and program activities are completed. Disposal of the tank wastes cannot begin until the supplemental EIS is completed.

## Background

Between 1943 and 1964, 149 single-shell tanks were built to store liquid radioactive wastes. Their capacities range from approximately  $2.08 \times 10^5$  L ( $5.5 \times 10^4$  gal) to  $3.78 \times 10^6$  L ( $1 \times 10^5$  gal). Some of the tanks have leaked. No wastes have been added since November 1980, and much of the originally stored waste has been pumped out. Today, the tanks hold about  $1.4 \times 10^8$  L ( $3.7 \times 10^7$  gal) of waste. The waste is in three general forms: sludge, salt cake, and liquid. The waste is a variety of types: low-level, high-level, 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  $7.6 \times 10^7$  L ( $2.0 \times 10^7$  gal) of liquid radioactive waste. These tanks have a second steel wall, and the space between the two walls is monitored for leaks. None are known to have leaked to date.

Sixty-six of the single-shell tanks have been classified as "suspected leakers." An exact count is not possible, because of an inadequate number and placement of monitoring wells. 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.

## Safety Issues

Potentially flammable gases are generated by the decomposition of waste in some tanks. Other tanks contain ferrocyanide and organic-nitrate

mixtures. Evaluating the risks related to these tanks, and remediating them, are complex technical questions. Risk scenarios include:

- combustion of hydrogen gas initiated by the presence of an ignition source and potential for a secondary crust reaction
- explosion of mixtures of ferrocyanide initiated by radiological decay heating
- ignition of organic compounds initiated by radiological decay heating, degradation of complexants, chemical reactions, and/or exothermic reaction in dry salt cake.

As a result of a review of existing data, 5 double-shell tanks and 18 single-shell tanks were identified as having a significant potential for hydrogen gas generation, entrapment, and episodic release. There would be an increased risk of release of nuclear waste if a flammable hydrogen gas mixture and an ignition source were present simultaneously. Operational restrictions were implemented at the 23 tanks to reduce the potential for ignition sources.

Current records at the Hanford Site show that 24 single-shell tanks may contain appreciable amounts of ferrocyanide. Concentrated ferrocyanide and nitrate and/or nitrite materials in the tanks potentially could explode if tank contents were allowed to heat up or if an uncontrolled exothermic reaction occurred. However, measured tank temperatures are far below the temperature required to cause an exothermic reaction. A program is planned to obtain the primary technical input required for the ferrocyanide explosion consequence portion of the supplemental EIS.

In eight single-shell tanks, high organic concentrations, which could lead to an exothermic reaction at higher temperatures, have been inferred. These eight single-shell tanks include three tanks identified as flammable gas-generating or ferrocyanide tanks. Currently, administrative and technical controls are in place to restrict activities that could cause unsafe chemical reactions to occur.

## Waste Minimization Program Status

In May 1990, the Hanford Site Waste Minimization and Pollution Prevention Awareness Plan was completed. This plan provides the overall plan for waste minimization and pollution prevention awareness for the Hanford Site and is supported by four contractor-specific waste minimization and pollution prevention awareness plans. In addition, a third tier of detailed plans for the larger generators has been developed by Westinghouse Hanford Company and PNL. There are currently 29 Westinghouse Hanford Company facility-specific and 8 PNL research-specific waste minimization plans.

The scope of the waste minimization program at Hanford covers nonhazardous, hazardous, radioactive, and mixed wastes in addition to hazardous substances or products. The first priority is to reduce the amount and toxicity of waste via source reduction. For waste that is nevertheless generated, the next priority is to recycle the waste materials for reuse, if possible. (See Section 3.1, "Environmental Restoration, Waste Management, and Technology Development," for additional information on the waste minimization program.)

## Wahluke Slope Waste Sites

The Wahluke Slope is an area of approximately 490 km<sup>2</sup> (189 mi<sup>2</sup>), located north of the Columbia River. The land is owned by DOE and lies roughly between the Vernita Bridge and Ringold. Before government acquisition and use, some of the land was homesteaded and used for agriculture.

After government acquisition in 1943, the area served as a base for the military defense of Hanford. Installations included seven anti-aircraft batteries. These were replaced in the 1950s with three NIKE missile sites. The area was essentially unused from 1960, when the military left, until 1975. Concerns had been raised regarding

potential hazards remaining from past uses of the land. Hazards of concern included physical hazards such as open wells, chemical hazards, and the possibility of military ordnance remaining onsite.

In 1975, the land was permitted for use by the U.S. Fish and Wildlife Service and the State of Washington Department of Wildlife. The portion permitted to the U.S. Fish and Wildlife Service has no public access and is used for a wildlife preserve. The portion permitted to the State of Washington Department of Wildlife is open to public access as a recreation area during daylight hours.

An investigation was completed in April 1990 to inventory sites of potential hazards. No major hazards were located. A burial site containing soil contaminated with a pesticide (2,4-D) exists, but this site was previously documented. Potential physical hazards include open cisterns, underground room structures, and partially excavated concrete military bunkers with exposed reinforcing steel. Immediate corrective actions were taken where necessary, and further corrective actions were scheduled as part of future operable unit cleanup work.





## 2.4 Environmental Occurrences

Onsite and offsite environmental occurrences (spills, leaks, etc.) of radioactive and nonradioactive effluent materials during 1990 were reported to DOE as specified in DOE Order 5000.3A and to other federal and state agencies as required by law. The specific agencies notified depended on the type, amount, and location of the individual occurrences. Generally, effluents either 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, particularly where contaminants may have reached ground water. All Emergency, Unusual, and Off-normal Occurrence Reports, including event descriptions and corrective actions, are available for review in the RL Public Reading Room at the Federal Building, 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 Occurrence Reports on file in the reading room for 1990. Unusual environmental occurrences are defined as non-emergency occurrences that have a "significant impact or potential for impact on safety, environment, health, security, or operations." The 1990 unusual occurrences with the most potential for environmental impact 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, security, environmental or health protection performance or operation of a facility." A large number of off-normal environmental occurrence reports were filed at Hanford during 1990 covering everything from automotive battery acid spills to leaks from overheated motor vehicle cooling systems. Because of the volume of reported off-normal occurrences, event summaries are not included here.

### Unusual Occurrences

#### Aluminum Sulfate Spill (WHC-UO-90-027-100N-01)

During a routine transfer of material on June 6, 1990, approximately 758 L (200 gal) of aluminum sulfate were discharged to the Columbia River via 100-N outfall 009. A valve permitting the material to gravity feed from one tank to another was inadvertently left open allowing the recipient tank to overflow. The release to the river was the result of a loose rubber expansion plug in an adjacent floor drain. Following a review of the incident, it was discovered that the NPDES pH limit for outfall 009 had been exceeded and the incident was reportable. In the future, plugs for floor drains will be leak tested when installed and periodically thereafter. Additionally, further training in the use of signoff sheets for similar material transfer assignments will be implemented.

#### Apparent Tank Leak (WHC-UO-90-23-TF-05)

On June 7, 1990, a gradual but unexpected decline in the liquid surface level in an underground single-shell waste storage catch tank in the 200-West Area was noted following increases in the fluid level from rain. Following an investigation, the decrease in the tank could not be accounted for and was assumed to indicate a leak. As a precautionary measure, the remaining contents of this tank were pumped to a double-contained receiver tank.

#### Chlorine Discharge to the Columbia River (WHC-UO-90-028-100N-02)

During an audit of an NPDES discharge monitoring report for an outfall in the 100-N Area, it

was discovered that the daily average loading limit for chlorine had been exceeded during April 1990. The calculated daily discharge average for this particular outfall was 227 g (0.5 lb). The NPDES permit limit for free chlorine releases at this location was 136 g (0.3 lb). To prevent similar occurrences in the future, all NPDES outfall data will have monthly projections calculated by the tenth of each month, using available data to ensure compliance. Additionally, the mid-month surveillance/compliance inspection checklist will be revised to include projected loadings and an operations review signoff.

### **Leaking Pipe (WHC-UO-90-33-SWM-03)**

On August 3, 1990, radioactive contamination was found on the outside of the 224-T Building. An inspection revealed that radioactive material was leaking from pipes originally used as tank vents for several abandoned process cells inside the building. Pending an evaluation for a long-term solution to the problem, all the pipes were wrapped in plastic and tape, and the contaminated soil was removed to prevent airborne spreading. The immediate area was roped off, and appropriate signs were posted.

### **Gasoline Leak (WHC-90-0337-100N)**

During a routine removal of an underground storage tank in the 100-N Area in December 1990, it was found that some of the soil surrounding the tank had been contaminated with unleaded gasoline. Further investigation revealed that the contamination had not penetrated the soil more than 10 cm (4 in.) below the bottom of the tank. The tank appeared to be in very good condition (no leaks), and it was suspected that the soil contamination was due to occasional overfilling of the tank and to a 314-L (83-gal) to 360-L (95-gal) spill that occurred on January 18, 1988 (reported to WDOE). Once the contaminated soil has been removed, the excavation will be sampled for organic vapors and then backfilled when clean.

### **Missing Ethylene Glycol (PNL-90-06)**

It has been assumed that approximately 1,325 to 1,514 L (350 to 400 gal) of a 50/50 mixture of

ethylene glycol and water were inadvertently released to the 300 Area sanitary sewer sometime between May 31 and June 20, 1990. This material was being used as an antifreeze/coolant for a heat exchanger in one of the 300 Area buildings. As no system leaks were found, it was assumed that the missing liquid was lost either through failure of an automatic vent valve or through the inadvertent opening of a ball valve in an area where other work was being done. To prevent further occurrences, all discharge pipes to the sewer, for systems in the 300 Area containing ethylene glycol, have been removed.

### **Unauthorized Disposal of Liquid Hazardous Waste (PNL-90-04)**

An investigation in May 1990 for a missing waste disposal container led to the discovery that in April 1990 approximately 4 L (1.1 gal) of hazardous wastes had been poured down a sanitary waste drain in the 300 Area. The sanitary waste drain ultimately discharges to the ground in a drain field north of the 300 Area. The contents of the waste container included (by weight) thioacetamide (0.25%), methylacetic acid (7.9%), hydrochloric acid (1.0%), ammonium hydroxide (1.0%), oxalic acid (1.6%), and water (88.25%). Based on Washington State and Hanford regulation limits, the materials discharged were assessed to be toxic, carcinogenic, and corrosive. An evaluation of the probable effect of this release revealed that most, if not all, of the material would be degraded, oxidized, or converted by biological and chemical agents within the septic system. To forestall another occurrence of this nature, a major retraining program was conducted for all building personnel.

### **Waste Container Failure (Kaiser 90-001)**

In March 1990, a 208-L (55-gal) U.S. Department of Transportation (DOT) steel drum containing approximately 114 L (30 gal) of Rubinate M ruptured explosively in a satellite waste holding area. Most (97%) of the released material was scattered around on the concrete pad and adjacent waste drums, fencing, buildings, and soil. Cleanup efforts were initiated immediately and continued until the spill was entirely cleaned up.

The cause of the rupture was probably the result of an increase in barrel pressure caused by the reaction of water and the Rubinate M.

### **Radionuclide Release (WHC-UO-90-031-B Plant-02)**

From 321,725 to 870,550 L (85,000 to 230,000 gal) of contaminated steam condensate water may have leaked to the soil column through a leaky floor expansion joint in the Electrical Gallery in B Plant. It was difficult to determine the amount of radioactivity involved because the steam condensate source was essentially free of contamination and the radioactivity occurred by flow through radioactive regions of the plant. Analysis of water found on the floor of the Electrical Gallery contained an average total beta activity of 87  $\mu\text{Ci/L}$  (range 10 to 128  $\mu\text{Ci/L}$ ), assumed to be  $^{90}\text{Sr}$ -equivalents, and an average total gamma activity of 7.52  $\mu\text{Ci/L}$  (range 4.61 to 9.46  $\mu\text{Ci/L}$ ), assumed to be  $^{137}\text{Cs}$ -equivalents. Based on the estimated release volume, the potential release to the environment may have ranged between 3.2 and 111 Ci of  $^{90}\text{Sr}$ -equivalents and between 1.5 and 8.2 Ci of  $^{137}\text{Cs}$ -equivalents. The origin of the leak was determined to be a steam condensate header draining to a wall nozzle in the Hot Pipe Trench. The wall nozzle was modified to eliminate the leak.

### **Contamination Control Loss in the 200-West Area (WHC-UO-90-007-SWM-1)**

On February 27, 1990, following a routine operation of depositing remotely handled waste into a

mixed fission products caisson, radioactive material (predominately tantalum-182) was detected on the delivery vehicle and on soil in the controlled and uncontrolled areas nearby. A check of the vehicle prior to dumping showed no evidence of contamination, implying that one of the containers inside the vehicle may have been breached after placement into the truck. A subsequent investigation, however, failed to locate an open or breached container within the caisson. There were also no apparent deviations from standard operating procedures for dumping the waste material. A check of the records for previous waste deposits at this location failed to turn up any helpful notes or anomalies. Cleanup included decontaminating the truck and fixing the contaminated soil with a binder. The soil was later removed and packaged as low-level waste. Corrective action included suspending normal operations until an occurrence evaluation was complete and initiating changes in the methods and means of packaging the waste. Additionally, Westinghouse Hanford Company's Solid Waste Nuclear Safety organization decided that the caissons do not meet present day requirements for disposal. Consequently, Solid Waste Nuclear Safety will be notified prior to the use of any caissons for waste-receiving activities.



## Environmental Program Information



### **3.0 Environmental Program Information**

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

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

This section summarizes significant activities conducted in 1990 to manage waste, restore contaminated active waste sites and facilities, develop new cleanup technologies, monitor the release of pollutants from facilities, conduct sampling and analysis of environmental media for pollutants, assess the status of wildlife and cultural resources, monitor the meteorology and climatology of the Site, and conduct special environmental programs.





## 3.1 Environmental Restoration, Waste Management, and Technology Development

The DOE intends to accomplish its mission of environmental restoration and cleanup within 30 years. The cornerstone and framework for DOE's strategy for Department-wide environmental restoration, waste management, and technology development is the DOE-HQ *Environmental Restoration and Waste Management Five-Year Plan* (DOE 1990d). This annually updated document was most recently released in June 1990. The document is now being revised and will be reissued in June 1991. The DOE-HQ Five-Year Plan addresses overall philosophy and environment- and waste-related activities under 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* (DOE 1989d) implements and supports the DOE-HQ Five-Year Plan. This detailed information volume is prepared so it can be used as a stand-alone document. The Hanford Site Five-Year Plan (DOE 1989d) 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 1990f). The overview volume provides a general plan description, and the activity data sheet volume provides supplemental data to the detailed information document.

### Environmental Restoration

The environmental restoration program has been established, as mandated by Congress in 1988, to remediate inactive waste sites, and to decontaminate and decommission surplus facilities. The Hanford Site has established two major programs for implementing these actions:

- environmental restoration remedial action program
- Hanford surplus facilities program.

The activities conducted within these programs are summarized below.

### Environmental Restoration Remedial Action Program

The environmental restoration remedial action 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 Hanford 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. The operable units in the 1100 Area have been given high priority because of their proximity to drinking water sources for the city of Richland. In addition, remedial investigations are being expedited at four other operable units to determine the need for remediation at these units.

The environmental restoration remedial action program will also support development of optimal waste retrieval and in-place disposal technologies for the several types of single-shell tank wastes. These efforts will include the removal and analysis of at least 177 core samples from the wastes.

### Hanford Surplus Facilities Program

Many DOE-owned facilities at the Hanford Site that were used for nuclear materials production have been retired from service and declared

surplus. The Hanford surplus facilities 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: large concrete and cement block structures used to house chemical separations processes, nuclear reactors, underground effluent water systems and storage tanks, and ancillary buildings. Included 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.

The activities currently under way include the 183-H Solar Evaporation Basins cleanup in accordance with the interim closure plan; decommissioning of the 201-C Strontium Semiworks; decommissioning of several 100 Areas ancillary facilities; and preparation of the final environmental impact statement (EIS) *Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington*. The draft EIS (DOE 1989c), which has been released for public review, discusses various methods for decommissioning these reactors. Decommissioning of the current inventory of surplus facilities by 2018 is estimated to cost \$800 million.

## 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 RL are to minimize the generation of waste, and to maintain safe and environmentally sound programs for storage, treatment, and disposal of newly generated and stored wastes. The Hanford Site Five-Year Plan (DOE 1989d) provides detailed descriptions of Hanford's waste management programs and other activities. Summary descriptions of major programs and activities are presented here.

### Waste Minimization

An important effort is to minimize the generation of waste. The four Site contractors have integrated waste minimization and pollution prevention

awareness programs into a single, coordinated initiative. This initiative is being implemented through awareness, training, and procurement programs appropriate to each contractor's mission and needs. These programs are being given top management support and are being coordinated by special task forces by the two largest contractors.

Waste minimization is being accomplished primarily by source reduction and recycling techniques. The program has achieved a number of successes in reducing both the quantity and the toxicity of generated waste. Some examples are finding users for surplus chemicals to prevent excess materials from becoming waste, buying road painting materials in returnable containers, recycling hydraulic oil, and optimizing plant operations to reduce overall waste generation.

### Soil Column Discharge

A major strategy for Hanford's waste management is to discontinue discharges of liquid contaminated 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 Tri-Party Agreement Action Plan.

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. Technology is being developed to treat the effluent streams.

### Stored Wastes

The major effort for cleanup of the Hanford Site will be the disposal of the stored wastes resulting from past production operations. The strategies for handling and disposing of these wastes, as well as newly generated wastes, were established

through the National Environmental Policy Act (NEPA) 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, retrievably 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 64 million L ( $1.7 \times 10^7$  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 in New Mexico.
- Cesium and strontium capsules (1,576 cesium capsules and 640 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.

For single-shell tank waste, transuranic-contaminated soil sites, and pre-1970 buried, suspect transuranic-contaminated solid waste, the recommended strategy is to continue disposal technology development and evaluation 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 supplemental EIS will be prepared for disposal of the single-shell tank wastes.

## Technology Development

The DOE Office of Technology Development was formed to consolidate and provide centralized management and oversight for research, development, demonstration, testing, evaluation activities, and support to DOE-HQ Offices of Environmental Restoration and Waste Management, Waste Operations, Defense Programs, Nuclear Energy, and Energy Research. The technology development activities are targeted toward coordination of new and more effective technologies to solve environmental restoration and waste management problems.

The Office of Technology Development's programmatic implementation strategy is founded on the concept of integrated demonstrations, integrated programs, and supporting technology programs. An integrated demonstration is a cost-effective mechanism that assembles a group of related and synergistic technologies to evaluate their performance individually and as part of a complete system in correcting environmental restoration and waste management problems from waste generation to disposal. An integrated program is a group of research, development, and/or demonstration tasks that relate to a single environmental restoration or waste management issue or function. Supporting technology programs, such as robotics and analytical laboratory management, are cross-cutting technical disciplines that support several integrated demonstrations and integrated programs.

The technology development program is implemented at Hanford through Technical Program Managers at both PNL and Westinghouse Hanford Company. During 1990, two integrated demonstrations were assigned to Hanford for lead coordination: 1) to stabilize and remediate underground storage tanks and close high-priority single-shell tank RCRA sites; and 2) to provide solutions for the expedited response action to remediate the carbon tetrachloride plume in the 200-West Area.



## 3.2 Environmental Monitoring at Hanford

Environmental monitoring of the Site consists of 1) effluent monitoring and 2) environmental surveillance. Effluent monitoring is performed as appropriate by the Site facility operators at the facility or at the point of release to the environment. 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 programs are to demonstrate compliance with federal, state, and local regulations; confirm adherence to DOE environmental protection policies; and support environmental management decisions.

The effluent monitoring and environmental surveillance programs are summarized in this section. Effluent monitoring data, environmental surveillance data, and dose assessment results appear in Section 4.0, "Environmental Monitoring Information."

### Effluent Monitoring

Effluent releases at Hanford are reported to RL and the public each calendar year. Such reports are required by DOE Orders 5484.1, "Environmental Protection, Safety, and Health Protection Information Reporting Requirements," and 5400.1, "General Environmental Protection Program." Data include the types and quantities of effluents that facilities discharge to the air, soil, and Columbia River. These data, which are derived from analyses of samples taken at the facilities, are compiled to evaluate the compliance status of both radioactive and nonradioactive constituents discharged on the Hanford Site.

#### Monitoring of Airborne Effluents

##### Nonradioactive

Nonradioactive air pollutants are monitored from power-generating and chemical-processing facilities on the Hanford Site. In compliance with

an existing Site Prevention of Significant Deterioration (PSD) permit (No. PSD-X80-14) in place for the Plutonium Uranium Extraction (PUREX) and Uranium Oxide (UO<sub>3</sub>) Plants, the effluents are monitored for nitrogen oxides. At the PUREX Plant, the main discharge stack is continuously monitored, while at the UO<sub>3</sub> Plant the plant calciner exhaust is equipped with a nitrogen oxides monitor. In compliance with air quality standards established by the Tri-Counties Air Pollution Control Authority, particulate matter, sulfur oxides, nitrogen oxides, carbon monoxide, and hydrocarbon emissions from the power houses are reported. These emissions are calculated from tons of fuel consumed using U.S. Environmental Protection Agency (EPA)-approved calculations. Emissions from the 200 Areas in excess of Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) reportable quantities of ammonia and ammonium hydroxide are reported annually to the EPA Region 10. Ammonia and ammonium hydroxide emissions from the tank farms are calculated based upon sampling data combined with measured stack flows. Ammonia and ammonium hydroxide emissions from the PUREX Plant are calculated from continuous monitoring data that are combined with measured stack flows to yield quantities of material released per day.

##### Radioactive

To monitor radioactive releases, samples are collected from each stack. These samples are analyzed for total alpha and beta activity and for certain specific radionuclides. Continuous real-time radiation monitoring systems are also provided when required to alert personnel of releases that could exceed normal operating parameters. Identification of the specific radionuclides and the potential source terms for sampling, analysis, and reporting is based on 1) an evaluation of emissions expected from the known radionuclide inventories in the facility, 2) sampling criteria described in DOE's 5400 Series orders, and 3) the potential contribution of a radionuclide to the effective dose equivalent received by the hypothetical maximally exposed individual from effluents.

## Monitoring of Liquid Effluents

### Nonradioactive

Liquid effluents from Hanford Site facilities are discharged to the environment, including the nearby Columbia River (100 and 300 Areas) and the City of Richland Publicly Owned Treatment Works (1100 Area), through cribs, ponds, ditches, trenches, drain pipes, and french drains. Where the potential exists for regulated materials to be transported to the soil or the Columbia River, samples are collected to ensure that the effluents do not exceed existing standards for uncontrolled release. In the 100 and 300 Areas, discharges to the Columbia River are analyzed to ensure compliance with the existing Hanford Site National Pollutant Discharge Elimination System permit. In the 200 Areas, liquid effluent releases of ammonia and ammonium hydroxide in excess of the reportable quantities are reported annually to EPA Region 10.

### Radioactive

Those effluents that have potential for or contain radioactive contamination include cooling water, steam condensates, process condensates, laboratory and chemical sewers, and laundry waste water. These streams are sampled, and the samples are analyzed in onsite laboratories for those radionuclides present in the facilities where the streams originate.

### Near-Facility Monitoring

The near-facility monitoring program is conducted by the operating and engineering contractor to ensure the effectiveness of facility effluent monitoring, demonstrate the adequacy of containment at waste disposal units, monitor and evaluate operating conditions, and evaluate and upgrade effluent monitoring capabilities.

Near-facility monitoring is performed through sample collection, sample analysis, and radiological surveys to ensure employee protection, environmental protection, and compliance with local, state, and federal regulations. Compliance with parts of DOE Orders 5400.1, "General Environmental Protection Program"; 5400.5,

"Radiation Protection of the Public and the Environment"; 5484.1, "Environmental Protection, Safety, and Health Protection Information Reporting Requirements"; and 5820.2A, "Radioactive Waste Management," is addressed through this program.

The program includes sampling and monitoring of near-facility ambient air, surface water, ground water, external radiation dose, soil, sediment, vegetation, and animals, depending on need. Parameters measured, as needed, include pH, water temperature, radiation exposure, and concentrations of radionuclides and hazardous constituents.

Samples are collected from likely effluent pathways (e.g., downwind of potential releases, liquid streams, or proximal to release points). To avoid duplication, the operating and engineering contractor uses existing sample locations (e.g., air sample stations in the 300 Area) that have been previously established by other Hanford contractors (Table 3.1).

Animal samples are collected on an as-needed basis only, and there are no specific sample points.

Surveys to detect surface radiological contamination are conducted near and on liquid-waste disposal sites (e.g., cribs, trenches, drains, retention basin perimeters, pond perimeters, ditch banks), solid-waste disposal sites (e.g., burial grounds, trenches), unplanned release sites, tank farm perimeters, stabilized-waste disposal sites, roads, and firebreaks in the operations areas. Surface radiological surveys are conducted at 391 sites (100 in the 100 Areas, 273 in the 200/600 Areas, and 18 in the 300/400 Areas).

## Environmental Surveillance

### Scope

Site 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

**Table 3.1. Near-Facility Routine Environmental Samples and Locations**

<u>Samples</u>	<u>Total</u>	<u>100 Areas</u>	<u>200 Areas</u>	<u>300/400 Areas</u>
Air	48	5	43	
Surface Water	34	22	12	
Ground-Water Monitoring Wells	110	20	89	1
External Radiation Monitors	397	310	72	15
Soil	117	32	70	15
Vegetation	95	40	40	15

greatest potential risk to humans. Surveillance is focused on routine releases from Hanford's DOE operations, but also reflects the need to respond to unusual releases and the existence of non-DOE nuclear operations on or near the Hanford Site. Surveillance results are formally reported annually through this report series, although unusual results or trends also are reported to DOE and the appropriate facility managers when they occur. Whereas effluent and near-facility monitoring is conducted by the facility operating contractor, environmental surveillance is conducted under an independent program.

## Objectives

Key surveillance objectives in 1990 were similar to previous years and included

- verifying compliance with DOE and EPA radiological dose standards for public protection
- measuring radionuclides, radiation, and chemicals in the onsite and offsite environment to
  - independently assess the adequacy of facility pollution control and abatement programs

- assess the environmental and public health impacts of Hanford operations
- identify and quantify potential environmental quality problems
- provide 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 the above stated objectives, applicable regulations, DOE Order 5400.1, and guidance published for DOE sites (Corley et al. 1981). Draft DOE Order 5400.xy was used by the Tiger Team as representing best management practices and also serves as a guide. [This draft has now been issued as DOE/EH-0173T (DOE 1991a).] 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 Hanford for more than 45 years has 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 its operating facilities. It is primarily designed to focus on determining environmental impacts and compliance with public health standards rather than 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 3.1 illustrates these primary potential 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. 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 and, for most radionuclides, to be below the level that can be detected by monitoring technology. To ensure that radiological analyses of samples are sufficiently sensitive, minimum detectable concentrations of 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 according to three surveillance zones that extend from main onsite operating areas to the offsite environs.

The first zone extends from near the operating facilities to the Site perimeter. The environmental concentrations of releases from facilities will generally be the highest in this zone and will be most easily detected before being transported off the Site. 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.

Finally, 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 effluents, but which could be expected to contain the same level of natural and nuclear testing fallout nuclides in environmental media.

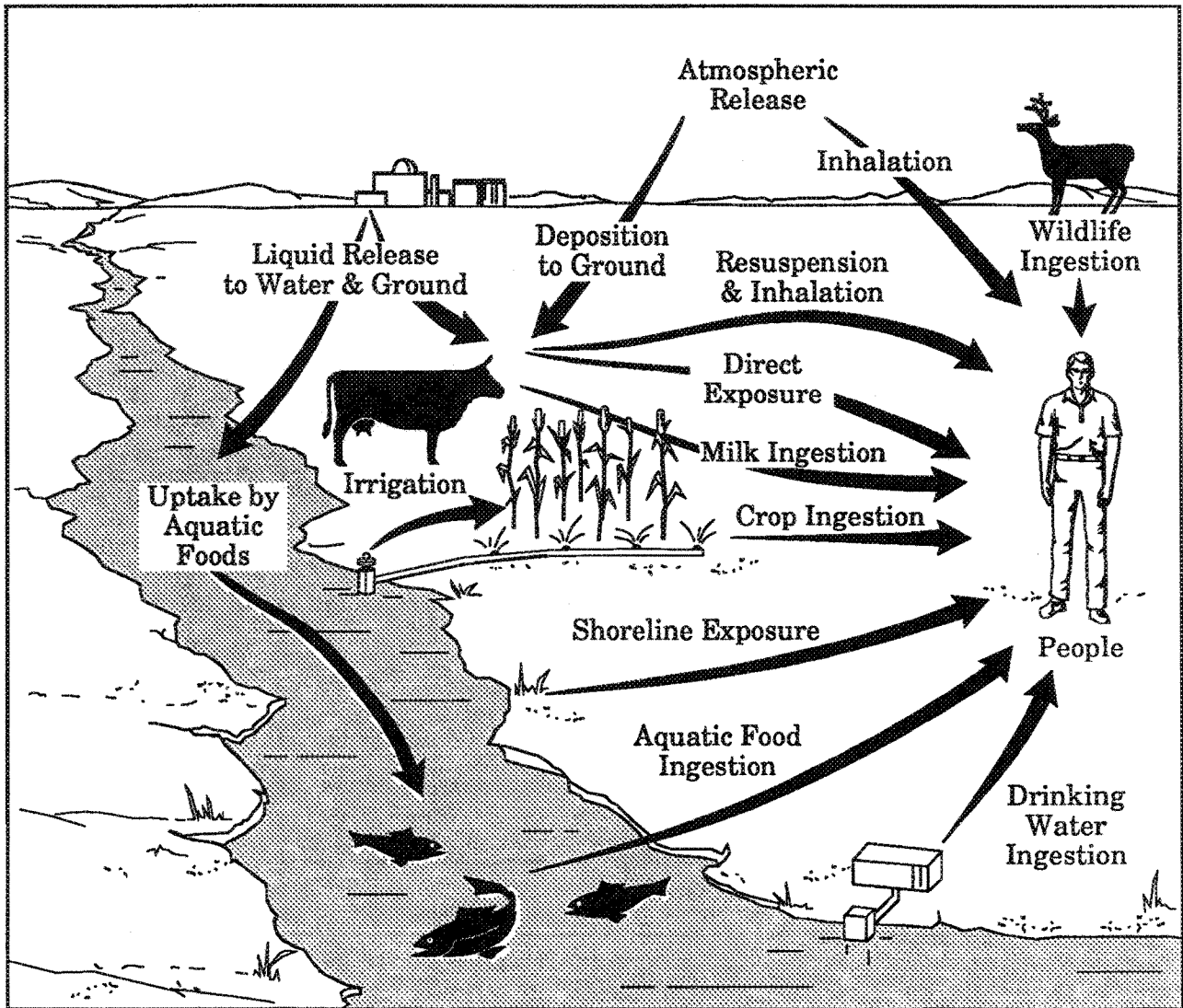
The potential radiation doses received by the public are calculated from environmental surveillance data when Hanford-related radionuclide concentrations are measurable and greater than doses calculated by modeling. However, data from the offsite environs near the Site at most locations do not indicate an effect from Hanford operations. In this case, when concentrations are too low to be detected by measurements, potential radiation doses to the public are calculated using data from effluent measurements and computer models.

## Program Description

The surveillance program in 1990 utilized both measurements and modeling to assess the effects of Hanford operations. Key media and locations were sampled and the samples analyzed for selected contaminants according to a predefined sampling plan. The data were interpreted primarily in terms of combined radiological exposure from all pathways, and by comparison of chemical contaminants to standards.

In the first zone, between the facilities and the perimeter, air monitoring stations were located around each operating area (see Figure 4.1)





S9104004.1

**Figure 3.1. Primary Exposure Pathways**

because air transport is a potentially key pathway for transport of radioactive materials off the Site. Surface-water impoundments potentially accessible to wildlife and drinking water sources were also sampled (see Figure 4.10). Ground water was sampled from wells located near operating areas and along potential transport pathways (see Figures 5.1, 5.2, and 5.3). In addition to air and water surveillance, samples of soil, native vegetation, and wildlife were collected (see Figures 4.33 and 4.27). Radiation was measured

to determine the effectiveness of effluent controls and to ascertain any build-up of contaminants from long-term operations. Selected onsite roads, rails, and retired waste disposal areas were also surveyed (see Figure 4.40).

In the second or perimeter zone, air monitoring stations 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 4.22 and 4.33) 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 of the Site at Priest Rapids Dam and 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 radiation measurements.

Table 3.2 summarizes the geographic distribution of scheduled sample types and measurement locations. Details of sampling locations, frequencies, media and analyses, and significant results

of scheduled and special sampling are discussed in Section 4.0. Key calendar year 1990 samples were analyzed and are reported. Not all scheduled samples were analyzed because of the shortage of analytical services between the termination and resumption of the primary analytical contract supporting surveillance.

Surveillance is conducted under established quality assurance plans and written procedures. 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 U.S. Testing Company, Inc., International Technology Corporation, PNL, and the Hanford Environmental Health Foundation, all 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 3.2. Routine Environmental Sample Types and Measurement Locations, 1990**

	Total Number	Sample Locations			
		Onsite	Site Perimeter	Nearby Communities	Distant Communities
Air	47	23	13	8	3
Ground Water	623	623			
Columbia River	4		2	2	
Irrigation Water	1		1		
Drinking Water	13	8	5 <sup>(a)</sup>		
Columbia River Sediments	5		3	1	1
Ponds	3	3			
Foodstuffs	12		5	3	4
Wildlife	16	11	1		4
Soil & Vegetation	38	15	14	3	6
TLDs <sup>(b)</sup>	93	33	45 <sup>(c)</sup>	9	6
Waste Site Surveys	73	73			
Railroad/Roadway Surveys	17	16	1		
Shoreline Surveys	14		14		
Aerial Survey	1		1		

(a) Includes four offsite water supplies.

(b) Thermoluminescent dosimeters.

(c) Includes locations in and along the Columbia River.

## 3.3 Environmental Studies and Programs

### Wildlife Resources

Wildlife populations inhabiting the Hanford Site are monitored to measure the success and condition of the populations, and to 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 commercially, recreationally, or aesthetically important statewide or locally.

#### 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 3.2). 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 protection of bald eagles at nesting locations off the Hanford Site and the nationwide elimination of DDT as an agricultural pesticide in 1972. On a local scale, the increasing food base in the form of salmon carcasses during fall and winter months has attracted more wintering eagles (Figure 3.2). Most of the eagles using the

Hanford Reach are concentrated in the section between the abandoned Hanford townsite and the 100-K Area.

The number of bald eagles wintering along the Hanford Reach varies each year in response to weather and food availability elsewhere in eastern Washington. 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.

#### Chinook Salmon

Chinook salmon are an important resource to the citizens of Washington. Salmon are caught commercially and for recreation. Today the most important natural spawning area in the mainstem Columbia River is found in the free-flowing Hanford Reach. The commercial and recreational catch is carefully managed to sustain the resource. In the early years of the Hanford Site, there were few spawning nests (redds) in the Hanford Reach (Figure 3.3). 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

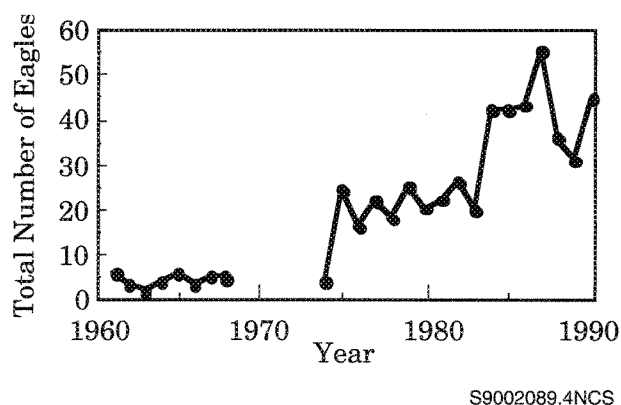


Figure 3.2. Bald Eagles Observed Along the Hanford Reach, Fall and Winter Months

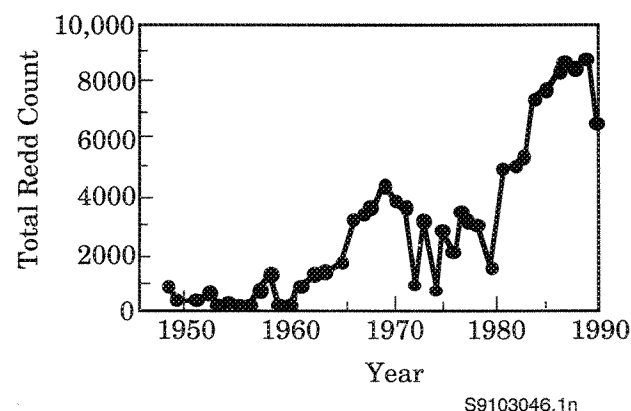


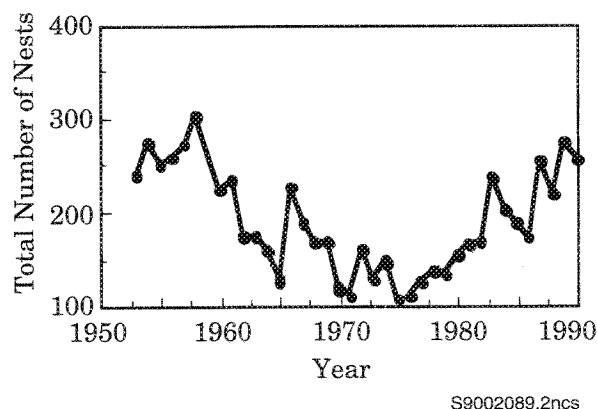
Figure 3.3. Chinook Salmon Spawning Redds in the Hanford Reach

in the mainstem Columbia River have also contributed to the observed increases. The number of redds 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.

## 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 3.4). The nesting population in the Hanford Reach was highest in the early 1950s, followed by a gradual decline to the early 1970s attributed to persistent coyote predation, mostly on the Columbia River islands upstream from the Hanford townsite. The Columbia River upstream from Richland contains 19 islands, but not all are used by nesting geese. Since the nesting surveys were initiated, the center of the nesting population has shifted from upstream to downstream islands, which in recent years have been relatively free from coyote predation. Following this shift, there has been a gradual increase in total numbers. Approximately 70% of the active Canada goose nests found in the Hanford Reach are on three of the ten downstream islands.

Canada goose populations are successful on the Hanford Reach because the islands are restricted

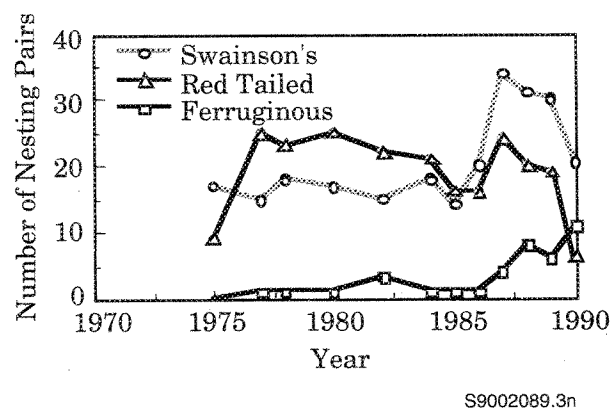


**Figure 3.4. Canada Goose Nests on Islands in the Hanford Reach**

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 semiarid areas of the Hanford Site provides nest sites and foods 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 listed by the Washington State Department of Wildlife as threatened. In recent years, the number of ferruginous hawks nesting on the Hanford Site has increased (Figure 3.5). 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 1990 probably are not due to changes in Hanford Site activities because the number of ferruginous hawk nests did not decline (Figure 3.5).



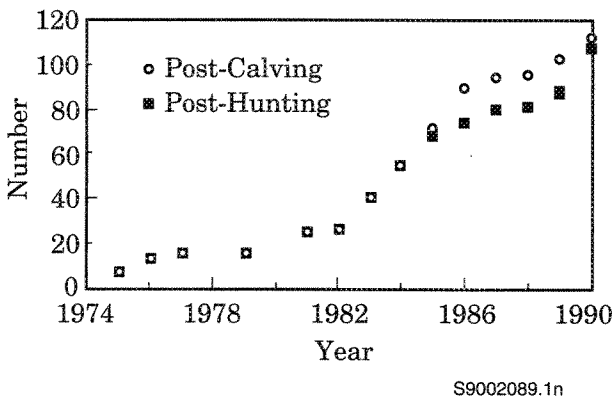
**Figure 3.5. Red-Tailed, Swainson's, and Ferruginous Hawks on the Hanford Site**

## Rocky Mountain Elk

Rocky Mountain elk did not inhabit the Hanford Site when it was established in 1943. Elk appeared on the Arid Lands Ecology (ALE) Reserve in the winter of 1972. A few animals stayed and reproduced. The greatest number of elk recorded

was 110 in the fall and winter of 1990-1991 (Figure 3.6). With a regulated hunting season on private lands adjoining the ALE Reserve, the elk population appeared to be holding at less than 100 animals. However, the Washington State Department of Wildlife reported that only three animals were shot during the 1990 hunting season. This number accounts for the high post-hunting-season count shown in Figure 3.6.

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.



**Figure 3.6. 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**

### White Pelican and Great Blue Heron

Historically, the white pelican has visited the Hanford Reach of the Columbia River in small numbers in 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.

Great blue herons nest in widely dispersed colonies along the shoreline of the Columbia River on the Hanford Site because there are tall trees suitable for nests and because the Columbia River shoreline is relatively free from human activities. Most of the foods for the herons consist of Columbia River fish. In the spring of 1990, 75 active heron nests were distributed among four separate rookeries.

### 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. The plant 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 it 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 (giant Columbia River spire snail) and short-faced lanx (great Columbia River limpet) as candidate species for listing as threatened or endangered. Both were confirmed as inhabitants of the Hanford Reach of the Columbia River. However, populations were also located in tributary streams in Washington, Oregon, and Idaho (Neitzel and Frest 1989).

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.

## Cultural Resources

The archaeological, historical, and cultural resources of the Hanford Site are managed by RL in a manner consistent with the National Historic Preservation Act of 1966, the Archaeological Resources Protection Act of 1979, and the American Indian Religious Freedom Act of 1978. Support is provided through the Hanford Cultural Resources Laboratory (HCRL), which was established by RL in 1987 at PNL.

Cultural resource reviews are conducted before each proposed ground-disturbing or building alteration/demolition project. During the 1990 fiscal year, Hanford contractors requested 122 reviews, 22 of which required archaeological surveys. The surveys covered a total of 302 ha and resulted in the discovery of 18 prehistoric archaeological sites and 4 historic archaeological sites. Projects were relocated to avoid any potential impact to two significant sites in the vicinity of the 300 Area.

The archaeological site monitoring program is designed to determine the current condition of cultural resources and thus to determine whether RL's cultural resource management and protection policies are effective. Results of monitoring are used in planning for cultural resource site management and protection. The conditions of 39 sites were monitored (including 11 cemeteries, 20 sites that are listed on the National Register of Historic Places, and 8 sites that have not been listed). Four conclusions were reached from the monitoring:

1. Natural erosion is the most destructive force operating on the inspected sites.
2. Sites inside the Hanford security fence show little sign of disturbance by workers.
3. Areas open to public use show more human impacts, although these impacts are not severe.
4. It is difficult to deter a determined looter with fences.

Based on these observations, the HCRL has recommended increased education and surveillance and revegetation of some areas subject to severe erosion.

Evaluations for potential nomination to the National Register of Historic Places were conducted for two properties during FY 1990, and documentation was completed for nomination of a third. Mapping, surface collection, and subsurface testing were conducted at two archaeological sites, both of which were found to meet criteria for nomination to the National Register. One site is a campsite occupied for approximately 3,000 years and was one of the places where tenets of the Washane religion were developed. The second is a bison kill and butchering site used approximately 1,500 to 2,000 years ago. The revised nomination of the B Reactor to the National Register has received concurrence by the Washington State Historic Preservation Officer and has been submitted to the National Register.

The cultural resources education program targets elementary and middle school students, secondary school students, and the general public. As part of this program, a brochure was prepared on cultural resources management at Hanford, and lectures were presented to six adult organizations.

Archaeological surveys of areas of the Hanford Site not targeted for development are required by the National Historic Preservation Act and the 1988 amendments to the Archaeological Resources Protection Act. Approximately 2 km<sup>2</sup> were surveyed in FY 1990.

## Meteorology and Climatology of the Hanford Area

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 weather in 1990 was much warmer and drier than normal. Precipitation for 1990 totaled 12.9 cm (5.08 in.), 81% of normal [15.9 cm (6.26 in.)], with only 18.8 cm (7.4 in.) of snow [compared to an annual normal of 34.9 cm (13.7 in.)].

With 2 weeks remaining in December, 1990 was about to become the warmest year on record. However, an Arctic outbreak on December 19 included some of the coldest minimum temperatures ( $-24.4^{\circ}\text{C}$ ) of the decade. The average temperature for 1990 was  $13.1^{\circ}\text{C}$ ,  $1.3^{\circ}\text{C}$  above normal ( $11.8^{\circ}\text{C}$ ). Eight months during 1990 were warmer than normal, each averaging at least  $0.4^{\circ}\text{C}$  above normal. Four months were colder than normal; however, only December was more than  $0.4^{\circ}\text{C}$  below normal. Much warmer than normal temperatures in March, April, and early May melted mountain snowpacks and contributed to high stream flows in spring and early summer. The Arctic outbreak in December, which followed the warmest fall on record, caused damage to agricultural crops (e.g., winter wheat and soft fruit); however, no adverse effects to wildlife were recorded.

Although 1990 was not the windiest year on record in terms of average wind speed (13.0 km/h, 0.6 km/h above normal), the number of days with wind gusts greater than or equal to 64 km/h (40 mi/h) and 80 km/h (50 mi/h) was the greatest on record. Seven months during 1990 recorded wind gusts greater than or equal to 80 km/h, including 57 days with gusts greater than or equal to 64 km/h (previous record 41 days in 1961), and 18 days with gusts greater than or equal to 80 km/h (previous record 10 days in 1972). Several of these high-wind events were accompanied by dust, causing reduced visibility, and the wind storm of January 8 [during which monitoring stations in Richland and Pasco recorded gusts greater than or equal to 128 km/h (80 mi/h)] caused significant property damage throughout the region. The wind roses (Figure 3.7) for telemetry stations located throughout the southern and eastern sections of the Hanford Site show a higher percentage of wind from the southwestern

quadrant (the direction from which the strongest winds were recorded) than previous years, which will be reflected in dose estimates for the air pathway for 1990.

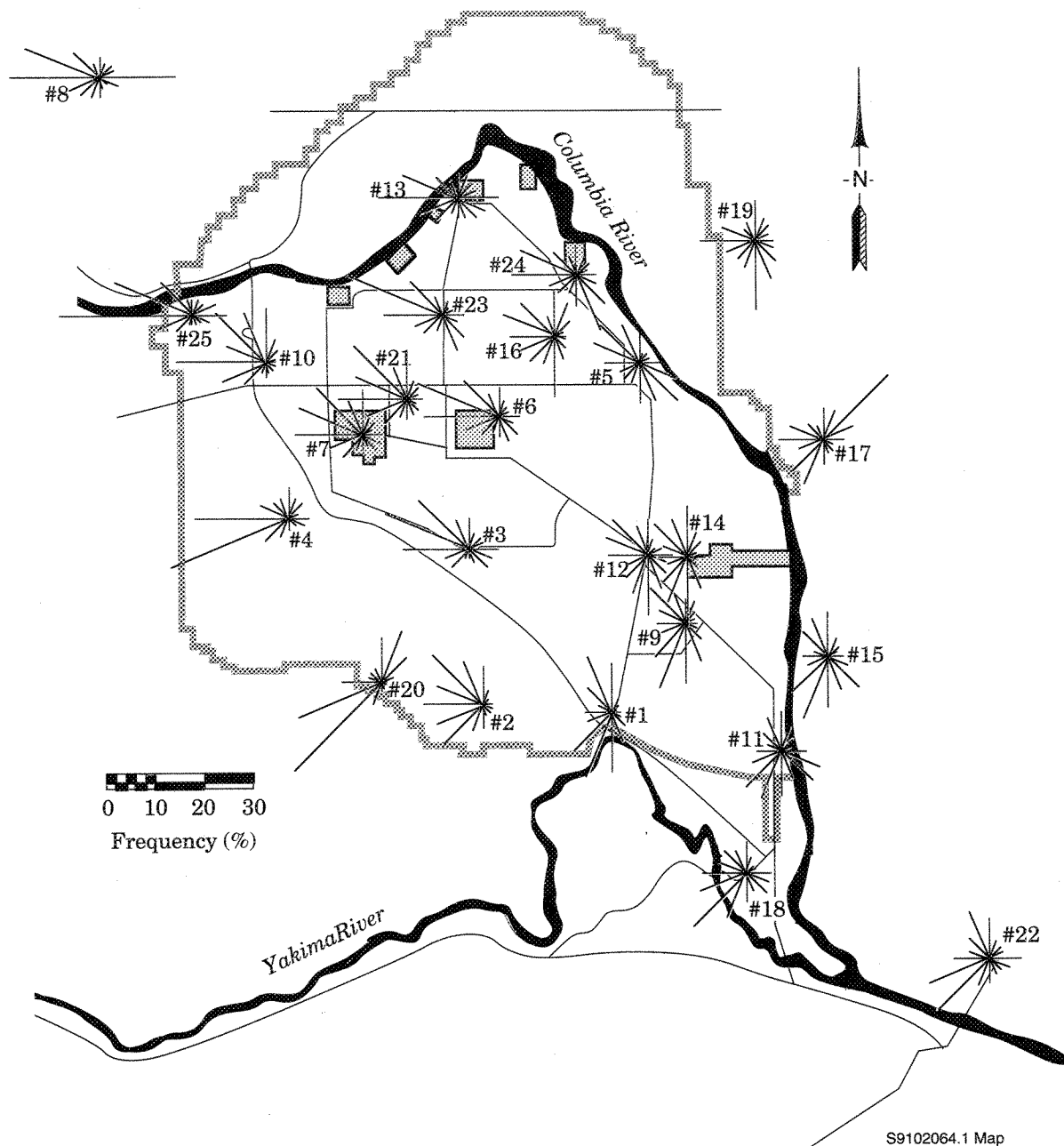
Table 3.3 provides monthly climatological data from the Hanford Meteorology Station for 1990.

## Hanford Environmental Dose Reconstruction Project

The objective of the Hanford Environmental Dose Reconstruction Project is to develop estimates of the radiation doses that people may have received from Hanford operations. The multiyear study, which began in 1988, was prompted by concern about potential health effects to the public from more than 45 years of nuclear operations at Hanford. An independent Technical Steering Panel directs the dose reconstruction effort, which is conducted by Battelle staff at PNL. In 1990, the DOE funded the work, but had no oversight or approval authority.

In 1990, scientists completed the first phase of the project. The objectives of this phase were to 1) determine whether enough historical information could be found or reconstructed to be used for dose estimation and 2) develop and test conceptual and computational models for calculating credible dose estimates. These objectives were met. Scientists found and/or reconstructed many types of historical data, including source terms; concentrations in environmental media; and human elements such as population distribution, agricultural practices, food consumption, and lifestyles. An integrated computer model was developed and tested that uses the actual or reconstructed historical data to calculate past radiation doses by simulating radionuclide transport through various environmental pathways.

As part of testing the dose computer model, preliminary dose estimates were made for populations that lived in the 10 Washington and Oregon counties closest to Hanford. The estimates were for exposure to atmospheric releases that occurred from 1944 through 1947 and for exposure to releases to the Columbia River from 1964 through 1966. The estimates varied greatly depending on



**Figure 3.7. Hanford Telemetry Network Wind Roses, 1990<sup>(a)</sup>**

- (a) Wind rose arrows indicate direction from which wind blows. Length of arrow is proportional to frequency of occurrence from a particular direction.



Table 3.3. Monthly Climatological Data from the Hanford Meteorology Station, 1990

Temperatures (°C)										Precipitation (cm)			Relative Humidity (%)		50-Foot Wind <sup>(a)</sup>				
Averages					Extremes					Snowfall		Average		Departure		Peak Gusts			
Month	Daily Maximum	Daily Minimum	Monthly	Departure <sup>(b)</sup>	Highest	Date	Lowest	Date	Total	Departure	Total	Departure	Average	Speed (km/h)	Departure	Average	Speed (km/h)	Direction	Date
J	9.1	0.3	4.7	+5.7	15.6	9 <sup>(c)</sup>	-5.6	18	2.0	-0.5	1.5	-12.2	67.2	-9.2	14.8	+4.3	117	SW	28
F	8.8	-2.6	3.1	-0.1	17.8	21+	-12.8	18	0.2	-1.2	1.8	-2.8	64.4	-6.3	14.3	+2.7	89	SW	7
M	16.3	1.6	8.9	+2.0	24.4	31	-4.4	25+	0.2	-0.8	T <sup>(d)</sup>	-1.3	50.9	-5.0	10.6	-3.2	82	SW	8
A	21.9	6.9	14.4	+3.1	27.2	16	2.8	9	1.0	0	0	T	45.3	-1.6	12.6	-2.2	93	W	25
M	22.7	9.2	15.9	-0.3	34.4	5	3.9	9+	2.2	+0.9	0	T	45.5	+2.5	14.0	-0.3	71	SW	20
J	28.6	13.7	21.2	+0.4	35.6	29+	8.3	1	0.9	-0.2	- <sup>(e)</sup>	-	39.8	+0.1	14.8	-0.2	74	WSW	12
J	35.1	19.1	27.1	+2.3	43.3	12	7.8	3	0.4	-0.1	-	-	31.7	-0.5	14.2	+0.3	72	NW	16
A	32.4	17.3	24.9	+1.2	42.2	5	11.1	31+	2.1	+1.4	-	-	40.3	+4.7	11.4	-1.5	64	WNW	29
S	31.4	13.5	22.4	+3.4	36.7	11	8.9	30	T	-0.7	-	-	38.0	-3.6	10.0	-1.9	69	NW	7
O	17.8	4.7	11.3	-0.4	26.7	4	-0.6	17	2.0	+0.8	0	T	55.4	-1.4	12.7	2.2	85	WSW	4
N	13.2	2.9	8.1	+3.9	20.0	10	-3.3	28+	0.1	-2.0	0	-3.6	63.1	-10.3	16.1	+6.4	95	SW	23
D	0.1	-8.8	-4.4	-5.0	13.9	4	-24.4	22	1.8	-0.6	15.5	+3.8	74.8	-5.2	11.1	+1.3	93	SW	4
<sup>(f)</sup>																			
Y	19.8	6.5	13.1	+1.3	43.3	12	-24.4	22	12.9	-3.0	18.8	-16.1	51.4	-3.0	13.0	+0.6	117	SW	Jan 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 (1951-1980) climatological normals.

(c) + after date indicates latest of several occurrences.

(d) Trace.

- No record of any snowfall during these months.

Yearly averages, extremes, and totals.

people's locations, food consumption, ages, and other factors. The highest preliminary doses were from  $^{131}\text{I}$  released to the atmosphere in the 1940s, primarily from drinking fresh milk from cows that ate pasture grass in counties downwind from Hanford.

Results of Phase I work were presented by the Technical Steering Panel to the public, media, and other organizations and individuals in July and August 1990. International attention from the media and public was focused on the preliminary dose estimates.

As the project continues, the dose computer model and input data will be analyzed to identify sources of uncertainties and evaluated to determine the effects of these uncertainties on dose estimates. Model and data uncertainties that significantly affect dose estimates will be reduced where feasible to improve dose estimates. Ultimately, final radiation dose estimates will be made for the final geographic area, time periods, radionuclides, and populations, as determined by the Technical Steering Panel.

The Technical Steering Panel has produced informational fact sheets to assist the public in understanding the Dose Reconstruction Project. Eleven pamphlets have been printed since July 1989 on such topics as the health effects of low-level radiation, uncertainties in dose estimates, and environmental radiation exposure pathways. These pamphlets are free to the public and can be obtained by calling 1-800-545-5581 or by writing to: Hanford Environmental Dose Reconstruction Project, Washington State Department of Ecology, Office of Nuclear and Mixed Waste, MS PV11, Olympia, WA 98504.

## **Community-Operated Environmental Surveillance Stations**

A community-operated environmental surveillance 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 surveillance issues, and facilitate public education.

Three community-operated environmental surveillance stations have been constructed and are scheduled to begin operation in March 1991. The stations are located downwind of the Hanford Site at Basin City Elementary School in Basin City, Edwin Markham Elementary School about 10 miles north of Pasco, and Leslie Groves Park in Richland. Local residents will have access to the monitoring stations to observe the instruments and results.

Schools will be able to use the stations in their science curricula. Local teachers are serving as managers of the stations and have attended training courses on the operations of the stations. The station managers will collect samples, submit them to an analytical laboratory, and receive, analyze, and summarize the results. Staff from PNL will work with the station managers to maintain the equipment, and coordinate sampling and analytical procedures with Hanford Site environmental surveillance operations.

The station managers will inform residents about the surveillance results and make DOE aware of community interests or concerns.

## **Other Environmental Activities**

Other significant environmental activities during 1990 included the initiation 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 NEPA. Each of these activities is summarized in Section 2.0, "Environmental Compliance Summary."

## Environmental Monitoring Information



## 4.0 Environmental Monitoring Information

Environmental monitoring of the Hanford Site consists of effluent monitoring and environmental surveillance. Section 3.2 described the Site effluent monitoring and environmental surveillance programs. Section 4.0 describes the results of these monitoring and surface surveillance programs for 1990 and includes an assessment of potential radiation doses from all pathways. Subsurface, or ground-water, surveillance is discussed in Section 5.0. Quality assurance and control for monitoring programs are discussed in Section 6.0.

In June 1990, the Pacific Northwest Laboratory (PNL) terminated the contract with United States Testing Company, Inc. (UST), to perform sample analyses for the monitoring programs (see Section 2.3). Samples continued to be collected and stored while an interim analytical contract with another laboratory was established. Consequently, analysis of 1990 samples was performed by two different laboratories. In some cases, differences in radionuclide concentrations determined by the two laboratories are apparent. These differences may be a result of the archival process itself or differences in the analytical techniques used by the laboratories. Because of these differences, the apparent discrepancies in 1990

results for some radionuclides may be a result of the change in laboratories rather than actual environmental changes. These potential impacts on the data are discussed in the results subsections.

The Helpful Information section at the beginning of this document is provided for the reader with less familiarity with the notation, units, and type of information being reported. 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 environmental surveillance data presented in the following sections are summaries prepared to describe the range of conditions observed during the year in different locations. Detailed results by specific sampling location are contained in a data volume *Hanford Site Environmental Data for Calendar Year 1990--Surface and Columbia River Data* (Bisping 1991).



## 4.1 Effluent Monitoring

The facility operators quantify and document the amounts of radioactive and nonradioactive liquids, gases, and solids released to, or disposed of in, the environment from their operations. These efforts determine the degree of compliance with applicable federal, state, and local regulations and permits. Major facilities have facility effluent monitoring plans that are part of the Site environmental monitoring plan required by DOE orders. Monitoring data are also used in pollution abatement programs that assess the effectiveness of effluent treatment and control. Effluent monitoring serves a different but related function to surveillance monitoring. Surveillance monitoring measures the effect on the environment from regulated effluents, whereas effluent monitoring measures the amounts of regulated constituents released into the environment.

### Air Emissions

Air emission discharge points were located in the 100, 200-East, 200-West, 300, 400, 600, and 1100 Areas. Brief descriptions of the gaseous emission sources in these areas are given below:

- Located in the 100 Areas are the N Reactor, eight inactive production reactors, and associated support facilities. Even though in preserved dry-layup status, N Reactor was the main contributor of radioactive emissions in the 100 Areas in 1990, with lesser contributions through several ventilation systems in other 100 Areas support facilities. The 184-N powerhouse, a past source of nonradioactive emissions, ceased operations in March 1990. During 1990, there were seven radioactive airborne discharge points in the 100 Areas.
- The 200 Areas contain the chemical separations and processing facilities and the waste handling and disposal facilities. Radioactive emission sources include the Plutonium Uranium Extraction (PUREX) Plant, the Uranium Oxide ( $\text{UO}_3$ ) Plant, the Plutonium Finishing Plant (PFP), B Plant, the Reduction Oxidation (REDOX) Plant, T Plant, the 222-S Laboratory, the Laundry Facility, underground storage tanks, waste evaporators, and waste storage tank farms. The PUREX Plant,  $\text{UO}_3$  Plant, PFP, and 200 Areas powerhouses also emit nonradioactive pollutants in the 200 Areas. There are 77 radioactive airborne discharge points and four nonradioactive discharge points (two stacks at each of the two 200 Areas powerhouses) in the 200 Area.
- The 300 Area consists primarily of laboratories, research facilities, and a steam plant. Radioactive emissions arise from research and development activities in the 300 Area. Nonradioactive emissions originate from the steam plant, an incinerator, and a thermal treatment facility. The steam plant contains two oil-fired burners with separate stacks, two coal-fired burners with a common stack, and one temporary oil-fired boiler with its own stack. The temporary boiler was used in 1990 while the two coal-fired burners underwent repairs. There are 40 radioactive airborne discharge points in the 300 Area. The N Reactor Fuel Fabrications Facility, which was once a source of radioactive emissions, is in standby mode and had no significant radioactive airborne emissions in 1990.
- The 400 Area contains the Fast Flux Test Facility, the Maintenance and Storage Facility, and the Fuels and Material Examination Facility. Airborne emissions consist of radioactive particulates and gases from activities associated with operation of the Fast Flux Test Facility and the Maintenance and Storage Facility. There are four radioactive airborne emissions sources and no nonradioactive emissions sources in the 400 Area.
- The 600 Area encompasses all the areas of the Hanford Site not assigned to the 100, 200, 300, and 400 Areas. Two airborne discharge points are sampled in the 600 Area at the ALE Reserve.

- The 1100 Area is located outside the Hanford Site. It contains warehouses, vehicle maintenance shops, excess equipment and materials storage, and office buildings. The 1100 Area emissions are generated from heating plants. Two oil-fired boilers emit only non-radioactive effluents such as oxides of sulfur, oxides of nitrogen, and particulates. In 1990, one boiler did not operate and the other was used intermittently for auxiliary heating during the winter.

Radioactive airborne effluents from facilities at the Hanford Site include volatile forms of radionuclides, noble gases, and radioactive particles. Radioactive effluent streams that have a potential of reaching 10% of discharge limits are monitored. Nonradioactive effluent streams are monitored that have a potential of reaching 50% of applicable standards for nonradioactive constituents.

Annual effluent discharge release reports are produced for each of the major operating areas and submitted to RL. Radioactive effluent and onsite discharge data are reported to the DOE's Idaho National Engineering Laboratory in Idaho Falls, Idaho, via the Effluent Information System-Onsite Discharge Information System (EIS-ODIS) in April of each year (DOE 1987a). A summary of air emissions from the Hanford Site for 1990 is given in Table 4.1. Table 4.2 summarizes the non-radioactive constituents released in the gaseous emissions.

## Liquid Effluents

Liquid effluents were discharged from facilities in each of the areas of the Hanford Site. Liquid effluent sources resulted in over 350 radioactive and nonradioactive liquid waste streams that discharge to the Columbia River, soil column, or sewer disposal systems. Total liquid effluent discharge volume in 1990 was approximately 12 million m<sup>3</sup> (15.7 million yd<sup>3</sup>).

Liquid effluent monitoring is performed to measure the discharge of both radioactive and nonradioactive constituents. Radioactive effluent monitoring is performed in the 100, 200, 300, and 400 Areas. Liquid effluents containing both radioactive and hazardous constituents produced in the

100, 200, 300, and 400 Areas are shipped to the 200 Areas for storage in double-shell storage tanks or monitored interim storage facilities. The 600 and 1100 Areas do not produce radioactive liquid effluents. Monitoring of regulated nonradioactive liquid effluents is also conducted in the 100, 200, 300, and 400 Areas.

Liquid effluent monitoring results are reported via the EIS-ODIS. Monitoring results for waste streams covered by the National Pollutant Discharge Elimination System permit are reported monthly to the U.S. Environmental Protection Agency (EPA). A summary of liquid effluents for 1990 is given in Table 4.3. Table 4.4 summarizes the nonradioactive constituents in radioactive effluents released from each of the areas. Table 4.5 summarizes the radionuclides released to the nearby Columbia River from the 100 Areas.

## Solid Waste

Solid wastes produced at Hanford are classified as radioactive, nonradioactive, and mixed waste. Radioactive waste consists of transuranic, high-activity, and low-activity wastes. Radioactive mixed waste consists of wastes that have both radioactive and hazardous nonradioactive components. Nonradioactive wastes are composed of hazardous or nondangerous wastes or both. Hazardous waste consists of dangerous wastes or extremely hazardous wastes or both, as defined in Washington State Department of Ecology Dangerous Waste Regulations.

Radioactive and mixed wastes are currently handled in several ways. High-activity liquid wastes are stored in double-shell tanks. Low-activity wastes are stored in double-shell tanks, on storage pads, or buried, depending on the source, composition, and concentration. Transuranic wastes are stored in vaults or underground storage pits, from which they 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 on and off the Site (DOE 1990c). Dangerous wastes are treated, stored, and prepared



Table 4.1. Radionuclides Discharged to the Atmosphere, 1990

Radionuclide	Half-Life	Release, Ci <sup>(a)</sup>			
		100 Areas	200 Areas	300 Area	400 Area
<sup>3</sup> H (as HTO)	12.3 yr		19	0.48	2.9
<sup>3</sup> H (as HT)	12.3 yr			9.2	
<sup>14</sup> C	5730 yr		0.56		
<sup>41</sup> Ar	1.8 h				29
<sup>54</sup> Mn	312 d	1.9 x 10 <sup>-4</sup>			
<sup>60</sup> Co	5.3 yr	0.0024			
<sup>90</sup> Sr <sup>(b)</sup>	28.8 yr	3.6 x 10 <sup>-4</sup>	0.0053	2.1 x 10 <sup>-4</sup>	
<sup>103</sup> Ru	39.4 d		2.2 x 10 <sup>-4</sup>		
<sup>106</sup> Ru	367 d		0.0028		
<sup>113</sup> Sn	115 d		2.4 x 10 <sup>-4</sup>		
<sup>125</sup> Sb	2.7 yr		0.0014		
<sup>129</sup> I	1.6 x 10 <sup>7</sup> yr		0.11		
<sup>131</sup> I	8 d		0.0014		
<sup>134</sup> Cs	2.1 yr	2.8 x 10 <sup>-5</sup>			
<sup>137</sup> Cs	30 yr	2.9 x 10 <sup>-4</sup>	6.9 x 10 <sup>-4</sup>		6.8 x 10 <sup>-6</sup>
<sup>147</sup> Pm	2.6 yr		1.9 x 10 <sup>-4</sup>		
<sup>155</sup> Eu	4.96 yr	1.1 x 10 <sup>-4</sup>			
<sup>208</sup> Tl	3.1 min		0.0060		
<sup>212</sup> Pb	10.6 h		0.030		
<sup>212</sup> Bi	60.6 min		0.018		
<sup>212</sup> Po	3.0 x 10 <sup>-7</sup> s		0.012		
<sup>216</sup> Po	0.15 s		0.27		
<sup>220</sup> Rn <sup>(c)</sup>	55.6 s		380		
<sup>234</sup> U	2.4 x 10 <sup>5</sup> yr		1.0 x 10 <sup>-11</sup>		
<sup>235</sup> U	7.0 x 10 <sup>8</sup> yr		3.6 x 10 <sup>-13</sup>		
<sup>236</sup> U	2.3 x 10 <sup>7</sup> yr		8.4 x 10 <sup>-13</sup>		
<sup>238</sup> U	4.5 x 10 <sup>9</sup> yr		6.1 x 10 <sup>-12</sup>	4.6 x 10 <sup>-8</sup>	
<sup>238</sup> Pu	87.7 yr	1.4 x 10 <sup>-7</sup>	1.0 x 10 <sup>-5</sup>		
<sup>239,240</sup> Pu <sup>(d)</sup>	2.4 x 10 <sup>4</sup> yr	9.7 x 10 <sup>-7</sup>	3.0 x 10 <sup>-4</sup>	7.3 x 10 <sup>-6</sup>	
<sup>241</sup> Pu	14.4 yr		0.0012		
<sup>241</sup> Am	433 yr		8.1 x 10 <sup>-5</sup>		

(a) 1 Ci equals 3.7 x 10<sup>10</sup> Bq.

(b) <sup>90</sup>Sr values include gross beta curies for those facilities where <sup>90</sup>Sr is not directly monitored.

(c) <sup>220</sup>Rn value is calculated from <sup>212</sup>Pb measurements.

(d) <sup>239,240</sup>Pu values include gross alpha curies for those facilities where <sup>239,240</sup>Pu is not directly monitored.

**Table 4.2. Nonradioactive Constituents Discharged to the Atmosphere, 1990**

Constituent	Release, kg			
	100 Areas	200 Areas	300 Area	1100 Area
Particulates	4,900	6,600	33,600	0.0
Nitrogen Oxides	13,000	137,700	88,000	27
Sulfur Oxides	65,300	482,000	444,800	54
Carbon Monoxide	1,200	114,700	8,000	0.0
Hydrocarbons	240	23,000	2,300	0.0
Ammonia	0.0	1,580	0.0	0.0

**Table 4.3. Radionuclides in Liquid Effluents Discharged to Ground Disposal Facilities, 1990**

Radionuclide	Half-Life	Release, Ci <sup>(a)</sup>		
		100 Areas	200 Areas	300 Area
<sup>3</sup> H	12.3 yr	38	5.2	
<sup>54</sup> Mn	312 d	0.26		
<sup>60</sup> Co	5.3 yr	7.8		
<sup>90</sup> Sr	28.8 yr	14	0.32	0.098 <sup>(b)</sup>
<sup>129</sup> I	1.6 x 10 <sup>7</sup> yr		0.0013	
<sup>134</sup> Cs	2.1 yr	0.12		
<sup>137</sup> Cs	30 yr	7.1	0.65	
<sup>147</sup> Pm	2.6 yr		4.3	
<sup>234</sup> U	2.4 x 10 <sup>5</sup> yr		0.00057	0.0019
<sup>235</sup> U	7.0 x 10 <sup>8</sup> yr		2.0 x 10 <sup>-5</sup>	7.6 x 10 <sup>-5</sup>
<sup>236</sup> U	2.3 x 10 <sup>7</sup> yr		4.7 x 10 <sup>-5</sup>	
<sup>238</sup> U	4.5 x 10 <sup>9</sup> yr		0.00034	0.0014
<sup>238</sup> Pu	87.7 yr	0.0025	0.012	
<sup>239,240</sup> Pu	2.4 x 10 <sup>4</sup> yr		0.13	
<sup>241</sup> Pu	14.4 yr	0.047	0.017	
<sup>241</sup> Am	433 yr		0.20	

(a) 1 Ci equals 3.7 x 10<sup>10</sup> Bq.(b) Reported as Gross Beta. Assumed to be <sup>90</sup>Sr for dose calculations.

for disposal at several Hanford Site facilities. Dangerous wastes generated at the Hanford Site are shipped offsite for disposal, destruction, or recycling. In 1990, 33,900 kg (74,800 lb) of dangerous wastes and 40,300 kg (88,900 lb) of extremely hazardous wastes were shipped offsite for disposal or recycling.

Nondangerous wastes generated at Hanford are buried in the Hanford Site Central Landfill.

These wastes are generated in the process and nonprocess areas at the Hanford Site and include construction debris, office trash, cafeteria waste, and packaging materials. Also generated as waste in some of the areas are solidified filter backwash and sludge from the treatment of river water, failed and broken equipment and tools, air filters, noncontaminated used gloves and other clothing, and certain chemical precipitates such

**Table 4.4. Nonradioactive Constituents in Liquids Discharged to Ground Disposal Facilities, 1990**

Constituent	Release, kg			
	100 Areas	200 Areas	300 Area	400 Area
Total Organic Carbon		10,950	4,100	42
Nitrates		18,250	1,400	
Copper			20	
Aluminum Sulfate	69,300		4,700	
Polyacrylamide	205		35	
Sodium Sulfate	110,230			
Lead			<11	
Silver			<9	
Total Effluent Volume (m <sup>3</sup> )	440,000	9,730,000	1,950,000	16,000

**Table 4.5. Radionuclides in Liquid Effluents Discharged to the Columbia River from the 100 Areas, 1990**

Radionuclide	Half-Life	Release, Ci ( $3.7 \times 10^{10}$ Bq)
<sup>3</sup> H	12.3 yr	38
<sup>54</sup> Mn	312 d	0.015
<sup>60</sup> Co	5.3 yr	0.04
<sup>90</sup> Sr	28.8 yr	1.9
<sup>106</sup> Ru	367 d	0.07
<sup>125</sup> Sb	2.7 yr	0.020
<sup>134</sup> Cs	2.1 yr	0.02
<sup>137</sup> Cs	30.2 yr	0.11
<sup>238</sup> Pu	87.7 yr	$3.6 \times 10^{-7}$
<sup>239,240</sup> Pu	$2.4 \times 10^4$ yr	$2.1 \times 10^{-6}$

as oxalates. Nonradioactive friable asbestos is buried in designated areas at the Hanford Site Central Landfill. Ash generated at the 200-East and 200-West Area powerhouses is buried in designated sites near the powerhouses. Demolition waste from decommissioning projects in the 100 Areas is buried in situ or in designated sites in the 100 Areas.

A summary of solid waste disposed of at Hanford is shown in Table 4.6. Solid waste program activities are related to Resource Conservation and Recovery Act and Toxic Substances Control Act regulations and are further discussed in Section 2.0, "Environmental Compliance Summary."

### **Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Continuous Emissions in Excess of the Reportable Quantities**

Section 103(f)(2) of CERCLA, as amended, requires annual reporting of releases of hazardous substances that are in excess of reportable quantities and continuous and stable in quantity and rate. On the Hanford Site, ammonia emissions from the PUREX Plant, 241-AP Tank Farm, and 241-AW Tank Farm, and ammonia and ammonium hydroxide emissions from the 242-A Evaporator/Crystallizer may exceed the reportable quantities

Table 4.6. Radioactive Solid Waste Disposal at Hanford, 1990

Constituent	Units	Transuranic Waste	Low-Level Waste	High-Level Waste	Other Solid Waste	Total
<b>Radioactive</b>						
Uranium	g <sup>(a)</sup>	670	2.6 x 10 <sup>6</sup>	670		2.6 x 10 <sup>6</sup>
Uranium-233	g		1.8	78		80
Plutonium	g	2200	2.0	19,000		21,700
Americium	g	1.5	0.31			1.8
Thorium	g	0.00052	51,000	0.00052		51,000
Strontium <sup>(b)</sup>	Ci	0.088	170	450		620
Ruthenium <sup>(b)</sup>	Ci	5 x 10 <sup>-6</sup>	1.7	1,000		1,000
Cesium <sup>(b)</sup>	Ci	0.097	320	24,000		24,000
Other Fission and Activation Products	Ci	0.18	270,000	26,000		296,000
<b>Nonradioactive</b>						
Nonhazardous Trash, Refuse	m <sup>3</sup>				36,000	
Asbestos	m <sup>3</sup>				610	
Septic sludge	m <sup>3</sup>				1,800	

(a) 1 Ci equals  $3.7 \times 10^{10}$  Bq.

(b) Values represent single isotopes only; decay products are included in other fission and activation products.

during routine operations. The emissions from the facilities are monitored, and quantities were reported to the EPA as the "Annual Notification of Continuous Releases of Ammonia and Ammonium Hydroxide That Are Above the Comprehensive Environmental Response, Compensation, and Liability Act Reportable Quantity Values."

During 1990, ammonia and ammonium hydroxide emissions from the facilities listed above did not exceed the reportable quantities. Fuel deacidification operations were not conducted at the PUREX Plant during 1990; therefore, no ammonia waste was generated. The 242-A Evaporator/Crystallizer did not process any PUREX Plant ammonia-bearing waste during 1990; therefore, no ammonia waste was generated. The two tank farms continued operation during 1990, storing PUREX Plant ammonia-bearing waste, but they did not receive any new waste; therefore, the emissions from the tank farms were substantially reduced to levels below reportable quantities.

### Superfund Amendments and Reauthorization Act of 1986 (SARA) Community Right-to-Know Hazardous Chemical Inventory Reporting at the Hanford Site

Within the CERCLA/SARA legislation, in Title III, the Emergency Planning and Community Right-to-Know Act is intended to provide the public with information about the hazardous chemicals in their community and to establish emergency planning and notification procedures to protect the public in the event of a release of hazardous chemicals. The law calls for creation of State Emergency Response Commissions to guide state-by-state planning for chemical emergencies. The state commissions have created Local Emergency Planning Committees to ensure community participation and planning.

Field representatives throughout the Hanford Site participate in annual training and recertification on the regulatory requirements of the SARA Title III community-right-to-know reporting and on supplying information to the newly developed Hazardous Material Inventory Database.

In compliance with requirements, the Hanford Tier-Two Emergency and Hazardous Chemical Inventory (DOE 1990a) was issued on March 1, 1990, to the State of Washington Department of Community Development, local county emergency management committees, and the local fire

department. This report provides information on hazardous material in storage across the Hanford Site. Table 4.7 summarizes the information contained in DOE (1989a) for those 10 chemicals stored in the greatest quantities at the Hanford Site. The Hanford Toxic Chemical Release Inventory (DOE 1989b) was issued to the EPA and the Washington State Department of Ecology for 1989 on July 1, 1990. This report, containing data on toxic releases and transfers, and waste management practices, provides the public with information about toxics that may affect health or the environment.

**Table 4.7. Hanford Tier-Two Emergency and Hazardous Chemical Inventory Average Balances of Chemicals Stored in Greatest Quantities on the Site**

Hazardous Material	Average Daily Balance, Gg <sup>(a)</sup>
Coal	36
Diesel Fuel	2.4
Nujol (Mineral Oil)	1.9
Sodium	1.2
Fuel Oil, No. 6	1.2
Sodium Hydroxide	1.1
Nitric Acid	0.77
Nitrogen	0.57
Uranium Nitrate Hexahydrate	0.40
Ethylene Glycol	0.28

(a) 1 Gg = 1 gigagram =  $10^9$  g.



## 4.2 Air Surveillance

Atmospheric releases from Hanford to the surrounding region could result in human exposure. Therefore, both radioactive and nonradioactive materials in air are monitored at a number of locations. This section discusses sample collection, analysis methods, and the results of the air surveillance program. Detailed results are contained in Bisping (1991).

### Sample Collection and Analysis

Radioactivity in air was sampled by a network of continuously operating samplers at 24 locations on the Hanford Site, 14 near the Site perimeter, 9 in nearby communities, and 6 in distant communities (Figure 4.1 and Table 4.8). Air samplers on the Hanford Site were located primarily around and near major operating 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, Connell, Eltopia, Kennewick, Mattawa, Othello, Pasco, Prosser, and Richland provided air concentrations at the nearest population centers. Samplers at McNary Dam and in the distant communities of Moses Lake, Sunnyside, Walla Walla, Washtucna, and Yakima provided data from communities essentially unaffected by Site operations. Yakima is a distant upwind location that provides reference regional background concentrations.

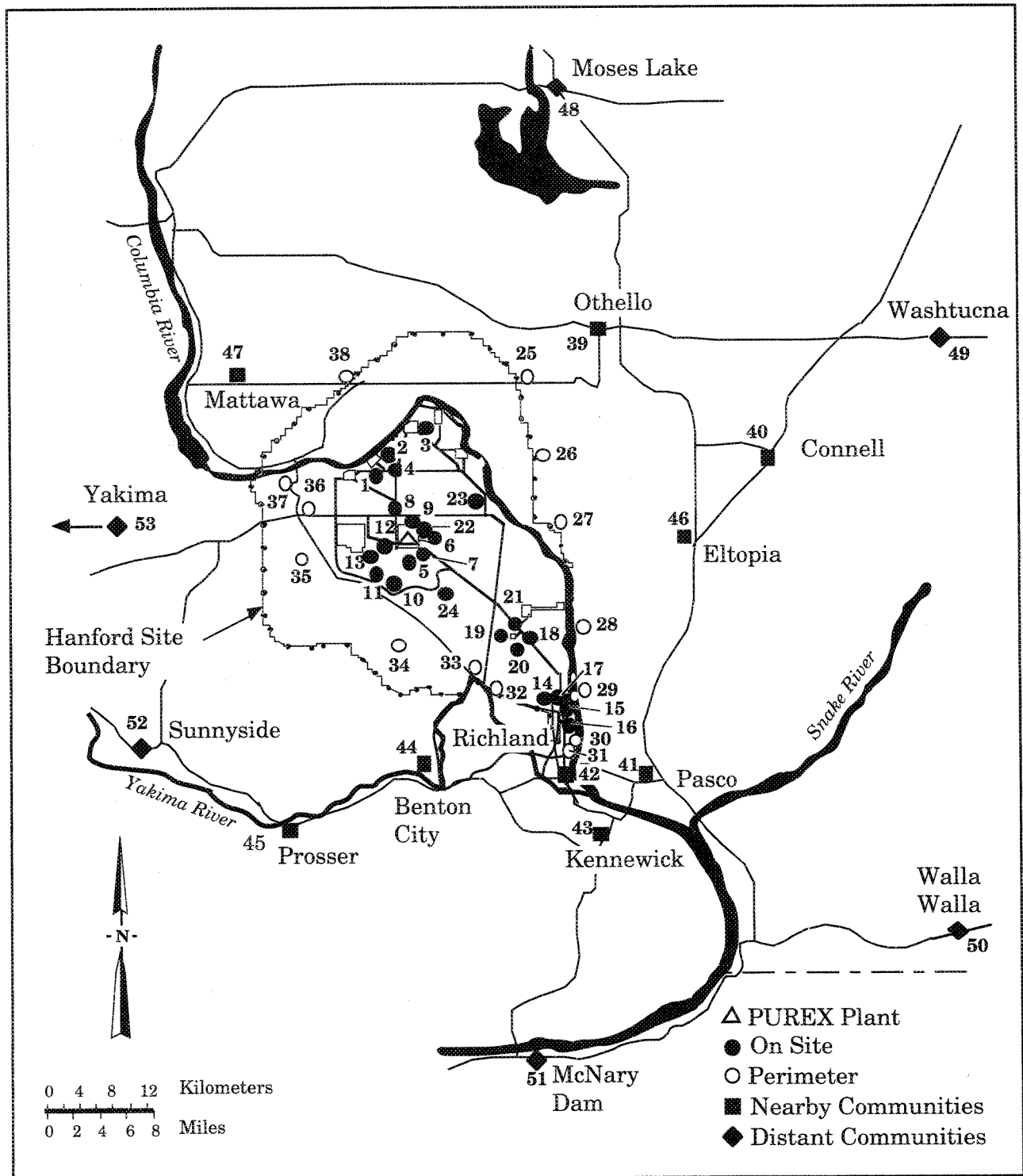
Samples were collected according to a schedule established before the monitoring year (Bisping 1990). The air sampling locations are listed in Table 4.8. Airborne particles were sampled at each of these locations by continuously drawing air through a glass fiber filter. The filters were collected every 2 weeks, field surveyed for gross radioactivity to detect any unusual occurrences, held for at least 7 days, and then analyzed for gross beta radioactivity. The holding period was

necessary to allow for the decay of short-lived, naturally occurring radionuclides that would otherwise obscure detection of longer-lived radionuclides potentially present from Hanford emissions. Gross radioactivity measurements are used to indicate changes in environmental trends that could warrant attention before the more detailed and sensitive laboratory analyses are completed. In addition, filters from selected locations were also analyzed for gross alpha radioactivity.

For most radionuclides, the amount of radioactive material collected on the filter during the 2-week period was too small to be measured with reasonable accuracy. The accuracy of sample analysis was increased by combining two bi-weekly samples into a monthly composite sample for each location. The monthly composites for a few nearby locations were then combined to form a geographical composite (Table 4.8). Each monthly geographical composite was analyzed for numerous specific gamma-emitting radionuclides, then combined into quarterly composites and analyzed for strontium and plutonium (DOE 1991b). Selected quarterly composites were also analyzed for uranium isotopes.

Gaseous  $^{131}\text{I}$  was sampled at several locations by drawing air through a cartridge containing activated charcoal. These cartridges were downstream of the particle filter at each air sampling station and were exchanged biweekly. Sampling was performed near operating facilities to maximize the potential for detecting facility releases and at distant locations near points of potential public exposure. Iodine-129 was sampled using the same technique with a special low-background charcoal cartridge. Samples were collected monthly and combined to form quarterly composite samples for each location.

Atmospheric water vapor was collected for  $^3\text{H}$  analysis by continuously passing air through cartridges of silica gel, which were exchanged every 4 weeks. The water vapor was removed



S9111057.22

Figure 4.1. Air Sampling Locations, 1990 (see Table 4.8 for location key)



Table 4.8 Air Sampling Locations and Sample Composite Groups

Composite Group	Sampling Location	Map Location <sup>(a)</sup>
<b>Onsite</b>		
100 Areas	100-K	1
	100-N	2
	100-D	3
	Fire Station	4
200-East Area	S of 200-East	5
	E of 200-East	6
	200-East SE	7
North of 200 Areas	Rt. 11A, Mi. 9	8
	N of 200-East	9
200-West Area	SW of BC Cribs	10
	Army Loop Camp	11
	GTE Building	12
200-West SE	200-West SE	13
300 Area	300 Pond	14
	ACRMS (3614-A Bldg.)	15
	300-South Gate	16
300 NE	300 NE	17
400 Area	400-East	18
	400-West	19
	400-South	20
	400-North	21
B Pond	B Pond	22
Hanford Townsite	Hanford Townsite	23
Wye Barricade	Wye Barricade	24
<b>Perimeter</b>		
Northeast Perimeter	Berg Ranch	25
	Sagehill	26
	Ringold	27
East Perimeter	Fir Road	28
	Pettett	29
Southeast Perimeter	Byers Landing	30
	RRC No. 64	31
Prosser Barricade	Horn Rapids Rd. Substation	32
	Prosser Barricade	33
ALE	ALE	34
West Perimeter	Rattlesnake Spring	35
	Yakima Barricade	36

**Table 4.8. Air Sampling Locations and Sample Composite Groups (contd)**

<u>Composite Group</u>	<u>Sampling Location</u>	<u>Map Location<sup>(a)</sup></u>
Northwest Perimeter	Vernita Bridge	37
	Wahluke Slope No. 2	38
<b>Nearby Communities</b>		
Northeast Communities	Othello	39
	Connell	40
Tri-Cities	Pasco	41
	Richland	42
	Kennewick	43
Benton City	Benton City	44
	Prosser	45
Eltopia	Eltopia	46
Mattawa	Mattawa	47
<b>Distant Communities</b>		
Outer Northeast	Moses Lake	48
	Washtucna	49
Outer Southeast	Walla Walla	50
	McNary Dam	51
Sunnyside	Sunnyside	52
Yakima	Yakima	53

(a) Locations are identified in Figure 4.1.

from the silica gel and analyzed. Atmospheric carbon dioxide was collected by continuously passing air through a soda-lime cartridge for 8 weeks. The trapped carbon dioxide was then analyzed for  $^{14}\text{C}$  content.

Samples of air were collected for  $^{85}\text{Kr}$  analysis using a small pump that continuously filled a collection bag at a low flow rate over a 4-week sampling period. Krypton-85 analysis was not available under the interim laboratory contract, limiting the number of samples analyzed in 1990 (see Section 2.3).

Three locations were sampled by the Hanford Environmental Health Foundation to assess  $\text{NO}_2$  concentrations. Sample locations are depicted in Figure 4.2 and identified in Table 4.9. The sampling was performed in accordance with EPA Method EQN-1277-028 (EPA 1977). The sampling unit consisted of a bubbler assembly operated to collect 24-hour integrated samples.

A detailed description of sampling and analytical techniques is provided in the Hanford Site Environmental Monitoring Plan (DOE 1991b). The

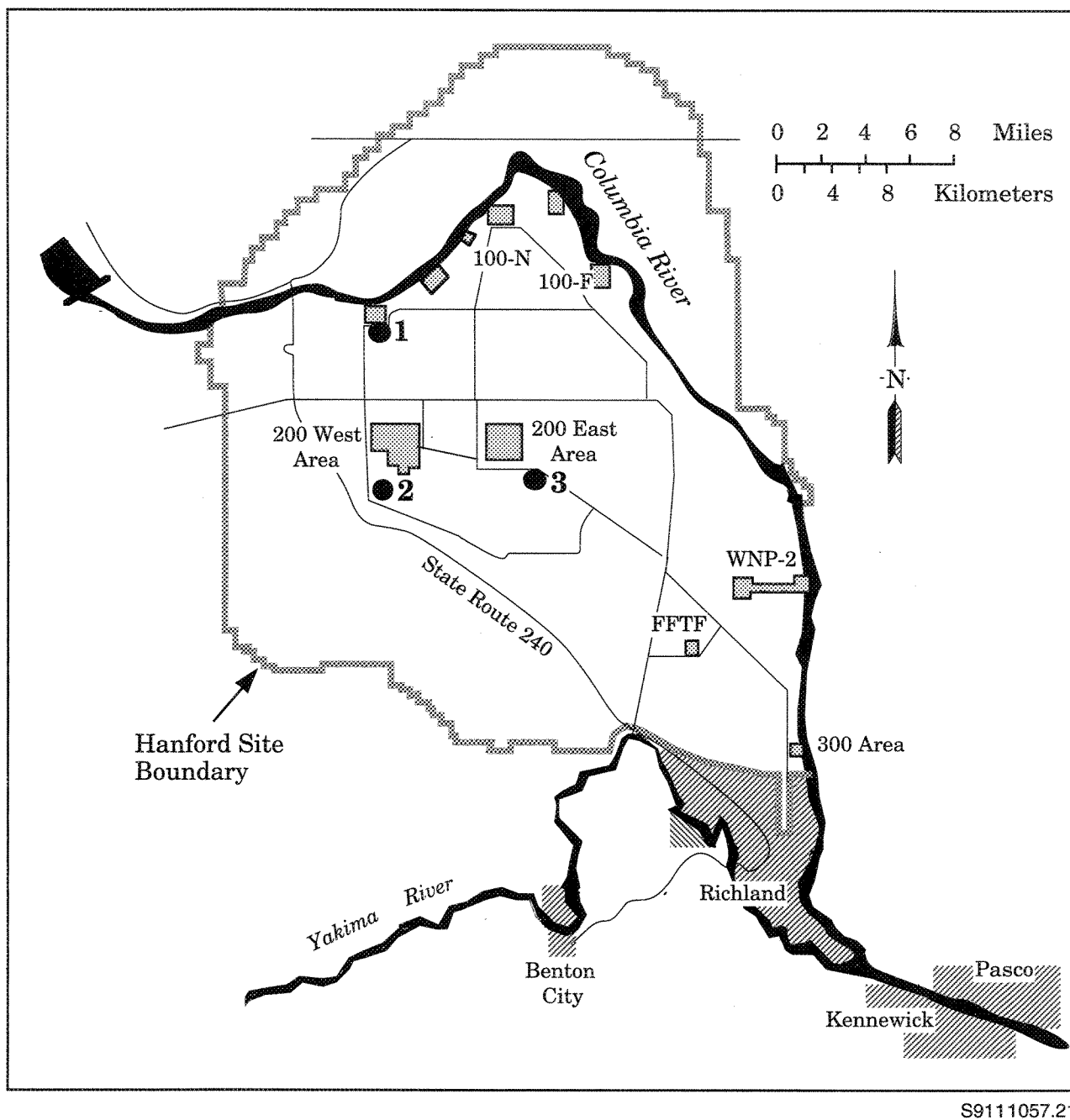


Figure 4.2. Nitrogen Dioxide (NO<sub>2</sub>) Sampling Locations, 1990

**Table 4.9. Ambient Nitrogen Dioxide (NO<sub>2</sub>) Concentrations in the Hanford Environs, 1990**

Location	Map Location <sup>(b)</sup>	Number of 24-h Samples	Annual Average, <sup>(a)</sup> ppmv NO <sub>2</sub>	% Samples Less Than Detection Limit, 0.003 ppmv NO <sub>2</sub>	Maximum 24-h Sample, ppmv NO <sub>2</sub>
100-B	1	236	<0.005 ± 6%	32.6	0.021
200-West	2	278	<0.005 ± 8%	29.1	0.034
Army Barracks	3	282	<0.006 ± 6%	7.8	0.018

(a) Annual averages ±2 standard errors of the mean (SEM). Samples less than detectable daily concentrations were assumed equal to the 24-h detection limit (0.003 ppmv).

(b) Locations are identified in Figure 4.2.

contract with the analytical laboratory (United States Testing Company, Inc; see Section 2.3) was terminated in June 1990. Air samples continued to be collected and were stored in a secure archive facility for approximately 9 months while an interim analytical contract was established.

## Results

### Radiological Results

Air sampling results for onsite, Site perimeter, nearby communities, and distant communities for gross beta, gross alpha, and specific radionuclides are summarized in Table 4.10. Numerous specific radionuclides were analyzed in the monthly composite gamma energy analyses (DOE 1991b), but none of Hanford origin were consistently detectable.

Gross beta levels for 1990, as shown in Figure 4.3, peaked during the winter, repeating a pattern of natural annual radioactivity fluctuations. As shown in Table 4.10, the average gross beta and gross alpha levels 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. An exception is an indication that elevated uranium levels in soil and air in the 300 Area are being reflected in the air gross alpha measurements at that location.

Measurements of <sup>85</sup>Kr have historically been an indicator of impacts from PUREX Plant operations. With the resumption of PUREX Plant operations in late 1983, ambient air concentrations of <sup>85</sup>Kr at most sampling locations increased above preoperational levels of about 19 pCi/m<sup>3</sup> (Sula and Price 1983). Because of nuclear operations worldwide, global background radiation has been increasing annually but appears to be leveling off and has been reported to be between 25 and 26 pCi/m<sup>3</sup> as measured by the EPA network in Nevada (EPA 1989a). The average local background in 1990 was 20 pCi/m<sup>3</sup> (±26%) as measured at the distant communities (Table 4.10). This value represents a decrease from past years and may reflect the fact that PUREX Plant operations have ceased. Concentrations onsite and at the Site perimeter in the past fluctuated, primarily in response to changing operating levels (Figure 4.4). The PUREX Plant did not operate during 1990; therefore, concentrations in 1990 were low onsite and at the Site perimeter. The Site perimeter concentrations were not statistically different (5% significance level) from those of distant or background locations. The Site perimeter annual average <sup>85</sup>Kr concentration (23 pCi/m<sup>3</sup> ± 32%) was 0.0008% of the Derived Concentration Guide (DCG) of 3,000,000 pCi/m<sup>3</sup>.

Strontium-90 concentrations in air (Table 4.10 and Figure 4.5) onsite, at the Site perimeter, and in nearby and distant communities were very low in 1990. Figure 4.5 shows the variations from 1985 to 1990 for the 200-East Area sample

Table 4.10. Airborne Radionuclide Concentrations in the Hanford Environs, 1990

Radionuclide	Composite Group <sup>(b)</sup>	No. of Samples	Concentration <sup>(a)</sup> , pCi/m <sup>3</sup> (10 <sup>-12</sup> µCi/mL)			Average	Concentration Guide <sup>(c)</sup> , pCi/m
			Maximum	Minimum			
<sup>3</sup> H	Onsite	48	71	± 2.3	-0.85	± 0.66	3.1 ± 47%
	Perimeter	96	12	± 1.3	-0.48	± 0.64	1.5 ± 14%
	Nearby Communities	4	0.64	± 0.72	-0.27	± 0.72	0.17 ± 110%
	Distant Communities	24	3.4	± 1.4	-1.04	± 1.03	1.3 ± 17%
<sup>14</sup> C	Onsite	6	1.75	± 0.082	1.31	± 0.12	1.45 ± 9.0%
	Distant Communities	6	1.58	± 0.12	1.34	± 0.13	1.47 ± 5.6%
<sup>85</sup> Kr	Onsite	6	85	± 13	5.9	± 11	33 ± 79%
	Perimeter	14	55	± 9.5	3.5	± 11	23 ± 32%
	Nearby Communities	11	36	± 15	5.5	± 8.7	19 ± 24%
	Distant Communities	6	29	± 6.2	13	± 7.6	20 ± 26%
<sup>90</sup> Sr	Onsite	15	0.000025	± 0.000032	-0.000046	± 0.000048	-0.0000079 ± 120%
	Perimeter	18	0.000049	± 0.000037	-0.000048	± 0.000036	0.0000012 ± 12,000%
	Nearby Communities	15	0.0013	± 0.00064	-0.000036	± 0.000050	0.000035 ± 86%
	Distant Communities	12	0.000022	± 0.000040	-0.000048	± 0.000049	-0.0000058 ± 190%
<sup>106</sup> Ru	Onsite	58	0.014	± 0.0094	-0.019	± 0.018	-0.00013 ± 1200%
	Perimeter	66	0.017	± 0.019	-0.012	± 0.015	0.00038 ± 370%
	Nearby Communities	55	0.012	± 0.011	-0.020	± 0.022	-0.0012 ± 140%
	Distant Communities	44	0.020	± 0.016	-0.013	± 0.012	0.000034 ± 6500%
<sup>129</sup> I	Onsite	4	0.00011	± 0.000011	0.000061	± 0.0000055	0.000084 ± 30%
	Perimeter	8	0.000052	± 0.0000039	0.0000094	± 0.00000019	0.000020 ± 50%
	Distant Communities	4	0.00000040	± 0.000000049	0.000000065	± 0.000000006	0.00000017 ± 88%
	Onsite	68	0.0045	± 0.0047	-0.0034	± 0.0046	0.00013 ± 360%
<sup>131</sup> I	Perimeter	50	0.0058	± 0.0058	-0.0049	± 0.0049	0.00047 ± 140%
	Nearby Communities	21	0.0035	± 0.0053	-0.0030	± 0.0040	0.00029 ± 230%
	Distant Communities	22	0.0037	± 0.0046	-0.0061	± 0.0063	-0.00038 ± 240%
<sup>137</sup> Cs	Onsite	58	0.0012	± 0.00087	-0.0012	± 0.00096	0.000099 ± 130%
	Perimeter	66	0.0014	± 0.0011	-0.0017	± 0.00088	-0.0000053 ± 3020%
	Nearby Communities	55	0.00099	± 0.0015	-0.0012	± 0.0014	-0.000013 ± 1000%
	Distant Communities	44	0.0013	± 0.0012	-0.0011	± 0.0013	0.000048 ± 330%
U (total) <sup>(d)</sup>	Onsite	10	0.00022	± 0.000035	0.000026	± 0.0000075	0.000083 ± 55%
	Perimeter	6	0.00012	± 0.000018	0.000056	± 0.000010	0.000084 ± 24%
	Nearby Communities	6	0.00013	± 0.000022	0.000024	± 0.000010	0.000054 ± 61%
	Distant Communities	12	0.0000053	± 0.0000030	-0.00000034	± 0.00000026	0.00000070 ± 140%

Table 4.10. Airborne Radionuclide Concentrations in the Hanford Environs, 1990 (contd)

Radionuclide	Composite Group <sup>(b)</sup>	No. of Samples	Concentration <sup>(a)</sup> , pCi/m <sup>3</sup> (10 <sup>-12</sup> µCi/mL)			Average	Concentration Guide <sup>(c)</sup> , pCi/m <sup>3</sup>
			Maximum	Minimum			
<sup>238</sup> Pu	Onsite	15	0.000014 ±	0.000017	-0.0000036 ±	0.0000035 ±	80%
	Perimeter	18	0.0000065 ±	0.000012	-0.0000097 ±	-0.0000014 ±	0.0000019
	Nearby Communities	15	0.0000040 ±	0.0000077	-0.0000035 ±	-0.0000015 ±	67%
<sup>239,240</sup> Pu	Onsite	15	0.0000051 ±	0.000030	0.0000024 ±	0.00000098 ±	66%
	Perimeter	18	0.0000024 ±	0.000023	-0.00000024 ±	0.0000010 ±	35%
	Nearby Communities	15	0.0000022 ±	0.000015	-0.00000035 ±	0.00000093 ±	41%
	Distant Communities	12	0.0000020 ±	0.000018	-0.0000030 ±	0.0000040 ±	180%
Gross Beta	Onsite	309	0.042 ±	0.0023	0.0032 ±	0.016 ±	5.0%
	Perimeter	339	0.084 ±	0.0030	0.0027 ±	0.017 ±	6.5%
	Nearby Communities	224	0.080 ±	0.0029	0.0011 ±	0.017 ±	8.2%
	Distant Communities	153	0.049 ±	0.0023	0.0037 ±	0.016 ±	8.1%
Gross Alpha	Onsite	268	0.025 ±	0.0019	-0.000060 ±	0.0014 ±	20%
	Perimeter	252	0.012 ±	0.0012	-0.000054 ±	0.0019 ±	12%
	Nearby Communities	50	0.0062 ±	0.0011	0.000039 ±	0.0016 ±	25%
	Distant Communities	50	0.0065 ±	0.00083	0.0000073 ±	0.0017 ±	28%

(a) Maximum and minimum single sample results  $\pm 2$  sigma counting errors. Averages of all samples  $\pm 2$  times the percent standard error of the calculated mean (SEM). Most entries have been rounded to two significant figures. The use of negative concentration values is explained in the section, Helpful Information.

(b) Onsite, Site perimeter, nearby communities, and distant sampling locations are identified in Figure 4.1 and Table 4.8.

(c) From DOE Derived Concentration Guide (see Appendix B).

(d) Summation of <sup>234</sup>U, <sup>235</sup>U, and <sup>238</sup>U.

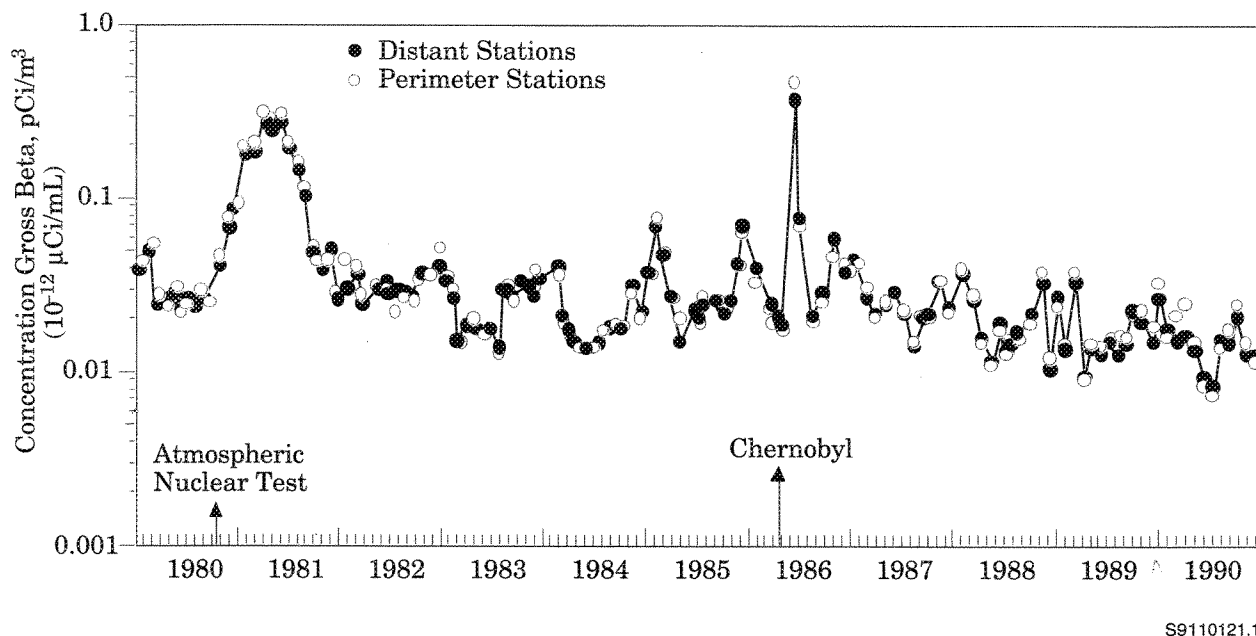


Figure 4.3. Monthly Average Gross Beta Radioactivity in Airborne Particulate Samples, 1980 Through 1990

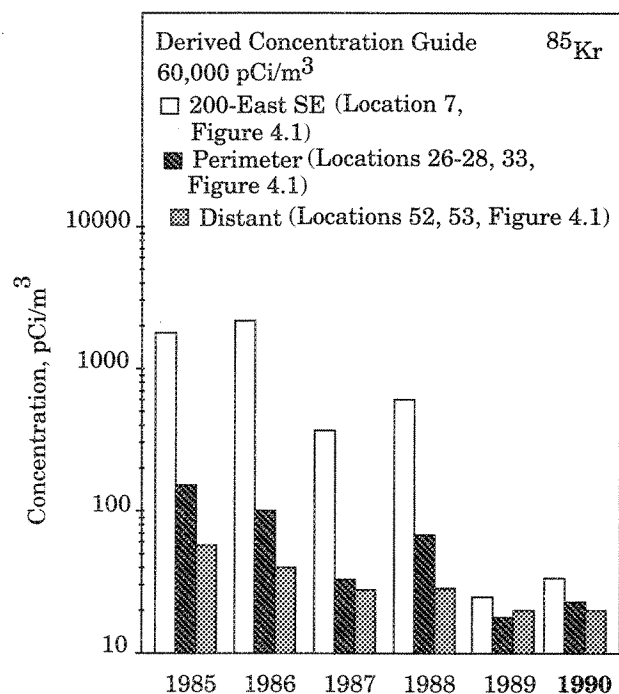
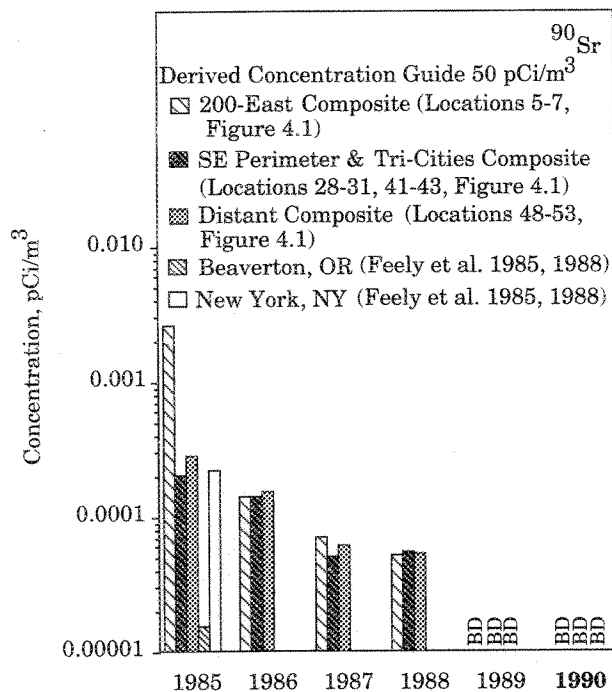


Figure 4.4. Annual Average Concentrations of Krypton-85 ( $^{85}\text{Kr}$ ) in Air at Selected Locations, 1985 Through 1990

composite, for a sample composite made up of samples from stations along the southeast perimeter of the Site and in the Tri-Cities, and for a sample composite from distant communities. Also shown are measurements for 1985 at two other U.S. locations in northern latitudes (New York, New York, and Beaverton, Oregon) reported by the DOE Environmental Measurements Laboratory (EML) as part of its international fallout monitoring program (Feely et al. 1985). The EML discontinued  $^{90}\text{Sr}$  analyses at the end of 1985 (Feely et al. 1988). Most of the increase noted in Figure 4.2-5 for the 200-East Area composite sample in 1985 was the result of an inadvertent airborne release from a liquid-waste diversion box in the C Tank Farm that occurred in January 1985 (Price 1986). The annual average Site perimeter concentration was not distinguishably greater than zero (below detection), and the maximum sample concentration was  $0.000049 \text{ pCi/m}^3 \pm 75\%$ , which is 0.0001% of the DCG of  $50 \text{ pCi/m}^3$ .

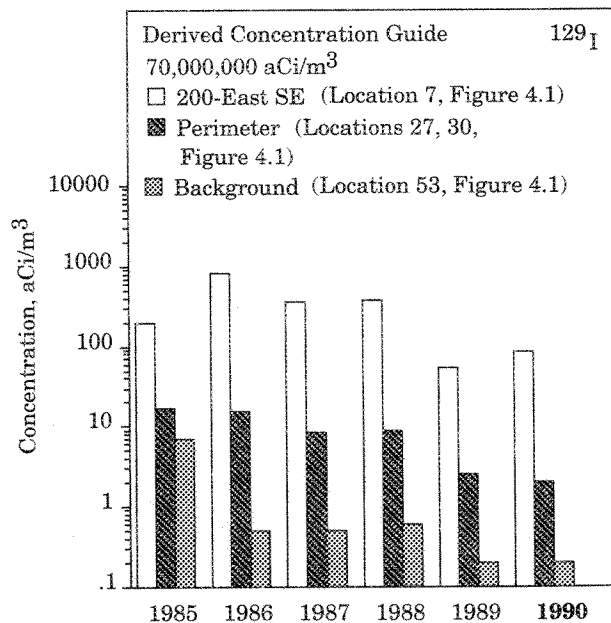
Quarterly air sampling for  $^{129}\text{I}$  began in July 1984. Iodine-129 was sampled onsite downwind



**Figure 4.5. Annual Average Concentrations of Strontium-90 ( $^{90}\text{Sr}$ ) in Air at the Hanford Environs Compared to Other U.S. Locations, 1985 Through 1990 (New York and Beaverton data not available after 1985; BD--below detection level of 0.00001 pCi/m<sup>3</sup>)**

of the PUREX Plant (200-East SE location), at two downwind perimeter locations, and at a distant background location (Yakima) in 1990. (Because of the low levels of  $^{129}\text{I}$ , concentrations are reported in aCi/m<sup>3</sup> rather than pCi/m<sup>3</sup>. One aCi/m<sup>3</sup> = 0.000001 pCi/m<sup>3</sup>.) Concentrations at the Site perimeter in 1990 were larger than those observed at Yakima (Figure 4.6). The average onsite and Site perimeter concentrations decreased in 1989 in response to decreased operations and remained at similar levels in 1990. The annual average  $^{129}\text{I}$  concentration at the perimeter ( $2.0 \text{ aCi/m}^3 \pm 50\%$ ) was 0.000003% of the DCG of 70,000,000 aCi/m<sup>3</sup> (70 pCi/m<sup>3</sup>).

Average  $^3\text{H}$  concentrations measured at the Fir Road perimeter location were slightly higher than at distant locations, even though the PUREX Plant did not operate during 1990 (Table 4.10). Figure 4.7 traces the annual trend of  $^3\text{H}$  concentrations for two onsite (200-East and 100-D Areas) and two downwind Site perimeter

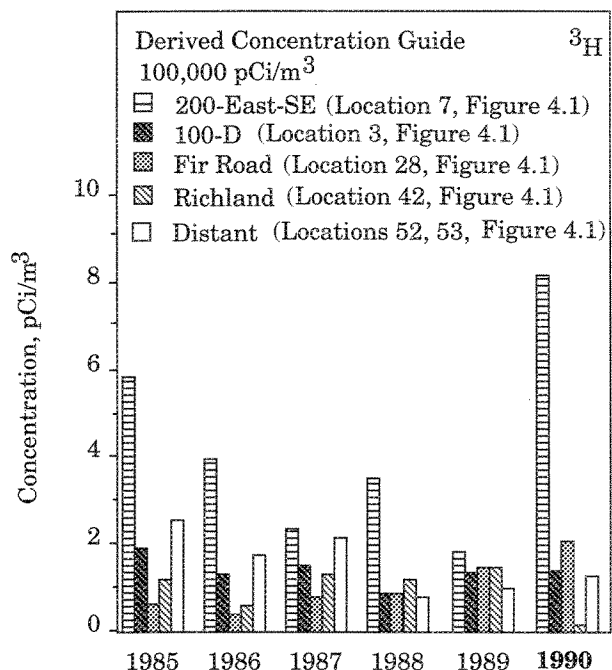


**Figure 4.6. Annual Average Concentrations of Iodine-129 ( $^{129}\text{I}$ ) in Air at the Hanford Environs, 1985 Through 1990**

locations (Fir Road and Richland), and the average for two distant community locations. The annual average  $^3\text{H}$  concentration for the 200-East SE location was greatly influenced by one unusual measurement of 71 pCi/m<sup>3</sup>. The cause for this single measurement was not clear; however, following measurements contained more typical concentrations. The average at this location, excluding this one measurement, was similar to previous years and background levels. Nevertheless, the annual average  $^3\text{H}$  concentration at the 200-East SE location was still only 0.008% of the DCG. The annual average Site perimeter concentration of  $^3\text{H}$  in air in 1990 was 0.0015% ( $1.5 \text{ pCi/m}^3 \pm 14\%$ ) of the DCG of 100,000 pCi/m<sup>3</sup>.

Air concentrations of  $^{239,240}\text{Pu}$  measured at sampling locations in 1990 were generally less than 2.0 aCi/m<sup>3</sup>. The annual averages of all onsite, Site perimeter, and near and distant community samples are shown in Table 4.10. The 1990 Site perimeter annual concentration was  $1.0 (\pm 35\%) \text{ aCi/m}^3$ , which is 0.005% of the DCG of 20,000 aCi/m<sup>3</sup>. The most recent regional data for  $^{239,240}\text{Pu}$  reported by the EPA for Seattle, Spokane, and Portland for 1985 through 1989 (EPA 1984a

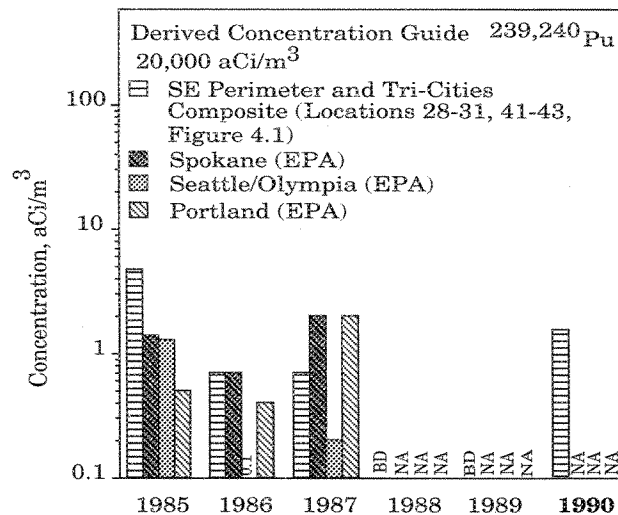




**Figure 4.7. Annual Average Concentrations of Tritium ( $^3\text{H}$ ) in Air at the Hanford Environs, 1985 Through 1990**

through 1988c, 1989b, 1989c) are compared in Figure 4.8 with measurements at the Hanford southeast perimeter and Tri-Cities composite locations. The annual average  $^{239,240}\text{Pu}$  concentration at the Site perimeter and Tri-Cities locations was higher than for 1988 and 1989 measurements; however, the average 1990 concentration at these locations was similar to those reported for these and other Northwest locations during 1985 to 1987 (see Figure 4.8). A general decrease in air concentrations in 1986 followed the installation of additional source controls at the PUREX Plant in late 1985.

Uranium concentrations ( $^{234}\text{U}$ ,  $^{235}\text{U}$ , and  $^{238}\text{U}$ ) in airborne particulate matter in 1990 were higher at the Site perimeter than at the distant communities (Table 4.10) as well as being elevated relative to values typical of Seattle/Olympia and Spokane as reported by the EPA for 1985 to 1987 (EPA 1986a through 1988c). This increase may be attributable to wind resuspension of soil in and around the 300 Area as reflected in the 300

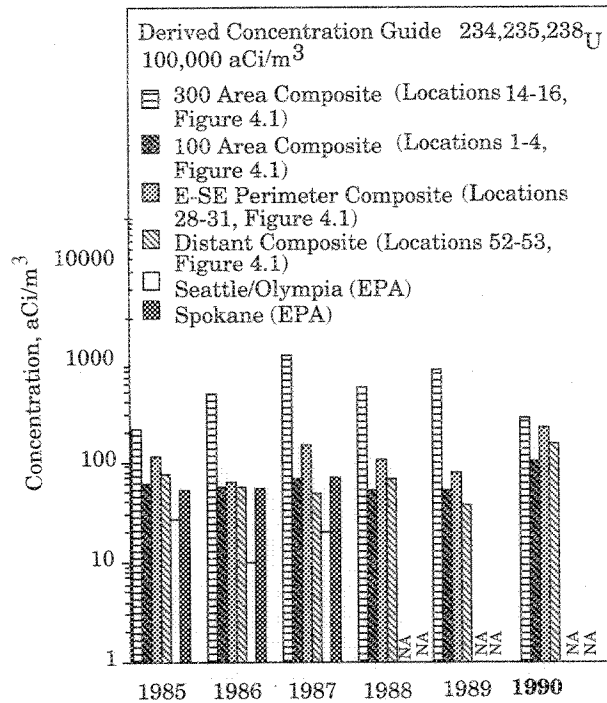


**Figure 4.8. Annual Average Concentrations of Plutonium-239, 240 ( $^{239,240}\text{Pu}$ ) in Air at Northwest and Hanford Environs, 1985 Through 1990 (NA: EPA data for 1988, 1989, and 1990 were not available; BD: below detection)**

Area elevated air concentrations shown in Figure 4.9. However, elevated natural uranium has been reported in offsite soils along the eastern site perimeter (Price and Kinnison 1982). The 1990 annual average concentration in a composite of southeast perimeter locations (map locations 25 to 28, Figure 4.1) was  $0.08\%$  ( $84 \text{ aCi/m}^3 \pm 24\%$ ) of the DCG of  $100,000 \text{ aCi/m}^3$ .

Ruthenium-106,  $^{131}\text{I}$ , and  $^{137}\text{Cs}$  were routinely monitored through gamma energy analyses and were generally below detectable levels both on and off the Hanford Site. The results obtained for 1990 are included in Table 4.10. Even the maximum individual measurements for these nuclides were a small fraction of their DCG.

The comparisons of radionuclide concentrations discussed in the previous paragraphs were based on measured numerical results. A statistical analysis of the air concentration data was conducted to evaluate the effect of Hanford operations on the environment. The regional background concentrations represented by measurements at Yakima and the average at the perimeter of the Hanford Site were compared.



**Figure 4.9. Annual Average Concentrations of Uranium ( $^{234}\text{U}$ ,  $^{235}\text{U}$ ,  $^{238}\text{U}$ ) in Air at Northwest and Hanford Environs, 1985 Through 1990 (NA: EPA data for 1988, 1989, and 1990 were not available)**

Site perimeter concentrations of  $^3\text{H}$ ,  $^{129}\text{I}$ , uranium, gross alpha, and gross beta were higher than regional background, and the differences were statistically significant (beyond the 5% significance level).

## Nonradiological Results

Nitrogen dioxide data collected in 1990 (see Table 4.9) indicate that the highest annual average concentration ( $<0.006 \text{ ppmv} \pm 6\%$ ) observed at the the sampling locations (Figure 4.2) was less than 12% of applicable Federal and Washington State annual average ambient air standard for  $\text{NO}_2$ , which is 0.05 ppmv.

## 4.3 Surface-Water Surveillance

Surface water on and near the Hanford Site is monitored to determine the potential affects 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. This section describes the surveillance effort and summarizes the results for these aquatic environments. Detailed analytical results are contained in Bisping (1991).

### Columbia River

The Columbia River is used as a source of drinking water at onsite facilities and at communities located downstream of Hanford. 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 of Hanford is also used extensively for crop irrigation.

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; McCormack and Carlile 1984). Effluents from each direct discharge point are routinely monitored and reported by the responsible operating contractor; they are summarized in "Effluent Monitoring," Section 4.1. Direct discharges are identified and regulated for nonradiological constituents under the National Pollutant Discharge Elimination System (NPDES). The NPDES-permitted discharges at Hanford and the regulated parameters are listed in Table B.7, Appendix B.

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). Water quality criteria and water use guidelines have been established in conjunction with this designation. Water quality criteria are

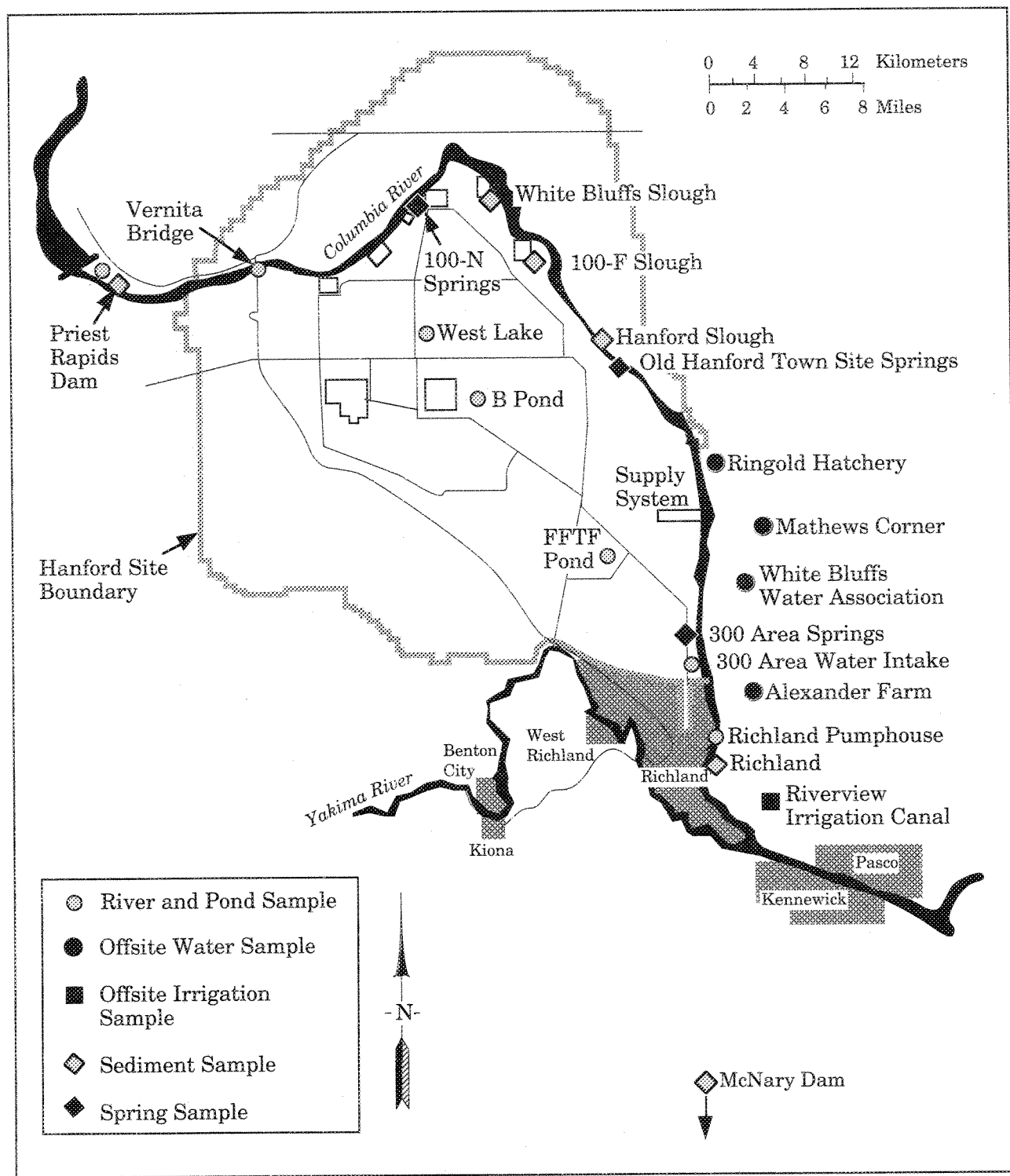
presented in Table B.1, Appendix B. The State of Washington and EPA drinking water standards (DWS) used in evaluating radionuclide concentrations in Columbia River water are provided in Table B.2, Appendix B.

### Sample Collection and Analysis

Samples of Columbia River water were collected throughout 1990 at the locations shown in Figure 4.10. Samples were collected upstream of 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 Pump house to identify any increase in contaminant concentrations at these locations from Hanford operations. The Richland Pump house is the first downstream point of 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).

Radiological analyses of water samples included gross alpha, gross beta, gamma scan,  $^3\text{H}$ ,  $^{90}\text{Sr}$ ,  $^{99}\text{Tc}$ ,  $^{129}\text{I}$ ,  $^{239,240}\text{Pu}$ , and isotopic uranium ( $^{234}\text{U}$ ,  $^{235}\text{U}$ , and  $^{238}\text{U}$ ). Gross alpha and gross beta measurements provided a general indication of the radioactive contamination. Gamma scans provided the ability to detect numerous specific radionuclides, most of which were not found in measurable quantities in the Columbia River. Specific radiochemical analyses and, in some cases, special sampling techniques were used to determine the concentrations of  $^3\text{H}$ ,  $^{90}\text{Sr}$ ,  $^{99}\text{Tc}$ ,  $^{129}\text{I}$ ,  $^{234}\text{U}$ ,  $^{235}\text{U}$ ,  $^{238}\text{U}$ , and  $^{239,240}\text{Pu}$  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.

Samples of Columbia River water were also collected from shoreline sites near the Vernita



S9111009.1

Figure 4.10. Onsite and Offsite Water and Sediment Sampling Locations, 1990

Bridge and near the Richland Pump house for analyses of various nonradiological water quality parameters. Water quality analyses performed during 1990 included pH, nitrate, total coliform and fecal coliform bacteria, and biological oxygen demand. All of these parameters are indicators of the quality of Columbia River water.

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). The USGS samples were collected every 2 months at Vernita Bridge and quarterly at Richland. Analyses for numerous physical, biological, and chemical constituents were performed at the USGS laboratory in Denver, Colorado. In addition to sampling, the USGS provided continuous river temperature monitoring, both upstream of the Site and at Richland, and provided flow rate measurements at Priest Rapids Dam.

Samples of Columbia River sediment were collected during 1990 at locations shown in Figure 4.10. Offsite samples were collected upstream of the Hanford Site behind Priest Rapids Dam, below the Site at Richland, and behind McNary Dam. Samples were also collected from sloughs at White Bluffs, 100-F Area, and the Hanford townsite. Samples were obtained from approximately 15 cm of the top sediment material using a dredge sampler. Analyses of the sediment samples include gamma scans,  $^{90}\text{Sr}$ ,  $^{235}\text{U}$ ,  $^{238}\text{U}$ ,  $^{238}\text{Pu}$ , and  $^{239,240}\text{Pu}$ .

## Results

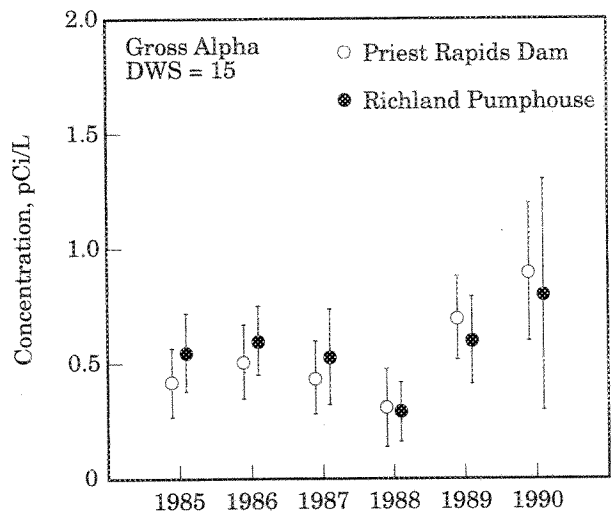
The contract with United States Testing Company, Inc. (UST), the analytical laboratory, was terminated by PNL in June 1990 (see Section 2.3). Water samples continued to be collected and were stored for approximately 9 months while an interim analytical contract was established. In some cases, differences in radionuclide concentrations determined by UST and the interim laboratory are apparent. This potential impact on the data is discussed for specific results in the following subsections.

In addition to the potential impact on the data, conditions of the interim contract precluded analysis of the continuous, filter/resin water samples. Therefore, sample results are not available for all samples collected using this system during 1990. The filter/resin samples were archived. Sediment samples collected during 1990 were not submitted to the interim laboratory. Therefore, no sediment sample results are available for discussion at this time.

## Radiological Parameters

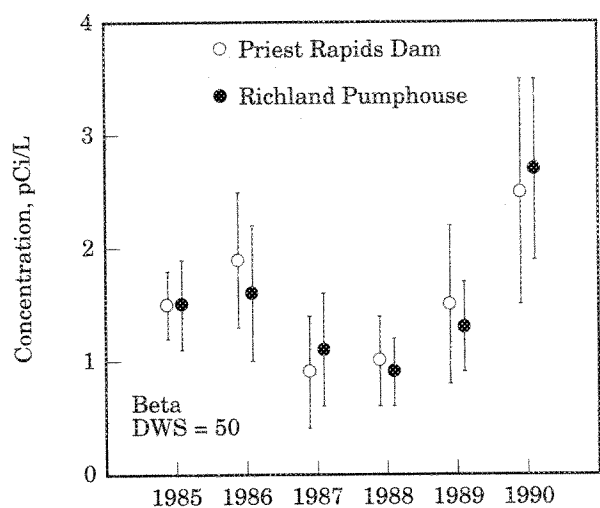
Results of the radiological analyses of Columbia River water samples collected at Priest Rapids Dam, the 300 Area, and the Richland Pump house during 1990 are contained in Bisping (1991). Significant results are discussed and illustrated in the following paragraphs, with comparisons to previous years provided. Levels throughout the year were extremely low, essentially undetectable without the use of special sampling techniques and analytical procedures. Radionuclides consistently measurable in river water during 1990 were  $^3\text{H}$ ,  $^{90}\text{Sr}$ ,  $^{234}\text{U}$ ,  $^{235}\text{U}$ , and  $^{238}\text{U}$ . Most of these radionuclides exist in worldwide fallout, as well as in effluents from Hanford facilities. In addition,  $^3\text{H}$  and uranium occur naturally in the environment.

Gross alpha and gross 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. The 1990 average gross alpha and gross beta concentrations in Columbia River water at Priest Rapids Dam, the 300 Area, and the Richland Pump house were approximately 5% of the applicable DWS of 15 and 50 pCi/L, respectively. Figures 4.11 and 4.12 illustrate the annual average gross alpha and gross beta concentrations, respectively, at Priest Rapids Dam and the Richland Pump house during the past 6 years. The 1990 gross beta and gross alpha concentrations were slightly higher than those previously reported. The cause of these increases during 1990 has not been determined; however, it appears to have been related to the change in analytical laboratories discussed earlier. The



S9111004.1

**Figure 4.11. Annual Average Gross Alpha Concentrations in Columbia River Water, 1985 Through 1990**



S9111004.2

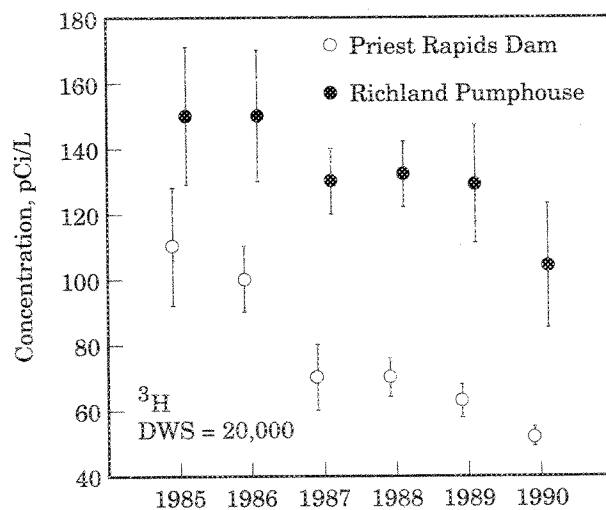
**Figure 4.12. Annual Average Gross Beta Concentrations in Columbia River Water, 1985 Through 1990**

increases were small and generally within the range of uncertainties associated with the annual averages. As in previous years, annual average gross alpha concentrations in 1990 were slightly higher at Priest Rapids Dam than at the Richland Pumphouse. Statistical analyses (paired

sample comparison and t test of differences) of gross alpha and gross beta concentrations at Priest Rapids Dam and the Richland Pumphouse indicated the differences were not significant (5% significance level) (Snedecor and Cochran 1980).

Annual average  $^3\text{H}$  concentrations at Priest Rapids Dam and the Richland Pumphouse during 1990 were  $52 \text{ pCi/L} \pm 6\%$  and  $104 \text{ pCi/L} \pm 18\%$ , respectively. Figure 4.13 compares the annual average  $^3\text{H}$  concentrations at Priest Rapids Dam and the Richland Pumphouse from 1985 through 1990. Tritium concentrations in Columbia River water during 1990 remained similar to those during recent years. The difference between the  $^3\text{H}$  concentrations at Priest Rapids Dam and the Richland Pumphouse was significant (paired sample comparison, t test of differences, 5% significance level). Tritium sources entering the river were effluent releases from the 100-N Area and ground-water seepage into the river along the Site (see "Effluent Monitoring," Section 4.1, and "Ground-Water Protection and Monitoring Program," Section 5.0). All  $^3\text{H}$  concentrations were 1% or less of the State of Washington and EPA DWS of 20,000 pCi/L.

Annual average  $^{90}\text{Sr}$  concentrations at Priest Rapids Dam and the Richland Pumphouse during

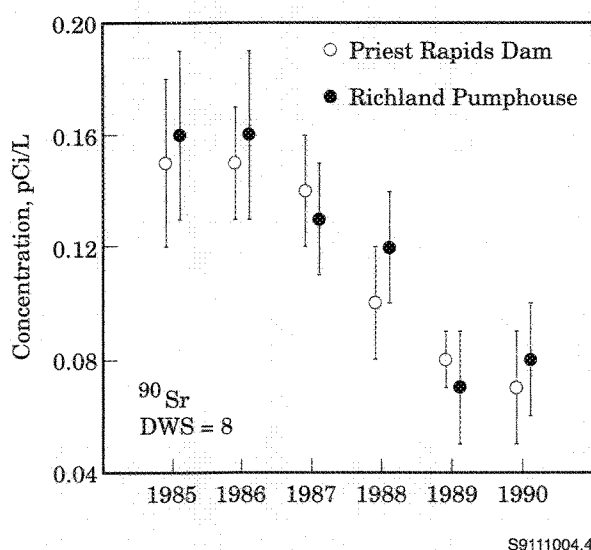


S9111004.3

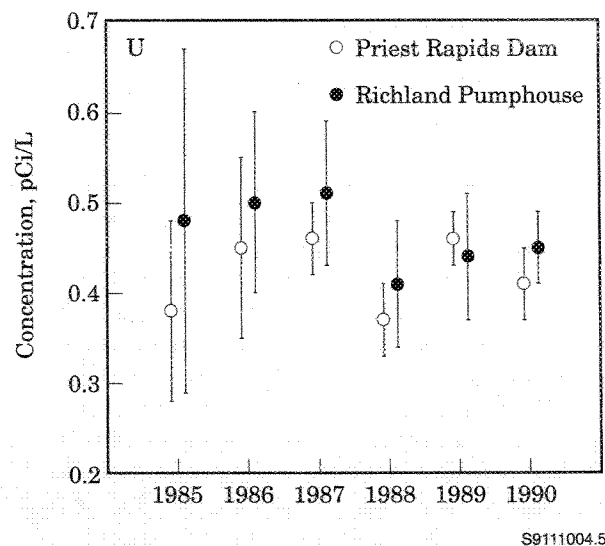
**Figure 4.13. Annual Average Tritium ( $^3\text{H}$ ) Concentrations in Columbia River Water, 1985 Through 1990**

1990 were  $0.07 \text{ pCi/L} \pm 29\%$  and  $0.08 \text{ pCi/L} \pm 25\%$ , respectively. Figure 4.14 shows the annual average  $^{90}\text{Sr}$  concentrations at these locations from 1985 through 1990. Although the Richland Pumphouse annual average concentrations were generally higher than those at Priest Rapids Dam, the differences since 1985 have been slight, especially when the uncertainty associated with the averages was considered. The difference between the  $^{90}\text{Sr}$  concentrations throughout the year at these locations was not significant at the 5% significance level. The primary source of  $^{90}\text{Sr}$  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 1990 remained below the State of Washington and EPA DWS of  $8 \text{ pCi/L}$  (approximately 1%).

Annual average uranium concentrations in 1990 were slightly higher in river water at the Richland Pumphouse than at Priest Rapids Dam (Figure 4.15). The difference in annual averages ( $0.04 \text{ pCi/L}$ ) is small and within the level of uncertainty associated with the means. There was no consistently measurable contribution to Columbia River water uranium concentrations at



**Figure 4.14. Annual Average Strontium-90 ( $^{90}\text{Sr}$ ) Concentrations in Columbia River Water, 1985 Through 1990**



**Figure 4.15. Annual Average Uranium Concentrations in Columbia River Water, 1985 Through 1990**

the Richland Pumphouse attributable to Hanford operations. Differences during the year were not 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 (see "Ground-Water Protection and Monitoring Program," Section 5.0) and has been detected at elevated levels in river-bank springs in this area (Dirkes 1990; McCormack and Carlile 1984). There is currently no DWS directly applicable to uranium. However, uranium concentrations in the river during 1990 were below those that would result in doses exceeding the State of Washington and EPA DWS of  $4 \text{ mrem/year}$ , which is applicable to human-produced radionuclides.

As discussed earlier in this report, the filter/resin water samples were not analyzed for part of 1990. Samples collected during the first quarter of 1990 were analyzed before the termination of the analytical contract. Iodine-129, the primary radionuclide of interest measured by these samples, enters the river along the Hanford Site through the seepage of contaminated ground water (Dirkes 1990; McCormack and Carlile 1984). Based on the first quarter's sample results, which were similar to previous years, and the observed concentrations of other

radionuclides associated with the contaminated ground water, it is anticipated that the 1990 average  $^{129}\text{I}$  concentrations will be similar to those of recent years.

During 1990,  $^{60}\text{Co}$ ,  $^{99}\text{Tc}$ ,  $^{106}\text{Ru}$ ,  $^{131}\text{I}$ ,  $^{134}\text{Cs}$ , and  $^{137}\text{Cs}$  were not consistently found in measurable quantities in the Columbia River at Priest Rapids Dam, the 300 Area water intake, or the Richland Pumphouse. Small quantities of  $^{60}\text{Co}$  and  $^{137}\text{Cs}$  were discharged to the Columbia River during 1990 (see Section 4.1). As in the case of  $^{129}\text{I}$ ,  $^{239,240}\text{Pu}$  concentrations are obtained from the filter/resin collection system. Because of this, no annual average  $^{239,240}\text{Pu}$  concentrations can be reported at this time. First quarter 1990 sample results were generally less than the analytical detection level, similar to those of recent years.

As previously discussed, sediment samples collected from the Columbia River during 1990 have not been available for discussion at this time. Surface sediments behind McNary Dam are known to contain low levels of radionuclides of Hanford origin (Beasley et al. 1981; Robertson and Fix 1977).

### Nonradiological Parameters

Nonradiological water quality data were compiled by PNL and the USGS during 1990. A number of parameters have no regulatory limits. These parameters are, however, useful as indicators of water quality. The PNL and USGS results were in agreement and were comparable to results from recent years. Applicable standards for Class A-designated water were met. There was no indication during 1990 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 4.16 shows Vernita Bridge and Richland results for the period 1985 through 1990 for several water quality parameters with respect to the applicable standards. The pH measurements above and below the Site were in close agreement and were within the acceptable range for Class A

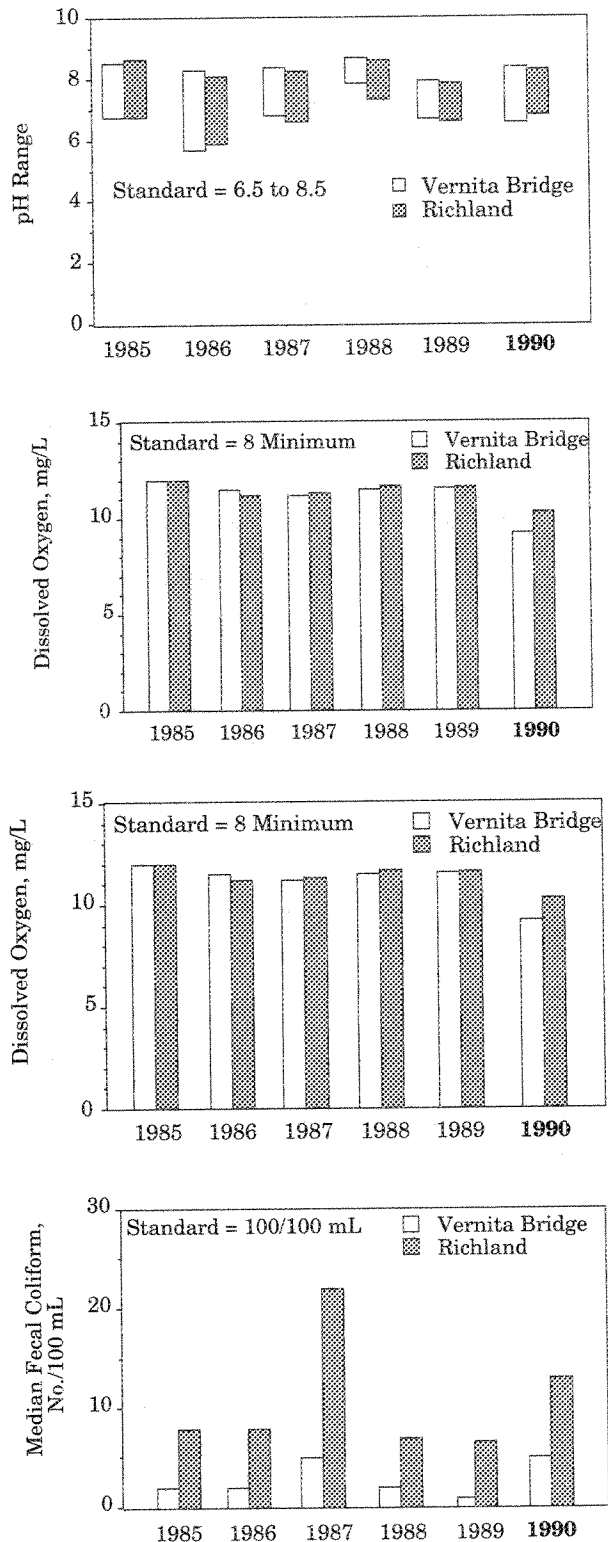
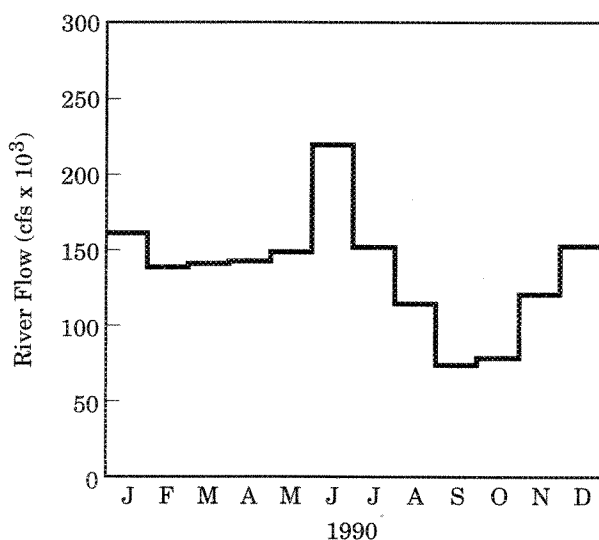


Figure 4.16. Columbia River Water Quality Measurements, 1985 Through 1990



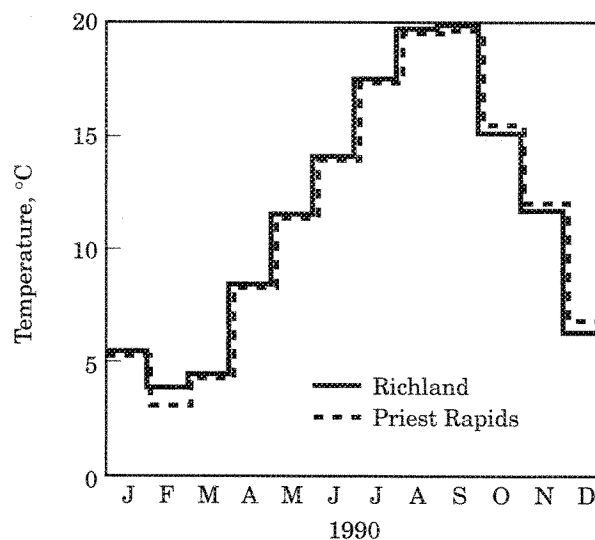
waters. Turbidity, median fecal coliform, and dissolved oxygen concentrations during 1990 were in compliance with Class A requirements at both locations as well.

The annual average flow rate of the Columbia River was 3,838 m<sup>3</sup>/s (135,520 cfs) during 1990, slightly higher than those of recent years. The monthly average flow rates at Priest Rapids Dam are shown in Figure 4.17. The peak monthly average flow occurred during June (6,134 m<sup>3</sup>/s, 216,592 cfs), and the lowest average monthly flow occurred during September (2,073 m<sup>3</sup>/s, 73,198 cfs). Daily average flow rates varied from 1,496 to 36,975 m<sup>3</sup>/s (52,824 to 1,305,587 cfs) during 1990.



**Figure 4.17. Monthly Average Flow Rates of the Columbia River During 1990 (measured at Priest Rapids Dam)**

Average monthly Columbia River water temperatures at Priest Rapids Dam and the Richland Pump house are shown in Figure 4.18. 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 Priest Rapids Dam and the Richland Pump house temperatures during 1990, in the absence of reactor operations, were similar to those in the past (Price 1986). Monthly average temperatures were higher at the Richland Pump house than at



S9111004.12

**Figure 4.18. Monthly Average Temperatures in Columbia River Water During 1990**

Priest Rapids Dam from January through September 1990. Cooler monthly average temperatures were observed at the Richland Pump house during October, November, and December. Temperatures along the Hanford Reach were in compliance with applicable State, Class A water quality requirements during the year.

## Riverbank Springs

The seepage of ground water into the Columbia River has been known to occur for many years. Spring discharges were documented along the Hanford Reach long before the startup of Hanford operations (Jenkins 1922). These relatively small springs flow intermittently, apparently influenced primarily by the changes in the river level. Contaminants associated with these groundwater discharges have been documented to enter the river along the Hanford Reach (Dirkes 1990; McCormack and Carlile 1984).

## Sample Collection and Analysis

Samples of the ground-water seepage were collected during 1990 at the locations identified in Figure 4.10. Sample collection methods are

described in the Hanford Site Environmental Monitoring Plan (DOE 1991b). The analyses, limited to radiological constituents in 1990, were selected based on findings of previous spring investigations and reviews of contaminant concentrations observed in nearby ground-water monitoring wells. At a minimum, spring samples collected during 1990 were analyzed for gross alpha, gross beta, gamma scan, and  $^3\text{H}$ . Uranium,  $^{90}\text{Sr}$ , and  $^{99}\text{Tc}$  analyses were included for those locations where these constituents are known to exist in the local ground water.

## Results

Hanford-origin contaminants were detected in spring water entering the Columbia River along the Hanford Site during 1990. The type and concentrations of contaminants in the spring water were similar to those known to exist in the ground water near the river. The location and extent of the contaminated discharges agreed with recent spring investigations, ground-water monitoring results, and ground-water model predictions.

Radionuclide concentrations were below DOE DCGs (see Appendix B), with the exception of  $^{90}\text{Sr}$  near the 100-N Area. Tritium, while below the DCG, was detected at concentrations above the EPA DWS in several springs. All other radionuclide concentrations were below DWS.

## Onsite Ponds

Three onsite ponds (see Figure 4.10) located near operating areas were sampled periodically during 1990. 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). This pond has not received direct effluent discharges from Site facilities. The Fast Flux Test Facility (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 (Coony et al. 1988). Although the ponds were inaccessible to the public and did not constitute a direct offsite environmental impact during 1990, they were accessible to migratory waterfowl, creating a potential biological pathway for the dispersion of contaminants (see "Wildlife Surveillance," Section 4.5). Periodic sampling of the ponds also provided an independent check on effluent control and monitoring systems.

## Sample Collection and Analysis

During 1990, 10-L (2.64-gal) grab samples were collected quarterly from each pond. Unfiltered aliquots of the samples were analyzed for gross alpha and gross beta activities, gamma-emitting radionuclides,  $^3\text{H}$ , and  $^{90}\text{Sr}$ . Sodium-22 analyses were performed on FFTF Pond samples to provide indications of process failure.

## Results

Analytical results from pond samples collected during 1990 are summarized in Bisping (1991). Maximum, minimum, and average concentration values are provided for various radionuclides at each pond. In all cases, radionuclide concentrations in the onsite pond water were below the DCG. Further discussion of individual constituents and comparisons with results obtained during previous years are provided below.

Annual average radionuclide concentrations in B Pond are shown in Figure 4.19. Radionuclide concentrations in B Pond water during 1990 were comparable to those observed during the previous 5 years. Gross alpha concentrations during the year were within the range observed during the previous 5 years and, as in past years, near the analytical detection limit. Gross beta concentrations in 1990 were elevated slightly; however, they were within the range associated with the uncertainties around the mean. Concentrations of  $^{90}\text{Sr}$  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

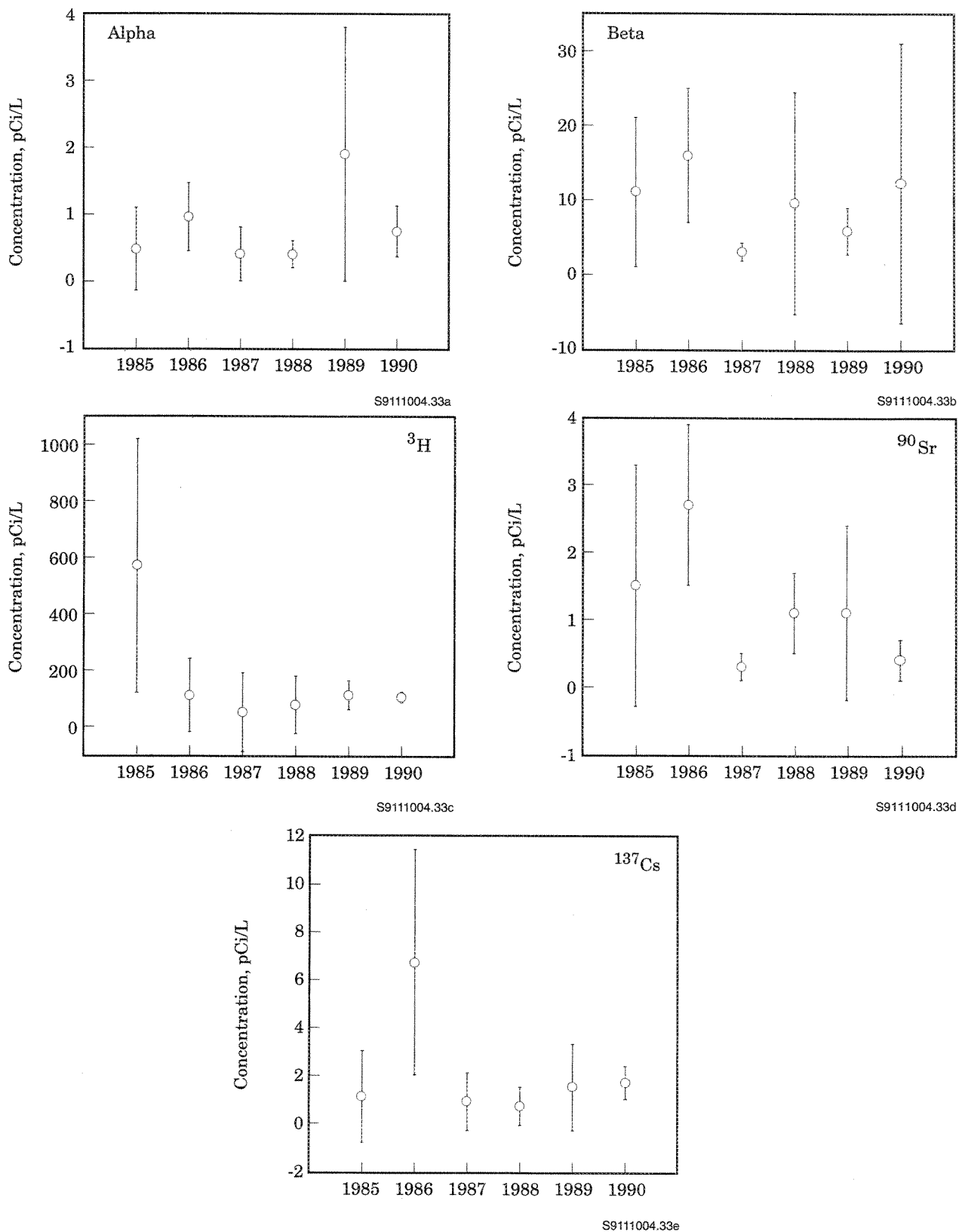


Figure 4.19. Annual Average Radionuclide Concentrations in B Pond, 1985 Through 1990

generally below the detection level during 1990 and, while slightly higher, were similar to concentrations observed in recent year, especially when considering the uncertainties associated with the results.

Figure 4.20 shows the annual average gross beta and  $^3\text{H}$  concentrations in FFTF Pond during 1990. As in the past, gross alpha,  $^{22}\text{Na}$ , and  $^{90}\text{Sr}$  concentrations were below the detection level during the year. Gross beta concentrations in FFTF Pond water were similar to those reported during the previous 5 years. The concentrations of  $^3\text{H}$  were also comparable to those measured in FFTF Pond in the past.

The 1990 annual average radionuclide concentrations in West Lake were comparable to those observed during recent years (Figure 4.21). Average gross alpha concentrations during 1990 were similar to those observed in the past. An apparently anomalous gross beta result was observed at West Lake during 1990. This result (271,000 pCi/L) is believed to be an outlier and not representative of beta concentrations in West Lake. The anomalous data point is approximately a factor of 1,200 higher than the annual averages observed during the past 6 years. In addition,

Poston (1991) reports the highest gross beta measurement observed in West Lake since 1983 to be two orders of magnitude below this sample result. As such, while not eliminated from the data base, the anomalous data point was omitted from the data evaluation presented in Figure 4.21 to portray the historical beta concentrations more realistically. Gross beta concentrations have remained relatively stable over the years. The 1990 concentration was similar to those observed during the previous 5 years. Gross alpha and gross beta concentrations in West Lake, which is recharged from ground water (Gephart et al. 1976), continued to be higher than the gross alpha and gross beta levels found in the other onsite ponds. These elevated levels are believed to result from high concentrations of naturally occurring uranium (Poston 1991; Speer et al. 1976). Annual average uranium concentrations were slightly elevated during 1990 and substantiate the elevated gross alpha and gross beta measurements. Strontium-90 concentrations during 1990 were slightly lower than those observed during the previous 5 years. Tritium concentrations in West Lake during 1990 were the lowest observed in the past 6 years and remained similar to those observed in the local ground water.

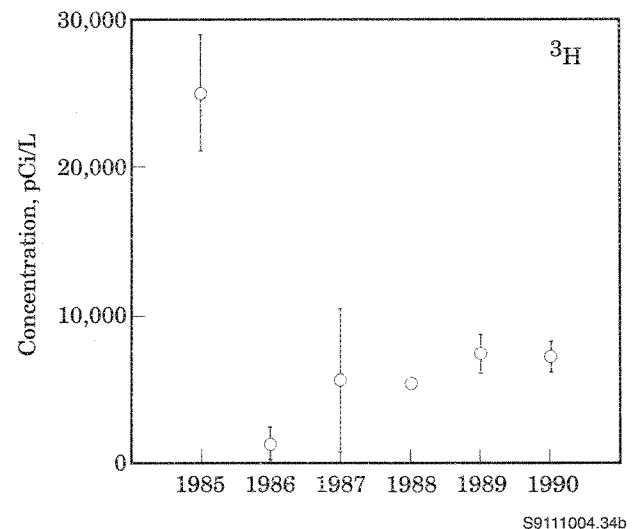
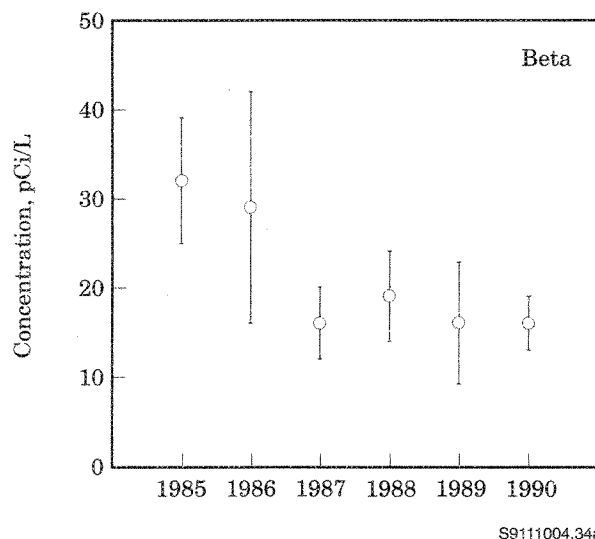
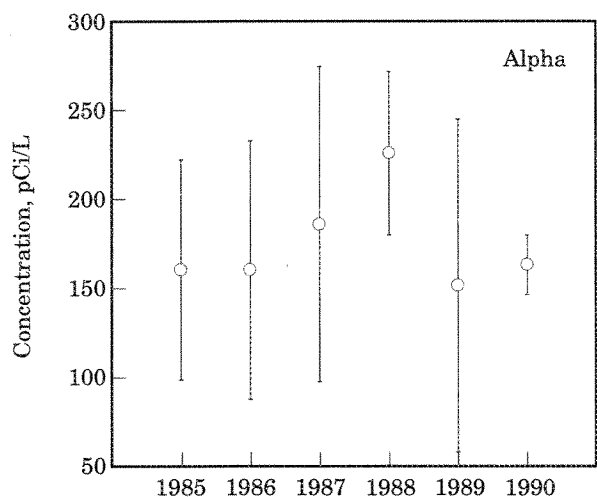
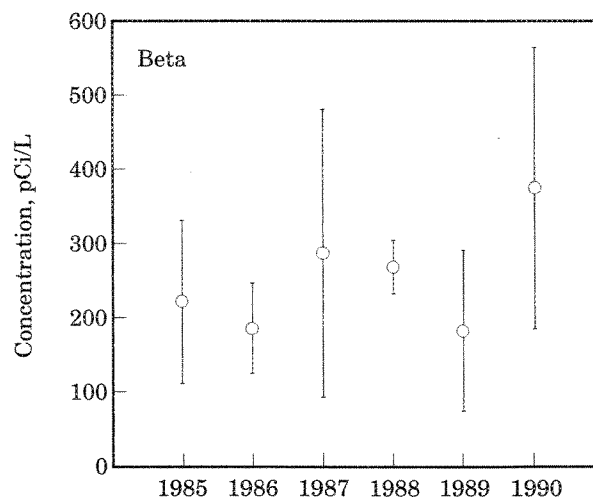


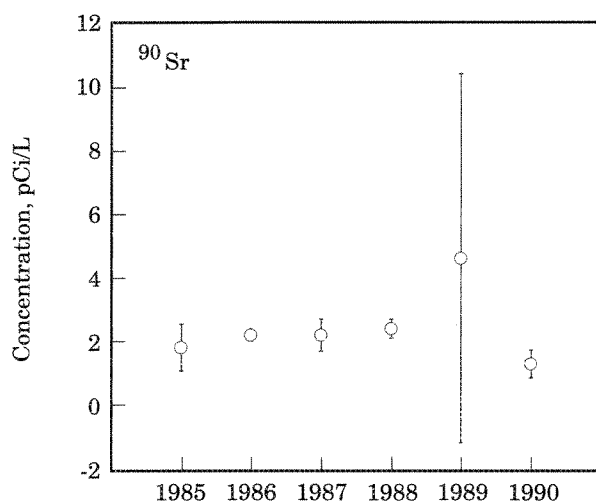
Figure 4.20. Average Gross Beta and Tritium ( $^3\text{H}$ ) Concentrations in FFTF Pond, 1990



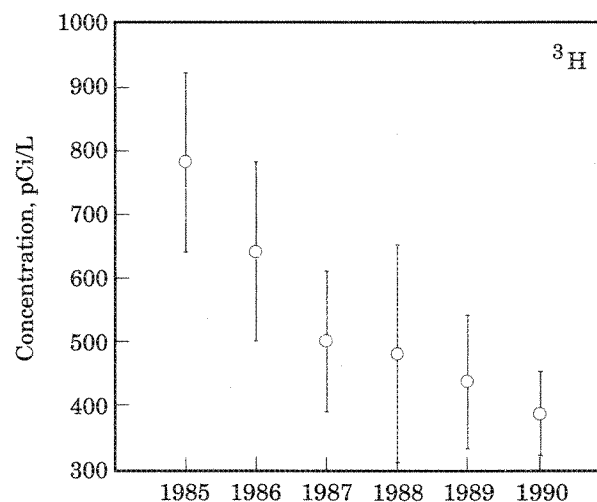
S9111004.35a



S9111004.35b



S9111004.35c



S9111004.35d

Figure 4.21. Annual Average Radionuclide Concentrations in West Lake, 1985 Through 1990

## Offsite Water

Water samples were collected from four water systems directly east of and across the Columbia River from the Hanford Site during 1990. Samples were also collected from an irrigation canal that obtains water from the Columbia River downstream of Hanford. Sampling was initiated to document the levels of radionuclides in the water used by the public and as a result of public concerns about the potential for Hanford-associated contaminants being present in offsite water.

Consumption of food irrigated with Columbia River water from downstream of the Site has been identified as one of the primary pathways contributing to the dose to the hypothetical maximally exposed individual (Jaquish and Mitchell 1988).

## Sample Collection, Analysis, and Results

Grab samples were collected quarterly from four offsite domestic water supplies during 1990 (see

Figure 4.10). Analyses of these samples included gross alpha, gross beta, gamma scan,  $^3\text{H}$ ,  $^{129}\text{I}$ ,  $^{234}\text{U}$ ,  $^{235}\text{U}$ , and  $^{238}\text{U}$ . Results are presented in Bisping (1991). Elevated gross alpha and gross beta concentrations are attributable to elevated natural uranium concentrations in the ground water of this area. The general levels observed in the offsite water supplies were comparable to those reported by the State of Washington (WDSHS 1987). Iodine-129 concentrations were within the range previously reported in offsite water. Annual average radionuclide concentrations in offsite water during 1990 were within applicable DWS.

The Riverview irrigation canal was sampled three times during the irrigation season. These samples were analyzed for gross alpha, gross beta, gamma emitters,  $^{90}\text{Sr}$ ,  $^{234}\text{U}$ ,  $^{235}\text{U}$ , and  $^{238}\text{U}$ . Results are presented in Bisping (1991). Strontium-90 was the primary radionuclide of 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 concentration of  $^{90}\text{Sr}$  during 1990 was similar to that reported for the Columbia River at Priest Rapids Dam and the Richland Pumphouse.

## 4.4 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 4.22). 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 levels of radioactivity that could be attributed to worldwide fallout. This section discusses sample collection and analysis and summary results for alfalfa and foodstuffs. Detailed results are available in Bisping (1991). The potential dose to members of the public from the consumption of local food and farm products is addressed in Section 4.8.

### Milk

#### Sample Collection and Analysis

Selected samples of raw, whole milk were collected from several dairy farms near the Site perimeter in the prevailing downwind directions to evaluate possible Hanford impacts. Milk samples were also collected from dairy farms near Sunnyside and Moses Lake to indicate the general concentrations of radionuclides attributable primarily to worldwide fallout. The general areas of sampling are shown in Figure 4.22. Samples were routinely collected every other week throughout the year from the Sagemoor and Sunnyside areas, and monthly from other areas. All biweekly and monthly samples collected during the first half of 1990 were analyzed for  $^{131}\text{I}$  and  $^{137}\text{Cs}$ . Samples collected following the loss of analytical services in June 1990 were analyzed for  $^{137}\text{Cs}$  only.

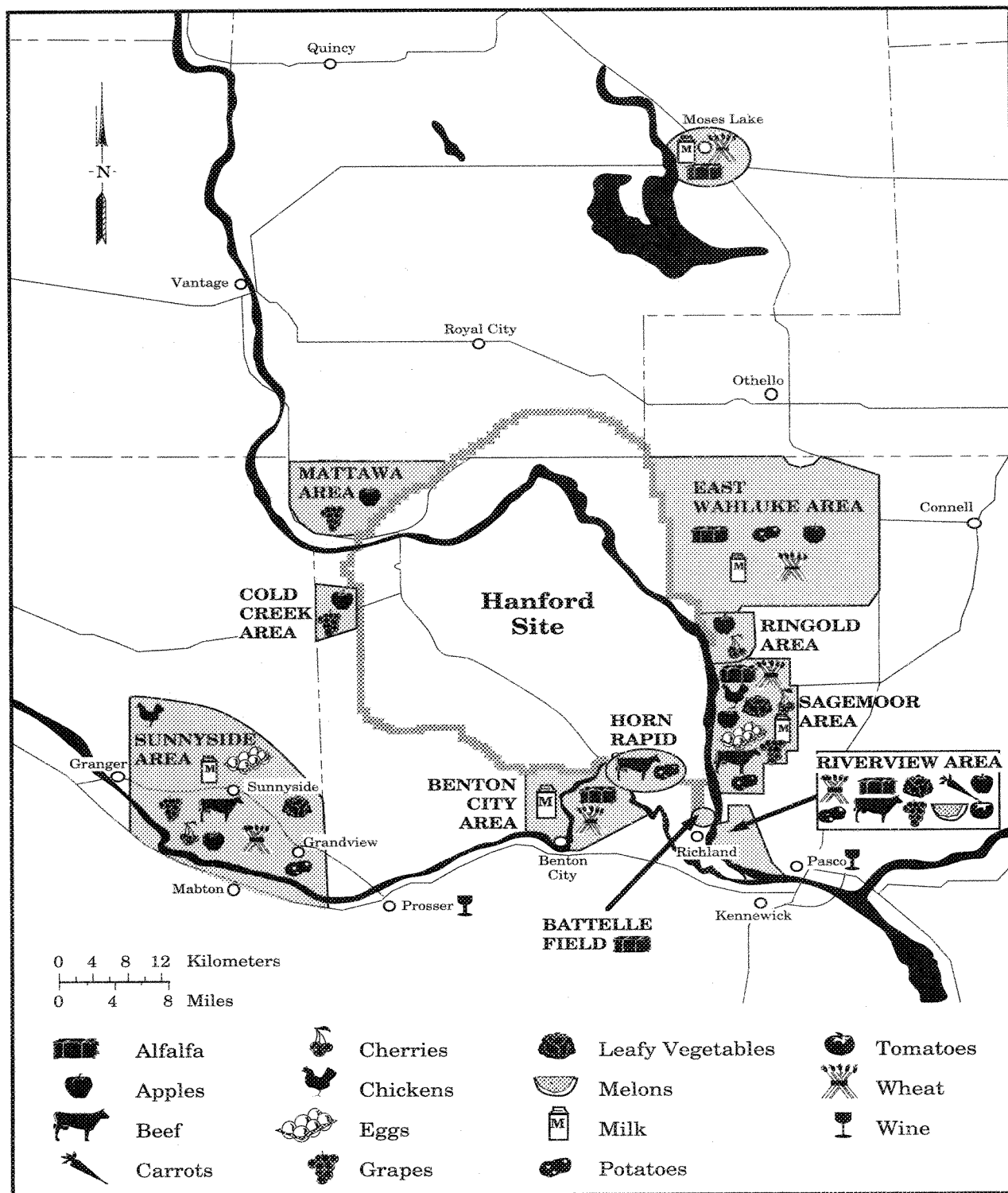
Tritium analyses were conducted on one sample per month,  $^{90}\text{Sr}$  analyses were conducted on one sample per quarter, and  $^{129}\text{I}$  analyses were conducted on one annual composite sample.

### Results

A total of 34 milk samples were collected and analyzed for  $^{131}\text{I}$  during the first six months of 1990. A small amount (about 1.4 mCi) of  $^{131}\text{I}$  was released from Hanford during 1990 (see Table 4.1), but it was not detected in any milk sample. Therefore, the assessment of potential radiation dose to humans from the release of  $^{131}\text{I}$  was performed by pathway modeling (see "Potential Radiation Doses from 1990 Hanford Operations," Section 4.8).

About 4% of the 85 milk samples collected and analyzed for  $^{137}\text{Cs}$  in 1990 contained detectable levels. However, all milk samples analyzed for  $^{90}\text{Sr}$  in 1990 contained low levels of  $^{90}\text{Sr}$ . Both  $^{137}\text{Cs}$  and  $^{90}\text{Sr}$  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. There were no clear differences in  $^{90}\text{Sr}$  concentrations in milk collected from downwind locations and more distant and upwind locations as shown in Table 4.11. Figure 4.23 shows the 5-year record for  $^{90}\text{Sr}$  and  $^{137}\text{Cs}$  in milk samples from all sampling areas. The influence of the Chernobyl incident on  $^{137}\text{Cs}$  in milk in 1986 is evident; otherwise, levels of both radionuclides have remained low and relatively constant over the past 3 years. The overall trend has been downward, primarily because of a decrease in fallout radionuclides.

Selected milk samples were analyzed for  $^3\text{H}$  and  $^{129}\text{I}$  in 1990. Tritium was identified in about 40% of the 56 samples analyzed, and maximum concentrations were near the detection limit of 300 pCi/L. Iodine-129 was identified in all five samples tested. Concentrations were very low and similar to those obtained in recent years. Concentrations of  $^{129}\text{I}$  tended to be slightly higher in milk samples collected from locations adjacent to Hanford (Benton City, Wahluke, and Sagemoor) when compared to those collected at distant control locations (Moses Lake and Sunnyside) as shown in Table 4.11.



S9111009.7

Figure 4.22. Food and Farm Product Sampling Locations, 1990



Table 4.11. Radionuclide Concentrations in Milk Samples, 1990

Location <sup>(b)</sup>	<sup>3</sup> H <sup>(a)</sup>					
	No. of Samples	Maximum	Average <sup>(c)</sup>			
<b>Downwind Perimeter</b>						
Wahluke East Area Composite	12	300 ± 90	100 ± 60%			
Sagemoor Area Composite	11	130 ± 100	30 ± 130%			
Benton City Area	12	200 ± 120	10 ± 540%			
<b>Upwind/Distant</b>						
Sunnyside Area	12	70 ± 110	-9 ± 300%			
Moses Lake Area	9	220 ± 130	160 ± 20%			

Location <sup>(b)</sup>	<sup>90</sup> Sr <sup>(a)</sup>			<sup>129</sup> I <sup>(a,d)</sup>		
	No. of Samples	Maximum	Average	No. of Samples	Maximum	Average
<b>Downwind Perimeter</b>						
Wahluke East Area Composite	3	1.78 ± 0.88	0.98 ± 90%	1	—	0.0014 ± 7%
Sagemoor Area Composite	3	1.13 ± 0.26	0.64 ± 76%	1	—	0.0022 ± 6%
Benton City Area	3	1.68 ± 0.36	1.00 ± 69%	1	—	0.0088 ± 8%
<b>Upwind/Distant</b>						
Sunnyside Area	3	0.58 ± 0.26	0.41 ± 70%	1	—	0.00049 ± 6%
Moses Lake Area	4	1.24 ± 0.28	0.99 ± 20%	1	—	0.00025 ± 12%

(a) Maximum values  $\pm 2$  sigma counting errors. Averages  $\pm 2$  times the standard error of the calculated mean, expressed as a percent. Values are in pCi/L ( $10^{-9}$   $\mu$ Ci/mL).

(b) Refer to Figure 4.22.

(c) Values greater than 100% or negative values (average sample counts were less than background) indicate values are less than detection limits.

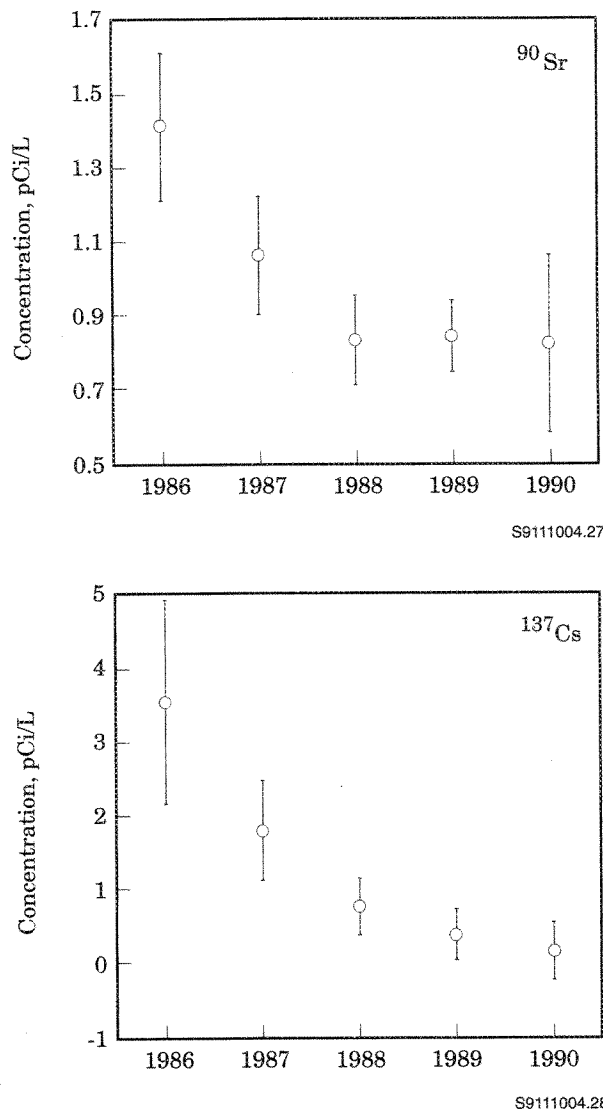
(d) Iodine-129 concentrations determined by mass spectroscopy on one annual composite sample.

## Vegetables

### Sample Collection and Analysis

Samples of leafy vegetables (cabbage, broccoli leaves, beet tops, or turnip greens), as well as samples of tomatoes, carrots, and potatoes, were obtained during the summer from gardens located within the sampling areas (see Figure 4.22). Leafy vegetables are sampled because they

are exposed to deposition from potential airborne contaminants. Three samples of vegetables and leafy vegetables were collected at each sampling location. All were analyzed for <sup>90</sup>Sr and <sup>137</sup>Cs; in addition, leafy vegetables and vegetables from selected locations were analyzed for <sup>239,240</sup>Pu. Samples were collected from the Riverview area particularly to assess potential contamination from the irrigation of crops at that location. Irrigation water at Riverview is drawn from the Columbia River downstream from Hanford.

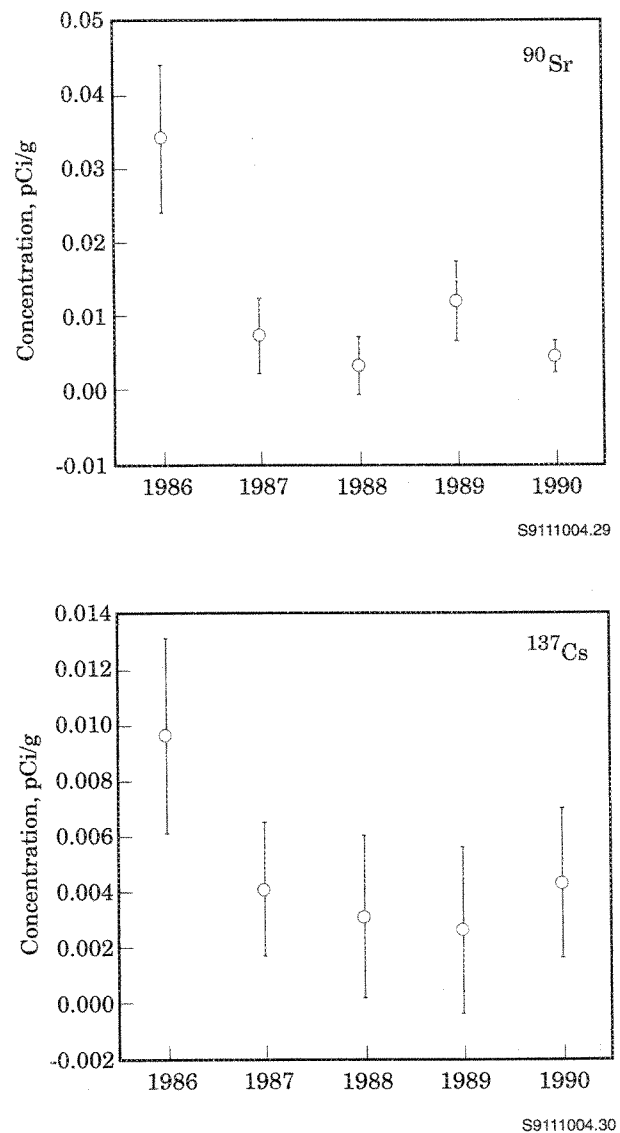


**Figure 4.23. Annual Average Cesium-137 ( $^{137}\text{Cs}$ ) and Strontium-90 ( $^{90}\text{Sr}$ ) Concentrations in Milk for All Sampling Locations, 1986 Through 1990. Values are means  $\pm 2$  times the standard error.**

## Results

Strontium-90 and  $^{137}\text{Cs}$  were identified in most leafy samples but with no apparent difference between distant and nearby locations. The observed concentrations of  $^{90}\text{Sr}$  and  $^{137}\text{Cs}$  at all locations are primarily attributed to worldwide fall-out. The concentrations were low in 1990 and similar to those in previous years (Figure 4.24).

Potatoes from the Riverview, Sagemoor, Wahluke East, and Sunnyside areas, and tomatoes and carrots from the Riverview area were analyzed and did not have detectable amounts of  $^{90}\text{Sr}$ ,  $^{137}\text{Cs}$ , or  $^{239,240}\text{Pu}$ .



**Figure 4.24. Annual Average Cesium-137 ( $^{137}\text{Cs}$ ) and Strontium-90 ( $^{90}\text{Sr}$ ) Concentrations in Leafy Vegetables for All Sampling Locations, 1986 Through 1990. Values are means  $\pm 2$  times the standard error.**

## Fruit

### Sample Collection and Analysis

Samples of apples, cherries, grapes, and melons were collected during harvest from the areas shown in Figure 4.22 (not all types were collected in each area). Each sample consisted of three replicates. The edible portions were analyzed for  $^3\text{H}$ ,  $^{90}\text{Sr}$ ,  $^{137}\text{Cs}$  and, for selected samples,  $^{239,240}\text{Pu}$ .

### Results

Cesium-137 and  $^{239,240}\text{Pu}$  were not detected in any fruit samples. Strontium-90 was detected in grapes from Riverview, Sagemoor, and Mattawa; melons from Riverview; and cherries from Sunnyside (0.002 to 0.003 pCi/g; mean of three samples from each location). The maximum concentration in any sample, however, was very low, 0.006 ( $\pm 50\%$ ) pCi/g wet weight. Tritium was not detectable except in grapes at Mattawa, where it was near background ( $217 \pm 48\%$  pCi/L of extracted water). No differences in radionuclide concentrations were detectable between fruit types or sampling locations, and the observed results were attributed to worldwide fallout.

## Wine

Locally produced red and white wines (1990 vintage) were analyzed for  $^3\text{H}$  and gamma-emitting radionuclides. The wines were made from grapes grown in the Columbia Basin and, for comparison, the Yakima Valley. Three samples of each wine type were obtained from each area. Cesium-137 was not detectable in red or white wines. Concentrations of  $^3\text{H}$  in 1990 wines ranged from <100 to 940 pCi/L with an MDC of about 600 pCi/L. These results are higher than expected apparently due to an elevated analytical detection level. Comparative analyses with the Washington State Department of Health showed significantly lower results. While a standard does not exist for wine, the  $^3\text{H}$  drinking water standard is 20,000 pCi/L.

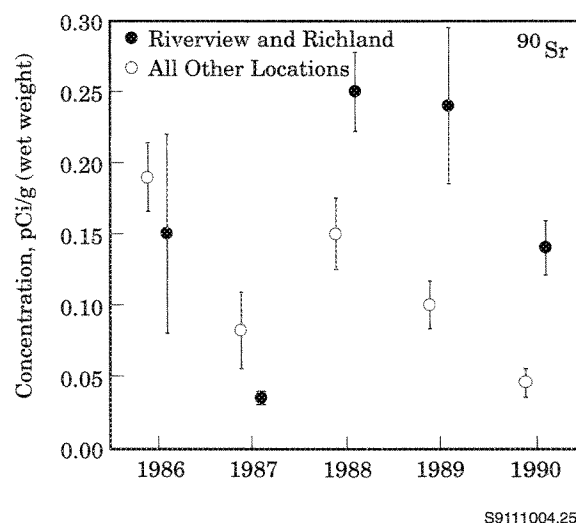
## Wheat and Alfalfa

### Sample Collection and Analysis

Samples of ripened wheat and mature alfalfa were collected from the areas shown in Figure 4.22. Three replicate samples of wheat and alfalfa were collected at each location and analyzed for  $^{90}\text{Sr}$  and  $^{137}\text{Cs}$ . Wheat samples from the Sagemoor and Sunnyside areas were also analyzed for  $^{239,240}\text{Pu}$ .

### Results

Strontium-90 was detected at very low concentrations in all samples. Concentrations in wheat did not show any association with proximity or downwind direction from Hanford, indicating that the primary source was worldwide fallout. Alfalfa collected from Richland and Riverview was irrigated with Columbia River water and concentrations of  $^{90}\text{Sr}$  were slightly elevated when compared to samples from locations that have not been irrigated with water from the Hanford Reach (Figure 4.25), suggesting a river

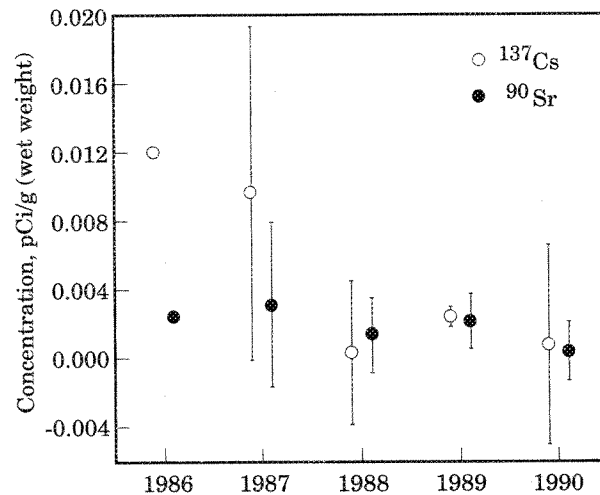


**Figure 4.25. Strontium-90 ( $^{90}\text{Sr}$ ) Concentrations in Alfalfa Collected at Riverview and Richland (irrigated with Columbia River water) and All Other Sampling Locations, 1986 Through 1990. Values are means  $\pm$  2 times the standard error.**

source potentially of Hanford origin. River water monitoring results for 1990, however, do not indicate a current Hanford source. Cesium-137 was identified at very low levels in a few samples. Plutonium was not detected in wheat samples collected in the Sagemoor and Sunnyside areas.

## Beef, Chickens, and Eggs

Samples of locally produced beef, poultry, and eggs were collected from the areas shown in Figure 4.22. Cesium-137 was not detected in beef, eggs, and poultry samples except for one beef sample collected at Riverview ( $0.010 \pm 80\%$  pCi/g); this concentration was near the detection limit. Strontium-90 was detected in poultry at Sunnyside and in beef from Horn Rapids but both were near detection limits. Cesium-137 and  $^{90}\text{Sr}$  concentrations were extremely low and are predominantly attributable to worldwide fallout. Strontium-90 and  $^{137}\text{Cs}$  concentration trends in beef for the previous 4 years are shown in Figure 4.26.



S9111004.16a

**Figure 4.26. Annual Average Cesium-137 ( $^{137}\text{Cs}$ ) and Strontium-90 ( $^{90}\text{Sr}$ ) Concentrations in Beef for All Sampling Locations, 1986 Through 1990. Values are means  $\pm$  2 times the standard error; symbols without error bars indicate only one sample was analyzed.**

## 4.5 Wildlife Surveillance

A number of wildlife species inhabit the Hanford Site. Waterfowl, clams, and fish use the Hanford Reach of the Columbia River for habitat. Wildlife have access to several areas near facilities that contain low levels of radionuclides attributable to Site operations (for example, waste-water ponds) and serve as biological indicators of environmental contamination. Onsite wildlife sampling was performed in areas where the potential exists for wildlife to ingest radionuclides from sources of surface or water contamination. Offsite wildlife control samples were also collected to provide information on background radionuclide concentrations in wildlife. Some samples were not analyzed because of the termination of analytical services (e.g., upland gamebirds). This section discusses sample collection and analyses and summarizes results for deer, fish, clams, waterfowl, and rabbits. Detailed sample results are contained in Bisping (1991).

### Deer

Samples taken from road kills (sampled from areas identified in Figure 4.27) indicate the general levels of radionuclides in Hanford Site deer. Six deer from the Site were sampled and analyzed for  $^{137}\text{Cs}$  in muscle. Bone was analyzed for  $^{90}\text{Sr}$  in two of the deer taken from the 100-N Area. Muscle is most likely to contain  $^{137}\text{Cs}$  when this radionuclide is present in the diet of deer. Results showed very low or nondetectable levels of  $^{137}\text{Cs}$  in muscle samples. The  $^{137}\text{Cs}$  concentrations were in the range generally attributed to worldwide fallout, and the average value was consistent with those observed in previous years (Figure 4.28). The  $^{90}\text{Sr}$  concentrations in deer bone range from 0.7 to 58 pCi/g in 1990 and are comparable to bone samples analyzed in 1985. Concentrations in bone of  $^{90}\text{Sr}$  attributable to fallout were approximately 1.0 pCi/g. Concentrations exceeding 10 pCi/g may indicate exposure to elevated levels of  $^{90}\text{Sr}$  in the environment.

### Fish

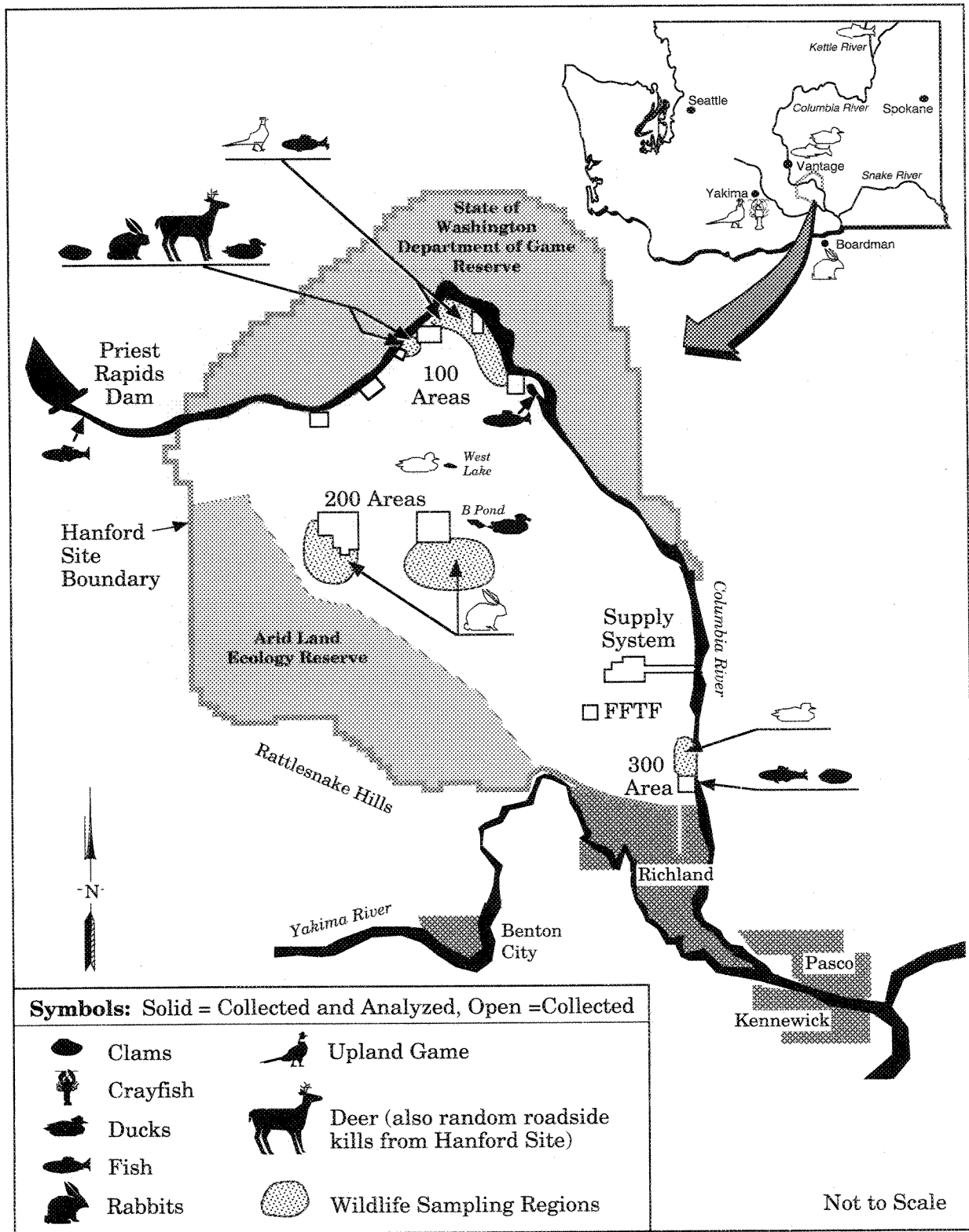
Whitefish, carp, and bass were collected at selected locations along the Columbia River (see Figure 4.27). Boneless fillets were analyzed for  $^{60}\text{Co}$ ,  $^{90}\text{Sr}$ , and  $^{137}\text{Cs}$ . The remaining carcasses were analyzed for  $^{90}\text{Sr}$ . Whitefish were collected near the 100-D, 100-N, and 300 Areas and upstream of the Hanford Site, just downstream of Priest Rapids Dam. Bass were collected near the 100-F Area and carp were collected near the 100-N Area.

The fish-muscle samples collected along the Hanford Reach from the 300 Area to the 100-N Area were analyzed for  $^{60}\text{Co}$ ,  $^{90}\text{Sr}$ , and  $^{137}\text{Cs}$ . However, there were no apparent differences between species, and all concentrations were typically below detection levels. Mean concentrations of  $^{137}\text{Cs}$  in whitefish and bass collected in 1990 from the 100-D Area and immediately downstream of Priest Rapids Dam are shown in Figure 4.29.

Because  $^{90}\text{Sr}$  accumulates in bone, fish carcasses (without viscera and fillets) were analyzed for this constituent. Strontium-90 concentrations were detected in all fish carcasses analyzed in 1990. Levels in whitefish collected near the 100-D Area were similar to those in whitefish collected just downstream from Priest Rapids Dam. However, bass collected at 100-F slough and carp collected from the 100-N Area had higher concentrations of  $^{90}\text{Sr}$  than whitefish (Figure 4.30).

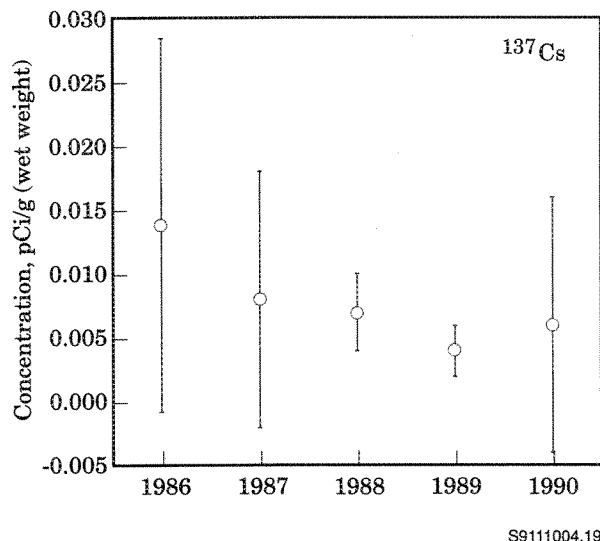
### Clams

Clams were collected from the Columbia River near 100-N and 300 Area shorelines and the soft tissues were analyzed for  $^{60}\text{Co}$ ,  $^{90}\text{Sr}$ , and  $^{137}\text{Cs}$ . Two samples of *Corbicula*, an introduced Asiatic, were collected from each location.



S9111009.8a

Figure 4.27. Wildlife Sampling Areas, 1990



**Figure 4.28. Mean Concentrations of Cesium-137 ( $^{137}\text{Cs}$ ) in Deer Muscle, 1986 Through 1990**

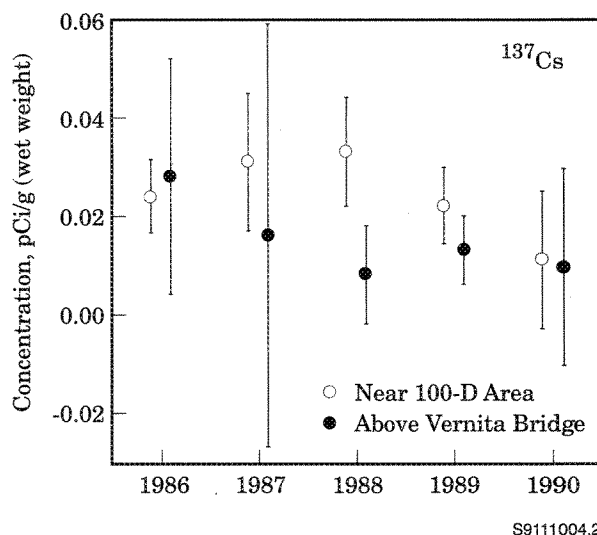
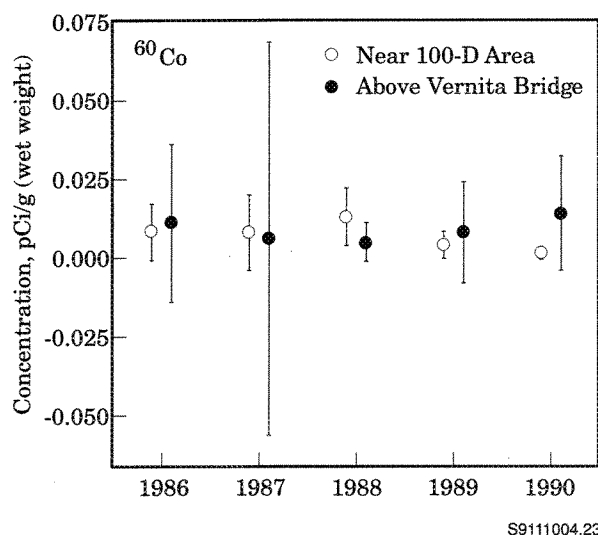
Concentrations of  $^{137}\text{Cs}$  were below detection levels in all samples; however,  $^{60}\text{Co}$  and  $^{90}\text{Sr}$  were detected in samples from the 100-N and 300 Areas at levels close to detection limits (Table 4.12). The shells of some clams collected from the 100-N Area had detectable gross beta activity.

## Waterfowl

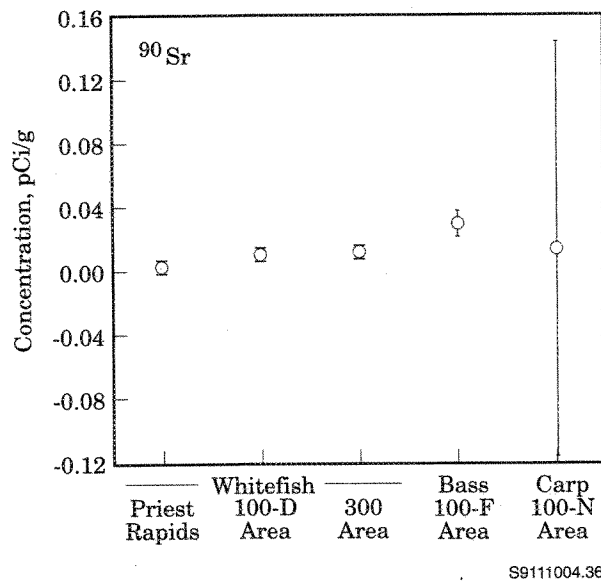
Mallard ducks were collected from B Pond in the 200 Areas and from the Columbia River adjacent to the 100-N Area (see Figure 4.27). Cesium-137 (Figure 4.31) was found in low concentrations in the breast meat of mallard ducks collected from B Pond and was not detected in ducks collected from the Columbia River near the 100-N Area. Cobalt-60 was not detected in ducks from either location. Samples from the Columbia River near the 100-N Area were analyzed for  $^{90}\text{Sr}$ , but none was detected.

## Rabbits

Rabbits were collected (see Figure 4.27) and analyzed to evaluate the general levels of environmental contamination near Site facilities. Hanford waste materials generated at Site facilities usually contains equal quantities (activities) of  $^{90}\text{Sr}$  and  $^{137}\text{Cs}$ . Muscle tissue does not retain  $^{137}\text{Cs}$  for long because of rapid biological turnover, whereas  $^{90}\text{Sr}$  remains incorporated in bone tissue for the lifetime of the animal. Liver tissue tends to accumulate and retain  $^{239,240}\text{Pu}$ , which may be present in food or water consumed by the animal.



**Figure 4.29. Mean Combined Concentrations of Cobalt-60 ( $^{60}\text{Co}$ ) and Cesium-137 ( $^{137}\text{Cs}$ ) in Muscle from Whitefish and Bass Samples Collected Above Vernita Bridge and Near the 100-D Area, 1986 Through 1990. Values are means  $\pm 2$  times the standard error.**



**Figure 4.30. Mean Concentrations of Strontium-90 ( $^{90}\text{Sr}$ ) in Fish Carcasses Collected from the Columbia River, 1990**

Cottontail rabbits were collected near the 100-N Area. Muscle samples were analyzed for  $^{137}\text{Cs}$  and other gamma-emitting radionuclides, bone samples were analyzed for  $^{90}\text{Sr}$ , and liver samples were analyzed for  $^{239,240}\text{Pu}$ . Jack rabbits collected from the 200 Areas were not analyzed in 1990.

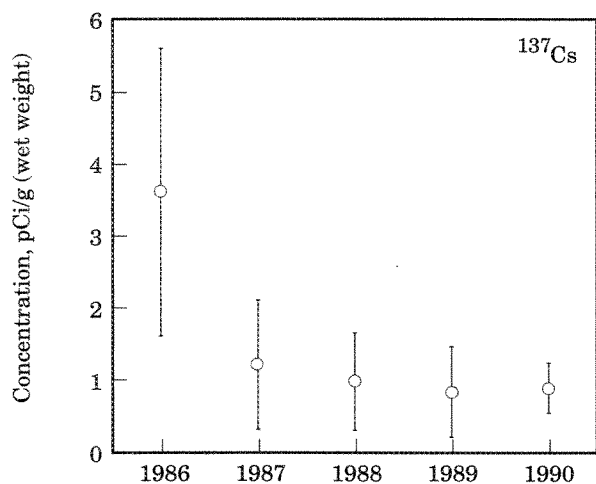
The levels of  $^{90}\text{Sr}$  (maximum value = 369 pCi/g) in bone samples indicated that most of the cotton-tails collected at the 100-N Area had at some time consumed food or water contaminated with  $^{90}\text{Sr}$ . Cesium-137 in muscle and  $^{239,240}\text{Pu}$  in liver were below detection limits. Mean concentrations of  $^{90}\text{Sr}$  in bone and  $^{137}\text{Cs}$  in muscle were similar to levels in previous years (Figure 4.32).

**Table 4.12. Cobalt-60 ( $^{60}\text{Co}$ ), Strontium-90 ( $^{90}\text{Sr}$ ), and Cesium-137 ( $^{137}\text{Cs}$ ) Concentrations (pCi/g wet weight) in Freshwater Clams Collected from the Columbia River Near the 100-N and 300 Areas, 1990**

River Sample Location	$^{60}\text{Co}^{(a)}$	$^{90}\text{Sr}^{(a)}$	$^{137}\text{Cs}^{(a)}$
100-N Area	$0.06 \pm 0.03$	$0.05 \pm 0.01$	$0.004 \pm 0.02$
	$0.02 \pm 0.04$	$0.02 \pm 0.01$	$0.02 \pm 0.03$
300 Area	$0.03 \pm 0.03$	$0.002 \pm 0.003$	$0.008 \pm 0.03$
	$0.005 \pm 0.02$	$0.003 \pm 0.003$	$-0.01 \pm 0.02$

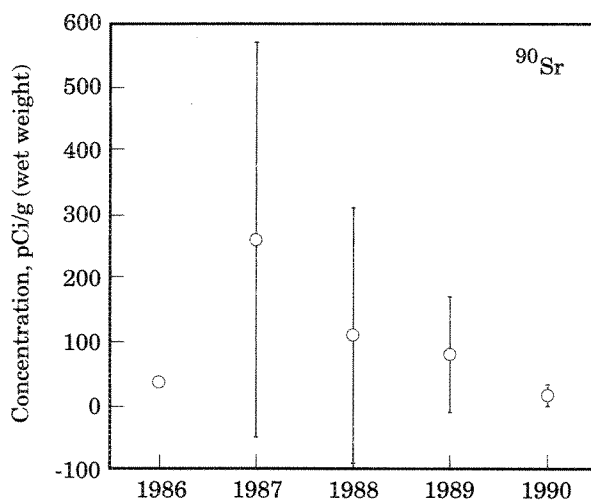
(a) Values are individual results  $\pm 2$  sigma counting error.



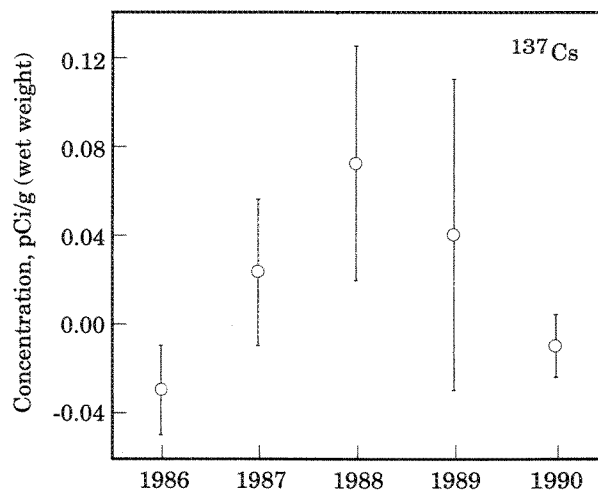


S9111004.22

**Figure 4.31. Median Concentrations of Cesium-137 ( $^{137}\text{Cs}$ ) in Mallard Ducks from B Pond, 1986 Through 1990. Values are means  $\pm 2$  times the standard error.**



S9111004.18



S9111004.17

**Figure 4.32. Median Concentrations of Strontium-90 ( $^{90}\text{Sr}$ ) in Bone and Cesium-137 ( $^{137}\text{Cs}$ ) in Muscle of Rabbits Collected from the 100-N Area, 1986 Through 1990. Values are means  $\pm 2$  times the standard error.**



## 4.6 Soil and Vegetation Surveillance

Hanford operations have a potential to deposit radionuclides by atmospheric transport on the soil or vegetation. In 1990, soil and vegetation samples were collected at a number of locations both on and off the Site. However, because of the loss of analytical services in June 1990 (see Section 2.3), the only samples analyzed in 1990 were collected from downwind, perimeter locations. These locations were selected because they were the areas with the highest potential effects. Soil and vegetation samples were taken from non-agricultural, relatively undisturbed sites so that natural deposition and accumulation processes would be represented. This section discusses the sample collection, sample analyses, and summary results for soil and vegetation samples. Detailed results are contained in Bisping (1991).

### Sample Collection and Analysis

Soil and vegetation samples were collected at the locations shown in Figure 4.33 and archived. Three soil samples and six vegetation samples were collected in a generally downwind direction, where any Hanford contribution of radionuclides in soil and vegetation would be most likely detected. A vegetation sample from a relatively distant and upwind location, Sunnyside, was also collected and analyzed for comparison. Samples of surface soil were collected at each location by combining five 1-in. deep cores and analyzed for gamma-emitting radionuclides,  $^{90}\text{Sr}$ ,  $^{238}\text{U}$ , and  $^{239,240}\text{Pu}$ . Background vegetation samples were collected at Sunnyside. The three soil sample locations were compared to background samples reported in the 1989 annual report.

When soil samples were collected, samples of mature perennial vegetation also were collected nearby. Vegetation samples included a mixture of rabbitbrush, sagebrush, and/or bitterbrush, in roughly the same proportions as occurred naturally at the sample site. A small amount of recent growth was cut from enough plants in the area to make up a sample weighing

approximately 1 kg. Vegetation samples were analyzed for gamma-emitting radionuclides,  $^{90}\text{Sr}$ ,  $^{239,240}\text{Pu}$ , and total uranium.

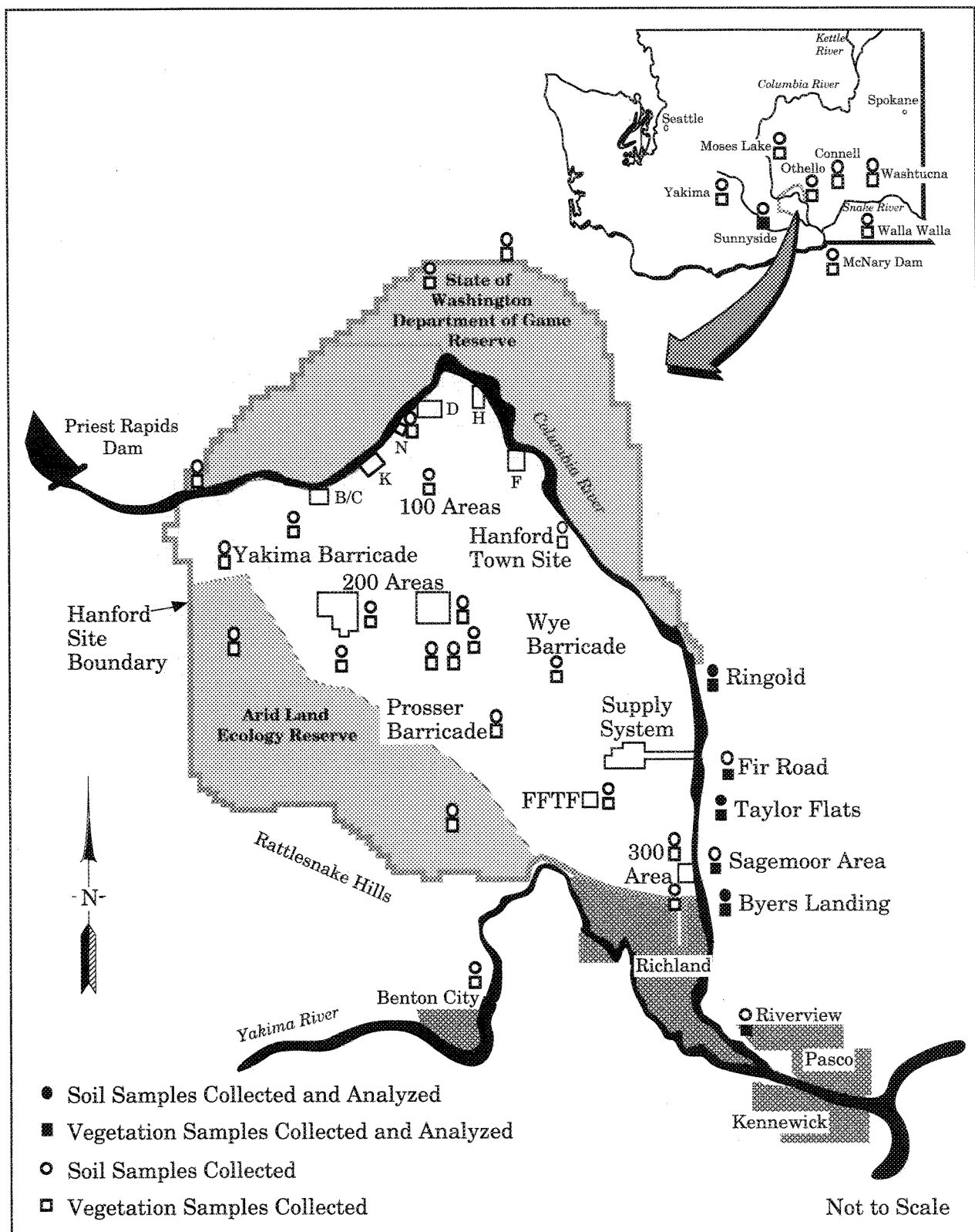
### Soil Results

Soil samples were analyzed from Ringold, Taylor Flats, and Byers Landing (Table 4.13). Cesium-137,  $^{90}\text{Sr}$ , and  $^{239,240}\text{Pu}$  concentrations were low and within the range of variability of results reported previously. The method used to analyze soil samples for uranium changed in 1988. Before 1988, samples were leached with acid and the leachate analyzed for total uranium. In 1988 and 1989, a nondestructive technique involves analyzing the entire sample, without acid treatment, using a low-energy photon detector system. The analysis is specific for the  $^{238}\text{U}$  isotope and can result in higher reported concentrations than the acid leaching technique. However, the 1990 samples were analyzed by the original acid-leaching method, and the results are reported and shown here as total uranium. Concentrations of total uranium in 1990 were higher than observed in prior years (Figure 4.34) for all locations sampled. As in past years, radionuclide concentrations in soil were low and highly variable over time at a single location.

### Vegetation Results

Analytical results for 1990 samples from the six downwind and one distant locations were selected for analysis. Samples for the other locations shown in Figure 4.33 were collected and archived for possible future analysis.

Radionuclide concentrations in vegetation samples collected offsite in 1990 were similar to those observed at the same locations during previous years (Figure 4.35 and Table 4.14). Differences over time for  $^{90}\text{Sr}$ , uranium, and  $^{239,240}\text{Pu}$  reflect natural variation. The elevated  $^{137}\text{Cs}$  value recorded in 1986 was attributed to the Chernobyl incident. The effect of Chernobyl was not noted in subsequent years.



S9111009.5a

Figure 4.33. Sampling Locations for Soil and Vegetation, 1990

Table 4.13. Radionuclide Concentrations (pCi/g dry weight) in Soil Collected from Perimeter Locations East of the Hanford Site and Sunnyside<sup>(a)</sup>

Location	Year					
	1985	1986	1987	1988	1989	1990
<b><sup>90</sup>Sr</b>						
East Perimeter Site <sup>(b)</sup>	0.14 ± 70%	0.26 ± 40%	0.13 ± 60%	0.14 ± 90%	0.15 ± 10%	0.09 ± 70%
Sunnyside <sup>(c)</sup>	0.26 ± 20%	0.05 ± 20%	0.25 ± 10%	0.26 ± 20%	0.13 ± 10%	NS
<b><sup>137</sup>Cs</b>						
East Perimeter Site <sup>(b)</sup>	0.46 ± 140%	0.70 ± 70%	0.61 ± 70%	0.90 ± 100%	1.06 ± 60%	0.43 ± 80%
Sunnyside	0.36 ± 10%	0.09 ± 30%	0.29 ± 10%	1.0 ± 30%	0.48 ± 10%	NS
<b><sup>239,240</sup>Pu<sup>(c)</sup></b>						
East Perimeter Site <sup>(b)</sup>	0.0068 ± 150%	0.012 ± 80%	0.013 ± 80%	0.015 ± 120%	0.019 ± 50%	0.007 ± 100%
Sunnyside	0.015 ± 10%	0.002 ± 50%	0.006 ± 20%	0.023 ± 30%	0.011 ± 20%	NS
<b>Total Uranium</b>			<b><sup>238</sup>U<sup>(c,d)</sup></b>			<b>Total Uranium<sup>(d)</sup></b>
East Perimeter Site <sup>(b)</sup>	0.84 ± 60%	0.60 ± 90%	0.58 ± 90%	0.87 ± 10%	0.6 ± 50%	1.51 ± 30%
Sunnyside	0.26 ± 30%	0.31 ± 30%	0.29 ± 30%	0.70 ± 60%	1.0 ± 30%	NS

(a) East perimeter sites were Byers Landing, Taylor Flats, and Ringold. Refer to Figure 4.33 for location of sampling sites.

(b) Values are the mean of three locations ±2 times the standard error expressed as a percent of the mean.

(c) Value ± the 2 sigma counting error expressed as a percent of the value.

(d) Soil samples were analyzed by a low-energy photon detection system during 1988 and 1989, and acid-leaching method in 1990 and other years preceding 1988.

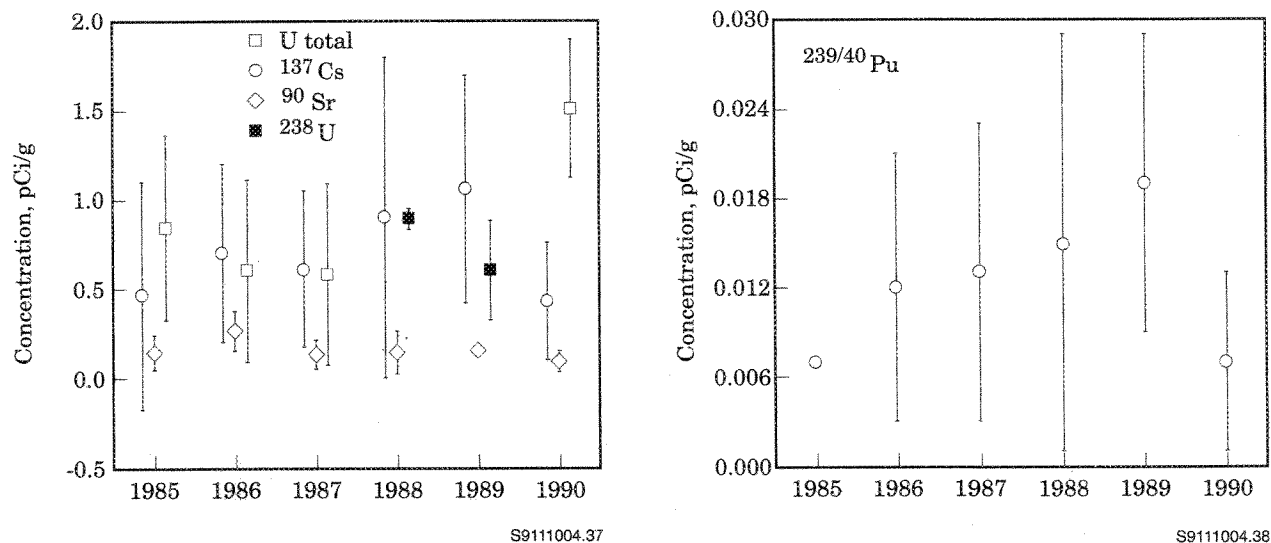


Figure 4.34. Combined Onsite and Offsite Measurements of Strontium-90 ( $^{90}\text{Sr}$ ), Cesium-137 ( $^{137}\text{Cs}$ ), Plutonium-239,240 ( $^{239,240}\text{Pu}$ ), and Uranium in Soil, 1985 Through 1990 (perimeter locations only for 1990). Values are means  $\pm 2$  times the standard error.

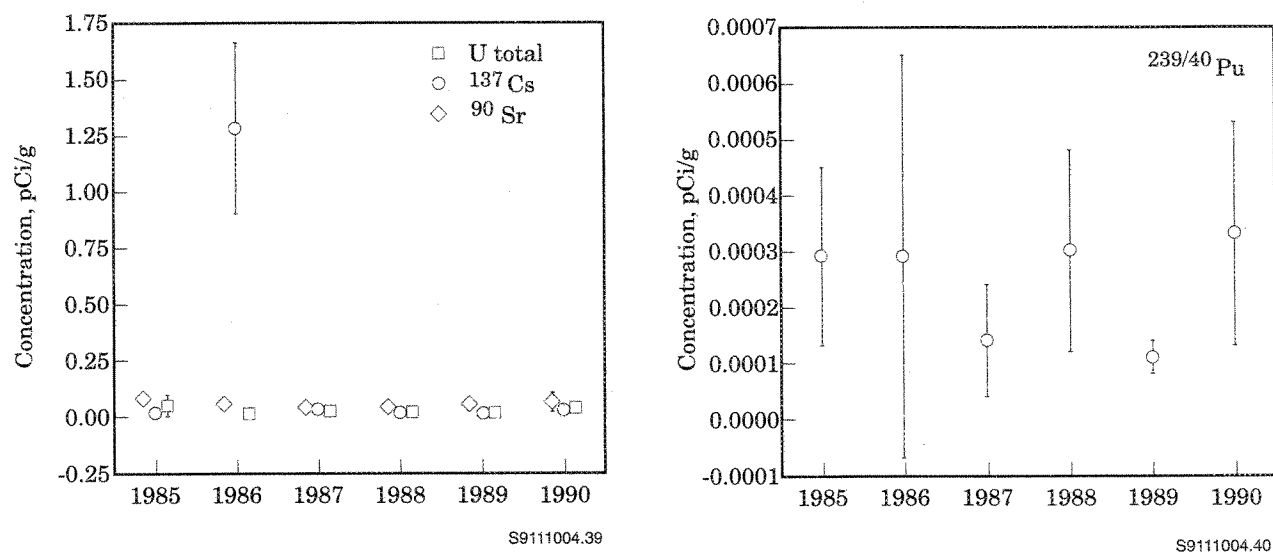


Figure 4.35. Median Strontium-90 ( $^{90}\text{Sr}$ ), Cesium-137 ( $^{137}\text{Cs}$ ), Plutonium-239,240 ( $^{239,240}\text{Pu}$ ), and Uranium Concentrations Measured in Vegetation at Onsite and Offsite Locations, 1985 Through 1990

**Table 4.14. Radionuclide Concentrations (pCi/g dry weight) in Vegetation Collected from Perimeter Locations East of the Hanford Site and Sunnyside<sup>(a)</sup>**

Location <sup>(b)</sup>	Year					
	1985	1986	1987	1988	1989	1990
<b><sup>90</sup>Sr</b>						
East Perimeter Sites <sup>(c)</sup>	0.078 ± 20%	0.058 ± 20%	0.031 ± 60%	0.031 ± 50%	0.055 ± 30%	0.063 ± 80%
Sunnyside <sup>(d)</sup>	0.061 ± 120%	0.044 ± 0%	0.061 ± 10%	0.067 ± 10%	0.053 ± 10%	0.049 ± 20%
<b><sup>137</sup>Cs</b>						
East Perimeter Sites <sup>(c)</sup>	0.011 ± 70%	1.4 ± 20%	0.034 ± 30%	0.013 ± 50%	0.009 ± 30%	0.026 ± 40%
Sunnyside	0.018 ± 80%	0.34 ± 10%	0.004 ± 580%	0.026 ± 50%	0.016 ± 140%	0.020 ± 60%
<b>Total Uranium</b>						
East Perimeter Sites <sup>(c)</sup>	0.053 ± 100%	0.014 ± 30%	0.026 ± 40%	0.015 ± 40%	0.013 ± 30%	0.034 ± 30%
Sunnyside	0.009 ± 70%	0.006 ± 30%	0.014 ± 30%	0.005 ± 40%	0.018 ± 30%	0.038 ± 20%
<b><sup>239,240</sup>Pu</b>						
East Perimeter Sites <sup>(c)</sup>	0.00031 ± 60%	0.00023 ± 40%	0.00014 ± 90%	0.00020 ± 30%	0.00010 ± 60%	0.0003 ± 60%
Sunnyside	0.00017 ± 80%	0.0006 ± 20%	0.00015 ± 110%	0.00003 ± 40%	0.00017 ± 90%	0.0004 ± 100%

(a) East perimeter sites were Riverview, Byers Landing, Sagemoor, Taylor Flats, Fir Road, and Ringold.

(b) Refer to Figure 4.33 for location of sampling sites.

(c) Values are the mean of six locations ±2 times the standard error expressed as a percent of the mean.

(d) Value ± the 2 sigma counting error expressed as a percent of the value.





## 4.7 External Radiation Surveillance

Gamma, high-energy beta, and x rays can be emitted from certain radionuclides attributable to Hanford operations and from naturally occurring external radiation sources (cosmic radiation and radionuclides in the air and ground). Natural external radiation is one of the components of the total natural background radiation dose each person receives (nominally 300 mrem/yr, see Figure 4.43, Section 4.8, "Potential Radiation Doses from 1990 Hanford Operations"). External radiation dose rates from natural and artificial sources were measured at a number of locations on and off the Hanford Site using thermoluminescent dosimeters (TLDs). In addition, external radiation and contamination surveys were performed at a number of locations on and around the Hanford Site. This section discusses how external radiation was measured and surveys were conducted, and the results of these measurements.

### External Radiation Measurements

An environmental TLD station consists of three dosimeters, each mounted approximately 1 m above the ground (except for two stations that are intentionally submerged in the Columbia River). Each dosimeter contains a card holding four LiF (TLD 700) chips and one  $\text{CaF}_2:\text{Dy}$  (TLD 200) chip, which are shielded from incoming radiation by approximately 1 mm of plastic. This design enables the chips to detect more types of lower energy radiation than previous designs. Measurements are taken at all stations quarterly, except for those at the 100-N shoreline locations, where they are taken monthly because of elevated radiation levels. The 12 TLD 700 chips at each location are analyzed to determine the average dose rate. The three TLD 200 chips are analyzed to determine dose rates only after a potential radiological emergency.

The TLDs were placed at numerous locations onsite, around the Site perimeter, in nearby and distant communities, and along the Hanford

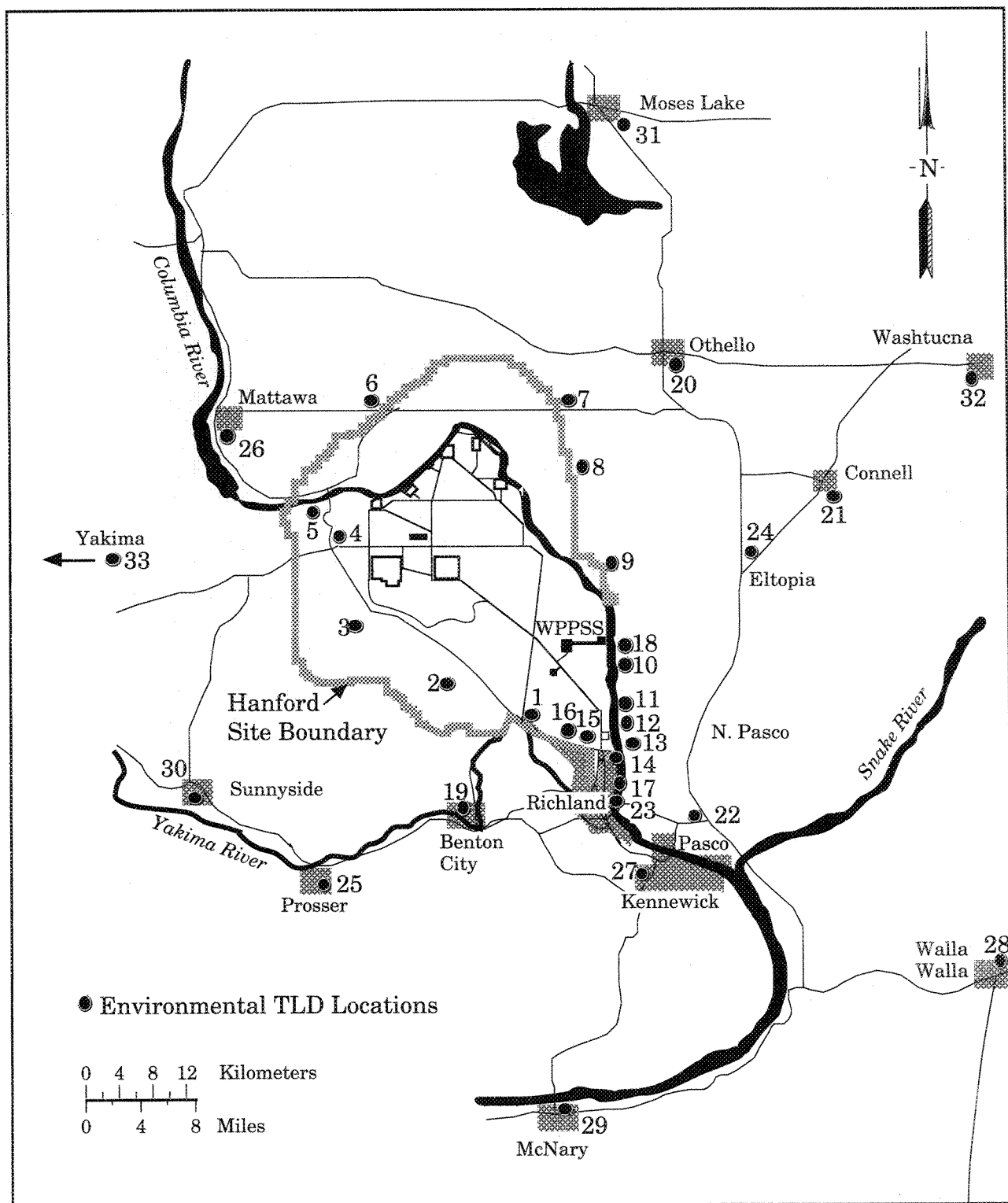
Reach of the Columbia River (Figure 4.36). All community and most of the onsite and perimeter TLD placements are located at air monitoring stations; however, none of the Columbia River shoreline TLD locations were adjacent to air monitoring stations. These placements were based on historical determinations of locations with the highest potential for public exposure (access areas, population centers downwind, etc.) from past and present Hanford operations. Placement of a TLD near an air sampler facilitates the confirmation of measurements.

Dose rates were recorded by TLDs at several shoreline locations along the Hanford Reach of the Columbia River (some accessible by the general public), and TLDs were submerged in the Columbia River at two locations (Coyote Rapids and Richland Pump House). Most of the shoreline TLD locations were in areas along the river where dose rates were historically elevated with respect to typical background levels. These elevated levels were identified in an extensive shoreline study in 1979 (Sula 1980) and were attributed to the radioactivity (primarily  $^{60}\text{Co}$  and  $^{154}\text{Eu}$ ) from past reactor operations in the 100 Areas. The submerged TLDs provided an estimate of external radiation dose rates that could be received by a person immersed in the river.

Although TLD measurements are made in units of exposure (milliroentgens, mR), values are reported in dose equivalent units (mrem) to allow comparison with dose standards and dose equivalents reported elsewhere in this report. The conversion factor relating mrem to mR is slightly less than 1.0 (approximately 3% less), but it is assumed to be 1.0 throughout this report for consistency with past data and does not affect the ability to distinguish differences in radiation levels between various locations.

### External Radiation Results

Perimeter and offsite locations were monitored with TLDs, primarily downwind of the Site and near population centers. Table 4.15 displays



S9111009.4

Figure 4.36. External Radiation Measurement Locations, 1990

**Table 4.15. Average Dose Rates for External Radiation at Perimeter and Community Locations, 1990**

Location	Map Location <sup>(b)</sup>	Dose Rate <sup>(a)</sup> , mrem/yr		
		Maximum	Minimum	Average <sup>(c)</sup>
Perimeter Stations	1-18	100 ± 9%	73 ± 10%	84 ± 4%
Nearby Communities	19-27	81 ± 10%	70 ± 15%	76 ± 4%
Distant Communities	28-33	86 ± 21%	73 ± 12%	79 ± 5%

(a) Quarterly integrated readings in mR were converted to annual dose equivalent rates.

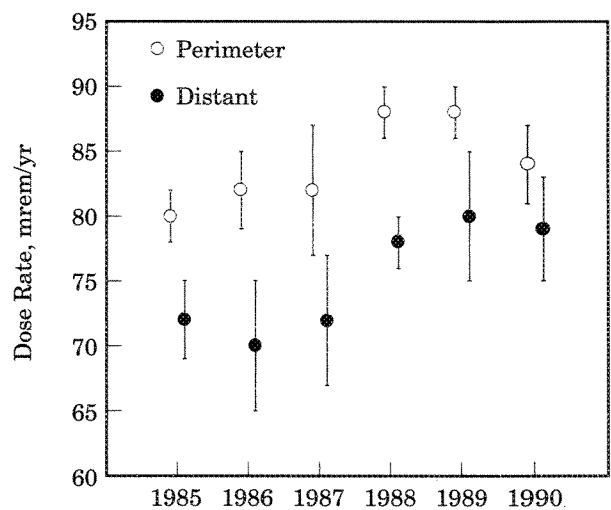
(b) Locations are identified in Figure 4.36.

(c) Averages  $\pm 2$  times the standard error of the calculated mean (SEM). The averages and 2 SEM were computed using station averages rather than individual measurements.

average dose rates for the Site perimeter and nearby and distant communities. The dose rates are similar to 1989 results and indicate no significant variation from their historical averages.

The background external radiation dose rate, calculated from the annual average results from upwind distant locations (Sunnyside, Yakima, and Moses Lake only), was 77 mrem/yr as compared to the perimeter average of 84 mrem/yr. The difference between these average dose rates is due to both natural geographic variations in terrestrial radiation and variations resulting from human activities. Many of the perimeter sites are richer in naturally occurring deposits of radioactive potassium and thorium (Rathbun 1989). On the other hand, distant locations are near public buildings. Land near public buildings has been altered by paving, gravel, etc. These alterations tend to lower the external radiation doses relative to natural conditions. Although not ideal for comparison with radiation from unaltered sites, the choice of the distant site locations was considered necessary for reasons of security and accessibility. Because of a 10% natural variability and a reduction of about 7 mrem/yr as a result of human activities, the difference between perimeter and distant location doses would have to increase to approximately 15 mrem/yr before a significant change could be observed.

Figure 4.37 shows average annual dose rates at perimeter and distant locations (all upwind and downwind) during 1990 and the previous 5 years. Dose rates for 1985 and 1986 have been revised to remove biases for self-dosing correction (8.8 mrem/yr), the difference between 4-week and 1-month monitoring periods (2.5 mrem/yr), and background dose subtractions. The net effect was



S9111004.6

**Figure 4.37. Annual Average Dose Rates at Perimeter and Distant Locations, 1985 Through 1990**

the reporting of annual doses that were low by 16 mrem/yr. Some year-to-year natural variability was apparent. Natural variability is due to several weather and climatic factors and to solar flare activity. Although difficult to quantify, year-to-year variations of 10% are not unlikely (NCRP 1987). The below-normal precipitation in 1988, 1989, and 1990 may account for more radiation from the soil reaching the TLDs by increasing radon percolation rates and decreasing the shielding of gamma ray emissions from natural radionuclides in the ground.

Figure 4.38 and Table 4.16 show the location of the TLDs on the Hanford Reach of the Columbia River and their average dose rates. There were no significant changes in these dose rates from the 1989 observations. Dose rates on the shoreline of the 100-N Area were approximately two to three times larger than the typical shoreline dose rates. This increase is attributed to waste management activities within the 100-N Area. The shoreline in the 100-N Area is not open for public usage.

The two immersed dose rates indicated swimmers at these locations receive about one-half the external radiation dose rate of a person at a typical background land location. This difference is expected because they would be receiving very little of the natural radiation from ground sources; cosmic radiation would be the main or only source of exposure.

Onsite external radiation was measured at locations shown in Figure 4.39 and listed in Table 4.17. Dose rates above background levels (approximately 20% to 70% larger) were observed at five onsite locations during 1990. Rates in excess of background observed near the 100-N, 200-East, and 300 Areas were attributed to direct radiation from waste handling and storage facilities. Some of the highest rates onsite are attributable to waste handling activities at U.S. Ecology (south of the 200-East Area), a non-DOE facility. Dose rates at the 400 Area FFTF Visitor Center and near the west perimeter of the 300 Area (two areas routinely visited by the public) were at typical background levels.

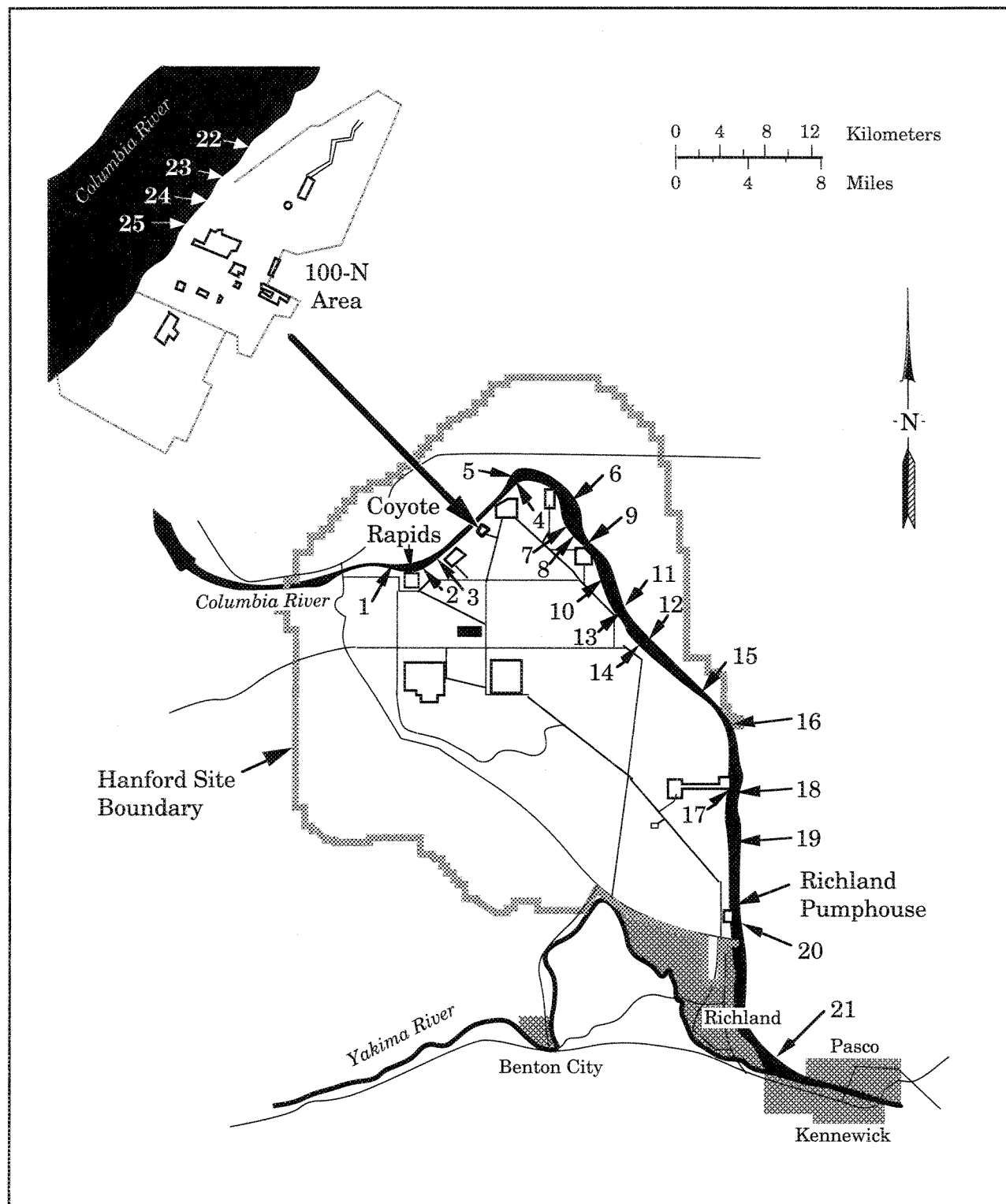
## Radiation Surveys

Various onsite roads, railroads, radioactive waste disposal sites outside of operating areas, Columbia River shoreline, and perimeter locations were surveyed routinely during 1990. Some public (offsite) roads were surveyed into north Richland. The frequency of surveys on specific routes for roads and railroads was based on their use and the potential for contamination. Scheduled waste sites were surveyed at least twice during 1990. Specific routes and frequencies for surveys in 1990 were defined in a master schedule developed by PNL (Bisping 1990).

Roads shown in Figure 4.40 were surveyed routinely using mobile scintillation detectors. No increased radiation was observed on Hanford Site roadways during 1990. Railroad routes (see Figure 4.40) were also surveyed using scintillation detectors. Two small areas (less than 1 square foot) with low-level radioactive contamination were identified and reported to Westinghouse Hanford Company in 1990. The contaminated material was appropriately removed.

Selected waste disposal sites outside operating area perimeter fences were surveyed during 1990 with portable instruments. The general physical condition of the sites was also visually inspected. Radiation surveys conducted at these waste sites during 1990 showed levels comparable to those observed in past years. Portable instrument surveys were also conducted routinely at many of the Columbia River shoreline TLD locations. The shoreline surveys showed that radiation levels at these locations were comparable to levels in the last few years (which agrees with the corresponding TLD dose rate observations in 1990).

An annual aerial survey of the Site perimeter was performed using a scintillation detector and indicated no unaccountable or unusual sources of radiation. Radiation levels near the 100-N Area were slightly elevated, as expected.



S9111009.3

**Figure 4.38. Thermoluminescent Dosimeter (TLD) Locations on the Hanford Reach of the Columbia River, 1990**

**Table 4.16. Locations and Average Dose Rates for External Radiation Along the Hanford Reach of the Columbia River, 1990**

Location	Map Location <sup>(a)</sup>	Dose Rate, mrem/yr		
		Maximum	Minimum	Average <sup>(b)</sup>
Typical Shoreline Area <sup>(c)</sup>	1-21	118 ± 16%	71 ± 15%	89 ± 6%
100-N Area Shoreline <sup>(d)</sup>	22-25	292 ± 7%	155 ± 14%	209 ± 31%
All Shoreline				108 ± 19%
Immersed in Columbia River <sup>(c)</sup>		38 ± 13%	37 ± 21%	37.5 ± 3%

(a) All locations shown in Figure 4.38; immersion points at Richland Pumphouse and Coyote Rapids.

(b) Averages  $\pm$  2 times the standard error of the calculated mean (SEM). The averages and 2 SEM were computed using station averages rather than individual measurements.

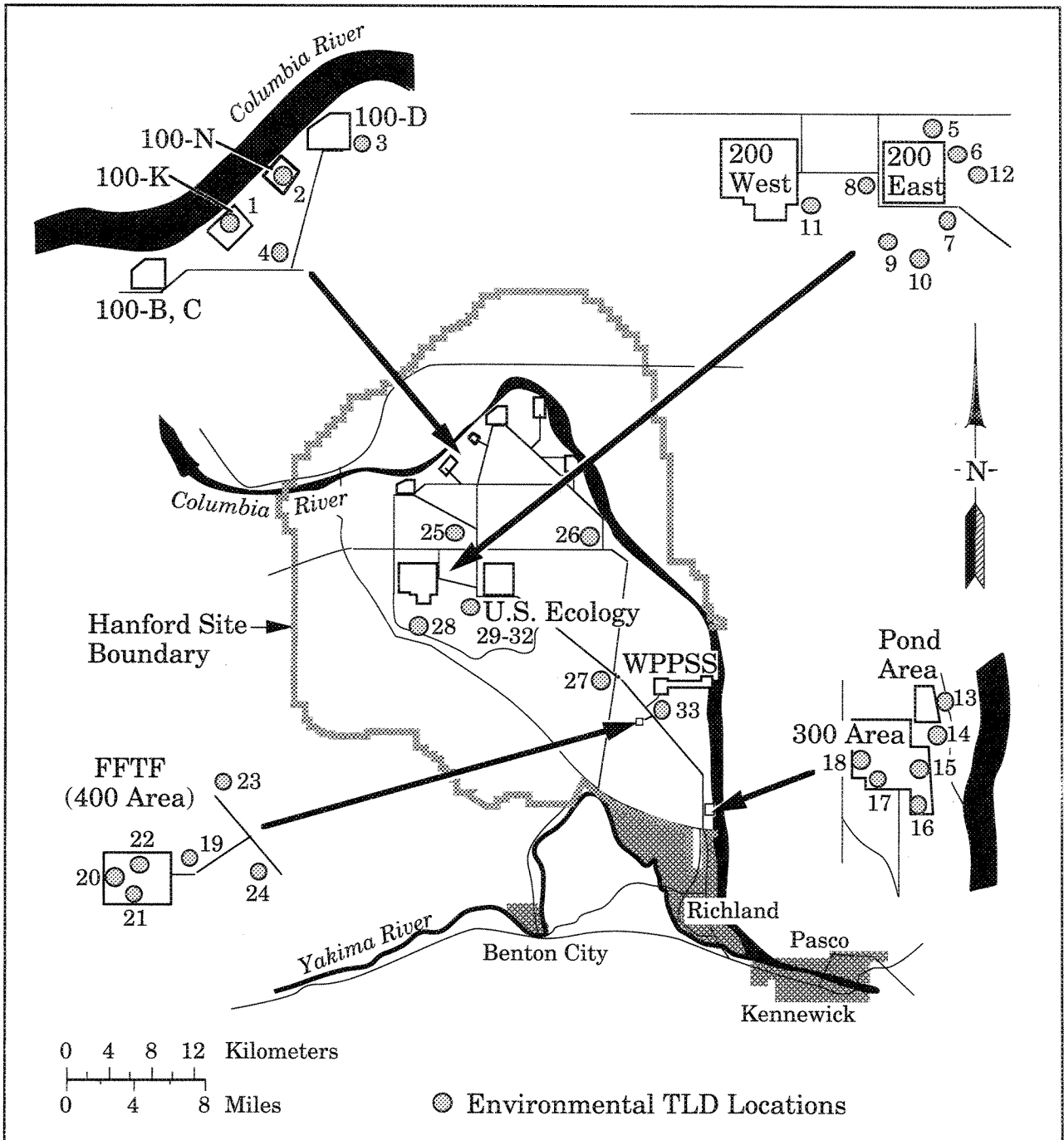
(c) Quarterly integrated readings in mR were converted to annual dose equivalent rates.

(d) Monthly integrated readings in mR were converted to annual dose equivalent rates.

Unlike many other monitoring results, road, rail, waste site, shoreline, and aerial survey results are not listed in Bisping (1991), but are kept in the files of the Surface Environmental Surveillance Project at PNL.

In 1988, an extensive aerial radiological survey capable of detecting very small changes in gamma ray radiation levels coming from ground-level sources was performed over the Site and the surrounding areas (EG&G 1990). The final report for this study was received and reviewed in October 1990. The data from this study indicated that the radionuclides and associated gamma rays detected were generally consistent with those expected from normal background sources and the past and present activities at the Site. The external dose rates interpreted from this

study were about 10  $\mu$ rem/hr, or 88 mrem/yr, which agrees well with average TLD-measured dose rates for the Site and perimeter locations during the past few years. Some operating areas were determined to have external gamma radiation levels approximately 100 times higher than this typical background level, but these are inaccessible to the public and are currently under operational safety controls. This study showed that the total amount of publicly accessible land area known to have elevated external radiation levels from past Hanford operations (primarily areas on the Hanford Reach of the Columbia River) has decreased since a similar 1978 study (EG&G 1978). This amount of land is expected to decline further in response to the decay of artificial radionuclides in some river sediments and changing Site operations.



S9111009.2

Figure 4.39. Onsite External Radiation Measurement Locations, 1990

Table 4.17. Onsite External Penetrating Dose Measurements, 1990

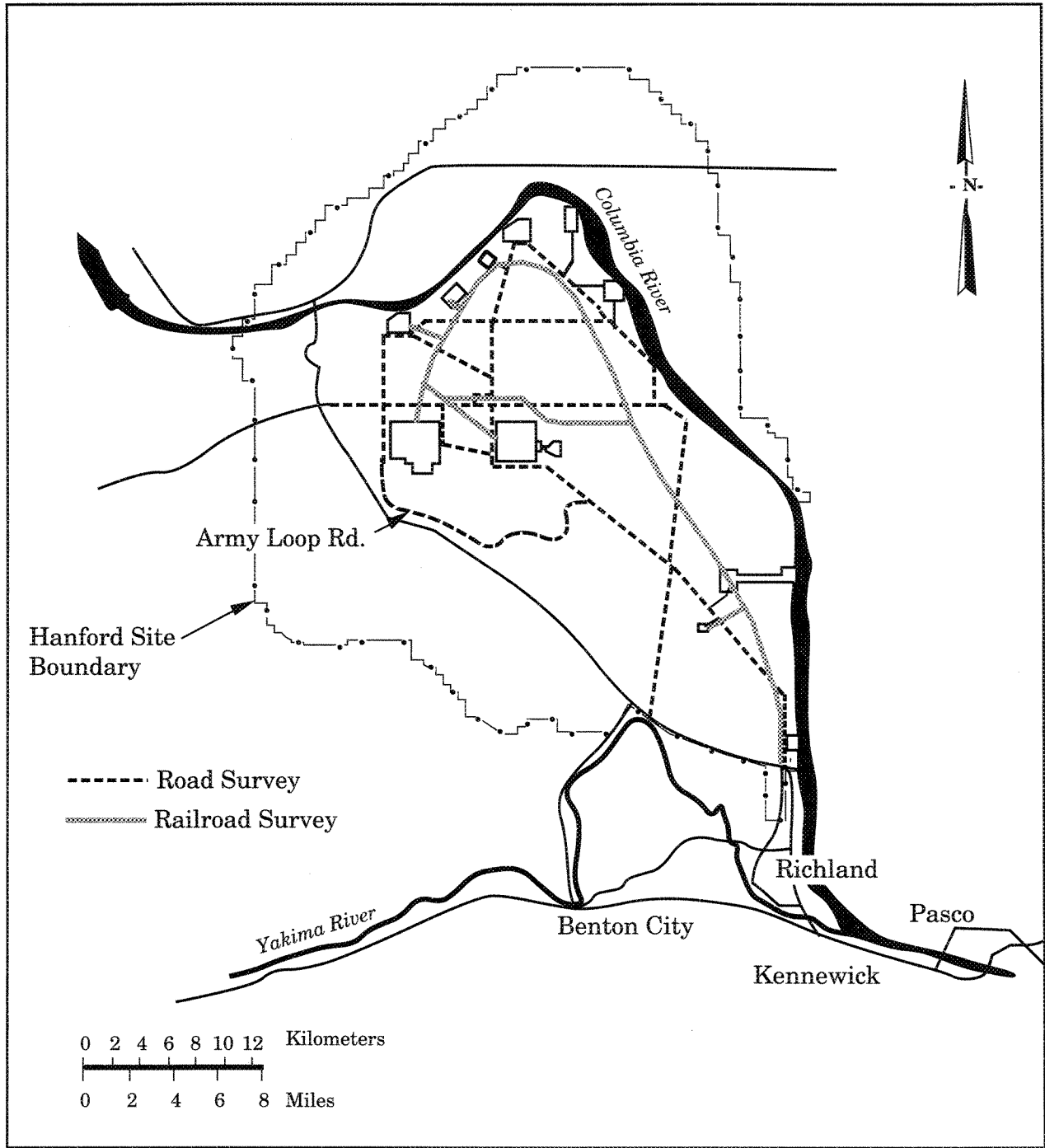
Location	Map Location <sup>(b)</sup>	Dose Rate <sup>(a)</sup> , mrem/yr		
		Maximum	Minimum	Average <sup>(c)</sup>
100 Areas	1-4	92 ± 12%	79 ± 10%	84 ± 7%
200 Areas	5-12	91 ± 12%	72 ± 11%	84 ± 5%
300 Area	13-18	88 ± 11%	79 ± 9%	82 ± 4%
400 Area	19-24	84 ± 12%	73 ± 14%	82 ± 4%
600 Area	25-33	145 ± 8%	81 ± 15%	93 ± 15%
All Onsite				86 ± 5%

(a) Quarterly integrated readings in mR were converted to annual dose equivalent rates.

(b) Locations are identified in Figure 4.39.

(c) Averages ± 2 times the standard error of the calculated mean (SEM). The averages and 2 SEM were computed using station averages rather than individual measurements.





S9111057.20

Figure 4.40. Road and Railroad Survey Routes, 1990



## 4.8 Potential Radiation Doses from 1990 Hanford Operations

Present and past operations at Hanford have resulted in the release of radionuclides into the surrounding environment. Members of the public have potentially been exposed to low levels of radiation from these effluents through a variety of pathways. The potential radiation doses<sup>(a)</sup> to the public in 1990 from Hanford operations were calculated for the hypothetical maximally exposed individual (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 1990 from Hanford operations was 0.03 mrem ( $3 \times 10^{-4}$  mSv), compared to 0.05 mrem ( $5 \times 10^{-4}$  mSv) reported for 1989. The potential dose to the local population of 340,000 persons from 1990 operations was 2 person-rem (0.02 person-Sv), compared to 1 person-rem (0.01 person-Sv) reported for 1989. The 1990 average dose to the population was 0.004 mrem ( $4 \times 10^{-5}$  mSv) per person. The current DOE radiation limit for an individual member of the public is 100 mrem/yr (1 mSv/yr) and the average dose from natural sources is 300 mrem/yr (3 mSv/yr). The MEI potentially received 0.03% of the limit and 0.01% of the dose from typical natural sources. The average individual potentially received 0.006% of the standard and 0.002% of that from typical natural sources.

During 1990, 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 waste-water 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, differing living habits of people, and the fact that the exposure scenarios employed are conservative, the results of the evaluations are maximum likely estimates of the radiation doses potentially received by residents of the area surrounding the Hanford Site.

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 1990 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 potentially received by native aquatic animal organisms.

During 1990, various unusual environmental occurrences involved the potentially uncontrolled release of radionuclides into the environment (see Section 2.4, "Environmental Occurrences"). 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 1990 were generally too small to be measured directly once they were dispersed in the offsite environment. For many of the measurable radionuclides, it was not possible to distinguish levels that resulted from worldwide fallout from those that resulted from Hanford releases. Therefore, in nearly all instances, potential offsite doses were estimated using environmental pathway models that calculated concentrations of radioactive materials in the environment from effluent releases reported by the operating contractors.

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. The only two radionuclides routinely found at higher concentrations than predicted from direct discharge from the 100 and 300 operating areas have been  $^3\text{H}$  and  $^{129}\text{I}$ . During 1989,  $^{99}\text{Tc}$  was detected at concentrations at or near the analytical detection limit in 3 of the 24 downstream river samples collected. Even though it was doubtful that this radionuclide was actually present in detectable concentrations, the conservative radiation doses calculated for 1989 included the potential contribution from  $^{99}\text{Tc}$ .

All of the measurements for  $^{99}\text{Tc}$  in the Columbia River water samples collected in 1990 were below the analytical detection limit, implying that the few positive measurements observed last year most likely resulted from the random measurement variation normally experienced with these types of measurements. Therefore, only the  $^3\text{H}$  and  $^{129}\text{I}$  concentrations in the river were used to calculate the doses from riverbank seepage for 1990.

Although the uncertainty associated with the radiation dose calculations has not been quantified, whenever Hanford-specific data were not available for parameter values (i.e., plant uptake and consumption factors) conservative values were selected for use in models. Thus,

doses calculated using these 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, available environmental pathways of exposure to radionuclides in Hanford effluents. In reality, such a combination of maximized parameters is unlikely to apply to a 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. For several years, the MEI was in the Riverview irrigation district across the river from Richland. At that location, the individual could be exposed not only to airborne pathways but also to drinking water and to irrigated crops, both of which rely on the Columbia River for their water source.

In 1988, Ringold was identified as the appropriate location for the MEI. Ringold is closer to the sources of airborne effluents and is still exposed to most of the river-water pathways affected by Hanford liquid discharges. The assumed Ringold MEI resides 26 km (16 mi) east-southeast from the 200 Areas, 30 km (19 mi) south-east of the 100-N Area, 13 km (8 mi) north of the 300 Area, and 11 km (7 mi) northeast of the 400 Area. Drinking water at Ringold is obtained from wells. Ringold contains several farms along the Columbia River across from the Hanford Site. Except for the Columbia River drinking water pathway, the MEI at Ringold can be exposed to all the same environmental pathways as the former MEI at Riverview. The calculated dose to the MEI at Ringold in 1990 was only slightly higher than the potential dose calculated for an MEI at the Riverview location.

The following exposure pathways were included in the calculation of doses potentially received by the MEI for 1990: 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, and consumption of fish taken from the Columbia River for recreation. The MEI for 1990 was postulated to be an individual who:

- was a resident of the Ringold area
- 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 from deep wells not affected by Hanford effluents.

Doses to the MEI were calculated using the effluent data in Section 4.1, Tables 4.1 through 4.7, and measured quantities of  $^3\text{H}$  and estimated quantities of  $^{129}\text{I}$  present in the Columbia River from river bank springs as input to the GENII code. The calculated doses for the MEI are summarized in Table 4.18. These values include the potential doses received from exposure to liquid and airborne effluents during 1990, as well as the committed dose from radionuclides that were deposited in the body during 1990 via inhalation and ingestion. Site-specific parameters for food pathways, diet, and recreational activity used for the dose calculations are contained in Appendix C.

The total dose to the hypothetical MEI in 1990 was calculated to be 0.03 mrem ( $3 \times 10^{-4}$  mSv)

**Table 4.18. Doses to the Hypothetical Maximally Exposed Individual from 1990 Hanford Operations**

		Operating Area Contribution				
		Doses, mrem <sup>(a)</sup>				
Effluent	Pathway	100 Areas	200 Areas	300 Area	400 Area	Pathway Total
Air	External <sup>(b)</sup>	3 x 10 <sup>-6</sup>	2 x 10 <sup>-5</sup>	1 x 10 <sup>-8</sup>	2 x 10 <sup>-4</sup>	2 x 10 <sup>-4</sup>
	Inhalation	2 x 10 <sup>-6</sup>	8 x 10 <sup>-4</sup>	5 x 10 <sup>-5</sup>	4 x 10 <sup>-6</sup>	8 x 10 <sup>-4</sup>
	Foods <sup>(c)</sup>	2 x 10 <sup>-6</sup>	0.01	2 x 10 <sup>-5</sup>	4 x 10 <sup>-5</sup>	0.01
Water	External <sup>(d)</sup>	2 x 10 <sup>-4</sup>	1 x 10 <sup>-7</sup>	(g)	(h)	2 x 10 <sup>-4</sup>
	Foods <sup>(e)</sup>	0.005	0.003	---	---	0.008
	Fish <sup>(f)</sup>	0.008	2 x 10 <sup>-4</sup>	---	---	0.008
	Total	0.01	0.02	7 x 10 <sup>-5</sup>	2 x 10 <sup>-4</sup>	0.03

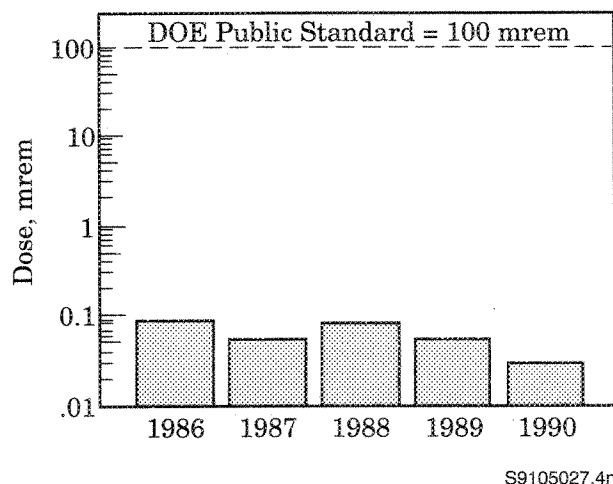
- (a) To convert these dose values to mSv, divide them by 100.  
 (b) Includes air submersion and exposure to ground-deposited radionuclides.  
 (c) Includes consumption of all foodstuffs contaminated via deposition from the air.  
 (d) External exposure during river recreation.  
 (e) Includes consumption of all foodstuffs contaminated via irrigation water and external exposure to ground contaminated via irrigation.  
 (f) Consumption of fish taken from the Columbia River.  
 (g) The 300 Area does not contribute doses at the maximally exposed individual's location through water pathways.  
 (h) There are no releases to the river from the 400 Area.

compared to 0.05 mrem ( $5 \times 10^{-4}$  mSv) in 1989. The primary reason for the decrease was the absence of detectable  $^{99}\text{Tc}$  in river water in 1990. The primary pathways contributing to this dose were:

- consumption of food containing radionuclides (primarily  $^{129}\text{I}$ ) deposited from the air (43%)
- consumption of fish containing radionuclides (primarily  $^{90}\text{Sr}$  and  $^{137}\text{Cs}$ ) from the Columbia River (28%)
- consumption of food irrigated with Columbia River water, primarily from  $^3\text{H}$  and  $^{90}\text{Sr}$  (23%).

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 0.03% of the DOE limit.

The dose from 1990 Hanford operations for the MEI at Ringold is compared with the doses reported for 1986 through 1990 in Figure 4.41. During each year the doses were estimated using methods and computer codes that were current at the time. Doses were estimated for the location determined to potentially result in the highest dose to the MEI. During the period 1986 through 1988 both the computer code to calculate the doses



**Figure 4.41. Calculated Effective Dose Equivalent to the Hypothetical Maximally Exposed Individual, 1986 Through 1990**

and the location of the MEI changed. Therefore, some of the change in dose from year to year is from these factors. Specifically, the principal reason for the change between 1987 and 1988 was the change in the location for the MEI. Soldat (1989) presents a comparison of the doses for the 5-year period 1983 through 1987 as calculated by these different methods.

## 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 fixed radiation dosimeters (TLDs) at locations of expected elevated dose rates onsite and at representative locations off-site. 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 a given 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 4.7, "External Radiation Surveillance." The 200 Areas were not used because they are not

accessible to the general public. Radiation measurements made at the 100-N Area shoreline were consistently above background level and represented 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 average dose rate along the 100-N shoreline during 1990 was 0.03 mrem/h ( $3 \times 10^{-4}$  mSv/h), or about 0.02 mrem above the average background dose rate of 0.01 mrem/h ( $1 \times 10^{-4}$  mSv/h) normally observed at offsite shoreline locations. In practice the public can approach the shoreline by boat, but is restricted from stepping onto the shoreline. However, if someone spent time at the 100-N Area shoreline, the external radiation dose rate from Hanford operations would be about 0.02 mrem ( $2 \times 10^{-4}$  mSv) above the background level, per hour spent there. Therefore, in one hour a person could receive a 0.02 mrem ( $2 \times 10^{-4}$  mSv) dose. This is equivalent to, and would be in addition to, the Ringold MEI dose, if such an event occurred.

The FFTF Visitors Center, located southeast of the FFTF Reactor building, provides public access to the 400 Area. Dose rates measured at this location during 1990 were essentially equal to normal background radiation levels [0.01 mrem/h ( $1 \times 10^{-4}$  mSv/h)].

### Sportsman Dose

Wildlife have free access to the Site, creating the potential for contamination. The potential also exists for the movement of some species 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 from the consumption of meat from the wildlife samples that contained the highest radionuclide concentrations, if the animals migrated offsite and were hunted and consumed. These doses would be in addition to the MEI dose. These results are based on 1989 and 1990 measurements.

- The dose from eating 1 kg<sup>(a)</sup> of meat containing the maximum concentration of  $^{137}\text{Cs}$  measured in a deer collected onsite in 1990 is estimated to be  $2 \times 10^{-3}$  mrem ( $2 \times 10^{-5}$  mSv).
- The dose from eating 1 kg of meat containing the maximum concentrations of  $^{60}\text{Co}$  and  $^{137}\text{Cs}$  measured in a duck collected onsite in 1990 is estimated to be 0.1 mrem (0.001 mSv).
- The dose from eating 1 kg of meat containing the maximum amount of  $^{60}\text{Co}$  and  $^{137}\text{Cs}$  measured in a pheasant collected onsite in 1989 is estimated to be 0.1 mrem (0.001 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 1990, ground water was used as a drinking water source at the FFTF Visitors Center. This water is sampled and analyzed throughout the year in accordance with applicable drinking water regulations. Radionuclide concentrations during 1990 were well below applicable drinking water standards, but concentrations of  $^3\text{H}$  and  $^{129}\text{I}$  were detected at levels above typical background values.

Based on measurements for the first 6 months, the potential dose received by a member of the public from drinking 1 L (0.26 gal) of drinking water during a visit to the FFTF Visitors Center was calculated to be  $6 \times 10^{-4}$  mrem ( $6 \times 10^{-6}$  mSv). The maximum organ dose (thyroid) was calculated to be  $7 \times 10^{-4}$  mrem ( $7 \times 10^{-6}$  mSv). These doses are very small percentages of the EPA limit of 4 mrem (0.04 mSv).

(a) 1 kg is approximately 2.2 lb.

## Comparison with Clean Air Act Standards

Limits for the radiation dose to the public from air pathways are provided in 40 CFR 61, Subpart H, of the Clean Air Act (EPA 1990). The regulation specifies that no member of the public should receive more than 10 mrem/yr (0.1 mSv/yr). The 1990 air emissions from Hanford facilities resulted in a calculated dose to the MEI of 0.009 mrem ( $9 \times 10^{-5}$  mSv), which is 0.09% of the limit. Thus, the estimated annual dose from Hanford airborne effluent releases in 1990 was well below the Clean Air Act standard. The dose calculated to demonstrate compliance with the Clean Air Act is required to be generated using the CAP-88 codes. The dose factors in these EPA codes, and other assumptions, differ somewhat from those specified in DOE publications (DOE 1988a, 1988b). For these reasons, the results from calculations performed with CAP-88 are not directly comparable to the air pathway results obtained with GENII.

## 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 and fish, consumption of irrigated foods, and external exposure during aquatic recreation. The regional population dose from 1990 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 4.19. Food pathway, dietary, residency, and recreational activity assumptions for these calculations are given in Appendix C.

The potential dose calculated for the population was 2 person-rem (0.02 person-Sv) in 1990,

Table 4.19. Population Doses from 1990 Hanford Operations

Effluent	Pathway	Operating Area Contribution Doses, person-rem <sup>(a)</sup>				Pathway Total
		100 Areas	200 Areas	300 Area	400 Area	
Air	External <sup>(b)</sup>	$4 \times 10^{-4}$	0.002	$6 \times 10^{-7}$	0.008	0.01
	Inhalation	$4 \times 10^{-4}$	0.1	0.004	$3 \times 10^{-4}$	0.1
	Foods <sup>(c)</sup>	$3 \times 10^{-4}$	1.3	$8 \times 10^{-4}$	0.002	1.3
Water	External <sup>(d)</sup>	$3 \times 10^{-4}$	$4 \times 10^{-7}$	$1 \times 10^{-6}$	(e)	$3 \times 10^{-4}$
	Foods <sup>(f)</sup>	0.006	0.003	$2 \times 10^{-4}$	---	0.009
	Fish <sup>(g)</sup>	0.003	$1 \times 10^{-4}$	$8 \times 10^{-5}$	---	0.003
	Drinking Water	0.01	0.1	$6 \times 10^{-4}$	---	0.1
	Total	0.02	2	0.006	0.01	2

(a) To convert these dose values to mSv, divide them by 100.

(b) Includes air submersion and exposure to ground-deposited radionuclides.

(c) Includes consumption of all foodstuffs contaminated via deposition from the air.

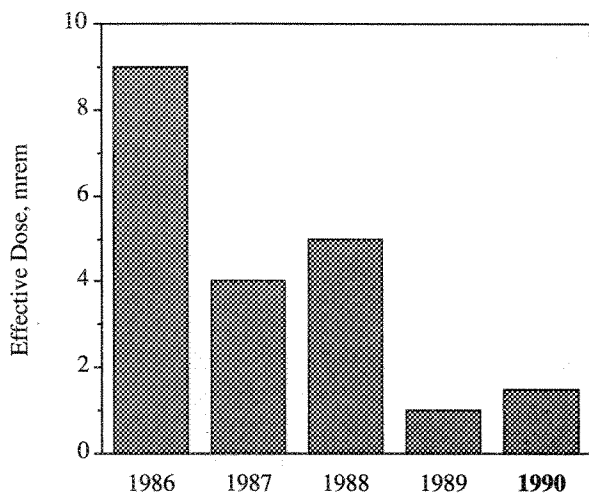
(d) External exposure during river recreation.

(e) There are no releases to the river from the 400 Area.

(f) Includes consumption of all foodstuffs contaminated via irrigation water and external exposure to ground contaminated via irrigation.

(g) Consumption of fish taken from the Columbia River.





**Figure 4.42. Calculated Effective Dose Equivalent to the Population Within 80 km (50 mi) of Hanford, 1986 Through 1990**

compared to 1 person-rem (0.01 person-Sv) in 1989. The increase in the estimated radiation dose for 1990 was a result of an increase in the annual average population-weighted atmospheric dispersion factor for the 100-N Area by a factor of 2, and an increase by 50% in this factor for the 200 Areas.

The 80-km (50-mi) population doses attributed to 1986 through 1990 Hanford operations are compared in Figure 4.42.

Primary pathways contributing to the 1990 dose to the population were:

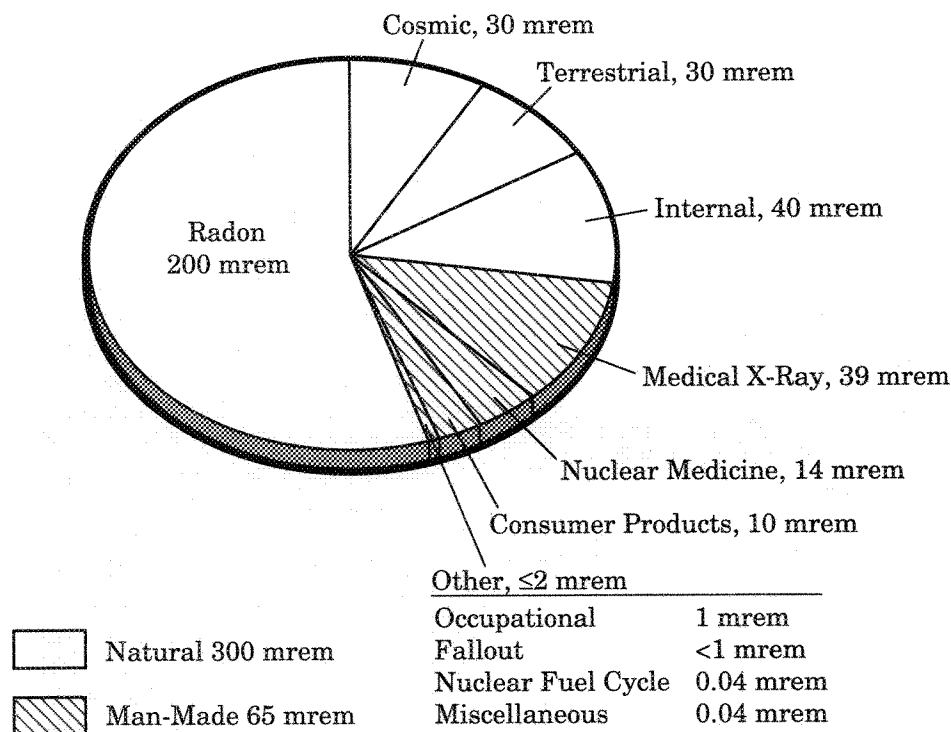
- consumption of foodstuffs contaminated with radionuclides, principally  $^{129}\text{I}$ , released with gaseous effluents from the PUREX Plant stack (87%)
- inhalation of and submersion in radionuclides, principally the radioactive decay products thoron ( $^{220}\text{Rn}$ ),  $^{239,240}\text{Pu}$ , and  $^{241}\text{Am}$  that were released to the air from the PUREX Plant stack (6%)
- consumption of drinking water contaminated with radionuclides, principally  $^3\text{H}$ , released to the Columbia River at Hanford (7%).

The average per capita dose from 1990 Hanford operations, based on a population of 340,000 within 80 km (50 mi), was 0.006 mrem ( $6 \times 10^{-5}$  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 internal body radioactivity, and inhalation of naturally occurring radon. The national average radiation doses from these other sources are illustrated in Figure 4.43. The estimated per capita dose to individual members of the public from Hanford sources is a small fraction (approximately one one-millionth) of the annual per capita dose (300 mrem) from natural background.

The dose to the MEI and the 80-km (50-mi) population from Hanford effluents is compared to appropriate standards and natural background radiation in Table 4.20. This table shows that the doses from Hanford operations in 1990 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 radioactive waste burial ground at Hanford operated by U.S. Ecology, the nuclear generating station at Hanford operated by Washington Public Power Supply System, the nuclear fuel production plant operated by Advanced Nuclear Fuels (now Siemens Nuclear Power Corporation), the low-activity radioactive waste compacting facility operated by Allied Technology Group Corporation, and a decontamination facility operated by Pacific Nuclear Services. With information gathered from the mentioned companies, it was conservatively determined that the total 1990 individual dose



S9111080.1

**Figure 4.43. Annual Radiation Doses from Various Sources (mrem) (NCRP 1987)**

**Table 4.20. Summary of Doses to the Public in the Vicinity of Hanford from Various Sources, 1990**

Source	Maximum Individual (mrem) <sup>(a)</sup>	80-km Population (person-rem) <sup>(a)</sup>
All Hanford Effluents	0.03	2
DOE Limit	100	---
Percent of DOE Limit	0.03%	---
Background Radiation	300	100,000
Hanford Doses Percent of Background	0.01%	0.002%
Gaseous Effluents from Hanford Calculated with CAP-88	0.009	---
EPA Air Standard	10	---
Percent of EPA Standard	0.09%	---

(a) To convert the dose values to mSv or person-Sv, divide them by 100.

from their activities is approximately equivalent to the MEI dose from Hanford DOE operations of 0.03 mrem ( $3 \times 10^{-4}$  mSv). Therefore, the combined dose from Hanford area non-DOE and DOE sources to a member of the public for 1990 was well below any regulatory dose limit.

## Hanford Public Radiation Dose in Perspective

Several scientific studies (NRC 1980; NRC 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 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 ( $4 \times 10^{-7}$ ) 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 1988e). 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. Following future scientific studies and data interpretation, the value used may eventually change and become more accurate.

Government agencies are trying to determine what level of risk is safe for members of the public exposed to pollutants from industrial activities (e.g., DOE facilities, nuclear power plants, chemical plants, and hazardous waste sites). All of these industrial activities are considered beneficial to people in some way--by providing electricity, national defense, waste disposal, and consumer products. These government agencies have a complex task in establishing environmental regulations that maintain levels of risks safe 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 4.21 compares the hypothetical 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 shown in Table 4.22. Listed are some activities considered approximately equal in risk to the hypothetical risk from the potential radiation dose from Hanford releases in 1990 received by an MEI.

**Table 4.21. Estimated Risk from Various Activities and Exposures<sup>(a)</sup>**

Activity or Exposure Per Year	Risk of Fatality Per Person
Riding or driving in a passenger vehicle (300 miles)	$2 \times 10^{-6}(b)$
Home accidents	$100 \times 10^{-6}(b)$
Drinking 1 can of beer or 4 ounces of wine per day (liver cancer/cirrhosis)	$10 \times 10^{-6}$
Pleasure boating (accidents)	$6 \times 10^{-6}(b)$
Firearms, sporting (accidents)	$10 \times 10^{-6}(b)$
Smoking 1 pack of cigarettes per day (lung/heart/other diseases)	$3600 \times 10^{-6}$
Eating 4 tablespoons of peanut butter per day (liver cancer)	$8 \times 10^{-6}$
Eating 90 pounds of charcoal-broiled steaks (gastrointestinal-tract cancer)	$1 \times 10^{-6}$
Drinking chlorinated tap water (trace chloroform--cancer)	$3 \times 10^{-6}$
Taking contraceptive pills (side effects)	$20 \times 10^{-6}$
Flying as an airline passenger (cross country roundtrip--accidents)	$8 \times 10^{-6}(b)$
Flying as an airline passenger (cross country roundtrip--radiation)	$0 \text{ to } 5 \times 10^{-6}$
Natural background radiation dose (300 mrem, 3 mSv)	$0 \text{ to } 120 \times 10^{-6}$
Dose of 1 mrem (0.01 mSv)	$0 \text{ to } 0.4 \times 10^{-6}$
Dose to the maximally exposed individual living near Hanford in 1990 (0.03 mrem, 0.0003 mSv)	$0 \text{ to } 0.01 \times 10^{-6}$

- (a) These values are generally accepted approximations with varying levels of uncertainty; there can be significant variation due to 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 current, accepted most conservative value.

**Table 4.22. Activities Comparable in Risk to that from the 0.03-mrem Dose Calculated for the 1990 Maximally Exposed Individual**

Driving or riding in a car 3 km (2 mi)  
 Smoking 1/40 of a cigarette  
 Flying 7 km (4 mi) on a commercial airline  
 Eating 2 tablespoons of peanut butter  
 Eating one 0.5-kg (18-ounce) charcoal-broiled steak  
 Drinking about 2.8 L (3 quarts) of chlorinated tap water  
 Being exposed to natural background radiation for about 1 hour in a typical terrestrial location  
 Drinking about one-half of a can of beer or one-half a glass of wine per week for a year

## Absorbed Dose Rates to Native Aquatic Animal Organisms

In accordance with a DOE Order 5400.5 interim requirement for management and control of liquid discharges, preliminary estimates have been made of the potential radiation doses to

native aquatic animal organisms. These preliminary dose estimates, which are based on very conservative exposure scenarios, indicate that the limit of 1 rad per day is unlikely to be exceeded, and that doses to organisms are probably a small percentage of the limit. Further analysis of sampling data and refined calculations are anticipated to result in better estimates of the doses to native aquatic animal organisms.

## Ground-Water Protection and Monitoring Program



## 5.0 Ground-Water Protection and Monitoring Program

Ground-water environmental surveillance is being performed at the Hanford Site as an integral part of the Hanford Site Groundwater Protection Management Program (DOE 1989e). The program includes monitoring at active waste disposal facilities to comply with the Resource Conservation and Recovery Act (RCRA); characterization of inactive waste disposal sites to comply with requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); operational monitoring in and adjacent to reactor and chemical processing facilities; and environmental surveillance to assess the impact of Hanford operations on ground water both onsite and offsite independently of the operating contractors' programs. This section discusses sample collection and analysis and the distribution of various radiological and nonradiological constituents in the unconfined and confined aquifers.

### Sample Collection and Analysis

Ground-water samples were collected from 623 monitoring wells during 1990. These samples were collected as part of the Hanford Ground-Water Environmental Surveillance Program and other ground-water monitoring programs. Ground-water monitoring was conducted at the facilities listed in Table 5.1 to comply with RCRA. The RCRA monitoring is the responsibility of the contractor operating each facility, and thus work was accomplished by Westinghouse Hanford Company and Pacific Northwest Laboratory (PNL). Additional monitoring was conducted by Westinghouse Hanford Company as part of a liquid effluent study (WHC 1990).

Although these three programs are managed by different organizations, all samples are collected by PNL sampling teams following a single set of procedures. United States Testing Company, Inc. (UST) analyzed the samples collected before

May 30, 1990, for all programs. The analytical services contract with UST was terminated at that time (see Section 2.3). Samples collected after June 1 were analyzed by IT-Analytical Services or PNL. A common data base is used by all three organizations so that each ground-water monitoring program has access to all data collected on the Hanford Site.

Most ground-water monitoring wells on the Site are 15 or 20 cm in diameter and are constructed of steel casing. Several small-diameter (5-cm) wells are sampled for radionuclides only. 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 some radionuclides were measured at a few locations on the Hanford Site (Eddy et al. 1978). Wells monitoring the confined aquifer have screens or perforated casing within the monitored aquifer. Wells drilled before 1985 were generally constructed with carbon steel casing. Wells recently constructed for RCRA monitoring projects have been constructed with stainless steel casing. Samples were collected following documented sampling procedures (PNL 1989a) based on EPA guidelines (EPA 1986b).

Analytical techniques used are described in the Hanford Site Environmental Monitoring Plan DOE (1991b). The species analyzed for are listed in Table 5.2.

### Radiological Analysis

Most ground-water samples for the Hanford Ground-Water Environmental Surveillance Program were analyzed for  $^3\text{H}$ . Selected samples were subjected to more extensive radiological analysis by alpha-, beta-, and gamma-counting techniques, in many cases accompanied by selective radiochemical separations. Uranium analyses were performed by a laser fluorescence

**Table 5.1. Facility-Specific Monitoring Projects**

<u>Area</u>	<u>Facility</u>
100-H	183-H Solar Evaporation Basins
100-D	100-D Pond
100-N	1301-N Crib
100-N	1324-N/NA Ponds
100-N	1325-N Crib
200	216-A-10 Crib
200	216-A-29 Ditch
200	216-A-36B Crib
200	Grout Treatment Facility
200	Liquid Effluent Retention Facility
200	216-B-63 Ditch
200	216-S-10 Pond
200	216-U-12 Crib
200	Single-Shell Tanks
200	Low-Level Burial Grounds
200	2101-M Pond
300	Process Trenches
600	216-B-3 Pond
600	Solid Waste Landfill
600	Nonradioactive Dangerous Waste Landfill

method. The radionuclides analyzed for are listed in Table 5.2. The radiological monitoring network for most areas on the Hanford Site is shown in Figure 5.1. Figure 5.2 shows confined aquifer monitoring wells. Figures 5.3 and 5.4 show environmental surveillance, RCRA, and other monitoring wells in the 200-East and 200-West Areas, respectively.

### **Chemical Analysis**

A subset of the radiological monitoring network was used for chemical surveillance. Chemical sampling wells were selected primarily for their proximity to known active and inactive chemical disposal sites in the 100, 200, 300, 400, and 600 Areas. Table 5.3 lists major contaminants found in the 100, 200, and 300 Areas. The list of chemicals analyzed for is presented in Table 5.2.

## **Results**

Detailed discussions of ground-water monitoring results are presented annually in another document (e.g., Evans et al. 1990). Tables of all results for each well and constituent are reported in a companion volume to this report (e.g., Bryce and Gorst 1990). Highlights of those results are discussed below. Ground-water monitoring information for the Liquid Effluent Study is reported by Westinghouse Hanford Company (WHC 1990) and for drinking water supplies on the Hanford Site by Hanford Environmental Health Foundation (Thurman 1991).

Concentrations of radionuclides and chemicals in ground water were compared to EPA's Drinking Water Standards (DWS), and DOE's Derived



**Table 5.2. Radiological and Chemical Constituents Analyzed for in the Hanford Ground-Water Environmental Surveillance Program**

Radiological Parameters	Chemical Parameters
<sup>60</sup> Co	pH (field and laboratory)
<sup>103</sup> Ru	Conductance (field)
<sup>106</sup> Ru	Alkalinity
<sup>125</sup> Sb	Total Carbon
<sup>131</sup> I	Total Organic Carbon
<sup>137</sup> Cs	Total Organic Halogens
<sup>241</sup> Am	Be, Na, Mg, Al, K
<sup>3</sup> H	Ca, V, Cr, Mn, Fe, Ni
<sup>14</sup> C	Cu, Zn, Sr, Ag, Cd, Sb, Ba
<sup>63</sup> Ni	F <sup>-</sup> , Cl <sup>-</sup> , NO <sub>3</sub> <sup>-</sup> , PO <sub>4</sub> <sup>-3</sup> , SO <sub>4</sub> <sup>-2</sup>
<sup>90</sup> Sr	As, Se, Pb, Bi
<sup>99</sup> Tc	Hg
<sup>129</sup> I	CN <sup>-</sup>
Uranium Isotopes	NH <sub>3</sub>
Uranium (total)	Volatile Organic Constituents
Plutonium Isotopes	Semi-Volatile Organic Constituents
Gross Alpha	
Gross Beta	

Concentration Guides (DCG) (Tables B.2, B.3, and B.6, Appendix B). Although none of the wells discussed is a drinking water supply well, the standards provide a basis for evaluating levels of contamination. 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 "Applicable Standards and Permits and Environmental Compliance Documentation," Appendix B). The DCG are available only for radionuclides. Derived Concentration Guides are presented in DOE Order 5400.5.

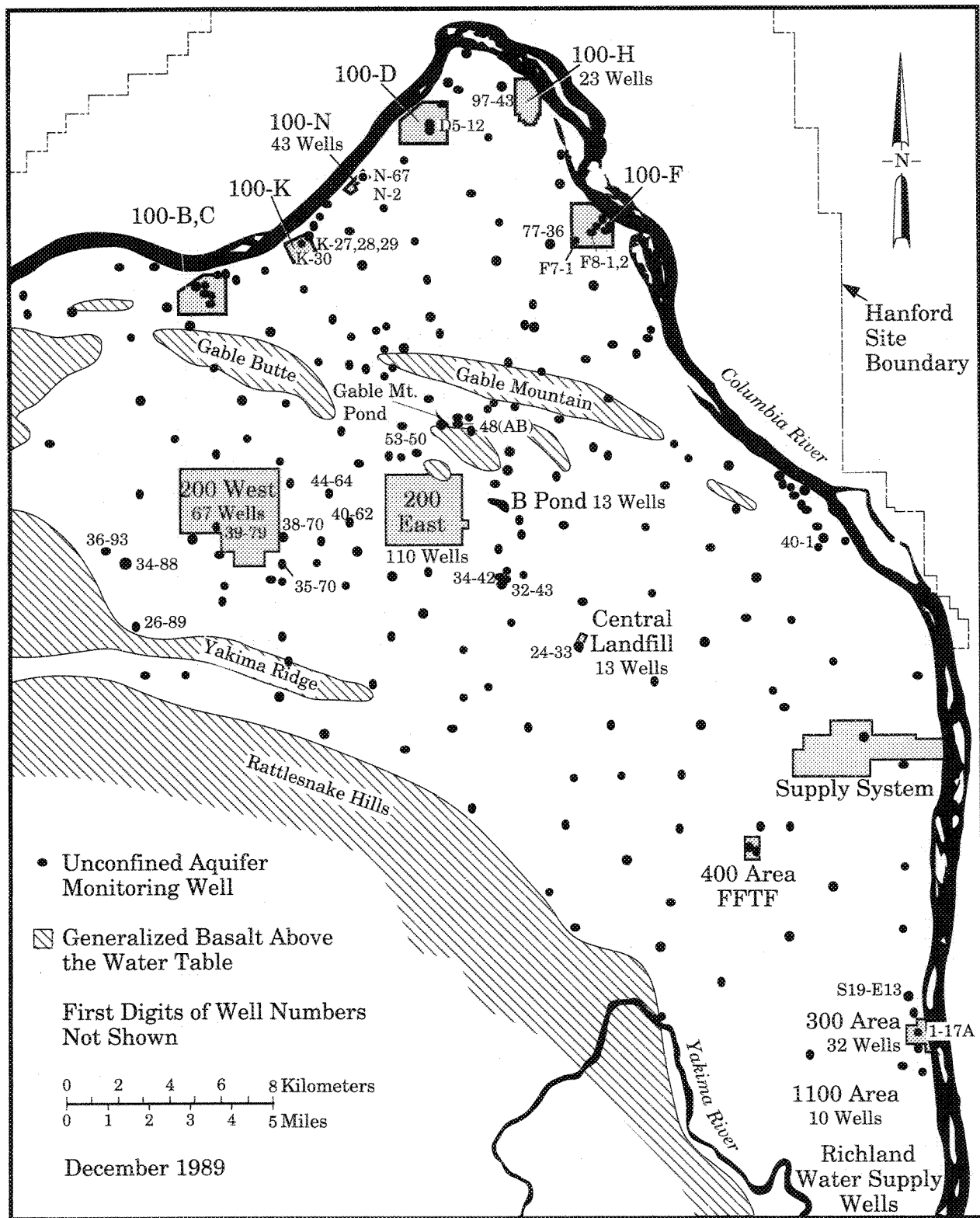
#### **Radiological Monitoring Results for the Unconfined Aquifer**

Radiological constituents monitored were selected based on known operational and waste management practices, physical and chemical

properties of radionuclides of interest, and potential dose considerations. How radiological monitoring constituents <sup>3</sup>H, <sup>60</sup>Co, <sup>90</sup>Sr, <sup>99</sup>Tc, <sup>129</sup>I, <sup>137</sup>Cs, and uranium relate to Site operations is shown in Table 5.3.

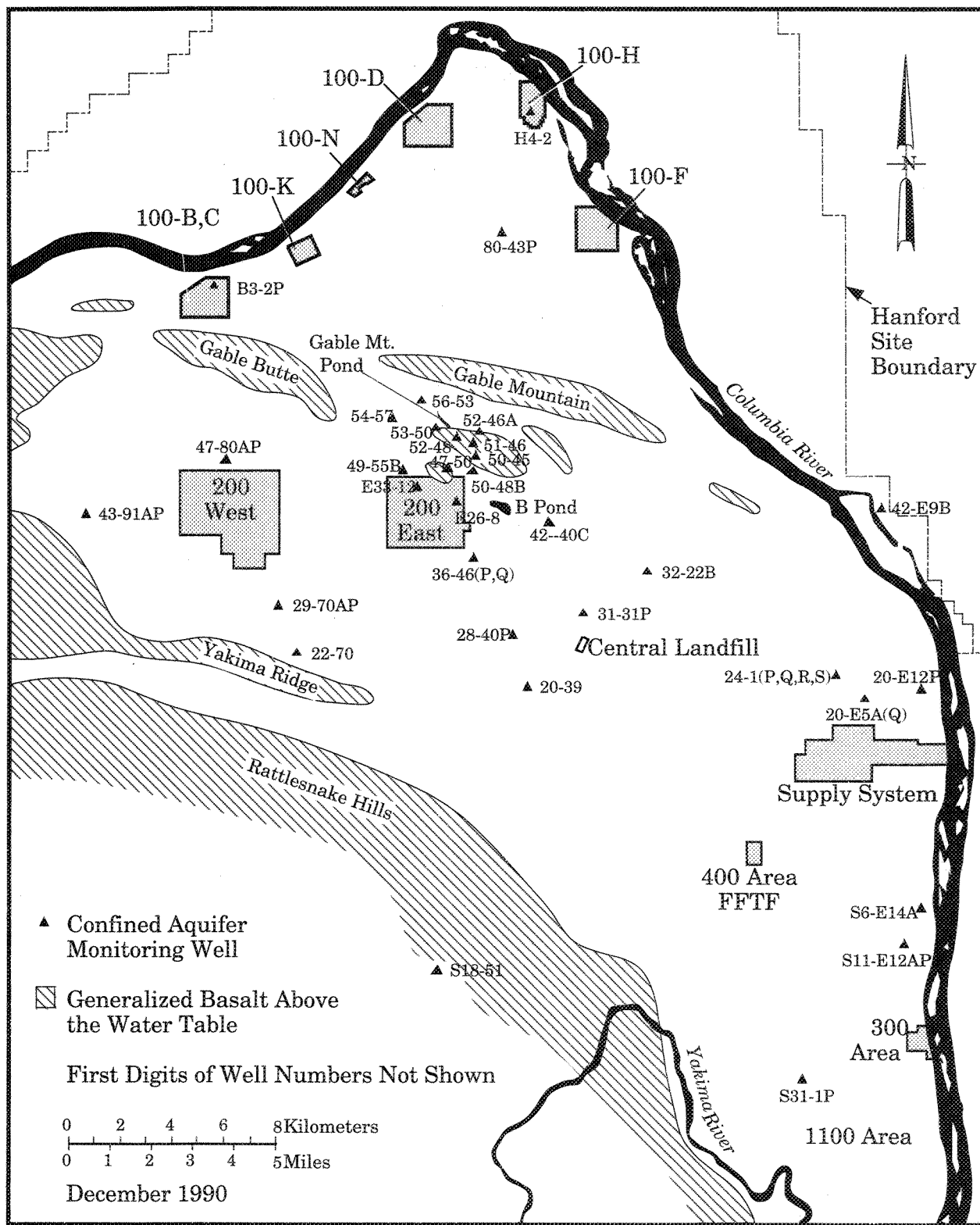
#### **Tritium Concentrations**

Tritium is present in many waste streams discharged to the soil column and is the most mobile radionuclide on the Hanford Site. As a result, <sup>3</sup>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 5.5 shows the 1990 distribution of <sup>3</sup>H in the unconfined aquifer resulting from more than 46 years of Site operations. Contours of <sup>3</sup>H concentrations were based on the analysis of ground-water samples collected from monitoring wells. For wells with multiple <sup>3</sup>H analyses during 1990, an average of the <sup>3</sup>H values for the year



S9111004.40

Figure 5.1. Hanford Site Unconfined Aquifer Monitoring Well Locations, 1990



S9111007.2A

Figure 5.2. Hanford Site Confined Aquifer Monitoring Well Locations, 1990

Figure removed as per DOE guidance.

**Figure 5.3. 200-East Area Monitoring Well Locations, 1990**

Figure removed as per DOE guidance.

**Figure 5.4. 200-West Area Monitoring Well Locations, 1990**

**Table 5.3. Major Chemical and Radiological Ground-Water Contaminants and Their Link to Site Operations**

Facilities Type	Area	Constituents
Reactor Operations	100	$^3\text{H}$ , $^{60}\text{Co}$ , $^{90}\text{Sr}$ , $\text{Cr}^{+6}$ , $\text{SO}_4^{2-}$
Irradiated Fuel Processing	200	$^3\text{H}$ , $^{137}\text{Cs}$ , $^{90}\text{Sr}$ , $^{129}\text{I}$ , $^{99}\text{Tc}$ , $\text{NO}_3^-$ , $\text{Cr}^{+6}$ , $\text{CN}^-$ , $\text{F}^-$ , Uranium, Plutonium
Plutonium Purification	200	$\text{CCl}_4$ , $\text{CHCl}_3$
Fuel Fabrication	300	Uranium, $^{99}\text{Tc}$ , $\text{Cr}^{+6}$ , Trichloroethylene

was used. Data from 1989 were used in locations where 1990 analyses were not available because of the termination of analytical services mid-year.

Tritium concentrations greater than the 20,000-pCi/L DWS were detected in portions of the 100-D, 100-K, 100-N, 200-East, 200-West, 400, and 600 Areas. Well 199-K-30 (Figure 5.6) continued to contain the highest  $^3\text{H}$  concentration within the 100 Areas with a maximum concentration of 823,000 pCi/L, similar to the high for 1989 but somewhat lower than the maximum of 1,220,000 pCi/L in 1988. Well 199-K-27 (Figure 5.6) continued to show a large increase in  $^3\text{H}$  concentrations relative to most of its past history with a maximum of 134,000 pCi/L in 1990. This concentration has risen sharply from a relatively constant level of approximately 2,000 pCi/L through mid-1988. Wells 199-K-28 and 199-K-29, located between and in proximity to the other two wells, continued to contain relatively low  $^3\text{H}$  concentrations (1,860 and 9,730 pCi/L, respectively). The reason for the changes in  $^3\text{H}$  concentration in ground water is not known. The nearby K-East Basins contain irradiated fuel elements and as a result water in the basins contains  $^3\text{H}$  at a concentration of 3,700,000 pCi/L. Records of basin operation show no indication of a leak in the basin, suggesting the basins are most likely not the source of the increased  $^3\text{H}$  observed in 199-K-27.

Tritium concentrations greater than the 2,000,000-pCi/L DCG were detected in eight wells in the 200-East Area. Several wells located in the 200-East Area with  $^3\text{H}$  concentrations greater than the DCG were not monitored in 1990 because

of problems associated with disposal, further compounded by the termination of analytical services in June. In addition,  $^3\text{H}$  concentrations in one well, 299-E17-13, dropped from a high of 3,340,000 pCi/L in 1989 to 751,000 pCi/L in 1990; however, the concentrations in two wells (299-E17-12 and 299-E25-19) rose above the DCG in 1990. The highest  $^3\text{H}$  concentrations in the 200-East Area continued to be in wells near cribs that have received effluents from the Plutonium Uranium Extraction (PUREX) Plant. Tritium concentrations greater than the DCG were present in wells near the 216-A-10, 216-A-36B, 216-A-37-1, and 216-A-45 cribs. The highest ground-water  $^3\text{H}$  concentration measured in the 200-East Area in 1990 was 4,170,000 pCi/L in well 299-E25-19 (January 1990). Tritium concentrations exceeding the DWS continued to occur in most other wells affected by these cribs.

The movement of the widespread  $^3\text{H}$  plume (see Figure 5.5) that extends from the southeastern portion of the 200-East Area to the Columbia River was consistent with patterns noted earlier (Evans et al. 1990; Jaquish and Bryce 1990). Separate  $^3\text{H}$  pulses associated with the two episodes of PUREX Plant 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. Elevated  $^3\text{H}$  concentrations measured in several wells (for example, wells 699-32-43, 699-33-42, 699-36-46, and 699-24-33) downgradient from the

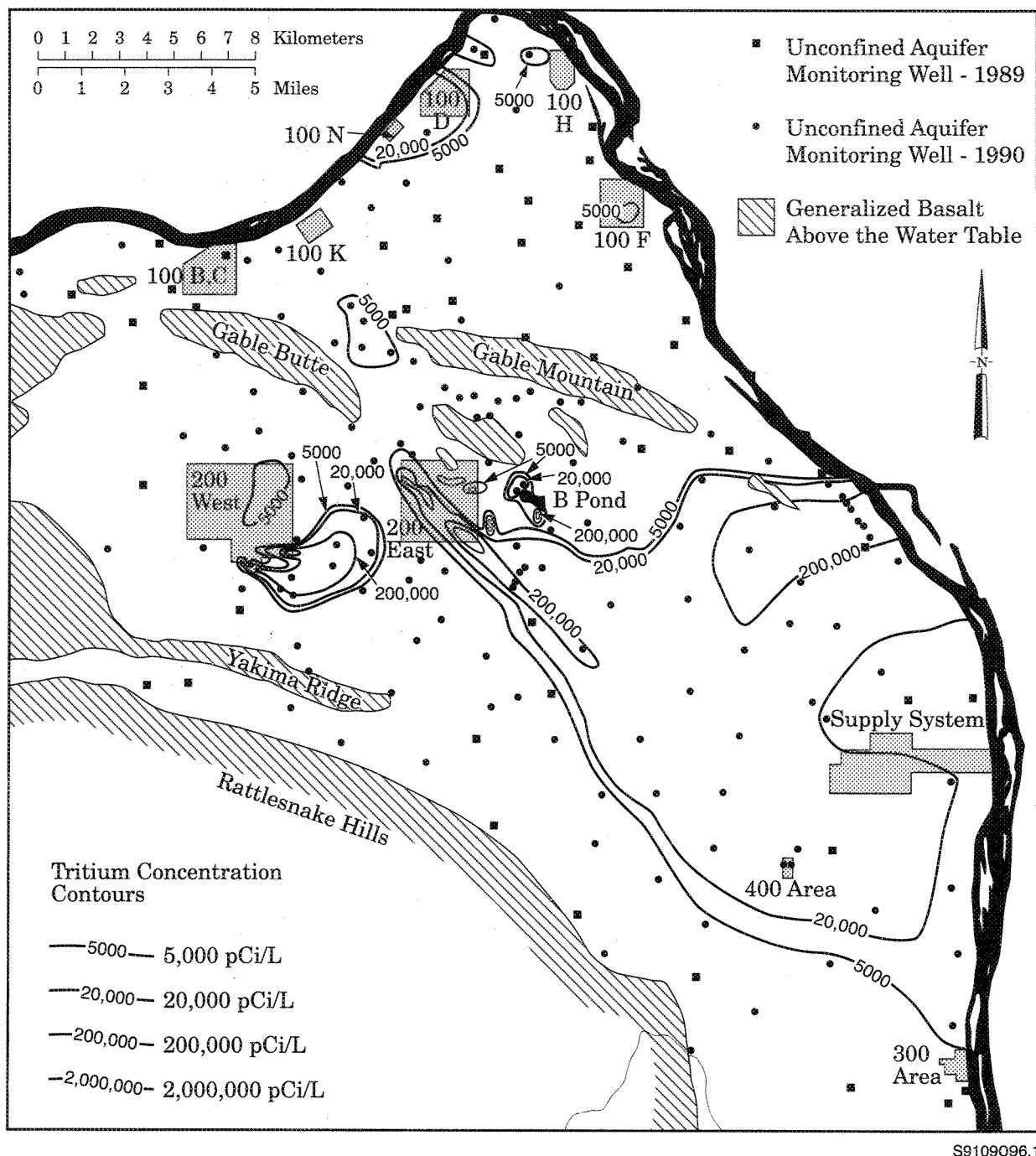
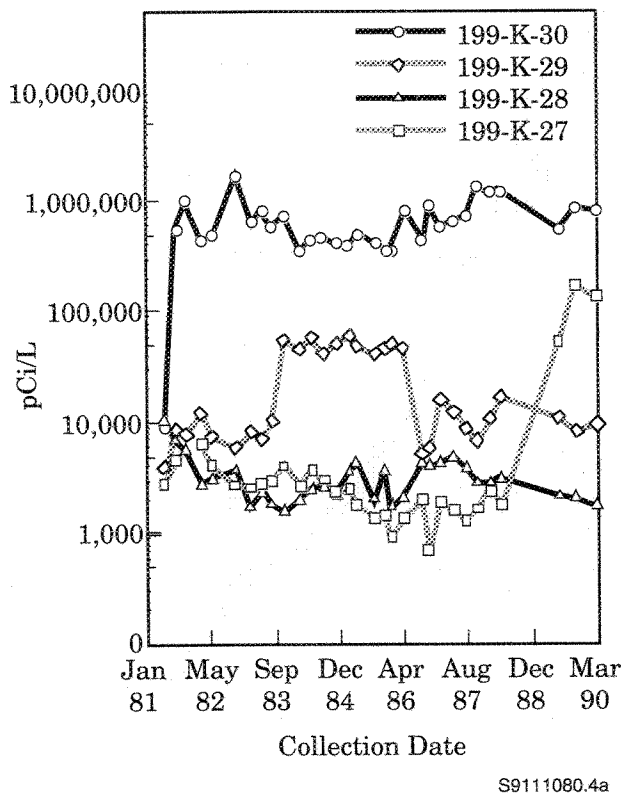


Figure 5.5. Tritium ( $^3\text{H}$ ) Concentrations in the Hanford Site Unconfined Aquifer, 1990



**Figure 5.6. Tritium ( $^3\text{H}$ ) Concentrations in 100-K Area Wells**

200-East Area represent a second pulse of  $^3\text{H}$  moving away from PUREX Plant waste disposal facilities. Large-scale movement of the leading edge of this plume is best observed in well 699-24-33, which clearly shows arrival of the plume in early 1987 following the passage of the plume from the earlier campaign that had reached much higher levels in the mid-1960s. A trend plot of  $^3\text{H}$  concentrations in well 699-24-33 is shown in Figure 5.7. By contrast, a trend plot of the  $^3\text{H}$  concentrations in well 699-40-1, located near the shore of the Columbia River, shows the arrival in the early 1970s of the plume from the first campaign. No effect from the second plume (Figure 5.8) has been observed and may not be at this location. Changes in disposal practices at the Hanford Site will most likely cause this second more recent plume of  $^3\text{H}$  from the 200 Areas to move farther south than did the first plume.

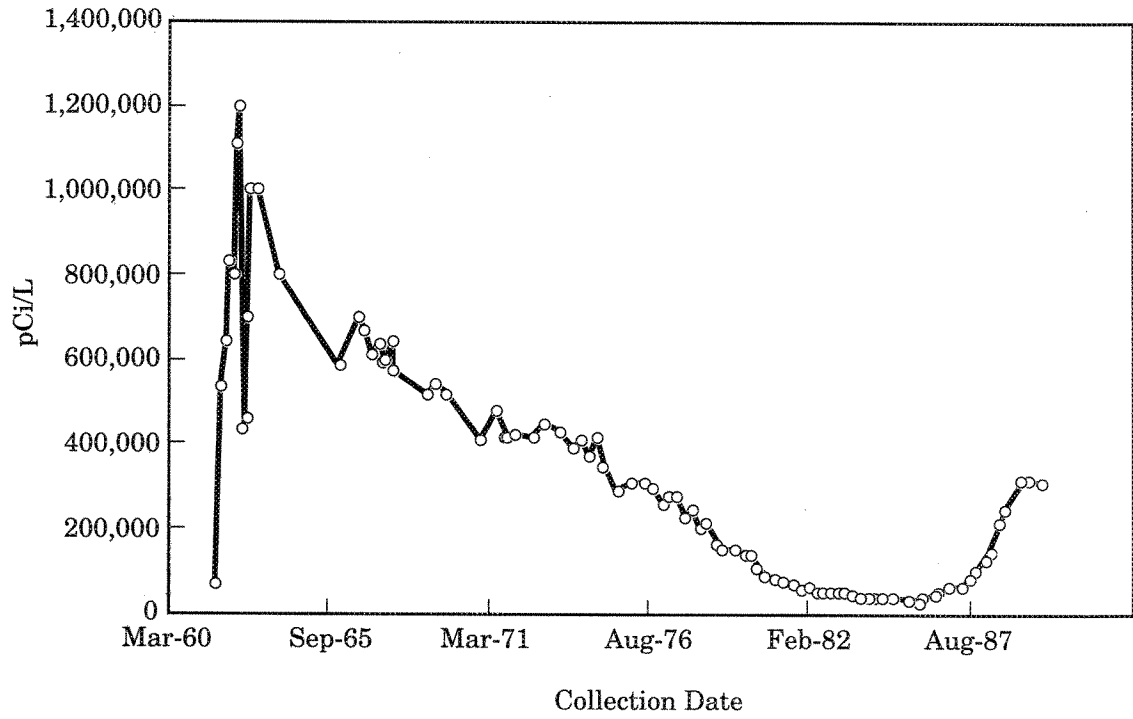
The eastern portion of the plume continues to move to the east-southeast and discharge into the

Columbia River. Migration of the plume continued farther to the south, as indicated by increased  $^3\text{H}$  concentrations in wells near the 300 Area. Figure 5.9 shows the trend of  $^3\text{H}$  concentrations in well 699-S19-E13, located just north of the 300 Area. In recent years, this well has shown a steady increase in  $^3\text{H}$ , having reached a new maximum value of 8,480 pCi/L in April 1990. The plume is not expected to move much farther south because of the influence of the Yakima River on ground-water flow in this area. The Yakima River is at a higher elevation than the ground water in this area, which is at a higher elevation than the Columbia River (Newcomer et al. 1991). As a result, ground water flows from west to east, preventing the contaminant plume from moving south.

The configuration of the western portion of the plume closely matches previous predictions of the direction of contaminant movement from the 200-East Area (Freshley and Graham 1988). Movement to the south may be enhanced 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.

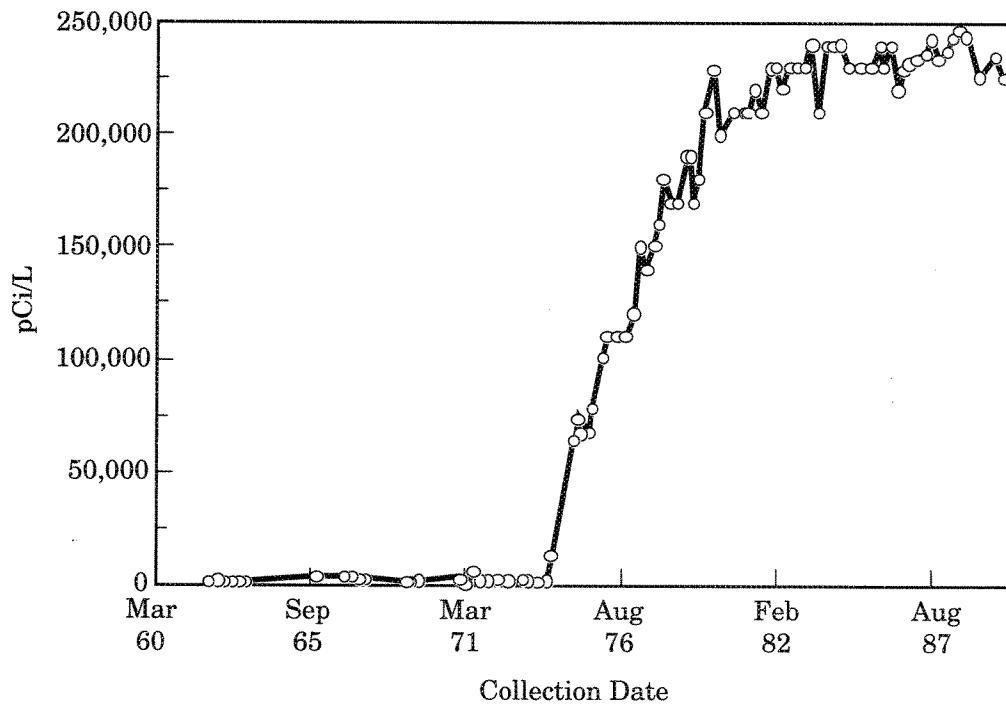
The movement of  $^3\text{H}$  plumes in the 200-West Area was also consistent with previous observations. The plume extending from near the Reduction Oxidation (REDOX) Plant in the southern part of the 200-West Area continued to move slowly to the east and north. Only one well in the 200-West Area (299-W22-9) continued to show  $^3\text{H}$  levels in excess of the DCG during 1990; however, that well contained the highest  $^3\text{H}$  levels of any ground-water well on the Hanford Site. Tritium concentrations in nearby wells within the 200-West Area and in the adjacent 600 Area remained above the DWS and were relatively constant throughout 1990 with the exception of concentrations in well 299-W23-9, which dropped by nearly an order of magnitude in 1990 after remaining nearly constant for several years. Movement of the  $^3\text{H}$  plume extending north and east from the REDOX Plant was indicated by changes in the  $^3\text{H}$  concentrations in several wells in the plume. Concentrations in well 699-35-70 continued to decrease slightly, suggesting that peak concentrations may have moved beyond this well,





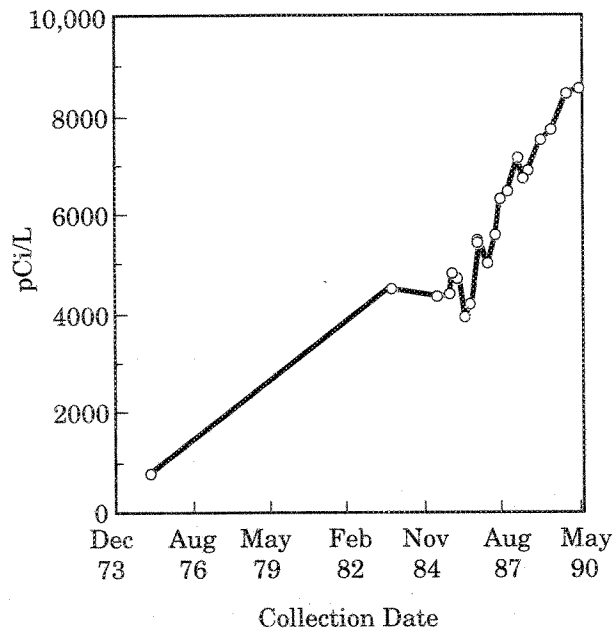
S9111080.3

**Figure 5.7. Tritium ( $^3\text{H}$ ) Concentrations in Well 699-24-33**



S9111080.14

**Figure 5.8. Tritium ( $^3\text{H}$ ) Concentrations in Well 699-40-1**



S9111080.13

**Figure 5.9. Tritium ( $^3\text{H}$ ) Concentrations in Well 699-S19-E13**

although at least part of the decreases seen in this well during the past several years can be accounted for by decay. Plume movement in that area is very slow because of the relatively low hydraulic conductivity of the sediments at the water table. Concentrations in wells near the center of the plume remained relatively constant. The northernmost extent of the plume appeared to be near well 699-40-62. Well 699-44-64, north of well 699-40-62, has shown a small but steady increase during the last 24 months, reaching a new high of 814 pCi/L in April 1990.

### Gross Alpha Concentrations

Gross alpha concentrations were detected in ground water from wells in several areas and may be attributable to the presence of isotopes of plutonium and/or uranium. The DWS for gross alpha is 15 pCi/L, not including uranium. Those wells in the 100-F, 100-H, 200, and 300 Areas where gross alpha exceeded 15 pCi/L contained uranium at levels that would account for the gross alpha level detected. Although levels in a few wells in the 200-East Area remained somewhat above the DWS, gross alpha levels in most

wells in the 200-East Area were low. The highest gross alpha levels measured on the Hanford Site continue to be in wells adjacent to the inactive 216-U-1 and 216-U-2 cribs. Concentrations in these wells continued to decrease during the last year. Wells adjacent to the 216-U-1 and 216-U-2 cribs contained uranium levels that would account for the gross alpha levels detected.

### Gross Beta Concentrations

Gross beta concentrations greater than the 50-pCi/L DWS were found in wells throughout the Site. Gross beta levels can be attributed to one or more of the following radionuclides in ground water:  $^{40}\text{K}$  (naturally occurring);  $^{60}\text{Co}$ ,  $^{90}\text{Sr}$ ,  $^{99}\text{Tc}$ ,  $^{125}\text{Sb}$ ,  $^{137}\text{Cs}$ ,  $^{234}\text{Th}$ , and  $^{234}\text{Pa}$  (uranium radioactive decay products); and to a lesser extent  $^{129}\text{I}$ . During past Site operations, some shorter-lived beta emitters (such as  $^{103}\text{Ru}$ ,  $^{106}\text{Ru}$ , or  $^{131}\text{I}$ ) may have been present. Tritium is not detected by the method used for assay of gross beta. Gross beta activity above natural background in most cases derives from a combination of uranium and  $^{99}\text{Tc}$  activity. Known exceptions include some wells in the 100 Areas (particularly 100-N) and a few wells in the 200-East Area that contain  $^{90}\text{Sr}$  at concentrations high enough to be detected with the gross beta technique.

Although gross beta levels greater than the DWS were widespread, the highest levels were in wells near several waste disposal facilities in the 100-N, 200-East, and 200-West Areas, and in the 600 Area adjacent to the 200 Areas. Wells in the 200-East Area with the highest gross beta levels in 1990 reflect past disposal of liquid waste to the inactive 216-B-5 Reverse Injection Well, BY cribs, and cribs near the PUREX Plant. Gross beta levels in wells 299-E28-23 (12,900 pCi/L) and 299-E28-25 (12,000 pCi/L) near the 216-B-5 Reverse Injection Well were some of the highest measured on the Hanford Site in 1990. All wells near this reverse injection well contained elevated levels of  $^{90}\text{Sr}$ , and three wells also contained measurable  $^{137}\text{Cs}$ . The 216-B-5 Reverse Injection Well received approximately 27.9 Ci of  $^{90}\text{Sr}$  and 31.8 Ci of  $^{137}\text{Cs}$  (both values decayed through April 1, 1986) when used from 1945 to 1947 (Stenner et al. 1988). The BY cribs (located at the north end of the 200-East Area) received

waste scavenged from U Plant. Wells monitoring the BY cribs have shown gross beta levels greater than the DWS, ranging up to 1,440 pCi/L (well 699-50-53); however, those wells were not monitored in 1990 because of purge water disposal considerations. Past monitoring of the BY crib wells showed the presence of  $^{60}\text{Co}$  and  $^{99}\text{Tc}$ , accounting for the majority of the gross beta activity.

The highest gross beta levels in the 200-West Area were found in wells near U Plant. Gross beta levels in wells near the 216-U-1 and 216-U-2 cribs remained above the DWS but are generally decreasing. Gross beta levels in these wells are dominated by uranium radioactive decay products.

Gross beta levels remained above the DWS in several wells near Gable Mountain Pond. These wells contain relatively high concentrations of  $^{90}\text{Sr}$ , which would account for the gross beta level measured.

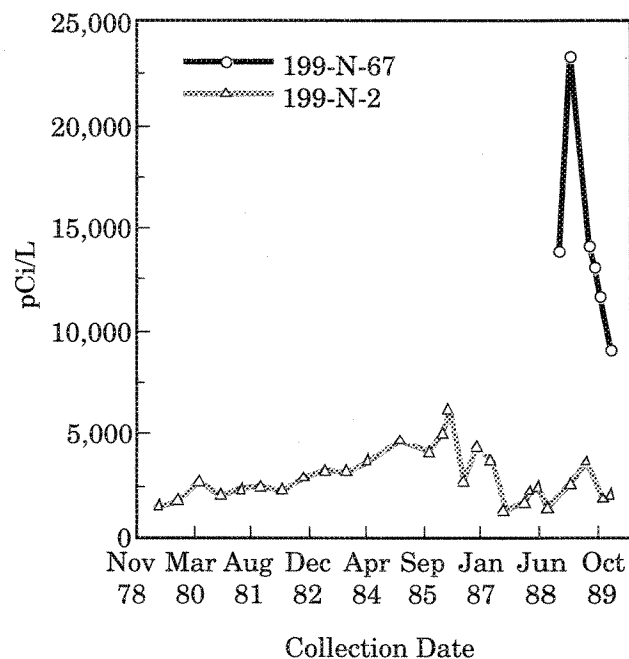
The highest gross beta levels on the Hanford Site in 1990 were found in wells monitoring the 1301-N Liquid Waste Disposal Facility (LWDF). Well 199-N-67 showed a gross beta concentration of 16,500 pCi/L in February 1990. The observed concentrations at this location are primarily due to  $^{90}\text{Sr}$ .

### Cobalt-60 Concentrations

All  $^{60}\text{Co}$  concentrations were consistently near or below the detection limit (20 pCi/L) for wells monitored in 1990. Concentrations of  $^{60}\text{Co}$  were above detection in a number of 100-N Area wells near the 1325-N LWDF but have dropped below detection in the past year. The highest concentrations of  $^{60}\text{Co}$  in Hanford Site ground water during 1989 were in well 699-50-53 (532 pCi/L), directly north of the 200-East Area. No additional monitoring was performed on that well in 1990 because of purge water disposal considerations. Cobalt-60 in this well 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

Concentrations of  $^{90}\text{Sr}$  were above the 8-pCi/L DWS in wells in the 100-B, 100-D, 100-F, 100-K, 100-N, 200-East, and 600 Areas. Concentrations of  $^{90}\text{Sr}$  were greater than the 1,000-pCi/L DCG in the 100-N and 200-East Areas, ranging up to 8,980 pCi/L in the 100-N Area (well 199-N-67), significantly reduced from the maximum of 23,400 pCi/L reached in March 1989. A trend plot of  $^{90}\text{Sr}$  concentrations in two of the 100-N Area wells is given in Figure 5.10. Concentrations of  $^{90}\text{Sr}$  ranged up to 6,200 pCi/L in the 200-East Area near the 216-B-5 Reverse Injection Well. Concentrations of  $^{90}\text{Sr}$  above the DWS (maximum of 240 pCi/L in well 699-53-48B) but less than the DCG were detected in several wells near Gable Mountain Pond.



S9111080.12

**Figure 5.10. Strontium-90 ( $^{90}\text{Sr}$ ) Concentrations in 100-N Area Ground-Water Wells Between 1301-N LWDF and the Shoreline of the Columbia River**

### **Technetium-99 Concentrations**

Concentrations of  $^{99}\text{Tc}$  greater than the 900-pCi/L DWS have been detected in past years (through 1989) in wells in the 100-H, 200-East, and 200-West Areas and in portions of the 600 Area. None of those wells had concentrations exceeding the 100,000-pCi/L DCG. None of the wells showing the highest  $^{99}\text{Tc}$  levels during past years were monitored for that parameter in 1990.

### **Ruthenium-106 Concentrations**

Because of its short half-life (367 days),  $^{106}\text{Ru}$  was detected in the past principally in wells near operating reactors and near active fuel reprocessing facilities. Past examples have included the 100-N Area and the 200-East Area near the PUREX Plant. Concentrations in wells in the 100-N Area were, at most, marginally detectable in 1987 and continued to decline in 1988 because the N Reactor was in cold standby. Ruthenium-106 was undetectable by routine detection methods in the 100-N Area in 1989. Concentrations of  $^{106}\text{Ru}$  in wells near LWDFs receiving effluents from the PUREX Plant generally increased in 1988, with well 299-E24-12 reaching a maximum of 547 pCi/L (DWS is 200 pCi/L) in April 1988. That trend reversed in 1989 as a result of interruption in the operation of the PUREX Plant, with the  $^{106}\text{Ru}$  concentrations in well 299-E24-12 dropping to below detectable levels. A  $^{106}\text{Ru}$  concentration of 257 pCi/L was found in well 299-E17-15 in September 1989. The concentration of  $^{106}\text{Ru}$  in that well dropped to below the detection limit in 1990. Ruthenium-106 has thus not been detectable by routine methods in any Hanford Site ground-water wells after 1989.

### **Antimony-125 Concentrations**

Antimony-125 ( $^{125}\text{Sb}$ ), a gamma emitter, was measured in the past in a few 100-N Area wells near the 1325-N LWDF. Results ranged up to 93.6 pCi/L in well 199-N-32 in 1989. Well 199-N-45, which had the highest  $^{125}\text{Sb}$  concentration in 1988, was not assayed for that radionuclide in 1989 or 1990. No positive detection of  $^{125}\text{Sb}$  was reported in 1990. The DWS for  $^{125}\text{Sb}$  is 300 pCi/L, and the DCG is 60,000 pCi/L.

### **Iodine-129 Concentrations**

The presence of  $^{129}\text{I}$  in ground water is significant, because of the radionuclide's relatively long half-life (16,000,000 years), potential for accumulation in the environment as a result of long-term releases from nuclear fuel reprocessing facilities (Soldat 1976), and relatively low DWS (1 pCi/L). At Hanford, the main contributor of  $^{129}\text{I}$  to ground water has been liquid discharge to cribs in the 200 Areas. The expanded  $^{129}\text{I}$  monitoring effort that began in 1988 was continued in 1990 with many new wells sampled. Assay of that isotope by high-sensitivity, direct-counting methods requires long counting times with correspondingly low analytical throughput. Unfortunately, the unexpected termination of the analytical contract in midyear severely limited the number of available measurements, and many samples submitted to the laboratory could not be retrieved. The highest concentration reported in 1990 was 10.7 pCi/L in well 699-35-70, located just outside the 200-West Area boundary and downgradient from the REDOX Plant. Wells sampled in the 200-West, 200-East, and 600 Areas had concentrations somewhat above the DWS; however, none was above the DCG (500 pCi/L).

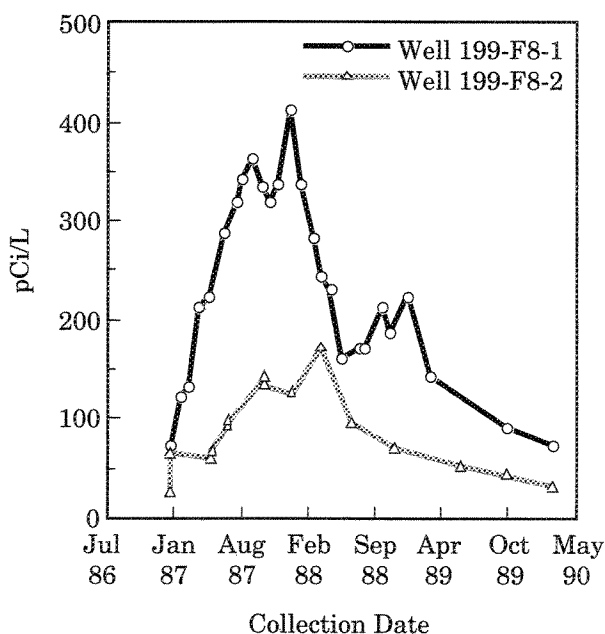
### **Cesium-137 Concentrations**

Concentrations of  $^{137}\text{Cs}$  were below the detection limit (23 pCi/L) except in three wells located near the 216-B-5 Reverse Injection Well. Ground water sampled at well 299-E28-23 contained 1,450 pCi/L; ground water at well 299-E28-25 contained 166 pCi/L. The concentration in well 299-E28-25 represents a small increase over the previous trend but is significantly less than the single measurement of 1,070 pCi/L reported for 1989, which may have been an analytical artifact or reporting error. Cesium-137 was detected for the first time in nearby well 299-E28-24 in 1989. Cesium-137 continued to increase in that well reaching a new high of 633 pCi/L in April 1990. The 216-B-5 Reverse Injection Well received an estimated 31.8 Ci of  $^{137}\text{Cs}$  (decayed through April 1, 1986) during its operation from 1945 to 1947 (Stenner et al. 1988). The DWS for  $^{137}\text{Cs}$  is 200 pCi/L, and the DCG is 3000 pCi/L.

### Uranium Concentrations

The highest uranium levels in Hanford ground water occur in wells adjacent to the inactive 216-U-1 and 216-U-2 cribs. Uranium concentrations in these wells have been decreasing during the last 4 years following remediation activities associated with those cribs. The total uranium concentration in well 299-W19-3 dropped from 16,000 pCi/L in January 1987 to 2,000 pCi/L in March 1989. No uranium measurements were available for that well in 1990, but the gross alpha measurement suggests that the uranium level is unchanged from 1989. Uranium concentrations in other nearby wells also tended to decrease during the past 3 years and now appear to have stabilized.

Uranium levels increased sharply in two 100-F Area wells in 1987. Levels in well 199-F8-1 reached a maximum of 414 pCi/L in January 1988 and generally have decreased thereafter, dropping to a low of 72 pCi/L in April 1990. A similar trend occurred in well 199-F8-2. A trend plot showing the uranium concentrations in those two wells as a function of time is given in Figure 5.11.



S9111080.11

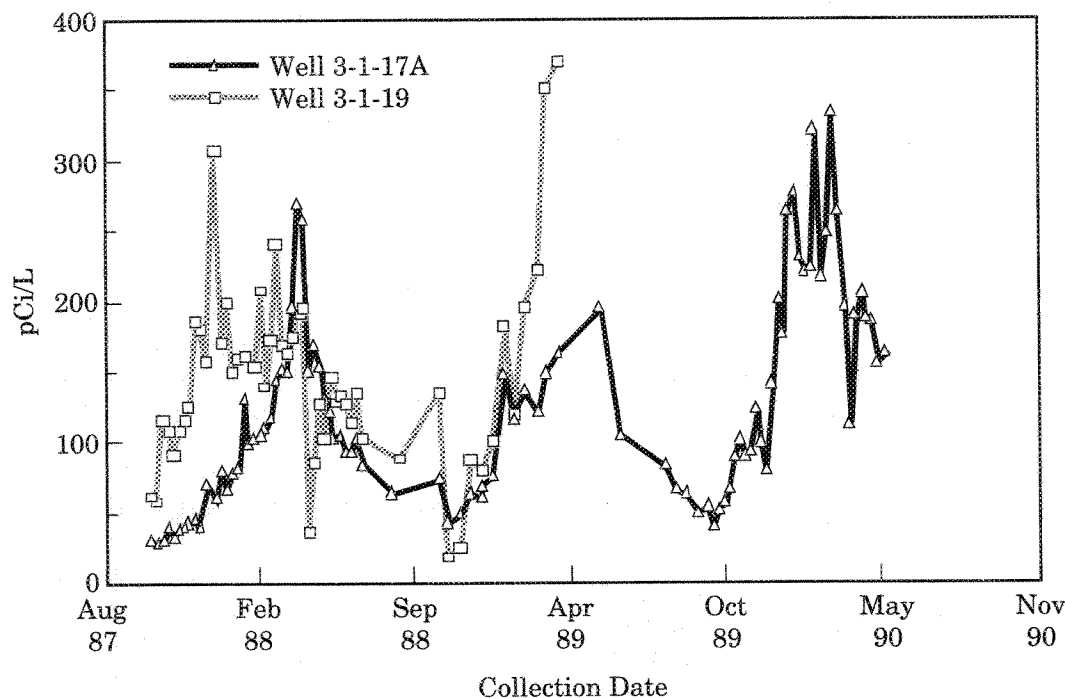
**Figure 5.11. Uranium Concentrations in Wells on the West Side of the 100-F Area**

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 was limited to an area downgradient from active and inactive LWDFs. Uranium concentrations in wells in and adjacent to the 300 Area ranged up to 334 pCi/L during 1990. These concentrations were similar to those measured in previous years. A trend plot for uranium concentrations in two 300 Area wells is shown in Figure 5.12. A contour map of the 300 Area uranium plume is shown in Figure 5.13.

### Plutonium Concentrations

Concentrations of  $^{239/240}\text{Pu}$  were below the detection limit in all wells, except three wells located near the 216-B-5 Reverse Injection Well and one well in the 200-West Area. Plutonium is generally considered to bind strongly to sediments and thus has limited mobility in the aquifer. Ground water sampled at well 299-E28-23 contained 21.7 pCi/L of  $^{239/240}\text{Pu}$ ; ground water at well 299-E28-24 contained 19.3 pCi/L. The measurement in well 299-E28-25 represents a confirmation of the observation made in 1989 that the plutonium concentrations in the ground water near the 216-B-5 Reverse Injection Well have dramatically increased. In addition,  $^{239/240}\text{Pu}$  was detected for the first time in 1989 in a nearby well, 299-E28-24 (72 pCi/L). Plutonium-239/240 has increased to 144 pCi/L in that well in 1990. Plutonium-238 is also detectable at much lower levels in all three wells. A trend plot of  $^{239/240}\text{Pu}$  concentrations in the three wells discussed is shown in Figure 5.14. The 216-B-5 Reverse Injection Well received an estimated 244 Ci of  $^{239/240}\text{Pu}$  during the well's operation from 1945 to 1947 (Stenner et al. 1988). The DCG of 300 pCi/L for  $^{239}\text{Pu}$  has been reduced to 30 pCi/L effective February 1990. There is no explicit DWS for  $^{239}\text{Pu}$ ; 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-239/240 was detected for the first time in a well located in the 200-West Area (299-W15-8). That well monitors the 216-Z-9 crib, which



S9111080.10

**Figure 5.12. Uranium Concentrations Near the South End of the 300 Area Process Trenches**

received a large burden of plutonium from Z Plant liquid effluent streams. No previous plutonium measurements are available for this well. Because the data were received just before termination of the analytical contract, verification of the data's validity was not possible. The measured concentration of  $^{239/240}\text{Pu}$  was 8.3 pCi/L. Plutonium-238 was also detected in the same sample (0.14 pCi/L).

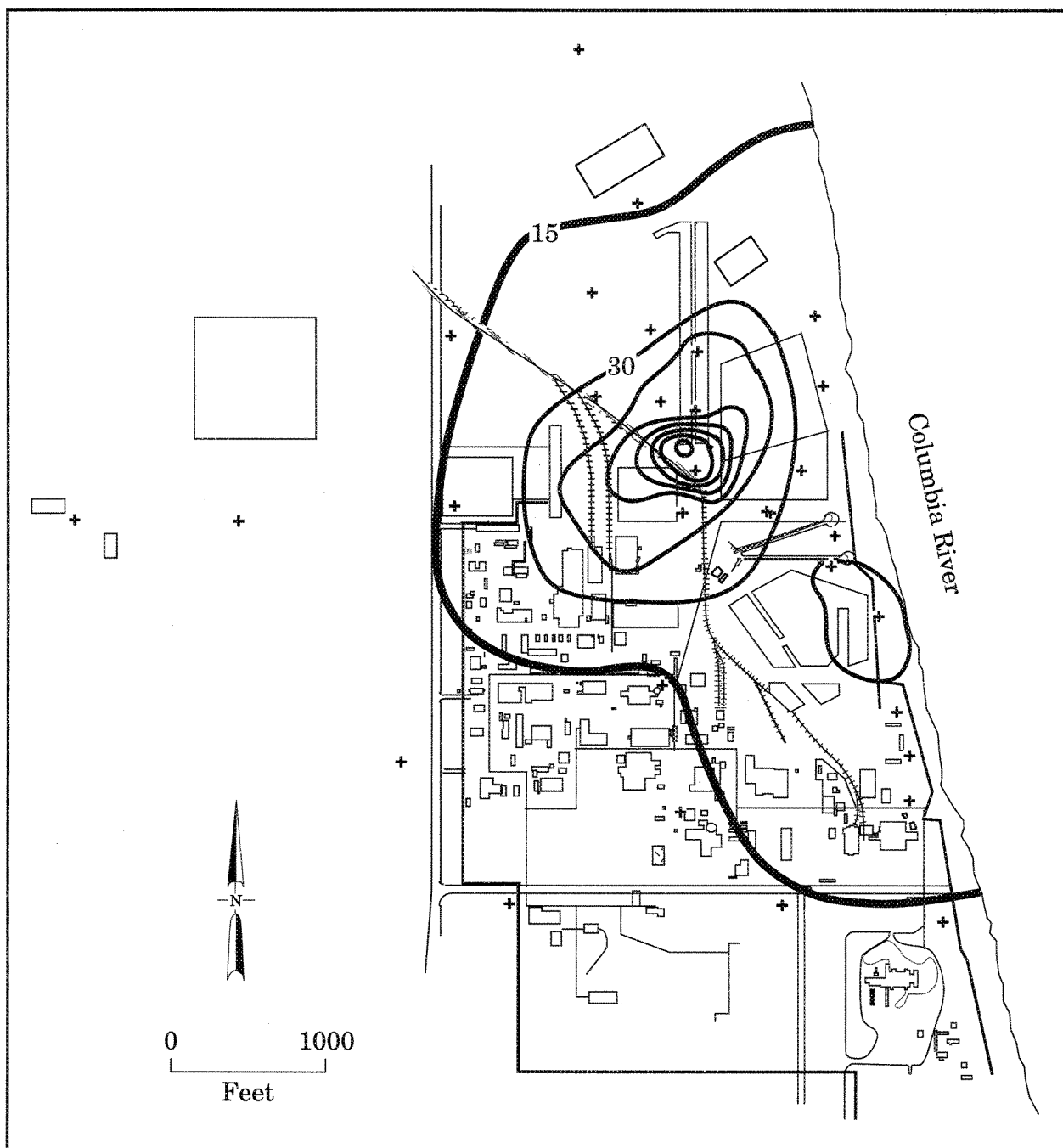
#### **Chemical Monitoring Results for the Unconfined Aquifer**

Chemical monitoring in 1990 continued to document the distribution of chemical contaminants from Hanford operations. Although the extensive distribution of nitrate from Hanford operations is documented in numerous reports, some of the other chemical results represent relatively recent findings (since 1987). Species of interest include nitrate, cyanide, fluoride, chromium, carbon tetrachloride, chloroform, and trichloroethylene.

#### **Nitrate Concentrations**

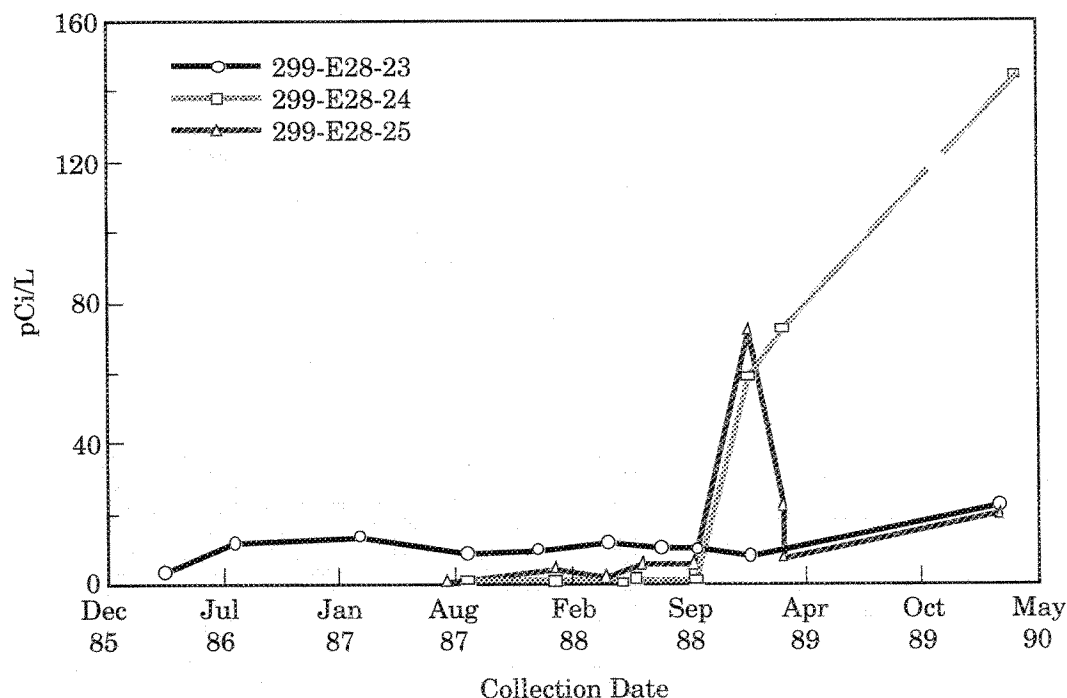
Most ground-water samples collected in 1990 were analyzed for nitrate. Nitrate was measured at concentrations greater than the DWS (45 mg/L nitrate ion) in wells in all operational areas, except the 400 Area.

Although nitrate is associated primarily with process condensate liquid wastes, other liquids discharged to ground also contain nitrate. Nitrate contamination in the unconfined aquifer reflects the extensive use of nitric acid in decontamination and chemical reprocessing operations. Nitrate, like  $^3\text{H}$ , can be used to define the extent of contamination because nitrate is present in many waste streams and is mobile in ground water. The distribution of nitrate on the Hanford Site is shown in Figure 5.15. Data from 1989 were used to construct the map in locations where 1990 data were not available because of the termination of analytical services mid-year.



S9111080.16

**Figure 5.13. Uranium Ground-Water Plume in the 300 Area. Minimum contour is 15 pCi/L. Contour interval is 15 pCi/L. Sampling locations are marked with + symbols.**



S9111080.9

**Figure 5.14. Plutonium Isotope Concentrations in Wells Located Close to the 216-B-5 Reverse Injection Well in the 200-East Area**

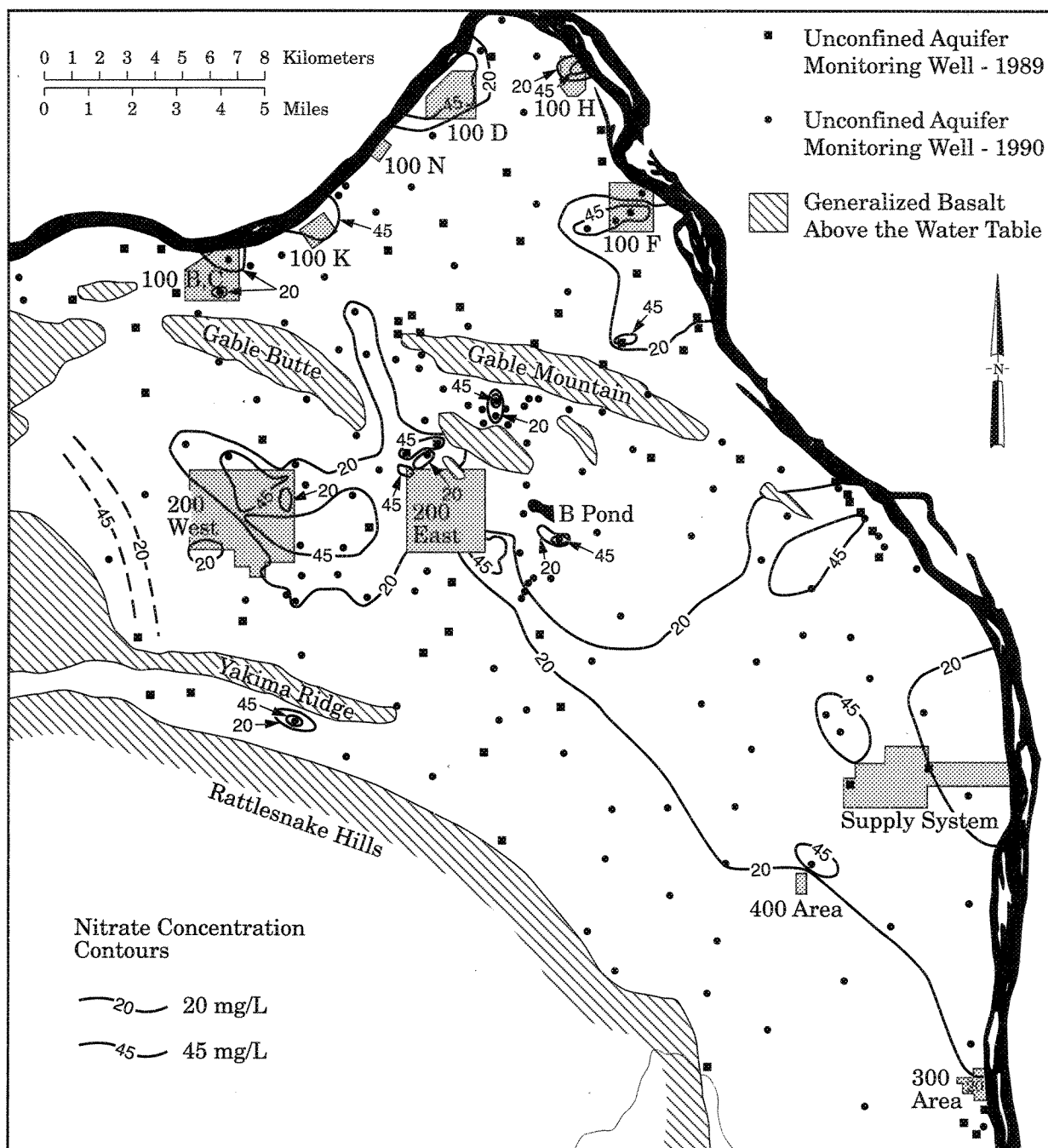
The distribution of this constituent in ground water at the Hanford Site is similar to the distribution of  $^3\text{H}$ , as can be seen from examining Figures 5.5 and 5.15. The nitrate distribution shown in Figure 5.15 is similar to previous evaluations, with one notable exception. The high nitrate concentrations observed in wells located on the far west of the Site near the Yakima Ridge have long been regarded as unrelated to Site operations and most probably of agricultural origin. Nevertheless, past versions of the plume map have, for reasons of conservatism, assumed a Hanford origin and combined these measurements as part of a single plume emanating from the southwest corner of the 200-West Area. That interpretation is now believed to be inconsistent with the known hydrology of that part of the Site. In addition, no known source of nitrate in that area is associated with Site operations, and intervening wells show no evidence of plume passage. Nitrate levels have fluctuated considerably in those wells during the past 30 years and again appear to be increasing, particularly in well 699-36-93. A trend plot of nitrate data associated

with wells near the Yakima Ridge is shown in Figure 5.16. The nitrate plume map (Figure 5.15) has been modified for 1990 to reflect this difference in interpretation.

The highest nitrate concentrations in the 200-East Area continued to be found near LWDFs that received effluent from PUREX Plant 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.

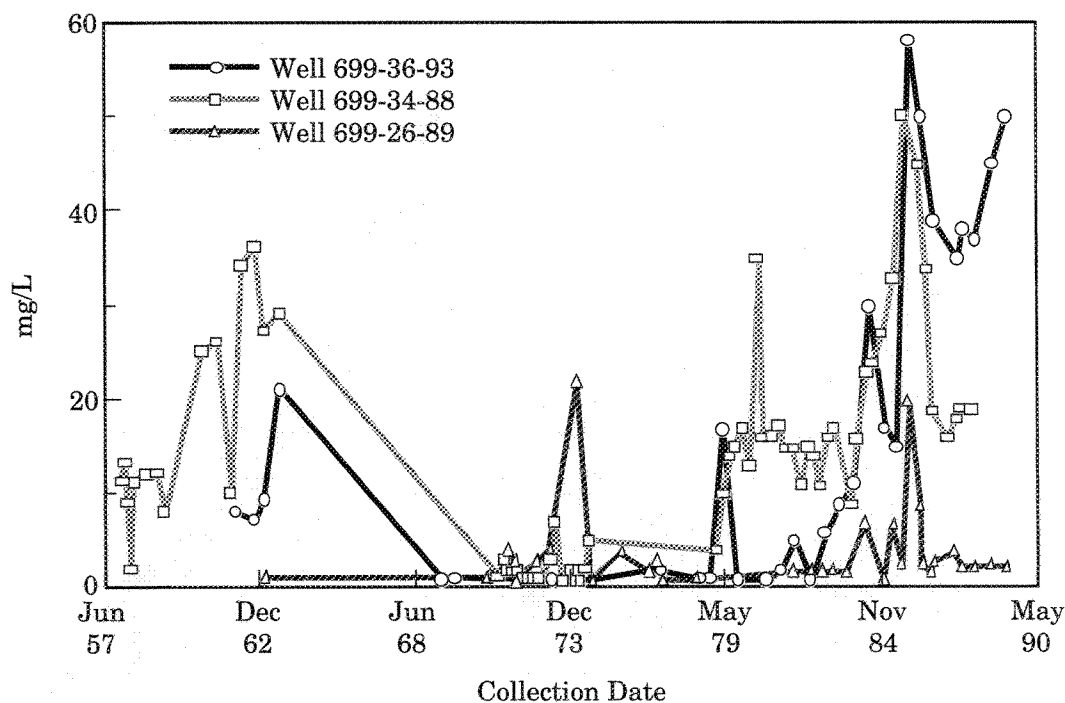
The configuration of the nitrate plume emanating from the 200-East Area shows the influence of two periods of PUREX Plant operation and recent changes in the operation of B Pond. The location of B Pond is shown in Figure 5.1. Increases in the volume of process cooling water discharged to B Pond may have resulted in the expanding area of lower nitrate concentrations in ground water to the east and south of that facility (see Figure 5.15).





S9109096.2

Figure 5.15. Nitrate ( $\text{NO}_3^-$ ) Concentrations in the Hanford Site Unconfined Aquifer, 1990



S9111080.8

**Figure 5.16. Nitrate ( $\text{NO}_3^-$ ) Concentrations in Ground-Water Wells Located Near the Western Margin of the Hanford Site Downslope from Yakima Ridge**

Nitrate concentrations above 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 northwestern 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 more than 1,000,000 kg of nitrate during their operation from 1951 to 1967 (Stenner et al. 1988). A maximum nitrate concentration of 1,360 mg/L was measured in well 299-W19-26 in 1989. Although no new measurements were available for that well in 1990, other nearby wells showed similarly elevated concentrations in 1990. Nitrate concentrations in wells located near the 216-U-1 and 216-U-2 cribs west of U Plant continued to decrease in 1988, with concentrations in

several of the wells dropping below the DWS. That trend continued in 1990 but appears to be stabilizing.

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 1988 ranged up to 699 mg/L in well 299-W15-4. The pattern in that area was similar in 1989 and 1990; however, less information was available because of the purge water disposal considerations discussed earlier, which limited the sampling effort in 1989 and 1990 in the most contaminated areas.

### Cyanide Concentrations

In past monitoring activities, cyanide was detected in samples collected from wells in and directly north of the 200-East Area.

Concentrations discussed in this section are for total cyanide because the EPA-recognized analytical technique used routinely for the detection of cyanide does not distinguish between free and complexed forms of cyanide. The cyanide source is believed to be wastes containing ferrocyanide disposed of in the BY cribs. Samples collected in January 1989 had a maximum cyanide concentration of 574  $\mu\text{g/L}$  in well 699-50-53, with lesser amounts present in four other wells in or near the northern side of the 200-East Area. Wells containing cyanide also contained concentrations of several radionuclides, including  $^{60}\text{Co}$ . Although usually immobile in the subsurface,  $^{60}\text{Co}$  appears to be chemically complexed and mobilized by cyanide or ferrocyanide. No additional monitoring of those wells was performed in 1990 because of considerations associated with disposal of purgewater and the termination of analytical services. Cyanide also has been detected in four widely spaced wells in the 200-West Area; the highest level reported in 1988 was 69  $\mu\text{g/L}$  in well 299-W14-2. No samples were taken from well 299-W14-2 in 1989 or 1990 because of considerations associated with disposal of purgewater. No final DWS has been established for cyanide. A proposed DWS of 200  $\mu\text{g/L}$  is currently being evaluated by the EPA.

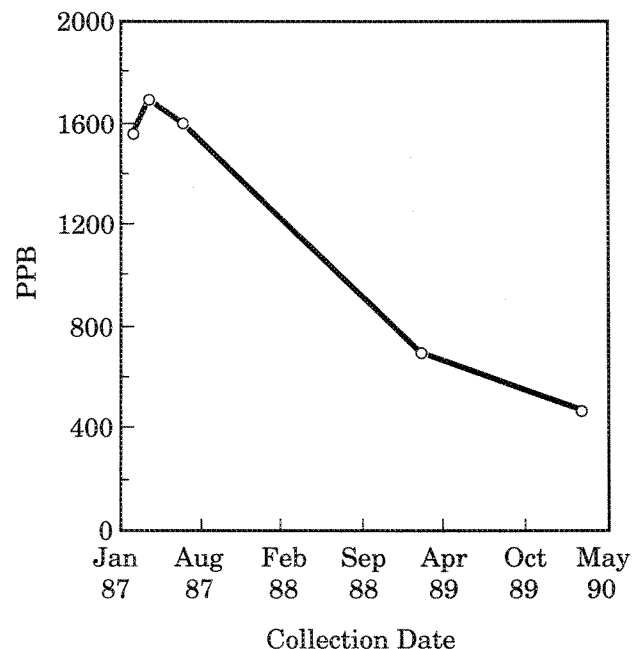
### Fluoride Concentrations

Fluoride concentrations above the DWS occurred in a few wells in the 200-West Area near T Plant. The maximum concentration in 1988 was 12.8 mg/L in well 299-W15-4. Because of considerations associated with disposal of purgewater, no 200-West Area wells in the fluoride plume were sampled in 1989 or 1990. All wells sampled outside the 200-West Area contained fluoride levels below the DWS. The DWS for fluoride is 2.0 mg/L.

### Chromium Concentrations

Chromium has been found in ground water from wells in the 100-B, 100-D, 100-H, and 100-K Areas. In addition, at least one well in the 100-F Area had detectable hexavalent chromium. The highest measured chromium concentrations on the Hanford Site in 1990 continued to be found in

well 199-D5-12 at 464  $\mu\text{g/L}$ , down more than a factor of three from measurements in 1987 and significantly reduced from the more recent measurement made in 1989. A trend plot of the concentrations of chromium with time is given in Figure 5.17. Detectable chromium was also found in various parts of the 600 Area, particularly near the 100-D and 100-H Areas. The highest concentration was found in well 699-97-43 (approximately 1 km west of the 100-H Area) at 192  $\mu\text{g/L}$ , four times the DWS. Two other wells in the same area had chromium levels greater than the DWS in 1989. None of those wells were monitored for chromium in 1990. Chromium contamination was previously found at several locations in the 200-West Area. The 1990 chromium concentration in well 299-W10-9 (135  $\mu\text{g/L}$ ) was similar to earlier measurements. The maximum chromium concentration found in the 200-West Area during 1990 was 301  $\mu\text{g/L}$  in well 299-W22-20, similar to previous measurements. Ground-water samples from at least eight other 200-West Area wells sampled in 1990 had detectable chromium, including two new wells (299-W10-15 and 299-W10-16) not previously



S9111080.7

**Figure 5.17. Chromium Concentrations in Well 199-D5-12**

sampled. A few wells in the 200-East Area also showed evidence of minor chromium contamination. The highest level found was in well 299-E13-14, with a chromium concentration of 67 µg/L in November 1988. That well was not sampled in 1989 because of considerations associated with purge water disposal, and the sample taken in May 1990 was not analyzed as a result of the termination of the analytical contract.

### **Carbon Tetrachloride Concentrations**

Extensive 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 similar in 1990, reaching a maximum of 8,700 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 is shown in Figure 5.18, which is based on a compilation of all available data taken since 1988, with replicates averaged. In most cases, that approach is appropriate because, in general, the plume moves very little on a timescale of a few years. The only discernible exception is the western or southwestern edge of the plume, which has shown considerable movement during the past 3 to 4 years. Figure 5.19 shows the time trends in carbon tetrachloride concentrations for four 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, suggesting plume movement past that location with relatively stable concentrations thereafter. The other three locations show little change. In contrast, Figure 5.20 shows the concentration trends for carbon tetrachloride samples taken from wells near the center of the plume, showing essentially constant levels at the highest point and some dropoff in two other nearby wells. The DWS for carbon tetrachloride is also 5 µg/L. In addition to carbon tetrachloride, other chlorinated hydrocarbon solvents were found at significant levels 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. Chloroform appears to be associated with, but not exactly coincident with, carbon tetrachloride. The DWS for chloroform is 100 µg/L (total trihalomethanes).

### **Trichloroethylene Concentrations**

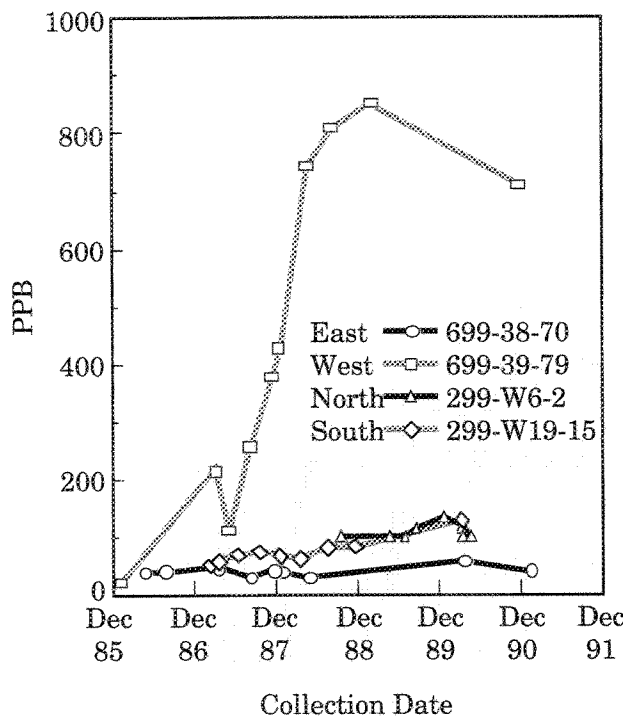
Trichloroethylene contamination in excess of the 5-µg/L DWS was found at several sites in 1990. Trichloroethylene was found in 600 Area wells on the west side of the 100-F Area. The highest level reported in 1989 was 32 µg/L in well 699-77-36. Trichloroethylene concentrations in that well appear to be constant with time. The well was not sampled in 1990. The trichloroethylene concentration in well 199-F7-1 rose to 35 µg/L, two to three times previous measurements. Several wells at the Solid Waste Landfill contained trichloroethylene close to, but slightly below, the DWS. Solid Waste Landfill wells had shown trichloroethylene concentrations above the DWS in previous years. Trichloroethylene and some of its partial degradation products [i.e., cisdichloroethylene (1,2-DCE)] were found in wells monitoring the lower portion of the unconfined aquifer in the 300 Area near the North Process Pond. Maximum concentrations were 23 µg/L trichloroethylene and 135 µg/L DCE in well 399-1-16B in December 1989, declining to 12 µg/L and 77 µg/L, respectively. Similar levels were found in nearby well 399-1-16C, which monitors the locally confined portion of the suprabasalt sediments. Trichloroethylene was not found in well 399-1-16A, which monitors the upper portion of the unconfined aquifer. Trichloroethylene contamination had been detected at levels exceeding the DWS in two locations inside the 200-West Area near T Plant and the REDOX Plant. The maximum level found in 1990 in the well near the REDOX Plant (299-W22-20) was 41 µg/L. The wells near T Plant were not sampled during 1989 or 1990 because of purge water disposal considerations.

### **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 was identified by Graham

Figure removed as per DOE guidance.

**Figure 5.18. Carbon Tetrachloride Ground-Water Plume in the 200-West Area. Minimum contour is 5  $\mu\text{g/L}$ . Contour intervals are 500  $\mu\text{g/L}$ . Bold contour line indicates DWS. + symbols mark sampling locations.**

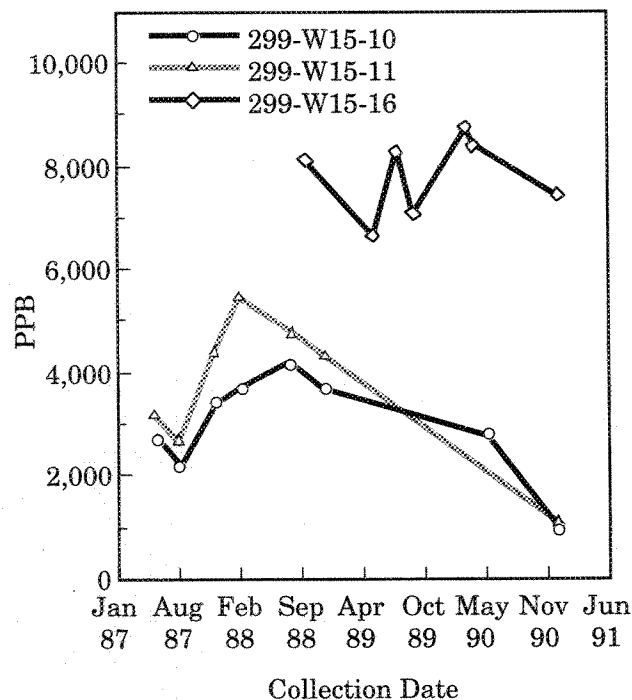


S9111080.6a

**Figure 5.19. Carbon Tetrachloride Concentrations in Monitoring Wells Located Near the Margins of the Z Plant Ground-Water Plume**

et al. (1984). Ground-water samples from the confined aquifer were analyzed for  $^3\text{H}$ , nitrate,  $^{129}\text{I}$ , and gamma-emitting radionuclides. In most cases, background levels of constituents were detected in these wells. Past 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). Samples were not collected from this well during 1990 because of loss of analytical services with the termination of the analytical contract with UST.

Intercommunication between the Rattlesnake Ridge confined aquifer and the unconfined aquifer north of the 200-East Area was indicated in the past by the concentrations of nitrate in well 699-47-50. This well is located near an erosional window (near an area where the confining layer is absent) in the confining basalt flow (Graham et al. 1984). Elevated levels of  $^3\text{H}$  (3,830 pCi/L) have been measured in ground water from the



S9111080.5a

**Figure 5.20. Carbon Tetrachloride Concentrations in Monitoring Wells Located Near the Center of the Z Plant Ground-Water Plume**

Rattlesnake Ridge interbed in well 699-42-40C. Elevated levels of  $^{129}\text{I}$  (0.15 pCi/L) previously have been observed in the same well. Wells 699-47-50 and 699-42-40C were not sampled in 1990 because of the loss of analytical services with the termination of the analytical contract with UST.

#### Ground-Water Quality Near Richland Water Supply Wells

During 1990, ground water from 31 monitoring wells in the southern portion of the Hanford Site was sampled and analyzed for hazardous chemicals and radiological constituents. This region is currently being characterized through a remedial investigation under the Comprehensive Environmental Response, Compensation, and Liability Act. Details of this study are provided in the Phase 1 Remedial Investigation Report for the Hanford Site 1100-EM-1 Operable Unit (DOE 1990h). No contaminants were observed in concentrations above the DWS in the vicinity of the Richland Water Supply Wells.

## Quality Assurance





## 6.0 Quality Assurance

A comprehensive quality assurance (QA) program, including various quality control (QC) practices, is maintained to ensure the quality of data collected through the surveillance programs. QA plans were 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, ASME 1989) and DOE orders.

In the surface and ground-water surveillance programs, extensive environmental data are obtained to minimize reliance on only a few results. New data collected were compared with both recent results and historical data to ensure that deviations from previous conditions were identified and promptly evaluated. Samples were collected using approved and documented procedures to ensure consistency. Samples were analyzed by documented standard analytical procedures. Analytical data quality was 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.

QA for ground-water surveillance also included procedures for 1) documenting instrument calibrations and procedures used in the field and the laboratory, 2) scheduling maintenance of wells to ensure well 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 how projects were managed, samples were collected, and results were analyzed. Where appropriate, the surface and ground-water environmental surveillance projects are discussed separately.

### Project Management Quality Assurance

The surveillance programs and related programs, such as processing of thermoluminescent dosimeters (TLDs) and dose calculations, are subject to the overall QA program of the Pacific Northwest Laboratory (PNL). This program implements the requirements of DOE Order 5700.6B, "Quality Assurance," and is based on ASME NQA-1, "Quality Assurance Program Requirements for Nuclear Facilities" (ASME 1989). The program is defined in the PNL QA manual (PNL 1989b). 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.

Each surveillance project has a current QA plan that describes the specific QA elements that apply to the project. These plans are approved and monitored by the QA organization within PNL, 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 services suppliers are conducted by professional QA organization and technical staff before awarding contracts for services or approving purchase requisitions having significant impact on a project's quality.

## **Sample Collection Quality Assurance**

Surface and ground-water samples were collected by trained radiation protection technologists using approved and documented procedures. Continuity of sampling location identities was maintained through documentation in logbooks. Samples for hazardous chemical monitoring were sealed with evidence tape to prevent tampering and were transported to the laboratory in accordance with the chain-of-custody procedures required by the EPA for Resource Conservation and Recovery Act (RCRA) monitoring programs.

## **Surface and Ground-Water Analytical Results Quality Assurance**

Routine radiochemical analyses for environmental surveillance samples were performed by United States Testing Company, Inc. (UST), and International Technology Corporation (IT). The analytical contracts with UST were terminated in June 1990 (see Section 2.3). Routine sample collection continued after this, with samples being preserved and stored using approved and documented archiving procedures. IT was awarded an interim contract for analytical services after a pre-award QA audit, which included performance evaluation analyses of blind standards. The first 1990 archived samples were submitted to IT in February 1991, and the last results for 1990 samples reported in this document were received in October 1991.

Quality at both analytical laboratories was evaluated in a number of ways. Both participated in the U.S. Department of Energy's (DOE's) Quality Assessment Program and the U.S. Environmental Protection Agency's (EPA's) Laboratory Intercomparison Studies. PNL conducted an additional QC program. Both laboratories also

maintained internal QC programs, which PNL audited and reviewed. Other audits and comparisons were conducted on specific types of samples. A final quality control check of data was performed by a computerized screening of each result against 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 Environmental Protection Agency Comparison Studies**

UST and IT participated in the DOE 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). Performance in these programs was evaluated through October 1991. Summaries of the 1990 and 1991 UST and IT results for the programs are provided in Tables 6.1 and 6.2. Over 90% of the results during the year were within the typically used "3-sigma control limits" ( $\pm 3$  standard errors of the mean). This level of performance was determined to be adequate 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 was maintained by PNL to evaluate analytical contractor precision and accuracy and to conduct special intercomparisons. This program included the use of blind samples and replicate samples. Blind standard QC samples and blanks were prepared and submitted to check the accuracy and precision of IT. The methods used to determine accuracy and

**Table 6.1. United States Testing Company, Inc., and International Technology Corporation Performances on DOE Quality Assessment Program Samples in 1990 and 1991**

Sample Media	Radionuclides	Number of Results Reported	Number Within Control Limits <sup>(a)</sup>
Air Filters	<sup>7</sup> Be, <sup>54</sup> Mn, <sup>57</sup> Co, <sup>60</sup> Co, <sup>90</sup> Sr, <sup>134</sup> Cs, <sup>137</sup> Cs, <sup>144</sup> Ce, <sup>239</sup> Pu, <sup>234</sup> U, <sup>238</sup> U	21	19
Soil	<sup>40</sup> K, <sup>90</sup> Sr, <sup>137</sup> Cs, <sup>238</sup> Pu, <sup>239</sup> Pu, <sup>234</sup> U, <sup>238</sup> U, <sup>241</sup> Am	15	15
Vegetation	<sup>40</sup> K, <sup>90</sup> Sr, <sup>137</sup> Cs, <sup>238</sup> Pu, <sup>239</sup> Pu, <sup>241</sup> Am, <sup>234</sup> U, <sup>238</sup> U	14	13
Water	<sup>3</sup> H, <sup>54</sup> Mn, <sup>57</sup> Co, <sup>60</sup> Co, <sup>90</sup> Sr, <sup>134</sup> Cs, <sup>137</sup> Cs, <sup>144</sup> Ce, <sup>239</sup> Pu, <sup>241</sup> Am, <sup>234</sup> U, <sup>238</sup> U, U (mass)	25	22

(a) Control limits from Sanderson (1985).

precision acceptability of the laboratory's results were taken from the EPA and DOE (Jarvis and Siu 1981; Sanderson 1985). Reviews of the results reported to date indicate that accuracy and precision performance were consistent with IT performance in the DOE and EPA Laboratory Intercomparison Studies Program and were acceptable.

Replicate samples were also routinely collected and analyzed to check sampling and analysis precision. Replicate data showed similar results as those of previous years. The variation in results, as expressed by the coefficient of variation, was generally less than 30% for samples with activities greater than the minimum detectable amount.

### Laboratory Internal Quality Control Programs

UST and IT were required to maintain internal QC programs, and PNL audited and reviewed their compliance with these programs. The internal QC programs involved 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. When available, calibration standards traceable to the National Institute of Standards and Technology were used for radiochemical calibrations.

**Table 6.2. United States Testing Company, Inc., and International Technology Corporation Performances on EPA Intercomparison Program Samples in 1990 and 1991**

Sample Media	Radionuclides	Number of Results Reported	Number Within Control Limits <sup>(a)</sup>
Water	Gross Alpha, Gross Beta, <sup>51</sup> Cr, <sup>65</sup> Zn, <sup>60</sup> Co, <sup>106</sup> Ru, <sup>131</sup> I, <sup>133</sup> Ba, <sup>134</sup> Cs, <sup>137</sup> Cs	35	34
Water	<sup>226</sup> Ra, <sup>228</sup> Ra, <sup>238</sup> U, U (nat), <sup>239</sup> Pu	15	15
Water	<sup>89</sup> Sr, <sup>90</sup> Sr	11	10
Water	<sup>3</sup> H	3	3
Milk	<sup>89</sup> Sr, <sup>90</sup> Sr, <sup>131</sup> I, <sup>137</sup> Cs	3	3
Air Filters	Gross Alpha, Gross Beta <sup>90</sup> Sr, <sup>137</sup> Cs	4	3

(a) Control limits from Jarvis and Siu (1981).

The PNL Process Quality Department conducted a formal audit of IT in April 1991. The audit resulted in three findings and six observations. IT's corrective actions had been completed for one finding and four observations at the time of this report.

Internal laboratory QC program data were summarized by UST and IT in quarterly reports to PNL. The second quarterly QC report to cover April through June 1990 was not received after the contract with UST was terminated. IT had not provided all of its internal laboratory 1991

quarterly QC reports covering all of the analyses for 1990 samples at the time of this report writing.

Verification of minimum detectable concentration (MDC) requirements for specific radionuclide-media combinations (for example, <sup>90</sup>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 1980) 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, a predesignated uncertainty multiplier, and other factors. The MDC verification is used to document historical performance to project detection goals. As of this report writing, three MDC verification reports had been completed for 15 radionuclide-media combinations, indicating that 13 MDCs had been achieved.

Although the QA requirements and QC performances for both UST and IT were similar, results of environmental samples that are at very low levels (barely detectable) may be expected to show some inconsistencies because of the change in analytical laboratories.

### Sample-Specific Audits and Comparisons

Additional audits and comparisons were conducted on several specific types of samples. A joint sampling of Columbia River seep springs, wells, and vegetation was conducted in September 1989 and the results analyzed by participants for analytical comparison. Participants included the States of Washington and Oregon, Washington Public Power Supply System, Search Technical Associates, and the Surface Environmental Surveillance Project (PNL). Samples of water and vegetation were collected and divided among the participants. Analytical results from all participants became available in late 1990, after the 1989 report writing. These results have been reviewed and indicate that PNL's analytical results were in good agreement with the other laboratories approximately 90% to 95% of the time. The results that did not agree did not indicate major discrepancies between laboratories.

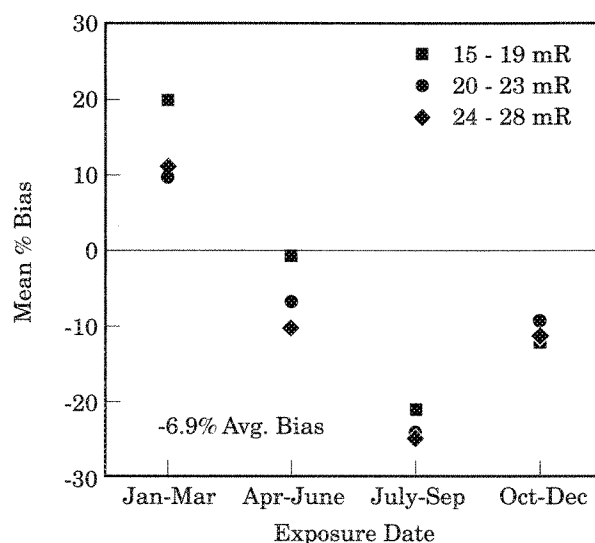
The Surface Environmental Surveillance Project also "split" duplicate samples in 1990 of various locally grown farm products with the U.S. Food and Drug Administration (FDA) and the State of Washington Department of Health for analytical intercomparison. Gamma scans and  $^{90}\text{Sr}$  and  $^3\text{H}$  analyses were performed by PNL and the FDA, and the results produced by both laboratories

were compared. All gamma scans and  $^3\text{H}$  results from both laboratories indicated the levels in these samples were less than their detection capabilities (not detectable by either laboratory). Strontium-90 was detected at low levels (near the detection limits) in eight samples by both laboratories, and the results from each were in acceptable agreement. The State of Washington results were not available for comparison at the time of this report.

Quality control for environmental TLDs included the audit exposures of three environmental TLDs to known values of radiation (between 14 to 28 mR), which were routinely processed quarterly. A summary of 1990 results is shown in Figure 6.1. On average, the TLD measurements were biased 7% lower than the known values. The average percent bias was calculated from

$$\frac{\sum \left[ \frac{\text{measured} - \text{known value}}{\text{known value}} \times 100\% \right]}{\text{Number of TLDs}}$$

This average bias is somewhat larger than those previously observed in 1988 and 1989, but is still considered to be acceptable for these very low exposure levels.



S9111004.14

**Figure 6.1. Comparison of Thermoluminescent Dosimeter Results With Known Exposures**

## Ground-Water Chemical Monitoring

Ground-water sampling and analysis were performed only during part of calendar year 1990 because of the delay associated with replacing US Testing as the primary analytical laboratory for ground-water analysis. The ground-water monitoring program at PNL had used the same comprehensive approach to QC used in previous years. This approach included the use of blanks, duplicate sample collection, interlaboratory comparisons, and blind standard samples. The blanks were used to detect and assess sample contamination caused by laboratory operations or by sample collection and handling before laboratory submittal. Duplicate samples were submitted to the primary laboratory to assess the variability of both laboratory measurements and sampling procedures. Interlaboratory comparisons were performed by collecting duplicate samples, and by submitting one to the primary laboratory and the other to an alternate laboratory. The analytical precision calculated from the results of interlaboratory comparisons was compared to the results of a nationwide study of laboratory performance conducted by EPA. Finally, blind standards were prepared and submitted as ground-water samples to determine both the precision and accuracy of laboratory measurements.

Four types of blank samples were submitted: bottle blanks to detect contamination arising from sample containers, trip blanks to detect contamination arising from sample handling, and two types of volatile organic analysis (VOA) blanks (transfer and transport blanks) designed to detect contamination arising during sampling and handling of VOA samples. In some cases, VOA blanks have indicated the presence of sample contamination, and the source of this contamination was in each case identified as common laboratory solvents.

The results of analysis of duplicate samples by the primary laboratory confirmed that (with the exception of occasional solvent-caused VOA contamination) the results of sampling and analytical practice are highly reproducible. In addition, both interlaboratory comparisons and the results of analysis of blind standards showed that the precision and accuracy of analytical measurement are comparable to the nationwide laboratory performance presented in the EPA survey. Analytes included in interlaboratory comparison and blind standard studies included anions, VOAs, metals, gross alpha, and gross beta.

## References





## 7.0 References

- Ames, B. N., R. Magaw and L. S. Gold. 1987. "Ranking Possible Carcinogenic Hazards." **Science** 236:271-280.
- American Society of Mechanical Engineers (ASME). 1989. **Quality Assurance Program for Nuclear Facilities, ASME NQA-1-1989 Edition**. American Society of Mechanical Engineers, New York.
- Atallah, S. 1980. "Assessing and Managing Industrial Risk." **Chemical Engineering** 9/8/80:94-103.
- Beasley, T. M., L. A. Ball, and J. E. Andrews III. 1981. "Hanford-Derived Plutonium in Columbia River Sediments." **Science** 214(20):913-915.
- Bisping, L. E. 1989. **Environmental Monitoring Master Sampling Schedule, January - December 1989**. PNL-6816, Pacific Northwest Laboratory, Richland, Washington.
- Bisping, L. E. 1990. **Environmental Monitoring Master Sampling Schedule, January - December 1990**. PNL-7257, Pacific Northwest Laboratory, Richland, Washington.
- Bisping, L. E. 1991. **Hanford Site Environmental Data for Calendar Year 1990 -- Surface and Columbia River**. PNL-7929, Pacific Northwest Laboratory, Richland, Washington.
- Bjornstad, B. N., and K. R. Fecht. 1989. "Pre-Wisconsin Glacial-Outburst Floods: Pedogenic and Paleomagnetic Evidence from the Pasco Basin and Adjacent Channeled Scabland." **Geological Society of America Program** 21(5):58 (Abstract).
- Brich, R. F., and R. A. Paasch. 1990. **United States Department of Energy-Richland Operations Office Environmental Protection Implementation Plan**. DOE/RL-89-18, U.S. Department of Energy-Richland Operations Office, Richland, Washington.
- Bryce, R. W., and W. R. Gorst. 1990. **Hanford Site Environmental Data for Calendar Year 1989- Ground Water**. PNL-7390, Pacific Northwest Laboratory, Richland, Washington.
- Chatters, J. C. (ed). 1989. **Hanford Cultural Resources Management Plan**. PNL-6942, Pacific Northwest Laboratory, Richland, Washington.
- Coony, F. M., D. B. Howe, and L. J. Voight. 1988. **Westinghouse Hanford Company Effluent Releases and Solid Waste Management Report for 1987: 200/600/1100 Areas**. WHC-EP-0141, Westinghouse Hanford Company, Richland, Washington.
- Corley, J. P., and C. B. Woolridge. 1969. **Evaluation of Radiological Conditions in the Vicinity of Hanford for 1967**. BNWL-983, Pacific Northwest Laboratory, Richland, Washington.
- Corley, J. P. 1970. **Evaluation of Radiological Conditions in the Vicinity of Hanford for 1969**. BNWL-1505, Pacific Northwest Laboratory, Richland, Washington.
- Corley, J. P. 1973. **Environmental Surveillance at Hanford for CY-1970**. BNWL-1669, Pacific Northwest Laboratory, Richland, Washington.
- Corley, J. P., D. H. Denham, R. E. Jaquish, D. E. Michels, A. R. Olsen, and D. A. Waite. 1981. **A Guide for: Environmental Radiological Surveillance at U.S. Department of Energy Installations**. DOE/EP-0023, U.S. Department of Energy, Washington, D.C.
- Cushing, C. E. (ed). 1990. **Hanford Site National Environmental Policy Act (NEPA) Characterization**. PNL-6415, Rev. 3., Pacific Northwest Laboratory, Richland, Washington.

## References

- Dauble, D. D., R. M. Ecker, L. W. Vail, and D. A. Neitzel. 1987. **Downstream Extent of the N Reactor Plume**. PNL-6310, Pacific Northwest Laboratory, Richland, Washington.
- Dinman, B. D. 1980. "The Reality and Acceptance of Risk." **Journal of the American Medical Association (JAMA)** (11):1226-1228.
- Dirkes, R. L. 1990. **1988 Hanford Riverbank Springs Characterization Report**. PNL-7500, Pacific Northwest Laboratory, Richland, Washington.
- DOE - See U.S. Department of Energy.
- Eberhardt, L. E., R. G. Anthony, and W. H. Rickard. 1989. "Survival of Juvenile Canada Geese During the Rearing Period." **Journal of Wildlife Management** 53:372-377.
- Eddy, P. A., D. A. Myers, and J. R. Raymond. 1978. **Vertical Contamination in the Unconfined Groundwater at the Hanford Site, Washington**. PNL-2724, Pacific Northwest Laboratory, Richland, Washington.
- EG&G Energy Measurements (EG&G). 1978. **An Aerial Radiological Survey of the U.S. Department of Energy's Hanford Site. Date of Survey: May/June 1978, Richland, Washington**. EGG-1183-1828. The Remote Sensing Laboratory, EG&G Energy Measurements for the U.S. Department of Energy, Las Vegas, Nevada.
- EG&G Energy Measurements (EG&G). 1990. **An Aerial Radiological Survey of the Hanford Site and Surrounding Area. Date of Survey: July/August 1988, Richland, Washington**. EGG-10617-1062. The Remote Sensing Laboratory, EG&G Energy Measurements for the U.S. Department of Energy, Las Vegas, Nevada.
- Emery, R. M., and M. C. McShane. 1980. "Nuclear Waste Ponds and Streams on the Hanford Site: An Ecological Search for Radiation Effects." **Health Physics** 38:787-809.
- EPA - See U.S. Environmental Protection Agency.
- ERDA - See U.S. Energy Research and Development Administration.
- Evans, J. C., R. W. Bryce, and D. R. Sherwood. 1989a. **Hanford Site Ground-Water Monitoring for January Through June 1988**. PNL-6886-1, Pacific Northwest Laboratory, Richland, Washington.
- Evans, J. C., R. W. Bryce, D. R. Sherwood, M. L. Kemner, and D. R. Newcomer. 1989b. **Hanford Site Ground-Water Monitoring for July Through December 1988**. PNL-7120, Pacific Northwest Laboratory, Richland, Washington.
- Evans, J. C., R. W. Bryce, D. J. Bates, and M. L. Kemner. 1990. **Hanford Site Ground-Water Surveillance for 1989**. PNL-7396, Pacific Northwest Laboratory, Richland, Washington.
- Feely, H. W., R. Larsen, and C. Sanderson. 1985. **Annual Report of the Surface Air Sampling Program**. EML-440, Environmental Measurements Laboratory, U.S. Department of Energy, New York.
- Feely, H. W., R. Larsen, and C. Sanderson. 1988. **Annual Report of the Surface Air Sampling Program**. EML-497, Environmental Measurements Laboratory, U.S. Department of Energy, New York.
- Fisher, W. L., and C. B. Wilson. 1970. **Evaluation of Radiological Conditions in the Vicinity of Hanford for 1968**. BNWL-1341, Pacific Northwest Laboratory, Richland, Washington.
- Fitzner, R. E., L. J. Blus, C. J. Henny, and D. W. Carlile. 1988. "Organochlorine Residues in Great Blue Herons from the Northwestern United States." **Colonial Waterbirds** 11:293-300.
- Fix, J. J., and M. L. Miller. 1978. **The Hanford Environmental  $\text{CaF}_2\text{:Mn}$  Thermoluminescent Dosimeter**. PNL-2489, Pacific Northwest Laboratory, Richland, Washington.
- Foster, R. F., and R. H. Wilson. 1964. **Evaluation of Radiological Conditions in the**

- Vicinity of Hanford for 1963.** HW-80991, U.S. Atomic Energy Commission, Washington, D.C.
- Foster, R. F., and R. H. Wilson. 1965. **Evaluation of Radiological Conditions in the Vicinity of Hanford for 1964.** BNWL-90, Pacific Northwest Laboratory, Richland, Washington.
- Foster, R. F. 1966. **Evaluation of Radiological Conditions in the Vicinity of Hanford for 1965.** BNWL-316, Pacific Northwest Laboratory, Richland, Washington.
- Freshley, M. D., and M. J. Graham. 1988. **Estimation of Ground-Water Travel Time at the Hanford Site: Description, Past Work, and Future Needs.** PNL-6328, Pacific Northwest Laboratory, Richland, Washington.
- Gee, G. W. 1987. **Recharge at the Hanford Site: Status Report.** PNL-6403, Pacific Northwest Laboratory, Richland, Washington.
- Gephart, R. E., P. A. Eddy, R. C. Arnett, and G. A. Robinson. 1976. **Geohydrologic Study of the West Lake Basin.** ARH-CD-775, Atlantic Richfield Hanford Company, Richland, Washington.
- Gephart, R. E., R. C. Arnett, R. G. Baca, L. S. Leonhart, and F. A. Spane, Jr. 1979. **Hydrologic Studies Within the Columbia Plateau, Washington: An Integration of Current Knowledge.** RHO-BWI-ST-5, Rockwell Hanford Operations, Richland, Washington.
- Graham, M. J., M. D. Hall, S. R. Strait, and W. R. Brown. 1981. **Hydrology of the Separations Area.** RHO-ST-42, Rockwell Hanford Operations, Richland, Washington.
- Graham, M. J., G. V. Last, and K. R. Fecht. 1984. **An Assessment of Aquifer Intercommunication in the B Pond - Gable Mountain Pond Area of the Hanford Site.** RHO-RE-ST-12P, Rockwell Hanford Operations, Richland, Washington.
- Hajek, B. F. 1966. **Soil Survey: Hanford Project in Benton County, Washington.** BNWL-243, Pacific Northwest Laboratory, Richland, Washington.
- Health Physics Society (HPS). 1987. **Health Physics Society Official Journal: Special Issue on Radiation Hormesis.** Vol. 52, No. 5.
- Honstead, J. F. 1967. **Evaluation of Radiological Conditions in the Vicinity of Hanford for 1966.** BNWL-439, Pacific Northwest Laboratory, Richland, Washington.
- Jaquish, R. E., and P. J. Mitchell. 1988. **Environmental Monitoring at Hanford for 1987.** PNL-6464, Pacific Northwest Laboratory, Richland, Washington.
- Jaquish, R. E., and R. W. Bryce. 1989. **Hanford Site Environmental Report for Calendar Year 1988.** PNL-6825, Pacific Northwest Laboratory, Richland, Washington.
- Jaquish, R. E., and R. W. Bryce. 1990. **Hanford Site Environmental Report for Calendar Year 1989.** PNL-7346, Pacific Northwest Laboratory, Richland, Washington.
- Jarvis, A. B., and L. Siu. 1981. **Environmental Radioactivity Laboratory Intercomparison Studies Program: Fiscal Year 1980-81.** EPA-600/4-81-004, U.S. Environmental Protection Agency, Las Vegas, Nevada.
- Jenkins, O. P. 1922. **Underground Water Supply of the Region About White Bluffs and Hanford.** State of Washington, Department of Conservation and Development, Olympia, Washington.
- Last, G. V., B. N. Bjornstad, M. P. Bergeron, R. W. Wallace, D. R. Newcomer, J. A. Schramke, M. A. Chamness, C. S. Cline, S. P. Airhart, and J. S. Wilbur. 1989. **Hydrogeology of the 200 Areas Low-Level Burial Grounds - An Interim Report.** PNL-6820, 2 volumes, Pacific Northwest Laboratory, Richland, Washington.
- McCormack, W. D., and J. M. V. Carlile. 1984. **Investigation of Ground-Water Seepage from the Hanford Shoreline of the Columbia River.** PNL-5289, Pacific Northwest Laboratory, Richland, Washington.

## References

- Millikin, E. J. 1989. **Annual Status Report for the Plan and Schedule to Discontinue Disposal of Contaminated Liquid into the Soil Column at the Hanford Site.** WHC-ET-0196-2, Westinghouse Hanford Company, Richland, Washington.
- Napier, B. A., R. A. Peloquin, D. L. Streng, and J. V. Ramsdell. 1988a. **Conceptual Representation.** Volume 1 of **GENII - The Hanford Environmental Radiation Dosimetry Software System.** PNL-6584, Vol. 1, Pacific Northwest Laboratory, Richland, Washington.
- Napier, B. A., R. A. Peloquin, D. L. Streng, and J. V. Ramsdell. 1988b. **User's Manual.** Volume 2 of **GENII - The Hanford Environmental Radiation Dosimetry Software System.** PNL-6584, Vol. 2, Pacific Northwest Laboratory, Richland, Washington.
- Napier, B. A., R. A. Peloquin, D. L. Streng, and J. V. Ramsdell. 1988c. **Code Maintenance Manual.** Volume 3 of **GENII - The Hanford Environmental Radiation Dosimetry Software System.** PNL-6584, Vol. 3, Pacific Northwest Laboratory, Richland, Washington.
- National Council on Radiation Protection and Measurements (NCRP). 1987. **Ionizing Radiation Exposure of the Population of the United States.** Report No. 93, NCRP, Bethesda, Maryland.
- National Research Council (NRC), Committee on the Biological Effects of Ionizing Radiation. 1980. **The Effects on Populations of Exposure to Low Levels of Ionizing Radiation.** National Academy Press, Washington, D.C.
- National Research Council (NRC), Committee on the Biological Effects of Ionizing Radiation. 1990. **Health Effects of Exposure to Low Levels of Ionizing Radiation.** National Academy Press, Washington, D.C.
- Neitzel, D. A., and T. J. Frest. 1989. **Survey of Columbia River Basin Streams for Giant Columbia River Spire Snail *Flumicola columbiana* and Great Columbia River Limpet *Fisherola nuttalli*.** PNL-7103, Pacific Northwest Laboratory, Richland, Washington.
- Newcomer, D. R., K. D. Pohlod, and J. P. McDonald. 1991. **Water-Table Elevations on the Hanford Site, 1990.** PNL-7693, Pacific Northwest Laboratory, Richland, Washington.
- Pacific Northwest Laboratory (PNL). 1989a. **Procedures for Ground-Water Investigations.** PNL-6894, Pacific Northwest Laboratory, Richland, Washington.
- Pacific Northwest Laboratory (PNL). 1989b. **Quality Assurance Manual.** PNL-7000, Pacific Northwest Laboratory, Richland, Washington.
- Poston, T. M., K. L. Price, and D. R. Newcomer. 1991. **An Evaluation of the Chemical, Radiological, and Ecological Conditions of West Lake on the Hanford Site.** PNL-7662, Pacific Northwest Laboratory, Richland, Washington.
- Price, K. R. and R. P. Kinnison. 1982. **Uranium and Other Heavy Metals in Soil and Vegetation from the Hanford Environs.** PNL-4466, Pacific Northwest Laboratory, Richland, Washington.
- Price, K. R. 1986. **Environmental Monitoring at Hanford for 1985.** PNL-5817, Pacific Northwest Laboratory, Richland, Washington.
- Rathbun, L. A. 1989. **The Determination of the Penetrating Radiation Dose at Hanford.** PNL-7124, Pacific Northwest Laboratory, Richland, Washington.
- Rickard, W. H., and L. E. Eberhardt. 1990. "Strontium-90 in Canada Goose Eggshells: Non-fatal Monitoring for Contamination in Wildlife." In **Twenty-Eighth Hanford Symposium on Health and the Environment: What Have We Learned?**, ed. R. H. Gray, pp. 25-331. PNL-6766, Pacific Northwest Laboratory, Richland, Washington.

- Rickard, W. H., and K. R. Price. 1990. "Strontium-90 in Canada Goose Eggshells and Reed Canary Grass." **Environmental Monitoring and Assessment** 14:71-76.
- Robertson, D. E., and J. J. Fix. 1977. **Association of Hanford Origin Radionuclides with Columbia River Sediment**. BNWL-2305, Pacific Northwest Laboratory, Richland, Washington.
- Routson, R. C., and V. G. Johnson. 1990. "Recharge Estimates for the Hanford Site 200 Areas Plateau." **Northwest Science** 64:150.
- Sanderson, C. G. 1985. **Semi-Annual Report of the Department of Energy, Operational Safety, Health and Environment Division, Quality Assessment Program Data Report**. EML-439, Environmental Measurements Laboratory, U.S. Department of Energy, New York.
- Serkowski, J. A., W. A. Jordan, and A. G. Law. 1989. **Operational Ground Water Monitoring at the Hanford Site - 1988**. WHC-EP-0260, Westinghouse Hanford Company, Richland, Washington.
- Smith, R. M., and W. R. Gorst. 1990. **RCRA Ground-Water Monitoring Projects for Hanford Facilities: Annual Progress Report for 1989**. PNL-7305, Pacific Northwest Laboratory, Richland, Washington.
- Snedecor, G. W., and W. G. Cochran. 1980. **Statistical Methods**. 7th ed. Iowa State University Press, Ames, Iowa.
- Soldat, J. K. 1962. **A Compilation of Basic Data Relating to the Columbia River Section 8 - Dispersion of Reactor Effluent in the Columbia River**. HW-69369, General Electric, Richland, Washington.
- Soldat, J. K. 1976. "Radiation Doses from Iodine-129 in the Environment." **Health Physics**. Vol. 30:61-70.
- Soldat, J. K. 1989. **Offsite Radiation Doses from Hanford Operations for the Years 1983 Through 1987: A Comparison of Results Calculated by Two Methods**. PNL-7135, Pacific Northwest Laboratory, Richland, Washington.
- Soldat, J. K., K. R. Price, and W. H. Rickard. 1990. **Methodology Used to Compute Maximum Potential Doses from Ingestion of Edible Plants and Wildlife Found on the Hanford Site**. PNL-7539, Pacific Northwest Laboratory, Richland, Washington.
- Somers, S. R. 1989. **Hanford Sanitary Water Quality Surveillance, CY-1988**. HEHF-74, Hanford Environmental Health Foundation, Richland, Washington.
- Speer, D. R., J. J. Fix, and P. J. Blumer. 1976. **Environmental Surveillance at Hanford for CY-1975**. BNWL-1979, Pacific Northwest Laboratory, Richland, Washington.
- Stenner, R. D., K. H. Cramer, K. A. Higley, S. J. Jette, D. A. Lamar, T. J. McLaughlin, D. R. Sherwood, and N. C. Van Houten. 1988. **Hazard Ranking System Evaluation of CERCLA Inactive Waste Sites at Hanford**. PNL-6456, Pacific Northwest Laboratory, Richland, Washington.
- Stone, W. A., J. M. Thorp, O. P. Gifford, and D. J. Hoitink. 1983. **Climatological Summary for the Hanford Area**. PNL-4622, Pacific Northwest Laboratory, Richland, Washington.
- Sula, M. J. 1980. **Radiological Survey of Exposed Shorelines and Islands of the Columbia River Between Vernita and the Snake River Confluence**. PNL-3127, Pacific Northwest Laboratory, Richland, Washington.
- Sula, M. J., and K. R. Price. 1983. **PUREX Environmental Radiological Surveillance--Preoperational and Operational Support Program Conducted by Pacific Northwest Laboratory**. PNL-4822, Pacific Northwest Laboratory, Richland, Washington.

## References

- Tallman, A. M., K. R. Fecht, M. C. Marratt, and G. V. Last. 1979. **Geology of the Separation Areas, Hanford Site, South-Central Washington**. RHD-ST-23, Rockwell Hanford Operations, Richland, Washington.
- Thurman, P. A. 1991. **Hanford Sanitary Water Quality Surveillance, CY 1990**. HEHF-82, Hanford Environmental Health Foundation, Environmental Health Sciences, Richland, Washington.
- Travis, C. C., and S. T. Hester. 1990. "Background Exposure to Chemicals: What Is the Risk?" **Risk Analysis** 10(4).
- United Nations Scientific Committee on the Effects of Atomic Radiations (UNSCEAR). 1988. **Sources, Effects and Risks of Ionizing Radiation**. Report E.88.IX.7, United Nations, New York.
- U.S. Department of Energy (DOE). 1986. **Environmental Assessment, Reference Repository Location, Hanford Site, Washington**. DOE/RW-0070, U.S. Department of Energy, Washington, D.C.
- U.S. Department of Energy (DOE). 1987a. **Effluent Information System (EIS)/Onsite Discharge Information System (ODIS)**. DOE/ID-187 (87), Idaho Operations Office, Idaho Falls, Idaho.
- U.S. Department of Energy (DOE). 1987b. **Final Environmental Impact Statement, Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes**. DOE/EIS-0113, U.S. Department of Energy, Richland, Washington.
- U.S. Department of Energy (DOE). 1988a. **Internal Dose Conversion Factors for Calculation of Dose to the Public**. DOE/EH-0071, U.S. Department of Energy, Washington, D.C.
- U.S. Department of Energy (DOE). 1988b. **External Dose-Rate Conversion Factors for Calculation of Dose to the Public**. DOE/EH-0070, U.S. Department of Energy, Washington, D.C.
- U.S. Department of Energy (DOE). 1988c. **SP-100 Ground System Test Site**. DOE/EA-0318, DOE, Washington, D.C.
- U.S. Department of Energy (DOE). 1989a. **Tier Two Emergency and Hazardous Chemical Inventory**. DOE/RL 89-04, DOE, Richland, Washington.
- U.S. Department of Energy (DOE). 1989b. **Toxic Chemical Release Inventory**. DOE/RL 89-11, U.S. Department of Energy, Richland, Washington.
- U.S. Department of Energy (DOE). 1989c. **Draft Environmental Impact Statement, Decommissioning of Eight Surplus Production Reactors at the Hanford Site**. DOE/RL-0119D, U.S. Department of Energy, Richland, Washington.
- U.S. Department of Energy (DOE). 1989d. **Environmental Restoration and Waste Management Site-Specific Plan for the Richland Operations Office: Detailed Information**. DOE/RL-89-10, U.S. Department of Energy, Richland, Washington.
- U.S. Department of Energy (DOE). 1989e. **Hanford Site Groundwater Protection Management Program**. DOE/RL 89-12, U.S. Department of Energy, Richland, Washington.
- U.S. Department of Energy (DOE). 1990a. **Hanford Tier-Two Emergency and Hazardous Chemical Inventory**. DOE/RL 90-2, U.S. Department of Energy, Richland, Washington.
- U.S. Department of Energy (DOE). 1990b. **Hanford Toxic Chemical Release Inventory**. DOE/RL-90-26, U.S. Department of Energy, Richland, Washington.
- U.S. Department of Energy (DOE). 1990c. **Hanford Site Annual Dangerous Waste Report for 1989**. DOE/RL 90-10, U.S. Department of Energy, Richland, Washington.
- U.S. Department of Energy (DOE). 1990d. **Environmental Restoration and Waste**

**Management Five-Year Plan, Fiscal Years 1992-1996.** DOE/S-0078P, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE). 1990e. **Hanford Site Stream-Specific Reports: Waste Management Advanced Effluent Technology Unit.** WHC-EP-0342, prepared for U.S. Department of Energy by Westinghouse Hanford Company, Richland, Washington.

U.S. Department of Energy (DOE). 1990f. **The Hanford Site Environmental Restoration and Waste Management Five-Year Plan Activity Data Sheets.** DOE/RL-89-17, U.S. Department of Energy, Richland, Washington.

U.S. Department of Energy (DOE). 1990g. **Tiger Team Assessment of the Hanford Site.** DOE/EH-0139, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE). 1990h. **Phase 1 Remedial Investigation Report for the Hanford Site 1100-EM-1 Operable Unit.** U.S. Department of Energy, Richland, Washington.

U.S. Department of Energy (DOE). 1991a. **Environmental Guide for Radiological Effluent Monitoring and Environmental Surveillance.** DOE/EH-0173T, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE). 1991b. **Hanford Site Environmental Monitoring Plan.** DOE/RL 91-50, U.S. Department of Energy, Richland, Washington.

U.S. Department of Interior (DOI). 1986. **Endangered and Threatened Wildlife and Plants.** Federal Register, 50 FR, Part 17.

U.S. Energy Research and Development Administration (ERDA). 1975. **Final Environmental Impact Statement of Waste Management Operations, Hanford Reservation, Richland, Washington,** 2 vols. ERDA-1538, U.S. Energy Research and Development Administration, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1977. **TGS-ANSA Method for the Determination of Nitrogen Dioxide in the Atmosphere.** EPA Designated Equivalent Method No. EQN-1277-028, Environmental Monitoring and Support Laboratory, Research Triangle Park, North Carolina.

U.S. Environmental Protection Agency (EPA). 1980. **Upgrading Environmental Radiation Data: Health Physics Society Committee Report HPSR-1 (1980).** EPA 520/1-80-012, U.S. Environmental Protection Agency, Washington D.C.

U.S. Environmental Protection Agency (EPA). 1982. **Test Methods for Evaluating Solid Waste: Physical/Chemical Methods.** 2nd ed. SW-846, Office of Solid Waste and Emergency Response, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1984a. **Environmental Radiation Data.** Report 37, January-March 1984, EPA 520/5-84/019, Office of Radiation Programs, Eastern Environmental Radiation Facility (EERF), Montgomery, Alabama.

U.S. Environmental Protection Agency (EPA). 1984b. **Environmental Radiation Data.** Report 38, April-June 1984, EPA 520/5-84/029, Eastern Environmental Radiation Facility (EERF), Montgomery, Alabama.

U.S. Environmental Protection Agency (EPA). (Luster, G. A., J. W. Gunter, and C. M. Petko). 1984c. **Environmental Radiation Data.** Report 39, July-September 1984, EPA 520/5-85/009, Office of Radiation Programs, Eastern Environmental Radiation Facility (EERF), Montgomery, Alabama.

U.S. Environmental Protection Agency (EPA). (Gunter, J. W.). 1985a. **Environmental Radiation Data.** Report 40, October-December 1985, EPA 520/5-85/022, Eastern Environmental Radiation Facility (EERF), Montgomery, Alabama.

U.S. Environmental Protection Agency (EPA). (Petko, C. M., and C. R. Phillips). 1985b. **Environmental Radiation Data.** Report 41,



## References

January-March 1985, EPA 520/5-85/030, Eastern Environmental Radiation Facility (EERF), Montgomery, Alabama.

U.S. Environmental Protection Agency (EPA). 1985c. **Environmental Radiation Data**. Report 42, April-June 1985, EPA 520/5-85/031, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1985d. **Environmental Radiation Data**. Report 43, December 1985, EPA 520/5-86-007, Office of Radiation Programs, Eastern Environmental Radiation Facility (EERF), Montgomery, Alabama.

U.S. Environmental Protection Agency (EPA). 1986a. **Environmental Radiation Data**. Report 44-45, June 1986, EPA 520/5-86-018, Office of Radiation Programs, Eastern Environmental Radiation Facility (EERF), Montgomery, Alabama.

U.S. Environmental Protection Agency (EPA). 1986b. **Environmental Radiation Data**. Report 46 Revised Edition, September 1986, EPA 520/5-87-004, Office of Radiation Programs, Eastern Environmental Radiation Facility (EERF), Montgomery, Alabama.

U.S. Environmental Protection Agency (EPA). 1987a. **Environmental Radiation Data**. Report 47, June 1987, EPA 520/5-87-008, Office of Radiation Programs, Eastern Environmental Radiation Facility (EERF), Montgomery, Alabama.

U.S. Environmental Protection Agency (EPA). 1987b. **Environmental Radiation Data**. Report 48, June 1987, EPA 520/5-87-017, Office of Radiation Programs, Eastern Environmental Radiation Facility (EERF), Montgomery, Alabama.

U.S. Environmental Protection Agency (EPA). 1987c. **Environmental Radiation Data**. Report 49, January 1987 - March 1987, EPA 520/5-87-018, Office of Radiation Programs, Eastern Environmental Radiation Facility (EERF), Montgomery, Alabama.

U.S. Environmental Protection Agency (EPA). 1987d. **Environmental Radiation Data**. Report 50, April-June 1987, EPA 520/5-88-001, Office of Radiation Programs, Eastern Environmental Radiation Facility (EERF), Montgomery, Alabama.

U.S. Environmental Protection Agency (EPA). 1988a. **Environmental Radiation Data**. Report 51, July-September 1987, EPA 520/5-88-013, Office of Radiation Programs, Eastern Environmental Radiation Facility (EERF), Montgomery, Alabama.

U.S. Environmental Protection Agency (EPA). 1988b. **Environmental Radiation Data**. Report 52, October-December 1987, EPA 520/5-88-054, Office of Radiation Programs, Eastern Environmental Radiation Facility (EERF), Montgomery, Alabama.

U.S. Environmental Protection Agency (EPA). 1988c. **Environmental Radiation Data**. Report 53, January-March 1988, EPA 520/5-88-057, Office of Radiation Programs, Eastern Environmental Radiation Facility (EERF), Montgomery, Alabama.

U.S. Environmental Protection Agency (EPA). 1988d. **Off-Site Environmental Monitoring Report, Radiation Monitoring Around United States Nuclear Test Areas, Calendar Year 1987**. EPA-600/14-88-021, Environmental Monitoring Systems Laboratory, Las Vegas, Nevada.

U.S. Environmental Protection Agency (EPA). 1989a. **Off-Site Environmental Monitoring Report, Radiation Monitoring Around United States Nuclear Test Areas, Calendar Year 1988**. EPA-600/14-89-019, Environmental Monitoring Systems Laboratory, Las Vegas, Nevada.

U.S. Environmental Protection Agency (EPA). 1989b. **Environmental Radiation Data**. Report 57, January-March 1989, EPA 520/5-89-021, Office of Radiation Programs, Eastern Environmental Radiation Facility (EERF), Montgomery, Alabama.



U.S. Environmental Protection Agency (EPA). 1989c. **Environmental Radiation Data**. Report 58, April-June 1989, EPA 520/5-89-034, Office of Radiation Programs, Eastern Environmental Radiation Facility (EERF), Montgomery, Alabama.

U.S. Environmental Protection Agency (EPA). 1990. **National Emission Standard for Hazardous Air Pollutants; Standards for Radionuclides**. 40 CFR 61, U.S. Government Printing Office, Washington, D.C.

U.S. Geological Survey (USGS). 1988. **Water Resources Data Washington Water Year 1986**. Report WA-86-1, U.S. Geological Survey, Denver, Colorado.

Washington Natural Heritage Program. 1990. **Endangered, Threatened, and Sensitive Vascular Plants of Washington**. Department of Natural Resources, Olympia, Washington.

Washington State Department of Ecology (WDOE). July 1986 (Amended). **Dangerous Waste Regulations**. Washington Administrative Code, Chapters 173-303, Olympia, Washington.

Washington State Department of Social and Health Services (WDSHS). 1987. **Environmental Radiation Program, Twenty-Fourth Annual Report**. Office of Radiation Protection, Olympia, Washington.

Westinghouse Hanford Company (WHC). 1990. **Liquid Effluent Study Final Project Report**. WHC-EP-0367, Westinghouse Hanford Company, Richland, Washington.

Wilson, R., and E. S. C. Crouch. 1987. "Risk Assessment and Comparisons: An Introduction." *Science* 236 (4799):267-270.

## U.S. Department of Energy Orders

**DOE Order 5484.1.** 1981. "Environmental Protection, Safety, and Health Protection Information Reporting Requirements."

**DOE Order 5440.1C.** 1985. "The National Environmental Policy Act."

**DOE Order 5480.1B.** 1986. "Environmental Safety and Health Programs for DOE Operations."

**DOE Order 5700.6B.** 1986. "Quality Assurance."

**DOE-RL Order 5440.1A.** 1987. "Implementation of the National Environmental Policy Act at the Richland Operations Office."

**DOE Order 5400.1.** 1988. "General Environmental Protection Program."

**DOE Order 5400.5.** 1990. "Radiation Protection of the Public and the Environment."

**DOE Order 5820.2A.** 1988. "Radioactive Waste Management."

**DOE Order 5000.3A.** 1990. "Occurrence Reporting and Processing of Operations Information."

## Appendixes



# Appendix A

## Glossary



# Appendix A

## 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.

**bankstorage** - 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 ( $1 \text{ Bq} = 1/\text{s}$ ). The conventional unit of activity, the curie, is related to the becquerel according to  $1 \text{ Ci} = 3.7 \times 10^{10} \text{ Bq}$ .

**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 ( $3.7 \times 10^{10}$ ) 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.

**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,  $\bar{X}$ , was computed as:

$$\bar{X} = \frac{1}{n} \sum_{i=1}^n X_i$$

where  $\bar{X}_i$  is the  $i$ th 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.

**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") and internal irradiation from the inhaled air in the lung.

**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  $^{239}\text{Pu}$ , which is produced by the irradiation of  $^{238}\text{U}$ . Routine analysis cannot distinguish between the  $^{239}\text{Pu}$  and  $^{240}\text{Pu}$  isotopes; hence, the term  $^{239,240}\text{Pu}$  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 non-ionizing 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." (See "Dose Equivalent" below.)
- **collective dose equivalent** - Sum of the 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.
- **cumulative dose equivalent** - Total dose one could receive in a period of 50 years following release of the radionuclides to the environment, including the dose that could occur as a result of exposure to residual radionuclides remaining in the environment beyond the year of release.

- **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.

**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  $\bar{X}$  was computed as

$$SE = \sqrt{\frac{S^2}{n}}$$

where  $S^2$ , the variance of the  $n$  measurements, was computed as

$$S_M^2 = \frac{1}{n-1} \sum_{i=1}^n (X_i - \bar{X})^2$$

This estimator,  $S^2$ , includes the variance among the samples and the counting variance. The estimated  $S^2$  may occasionally 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.

**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 relatively uniform 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, usually based on yearly averages.



## **Appendix B**

### **Applicable Standards and Permits**



# Appendix B

## 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 1990 are listed in the following tables. The State of Washington has promulgated water quality standards for the Columbia River (WDOE 1982). 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 B.1. Drinking water standards promulgated by the U.S. Environmental Protection Agency (EPA) in 40 CFR 141 (EPA 1990a) are summarized in Tables B.2 and B.3. Tri-Counties Air Pollution Control Authority air quality standards are shown in Table B.4. Applicable radiation standards pursuant to the Clean Air Act for sources of radionuclide emissions to the air, 40 CFR 61 (EPA 1990b), are summarized in Table B.5. Environmental radiation protection standards are published in 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 B.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 B.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 B.7.

**Table B.1. Washington State Water Quality Standards for the Hanford Reach of the Columbia River**

Parameter	Permissible Levels
Fecal Coliform	1) $\leq 100$ organisms/100 mL 2) $\leq 10\%$ of samples may exceed 200 organisms/100 mL
Dissolved Oxygen	$> 8$ mg/L
Temperature	1) $\leq 20^{\circ}\text{C}$ ( $68^{\circ}\text{F}$ ) due to human activities 2) When natural conditions exceed $20^{\circ}\text{C}$ , no temperature increase of greater than $0.3^{\circ}\text{C}$ allowed. 3) Increases not to exceed $34/(T+9)$ , where T = highest existing temperature in $^{\circ}\text{C}$ outside of dilution zone.
pH	1) 6.5 to 8.5 range 2) $< 0.5$ unit induced variation
Turbidity	$\leq 5$ NTU <sup>(a)</sup> 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 B.2. 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
Gross Alpha (excluding uranium)	15 pCi/L
Combined $^{226}\text{Ra}$ and $^{228}\text{Ra}$	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 for $^3\text{H}$ and $^{90}\text{Sr}$ are less than 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 (40 CFR 141).

Radionuclide	Critical Organ	Concentration, pCi/L
$^3\text{H}$	Whole body	20,000
$^{14}\text{C}$	Fatty tissue	2,000
$^{60}\text{Co}$	GI (LLI) <sup>(a)</sup>	100
$^{89}\text{Sr}$	Bone	20
$^{89}\text{Sr}$	Bone marrow	80
$^{90}\text{Sr}$	Bone marrow	8
$^{95}\text{Zr}$	GI (LLI)	200
$^{95}\text{Nb}$	GI (LLI)	300
$^{99}\text{Tc}$	GI (LLI)	900
$^{103}\text{Ru}$	GI (LLI)	200
$^{106}\text{Ru}$	GI (LLI)	30
$^{125}\text{Sb}$	GI (LLI)	300
$^{129}\text{I}$	Thyroid	1
$^{131}\text{I}$	Thyroid	3
$^{134}\text{Cs}$	GI (S) <sup>(b)</sup>	20,000
$^{137}\text{Cs}$	Whole body	200

(a) Gastrointestinal tract (lower large intestine).

(b) Stomach.

**Table B.3. 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)**

<u>Chemical Constituent</u>	<u>Concentration</u>
As	50 µg/L
Ba	1 mg/L
CCl <sub>4</sub>	5 µg/L
Cd	10 µg/L
Cr	50 µg/L
Cu	1 mg/L
F	2 mg/L
Hg	2 µg/L
NO <sub>3</sub> <sup>-</sup>	45 mg/L
Pb	50 µg/L
Se	10 µg/L

**Table B.4. Benton-Franklin-Walla Walla Counties (Tri-Counties) Air Pollution Control Authority Ambient Air Quality Standards<sup>(a)</sup>**

<u>Parameter</u>	<u>Type of Standard<sup>(b)</sup></u>	<u>Sampling Period</u>	<u>Permissible Level</u>
NO <sub>2</sub>	Secondary and primary	Annual average	0.05 ppmv

(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 B.5. Radiation Standards for Protection of the Public from All Routine DOE Activities

**RADIATION DOSE LIMITS<sup>(a)</sup>****ALL PATHWAYS** [limits from DOE Order 5400.5]

The effective dose equivalent for any member of the public from all routine DOE activities<sup>(b)</sup> shall not exceed the values given below.

	Effective Dose Equivalent <sup>(c)</sup>	
	mrem/yr	(mSv/yr)
Routine Public Dose	100	(1)
Potential Authorized Temporary Public Dose <sup>(d)</sup>	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<sup>(e)</sup> 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 <sup>(c)</sup>	
	mrem/yr	(mSv/yr)
Public Dose Limit at Location of Maximum Annual Air Concentration as a Consequence of Routine DOE Activities <sup>(b)</sup>	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 B.6. Derived Concentration Guides<sup>(a,b,c)</sup>**

Radionuclide	Water, pCi/L ( $10^{-9}$ $\mu$ Ci/mL)	Air, pCi/m <sup>3</sup> ( $10^{-12}$ $\mu$ Ci/mL)
<sup>3</sup> H	2,000,000	100,000
<sup>14</sup> C	70,000	500,000
<sup>51</sup> Cr	1,000,000	60,000
<sup>54</sup> Mn	50,000	2,000
<sup>60</sup> Co	5,000	80
<sup>65</sup> Zn	9,000	600
<sup>85</sup> Kr	NS <sup>(d)</sup>	3,000,000
<sup>90</sup> Sr	1,000	50
<sup>99</sup> Tc	100,000	2,000
<sup>103</sup> Ru	50,000	2,000
<sup>106</sup> Ru	6,000	30
<sup>125</sup> Sb	60,000	1,000
<sup>129</sup> I	500	70
<sup>131</sup> I	3,000	400
<sup>137</sup> Cs	3,000	400
<sup>144</sup> Ce	7,000	30
<sup>234</sup> U	500	0.09
<sup>235</sup> U	600	0.1
<sup>238</sup> U	600	0.1
<sup>238</sup> Pu	40	0.03
<sup>239</sup> Pu	30	0.02
<sup>240</sup> 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 <sup>85</sup>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 B.7. Environmental Permits****Clean Water Act Permit**

NPDES Permit No. WA-000374-3, issued to the DOE Richland Field Office 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:

Measurement	Location		
	100-K Area (2 discharges)	100-N Area (5 discharges)	300 Area (1 discharge)
Flow Rate	X	X	X
Suspended Solids	X	X	X
Temperature	X	X	--- <sup>(a)</sup>
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  $\text{NO}_x$  to the atmosphere from the Plutonium Uranium Extraction (PUREX) Plant and the Uranium Oxide ( $\text{UO}_2$ ) 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, 1989, the permit is for a 2-year period.

**Wildlife Sampling Permits**

Scientific Study or Collection Permit No. 040, issued by Washington State Department of Wildlife to Pacific Northwest Laboratory for 1990, covers the collection of wildlife, including fish, for environmental monitoring purposes. Renewed annually.

Federal Fish and Wildlife Permit No. 671877, issued to Pacific Northwest Laboratory by U.S. Fish and Wildlife Service. No expiration date.

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 Field Office  
Richland, WA 99352

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

## References

Benton-Franklin-Walla Walla Counties Air Pollution Control Authority. 1980. General Regulation 80-7. Air Pollution Control Authority, Richland, Washington

**DOE Order 5400.5.** 1990. "Radiation Protection of the Public and the Environment."

U.S. Environmental Protection Agency (EPA). 1990a. **National Primary Drinking Water Regulations.** 40 CFR 41, U.S. Government Printing Office, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1990b. **National Emission Standard for Hazardous Air Pollutants; Standards for Radionuclides.** 40 CFR 61, U.S. Government Printing Office, Washington, D.C.

Washington State Department of Ecology (WDOE). 1982. **Water Quality Standards for Waters of the State of Washington.** Washington Administrative Code, Chapter 173-201, Olympia, Washington.

## **Appendix C**

### **Dose Calculations**





# Appendix C

## Dose Calculations

The radiation dose that the public could have potentially received in 1990 from Hanford operations was calculated in terms of the "effective dose equivalent." These dose quantities are given in units of millirem (mrem) [millisievert (mSv)]<sup>(a)</sup> 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 B.5, Appendix B). 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 then 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 ICRP Reports (1979-1982). The assumptions and input data used in these calculations are described below.

### Types of Dose Calculations Performed

#### Revised DOE Guidance for Dose Calculations

Calculations of radiation doses to the public from radionuclides released into the environment are performed to demonstrate compliance with applicable standards and regulations.

Beginning in 1985, the DOE required 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 revised biokinetic models and metabolic parameters for radionuclides given by the ICRP 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.

Estimated radiation doses from DOE operations have previously been reported in terms of the dose equivalent (or simply, dose), which is a measure of the energy absorbed by tissue (rads), multiplied by a radiation quality factor, and modified by any other necessary factors. Under this system, standards for radiation protection were presented in terms of the critical organ dose limits and were expressed in rem (or mrem).

---

(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 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" Whole-Body 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 life-style 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

- drinking of uncontaminated water from deep wells
- 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 represent 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 with the addition of drinking water drawn from the Columbia River. 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 reside adjacent to the river within 80 km (50 mi) of the Hanford Site and 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 1990 - Surface and Columbia River." These distributions are based on 1980 Bureau of Census data (Sommer et al. 1981) because the 1990 data were not yet available in a usable format. 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 1990 - Surface and Columbia River." These data describe the transport and dilution of airborne radioactive material, and influence

doses to the maximally exposed individual and public by estimating 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 C.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 C.2 through C.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 the "Hanford Site Environmental Data for Calendar Year 1990 - Surface and Columbia River."

Table C.1. Food Pathway Parameters Used in 1990 Dose Calculations

	Holdup, days (except as noted) <sup>(a)</sup>		Growing Period, days	Yield, kg/m <sup>2</sup>	Irrigation Rate, L/m <sup>2</sup> /month
	Maximally Exposed Individual	Average Individual			
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) <sup>(b)</sup>	(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	24 h	24 h	---	---	---
Drinking Water	24 h	24 h	---	---	---

(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 C.2. Dietary Parameters Used in 1990 Dose Calculations

	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 <sup>(a)</sup>	270	230
Red Meat	80	70
Poultry	18	8.5
Fish	40	--- <sup>(b)</sup>
Drinking Water <sup>(a)</sup>	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 C.3. Residency Parameters Used in the 1990 Dose Calculations**

<u>Parameter</u>	<u>Exposure, h/yr</u>	
	<u>Maximally Exposed Individual</u>	<u>Average Individual</u>
Ground Contamination	4,383	2,920
Air Submersion	8,766	8,766
Inhalation <sup>(a)</sup>	8,766	8,766

(a) Inhalation rates: Adult 270 cm<sup>3</sup>/s.

**Table C.4. Recreational Parameters Used in the 1990 Dose Calculations**

<u>Parameter</u>	<u>Exposure, h/yr<sup>(a)</sup></u>	
	<u>Maximally Exposed Individual</u>	<u>Average Individual</u>
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.

## References

International Commission on Radiological Protection (ICRP). 1977. **Recommendations of the International Commission on Radiological Protection**. ICRP Publication 26, Annals of the ICRP, Vol. 1, No. 3, Pergamon Press, Elmsford, New York.

International Commission on Radiological Protection (ICRP). 1979-1982. **Limits for Intakes of Radionuclides by Workers**. ICRP Publication 30, Annals of the ICRP, Vol. 2, No. 3/4, through Vol. 8, No. 4, Pergamon Press, Elmsford, New York.

Napier, B. A., R. A. Peloquin, D. L. Streng, and J. V. Ramsdell. 1988a. **Conceptual Representation**. Volume 1 of **GENII - The Hanford Environmental Radiation Dosimetry Software System**. PNL-6584, Vol. 1, Pacific Northwest Laboratory, Richland, Washington.

Napier, B. A., R. A. Peloquin, D. L. Streng, and J. V. Ramsdell. 1988b. **User's Manual**. Volume 2 of **GENII - The Hanford Environmental Radiation Dosimetry Software System**. PNL-6584, Vol. 2, Pacific Northwest Laboratory, Richland, Washington.

Napier, B. A., R. A. Peloquin, D. L. Streng, and J. V. Ramsdell. 1988c. **Code Maintenance Manual**. Volume 3 of **GENII - The Hanford Environmental Radiation Dosimetry Software System**. PNL-6584, Vol. 3, Pacific Northwest Laboratory, Richland, Washington.

Sommer, D. J., R. G. Rau, and D. C. Robinson. 1981. **Population Estimates for the Areas Within a 50-Mile Radius of Four Reference Points on the Hanford Site**. PNL-4010, Pacific Northwest Laboratory, Richland, Washington.

# Distribution

**No. of  
Copies**

**No. of  
Copies**

**OFFSITE**

A. Aldrich  
Bureau of Land Management  
Spokane District Office  
E. 4217 Main Avenue  
Spokane, WA 99202

S. R. Arlt  
City of Richland  
Director  
Water and Waste Department  
P.O. Box 190  
Richland, WA 99352

C. K. Ashbaker  
Industrial and Onsite Waste Manager  
Oregon State Department of  
Environmental Quality  
Water Quality Division  
811 S.W. Sixth Avenue  
Portland, OR 97204

Basin City Branch of the Mid-Columbia  
Library  
50-A N Canal Blvd  
Basin City, WA 99343

T. M. Beasley  
Environmental Measurements Laboratory  
376 Hudson Street  
New York, NY 10014

Benton City Branch of the Mid-Columbia  
Library  
City Hall  
Benton City, WA 99320

W. Bishop  
Nuclear Waste Advisory Council  
Department of Ecology  
P.O. Box 47600  
PV-11  
Olympia, WA 98504-7600

M. L. Blazek  
Manager, Radioactive Materials Dept.  
Oregon Department of Energy  
625 Marion St. N.E.  
Salem, OR 97310

B. Boyum  
Washington State Dept. of Natural  
Resources, Southeast Region  
713 E. Bowers Rd.  
Ellensburg, WA 98926

M. Brown  
Brown and Guis Farms  
Star Route 1  
Royal City, WA 99357

R. C. Bubeck  
Water Resources Division  
U.S. Geological Survey  
345 Middlefield Road, M/S-470  
Menlo Park, CA 94025

Jackie Campbell  
U.S. Fish and Wildlife Service  
Water Rights Acquisition Planning  
2600 S.E. 98th St., Suite 130  
Portland, OR 97266

C. J. Card  
Senior Health Physicist  
Washington Public Power Supply System  
Mail Stop 1020  
P.O. Box 968  
Richland, WA 99352

R. Chitwood  
Manager, Emergency Planning  
Washington Public Power Supply System  
Mail Stop 1020  
P. O. Box 968  
Richland, WA 99352

**No. of  
Copies**

R. T. Clark  
A.T.G.  
2520 Battelle Blvd.  
Richland, WA 99352

Confederated Tribes of the Umatilla  
Indian Reservation  
P.O. Box 638  
Pendleton, OR 97801

A. W. Conklin  
Division of Radiation Protection  
Washington State Department of  
Health  
Airindustrial Center  
Building 5  
LE-13  
Olympia, WA 98504

Connell Branch of the Mid-Columbia  
Library  
130 Columbia  
Connell, WA 99326

Corps of Engineers  
Resource Manager  
Ice Harbor Project  
Route 6, Box 693  
Pasco, WA 99301

K. Darrington  
COESP Alternate Manager  
Edwin Markham Elementary School  
4031 Elm Road  
Pasco, WA 99301

Ken R. Dixon  
Washington State Department of Wildlife  
600 Capital Way N.  
Olympia, WA 98501-1091

R. W. Donovan  
Technological Hazards Branch Chief  
Federal Emergency Management  
Agency  
Region X, Federal Regional Center  
130 228th Street S.W.  
Bothell, WA 98021-9796

**No. of  
Copies**

Brian Drost  
U.S. Geological Survey  
1201 Pacific Ave.  
Suite 600  
Tacoma, WA 98402

T. G. Eaton  
Office of Hazardous and Solid Waste  
Washington State Department of Ecology  
P.O. Box 47600  
PV-11  
Olympia, WA 98504-7600

Don R. Elle MS-505  
U.S. Department of Energy  
Nevada Operations Office  
Health Protection Division  
P.O. Box 98518  
Las Vegas, NV 89193-8518

J. L. Erickson  
Division of Radiation Protection  
Washington State Department of Health  
Airindustrial Center  
Building 5  
LE-13  
Olympia, WA 98504

B. B. Ernst  
American Nuclear Insurers  
The Exchange Suite 245  
270 Farmington Avenue  
Farmington, CN 06032

P. K. Fitzsimmons MS-505  
U.S. Department of Energy  
Nevada Operations Office  
Health Protection Division  
P.O. Box 98518  
Las Vegas, NV 89193-8518

Gretchen Gallegos  
Technical Document Manager  
Environmental Monitoring Group  
Lawrence Livermore National Laboratory  
University of California  
P.O. Box 5507  
Livermore, CA 94550



**No. of  
Copies**

Tom Gilmore  
COESP Alternate Manager  
Hanford School  
450 Hanford  
Richland, WA 99352

Ray Issacson  
Commissioner  
P.O. Box 190  
Prosser, WA 99350

Stan Jackson  
Washington State Division of  
Emergency Management  
PT-11  
4200 East Martin Way  
Olympia, WA 98504

L. D. Jecha  
Benton-Franklin District Health  
Department  
506 McKenzie  
Richland, WA 99352

Kahlotus Branch of the Mid-Columbia  
Library  
255 E Weston  
Kahlotus, WA 99335

Kennewick Branch of the Mid-Columbia  
Library  
405 S Dayton  
Kennewick, WA 99336

W. A. Kiel  
Washington Public Power Supply System  
Mail Stop 280  
3000 George Washington Way  
Richland, WA 99352

J. King  
Richland City Manager  
P.O. Box 190  
Richland, WA 99352

Library, Nuclear and Mixed Waste  
Program  
Washington State Department of Ecology  
PV-11  
Olympia, WA 98405-8711

**No. of  
Copies**

S. R. Lockhaven  
Safety and Security Department  
Siemens Nuclear Power Corp.  
2101 Horn Rapids Road  
Richland, WA 99352

Mitch Madison  
COESP Manager  
Edwin Markham Elementary School  
4031 Elm Road  
Pasco, WA 99301

C. W. Malody  
Siemens Nuclear Power Corp.  
2101 Horn Rapids Road  
Richland, WA 99352

J. B. Martin  
U.S. Nuclear Regulatory Commission  
1450 Maria Lane, Suite 210  
Walnut Creek, CA 94596

Elizabeth McDowell MS 412  
Reynolds Electric & Engineering Co. Inc.  
P.O. Box 98521  
Las Vegas, NV 89193-8521

Merrill's Corner Branch of the Mid-  
Columbia Library  
5240 Eltopia Way  
Eltopia, WA 99330

T. L. Milne  
Executive Director  
Southwest Washington Health District  
P.O. Box 1870  
Vancouver, WA 98668-1870

C. E. Palmer  
Director of Natural Resources  
Yakima Indian Nation  
P.O. Box 151  
Toppenish, WA 98948

R. D. Paris  
Manager, Radiation Control Section  
1400 S.W. 5th Ave.  
Oregon State Health Division  
Portland, OR 97201

**No. of  
Copies**

**No. of  
Copies**

Pasco Branch of the Mid-Columbia  
Library  
1320 W. Hopkins  
Pasco, WA 99301

Richland Public Library  
955 Northgate  
Richland, WA 99352

Roza Branch of the Mid-Columbia Library  
Johnson and Hinzerling Rd  
Prosser, WA 99350

Delano Saluskin  
Yakima Indian Nation  
P.O. Box 151  
Toppenish, WA 98948

S. R. Sander  
Environmental Specialist  
Bonneville Power Authority  
P.O. Box 3621 AJ  
Portland, OR 97208

D. Silver  
Special Assistant to the Governor on  
Hanford  
Office of the Governor  
100 Insurance Bldg.  
MS-AQ44  
Olympia, WA 98504

R. Stanley  
Washington State Department of Ecology  
Nuclear and Mixed Waste Programs  
PV-11  
Olympia, WA 98504-8711

C. Stevenson  
COESP Manager  
Basin City Elementary School  
303 Baillie Blvd.  
Mesa, WA 99343

D. Stewart-Smith  
Administrator, Nuclear Safety and Energy  
Facility Division  
Oregon Department of Energy  
625 Marion Street NE  
Salem, OR 97310

T. R. Strong  
Director, Division of Radiation Protection  
Washington State Department of Health  
P.O. Box 47827  
LE-13  
Olympia, WA 98504-7827

D. A. Tallman  
Safety Officer  
U.S. Ecology  
P.O. Box 638  
Richland, WA 99352

G. E. Toombs  
Environmental Radiation Surveillance  
Supervisor  
Radiation Control Section  
Oregon State Health Division  
1400 S.W. 5th Ave.  
Portland, OR 97201

Newell Trash  
Chief, Nuclear Waste Hydrology  
U.S. Geological Survey  
12201 Sunrise Valley Dr.  
MS-411  
Reston, VA 22092

U.S. Fish and Wildlife Service  
McNary National Wildlife Refuge  
P.O. Box 308  
Burbank, WA 99323

U.S. Fish and Wildlife Service  
Umatilla National Wildlife Refuge  
P.O. Box 239  
Umatilla, OR 97882

J. E. Vorbach  
U.S. Coast Guard  
Federal Building, Rm 3590  
District Commander  
915 2nd Avenue  
Seattle, WA 98174

C. Wagner  
COESP Manager  
Hanford School  
450 Hanford  
Richland, WA 99352

**No. of  
Copies**

**No. of  
Copies**

Washington State Department of Ecology  
Library  
PV-11  
Olympia, WA 98504

West Richland Branch of the Mid-Columbia  
Library  
5456 Van Giesen  
West Richland, WA 99352

K. F. Wolk  
Radiation Safety Officer  
P.N. Services, Inc.  
2939 Park Drive  
Richland, WA 99352

**U.S. Department of Energy**

- 12 DOE/Office of Scientific and  
Technical Information
- 5 R. Barber  
EH-33  
U.S. Department of Energy  
Director, Office of Safety Compliance  
Washington, DC 20545
- 2 J. H. Barry  
Manager, Office of Environmental  
Safety & Health Oversight  
MS 1218  
U.S. Department of Energy  
785 DOE Place  
Idaho Falls, ID 83402
- 2 C. M. Borgstrom  
Director, Office of NEPA Project  
Assistance  
U.S. Department of Energy  
EH-25  
Washington, DC 20585
- 10 P. N. Brush  
Principle Deputy Assistant Secretary  
Office of Environment Safety and Health  
U.S. Department of Energy  
EH-2  
Washington, DC 20585

Joe Boda  
U.S. Department of Energy  
Trevion-2 Building  
EM-322  
Washington, DC 20585

- 2 Director, Office of Environmental Audit  
U.S. Department of Energy  
EH-24  
Washington, DC 20585

V. Fayne  
U.S. Department of Energy  
Environmental Audit  
EM-24  
Washington, DC 20585

D. J. Galas  
Assoc. Director for Health and  
Environmental Research  
Office of Health and Environmental  
Research  
U.S. Department of Energy (GTN)  
ER-70  
Washington, DC 20545

- 2 H. M. McCammon  
Director, Ecological Research Division  
ER-74 (GTN)  
U.S. Department of Energy  
Washington, DC 20545

- 2 K. Olson  
Ecological Research Division  
U.S. Department of Energy  
ER-75, MS-226  
Washington, DC 20545

R. Pelletier  
Director, Environmental Guidance  
Division  
U.S. Department of Energy  
EH-23  
Washington, DC 20545

**No. of  
Copies**

- 5 J. C. Tseng  
Associate Deputy Assistant Secretary for  
Environment  
U.S. Department of Energy  
EM-35  
Washington, DC 20585

**U.S. Environmental Protection Agency**

James Elder  
Director, Office of Ground Water  
Protection  
U.S. Environmental Protection Agency  
WH-5508  
401 M Street, SW  
Washington, DC 20460

- 2 J. William Gunter  
Director, Criteria and Standards Division  
Office of Air & Radiation  
U.S. Environmental Protection Agency  
MS ANR460 W  
2800 Crystal Dr.  
Arlington, VA 22202

- 3 J. M. Leitch  
Environmental Protection Agency  
Region X  
AT-082  
1200 6th Avenue  
Seattle, WA 98101

Ken Mosbaugh  
Environmental Protection Agency  
Region X  
WD-134  
1200 6th Avenue  
Seattle, WA 98101

Dana Rasmussen  
Environmental Protection Agency  
Region X  
SO-141  
1200 6th Avenue  
Seattle, WA 98101

**No. of  
Copies**

**ONSITE**

**40 DOE Richland Field Office**

T. A. Bauman (3)  
R. F. Brich (25)  
P. F. X. Dunigan  
R. E. Gerton  
R. D. Hildebrand  
R. A. Holten  
R. D. Izatt  
J. R. Shadel  
J. J. Sutey  
R. R. Tibbatts  
M. W. Tiernan  
J. D. Wagoner  
DOE Public Reading Room (2)

**3 Hanford Environmental Health  
Foundation**

R. L. Kathren  
L. J. Maas  
W. L. Meader

**85 Westinghouse Hanford Company**

M. R. Adams  
R. E. Allen  
H. Babad  
J. A. Bates (3)  
R. J. Bliss  
G. F. Boothe  
L. C. Brown  
M. J. Brown  
J. G. Burk  
G. D. Carpenter  
Y.-M. Chien  
D. J. Connell  
C. Defigh-Price  
L. P. Diediker  
W. T. Dixon  
J. J. Dorian  
G. W. Duffield  
Cos Edwards (12)

**No. of  
Copies**

K. R. Fecht  
M. R. Fox  
K. A. Gano  
L. A. Garner  
E. M. Greager  
W. H. Hamilton  
D. I. Herborn  
D. O. Hess  
M. E. Hevland  
R. C. Hill  
M. C. Hughes  
G. W. Jackson  
I. D. Jacques  
A. R. Johnson (6)  
D. H. Jones  
W. A. Jordan  
A. G. Law  
R. E. Lerch  
D. W. Lindsey  
J. J. Luke  
H. E. McGuire  
R. M. Mitchell  
J. M. Nickels  
S. M. O'Toole (2)  
C. J. Perkins  
D. R. Pratt  
W. H. Price  
J. M. Ring  
J. W. Schmidt  
Sylvia Segovia  
J. A. Serkowski  
D. E. Simpson  
D. J. Swain  
S. P. Thomas  
E. C. Vogt  
J. L. Waite  
D. J. Watson  
W. P. Whiting  
D. D. Wodrich  
R. D. Wojtasek  
D. E. Wood  
EDMC (6) Attention Susan Wray  
Westinghouse Central Files (L8-04)

**200 Pacific Northwest Laboratory**

R. L. Aaberg  
C. R. Allen  
M. E. Almarode

**No. of  
Copies**

G. L. Andersen  
L. M. Andor  
W. J. Bair  
D. A. Baker  
K. R. Barton  
D. J. Bates  
D. M. Beck  
L. L. Belt  
L. E. Bisping  
C. A. Brandt  
F. P. Brauer  
T. L. Brown (10)  
R. W. Bryce (10)  
L. L. Cadwell  
J. C. Chatters  
C. E. Cushing  
D. D. Dauble  
R. L. Dirkes  
P. G. Doctor (6)  
J. J. Evanoff  
J. C. Evans  
J. W. Falco  
J. J. Fix  
M. D. Freshley  
S. L. Friant  
R. M. Fruland  
R. E. Gephart  
R. O. Gilbert  
R. H. Gray  
J. M. Hales  
R. W. Hanf (57)  
P. C. Hays  
C. M. Heeb  
E. L. Hilty  
D. J. Hoitink  
C. J. Hostetler  
J. R. Houston  
A. K. Stalker  
T. A. Ikenberry  
J. A. Jahnke  
W. R. James  
R. E. Jaquish (20)  
J. R. Johnson  
W. E. Kennedy  
R. R. LaBarge  
T. R. Lakey  
G. V. Last  
J. J. Lopez  
S. O. Link

**No. of  
Copies**

R. E. Lundgren (2)  
E. W. Lusty  
D. L. Mackliet  
D. L. Merrill  
E. B. Moore  
D. A. Mueller  
E. M. Murphy  
B. A. Napier  
I. C. Nelson  
T. A. Nelson  
K. B. Olsen  
B. E. Opitz  
G. W. Patton  
T. M. Poston  
K. R. Price  
L. L. Rader  
J. V. Ramsdell  
J. J. Reck  
K. Rhoads  
J. T. Rieger  
J. T. A. Roberts

**No. of  
Copies**

L. H. Sawyer  
R. Schalla  
R. G. Schreckhise  
D. B. Shipler  
R. L. Skaggs  
J. L. Smoot (4)  
J. K. Soldat  
F. A. Spane  
R. D. Stenner  
D. L. Stewart  
B. L. Tiller  
G. D. Trump  
T. L. Van Arsdale  
W. H. Walters  
H. E. Westerdahl  
R. E. Wildung  
W. R. Wiley  
R. K. Woodruff  
Historical File—R. K. Woodruff  
Publishing Coordination  
Technical Report Files (5)