

HANFORD SITE ENVIRONMENTAL REPORT FOR CALENDAR YEAR 2002

(INCLUDING SOME EARLY 2003 INFORMATION)



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SEPTEMBER 2003

Prepared for the U.S. Department of Energy by
Pacific Northwest National Laboratory
under contract DE-AC06-76RL01830, with
contributions from CH2M HILL Hanford Group,
Inc.; S. M. Stoller Corporation; Fluor Hanford, Inc.
and its subcontractors; Bechtel National, Inc.; and
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PACIFIC NORTHWEST NATIONAL LABORATORY

operated by

BATTELLE

for the

UNITED STATES DEPARTMENT OF ENERGY

under Contract DE-AC06-76RL01830

Printed in the United States of America

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Cover Photo: The present and past natural history of the Hanford Site come together along the Columbia River. The active sand dunes of the Hanford Reach National Monument march eastward across the desert with the ancestral Columbia River deposits of the White Bluffs forming a backdrop. Franklin County farmland is in the distance. The cover photo is from LMSI (92100762-24cn), Richland, Washington.



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PREFACE

The Hanford Site environmental report is prepared annually for the U.S. Department of Energy (DOE) in accordance with the requirements in the DOE Environment, Safety and Health Reporting Manual (DOE M 231.1-1). The report provides an overview of activities at the site during 2002; demonstrates the status of the site's compliance with applicable federal, state, and local environmental laws and regulations, executive orders, and DOE policies; and summarizes environmental data that characterize Hanford Site environmental management performance. The report also highlights significant environmental programs and efforts. Some historical and early 2003 information is included where appropriate. More detailed environmental compliance, monitoring, and surveillance information may be found in additional reports referenced in the text.

Although this report was primarily written to meet DOE reporting requirements and guidelines, it also provides useful summary information to members of the public, public officials, regulators, Hanford Site contractors, and elected representatives. Appendix A of this report lists acronyms, abbreviations, unit conversion information, and nomenclature that may help readers understand the report.

The Pacific Northwest National Laboratory's Public Safety and Resource Protection Program produced this report for the DOE Richland Operations Office, Closure Division. The Battelle Memorial Institute (Battelle) operates the Pacific Northwest National Laboratory for DOE. Battelle is a non-profit, independent, contract research institute. Personnel from the Pacific Northwest National Laboratory and Fluor Hanford, Inc. and its subcontractors wrote

major portions of the report. Bechtel National, Inc., CH2M HILL Hanford Group, Inc., Bechtel Hanford, Inc. and its subcontractors, and the S. M. Stoller Corporation also prepared or provided significant input to selected sections.

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REPORT AVAILABILITY

This report was produced in both paper and electronic formats. The paper formats include this technical report and a less detailed summary report (PNNL-14295-SUM). Electronically, the report is available in portable document format (PDF) on compact disk (CD), and on the Internet at <http://hanford-site.pnl.gov/envreport>. Copies of the report are also available at libraries in communities around the Hanford Site, at several university libraries in Washington and Oregon, and at the DOE's Public Reading Room located at the Consolidated Information Center in Richland, Washington. All versions of the report can be obtained from Mr. R. W. (Bill) Hanf, Pacific Northwest National Laboratory, P.O. Box 999, MS K6-75, Richland, Washington 99352 (bill.hanf@pnl.gov) while supplies last. The report may also be available for purchase from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161.



SUMMARY

L. F. Morasch

Each year, the U.S. Department of Energy (DOE) publishes this integrated environmental report about the Hanford Site to summarize environmental data and information, describe environmental management performance, demonstrate the status of compliance with environmental regulations, and highlight major environmental programs and efforts. Individual sections of the report are designed to:

- Describe the Hanford Site and its mission.
- Summarize the status of compliance with environmental regulations.
- Describe the environmental programs at the Hanford Site.
- Discuss the estimated radiation exposure to the public from 2002 Hanford Site activities.
- Present effluent monitoring, environmental surveillance, and groundwater protection and monitoring information.
- Discuss activities to assure quality.

DOE's current mission at the Hanford Site includes cleaning up and shrinking the size of the site. It is the policy of DOE that all activities be carried out to comply with applicable federal, state, and local laws and regulations, DOE Orders, Secretary of Energy Notices, and directives, policies, and guidelines from DOE Headquarters and site operations.

COMPLIANCE WITH ENVIRONMENTAL REGULATIONS IN 2002

The site's compliance with federal acts in 2002 is summarized in Table S.1. For a detailed discussion of the site's compliance with environmental regulations during 2002, refer to Chapter 2 of this report.

A key element in Hanford's compliance program is the Tri-Party Agreement. The Tri-Party Agreement is an agreement among the Washington State Department of

Ecology, U.S. Environmental Protection Agency (EPA), and DOE to achieve compliance with the remedial action provisions of the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) and with treatment, storage, and disposal unit regulation and corrective action provisions of the *Resource Conservation and Recovery Act* (RCRA). During 2002, there were 40 specific cleanup milestones scheduled for completion: 36 were completed on or before their required due dates, 2 were completed beyond their established due dates, and 2 are yet to be completed.

Cleanup activities on the Hanford Site generate radioactive, mixed, and hazardous waste (Section 2.5). Mixed waste has both radioactive and hazardous non-radioactive substances. Hazardous waste contains either dangerous waste or extremely hazardous waste or both. This waste is handled and prepared for safe storage on the site or shipped to offsite facilities for treatment and disposal. In 2002, cleanup activities generated 1 million kilograms (2.2 million pounds) of solid mixed waste and 1.6 million kilograms (3.5 million pounds) of radioactive waste on the Hanford Site. There were 111,655 kilograms (246,199 pounds) of mixed waste and 1.5 million kilograms (3.3 million pounds) of radioactive waste received at Hanford from offsite. During 2002, a total of 132,583 kilograms (292,346 pounds) of hazardous waste was shipped off the Hanford Site. Liquid waste also was generated on the Hanford Site (Table 2.5.5). During 2002, there were 9.3 million liters (2.5 million gallons) of waste added to the double-shell tanks; the total volume of liquid waste in the double-shell tanks at the end of 2002 was 87.7 million liters (23.1 million gallons).

In addition to newly generated waste, significant quantities of legacy waste remain from years of nuclear material production and waste management activities. Most legacy waste from past operations at the Hanford Site resides in RCRA-compliant waste sites or is stored in several places awaiting cleanup and ultimate safe storage or disposal.

Table S.1. Compliance with Federal Acts at the Hanford Site in 2002

<u>Regulation</u>	<u>What it Covers</u>	<u>2002 Status</u>
Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)	Sites already contaminated by hazardous materials.	Work on these sites followed CERCLA requirements and met the schedules established by the Tri-Party Agreement.
Emergency Planning and Community Right-to-Know Act	The public's right to information about hazardous chemicals in the community and establishes emergency planning procedures.	The Hanford Site met the reporting requirements contained in this act.
Resource Conservation and Recovery Act (RCRA)	Hazardous waste being generated, transported, stored, treated, or disposed. The act primarily covers ongoing waste management at active facilities.	The Washington State Department of Ecology identified two non-compliance issues during 2002. One non-compliance issue was the leak detection system used with the temporary transfer lines at the single-shell tank farms. The other concerns were at the 600 Area Purge-water, Storage, and Treatment Facility; however, the letter citing this concern was rescinded.
Clean Air Act	Air quality, including emissions from facilities and diffuse and unmonitored sources.	According to the Washington State Department of Health, air emissions from Hanford Site facilities were well below state and federal standards. However, the Washington State Department of Health issued one non-compliance order regarding notification requirements in 2002. Corrective efforts were completed.
Clean Water Act	Discharges to U.S. waters.	The Hanford Site had two National Pollutant Discharge Elimination System Permits and seven State Wastewater Discharge Permits in 2002.
Safe Drinking Water Act	Drinking water supplies operated by DOE.	There were nine public water systems on the Hanford Site in 2002. The systems were monitored and all analytical results for 2002 met the requirements of the Washington State Department of Health.
Toxic Substances Control Act	Primarily chemicals called polychlorinated biphenyls.	Five hundred ninety-three drums of depleted uranium in oil containing polychlorinated biphenyl were moved from the 300 Area to the Environmental Restoration Disposal Facility staging area where they will remain pending treatment and disposal.
Federal Insecticide, Fungicide, and Rodenticide Act	Storage and use of pesticides.	At the Hanford Site, pesticides are applied by licensed commercial pesticide operators.
Endangered Species Act of 1973	Rare species of plants and animals.	Hanford activities followed the requirements of this act. The Hanford Site has eleven plant species, two fish species, and six bird species on the federal or state lists of threatened or endangered species.
American Indian Religious Freedom Act, Antiquities Act, Archaeological and Historic Preservation Act, Archaeological Resources Protection Act of 1979, Historic Sites Buildings and Antiquities Act, National Historic Preservation Act, and Native American Graves Protection and Repatriation Act	Cultural resources.	One hundred sixty-four cultural resource reviews were conducted on the Hanford Site.
National Environmental Policy Act	Environmental impact statements for federal projects.	Environmental impact statements and environmental assessments were prepared or conducted as needed. In 2002, there were 20 site-wide categorical exclusions.
Migratory Bird Treaty Act	Migratory birds or their feathers, eggs, or nests.	Hanford activities used the ecological review process as needed to minimize any adverse effects to migratory birds. There are over 100 species of birds that occur on the Hanford Site that are protected by this act.

Examples include high-level radioactive waste stored in single- and double-shell tanks and transuranic waste stored in vaults and on storage pads (see Section 2.5 for details).

ENVIRONMENTAL OCCURRENCES

Environmental releases of radioactive and regulated materials from the Hanford Site are reported to DOE and other federal and state agencies as required by law. The specific agencies notified depend on the type, amount, and location of the individual occurrence. The Hanford Site Occurrence Notification Center maintains both a computer database and a hardcopy file of event descriptions and corrective actions.

During 2002, there were no environmentally significant emergency occurrence reports or environmentally significant unusual occurrence reports filed. Two off-normal occurrences with environmental impact are discussed in Section 2.4.3. One was the spread of contamination after a period of high winds on January 21, 2002; additional soil fixatives are now being used at excavation sites. The second event was a spill of radioactive liquid at the TX Tank Farm. The liquid spilled from a water lance when it was removed from a tank. To prevent similar occurrences in the future, the O-ring materials will be changed, and the joint will be welded.

ENVIRONMENTAL MONITORING

Environmental monitoring at the Hanford Site includes near-facility environmental monitoring, surface environmental surveillance, groundwater monitoring, and vadose zone monitoring. Near-facility monitoring includes the analysis of environmental samples collected near major nuclear-related installations, waste storage and disposal units, and remediation sites. Surface environmental surveillance consists of sampling and analyzing various media on and around the site (including the Columbia River) to detect potential contaminants and to assess their significance to environmental and human health. Groundwater sampling is conducted on the site to determine the distribution of radiological and chemical

constituents in groundwater. The strategy for managing and protecting groundwater resources at the Hanford Site focuses on protection of the Columbia River, human health, the environment, treatment of groundwater contamination, and limitation of groundwater migration (Chapter 6). Vadose monitoring was conducted to better understand and alleviate the spread of subsurface contamination (Chapter 7).

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

Environmental monitoring and surveillance results for 2002 are summarized in Table S.2. For detailed discussions of results, refer to the appropriate sections of this report.

FACILITY EFFLUENT MONITORING

Liquid and airborne effluent that may contain radioactive or hazardous constituents is continually monitored when released to the environment at the Hanford Site. Facility operators perform the monitoring mainly through analyzing samples collected at points of release into the environment. Effluent monitoring data are evaluated to determine the degree of regulatory compliance for each facility and/or the entire site. The evaluations are also useful to assess the effectiveness of effluent treatment and pollution-management practices.

In 2002, only facilities in the 200 Areas discharged radioactive liquid effluent to the ground, which went to the State-Approved Land Disposal Site (Section 3.1.3). Radioactive air emissions usually come from a building stack or vent. Radioactive emission discharge points are located in the 100, 200, 300, 400, and 600 Areas. Table 3.1.1 of this document provides a summary of radionuclides discharged to the atmosphere at the Hanford Site in 2002. Non-radioactive air pollutants from such things as diesel-powered electrical generating plants were monitored. Table 3.1.2 summarizes the non-radioactive discharges to the air on the Hanford Site during 2002.

Table S.2. Hanford Site Monitoring Results for 2002

	<u>What was Monitored?</u>	<u>The Bottom Line</u>
Air	Air sampling equipment collected particles and gases, which were analyzed for radioactive materials. Air was sampled at 24 locations on Hanford, at 11 perimeter locations, in 8 nearby communities, and in 2 distant communities. In addition, near-facility monitoring collected air samples at 82 locations near Hanford facilities.	All measurements of radioactive materials in air were below recommended guidelines.
Columbia River Water	Columbia River water was collected from multiple sampling points throughout the year. Water samples were analyzed for radioactive and chemical materials. Water in the Columbia River continues to be designated Class A (Excellent) by the state of Washington. This designation means that the water is usable for substantially all needs.	As in past years, small amounts of radioactive materials were detected downriver from Hanford. However, the amounts were far below federal and state limits. During 2002, there was no indication of any deterioration of Columbia River water quality resulting from operations at Hanford.
Columbia River Shoreline Springs	Groundwater discharges to the Columbia River via surface and subsurface locations. Discharges above the water level of the river are identified as riverbank springs. Samples of spring water were collected at locations along the Columbia River shoreline.	Samples collected at the springs contained some contaminants at levels above drinking water standards. However, concentrations in river water downstream of the shoreline springs remained far below federal and state limits.
Groundwater	Groundwater samples were collected from 658 wells to monitor contaminant concentrations. Water levels were measured in several hundred wells on the site to map groundwater movement.	Samples show that groundwater contaminant plumes are moving slowly from beneath former waste sites toward the Columbia River. Contaminant concentrations are declining in the largest plumes because of spreading and radioactive decay.
Vadose Zone	The vadose zone is the region between the ground surface and the top of the water table. Vadose zone characterization and monitoring are conducted to better understand and alleviate the spread of subsurface contamination.	Vadose zone characterization was conducted at five operable units in the 200 Areas. Vadose zone monitoring occurred at the tank farms in the 200-East, and 200-West Areas. Tech-demonstrations are designed to result in new, innovative methods for environmental monitoring and cleanup on the Hanford Site. In 2002, thirteen technical studies were conducted.
Drinking Water	The quality of the drinking water supplied by nine DOE-owned systems on the Hanford Site was analyzed.	All DOE-owned drinking water systems on the Hanford Site met Washington State and EPA regulations.
Food and Farm Products	Samples of cherries, leafy vegetables, milk, potatoes, tomatoes, and wine were collected from 17 locations upwind and downwind of the Hanford Site.	Radionuclide levels in samples of food and farm products were at normal environmental levels.
Fish and Wildlife	Game animals on the site and along the Hanford Reach and fish from the Columbia River were monitored at thirteen locations. Carcass, bone, and muscle samples were analyzed to evaluate radionuclide levels.	Samples of carp, bass, California quail, and mule deer were collected and analyzed. Radionuclide levels in wildlife samples were well below levels that are estimated to cause adverse health effects to animals or to the people who may consume them.
Effluent Monitoring	Liquid effluent and airborne emissions that may contain radioactive or hazardous constituents are continually monitored on the Hanford Site.	Some quantities of radionuclides were released to the environment at state and federally permitted release points. Compliance with all applicable effluent monitoring requirements was achieved in 2002.

WASTE SITE REMEDIATION

Full-scale remediation of waste sites began in the 100 Areas in 1996 and continued in 2002 at several liquid waste disposal sites in the 100-B/C and 100-F Areas (Section 2.3.12.2). Also, remediation of the treatment, storage, and disposal units at the 100-N Area continued and remediation began in the 100-K Area. From 1996 through 2001, 413,000 metric tons (455,000 tons) of contaminated soil were removed from the 100-H Area and shipped to the Environmental Restoration Disposal Facility. No soil was excavated during 2002 at the 100-H Area. In 2002, the following activities were completed:

- **100-B/C Area** – 137,000 metric tons (151,000 tons) of contaminated soil and 3,100 linear meters (11,800 linear feet) of pipeline were removed and shipped to the Environmental Restoration Disposal Facility in 2002; a total of 870,000 metric tons (957,000 tons) of soil and 5,200 linear meters (17,100 linear feet) of pipeline have been removed since startup.
- **100-F Area** – 279,000 metric tons (307,000 tons) of contaminated soil were removed and shipped to the Environmental Restoration Disposal Facility in 2002; a total of 749,000 metric tons (824,000 tons) has been removed since startup.
- **100-N Area** – 122,605 metric tons (134,731 tons) of contaminated soil were removed and shipped to the Environmental Restoration Disposal Facility in 2002; a total of 259,855 metric tons (285,853 tons) have been removed since startup.
- **100-K Area** – 4,842 metric tons (5,321 tons) of contaminated soil were removed and disposed at the Environmental Restoration Disposal Facility in 2002.

In 2002, a remedial design for the 100-B/C Area burial sites was issued for review. Decontamination and decommissioning activities continued in 2002 at the 100-D/DR, 100-H, and 100-F Areas. These activities were conducted to support the interim safe storage of the four reactor buildings for up to 75 years. The interim safe storage minimizes the potential risk to the environment, employees, and the public and reduces surveillance and maintenance costs. These activities are conducted as non-time-critical actions under CERCLA.

The environmental restoration contractor completed the final draft feasibility study for the Canyon Disposition

Initiative in 2002. The purpose of this initiative is to investigate the potential for using the five canyon buildings at the Hanford Site as disposal facilities for remediation waste, rather than demolishing the structures. The U Plant was used as a pilot project.

Remediation work at the 300-FF-1 and 300-FF-2 Operable Units continued. Excavation of the 618-4 burial ground was completed and 510,000 metric tons (560,000 tons) of contaminated material and debris were taken to the Environmental Restoration Disposal Facility. Excavation of the 618-5 burial ground began in 2002 with the removal of 10,349 metric tons (11,373 tons) of contaminated soil, which was disposed at the Environmental Restoration Disposal Facility. Closure of the 618-4 and 618-5 burial grounds is scheduled for 2003.

During 2002, activities continued across the Hanford Site to clean up waste from past practices. The activities are guided by the Tri-Party Agreement, an agreement to achieve compliance with CERCLA remedial action provisions and with RCRA treatment, storage and disposal unit regulations and corrective action provisions. Many programs are an integral part of Hanford cleanup.

Pollution Prevention Program. This program (Section 2.3.1) focuses on conservation of resources and energy, reduction of hazardous substance use, and prevention or minimization of pollutant releases. In 2002, the efforts of the program reduced the quantity of disposed waste by recycling 142,908 cubic meters (5 million cubic feet) of radioactive and mixed waste, 737 metric tons (812 tons) of RCRA hazardous waste, and 3,936 metric tons (4,339 tons) of sanitary waste. The cost savings for waste disposal in 2002 exceeded \$37 million for these activities. During 2002, the Hanford Site also recycled 547 metric tons (603 tons) of paper products and 559 metric tons (616 tons) of various metals.

Spent Nuclear Fuel Project. This project (Section 2.3.2) provides safe, economic, and environmentally sound management of Hanford spent nuclear fuel and prepares the fuel for long-term storage. In 2002, the project continued to make progress on an accelerated strategy to remove spent fuel from underwater storage in the K Basins and place it in dry interim storage in the 200-East Area. The spent fuel will be maintained in dry storage pending a decision by the Secretary of Energy on final disposition.

Major accomplishments of the Spent Nuclear Fuel Project during 2002 included the following items:

- A total of 730.5 metric tons (805 tons) of spent nuclear fuel were removed from the K-West Basin, transported to the Cold Vacuum Drying Facility for processing, and moved to the Canister Storage Building for storage.
- A total of 260 fuel canisters (or ~82 metric tons [~90 tons]) of spent nuclear fuel were transferred from the K-East Basin to the K-West Basin for cleaning and re-packaging before transport to the Cold Vacuum Drying Facility for processing.
- A total of 1,133 fuel storage canisters and 917 fuel storage canister lids were cleaned for disposal at the Environmental Restoration Disposal Facility. A total of 1,172 canisters were shipped to the Environmental Restoration Disposal Facility for disposal.
- Construction of the sludge removal system for the K-East Basin progressed to 95% completion.
- Three cask shipments containing non-defense spent nuclear fuel were received for storage at the 200 Areas Interim Storage Area near the Canister Storage Building facility.

Central Plateau Remediation Project. This project's mission (Section 2.3.3) is to transition the Central Plateau from its current post-operational state by deactivating and closing facilities in a safe and compliant manner until they can be turned over to the site contractor responsible for final disposition. The Central Plateau Remediation Project includes the Accelerated Deactivation Project, 324 and 327 Facilities Deactivation Project, Equipment Disposition Project, 233-S Plutonium Concentration Facility Decommissioning Project, 200 Area Facilities Disposition Project, and Canyon Disposition Project.

Advanced Reactors Transition Project. The mission of this project (Section 2.3.5) is to transition or convert the Plutonium Recycle Test Reactor facility, and facilities used for nuclear research, into structures that are in a safe and stable condition suitable for reuse or low cost surveillance and maintenance. The only facilities remaining to be cleaned up are in the southeastern part of the 300 Area, the high bay of the 337 Building, and the adjacent storage tank building, 3718M.

Solid Waste Management. Solid waste management at the Hanford Site included the treatment, storage, and disposal of solid waste at many Hanford locations (Section 2.3.9). The solid waste facilities include the Central

Waste Complex, Waste Receiving and Processing Facility, Radioactive Mixed Waste Disposal Facility, and T Plant Complex. During 2002, 656 cubic meters (23,163 cubic feet) of low-level mixed waste were treated and/or directly disposed onsite. Eight packages containing defueled reactor compartments from the U.S. Navy were received and disposed of at the 200-East Area in 2002.

Liquid Effluent Treatment. Liquid effluent is managed in facilities that comply with RCRA and state regulations (Section 2.3.10). The 242-A evaporator completed one campaign during 2002 to concentrate dilute liquid tank waste and reduce its volume to eliminate the need to construct additional double-shell tanks. The volume of waste treated was ~3.9 million liters (~1 million gallons) and the waste volume reduction was ~1.6 million liters (413,500 gallons) or 41%.

Approximately 44 million liters (11.6 million gallons) of liquid waste were stored at the Liquid Effluent Retention Facility at the end of 2002, and 83.5 million liters (22 million gallons) of liquid waste were treated at the 200 Area Effluent Treatment Facility in 2002. The 200 Area Treated Effluent Disposal Facility received 863 million liters (227.9 million gallons) of unregulated effluent for disposal in 2002. The major source of this effluent is uncontaminated cooling water and steam condensate from the 242-A evaporator.

Industrial wastewater generated throughout the Hanford Site is collected and treated in the 300 Area Treated Effluent Disposal Facility. The wastewater consists of once-through cooling water, steam condensate, and other industrial wastewater (Section 2.3.10.5). The volume of industrial wastewater treated and disposed of during 2002 was 163.7 million liters (43.2 million gallons). The volume of wastewater monitored and released to the 300 Area Treated Effluent Disposal Facility for treatment and disposal from the 307 Retention Basins in 2002 was 5.5 million liters (1.5 million gallons).

Revegetation and Mitigation Planning. The DOE Richland Operations Office and U.S. Fish and Wildlife Service cooperatively worked on a plan to re-vegetate land on the Fitzner/Eberhardt Arid Lands Ecology Reserve to compensate for damage to the environment caused by the construction of cells 1 and 2 at the Environmental Restoration Disposal Facility. The Environmental Restoration

Disposal Facility mitigation project includes three separate planting elements: native grass seeding planting, shrub seedling planting, and native grass plug planting. Approximately 65 hectares (~160 acres) were planted with native grass seed, and 139,000 shrubs were planted across ~125 hectares (~310 acres) during 2002.

Monitoring of survival and growth continued for ~90,000 sagebrush seedlings that were planted on ~90 hectares (~222 acres) at nine locations on the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit during December 2000. This effort was the last phase of sagebrush transplanting as compensatory mitigation for the disturbance of sagebrush habitat resulting from the development of the site and infrastructure for the planned waste vitrification facility. Monitoring of these plants will continue during 2004.

Groundwater Protection Program. The Groundwater Protection Program (Section 2.3.13) coordinates all projects at Hanford involved in characterizing, monitoring, and remediating groundwater and the vadose zone. The

goal of groundwater remediation is to prevent contaminants from entering the Columbia River, reduce the contamination in areas of high concentration, prevent the movement of contamination, and protect human health and the environment. Table S.3 lists a summary of the activities in 2002. Figure S.1 shows the location of groundwater remediation systems.

Office of River Protection. The Office of River Protection manages DOE's River Protection Project, which is responsible for storage, retrieval, treatment, and disposal of high-level tank waste and closure of the tank farms on the Hanford Site (Section 2.3.8). The status of 177 waste tanks on the Hanford Site was reported in *Waste Tank Summary Report for Month Ending December 31, 2002*.

To date, 132 of the 149 (89%) single-shell tanks have been stabilized, and the stabilization program is on schedule to be completed by the end of September 2004. During 2002, three tanks (241-SX-105, 241-U-102, and 241-U-109) were declared stabilized. Waste was pumped

Table S.3. Summary of Groundwater Pump-and-Treat Systems and a Soil-Vapor Extraction System

<u>Location</u>	<u>Startup Date</u>	<u>Contaminant</u>	<u>Mass Removed (Groundwater Processed) in 2002</u>	<u>Mass Removed (Groundwater Processed) Since Startup</u>
Groundwater Pump-and-Treat Systems				
100-D Area	1997	Hexavalent chromium	28.7 kilograms (166.4 million liters)	130.6 kilograms (797.7 million liters)
100-H Area	1997	Hexavalent chromium	3.3 kilograms (184.1 million liters)	30.45 kilograms (734.1 million liters)
100-K Area	1997	Hexavalent chromium	35.3 kilograms (445.7 million liters)	184.1 kilograms (1.69 billion liters)
100-N Area	1995	Strontium-90	0.20 curies (121.7 million liters)	1.3 curies (788.2 million liters)
200-West Area (200-ZP-1) Operable Unit	1994	Carbon tetrachloride	965.8 kilograms (281 million liters)	7,049 kilograms (1.95 billion liters)
200-West Area (200-UP-1) Operable Unit	1994	Carbon tetrachloride	2.7 kilograms (79.1 million liters)	23,315 grams (633.6 million liters)
	1994	Nitrate	3,665 kilograms (79.1 million liters)	24,152 kilograms (633.6 million liters)
	1994	Technetium-99	14.9 grams (79.1 million liters)	93.5 grams (633.6 million liters)
	1994	Uranium	27.6 kilograms (79.1 million liters)	164,340 grams (633.6 million liters)
Soil-Vapor Extraction				
200-West Area	1992	Carbon tetrachloride	628 kilograms	77,798 kilograms

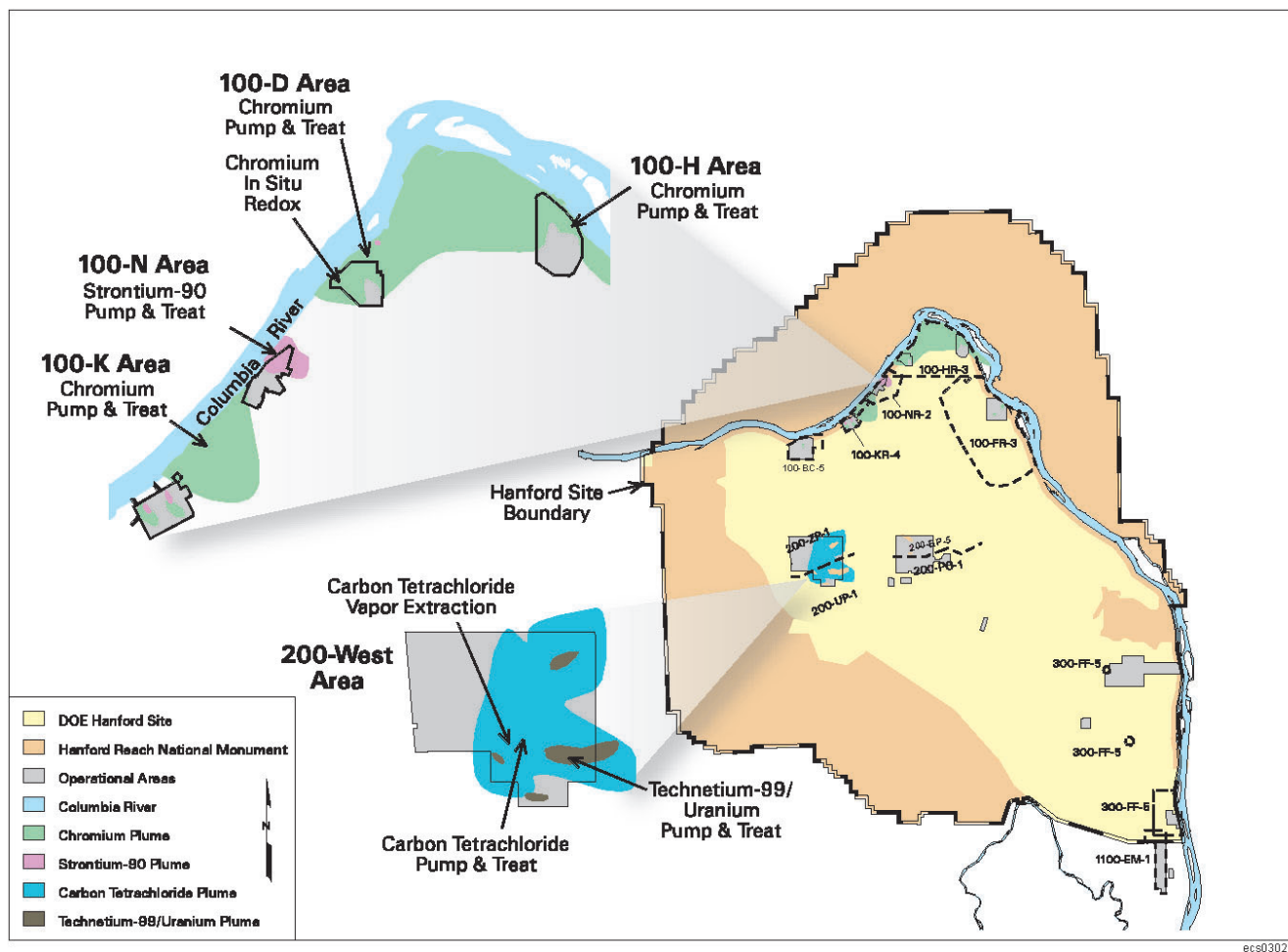


Figure S.1. Hanford Site Pump-and-Treat and Soil-Vapor Extraction Systems

from 17 single-shell tanks into the double-shell tank system. The pumping removed 5.3 million liters (1.4 million gallons) of waste.

To assure safe storage and retrieval, 154 of the 177 (87%) tanks have been characterized. All of the double-shell tanks and most of the single-shell tanks have been sampled; however, a number of these tanks were analyzed for a limited number of analytes.

During 2002, CH2M HILL Hanford Group, Inc. began proof-of-concept testing techniques to dissolve saltcake in waste tanks and evaluated three supplemental waste treatment technologies (containerized grout, steam reforming, and bulk vitrification), all intended for use on retrieved tank waste. CH2M HILL Hanford Group, Inc. also began evaluating a separate disposal path for mixed transuranic tank waste that would include onsite treatment and packaging for shipment to the DOE Waste Isolation Pilot Plant in New Mexico.

Geophysical Logging. Geophysical logging at the Hanford Site is performed using capabilities and experience established for the National Uranium Resource Evaluation Program. Until 2002, this work was performed by MACTEC-ERS. On July 21, 2002, vadose zone logging and monitoring activities were transferred from MACTEC-ERS to the S. M. Stoller Corporation. Under the new contract, S. M. Stoller Corporation is responsible for all geophysical logging at the Hanford Site. Logging activities are now integrated across multiple organizations and projects and consistent procedures and data quality objectives are in use. Plans and procedures are being updated to reflect the transition to the new contractor. In addition, responsibility for day-to-day program management was transferred from the DOE Grand Junction Office to the DOE Richland Operations Office. S. M. Stoller Corporation performs geophysical logging for both the DOE Richland Operations Office and DOE Office of River Protection. The primary goal of logging activities

performed for the DOE Richland Operations Office is characterization of waste sites on the Central Plateau. For the DOE Office of River Protection, the logging effort involves vadose zone monitoring around the single-shell tanks.

Single-Shell Tank Monitoring. Monitoring activities at the single-shell tank farms identified subsurface contaminant plumes. Cobalt-60, cesium-137, europium-152, europium 154, uranium-235, and uranium-238 were the predominant gamma-emitting contaminants. Minor amounts of tin-126 and antimony-125 were also detected. Since specific contaminants have been identified and quantified, the primary focus of the monitoring was to identify changes in contaminant levels.

During 2002, monitoring activities were performed in a total of 385 boreholes, representing ~6,706 meters (~22,000 feet) of logging. The high-priority boreholes in each tank farm were monitored at least once. In addition to routine activities, monitoring was also performed to support tank farm operations or to investigate potential anomalies. Monitoring of boreholes in the vicinity of tank U-107 was performed to support the planned tests for saltcake dissolution.

During 2002, the neutron moisture logging system was used to measure volumetric moisture content in the vadose zone around tank U-107. Experience with the neutron moisture log at Hanford has indicated that it is useful for identifying changes in soil moisture that may be related to ongoing contaminant migration and for delineating fine-grained beds for stratigraphic correlation.

Waste Immobilization. The Waste Treatment Plant is being built on 26 hectares (65 acres) located on the Central Plateau outside of the Hanford 200-East Area to treat radioactive and hazardous waste currently stored in 177 underground tanks. Currently, three major facilities are scheduled to be constructed: a pretreatment facility, a high-level waste vitrification facility, and a low-activity waste vitrification facility. Supporting facilities will be constructed also. The River Protection Project is currently upgrading tank farm facilities to deliver waste to the Waste Treatment Plant.

During 2002, the contractor began pouring concrete for the Pretreatment Plant, High-Level Waste Vitrification

Plant, and the Low-Activity Waste Vitrification Plant. The potable water services and the sewage system for the plant began operating.

POTENTIAL RADIOLOGICAL DOSES FROM 2002 HANFORD OPERATIONS

During 2002, potential radiological doses to the public and biota from Hanford operations were evaluated to determine compliance with pertinent regulations and limits (Chapter 5). These doses were calculated using reported effluent releases and environmental surveillance data using version 1.485 of the GENII computer code and Hanford-specific parameters. The potential dose to the maximally exposed individual in 2002 from site operations was 0.02 mrem (0.2 μ Sv). To put this value into perspective, the national average dose from background sources (Figure S.2), according to the National Council on Radiation Protection, is ~300 mrem/yr (3 mSv/yr), and the current DOE radiological dose limit for a member of the public is 100 mrem/yr (1 mSv/yr).

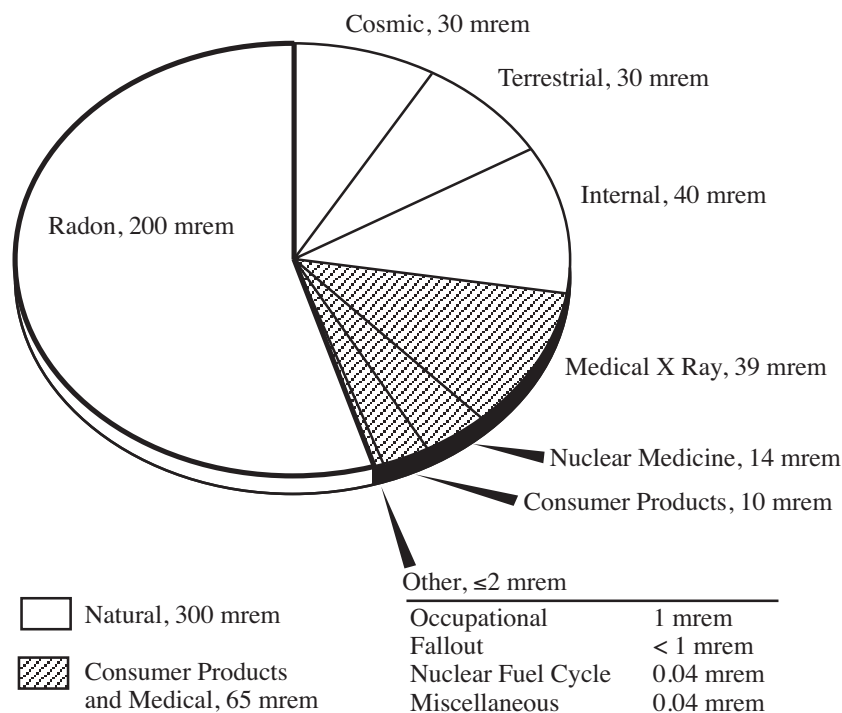
OTHER HANFORD ENVIRONMENTAL PROGRAMS

CLIMATE AND METEOROLOGY

Meteorological measurements are taken to support Hanford Site emergency preparedness, site operations, and atmospheric dispersion calculations. Weather forecasting and maintenance and distribution of climatological data are provided. The data are provided by the Hanford Meteorology Station, which is located on the Central Plateau. A complete report of climatological data for calendar year 2002 is contained in *Hanford Site Climatological Data Summary 2002 with Historical Data*.

CULTURAL RESOURCES

Management of archaeological, historical, and traditional cultural resources at the Hanford Site complies with the requirements of various federal laws. During 2002, 164 cultural resource reviews were requested and conducted on the Hanford Site to comply with Section 106 of the *National Historic Preservation Act*.



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Figure S.2. National Annual Average Radiological Doses from Various Sources (National Council on Radiation Protection and Measurements 1987)

Monitoring conducted during 2002 focused on: Locke Island erosion, archaeological sites affected by visitors or nature, historic buildings, and Native American sites. A total of 66 archaeological sites, 5 buildings, and cemetery or burial locations were monitored during 2002.

Public involvement is an important component of cultural resource management. To accomplish this goal, DOE developed mechanisms that allow the public access to cultural resources information and the ability to comment and make recommendations concerning the management of cultural resources on the Hanford Site. During 2002, seven tribal meetings on cultural resources provided a venue for the exchange of information between DOE, tribal staff members, and site contractors about projects and work on the Hanford Site.

The final *Hanford Cultural Resources Management Plan* was approved in December 2002, and the *History of the Plutonium Production Facilities at the Hanford Site Historic District, 1943-1990* was published. During 2002, DOE also continued to document the oral histories of early residents of areas now part of the Hanford Site as well

as Native Americans, former Hanford Site workers, and current site employees. A total of eight interviews were conducted during 2002.

BIOLOGICAL CONTROL PROGRAM

The program was established in 1998 to prevent, limit, clean up, or remediate the impact to the environment, or human health and safety, from contaminated or undesirable plants or animals. The program is responsible for integration of (1) expanded radiological surveillance, (2) control of plants and animals, (3) cleanup of legacy and new contamination, and (4) restoration of sites affected by radioactive contamination spread by plants and animals. During 2002, there were no incidents of offsite contamination from plants or animals, and all reported cases of new contamination on the site were cleaned up or scheduled for cleanup. Flying insects were routinely monitored on Hanford and one contaminated housefly was captured in an inactive liquid waste transfer facility in the 200-West Area. The source of the contamination was identified and sealed. There were 10 contaminated animals detected, the same number as in 2001.

There are ten plant species targeted by the Noxious Weed Control Program: yellow starthistle, rush skeleton-weed, medusahead, babysbreath, dalmatian toadflax, spotted knapweed, diffuse knapweed, Russian knapweed, saltcedar, and purple loosestrife. They are controlled by chemical or physical means or by introducing natural insect predators.

COMMUNITY OPERATED SURVEILLANCE PROGRAM

This program was initiated in 1990 to increase the public's involvement in and awareness of Hanford's surveillance program. During 2002, nine radiological air sampling stations were operated at selected locations around the site perimeter. Four of the stations are operated by area teachers at Basin City, Richland, and Toppenish, Washington, and at Edwin Markham Elementary School in Franklin County.

QUALITY ASSURANCE

Comprehensive quality assurance programs, which include various quality control practices and methods to verify

data, are maintained for data quality. The programs are implemented through quality assurance plans designed to meet requirements of the American National Standards Institute/American Society of Mechanical Engineers and DOE Orders. Quality assurance plans are maintained for all activities, and auditors verify conformance. Quality control methods include, but are not limited to, replicate sampling and analysis, analysis of field blanks and blind 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 submitted double blind samples, the EPA Laboratory Intercomparison Studies Program, and the national DOE Quality Assessment Program indicated that laboratory performance was adequate overall, was excellent in some areas, and needed improvement in others.



ACKNOWLEDGMENTS

The production of this report was managed by the Pacific Northwest National Laboratory's Public Safety and Resource Protection Program under the direction of R. L. Dirkes.

Community-operated environmental surveillance stations were managed by local teachers who were responsible for collecting the samples and maintaining the stations. The managers and alternate managers for each station included the following:

Leslie Groves Park, Richland: C. A. Wagner, Manager, and D. R. Johns, Alternate Manager

Basin City Elementary School, Basin City: C. L. Stevenson, Manager, and K. McEachen, Alternate Manager

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

Heritage College, Toppenish: R. A. Landvoy, Manager, and Holly Ferguson, Alternate Manager.

The authors appreciate the comprehensive reviews of the draft report by A. L. Bunn, D. A. Neitzel, and K. R. Price (Pacific Northwest National Laboratory).

The report was prepared by Pacific Northwest National Laboratory staff: L. F. Morasch, text editor, and K. R. Neiderhiser, text processor. The index was prepared by K. L. Manke. Graphics were prepared by D. L. Liddell (Lockheed Martin Services, Inc.), M. A. Chamness, C. A. Newbill, D. C. Lanigan, J. T. Rieger, W. D. Webber, and R. K. Zufelt (Pacific Northwest National Laboratory), and P. Call (U.S. Fish and Wildlife Service). J. Winslow (WinSome Design, Richland, Washington) designed the report cover and layout. Duplicating and printing arrangements were managed by S. J. Kophs, who was supported by G. A. Rowlette and M. I. Barrera. This report was produced using Adobe® PageMaker and formatted for the Internet by A. E. Madden and others in Pacific Northwest National Laboratory's Scientific and Technical Information Department.



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1.0 INTRODUCTION

R. W. Hanf

This report, published annually since 1958, includes information and summary data that (1) provide an overview of activities at the Hanford Site during 2002; (2) demonstrate the status of the site's compliance with applicable federal, state, and local environmental laws and regulations, executive orders, and U.S. Department of Energy (DOE) policies; (3) summarize environmental data that characterize Hanford Site environmental management performance; and (4) highlight significant environmental programs.

Specifically, this report provides a short introduction to the Hanford Site, discusses the site mission, and briefly highlights the site's various environmental-related programs. Included are sections discussing compliance issues, site operations, environmental occurrences, and waste management and chemical inventories. Also included are descriptions of work defined by the Effluent and Near-Facility Environmental Monitoring Programs, the Surface Environmental Surveillance Project, the Hanford Groundwater Monitoring Project, Vadose Zone Monitoring, the Meteorological and Climatological Services Project, Ecosystem Monitoring and Ecological Compliance, the Hanford Cultural Resources Laboratory, and information about other programs and projects. Readers interested in more detail than that provided in this report should consult the technical documents cited in the text and listed in the reference sections. Descriptions of specific analytical and sampling methods used in the monitoring efforts are contained in the Hanford Site environmental monitoring plan (DOE/RL-91-50).

The appendices of this report contain additional information that will assist the reader in understanding this report and provide additional details about monitoring. Appendix A contains helpful information about units of measure, scientific notation, and other nomenclature. Appendix B contains additional monitoring results for 2002 to supplement the information provided in the body

of the report. Appendix C is a glossary of terms used in this report. Appendix D contains information about a variety of government standards and permits governing Hanford Site operations. Appendix E contains information about dose calculations. Appendix F contains information about radionuclides detected by gamma spectroscopy. Appendix G contains information about threatened and endangered species, candidate or sensitive animal species, and plant species of concern potentially found on the Hanford Site. Appendix H identifies errata that were found in last year's annual environmental report (PNNL-13910).

1.0.1 CURRENT SITE MISSION

For more than 40 years, Hanford Site facilities were dedicated primarily to the production of special nuclear materials for national defense and to the management of the resulting waste. Hanford was the first plutonium production site in the world. In recent years, efforts have shifted from production to the development of new waste treatment and disposal technologies and characterizing and cleaning up materials and contamination left from historical operations.

Currently, the Hanford Site's primary mission includes cleaning up and shrinking the size of the site from ~1,517 square kilometers (~586 square miles) to ~194 square kilometers (~75 square miles) by the target date of 2012. The on-line report *Hanford 2012: Accelerating Cleanup and Shrinking the Site* (DOE/RL-2000-62) states that the cleanup mission includes three strategies:

1. Restore the Columbia River corridor by continuing to clean up Hanford Site sources of radiological and chemical contamination that threaten the air, groundwater, or Columbia River. It is expected that most river corridor projects will be completed by 2012.

2. Transition the Central Plateau (200-East and 200-West Areas) from primarily waste storage to waste characterization, treatment, storage, and disposal operations, which are expected to last for another 40 years.
3. Prepare the site for future activities such as long-term stewardship, other DOE and non-DOE federal missions, and other public and private sector uses.

The goal of these strategies is to complete major portions of the site cleanup by 2012 and to do so in a manner that protects the environment and uses taxpayers' dollars wisely and efficiently.

1.0.2 OVERVIEW OF THE HANFORD SITE

The Hanford Site lies within the semi-arid Pasco Basin of the Columbia Plateau in southeastern Washington State (Figure 1.0.1). The site occupies an area of ~1,517 square kilometers (~586 square miles) located north of the city of Richland (DOE/EIS-0222-F). This area has restricted public access and provides a buffer for areas on the site that were used for production of nuclear materials, waste storage, and waste disposal. The Columbia River flows eastward through the northern part of the site and then turns south, forming part of the eastern site boundary.

The major DOE operational, administrative, and research areas on and around the Hanford Site (Figure 1.0.1) include

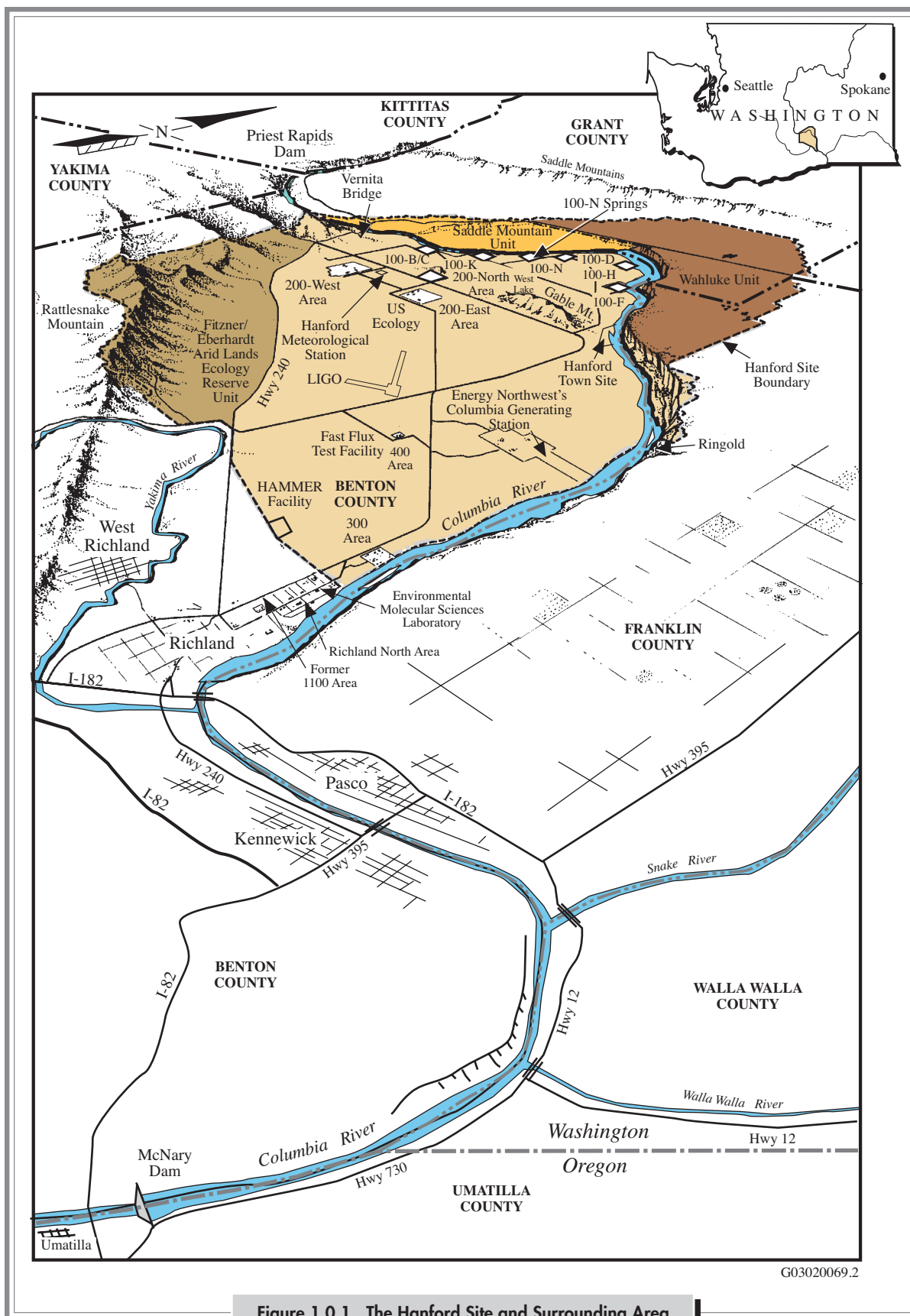
- **100 Areas** – located along the south and west shores of the Columbia River. These are the sites of nine retired plutonium production reactors. The 100 Areas occupy a total of ~11 square kilometers (~4 square miles).
- **200-West and 200-East Areas** – centrally located on a plateau. These areas are ~8 and 11 kilometers (~5 and 7 miles), respectively, south and west of the Columbia River. These areas house facilities that received and dissolved irradiated fuel and then separated out the plutonium. These facilities were called “separations plants.” The 200 Areas cover a total of ~16 square kilometers (~6 square miles).
- **300 Area** – located just north of Richland, Washington. From the early 1940s until the advent of the cleanup mission, most research and development at the Hanford Site were carried out in the 300 Area. The 300 Area was also the location of nuclear fuel fabrication. This area covers ~1.5 square kilometers (~0.6 square mile).

- **400 Area** – located northwest of the 300 Area. The 400 Area is the location of the Fast Flux Test Facility, which is scheduled for deactivation during 2003. This nuclear reactor was designed to test various types of nuclear fuel. The 400 Area covers ~0.61 square kilometer (~0.23 square mile).
- **600 Area** – includes all of the Hanford Site not occupied by the 100, 200, 300, and 400 Areas.
- **Former 1100 Area** – located generally between the 300 Area and the city of Richland covering an area of 311 hectares (768 acres). On October 1, 1998, this area was transferred to the Port of Benton as a part of DOE's Richland Operations Office economic diversification efforts and is no longer part of the Hanford Site. However, DOE contractors continue to lease facilities in this area.
- **Richland North Area (off the site)** – includes the Environmental Molecular Sciences Laboratory and other DOE and contractor facilities, mostly leased office buildings, generally located in the northern part of the city of Richland.
- **Volpentest Hazardous Materials Management and Emergency Response Training and Education Center (also called HAMMER)** – a worker safety training facility located on the site near the city of Richland. It consists of a 32-hectare (80-acre) main site and a 4,000-hectare (10,000-acre) law enforcement and security training site. The facility is owned by DOE, managed by Fluor Hanford, Inc., and used by site contractors, federal and state agencies, tribal governments, and private industry.

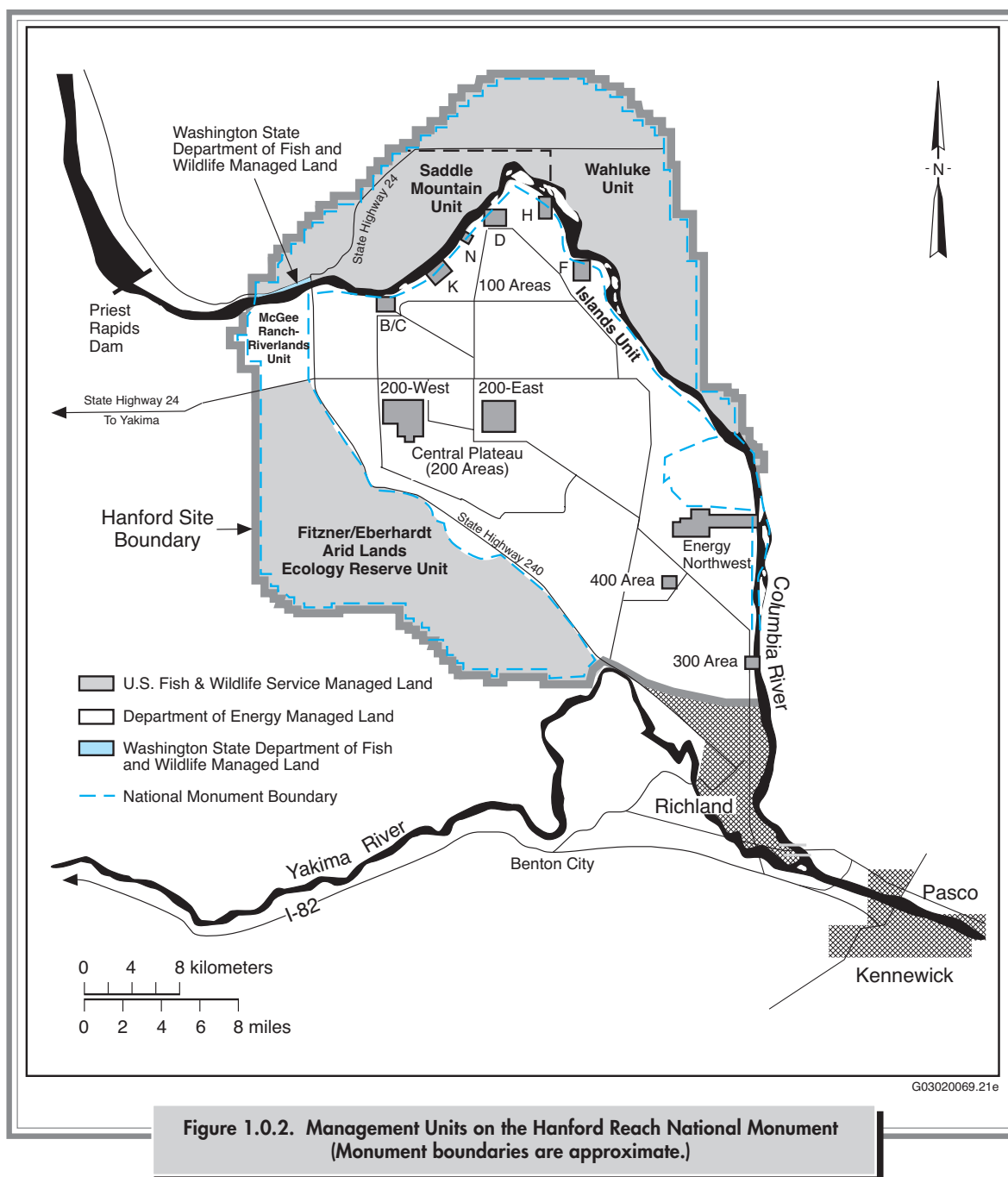
Other site related facilities (office buildings) are located within the Richland, Pasco, and Kennewick (Tri-City) area.

The 78,900-hectare (195,000-acre) Hanford Reach National Monument (Figure 1.0.2) was established on the Hanford Site by a Presidential Proclamation in June 2000 (65 FR 114) to protect the nation's only non-impounded stretch of the Columbia River upstream of Bonneville Dam in the United States and a remnant of a large shrub-steppe ecosystem that once blanketed the Columbia River Basin.

Non-DOE operations and activities on Hanford Site leased land or in leased facilities include commercial power production by Energy Northwest at the Columbia Generating Station (4.4 square kilometers [1.6 square miles]) and operation of a commercial low-level radioactive waste burial site by US Ecology, Inc. (0.4 square kilometer



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[0.2 square mile]). The Laser Interferometer Gravitational-Wave Observatory (LIGO) was constructed between 1994 and 1999 and is operated jointly by the California and Massachusetts Institutes of Technology. R. H. Smith Distributing operates vehicle-fueling stations in the 200 Areas. Washington State University at Tri-Cities operated several laboratories in the 300 Area until March 2002. Johnson Controls, Inc. operates 42 diesel and natural gas package boilers to produce steam in the 200

and 300 Areas and has compressors supplying compressed air to the site. Kaiser Aluminum and Chemical Corporation leased the 313 Building in the 300 Area from 1994 until January 2002 to use an extrusion press that was formerly DOE owned.

Near the city of Richland, immediately adjacent to the southern boundary of the Hanford Site, Framatome ANP, Inc. operates a commercial nuclear fuel fabrication facility

and Allied Technology Group Corporation operates a low-level radioactive waste decontamination, super compaction, and packaging facility.

1.0.3 SITE MANAGEMENT

The DOE Richland Operations Office and the DOE Office of River Protection jointly manage the Hanford Site through several contractors and their subcontractors. Each contractor is responsible for safe, environmentally sound, maintenance and management of its activities or facilities; for waste management; and for monitoring any potential effluent to assure environmental compliance. The U.S. Fish and Wildlife Service was a joint steward of portions of the Hanford Reach National Monument with DOE.

DOE Richland Operations Office. The DOE Richland Operations Office manages legacy cleanup, research, and other programs at the Hanford Site.

During 2002, the principal contractors for the DOE Richland Operations Office, and their respective responsibilities, included the following:

- **Bechtel Hanford, Inc.** is the environmental restoration contractor for the Hanford Site. Bechtel Hanford, Inc., a subsidiary of Bechtel National, Inc., plans, manages, and executes activities for the cleanup of contaminated soil and inactive nuclear facilities, with a major focus of protecting the Columbia River. Bechtel Hanford, Inc.'s subcontractors were **CH2M HILL Hanford, Inc.** and **Eberline Services Hanford, Inc.**
- **Fluor Hanford, Inc.** is the prime contractor for the Project Hanford Management Contract. It manages and integrates work to support cleanup of former DOE nuclear production facilities at the site. Fluor Hanford, Inc.'s principal subcontractors were **Framatome ANP DE&S, Inc.**; **Duratek Federal Services of Hanford, Inc.**; **Numatec Hanford Corporation**; and **Westinghouse Safety Management Solutions**. Other subcontractors to Fluor Hanford, Inc. included **Day & Zimmerman Protection Technology Hanford**, **Lockheed Martin Information Technology**, and **Fluor Federal Services**.
- **Hanford Environmental Health Foundation** works to identify and analyze the hazards that Hanford personnel face in the work environment. During 2002, the foundation's occupational health services provided occupational medicine and nursing, medical surveillance, ergonomics assessment, exercise physiology, case management,

psychology and counseling, fitness for duty evaluations, health education, infection control, immediate health care, industrial hygiene, and health, safety, and risk assessment.

- **S. M. Stoller Corporation** performs geophysical logging for both the DOE Richland Operations Office and DOE Office of River Protection as of July 21, 2002. Until then, this work was performed by MACTEC-ERS. In addition, responsibility for day-to-day program management was transferred from the DOE Grand Junction Office to the DOE Richland Operations Office. The primary goal of logging activities performed for the DOE Richland Operations Office is characterization of waste sites on the Central Plateau. For the DOE Office of River Protection, the logging effort involves vadose zone monitoring around the single-shell tanks.
- **Pacific Northwest National Laboratory** is a DOE facility operated by Battelle Memorial Institute for DOE's national security and energy missions. The core mission is to deliver environmental science and technology in the service of the nation and humanity. On July 23, 2002, DOE announced a two-year restructuring project that will re-engineer management processes to comply with the President's Management Agenda to improve efficiency and reduce the cost of operations. The effort is aimed at reducing layers of management, streamlining decision-making processes, clarifying lines of authority, making more efficient use of resources, and reshaping and rebuilding the DOE Office of Science work force. A Pacific Northwest Site Office will be established to provide oversight of Pacific Northwest National Laboratory. When the office is established, Pacific Northwest National Laboratory will report directly to the Office of Science in DOE Headquarters rather than the DOE Richland Operations Office.

DOE Office of River Protection. The DOE Office of River Protection was established by Congress in 1998 as a field office to manage DOE's largest, most complex environmental cleanup project—Hanford tank waste retrieval, treatment, and disposal. Sixty percent of the nation's high-level radioactive waste is stored at Hanford in tanks.

The principal contractors for the DOE Office of River Protection in 2002 and their respective responsibilities included the following:

- **Bechtel National, Inc.** – Bechtel National, Inc.'s contract mission is to design, build, and start up facilities on a 26.3-hectare (65-acre) site on the Central Plateau of Hanford to convert liquid radioactive waste into a stable glass form (vitrification). The 10-year contract for this work was awarded in December 2000.

- **Washington Group International** – A prime subcontractor to Bechtel National, Inc. Washington Group International is a participant in the mission to design, construct, and start up the Waste Treatment (vitrification) Plant.
- **CH2M HILL Hanford Group, Inc.** – The DOE Office of River Protection's prime contractor has the responsibility to store and retrieve for treatment ~201 million liters (~53 million gallons) of radioactive and hazardous waste stored in 177 underground tanks at Hanford. The company's role also includes storing the treated waste until permanent disposal facilities are available. The contract for CH2M HILL Hanford Group, Inc. runs through 2006.

Additional information about Hanford Site management and contractors can be found on the Internet at <http://www.hanford.gov/top/whowho.html> and <http://www.gjo.doe.gov/programs/hanf/HTFVZ.html>.

During 2002, DOE, the U.S. Fish and Wildlife Service, and the Washington State Department of Fish and Wildlife were joint stewards of the Hanford Reach National Monument. The U.S. Fish and Wildlife Service administered three major management units of the monument totaling ~66,775 hectares (~165,000 acres). These included (1) the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit, a 312-square-kilometer (120-square-mile) tract of land in the southwestern portion of the Hanford Site; (2) the Saddle Mountain Unit, a 130-square-kilometer (50-square-mile) tract of land located north-northwest of the Columbia River and generally south and east of State Highway 24; and (3) the Wahluke Unit, a 225-square-kilometer (87-square-mile) tract of land located north and east of both the Columbia River and the Saddle Mountain Unit (Figure 1.0.1).

The portion of the monument administered by DOE included the McGee Ranch/Riverlands Unit (north and west of State Highway 24 and south of the Columbia River), the Columbia River islands in Benton County, the Columbia River corridor (one-quarter mile inland from

the Hanford Reach shoreline) on the Hanford (Benton County) side of the river, and the sand dunes area located along the Hanford side of the Columbia River north of the Columbia Generating Station.

Approximately 162 hectares (~400 acres) along the north side of the Columbia River, west of the Vernita Bridge, and south of State Highway 243 was managed by the Washington State Department of Fish and Wildlife. All of these lands have served as a safety and security buffer zone for Hanford Site operations since 1943, resulting in an ecosystem that has been relatively untouched for nearly 60 years.

1.0.4 REFERENCES

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PNNL-13910. 2002. *Hanford Site Environmental Report for Calendar Year 2001*. T. M. Poston, R. W. Hanf, R. L. Dirkes, and L. F. Morasch (eds.), Pacific Northwest National Laboratory, Richland, Washington.



2.0 ENVIRONMENTAL REGULATORY COMPLIANCE

J. P. Duncan

This section describes how the U.S. Department of Energy (DOE) and its contractors achieve and maintain environmental and regulatory compliance. Subsections include (1) stakeholder and tribal involvement in the environmental restoration and waste management missions at the Hanford Site, (2) the current compliance status of principal regulations and permits, (3) Hanford cleanup operation issues and actions arising from compliance efforts, (4) an annual summary of environmentally significant occurrences, and (5) waste management and chemical inventory information. It is the policy of DOE that all activities are carried out in compliance with applicable federal, state, and local environmental laws and

regulations, DOE Orders, Secretary of Energy Notices, DOE Headquarters and site operations office directives, policies, and guidance. This includes those specific requirements, actions, plans, and schedules identified in the Hanford Federal Facility Agreement and Consent Order (also known as the Tri-Party Agreement; Ecology et al. 1998) and other compliance or consent agreements. Both the DOE Richland Operations Office and the DOE Office of River Protection recognize the importance of maintaining a proactive program of self-assessment and regulatory reporting to assure that environmental compliance is achieved and maintained at the Hanford Site.



2.1 STAKEHOLDER AND TRIBAL INVOLVEMENT

J. P. Duncan

Many stakeholders have a role in DOE's mission of environmental restoration, waste management, and protection of the Columbia River at the Hanford Site. Stakeholders include federal, state, and local regulatory agencies; environmental groups; regional communities and governments; and the public. Indian Tribes and Nations have a government-to-government relationship with DOE. The following sections describe the roles of the principal agencies, groups, organizations, and the public at the Hanford Site.

2.1.1 REGULATORY OVERSIGHT

K. A. Peterson

Several federal, state, and local regulatory agencies are responsible for monitoring and enforcing compliance with applicable environmental regulations at the Hanford Site. The agencies include the U.S. Environmental Protection Agency (EPA), Washington State Department of Ecology, Washington State Department of Health, and Benton Clean Air Authority.

EPA is the primary federal regulatory agency that develops, promulgates, and enforces environmental regulations and standards as directed in statutes enacted by Congress. In some instances, EPA has delegated authority to the state or authorized the state program to operate in lieu of the federal program when the state's program meets or exceeds EPA's requirements. For instance, EPA has delegated the authority for enforcement of certain air pollution control and hazardous waste management to the Washington State Department of Ecology. In other activities, the state program is assigned direct oversight of the DOE Richland Operations Office as provided by federal law. For example, the Washington State Department of Health has direct authority under the *Clean Air Act* to enforce the standards

and requirements under a state-wide program to regulate radionuclide air emissions at the Hanford Site. In accordance with Title 40, Code of Federal Regulations, Part 61 (40 CFR 61), Subpart H, the Hanford Site is required to submit an annual report on its radionuclide emissions. Where federal regulatory authority is not delegated or only partially authorized to the state, EPA Region 10 is responsible for reviewing and enforcing compliance with EPA regulations as they pertain to the Hanford Site. EPA periodically reviews the state environmental programs and reserves the right to directly enforce federal environmental regulations.

Although Oregon does not have regulatory authority at the Hanford Site, DOE recognizes its interest in Hanford Site cleanup because of the state's location along the Columbia River. Oregon has seats on the Hanford Advisory Board and participates in the State and Tribal Government Working Group for the Hanford Site, which reviews the site's cleanup plans.

2.1.2 HANFORD FEDERAL FACILITY AGREEMENT AND CONSENT ORDER

R. D. Morrison

The Hanford Federal Facility Agreement and Consent Order (also known as the Tri-Party Agreement; Ecology et al. 1998) is an agreement among the Washington State Department of Ecology, EPA, and DOE to achieve environmental compliance at the Hanford Site with the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA), including the *Superfund Amendments and Reauthorization Act* remedial action provisions, and with the *Resource Conservation and Recovery Act* (RCRA) treatment, storage, and disposal unit regulations

and corrective action provisions. The Tri-Party Agreement (1) defines RCRA and CERCLA cleanup commitments, (2) establishes responsibilities, (3) provides a basis for budgeting, and (4) reflects a concerted goal to achieve regulatory compliance and remediation with enforceable milestones. A companion document to the Tri-Party Agreement is the *Hanford Site Tri-Party Agreement Public Involvement Community Relations Plan* (Tri-Party Agreement Agencies 2002). This plan describes how public information and involvement activities are conducted for Tri-Party Agreement decisions.

The Tri-Party Agreement has evolved as cleanup of the Hanford Site has progressed. Significant changes to the agreement have been negotiated between the Washington State Department of Ecology, EPA, and DOE to meet the changing conditions and needs of the cleanup. All significant changes to the agreement undergo a process of public involvement that enhances communication and addresses the public's concerns prior to final approvals. Copies of the agreement are publicly available at the DOE's Public Reading Room located in the Consolidated Information Center on the campus of Washington State University at Tri-Cities, Richland, Washington, and at information repositories in Seattle and Spokane, Washington, and Portland, Oregon. The Tri-Party Agreement can be viewed on the Internet at <http://www.hanford.gov/tpa/tpahome.htm>. To be placed on the mailing list to obtain Tri-Party Agreement information, contact the EPA or DOE directly, or call the Washington State Department of Ecology at 1-800-321-2008. Requests can be sent to:

Hanford Mailing List
P.O. Box 1000
M/S B3-30
Richland, WA 99352

2.1.3 THE ROLE OF INDIAN TRIBES AND NATIONS

K. V. Clarke

The Hanford Site is located on land ceded to the United States government by the Yakama Nation and the Confederated Tribes of the Umatilla Indian Reservation in the Treaties of 1855. These tribes, as well as the Nez Perce

Tribe, have treaty fishing rights on portions of the Columbia River. These tribes reserved the right to fish at all usual and accustomed places and the privilege to hunt, gather roots and berries, and to pasture horses and cattle on open and unclaimed land. The Wanapum are not a federally recognized tribe; however, they have historic ties to the Hanford Site as do the Confederated Tribes of the Colville Reservation, whose members are descendants of people who used the area known as the Hanford Site.

The Hanford Site environment supports a number of Native American foods and medicines and contains sacred places important to tribal cultures. The tribes hope to safely use these resources in the future and want to assure themselves that the Hanford environment is clean and healthy.

American Indian Tribal Governments have a unique legal and political relationship with the United States Government defined by history, treaties, statutes, court decisions, and the U.S. Constitution. In recognition of this relationship, DOE and each tribe interact and consult directly. Tribal government representatives from the Yakama Nation, Confederated Tribes of the Umatilla Indian Reservation, and Nez Perce Tribe participate in DOE supported groups such as the State and Tribal Government Working Group, the Hanford Natural Resources Trustee Council, the Hanford Site Groundwater Protection Program, the Hanford Cultural Resources Program, and provide review and comments on draft documents. Both the Wanapum and the Confederated Tribes of the Colville Reservation are provided an opportunity to comment on documents and participate in cultural resource management activities.

DOE's American Indian and Alaska Native Tribal Government Policy (revised in November 2000) guides DOE's interaction with tribes for Hanford plans and activities. The policy states, among other things, "The Department will consult with any American Indian or Alaska Native tribal government with regard to any property to which that tribe attaches religious or cultural importance which might be affected by a DOE action." In addition to the DOE's American Indian and Alaska Native Tribal Government Policy, laws such as the *American Indian Religious Freedom Act*, the *Archaeological Resources Protection Act of 1979*, the *National Historic Preservation Act*, and the *Native American Graves Protection and Repatriation Act* require consultation with tribal governments. The combination of the Treaties of 1855, federal policy, executive orders, laws,

regulations and the federal trust responsibility, provide the basis for tribal participation in Hanford Site plans and activities. DOE provides financial assistance to affected tribal governments through cooperative agreements with the Yakama Nation, Confederated Tribes of the Umatilla Indian Reservation, and Nez Perce Tribe to support their involvement in environmental management activities at the Hanford Site.

2.1.4 HANFORD NATURAL RESOURCE TRUSTEE COUNCIL

S. H. Wisness

The President of the United States, by Executive Order, has appointed the heads of some federal departments to act on behalf of the public as trustees for natural resources when natural resources may be injured, destroyed, lost, or threatened as a result of a release of hazardous substances. For example, the President appointed the Secretary of Energy as the primary trustee for all natural resources located on, over, or under land administered by DOE, including the Hanford Site. Other designated federal trustees for Hanford natural resources include the U.S. Department of the Interior represented by the U.S. Fish and Wildlife Service and the Bureau of Land Management, and the U.S. Department of Commerce represented by the National Oceanic and Atmospheric Administration.

CERCLA authorizes state governors to designate a state trustee to coordinate all state trustee responsibilities. CERCLA further states that chairmen (or heads of governing bodies) of Indian tribes have essentially the same trusteeship over natural resources belonging to or held in trust for the tribe as state trustees. Indian tribes and state organizations have been designated as natural resource trustees for certain natural resources at or near the Hanford Site. Indian tribes include the Yakama Nation, Confederated Tribes of the Umatilla Indian Reservation, and Nez Perce Tribe. State organizations include the Washington State Department of Ecology, Washington State Department of Fish and Wildlife, and Oregon Department of Energy.

The trustees cooperate with project managers to coordinate assessments, investigations, and planning; carry out damage assessments; and devise and implement restoration plans. The Hanford trustees signed a Memorandum of Agreement (1996) establishing the Hanford Natural Resource Trustee Council. The primary purpose of the council is to facilitate the coordination and cooperation of the trustees in their efforts to mitigate the effects to natural resources that result from either hazardous substance releases within the Hanford Site or the remediation of those releases. The council also adopted bylaws to direct the process of arriving at consensus agreements.

The trustees met as a formal council four times during 2002 to discuss cleanup issues on the Central Plateau and in the Columbia River Corridor. In addition to cooperation and information sharing, the council was instrumental in acquiring funds for the restoration of naturally damaged shrub-steppe habitat on Fitzner/Eberhardt Arid Lands Ecology Reserve Unit as mitigation for construction of Environmental Restoration Disposal Facility cells 1 and 2.

During 2000, the council completed a pre-assessment of the former Hanford 1100 Area. Litigation continues between DOE and one of the trustees, the Yakama Nation, regarding potential injury to natural resources.

Information about the council, including its history and projects, can be found at <http://www.hanford.gov/boards/nrtc>.

2.1.5 PUBLIC PARTICIPATION

B. K. Wise

Individuals may influence Hanford Site cleanup decisions through public participation activities. The public is provided opportunities to contribute their input and influence decisions through many forums, including but not limited to Hanford Advisory Board meetings, Tri-Party Agreement activities, *National Environmental Policy Act* public meetings on various environmental impact statements, and other involvement activities. The Offices of Communications (DOE Richland Operations Office and the DOE Office of River Protection) coordinate the planning and scheduling of public participation activities for the Hanford Site.

The *Hanford Site Tri-Party Agreement Public Involvement Community Relations Plan* (Tri-Party Agreement Agencies 2002) outlines how public information and involvement activities are conducted for Tri-Party Agreement decisions. Washington State Department of Ecology, DOE, and EPA developed and revised the plan with input from the public. The plan was approved in 1990. The plan is updated on an as-needed basis; the most recent revision occurred during January 2002. The plan can be found on the Internet at <http://www.hanford.gov/crp/toc.htm>.

A mailing list of about 3,300 individuals who have indicated an interest in participating in Hanford Site decisions is maintained. The mailing list also is used to send topic-specific information to those people who have requested it. Information is provided on upcoming decisions to elected officials, community leaders, special interest groups, and the media.

To inform the public of upcoming opportunities for public participation, *The Hanford Update/Hanford Happenings*, a synopsis and calendar of all ongoing and upcoming Tri-Party Agreement public involvement activities, is published bimonthly and distributed to the entire mailing list. To allow Hanford stakeholders and others to access up-to-date information, documents from the Tri-Party Agreement's Administrative Record and Public Information Repository are available at <http://www2.hanford.gov/arpir>.

The public can obtain information about cleanup activities at (800) 321-2008. The public can request information about public participation activities and receive a response by contacting the Office of Communications (DOE Richland Operations Office) at (509) 376-7501. Also, a calendar of public involvement opportunities can be found at <http://www.hanford.gov/calendar/>.

2.1.6 HANFORD ADVISORY BOARD

B. K. Wise

The Hanford Advisory Board was chartered during January 1994 under the *Federal Advisory Committee Act* to advise DOE, EPA, and Washington State Department of Ecology on major Hanford Site cleanup policy issues. The Hanford Advisory Board was the first of many such advisory groups

created by DOE at weapons production cleanup sites across the nation. The board consists of 31 members who represent a broad cross section of interests, including environmental, local governments, public health, business, tribal governments, and the public. Each board member has at least one alternate. Todd Martin, Citizens for a Clean Eastern Washington, is the current chairperson. The board has five standing committees: (1) Budgets and Contracts, (2) River and Plateau, (3) Health Safety and Environmental Management, (4) Tank Waste, and (5) Public Involvement and Communications.

The board held seven 2-day meetings during 2002. Members are engaged in discussions with representatives from the Tri-Party Agreement agencies on major cleanup issues, plans to treat tank waste, and budget priorities. The board produced 14 new pieces of consensus advice (making a total of 134), engaged in a series of meetings, participated in several workshops, and engaged in informational exchanges with each other and representatives from the Tri-Party Agreement agencies. In addition, the board created the Exposure Scenarios Task Force to identify values and possible future uses of the land and resources of the Hanford Site and the exposure scenarios the Tri-Party agencies should consider in making cleanup decisions. The task force held five workshops in 2002. Information about the Hanford Advisory Board, including copies of its advice and responses can be found at <http://www.hanford.gov/boards/hab/index.htm>.

2.1.7 HANFORD SITE TECHNOLOGY COORDINATION GROUP

J. P. Duncan

The Hanford Site Technology Coordination Group was established in 1994 to assess science and technology needs, enhance communications, and provide technology-transfer functions. It consisted of a Management Council and five subgroups aligned with the Environmental Management Focus Areas: (1) deactivation and decommissioning, (2) mixed waste, (3) subsurface contaminants, (4) tanks, and (5) nuclear materials. The primary objective of the Hanford Site Technology Coordination Group was the timely and cost-effective demonstration and implementation of technologies recognized for site cleanup.

During 2002, the subgroups endorsed the science and technology needs developed by the site contractors for submittal to the Environmental Management Focus Areas and the Environmental Management Science Program. Nine new technologies were deployed at the Hanford Site as a result of development efforts.

As of July 1, 2002, funding for the Hanford Site Technology Coordination Group was discontinued, resulting in its dissolution. DOE remains committed to the deployment of new and innovative technologies that will expedite cleanup efforts.



2.2 COMPLIANCE STATUS

J. P. Duncan

This section summarizes the status of Hanford Site activities with regard to federal environmental protection statutes and associated state and local environmental regulations. Permits required under specific environmental protection regulations are discussed.

2.2.1 HANFORD FEDERAL FACILITY AGREEMENT AND CONSENT ORDER

R. D. Morrison

The Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement; Ecology et al. 1998) commits DOE to achieve compliance with the remedial action provisions of CERCLA and with the treatment, storage, and disposal unit regulations and corrective action provisions of RCRA, including the state's implementing regulations. From 1989 through 2002, a total of 773 milestones and 274 target dates have been completed. During 2002, there were 40 specific cleanup milestones scheduled for completion: 36 were completed on or before their required due dates, 2 were completed beyond their established due dates, and 2 are yet to be completed.

2.2.1.1 TRI-PARTY AGREEMENT MILESTONES

The Tri-Party Agreement is an agreement for achieving compliance with CERCLA remedial action provisions and with RCRA treatment, storage, and disposal unit regulations and corrective action provisions. The Tri-Party Agreement contains a schedule, using numerous enforceable major and interim milestones, which reflects a concerted goal of achieving full regulatory compliance and remediation.

The following list contains the calendar year 2002 milestones completed under the terms of the Tri-Party Agreement:

- **M-013-00M** – Submit one 200 National Priority List remedial investigation/feasibility study work plan for the 200-IS-1 tanks/lines/pits/diversion boxes operable unit. Includes waste sites in the 200-ST-1 Operable Unit.
- **M-015-41B** – Submit 200-TW-1 and 200-TW-2 Operable Units remedial investigation report to EPA and Washington State Department of Ecology and include the past-practice waste sites in the 200-PW-5 fission product-rich process waste group.
- **M-016-03A** – Establish date for completion of 300 Area remedial actions.
- **M-016-03G** – Establish an Environmental Restoration Disposal Facility staging area that is ready to receive drummed waste from the 618-4 burial ground in accordance with an Environmental Restoration Disposal Facility record of decision amendment.
- **M-016-26B** – Complete remediation and backfill of 51 liquid waste sites in the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2 and 100-HR-1 Operable Units and process effluent pipelines in the 100-DR-1, 100-DR-2, and 100-HR-1 Operable Units. Complete revegetation of 36 liquid waste sites in the 100-BC-1, 100-DR-1, 100-DR-2, and 100-HR-1 Operable Units as defined in the remedial design report/remedial action work plan for the 100 Areas (DOE/RL-96-17).
- **M-016-41B** – Submit closeout verification package for J.A. Jones 1 and 600-23 waste sites for EPA approval.
- **M-019-00** – Complete treatment and/or direct disposal of at least 1,644 cubic meters (2,150 cubic yards) of contact-handled low-level mixed waste already in storage as of October 1, 1995, as well as newly generated Hanford Site low-level mixed waste.
- **M-023-23** – Submit a document that defines leak detection and monitoring functions and requirements for single-shell tank systems to Washington State Department of Ecology for approval.

- **M-023-24** – Submit single-shell tank system integrity assessment report and associated certification(s) and determination(s) pursuant to 40 CFR 265, Subpart J. This report shall document and assess the integrity of DOE's single-shell tank system pursuant to the requirements of 40 CFR 265, Subpart J.
- **M-023-25A** – Complete installation of the first four liquid observation wells and begin weekly liquid observation monitoring at four single-shell tanks by March 31, 2002.
- **M-023-25B** – Complete installation of the second four liquid observation wells and begin weekly liquid observation monitoring at four single-shell tanks by September 30, 2002.
- **M-024-00N** – Install RCRA groundwater monitoring wells at the rate of 29 in calendar year 1989, 30 in calendar year 1990, and up to 50 per year thereafter as specified by agreed interim milestones until all land disposal units and single-shell tanks are determined to have RCRA-compliant monitoring systems.
- **M-024-56** – Install two additional wells at single-shell tank Waste Management Area TX-TY. Location 1: well installed downgradient (perimeter) between wells 299-W14-6 and 299-W14-14. Location 2: well installed ~55 meters (~180 feet) south of well 299-W15-22. Water quality screening as described above with standard-design top-of-table well completion.
- **M-026-01L** – Submit an annual Hanford Land Disposal Restrictions Report in accordance with Tri-Party Agreement requirements to cover the period from January 1 of the previous year through December 31 of the reporting year.
- **M-034-17** – Initiate removal of spent nuclear fuel from the K-East Basin and transport to the K-West Basin.
- **M-035-09C** – Conduct biennial assessments of information and data access needs with EPA and Washington State Department of Ecology. DOE will propose implementation schedules (Tri-Party Agreement milestones) for enhancements as a result of the biennial assessments.
- **M-043-15** – Start construction for upgrades in the AW Tank Farm.
- **M-044-00A** – Complete delivery of information requirements as identified in the annually submitted Waste Information Requirements Document.
- **M-044-15F** – Complete characterization deliverables consistent with Waste Information Requirements Document developed for 2000. Reporting on progress of these deliverables will be done in quarterly reports due at the end of the month following each fiscal year quarter. The fourth quarter report due at the end of October will also include a year-end summary of all deliverables due for the fiscal year.
- **M-044-16F** – Complete input of characterization information for high-level waste tanks for which sampling and analysis were completed per Waste Information Requirements Document into an electronic database. Offsite access to the database containing tank waste characterization information will be made available to EPA and Washington State Department of Ecology.
- **M-045-00C** – Complete re-negotiation of second phase activities (i.e., September 30, 2006 through September 30, 2015) for the single-shell tank waste retrieval.
- **M-045-02K** – Submit annual update of single-shell tank retrieval sequence document.
- **M-046-00I** – This new milestone replaces existing milestone M-31-02. A tank volume projection report shall be submitted on an annual basis to the Washington State Department of Ecology and EPA. This report shall include discussions covering all assumptions which form the basis of the projection. The report shall include or shall be accompanied by DOE's plans for acquisition of additional tanks based on the tank volume projection.
- **M-046-01H** – Concurrence of additional tank acquisition. The three parties shall meet to establish new milestones, if required, for acquisition of additional tanks.
- **M-048-02D** – Submit to the Washington State Department of Ecology a report assessing technology development by March 31, 2002. Develop ultrasonic testing equipment, or an equivalent technology, to assess material thickness and defects of the predicted maximum stress region of the lower knuckle base metal of double-shell tanks.
- **M-048-02E** – Submit to the Washington State Department of Ecology a report assessing technology development by September 30, 2002. Develop ultrasonic testing equipment, or an equivalent technology, to assess material thickness and defects of the predicted maximum stress region of the lower knuckle base metal of double-shell tanks.
- **M-048-10** – Submit a written report to the Washington State Department of Ecology documenting results of ultrasonic testing of the primary tank walls in four double-shell tanks not previously examined by ultrasonic testing.
- **M-062-01E** – Submit semiannual project compliance report.
- **M-062-06** – Start construction of Phase I Treatment Complex. First placement of structural concrete at one of the treatment complex principal facilities (i.e., pretreatment, low-activity waste vitrification, or high-level waste vitrification facilities).
- **M-083-09** – Complete repackaging and shipment of all Hanford ash mixed waste currently stored in the Plutonium

Finishing Plant to the Central Waste Complex for storage. Repackaging and shipment of Hanford ash mixed waste does not include those items identified as non-destructive assay standards or set aside for Waste Isolation Pilot Plant verification sampling.

- **M-083-10** – Complete solidification of selected plutonium-bearing solutions currently located in the Plutonium Finishing Plant and shipment to the Central Waste Complex for storage.
- **M-083-21** – Submit a residual chemical hazards assessment for the Plutonium Finishing Plant to the Washington State Department of Ecology as a primary document. The document will list the processing equipment including tanks, piping, and waste lines that may contain residual chemicals and an evaluation of the associated hazards. The document will describe the evaluation, criteria, and processes to accomplish these tasks. It will also categorize the items based on risk to human health and the environment, include considerations on whether response actions are required, and provide a schedule for actions necessary to address significant risks prior to final deactivation. The methods for defining the categories will be described in the document.
- **M-092-14** – Complete removal, transfer, and initiate storage of Phase I 300 Area special case waste and materials. Phase I inventory will consist of, at minimum, one-third the total curie content of all 300 Area special case waste.
- **M-093-06** – Complete removal action work plan/surveillance and maintenance plan for B Reactor.
- **M-093-13** – Initiate characterization and design of interim safe storage for the DR Reactor.
- **M-094-02** – Submit an amendment to the existing 324 Building Radiochemical Engineering Cells, High-Level Vault closure plan (DOE/RL-96-73) for Washington State Department of Ecology review and approval. The amendment shall change the existing closure plan path from clean closure to a path where the high-risk materials and waste are removed from the facility followed by complete disposition.

Milestones completed after their established due dates in 2002 under the terms of the Tri-Party Agreement include the following items:

- **M-034-18A** – Complete removal of spent nuclear fuel equivalent to 957 metric tons (1,053 tons) heavy metal from the K-West Basin. This interim milestone will be complete when spent nuclear fuel equivalent to 957 metric tons (1,053 tons) heavy metal has been removed from K-West Basin and transported to the Cold Vacuum Drying Facility.

- **M-034-29** – Complete K-East and K-West Basin facility modifications for an alternate fuel transfer strategy.

Milestones not completed in 2002 under the terms of the Tri-Party Agreement include the following two items:

- **M-034-08** – Initiate full-scale K-East Basin sludge removal. DOE shall complete and approve K-East sludge removal definitive design documents, all associated construction, and readiness assessments, and initiate removal of sludge from the basin.
- **M-091-20** – Prepare T Plant to receive the first canister of K Basins floor and pit sludge. This interim milestone will be complete when all T Plant readiness activities have been completed to accept pit and floor sludge. Readiness is defined as the issuance of the readiness to proceed letter by the approval authority.

2.2.1.2 APPROVED MODIFICATIONS TO THE TRI-PARTY AGREEMENT

During 2002, twenty-five negotiated change requests to the Tri-Party Agreement were approved (Table 2.2.1). These approved change requests may be viewed in their entirety in the Tri-Party Agreement Administrative Record at <http://www2.hanford.gov/arpir/>.

2.2.2 ENVIRONMENTAL MANAGEMENT SYSTEMS

H. T. Tilden II, G. D. Cummins, and D. M. Yasek

Contractors at the Hanford Site have established integrated environment, safety, and health management systems. These systems, contractually mandated by DOE, are intended to protect the worker, public, and environment by integrating environment, safety, and health into the way work is planned, performed, and improved. The international voluntary consensus standard ISO 14001, *Environmental Management Systems – Specifications with Guidance for Use*, and DOE P 450.4, *Safety Management System Policy*, were used during the development of the systems. Basic elements of these systems include environmental policy, planning, implementation, checking and corrective action, and management review.

Table 2.2.1. Hanford Site Tri-Party Agreement Change Requests Approved During 2002

<u>Change Request</u>	<u>Date Approved</u>	<u>Title</u>
M-13-02-01	06/05/02	Modification of Central Plateau 200 Areas non-tank farm remedial action work plans (M-013 series milestones)
M-15-01-03	09/11/02	Interim milestones for 200-LW-1
M-15-01-04	07/12/02	Interim milestones for 200-MW-01 miscellaneous waste group operable unit remedial investigation/feasibility study work plan
M-15-02-01	06/05/02	Modify Tri-Party Agreement milestone series M-015 in accordance with the Central Plateau Agreement in Principle
M-16-01-05	04/30/02	Establish date for completion of all 100 Areas remedial actions (M-016-00F)
M-16-01-06	04/30/02	Establish date for completion of all 300 Area remedial actions
M-16-02-01	06/05/02	Modification of the M-016 series milestones
M-16-02-02	07/11/02	Modify in situ redox manipulation phase III barrier emplacement interim milestone M-016-27C
M-16-02-04	11/13/02	Additional extraction well and monitoring well for 100-KR-4 pump-and-treat system
M-20-01-01	06/03/02	Modify Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) M-020 series milestones
M-20-02-01	06/05/02	Modify Tri-Party Agreement milestone series M-020 in accordance with the Central Plateau Agreement in Principle
M-23-02-01	02/26/02	Modifications to the M-23-23 milestone
M-24-02-01	09/24/02	Define <i>Resource Conservation and Recovery Act</i> wells to be drilled in 2002
M-34-02-01	06/11/02	Measurement of spent nuclear fuel from K-West Basin changes from multi-canister overpack to metric tons of heavy metal
M-34-02-02	07/23/02	M-34-17 - deletion of requirement for initiation of sludge containerization
M-45-02-01	02/11/02	Change in delivery dates for M-045-55-T02 and M-045-55-T03
M-45-02-04	10/30/02	Re-align completion date for Tri-Party Agreement Target M-045-55-T03
M-45-02-05	12/17/02	Modification of M-45-05D to allow time to finalize M-45-02-03
M-46-02-01	11/25/02	Change due date of M-046-01I "Concurrence of additional tank acquisition. The three parties shall meet to establish new milestones, if required, for acquisition of additional tanks." from November 30, 2002 to February 28, 2003
M-62-01-03	06/03/02	Modifications to the M-062-06, M-062-07, M-062-10 M-062-11, M-4500C, M-090-08, M-090-09-T01, and M-90-11 milestones that are necessary to provide consistency between Tri-Party Agreement milestone language, completion schedule for contract numbers DE-AC27-01RV14136, DE-AC27-99R114047, and DOE Office of River Protection baseline schedule
M-83-01-03	10/29/02	Establish milestones and target dates for the Plutonium Finishing Plant transition, milestone series M-83A
M-90-01-03	06/03/02	Modification of Tri-Party Agreement M-90 series to resolve inconsistencies between Tri-Party Agreement requirements and the DOE Office of River Protection baseline schedule
M-93-01-02	04/30/02	Modification to the Tri-Party Agreement M-93 series milestones complete final disposition of all 100 Areas surplus production reactor buildings
M-94-01-01	04/30/02	Establish date for final disposition of all 300 Area surplus facilities under the M-094 series milestones
P-06-02-01	05/21/02	Quality assurance sections of the Tri-Party Agreement

DOE has verified the following Hanford contractors as having adequately implemented an integrated environmental, safety, and health system: Bechtel Hanford, Inc. (May 2000), CH2M HILL Hanford Group, Inc. (May 2000), Fluor Hanford, Inc. (August 2000), and the Pacific Northwest National Laboratory (1998). Efforts continued in 2002 to implement and improve these environmental, safety, and health programs. The Pacific Northwest National Laboratory obtained ISO 14001 third-party registration of its Environmental Management System in 2002. The registration certificate can be viewed online at <http://www.pnl.gov/iso14001/registration.htm>. Bechtel Hanford, Inc. is pursuing ISO 14001 registration through either self-certification to the standard or certification by third-party registrars. During 2002, Bechtel Hanford, Inc. implemented performance measures and indicators to monitor the health function of their Integrated Safety Management System (BHI-01550). The performance measures encompass all of the Integrated Safety Management System core functions and guiding principles. Bechtel Hanford, Inc. found that the ability to effectively monitor the critical performance measures and indicators associated with each of these core functions enabled management to stay current with efforts to maintain and sustain Integrated Safety Management System and established a basis to evaluate and balance priorities.

2.2.3 CHEMICAL MANAGEMENT SYSTEMS

M. T. Jansky

The Hanford Site, through its contractors, facilities, and processes, uses a variety of approaches for chemical management. The contractors developed and documented formal systems for the management of chemicals during 1997. These management systems are applicable to the acquisition, use, storage, transportation, and final disposition of chemicals including hazardous chemicals as defined in the Occupational Safety and Health Administration's Hazard Communication Standard (29 CFR 1910, Subpart Z, Appendices A and B). The chemical management systems have been reviewed periodically and improved as needed. Details on the chemical inventories stored at the Hanford Site may be found in Section 2.5.

2.2.4 COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT

L. M. Dittmer

During 1980, the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) was enacted to address response, compensation, and liability for past releases or potential releases of hazardous substances, pollutants, and contaminants to the environment. During 1986, CERCLA was extensively amended by the *Superfund Amendments and Reauthorization Act*, which made federal facilities subject to the provisions of CERCLA. EPA is the lead regulatory agency responsible for oversight of DOE's implementation of CERCLA. There is significant overlap between the state RCRA corrective action program (Section 2.2.6) and CERCLA. Many waste management units are subject to remediation under both programs. The CERCLA program is implemented via 40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," which establishes procedures for characterization, evaluation, and remediation. The Tri-Party Agreement addresses CERCLA implementation at Hanford and is generally consistent with the national contingency plan process.

There are several remediation activities under way at Hanford that are accomplished using the CERCLA process (e.g., remedial investigation in the 200 Areas, cleanup in the 100 and 300 Areas). Specific project activities and accomplishments are described in Sections 2.3.2 and 2.3.12.

2.2.5 EMERGENCY PLANNING AND COMMUNITY RIGHT-TO-KNOW ACT

D. E. Zaloudek

The *Emergency Planning and Community Right-to-Know Act* requires states to establish a state emergency response commission and local emergency planning committees

and to develop a process to distribute information on hazardous chemicals present in facilities. These organizations gather information and develop emergency plans for local planning districts. Facilities that produce, use, or store extremely hazardous substances in quantities above threshold planning quantities must identify themselves to the state emergency response commission and the local emergency planning committee, and periodically provide information to support the emergency planning process. Facilities must also notify the state emergency response commission and the local emergency planning committee immediately after an accidental release of an extremely hazardous substance (40 CFR 355, Appendices A and B) over the reportable quantity. Two annual reports are required by the *Emergency Planning and Community Right-To-Know Act*. The 2002 *Hanford Site Tier Two Emergency and Hazardous Chemical Inventory* (DOE/RL-2003-07) contains information about hazardous chemicals stored at the facility in amounts exceeding minimum threshold levels. The 2002 *Hanford Site Toxic Chemical Release Inventory* (DOE/RL-2003-18) contains information about total annual releases of certain toxic chemicals and associated waste management activities.

For reporting year 2002, the Hanford Site issued the reports and notifications required by the *Emergency Planning and Community Right-To-Know Act*. The 2002 *Hanford Site Tier Two Emergency and Hazardous Chemical Inventory* (DOE/RL-2003-07) was provided to the Washington State Department of Ecology's Community Right-To-Know Unit; local emergency planning committees for

Benton, Franklin, and Grant Counties; and to both the Richland and Hanford Site fire departments. The 2002 *Hanford Site Toxic Chemical Release Inventory* report (DOE/RL-2003-18), which included releases and waste management activities involving lead, was provided to EPA and the Washington State Department of Ecology.

Table 2.2.2 provides an overview of 2002 reporting under the *Emergency Planning and Community Right-To-Know Act*.

2.2.6 RESOURCE CONSERVATION AND RECOVERY ACT

M. J. Hartman

The *Resource Conservation and Recovery Act* (RCRA) was enacted during 1976 with the objective of protecting human health and the environment. During 1984, the Hazardous and Solid Waste Amendments re-authorized RCRA and imposed new requirements on the management of hazardous waste. The most important aspect of RCRA is its establishment of "cradle-to-grave" management to track hazardous waste from generator to treatment, storage, and disposal. The Washington State Department of Ecology has the authority to enforce RCRA requirements in the state. At Hanford, RCRA applies to ~70 hazardous waste treatment, storage, or disposal units that have received waste since implementation of the act.

Table 2.2.2. Emergency Planning and Community Right-to-Know Act Compliance Reporting at the Hanford Site During 2002

<u>Sections of the Act</u>	<u>Yes^(a)</u>	<u>No^(a)</u>	<u>Not Required^(a)</u>
302-303: Planning notification	X ^(b)		
304: Extremely hazardous substances release notification			X
311-312: Material safety data sheet/chemical inventory	X		
313: Toxic chemical release inventory reporting	X		

(a) "Yes" indicates that notifications were provided and/or reports were issued under the applicable provisions. "No" indicates that notifications or reports should have been provided but were not. "Not Required" indicates that no actions were required under the applicable provisions, either because triggering thresholds were not exceeded or no releases occurred.

(b) These notifications apply to the Hanford Site but were completed prior to 2002.

2.2.6.1 HANFORD FACILITY RCRA PERMIT

S. A. Thompson

The Hanford Facility RCRA Permit (WA7890008967), Dangerous Waste Portion was issued by the Washington State Department of Ecology during September 1994. The permit is the foundation for RCRA permitting on the Hanford Site in accordance with provisions of the Tri-Party Agreement (Ecology et al. 1998). Revision 8 of the Hanford Facility RCRA Permit is scheduled to be published in April 2003.

2.2.6.2 RCRA/DANGEROUS WASTE PERMIT APPLICATIONS AND CLOSURE PLANS

S. A. Thompson

For purposes of RCRA and Washington State dangerous waste regulations (WAC 173-303), the Hanford Site is considered a single facility that encompasses ~70 treatment, storage, and disposal units. The Tri-Party Agreement recognized that all of the units could not be issued permits simultaneously, and a schedule was established to submit unit-specific Part B dangerous waste permit applications and closure plans (DOE/RL-88-20) to the Washington State Department of Ecology.

During 2002, 24 Part A, Form 3, revisions were certified and submitted to the Washington State Department of Ecology. One Part B permit application (DOE/RL-88-20) (Low-Level Burial Grounds) for final status was submitted to the Washington State Department of Ecology.

2.2.6.3 RCRA GROUNDWATER MONITORING

M. J. Hartman and B. A. Williams

RCRA groundwater monitoring is part of the Hanford Site Groundwater Monitoring Project (Section 6.2). Table 2.2.3 lists the 24 facilities and units (or waste management areas) that require groundwater monitoring and notes their monitoring status, and Figure 6.1.3 shows the locations of these units. RCRA samples were collected from 285 wells site-wide during 2002. A summary of

groundwater monitoring activities for these sites during 2002 is provided in Section 6.4.

Groundwater samples were analyzed for a variety of dangerous waste constituents and site-specific constituents. The constituent lists meet the minimum RCRA regulatory requirements and are integrated to supplement other groundwater monitoring project requirements (e.g., *Atomic Energy Act of 1954*, CERCLA) at the Hanford Site.

DOE and Washington State Department of Ecology negotiations resulted in an agreement to install four wells, two RCRA and two CERCLA, during the fourth quarter of 2002. The agreement required one new CERCLA well to be installed in support of the 200-ZP-1 Operable Unit and one new well installed to support the 200-UP-1 Operable Unit. Additionally, Tri-Party Agreement Milestone M-24-00N (Ecology et al. 1998) required the installation of two new RCRA groundwater monitoring wells by December 31, 2002. Fluor Hanford, Inc. successfully installed these two wells ahead of the completion deadline (Table 2.2.4). Both of these RCRA wells were installed at Waste Management Area TX-TY, located in the 200-West Area. The wells were completed as shallow (top of the aquifer) monitoring wells, with well screens ~10.7 meters (35 feet) long.

DOE's Cleanup, Constraints, and Challenges Team was formed during 2002 to assess and define the total number of groundwater monitoring wells required to complete and/or integrate all the monitoring networks on the Central Plateau. The result of this work was an integrated CERCLA/RCRA data quality objectives document that is pending approval by the Tri-Parties. The document identifies all of the 200 Areas groundwater monitoring wells required to fulfill RCRA and CERCLA monitoring requirements. If approved, the Tri-Parties will prioritize these wells and schedule them for installation from 2003 through 2006. The wells to be installed annually will continue to be approved via the Tri-Party Agreement (Milestone M-24-00).

No major changes to RCRA facility groundwater monitoring occurred during 2002 at the waste management units. At the end of 2002, 15 RCRA waste management areas were monitored to detect whether they are contaminating groundwater with hazardous constituents. Seven waste management areas were monitored to assess the

Table 2.2.3. RCRA Interim and Final Status Groundwater Monitoring Projects at the Hanford Site, September 2002

TSD Units, date initiated	Interim Status TSD Unit Groundwater Monitoring		Final Status TSD Unit Groundwater Monitoring			Groundwater Monitoring Regulations	Calendar Year Scheduled for Part B ^(b) or Closure
	Indicator Parameter Evaluation ^(a)	Groundwater Quality Assessment, date initiated	Detection Evaluation	Compliance Evaluation	Corrective Action, date initiated		
116-N-1 (1301-N) LWDF, December 1987			X ^(c)			40 CFR 265.93(b) WAC 173-303-400	1999 ^(d)
120-N-1, 120-N-2 (1324-N/NA) LWDF, December 1987			X ^(c)			40 CFR 265.93(b) WAC 173-303-400	1999 ^(d)
116-N-3 (1325-N) LWDF, December 1987			X ^(c)			40 CFR 265.93(b) WAC 173-303-400	1999 ^(d)
116-H-6 (183-H) evaporation basins, June 1985					X, 1998	40 CFR 264 WAC 173-303-645(11)	1994 ^(d)
216-A-29 ditch, November 1988	X					40 CFR 265.93(b) WAC 173-303-400	2005 ^(d)
216-B-3 pond, November 1988	X ^(e)					40 CFR 265.93(b) WAC 173-303-400	2003 ^(d)
216-B-63 trench, August 1991	X					40 CFR 265.93(b) WAC 173-303-400	2005 ^(d)
216-S-10 pond and ditch, August 1991	X					40 CFR 265.93(b) WAC 173-303-400	2005 ^(d)
216-U-12 crib, September 1991		X, 1993				40 CFR 265.93(d) WAC 173-303-400	2005 ^(d)
316-5 process trenches, June 1985					X, ^(e) 1998	40 CFR 264 WAC 173-303-645(11)	1996 ^(d,f)
LERF, July 1991						40 CFR 265.93(b) WAC 173-303-400	1998 ^(g)
LLWMA 1, September 1988	X					40 CFR 265.93(b) WAC 173-303-400	2002 ^(h)

Table 2.2.3. (contd)

	TSD Units, date initiated	Indicator Parameter Evaluation ^(a)	Groundwater Quality	Detection Evaluation	Compliance Evaluation	Corrective Action, date initiated	Groundwater Monitoring Regulations	Calendar Year
			Assessment, date initiated					Scheduled for Part B ^(b) or Closure
◆ 2.17 ◆	LLWMA 2, September 1988	X					40 CFR 265.93(b) WAC 173-303-400	2002 ^(h)
	LLWMA 3, October 1988	X					40 CFR 265.93(b) WAC 173-303-400	2002 ^(h)
	LLWMA 4, October 1988	X					40 CFR 265.93(b) WAC 173-303-400	2002 ^(h)
	NRDWL, October 1986	X					40 CFR 265.93(b) WAC 173-303-400	2004 ^(d)
	PUREX cribs ⁽ⁱ⁾ 1988		X, 1997				40 CFR 265.93(d) WAC 173-303-400	TBD ^(d)
	WMA A-AX, February 1990	X					40 CFR 265.93(b) WAC 173-303-400	TBD
	WMA B-BX-BY, February 1990		X, 1996				40 CFR 265.93(d) WAC 173-303-400	TBD
	WMA C, February 1990	X					40 CFR 265.93(b) WAC 173-303-400	TBD
	WMA S-SX, October 1991		X, 1996				40 CFR 265.93(d) WAC 173-303-400	TBD
	WMA T, February 1990		X, 1993				40 CFR 265.93(d) WAC 173-303-400	TBD
	WMA TX-TY, September - October 1991		X, 1993				40 CFR 265.93(d) WAC 173-303-400	TBD

Table 2.2.3. (contd)

TSD Units, date initiated	Interim Status TSD Unit Groundwater Monitoring		Final Status TSD Unit Groundwater Monitoring			Groundwater Monitoring Regulations	Calendar Year Scheduled for Part B ^(b) or Closure
	Indicator Parameter Evaluation ^(a)	Groundwater Quality Assessment, date initiated	Detection Evaluation	Compliance Evaluation	Corrective Action, date initiated		
WMA U, October 1990		X, 2000				40 CFR 265.93(b) WAC 173-303-400	TBD

(a) Contamination indicator parameters (pH, specific conductance, total organic carbon, and total organic halides) used to determine if a facility is affecting groundwater quality. Exceeding the established limits means that additional evaluation and sampling are required (i.e., groundwater quality assessment). An X in the assessment column indicates whether an evaluation was needed or an assessment was required.

(b) Part B of RCRA permit application.

(c) Monitored according to interim status plan as specified in closure plans.

(d) Closure/post-closure plan; TSD unit will close under WAC 173-303-610.

(e) Implementing alternative statistical method for a 2-year trial period as a demonstration of, and in accordance with, a Washington State Department of Ecology directive (letter from D. Goswami to M. Furman, dated May 7, 2001).

(f) Closure plan pending Washington State Department of Ecology approval.

(g) Statistical evaluations suspended in January 2001 because only one downgradient well is not dry.

(h) Draft facility Part B permit application and final status groundwater monitoring plan submitted in 2002.

(i) 216-A-10, 216-A-36B, and 216-A-37-1 combined into one RCRA monitoring unit. RCRA monitoring will be performed according to interim status groundwater quality assessment requirements.

CFR = Code of Federal Regulations.

LERF = Liquid effluent retention facility.

LLWMA = Low-level waste management area.

LWDF = Liquid waste disposal facility.

NRDWL = Nonradioactive Dangerous Waste Landfill.

PUREX = Plutonium-Uranium Extraction (Plant).

RCRA = *Resource Conservation and Recovery Act*.

TBD = To be determined.

TSD = Treatment, storage, or disposal (unit).

WAC = Washington (state) Administrative Code.

WMA = Waste management area.

extent of known contaminants and two were monitored to determine the progress. The facilities monitored under RCRA are scheduled for closure under the Hanford Site Part B RCRA Permit except for the Liquid Effluent Retention Facility and the low-level burial grounds (Low-Level Waste Management Areas 1 to 4), which are operating facilities. DOE submitted an application to the Washington State Department of Ecology during June 2002 to incorporate Low-Level Waste Management Areas 1 to 4 into the Hanford Site Part B RCRA Permit. The application included new groundwater monitoring programs.

2.2.6.4 RCRA INSPECTIONS

R. C. Bowman

Hanford Site contractors and DOE are working to resolve outstanding notices of violation and warning letters of non-compliance that were received from the Washington State Department of Ecology during 2002. These documents identify conditions that are alleged to be non-compliant with RCRA requirements. The following RCRA non-compliance issues are being addressed:

- **Notice of Non-Compliance for Temporary Transfer-Line Leak Detection** – The Washington State Department of Ecology issued a Notice of Non-Compliance letter to the DOE Office of River Protection on August 8, 2002, that documents their concerns regarding the leak detection system associated with temporary transfer lines used at the single-shell tank farms. The Washington State Department of Ecology alleged that the leak detection system associated with temporary transfer lines used at the single-shell tank farms does not meet the requirements of WAC 173-303-400. The Notice of Non-Compliance identified two alleged violations and two concerns. DOE sent a temporary transfer-line management plan to the Washington

State Department of Ecology on December 17, 2002, as requested by the Notice of Non-Compliance.

- **Compliance Issue at the 600 Area Purgewater Storage and Treatment Facility** – The Washington State Department of Ecology letter, dated August 2, 2002, provides their compliance concern associated with the 600 Area Purgewater Storage and Treatment Facility. On March 25, 2002, DOE informed the Washington State Department of Ecology that chromium (D007) waste had been accepted at the 600 Area Purgewater Storage and Treatment Facility at levels above the dangerous waste characteristic designation level (5.0 mg/L [5 ppm]). State regulation WAC 173-303-805 (7)(a)(i) states that the owner/operator must submit a revised Part A to include new information prior to storage, treatment, or disposal of a new constituent. The Washington State Department of Ecology claimed that D007 could not be added to the Part A after acceptance and management of this waste. A Washington State Department of Ecology letter, dated September 10, 2002, rescinded the August 2, 2002, letter citing the violation of WAC 173-303-805(7)(a)(I). No further action was required.

2.2.7 CLEAN AIR ACT

K. A. Peterson

Federal, state, and local agencies enforce the standards and requirements of the *Clean Air Act* to regulate air emissions at facilities such as the Hanford Site. DOE and EPA signed the *Federal Facility Compliance Agreement for Radionuclides NESHAP* (EPA 1994). The agreement provides a compliance plan and schedule that are being followed to bring the Hanford Site into compliance with *Clean Air Act* requirements under 40 CFR 61, Subpart H, for continuous measurement of emissions from applicable airborne emission sources. Scheduled milestones of the *Federal*

Facility Compliance Agreement (EPA 1994) were met during 2002, and Hanford Site air emissions remained well below the levels that approach the state and EPA offsite emission standard of 10 mrem (100 μ Sv) per year. The requirements for flow and emissions measurements, quality assurance, and sampling documentation have been implemented at Hanford Site emission sources and/or are monitored for milestone progress in accordance with a schedule approved by EPA and monitored by the Washington State Department of Health. Data for the sources are documented

Table 2.2.4. New RCRA Well Installation Summary for the Hanford Site, 2002^(a)

<u>Well Number</u>	<u>Well ID</u>	<u>RCRA Site</u>	<u>Operational Area</u>
299-W14-19	C3957	WMA TX-TY	200-West
299-W15-44	C5956	WMA TX-TY	200-West

(a) Tri-Party Agreement Milestone M-24-00N.

ID = Identification number.

RCRA = *Resource Conservation and Recovery Act*.

WMA = Waste management area.

annually in the *Radioactive Air Emissions Report for the Hanford Site* (e.g., DOE/RL-2003-21).

The Washington State Department of Health's Division of Radiation Protection regulates radioactive air emissions statewide through delegated authority from EPA and Washington State legislative authority. The Washington State Department of Health implements the federal/state requirements under state regulation WAC 246-247. Prior to beginning any work that would result in creating a new or modified source of radioactive airborne emissions, a notice of construction application must be submitted to the Washington State Department of Health and EPA for review and approval. Typical requirements for radioactive air emission sources include adequate emission controls, emission monitoring/sampling, and/or annual reporting of air emissions. The Hanford Site operates under state license FF-01 for such emissions. Conditions specified in the FF-01 license were incorporated into the Hanford Site air operating permit issued in July 2001. The Hanford Site air operating permit was issued in accordance with Title V of the *Clean Air Act Amendments of 1990*, and will be implemented through federal and state programs under 40 CFR 70 and WAC 173-401. The permit provides a compilation of applicable *Clean Air Act* requirements both for radioactive and non-radioactive emissions at the Hanford Site. The permit requires the DOE Richland Operations Office to submit periodic reports (e.g., *Hanford Site Air Operating Permit Semiannual Report for the Period January 1, 2002 through June 30, 2002* [DOE/RL-2002-38]) and an annual compliance certification to the Washington State Department of Ecology.

The Washington State Department of Ecology's Nuclear Waste Program regulates air toxic and criteria pollutant emissions from the Hanford Site. The Department enforces state regulatory controls for air contaminants as allowed under the Washington *Clean Air Act* (RCW 70.94). The Washington State Department of Ecology's implementing requirements (e.g., WAC 173-400; WAC 173-460) specify a review of new source emissions, permitting, applicable controls, reporting, notifications, and provisions of compliance with the general standards for applicable sources of Hanford Site emissions.

EPA regulates other potential air emission sources under the *Clean Air Act* at the Hanford Site. For example,

40 CFR 82 requires regulation of the service, maintenance, repair, and disposal of certain systems containing Class I and Class II ozone-depleting substances (refrigerants) within facility systems at the Hanford Site. Implementation of the ozone-depleting substance management requirements on the Hanford Site is administered at the facility/project level, as applicable.

At the local level, EPA designated the Benton Clean Air Authority as the agency to establish a local oversight and compliance program for asbestos renovation and/or demolitions. The Benton Clean Air Authority imposes additional requirements on sources within the local agency's jurisdiction and incorporates EPA's regulation by reference, (i.e., the "National Emission Standards for Hazardous Air Pollutants" [40 CFR 61, Subpart M]). In addition, the Benton Clean Air Authority regulates open burning as an extension of the Washington State Department of Ecology's open burning requirements (WAC 173-425).

CLEAN AIR ACT ENFORCEMENT INSPECTIONS

R. C. Bowman

Hanford Site contractors and DOE have worked to resolve notices of violation and warning letters of non-compliance that were received from the Washington State Department of Health and Washington State Department of Ecology during 2002. These documents identify conditions that are alleged to be non-compliant with *Clean Air Act* requirements. The following non-compliance issue has been addressed:

- A Notice of Violation and Compliance Order was received from the Washington State Department of Health on December 18, 2002. The Notice of Violation and Compliance Order identified one alleged violation and two corrective measures. The department alleges that DOE and its contractors (Fluor Hanford, Inc. and CH2M HILL Hanford Group, Inc.) are in violation of the notification requirements of WAC 246-247-080(5). In their letter, the Washington State Department of Health cites a number of historical examples that are used to document their concerns with DOE/contractor notification practices. The Notice of Violation and Compliance Order requires DOE to provide a response within 60 days of the date of receiving the Washington State Department of Health letter.

2.2.8 CLEAN WATER ACT

W. E. Toebe

The *Clean Water Act* applies to point source discharges to surface waters of the United States. At the Hanford Site, the regulations are applied through National Pollutant Discharge Elimination System (40 CFR 122) permits that govern effluent discharges to the Columbia River. There is one National Pollutant Discharge Elimination System permit, WA-002591-7, for the Hanford Site. The permit covers three active outfalls: outfall 001 for the 300 Area Treated Effluent Disposal Facility and outfalls 003 and 004 in the 100-K Area. Fluor Hanford, Inc. is the holder of this permit.

The Hanford Site was covered by one stormwater permit during 2002. EPA's National Pollutant Discharge Elimination System Storm Water Multi-Sector General Permit WAR05A57F establishes the terms and conditions under which stormwater discharges associated with industrial activity are authorized. This permit was issued on May 30, 2001, and supersedes all other National Pollutant Discharge Elimination System stormwater permits previously in effect at the site.

Wastewater from the William R. Wiley Environmental Molecular Sciences Laboratory located in the Richland North Area, is discharged to the city of Richland's wastewater treatment facility under pretreatment permit CR-IU005. This permit, formerly issued by the city to the DOE Richland Operations Office, was re-issued to Battelle on October 1, 2001.

There are numerous sanitary waste discharges to the ground throughout the site. Sanitary waste from the 400 Area is discharged to a treatment facility of Energy Northwest's Columbia Generating Station (Figure 1.0.1). Sanitary waste from the 300 Area, the former 1100 Area, and other facilities north of, and in, Richland discharge to the city of Richland treatment facility. Sanitary wastewater in the 200 Areas of the Hanford Site is primarily treated in a series of septic tanks and drainfields. The placement of these systems is based on population centers and facility locations. In recent years, extensive efforts have been made to regionalize the wastewater treatment systems. Many of the small, single-facility sewer systems

have been replaced with large systems capable of processing as much as 54,883 liters (14,500 gallons) per day. These large systems (with a design capacity of 13,248 to 54,883 liters [3,500 to 14,500 gallons] per day) are permitted by the Washington State Department of Health and treat wastewater from several facilities rather than a single facility.

State Wastewater Discharge Permit Program. The Washington State Department of Ecology, State Wastewater Discharge Permit Program, regulates the discharge or disposal of wastewater to ground waters.

DOE is voluntarily complying with this program at the Hanford Site and is currently holding several state wastewater discharge permits. During 2002, the Hanford Site had seven state waste discharge permits issued by the Washington State Department of Ecology. A brief summary of each permit is included in Appendix D, Table D.6.

2.2.9 SAFE DRINKING WATER ACT

L. M. Kelly

There were nine public water systems on the Hanford Site in 2002. All public water systems are required to meet the *Safe Drinking Water Act*, the *Safe Drinking Water Act Amendments of 1986*, and the *Safe Drinking Water Act Amendments of 1996*. Specific performance requirements are defined within the federal regulations (40 CFR 141; EPA-570/9-76-003; EPA 822-R-96-001) and WAC 246-290. The drinking water program has been updated to comply with the changing regulatory requirements. A complete revision of WAC 246-290 was issued on April 9, 1999, and all site water programs have had the necessary changes incorporated.

Eight of the nine public drinking water systems on site were supplied from the Columbia River. The water treatment plants supplied from the Columbia River must effectively demonstrate compliance with the filtration and disinfection requirements set forth in the Surface Water Treatment Rule. The 283-W water treatment plant in 200-West Area provides water to customers in both 200 Areas as the primary water supply. The 200-East Area water treatment plant remains on standby if needed. The 300 Area is supplied from the city of Richland, but the

300 Area water treatment plant also remains on standby. The well that supplied water to the Hanford Patrol Training Academy was taken out of service for potable use during May 1999. The training academy water is now supplied by the city of Richland, which maintains the system and samples the quality of the drinking water. Drinking water at the Fast Flux Test Facility (400 Area) was primarily drawn from a local groundwater well (499-S1-8J). Section 4.3 provides further information for each public water system.

The compliance monitoring program elements are updated annually with monitoring cycles beginning in January. Drinking water is monitored for radionuclides, inorganics, synthetic and volatile organics, lead, copper, asbestos, arsenic, disinfectant byproducts, and coliform (total and fecal) bacteria. All analytical results for 2002 met the requirements of the Washington State Department of Health. Sample results for radiological monitoring of drinking water are discussed in Section 4.3.

2.2.10 TOXIC SUBSTANCES CONTROL ACT

A. L. Prignano

Requirements in the *Toxic Substances Control Act* that apply to the Hanford Site primarily involve regulation of polychlorinated biphenyls. Federal regulations for use, storage, and disposal of certain classes of polychlorinated biphenyls are found in 40 CFR 761. Washington State also regulates certain classes of polychlorinated biphenyls (not regulated under the *Toxic Substances Control Act*) through the *Dangerous Waste Regulations* in WAC 173-303. Non-radioactive and certain categories of radioactive polychlorinated biphenyl waste are stored and disposed in accordance with 40 CFR 761. Other radioactive polychlorinated biphenyl waste remains in storage on the Hanford Site pending the development of adequate treatment and disposal technologies and capacities. For example, during 2002, 593 drums of depleted uranium in oil containing polychlorinated biphenyl were moved from the 300 Area to the Environmental Restoration Disposal Facility staging area where they will remain pending treatment and disposal. Electrical equipment that might

contain polychlorinated biphenyls or polychlorinated biphenyl items is maintained and serviced in accordance with 40 CFR 761.

The "Framework Agreement for Management of Polychlorinated Biphenyls in Hanford Tank Waste" signed on August 31, 2000, resulted in the EPA, the Washington State Department of Ecology, and DOE and its Hanford Site contractors working together to resolve the regulatory issues associated with managing polychlorinated biphenyl waste at the Waste Vitrification Plant (now under construction), in tank farms, and at affected units upstream and downstream of tank farms (<http://yosemite.epa.gov/R10/OWCM.NSF/0/ce50d3fe12e371f488256a00006ffa0f?OpenDocument>). The flexibility of the 1998 polychlorinated biphenyl disposal revisions found in 40 CFR 761 is used at the Hanford Site to allow necessary storage and to expedite disposal of polychlorinated biphenyl waste regulated by the *Toxic Substances Control Act*.

During June 2002, EPA approved an extension of the risked-based disposal approval for operation of the Hanford Site 242-A evaporator. The original risked-based disposal approval was for operation through March 2001. The extension allows continued operations through early 2003. The 242-A evaporator is located in the 200-East Area and its operation results in reduction of tank waste volume. Two new applications for risked-based disposal approvals were submitted to EPA during 2002. In January 2002, an application for risked-based disposal approval for the double-shell tank system was submitted to EPA. It evaluated risk and exposure pathways associated with operations, storage, handling, and processing of waste in the double-shell tank system. A second application for a risked-based disposal approval was submitted to EPA during February 2002 for operation of the Hanford Site 200 Areas liquid waste processing facilities. The risk evaluation indicated that liquid waste processing facilities could accept aqueous waste streams with up to 6,000 mg/L polychlorinated biphenyls without posing an unreasonable risk to human health or the environment. The applications for the double-shell tank system and the liquid waste processing facilities risked-based disposal approvals are under review by EPA; no responses or comments have been received to date.

2.2.11 FEDERAL INSECTICIDE, FUNGICIDE, AND RODENTICIDE ACT

J. M. Rodriguez

The *Federal Insecticide, Fungicide, and Rodenticide Act* is administered by EPA. The standards administered by the Washington State Department of Agriculture to regulate the implementation of the act in Washington State include: *Washington Pesticide Control Act* (RCW 15.58), *Washington Pesticide Application Act* (RCW 17.21), and rules relating to general pesticide use codified in WAC 16-228. At the Hanford Site, pesticides are applied by commercial pesticide operators who are listed on one of two commercial pesticide applicator licenses and by a private commercial applicator.

2.2.12 ENDANGERED SPECIES ACT OF 1973

R. K. Zufelt

Several protected species of plants and animals exist on the Hanford Site and in the Hanford Reach of the Columbia River. The bald eagle (*Haliaeetus leucocephalus*) occurs on the site and steelhead (*Oncorhynchus mykiss*) and spring-run chinook salmon (*Oncorhynchus tshawytscha*) are listed by the U.S. Fish and Wildlife Service as either threatened or endangered (50 CFR 17, Subpart B) and occur onsite. Other species are listed by the Washington Department of Fish and Wildlife as endangered, threatened, or sensitive species (Appendix G).

Bald eagles are seasonal visitors to the Hanford Site. The Pacific Northwest National Laboratory documented several nesting attempts along the Hanford Reach during the 1990s. The Hanford Site bald eagle management plan (DOE/RL-94-150) was finalized in 1994. This plan established seasonal 800-meter (2,600-foot) zones of restricted access around all active nest sites and five major communal roosting sites. If nesting activities are observed during January and early February, all Hanford-related activities within the restricted access zone are constrained or limited until the pair abandons nesting or successfully rears young.

Steelhead and spring-run chinook salmon are regulated as evolutionary significant units by the National Oceanic and Atmospheric Administration Fisheries based on their historical geographic spawning areas. The evolutionary significant units for the upper Columbia River steelhead and the upper Columbia River spring-run chinook salmon were listed as endangered during August 1997 and March 1999, respectively. A Hanford Site steelhead management plan (DOE/RL-2000-27) was prepared and serves as the formal plan for the National Oceanic and Atmospheric Administration Fisheries as required under the *Endangered Species Act of 1973*. Like the bald eagle management plan, the steelhead management plan discusses mitigation strategies and lists activities that can be conducted without impacting steelhead or their habitats.

2.2.13 MIGRATORY BIRD TREATY ACT

M. R. Sackschewsky

The *Migratory Bird Treaty Act* prohibits taking or disturbing specified migratory birds or their feathers, eggs, or nests. There are over 100 species of birds that regularly occur on the Hanford Site that are protected by the *Migratory Bird Treaty Act*.

All Hanford Site projects with a potential to affect federally- or state-listed species of concern complied with the requirements of this act by using the ecological review process as described in the *Hanford Site Biological Resources Management Plan* (DOE/RL-96-32). When applicable, the ecological reviews produced recommendations to minimize the adverse impact to migratory birds, such as performing work outside of the nesting season and minimizing the loss of habitat.

2.2.14 CULTURAL RESOURCES

D. W. Harvey

Cultural resources on the Hanford Site are mainly subject to the provisions of the following seven acts, one executive order, and one Presidential Proclamation: *American Indian Religious Freedom Act*; *Antiquities Act of 1906*;

Archaeological and Historic Preservation Act; *Archaeological Resources Protection Act of 1979*; Executive Order 11593, *Protection and Enhancement of the Cultural Environment* (36 FR 8921); *Historic Sites, Buildings, and Antiquities Act*; *National Historic Preservation Act*; *Native American Graves Protection and Repatriation Act*, and Proclamation 7319 of June 9, 2000 (65 FR 37253). Compliance with these regulations is accomplished through an active management and monitoring program. Included in the program is the review of all proposed projects to assess their potential impact on cultural resources and the periodic inspection of known archaeological sites and historic buildings to determine their condition and eligibility for listing in the National Register of Historic Places. The effects of land management policies on archaeological sites and buildings, and management of a repository for federally owned archaeological collections and Manhattan Project and Cold War era artifacts are evaluated. Federal agencies, as a matter of policy, are directed by Executive Order 11593 and Section 110 of the *National Historic Preservation Act* to administer the cultural and historic properties under their control in a spirit of stewardship and trusteeship for future generations.

During 2002, 164 cultural resource reviews were conducted on the Hanford Site to comply with Section 106 of the *National Historic Preservation Act*. The *American Indian Religious Freedom Act* requires federal agencies to help protect and preserve the rights of Native Americans to practice their traditional religions. DOE cooperates with Native Americans by providing site access for organized religious activities. The regulations of the *Native American Graves Protection and Repatriation Act* provides a process to determine the rights of Indian Tribes “to certain Native American human remains, funerary objects, sacred objects, or objects of cultural patrimony with which they are affiliated” (43 CFR 10).

Proclamation 7319 of June 9, 2000 (65 FR 37253), established the Hanford Reach National Monument that incorporated selected areas of the Hanford Site. Administered by DOE Richland Operations Office and the U.S. Fish and Wildlife Service, “the monument is one of the few remaining archaeological rich areas in the western Columbia Plateau, containing well-preserved remnants of human history spanning more than 10,000 years” (65 FR 37253). President Clinton issued a memorandum to the Secretary of Energy the same day the proclamation

was signed directing DOE to manage and protect “...objects of scientific and historic interest...where practical” in the site’s central area as if they were in monument lands.

See Section 8.3 for more details regarding the cultural resources program on the Hanford Site.

2.2.15 NATIONAL ENVIRONMENTAL POLICY ACT

M. T. Jansky

The *National Environmental Policy Act* requires consideration of the effects of major federal actions before those actions are taken. The preparation of an environmental impact statement is required for major federal actions with the potential to impact the quality of the human environment. Other *National Environmental Policy Act* documents include the environmental assessment which is prepared when it is uncertain if a proposed action has the potential to significantly impact the environment and, therefore, would require the preparation of an environmental impact statement. A supplemental analysis is prepared to consider new information developed since issuance of a *National Environmental Policy Act* environmental impact statement and record of decision. The purpose is to consider if the federal action is still bounded by the original environmental impact statement and record of decision or if a supplemental environmental impact statement is required.

Additionally, certain types of actions may fall into typical classes that have already been analyzed by DOE and have been determined not to result in a significant environmental impact. These actions are called categorical exclusions, and, if eligibility criteria are met, they are exempt from *National Environmental Policy Act* environmental assessment or environmental impact statement requirements. Typically, the DOE Richland Operations Office documents more than 20 specific categorical exclusions annually, involving a variety of actions by multiple Hanford Site contractors. In addition, site-wide categorical exclusions are applied to routine, typical actions conducted daily on the Hanford Site. In 2002, there were 20 site-wide categorical exclusions.

National Environmental Policy Act documents for the Hanford Site are prepared and approved in accordance with

Council on Environmental Quality National Environmental Policy Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act (40 CFR 1500-1508), DOE *National Environmental Policy Act* implementation procedures (10 CFR 1021), and DOE Order 451.1B. In accordance with the Order, DOE documents prepared for CERCLA projects incorporate *National Environmental Policy Act* values such as analysis of cumulative, offsite, ecological, and socioeconomic impacts to the extent practicable in lieu of preparing separate *National Environmental Policy Act* documentation.

2.2.15.1 RECENT ENVIRONMENTAL IMPACT STATEMENTS

The potential environmental impact associated with ongoing, major operations at the Hanford Site has been documented in environmental impact statements and in the ensuing records of decision. Additional *National Environmental Policy Act* reviews and supplemental analyses as appropriate are conducted during the course of the actions, as described in the records of decision.

A final environmental impact statement for the stabilization of plutonium-bearing materials at the Plutonium Finishing Plant was issued in May 1996 (DOE/EIS-0244F). The proposed action is to stabilize selected plutonium-bearing materials for interim storage and immobilize some materials for transport to a Hanford Site solid waste management facility. The record of decision was issued in July 1996 (61 FR 36352). In 2002, two supplemental analyses were prepared to provide the basis for determining if a supplemental environmental impact statement would be required. Seven previously prepared supplemental analyses (DOE/EIS-0244-FS/SA1 through DOE/EIS-0244-FS/SA7) resulted in determinations that the *National Environmental Policy Act* required no additional analyses.

A supplemental analysis (DOE/EIS-0244-FS/SA8) was issued on April 15, 2002, and provided the basis for determining if a supplemental environmental impact statement was required before thermal stabilization of polycubes and combustibles at the Plutonium Finishing Plant. It was determined that additional *National Environmental Policy Act* analysis was not required.

A supplemental analysis (DOE/EIS-0244-FS/SA9) was issued on December 10, 2002, and provided the basis for determining if a supplemental environmental impact statement was required before disposition of hold-up plutonium-bearing material, mixed oxide materials, and alloy/oxide and metal materials at the Plutonium Finishing Plant. It was determined that additional *National Environmental Policy Act* analysis was not required.

2.2.15.2 PROGRAMMATIC AND OFFSITE ENVIRONMENTAL IMPACT STATEMENTS

The final environmental impact statement was issued in May 1997 (DOE/EIS-0200F) to evaluate management and national siting alternatives for the treatment, storage, and disposal of five types of radioactive and hazardous waste. The Hanford Site was considered in all alternatives. A record of decision was issued in January 1998 (63 FR 3623) on treatment and storage of transuranic waste. A subsequent record of decision on hazardous waste treatment was issued in August 1998 (63 FR 41810). A record of decision for storage of immobilized high-level waste was issued in August 1999 (64 FR 46661). A record of decision for the treatment and disposal of low-level waste and mixed low-level waste was issued in February 2000 (65 FR 10061). A revised record of decision for treatment and storage of transuranic waste was issued in September 2002 (67 FR 56989).

The *Idaho High-Level Waste & Facilities Disposition Final Environmental Impact Statement* (DOE/EIS-0287) was issued by the Idaho National Engineering and Environmental Laboratory in August 2002 for the disposition of Idaho high-level waste and facilities in which Hanford was listed as an alternative disposal site. A record of decision is expected to be issued in 2003.

The final environmental impact statement affecting the Fast Flux Test Facility (DOE/EIS-0310) was issued in December 2000. The final statement evaluated the expanded civilian nuclear energy research and development and isotope production missions in the United States including the role of the Fast Flux Test Facility at the Hanford Site. A record of decision was issued in January 2001 (66 FR 7877) indicating the Fast Flux Test

Facility would be permanently deactivated, but the ruling was later postponed pending review.

2.2.15.3 SITE-SPECIFIC ENVIRONMENTAL IMPACT STATEMENTS IN PROGRESS

Work on a draft environmental impact statement for the Hanford Site Solid (Radioactive and Hazardous) Waste Program continued during 2002.^(a) The draft environmental impact statement will be issued for public comment.

US Ecology operates a commercial low-level radioactive waste disposal site near the 200 Areas on land leased from the federal government by the state of Washington. The Washington State Department of Health and Washington State Department of Ecology distributed a draft environmental impact statement for the facility for comment in August 2000. This *Washington State Environmental Policy Act* (RCW 43.21C) impact statement considers the renewal of US Ecology's license to operate the waste site, an increase to the upper limit for disposal of naturally occurring radioactive materials, and an approval of the site stabilization and closure plan. A final decision is pending review.

A draft comprehensive conservation plan and environmental impact statement for the Hanford Reach National Monument/Saddle Mountain National Wildlife Refuge is being prepared by the U.S. Fish and Wildlife Service to evaluate management alternatives for the monument and national wildlife refuge. As co-manager of the monument, DOE Richland Operations Office is a cooperating agency. The draft environmental impact statement will be issued for public comment.

A draft environmental impact statement is being prepared on retrieval, treatment, and disposal of tank waste and closure of single-shell tanks. The environmental impact statement will consider the impact of the proposed retrieval, treatment, and disposal of the waste being managed in the high-level waste tank farms, and closure of the 149 single-shell tanks and associated facilities in the tank farms. The Washington State Department of Ecology

is a cooperating agency in the preparation of this environmental impact statement. The draft environmental impact statement will be issued for public comment.

2.2.15.4 RECENT ENVIRONMENTAL ASSESSMENTS

An environmental assessment was prepared to determine whether an environmental impact statement would be required for the retrieval of drummed, post-1970 transuranic waste from storage trenches for storage and eventual disposal (DOE/EA-1405). The analysis of the anticipated impact led to a conclusion that no significant effects were expected. A finding of no significant impact was issued on March 22, 2002, determining that no further review was required under the *National Environmental Policy Act*.

An environmental assessment was prepared to determine whether an environmental impact statement would be required for expansion of the Volpentest Hazardous Materials Management and Emergency Response Training and Education Center, including additional training modules and an emergency vehicle-training course (DOE/EA-1412). The assessment led to a conclusion that no significant impact was expected. A finding of no significant impact was issued on November 6, 2002, determining that no further review was required under the *National Environmental Policy Act*.

2.2.16 THE HANFORD SITE INSTITUTIONAL CONTROLS PLAN

A. E. Teimouri

Institutional control requirements are included within most of the Hanford Site CERCLA records of decision. These requirements vary somewhat between records of decision, but typically include procedural restrictions for access, warning notices, and land-use controls. The initial records of decision for the Hanford Site established requirements only for the specific waste sites addressed by the cleanup action. More recent records of decision

(a) A draft report (DOE/EIS-0286), *Hanford Site Solid (Radioactive and Hazardous) Waste Program Environmental Impact Statement*, is being prepared by the U.S. Department of Energy, Richland Operations Office, Richland, Washington.

include both site-specific and site-wide requirements. The 100 Area burial ground interim action record of decision (issued during September 2000) (EPA 2000a) required that DOE develop and submit a site-wide institutional control plan for EPA and Washington State Department of Ecology approval. The plan, the *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions* (DOE/RL-2001-41), was approved by the regulatory agencies in July 2002. The plan requires DOE to submit an annual assessment of the performance of the institutional controls for the Hanford Site with the first submittal due July 2003.

Several site-specific institutional controls established in CERCLA records of decision are applicable to waste sites under each project. These institutional controls can be characterized into five general categories, as follows:

- **Procedural access controls** – Access controls are achieved through the DOE badging program and via escorting of visitors entering any of the controlled waste sites.
- **Land-use management controls** – Controls that specifically identify prohibitions against unauthorized disturbance (e.g., well drilling or intrusive work) of waste sites are addressed by various records of decision.
- **Warning notices/signs** – Signs required by records of decision along the Columbia River shoreline as well as along access roads; some records of decision simply state that existing signs must be maintained. Warning signs at the Hanford Site are typically “layered” from the general to the more specific and may include general signs prohibiting trespass, waste-site-specific postings warning of hazards, and/or radioactive area postings. This layered approach reflects a graded approach based on site hazards. For waste sites behind security checkpoints (i.e., badge houses), all entrants must have appropriate access training prior to entrance. Warnings such as “restricted access,” “no trespassing,” or similar signs are typically present at access roads leading to waste sites, whether the sites are within or outside of security checkpoints. Waste sites outside of security checkpoints are often fenced, with warning signs present on the fencing. Sites undergoing active remediation include notification signs warning of the cleanup activities, and the sites themselves are generally fenced. Finally, sites with radioactive contamination are posted with radioactive control signs or markers at the actual waste site.
- **Notification of trespass events** – Trespass incidents must be reported under the terms of the various records of decision. DOE is required to notify EPA and the Washington State Department of Ecology in the event of trespass incidents. For example, the 100 Areas burial grounds (EPA 2000a), the 100-NR-1 Operable Unit (EPA 2000b), the 100 Areas remaining sites (EPA 1999), and the 300-FF-2 Operable Unit (EPA 2001). In addition, the latter three records of decision also stipulate that trespass events be reported to the Benton County Sheriff’s Office.
- **Recordkeeping on remedial action information** – A tracking system that identifies all land under restriction or control is required in some records of decision such as the 100 Area burial grounds record of decision (EPA 2000a). The 300-FF-1 and 300-FF-5 record of decision (EPA 1996) contains a requirement for placing written notification of remedial action in the facility land-use master plan. Institutional controls for individual remediated waste sites are identified in the cleanup verification packages approved by the lead regulatory agency. Institutional controls identified in the cleanup verification packages are typically entered into the Waste Information Data System. The Waste Information Data System serves as the primary mechanism used by site contractors to record institutional controls associated with remediated waste sites.



2.3 HANFORD CLEANUP OPERATIONS

J. P. Duncan

This section describes continuing Hanford Site environmental and regulatory activities. Included are project compliance activities, solid waste management, liquid effluent treatment, revegetation and mitigation, environmental restoration, groundwater protection, and waste tank research. Activities, accomplishments, and relevant issues are presented and discussed openly with the regulators and with the public to assure resolution.

2.3.1 POLLUTION PREVENTION PROGRAM

J. G. Coenenberg

Pollution prevention is DOE's preferred approach to environmental management. The Hanford Site Pollution Prevention Program is an organized and continuing effort to reduce the quantity and toxicity of hazardous, radioactive, mixed, and sanitary waste. The program fosters the conservation of resources and energy, the reduction of hazardous substance use, and the prevention or minimization of pollutant releases to all environmental media from all operations and site cleanup activities.

The program is designed to satisfy DOE requirements, executive orders, and federal and state regulations and requirements. In accordance with sound environmental management, the first priority is to prevent pollution through source reduction. When source reduction is not possible or practical, waste treatment to reduce quantity, toxicity, or mobility is considered. The second priority is environmentally safe recycling; and the third priority is approved disposal to the environment at permitted sites.

DOE Richland Operations Office is responsible for the Hanford Site Pollution Prevention Program. The office defines program requirements that each Hanford Site contractor must meet.

Hanford Site pollution prevention efforts during 2002 helped to reduce disposal quantities through source reduction and recycling of an estimated 142,908 cubic meters (5 million cubic feet) of radioactive and mixed waste, 737 metric tons (812 tons) of RCRA hazardous/dangerous waste, and 3,936 metric tons (4,339 tons) of sanitary waste. Waste disposal cost savings during 2002 exceeded \$37 million for these activities. During 2002, the Hanford Site recycled 547 metric tons (603 tons) of paper products and 559 metric tons (616 tons) of various metals.

2.3.2 SPENT NUCLEAR FUEL PROJECT

D. J. Watson

The Spent Nuclear Fuel Project was established in February 1994 to provide safe, economical, and environmentally sound management of Hanford Site spent (irradiated) nuclear fuel and to prepare the fuel for long-term storage or final disposal. During 2002, the project continued to make progress on an accelerated strategy to move spent fuel stored in the K-West and K-East Basins (K Basins) in the 100-K Area, away from the Columbia River into the Canister Storage Building in the 200-East Area. The 40-year-old K Basins were used to temporarily store 2,100 metric tons (2,300 tons) of N Reactor spent fuel and a small quantity of slightly irradiated single-pass reactor fuel. The spent fuel is being removed from underwater storage in the K Basins and placed in dry interim storage in the 200-East Area. Prior to interim storage, the fuel is cleaned and packaged in containers called multi-canister overpacks. The overpacks are vacuum processed to remove any water and then mechanically sealed at the Cold Vacuum Drying Facility located in the 100-K Area. The dried overpacks are transported to the Canister Storage Building, a welded cap is attached over the mechanical

seal, and the overpack is put in dry storage. The multi-canister overpacks will be maintained in dry storage pending a decision by the Secretary of Energy on final disposition. If necessary, the re-packaged spent fuel could remain in dry storage for up to 40 years. This strategy supports completion of fuel removal from the K Basins by the Tri-Party Agreement (Ecology et al. 1998) date of July 2004.

The corrosion of the fuel in the K Basins, as well as fuel handling operations, have led to the accumulation of sludge and debris in old fuel storage canisters and on the floors of the basins. The majority of the sludge is in the K-East Basin. The sludge, debris, and empty storage canisters will be removed at the same time the spent nuclear fuel is removed. Water remaining in the basins will also be removed, treated at the Effluent Treatment Facility and disposed of onsite. Debris and old fuel canisters will be transported to the Environmental Restoration Disposal Facility for disposal to the extent possible. Debris that does not meet acceptance criteria for the Environmental Restoration Disposal Facility will be transferred to the appropriate onsite waste management facility. The K Basins will then be prepared for interim stabilization pending final remediation.

The Spent Nuclear Fuel Project also includes in its mission, the gathering of other spent nuclear fuel stored elsewhere on the Hanford Site and the relocation of that spent nuclear fuel to the 200-East Area Interim Storage Area or to the Canister Storage Building. Other spent nuclear fuel and its storage locations include the following:

- Fuel from the Fast Flux Test Facility in the 400 Area.
- Fuel from the Training, Research, and Isotope Production General Atomics in the 400 Area.
- Fuel originally from the Shippingport reactor in Pennsylvania and now stored at T Plant in the 200-West Area.
- Fuel from research reactors and miscellaneous special case fuel in the 324, 325, and 327 Buildings in the 300 Area.

Major accomplishments of the Spent Nuclear Fuel Project in 2002 included the following items:

- A total of 730.5 metric tons (805 tons) of spent nuclear fuel were removed from the K-West Basin and transported to the Cold Vacuum Drying Facility for processing and then taken to the Canister Storage Building for storage.

- A total of 260 fuel canisters (or ~82 metric tons [90 tons]) of spent nuclear fuel were transferred from the K-East Basin to the K-West Basin for cleaning and re-packaging before transport to the Cold Vacuum Drying Facility for processing.
- A total of 1,133 fuel storage canisters and 917 fuel storage canister lids were cleaned for disposal at the Environmental Restoration Disposal Facility. A total of 1,172 canisters were shipped to Environmental Restoration Disposal Facility for disposal.
- Construction of the sludge removal system for the K-East Basin progressed to 95% completion.
- Three cask shipments containing non-defense spent nuclear fuel were received for storage at the 200 Areas Interim Storage Area near the Canister Storage Building facility.

2.3.3 CENTRAL PLATEAU REMEDIATION PROJECT

J. K. Perry

The Central Plateau Remediation Project's mission is to transition the Central Plateau from its current post-operational state to a state where excess facilities and waste sites are cleaned up, and waste characterization, retrieval, treatment, storage, and disposal operations are performed in an environmentally sound, safe, secure, and efficient manner.

On July 1, 2002, the Central Plateau Remediation Project began working on activities transferred from the environmental restoration contractor. The activities include the Groundwater Protection Program, the 200 Area Facility Surveillance Maintenance Program, and the Plutonium Concentration Facilities Demolition Project. The Central Plateau Remediation Project will continue to manage the 300 Area activities until the work is transferred to the new river corridor contractor. The activities discussed in the following sections were performed during 2002.

2.3.3.1 ACCELERATED DEACTIVATION PROJECT

C. R. Haas

The mission of the Accelerated Deactivation Project is to complete facility deactivation and closure activities while

maintaining the facilities in a safe and compliant status until they are turned over to the site contractor responsible for final disposition of the facilities.

300 Area Accelerated Deactivation Project. Accelerated deactivation in the 300 Area focuses on several 300 Area buildings and structures that date back to 1943. It includes fuel supply facilities that were used to support the manufacturing of nuclear fuel for the Hanford Site reactors. Significant accomplishments during 2002 included the following activities:

- Received certification of partial RCRA closure for the 300 Area Waste Acid Treatment System from the Washington State Department of Ecology.
- Performed surveillance and maintenance of 300 Area Accelerated Deactivation Project facilities.

2.3.3.2 327 AND 324 FACILITIES DEACTIVATION PROJECT

C. R. Haas

Construction of the 327 and 324 Buildings was completed and operations began in 1953 and 1966, respectively. These buildings contain hot cells that were used for radiological research and development work. Both facilities were transferred to Fluor Hanford, Inc. during 1996 for deactivation. Facility disposition is to be completed by the new river corridor contractor, pending award of the contract.

Significant accomplishments achieved at the 327 Building during 2002 included the following:

- Continued collecting and packaging special case waste comprised of metallurgical specimens removed from the dry storage carousel and legacy waste buckets from hot cells in support of special case waste disposition activities relating to Tri-Party Agreement Milestone M-92-16.
- Shipped three of five remaining legacy waste containers to the Central Waste Complex from the 327 Building.

Significant accomplishments achieved at the 324 Building during 2002 include the following:

- Completed radiochemical engineering cells airlock pipe trench waste collection activities and subsequent shipment of waste to the Central Waste Complex.

- Completed transfer of five pressurized water reactor spent nuclear fuel assemblies to the 200 Areas for storage.
- Completed consolidation and removal of the remaining 324 Building spent nuclear fuel, including the boiling water reactor fuel assemblies stored in B-Cell and loose boiling water reactor and pressurized water reactor pins stored in B and D cells.
- Completed packaging and shipment of spent nuclear fuel segments and fragments in support of the Special Case Waste Project per Tri-Party Agreement Milestone M-92-16. Spent nuclear fuel removal and shipment activities were completed on budget and 4 months ahead of baseline schedule.

2.3.3.3 EQUIPMENT DISPOSITION PROJECT

D. L. Klages

When the Hanford Site was dedicated to the defense production mission, rail and other heavy equipment was used to handle and transport radioactive or hazardous materials and/or enter facilities where radioactive and hazardous materials were present. Through use, the equipment became radiologically and/or chemically contaminated to the point where it was either removed from service and buried onsite or managed for future use or disposition.

During 1995, the need to manage radiologically contaminated rail equipment became apparent and the Equipment Disposition Project was established. The technical objective of the project is the disposition of 37 contaminated railcars, 5 pieces of heavy equipment, 1 condenser, 1 skid-mounted concrete burial box filled with K-Basin materials, and 2 skid-mounted concrete burial boxes filled with ion exchange columns left over from past Hanford programs.

During 2002, a radiologically contaminated crane measuring 162 cubic meters (5,721 cubic feet) was transferred to an offsite U.S. Nuclear Regulatory Commission-licensed company for equipment reuse. Four railroad flatcars (235.5 cubic meters [8,317 cubic feet]) and 0.52 cubic meter (18.4 cubic feet) of lead bearings from railcars were radiologically surveyed and released for unrestricted re-use offsite. The condenser (32.2 cubic meters [1,137 cubic feet]) was shipped to Duratek in Tennessee for recycling of the contaminated steel into shield blocks for DOE. One

of the skid-mounted concrete burial boxes (67.28 cubic meters [2,376 cubic feet]) was placed in onsite reuse as a burial grout form within the low-level burial grounds. Three tall fuel-cask railroad cars (480 cubic meters [16,951 cubic feet]) were shipped to Duratek in Tennessee. The steel was recycled into shield blocks for DOE, and the lead was used for lining containers. Also during 2002, 3 flatcars (176.6 cubic meters [6,237 cubic feet]), 12 railcar wheel assemblies (36 cubic meters [1,271 cubic feet]), and the 2 skid-mounted concrete burial boxes of grouted ion exchange columns (134.6 cubic meters [4,753 cubic feet]) were placed in the low-level burial grounds for disposal.

2.3.3.4 233-S PLUTONIUM CONCENTRATION FACILITY DECOMMISSIONING PROJECT

D. L. Klages

Decontamination and decommissioning activities continued in 2002 at the 233-S Plutonium Concentration Facility located in the 200-West Area adjacent to the Reduction-Oxidation Plant. This work is being performed as a non-time-critical removal action under CERCLA. The 233-S facility and associated process equipment were used to concentrate plutonium produced at the Reduction-Oxidation Plant from 1955 to 1967.

Equipment cleaning and waste disposal activities continued throughout 2002, along with decontamination efforts on the facility's interior surfaces. Contamination levels within the facility were significantly reduced and the majority of fissile material was removed. The facility is scheduled for demolition.

2.3.3.5 200 AREA FACILITIES DISPOSITION PROJECT

G. J. LeBaron

Disposition of 200 Areas facilities includes the surveillance, maintenance, and deactivation of buildings and waste sites in the 200-East Area, 200-West Area, and Fitzner/Eberhardt Arid Lands Ecology Reserve. A plan, including a cost estimate and schedule, was prepared for removing facilities and making other necessary changes

to transfer the Fitzner/Eberhardt Arid Lands Ecology Reserve to the U.S. Fish and Wildlife Service.

Included in the facilities managed by the project are interim status RCRA treatment, storage, and disposal units awaiting closure. In July 2002, responsibility for additional facilities, including the "canyon" facilities (Plutonium-Uranium Extraction Plant, B Plant, Reduction-Oxidation Plant, and U Plant), was transferred from Bechtel Hanford, Inc. to the 200 Area Facilities Disposition Project. Three major air emission units and three minor emission stacks as defined by 40 CFR 61 are now maintained by the project.

Facility work conducted under this program during 2002 included work in the 224-T facility in the 200-West Area. The cells at the 224-T facility were deactivated and closed during the 1960s. However, no documentation could be found concerning the flushing and final state of the cells and few entries had been made since its closure. During 2002, each cell was entered to perform detailed radiological surveys and to clean the cells to reduce the potential of personnel contamination or release to the environment. Preparations were made to remove the water that had accumulated in the deep portion of C-Cell. Plans are ongoing to inspect the cells and more fully characterize their contents.

During 2002, non-destructive analyses were conducted to characterize the radionuclides in the duct work at the former Plutonium Finishing Plant in the 200-West Area. Metal roofs were installed on the B Plant and Plutonium-Uranium Extraction Plant "canyon" facilities. The metal roofs are designed to last 50 years.

Outdoor tasks within the 200 Area Facilities Disposition Project include the Radiation Area Remedial Action Program, which is responsible for the surveillance, maintenance, and decontamination or stabilization of over 500 waste sites including former cribs, ponds, ditches, trenches, unplanned release sites, and burial grounds. These sites are maintained by performing periodic surveillances, radiation surveys, and herbicide applications and by initiating timely responses to identified problems. The overall program objective is to maintain these sites in a safe and stable configuration and to prevent contaminants at these sites from spreading in the environment while final remediation strategies are identified and implemented.

2.3.3.6 CANYON DISPOSITION INITIATIVE

G. J. LeBaron

The purpose of the Canyon Disposition Initiative is to investigate the potential for using the five canyon buildings at the Hanford Site as disposal facilities for Hanford Site remediation waste, rather than demolishing the structures. (Note: “canyon” is a vernacular term used at the Hanford Site for the chemical separations plants, inspired by their long, high, narrow structure.) While planning and sampling activities of the Canyon Disposition Initiative actually began in the mid-1990s, the bulk of the work to prepare the feasibility study (DOE/RL-2001-11) was completed in 2001 as the final phase in the CERCLA remedial investigation/feasibility study for disposition of the 221-U Chemical Processing Facility (U Plant). The U Plant was used as the pilot project for the Canyon Disposition Initiative. During 2002, work was done to finalize the draft feasibility study and preparations were made to prepare the other CERCLA documentation for final disposition of the U Plant.

The Tri-Parties considered whether the pilot activities at U Plant could also apply to the remaining four canyon buildings. There were four options selected for final evaluation and screening: (1) full removal and disposal, (2) entombment with internal waste disposal, (3) entombment with internal/external waste disposal, and (4) close in place – collapsed structure. The feasibility study (DOE/RL-2001-11) determined that options 2 and 3 met the requirements to protect human health and the environment, as well as being consistent with the 2012 cleanup plan for the Central Plateau. The final option will be selected during the record of decision process. Selecting the final option for the five canyon buildings figures prominently in DOE’s plan to use the Central Plateau as an area for long-term treatment, storage, and disposal of waste to support Hanford cleanup operations.

2.3.4 FAST FLUX TEST FACILITY

N. R. Dahl

The Fast Flux Test Facility is a 400-megawatt thermal, liquid-metal-cooled reactor located in the 400 Area. It

was built in the late 1970s to test plant equipment and fuel for the Liquid Metal Fast Breeder Reactor Program. The Fast Flux Test Facility operated from April 1982 to April 1992, during which time it successfully tested advanced nuclear fuels, materials, and safety designs and also produced a variety of isotopes for medical research. The reactor has been in a standby mode since December 1993. Fuel has been removed from the reactor vessel and stored in two sodium-filled vessels and in aboveground dry-storage casks. Twenty-three of the facility’s 100 plant systems were deactivated during the previous deactivation period from 1993 to 1997.

During September 2002, deactivation and decommissioning activities were transferred from the DOE Office of Nuclear Energy to the DOE Office of Environmental Management, an indication of DOE’s intention to permanently shut down the reactor. In November 2002, Benton County filed a motion in the U.S. District Court for the Eastern District of Washington to halt decommissioning work on the Fast Flux Test Facility. Subsequently, Benton County and federal attorneys agreed to a 120-day stoppage of the deactivation activities.

In an effort to reduce shutdown costs and accelerate the decommissioning schedule, upgrades aimed at increasing the efficiency and reliability of the refueling system were the primary focus of 2002 activities. The acceptance test procedure for the closed-loop ex-vessel machine was completed on August 1, 2002, following 10 months of testing. The closed-loop ex-vessel machine was used to install the immersion heaters and is ready to support the commencement of fuel wash activities. Acceptance testing for the sodium removal system was completed in September 2002. Major repairs and modifications to the solid waste cask are nearing completion. Upon completion of the cask assembly, acceptance testing will begin.

During 2002, one argon and three nitrogen storage tanks were removed during the facility closure process. In addition, parts of the Mobiltherm and Containment Margins systems were removed before closure activities were put on hold. The Mobiltherm System was a heat transfer system used in the sodium purification process. The Containment Margins System was designed to vent the containment dome after a gas buildup caused by an accident.

2.3.5 ADVANCED REACTORS TRANSITION PROJECT

M. W. Benecke and W. F. Brehm

The mission of the Advanced Reactors Transition Project is to convert the Plutonium Recycle Test Reactor facility and the nuclear energy legacy facilities into structures that are suitable for re-use or low-cost surveillance and maintenance. Legacy facilities are those used for nuclear research projects conducted in the past at the Hanford Site. Although these legacy facilities existed in many areas of the Hanford Site, the only facilities remaining to be cleaned up are in the southeastern part of the 300 Area, the 337 Building high bay area, and the adjacent storage tank building, 3718-M. Deactivation of legacy facilities includes the disposition of non-radioactive sodium and sodium-potassium alloy originally used in the development and testing of components for use in liquid-metal-cooled reactors.

During 2001, roof repairs were completed on the support buildings attached to the dome at the Plutonium Recycle Test Reactor/309 Building, located in the 300 Area. Despite further deterioration of the weather coating on the dome, this facility is in a condition for low-cost surveillance and maintenance until deactivation, decontamination, and decommissioning are performed in accordance with the 300 Area Accelerated Closure Project Plan (HNF-6465).

In 2002, all remaining sodium-wetted piping was removed from the 337 Building, placed in shipping drums, and sent to an offsite treatment center. The remaining large cold trap (a device used in sodium systems to remove chemical impurities in the sodium) was stripped of insulation and heaters and moved to the main floor of the 337 Building high bay. Asbestos abatement techniques were required to remove all the insulation and heaters. The cold trap and associated heat exchanger piping were prepared for shipment to Argonne National Laboratory-West in Idaho, where the sodium will be drained and recycled and the trap cleaned. The total sodium volume is ~2,650 liters (~700 gallons).

A request for proposal to remove sodium residuals from the 3718-M and Composite Reactor Component Test

Activity tanks was sent to 11 prospective bidders who attended an information meeting held at Hanford in October 2002.

2.3.6 PLUTONIUM FINISHING PLANT

M. S. Gerber

During 1949, the Plutonium Finishing Plant began processing plutonium nitrate solutions into metallic form for shipment to nuclear weapons production facilities. Operation of this plant continued into the late 1980s. During 1996, DOE issued a shutdown order for the plant, authorizing deactivation and transition of the plutonium processing portions of the facility in preparation for decommissioning.

Today's mission is to stabilize, immobilize, re-package and/or properly dispose of plutonium-bearing materials in the plant; to deactivate and dismantle the processing facilities; and to provide for the safe and secure storage of nuclear materials until final disposition. Workers at the Plutonium Finishing Plant are making progress to stabilize plutonium and deactivate the facilities.

Significant accomplishments achieved at the Plutonium Finishing Plant during 2002 included the following:

- Completed re-packaging of ~547 items of plutonium-bearing ash from a historical Hanford incinerator (February 2002).
- Completed stabilization of 4,500 liters (1,189 gallons) of plutonium-bearing solutions ahead of a revised Tri-Party Agreement milestone and nearly \$3 million under budget (July 2002).
- Began stabilizing over 860 plutonium-bearing polycubes using a unique thermal stabilization method devised specifically for this project. About 75% of polycubes, i.e., small cubes of polystyrene containing plutonium oxide, were stabilized by the end of 2002.
- Attained 1 million safe work hours and achieved safety Merit Status in DOE's Voluntary Protection Plan (November 2002).
- Continued welding stabilized plutonium forms into sturdy, triple-layered cans meeting strict specifications of DOE's "3013" safety standard (November 2002).
- Completed re-packaging the entire "sand, slag, and crucible" group of plutonium-bearing residues for permanent

disposal; began re-packaging another large group of residues known as “mixed oxides” (December 2002).

- Stabilized more than 55% of the total plutonium inventory by the end of 2002, and advanced the stabilization completion date for the Plutonium Finishing Plant Project to February 2004.
- Deployed four field teams to clean chemical residues and legacy plutonium held up in process equipment, as part of deactivation work; completed key environmental documentation in preparation for additional deactivation work and established an accelerated comprehensive deactivation schedule.

2.3.7 WASTE ENCAPSULATION AND STORAGE FACILITY PROJECT

F. M. Simmons

The mission of the Waste Encapsulation and Storage Facility Project is to provide safe interim storage of encapsulated radioactive cesium and strontium. The facility was initially constructed as a portion of the B Plant complex and began service in 1974. There are currently 601 strontium fluoride capsules and 1,335 cesium chloride capsules stored at the facility. The capsules will be stored at the Waste Encapsulation and Storage Facility until 2018. The Waste Treatment Plant pretreatment facility will be designed to connect to a potential new facility to receive and treat the capsules. The final capsule shipment is scheduled for 2022.

The renewal of the U.S. Nuclear Regulatory Commission Certificate of Compliance number 9511, Revision 3 for the Beneficial Uses Shipping System (BUSS R-1) was issued on July 26, 2002, for a 5-year term that expires on July 31, 2007. A Beneficial Uses Shipping System cask is used at the Waste Encapsulation and Storage Facility for the onsite transportation of cesium and strontium capsules. The Beneficial Uses Shipping System cask is the only DOE licensed and certified Type B container for shipment of cesium chloride and strontium fluoride capsules.

2.3.8 OFFICE OF RIVER PROTECTION

Congress established the Office of River Protection during 1998 as a DOE field office reporting directly to the DOE Assistant Secretary for Environmental Management. The Office of River Protection is responsible for managing DOE's River Protection Project to store, retrieve, treat, and dispose of high-level tank waste and close the tank farm facilities at the Hanford Site. The main tasks of the Office of River Protection are discussed in the following sections.

2.3.8.1 WASTE TANK STATUS

P. A. Powell

A monthly summary report documents the status of waste tanks. The December 2002 report, HNF-EP-0182, *Waste Tank Summary Report for Month Ending December 31, 2002*, provides the following information:

- The Hanford tank farms contain 177 high-level radioactive waste tanks, of which 149 are single-shell tanks and 28 are double-shell tanks.
- Of the 177 tanks, 67 are assumed to have leaked at some time in the past; all 67 are single-shell tanks.
- The volume of liquid waste that may have leaked from these tanks is estimated to be between 2.84 and 3.97 million liters (750,000 and 1,000,000 gallons).

To date, 132 of the 149 (89%) single-shell tanks have been stabilized, and the stabilization program is on schedule to be completed by the end of September 2004. During 2002, three tanks (241-SX-105, 241-U-102, and 241-U-109) were declared stabilized. Waste was pumped from 17 single-shell tanks into the double-shell tank system. The following single-shell tanks were pumped during 2002: 241-A-101, 241-AX-101, 241-BY-105, 241-BY-106, 241-C-103, 241-C-106, 241-S-101, 241-S-102, 241-S-107, 241-S-111, 241-S-112, 241-SX-101, 241-SX-102, 241-SX-103, 241-U-107, 241-U-108, and 241-U-111. The pumping removed 5.3 million liters (1.4 million gallons) of waste. For the safe and timely removal of this waste, temporary transfer piping (above ground pipe in pipe which is shielded) was installed.

To assure safe storage and retrieval, 154 of the 177 (87%) tanks have been characterized. All of the double-shell tanks and most of the single-shell tanks have been sampled; however, a number of these tanks were analyzed for a limited number of analytes.

During 2002, CH2M HILL Hanford Group, Inc. began proof-of-concept testing on techniques to dissolve saltcake in waste tanks. Simply put, water was sprayed onto the saltcake to dissolve and mobilize the waste for retrieval through a centrally-located pump. Variations in the volume, pressure, and method of application were evaluated. Saltcake dissolution technology, intended for initial use in tank 241-S-112, was demonstrated in tank 241-U-107. A separate retrieval technology, involving use of a remote-controlled mobile retrieval system (tank crawler) was also evaluated during 2002. The tank crawler was designed to facilitate retrieval of insoluble waste, typically sludge; it was intended to function much like a small bulldozer, pushing solids to a central location in the tank for extraction. The system, planned for initial application in tank 241-C-104, was demonstrated at Hanford's Cold Test Facility.

2.3.8.2 WASTE TANK CLOSURE ACCELERATION

P. A. Powell

During 2002, DOE initiated plans to accelerate Hanford tank cleanup and closure. Early in 2002, DOE, the Washington State Department of Ecology, Hanford stakeholders, and CH2M HILL Hanford Group, Inc. began planning how to accelerate the cleanup and closure of the single-shell tanks. At the end of the year, an integrated plan for the cleanup was released in draft form. In addition, a closure plan for the single-shell tank system was submitted to Washington State Department of Ecology for review; the document (RPP-13774) defines the process and integration necessary to achieve accelerated closure of single-shell tanks and tank farms as well as defines the first closure activities to be performed on tank 241-C-106.

A key concept in the accelerated cleanup approach is the use of supplemental technologies to provide treatment capacity beyond that of the Waste Treatment Plant. During 2002, CH2M HILL Hanford Group, Inc. evaluated three supplemental waste treatment technologies

(containerized grout, steam reforming, and bulk vitrification), all intended for use on retrieved tank waste. Containerized grout technology involves mixing waste with a very thick grout formula and allowing the mixture to solidify in a container. Both steam reforming and bulk vitrification would immobilize the waste in an aluminosilicate waste form. CH2M HILL Hanford Group, Inc. also began evaluating a separate disposal path for mixed transuranic tank waste that would include onsite treatment and packaging for shipment to the DOE Waste Isolation Pilot Plant in New Mexico.

2.3.8.3 GEOPHYSICAL LOGGING FOR VADOSE ZONE CHARACTERIZATION AND MONITORING

R. G. McCain, P. D. Henwood, S. M. Sobczyk, A. W. Pearson, and S. E. Kos

Geophysical logging at the Hanford Site is performed under the direction of the DOE Grand Junction Office, using capabilities and experience established for National Uranium Resource Evaluation program. Until 2002, this work was performed by MACTEC-ERS. On July 21, 2002, vadose zone logging and monitoring activities were transferred from MACTEC-ERS to the S. M. Stoller Corporation. Most MACTEC-ERS personnel were retained by the new contractor, and the work continued without interruption. Under the new contract, S. M. Stoller Corporation is responsible for all geophysical logging at the Hanford Site. Logging activities are now integrated across multiple organizations and projects, and consistent procedures and data quality objectives are in use. Logging equipment previously used by other organizations on the site is being transferred to S. M. Stoller Corporation. Plans and procedures are being updated to reflect the transition to the new contractor. In addition, responsibility for day-to-day program management was transferred from the DOE Grand Junction Office to the DOE Richland Operations Office.

S. M. Stoller Corporation performs geophysical logging for both the DOE Richland Operations Office and DOE Office of River Protection. The primary goal of logging activities performed for the DOE Richland Operations Office is characterization of waste sites on the Central

Plateau. For the DOE Office of River Protection, the logging effort involves vadose zone monitoring around the single-shell tanks.

2.3.8.4 MONITORING ACTIVITIES IN THE SINGLE-SHELL TANK FARMS

R. G. McCain, P. D. Henwood, S. M. Sobczyk, A. W. Pearson, and S. E. Kos

The tank farm baseline characterization effort identified subsurface contaminant plumes in the vicinity of the single-shell tank farms. Cobalt-60, cesium-137, europium-152, europium-154, uranium-235, and uranium-238 were the predominant gamma-emitting contaminants. Minor amounts of tin-126 and antimony-125 were also detected. Since specific contaminants have been identified and quantified by the baseline characterization, the primary focus of the monitoring program is to identify changes in contaminant levels between successive log runs.

Specific borehole and depth intervals for monitoring are selected on the basis of intersection with known contaminant plumes, proximity to tanks known to have leaked or to subsurface contaminant plumes, or proximity to tanks containing relatively large volumes of drainable liquid. The logging frequency is determined by the overall priority. Most boreholes of interest will be logged on at least a yearly basis. The goal of the monitoring program is to collect data from all boreholes at least once in a 5-year period.

During 2002, monitoring activities were performed in a total of 385 boreholes, representing ~6,706 meters (~22,000 feet) of logging. The high-priority boreholes in each tank farm were monitored at least once. In addition to routine activities, monitoring was also performed to support tank farm operations or to investigate potential anomalies. Monitoring of boreholes in the vicinity of tank U-107 was performed to support the planned tests for saltcake dissolution.

During 2002, the neutron moisture logging system was used to measure volumetric moisture content in the vadose zone around tank U-107. Experience with the neutron moisture log at Hanford has indicated that it is

useful for identifying changes in soil moisture that may be related to ongoing contaminant migration and for delineating fine-grained beds for stratigraphic correlation.

2.3.8.5 WASTE IMMOBILIZATION

B. Curn

The Waste Treatment Plant is being built on 26 hectares (65 acres) located on the Central Plateau outside of the Hanford 200-East Area to treat radioactive and hazardous waste currently stored in 177 underground tanks. Currently, three major facilities are being constructed: a pretreatment facility, a high-level waste vitrification facility, and a low-activity waste vitrification facility. Supporting facilities are being constructed also. The River Protection Project is currently upgrading tank farm facilities to deliver waste to the Waste Treatment Plant.

During 2002, the contractor began pouring concrete for the Pretreatment Plant, High-Level Waste Vitrification Plant, and the Low-Activity Waste Vitrification Plant. The potable water services and the sewage system for the plant began operating.

2.3.9 SOLID WASTE MANAGEMENT

Solid waste management includes the treatment, storage, and/or disposal of solid waste produced as a result of Hanford Site operations or from offsite sources that are authorized by DOE to ship waste to the site. The following sections contain information regarding specific site locations.

2.3.9.1 CENTRAL WASTE COMPLEX

D. G. Saueressig

Waste is received at the Central Waste Complex in the 200-West Area from sources at the Hanford Site and any offsite sources that are authorized by DOE to ship waste to the Hanford Site for treatment, storage, and disposal. Ongoing cleanup, research, and development activities on the Hanford Site, as well as remediation activities, generate

most of the waste received at the Central Waste Complex. Offsite waste has been primarily from other DOE sites and U.S. Department of Defense facilities. The characteristics of the waste received vary greatly, including low-level, transuranic, or mixed waste, and radioactively contaminated polychlorinated biphenyls.

The Central Waste Complex can store as much as 22,710 cubic meters (801,996 cubic feet) of low-level mixed waste and transuranic waste. This capacity is adequate to store the projected volumes of low-level, transuranic, mixed waste, and radioactively contaminated polychlorinated biphenyls to be generated from the sites identified above, assuming on-schedule treatment of the stored waste. Treatment will reduce the amount of waste in storage and make room for newly generated mixed waste. The dangerous waste designation of each container of waste is established at the point of origin based on process knowledge or sample analysis.

2.3.9.2 WASTE RECEIVING AND PROCESSING FACILITY

H. C. Boynton

Waste destined for the Waste Receiving and Processing Facility includes legacy waste as well as newly generated waste from current site cleanup activities. The waste consists primarily of contaminated cloth, paper, rubber, metal and plastic. Processed waste that qualifies as low-level waste and meets disposal requirements is direct buried onsite. Low-level waste not meeting direct burial requirements is processed in the facility for onsite burial or prepared for future treatment at other onsite or offsite treatment, storage, and disposal facilities. Waste designated at the facility to be transuranic is certified and packaged for shipment to the Waste Isolation Pilot Plant in Carlsbad, New Mexico, for permanent disposal. Other materials requiring further processing to meet disposal criteria are retained, pending treatment.

The Waste Receiving and Processing Facility began operations in 1997 and analyzes, characterizes, and prepares drums and boxes of waste for disposal. The 4,800-square meter (52,000-square foot) facility is located near the Central Waste Complex in the 200-West Area. The facility generated 967 drums and 144 boxes during 2002.

2.3.9.3 RADIOACTIVE MIXED WASTE DISPOSAL FACILITY

L. T. Blackford

The Radioactive Mixed Waste Disposal Facility is located in the 218-W-5 low-level waste burial ground in the 200-West Area and is designated as trenches 31 and 34. Trench 34 began to be used for disposal during September 1999. Currently, there are ~1,450 cubic meters (~51,200 cubic feet) of waste contained in about 883 waste packages in trench 34. No waste is currently stored in trench 31. However, trench 31 will be used for storage, when needed, to accommodate large items awaiting disposal into trench 34. The trenches are rectangular landfills, with approximate base dimensions of 76 by 30 meters (250 by 100 feet). The bottom of the excavations slopes slightly, giving a variable depth of 9 to 12 meters (30 to 40 feet). These trenches comply with RCRA requirements because they have double liners and systems to collect and remove leachate. The bottom and sides of the facilities are covered with a layer of soil 1 meter (3.3 feet) deep to protect the liner system during fill operations. There is a recessed section at the end of each excavation that houses a sump for leachate collection. Access to the bottom of each trench is provided by ramps along the perimeter walls.

2.3.9.4 T PLANT COMPLEX

B. M. Barnes

The T Plant Complex in the 200-West Area provides waste treatment and storage and decontamination services for the Hanford Site. The T Plant Complex currently operates under RCRA interim status. In 2002, the following activities occurred at the T Plant complex:

- Head-space gas sampling was performed on ~70 containers of transuranic waste in support of the Waste Isolation Pilot Plant Project.
- Numerous containers and boxes of waste were re-packaged, treated, sampled, and characterized to meet waste acceptance criteria and land disposal restriction requirements.
- Eight process cells in the 221-T Building were cleaned to support the K Basin sludge storage mission. Four of the cleaned process cells were re-fitted with K Basin sludge storage equipment.
- The EC-1 condenser was shipped to Duratek's facility in Tennessee for recycling.

- Four pressurized Shippingport reactor fuel elements were shipped to the Canister Storage Building. The remaining 44 pressurized Shippingport reactor fuel elements are tentatively scheduled to be shipped to the Canister Storage Building during 2003.
- Approximately 30 containers of material were shipped to the 400 Area Consolidation Center for recycling.
- Equipment was decontaminated for re-use or disposal as waste.

The T Plant Complex Part B Permit was submitted to Washington State Department of Ecology in September 2002 for inclusion in the Hanford Site RCRA Permit. It is presently under review.

The date for T Plant's Tri-Party Agreement Milestone M-91-20 (T Plant readiness to receive canisters of K Basin sludge) was December 31, 2003. The milestone was revised and now has a readiness date of May 28, 2003. Crane upgrades, purge system installation, and the receipt of a second transporter will occur as a result of this milestone change.

2.3.9.5 RADIOACTIVE MIXED WASTE TREATMENT AND DISPOSAL

L. T. Blackford

During 2002, 656 cubic meters (23,163 cubic feet) of mixed low-level waste were treated, recycled, and/or direct disposed:

- 356 cubic meters (12,570 cubic feet) of waste, or ~1,395 drum equivalents (based on a standard 55-gallon drum), were non-thermally treated to RCRA land disposal restriction standards at the Allied Technology Group Corporation Richland, Washington, facility and returned for disposal at the Hanford Radioactive Mixed Waste Disposal Facility.
- 101 cubic meters (3,566 cubic feet), or about 395 drum equivalents of waste, were removed from inventory at the Central Waste Complex after it was determined that it met disposal standards. This waste was direct disposed in the Hanford Site low-level burial grounds.
- 167 cubic meters (5,896 cubic feet) of mixed low-level waste were disposed directly into the Radioactive Mixed Low-Level Waste Facility. This waste came from various Hanford Site operations and either met land disposal restriction standards in the "as generated" state, or were treated according to Treatment-By-Generator provisions

in WAC 173-303-170(3)(b) to treat the waste to meet RCRA and state land disposal restrictions.

- 32 cubic meters (1,130 cubic feet) of waste, specifically a legacy evaporator condenser, was recycled through Duratek's facility in Tennessee. The condenser was shipped to the facility, cut up, and melted; the metal was used to construct shield blocks for other DOE facilities.

2.3.9.6 RADIOACTIVE MIXED WASTE TREATMENT CONTRACTS

L. T. Blackford

In December 2001, Allied Technology Group Corporation, Fluor Hanford, Inc.'s primary contractor for treating mixed low-level waste, filed for Chapter 11 bankruptcy protection. During 2002, Fluor Hanford, Inc. worked with Allied Technology Group Corporation during bankruptcy proceedings to maintain a viable treatment capacity to support Hanford Site needs and assure that this capacity was used to the maximum extent possible.

Fluor Hanford, Inc. was able to work with Allied Technology Group Corporation to complete processing of waste removed from the Central Waste Complex and stored at Allied Technology Group Corporation for non-thermal waste treatment. Additional negotiations were concluded with the trustee, for management of the Allied Technology Group Corporation bankruptcy, and non-thermal waste treatment processing was continued. During 2002, 356 cubic meters (12,570 cubic feet) of waste were treated at the Allied Technology Group Corporation facility and returned for disposal at the Hanford Radioactive Mixed Waste Disposal Facility. Due to bankruptcy proceedings and financial viability, the thermal treatment processing line at the Allied Technology Group Corporation facility did not operate during 2002. Approximately 115 cubic meters (~4,060 cubic feet) of thermally treatable waste removed from the Central Waste Complex during 2001 remain in compliant storage at the Allied Technology Group Corporation facility waiting processing.

Additional thermal treatment options were explored during 2002 using other commercial capabilities. A potential for treating a minor portion of the Hanford waste streams was identified by the PERMA-FIX company and their Thermal Desorption process. A proposal was prepared,

and funding was secured through the DOE Technology Development Program. Contract negotiations with PERMA-FIX were begun during December 2002, with a target date to commence shipment of ~15 cubic meters (~530 cubic feet) of waste during March 2003.

2.3.9.7 NAVY REACTOR COMPARTMENTS

S. G. Arnold

Eight disposal packages containing defueled United States Navy reactor compartments were received and placed in trench 94 in the 200-East Area during 2002. Six were submarine reactor compartments, and two were cruiser reactor compartments. This brings the total number of reactor compartments received to 110. All Navy reactor compartments shipped to the Hanford Site for disposal have originated from decommissioned nuclear-powered submarines or cruisers. Decommissioned submarine reactor compartments are ~10 meters (33 feet) in diameter and 14.3 meters (47 feet) long. They weigh between 908 and 1,362 metric tons (1,000 and 1,500 tons) and are transported on their side. Decommissioned cruiser reactor compartments are ~10 meters (33 feet) in diameter and 12.8 meters (42 feet) high. They weigh ~1,362 metric tons (1,500 tons) and are transported on their end.

2.3.10 LIQUID EFFLUENT TREATMENT

S. S. Lowe

Facilities are operated on the Hanford Site to store, treat, and dispose of various types of liquid effluent generated by site cleanup activities. These facilities are operated and maintained in accordance with state and federal regulations and facility permits.

2.3.10.1 242-A EVAPORATOR

S. S. Lowe

The 242-A evaporator in the 200-East Area concentrates dilute liquid tank waste by evaporation. This reduces the volume of tank waste and eliminates the need to construct additional double-shell tanks. The concentrated tank

waste is returned to the double-shell tanks for storage. The 242-A evaporator completed one campaign during 2002. The volume of waste treated was ~3.9 million liters (~1 million gallons) and the waste volume reduction was ~1.6 million liters (~413,500 gallons) or 41%.

One cold run was completed at the 242-A evaporator during 2002. Cold runs are performed for training purposes to maintain operator proficiency. Water rather than actual tank waste was added to the process vessels and processed.

Effluent treatment and disposal capabilities are available to support the continued operation of the 242-A evaporator. The Effluent Treatment Facility in the 200-East Area (Section 2.3.10.3) was constructed to treat the process condensate from the evaporator and other radioactive liquid waste. The process condensate is sent to the Liquid Effluent Retention Facility for interim storage while awaiting treatment in the Effluent Treatment Facility. Cooling water and non-radioactive steam condensate from the 242-A evaporator are discharged to the 200 Area Treated Effluent Disposal Facility.

2.3.10.2 LIQUID EFFLUENT RETENTION FACILITY

S. S. Lowe

The Liquid Effluent Retention Facility in the 200-East Area consists of three RCRA-compliant surface basins to temporarily store process condensate from the 242-A evaporator and other aqueous waste. The Liquid Effluent Retention Facility provides equalization of the flow and pH of the feed to the Effluent Treatment Facility. Each basin has a maximum capacity of 29.5 million liters (7.8 million gallons). Generally, spare capacity is maintained in the event a leak should develop in an operational basin. Each basin is constructed of two, flexible, high-density polyethylene membrane liners. A system is provided to detect, collect, and remove leachate from between the primary and secondary liners. Beneath the secondary liner is a soil/bentonite clay barrier should the primary and secondary liners fail. Each basin has a floating membrane cover constructed of very low-density polyethylene to keep out unwanted material and to minimize evaporation of the basin contents. The facility began operating in April 1994 and receives liquid waste from

both RCRA- and CERCLA-regulated cleanup activities. The volume of wastewater received for interim storage during 2002 was 100 million liters (26.4 million gallons).

The wastewater received for interim storage during 2002 included 2.9 million liters (766,000 gallons) of RCRA-regulated wastewater (primarily 242-A evaporator process condensate), and 97 million liters (25.7 million gallons) of CERCLA-regulated wastewater (primarily Environmental Restoration Disposal Facility leachate and contaminated groundwater from the 200-UP-1 Operable Unit in the 200-West Area).

The volume of wastewater transferred to the Effluent Treatment Facility for treatment and disposal during 2002 was 83 million liters (22 million gallons).

The volume of wastewater being stored in the Liquid Effluent Retention Facility at the end of 2002 was 44 million liters (11.6 million gallons). This included 2.9 million liters (762,000 gallons) of RCRA-regulated wastewater and 41 million liters (10.9 million gallons) of CERCLA-regulated wastewater.

2.3.10.3 EFFLUENT TREATMENT FACILITY

S. S. Lowe

Liquid effluent is treated in the Effluent Treatment Facility (200-East Area) to remove toxic metals, radionuclides, and ammonia and destroy organic compounds. The treated effluent is stored in verification tanks, sampled and analyzed, and discharged to the State-Approved Land Disposal Site (also known as the 616-A crib). The treatment process constitutes best available technology and includes pH adjustment, filtration, ultraviolet light/peroxide destruction of organic compounds, reverse osmosis to remove dissolved solids, and ion exchange to remove the last traces of contaminants. The facility began operating in December 1995. Treatment capacity of the facility is a maximum of 570 liters (150 gallons) per minute. The volume of wastewater treated and disposed of in 2002 was 83.5 million liters (22 million gallons), which included 5.6 million liters (1.5 million gallons) of RCRA-regulated wastewater (primarily 242-A evaporator process condensate), and 78 million liters (20.6 million gallons) of

CERCLA-regulated wastewater (primarily groundwater from the 200-UP-1 Operable Unit in the 200-West Area).

2.3.10.4 200 AREA TREATED EFFLUENT DISPOSAL FACILITY

S. S. Lowe

The 200 Area Treated Effluent Disposal Facility is a collection and disposal system for non-RCRA-permitted waste streams. The individual waste streams must be treated or otherwise comply with best available technology/all known available and reasonable treatment in accordance with WAC 173-240, which is the responsibility of the generating facilities. The 200 Area Treated Effluent Disposal Facility consists of ~18 kilometers (~11 miles) of buried pipeline connecting three pumping stations, one disposal sample station (6653 Building) and two 2-hectare (5-acre) disposal ponds located east of the 200-East Area. The facility began operating in April 1995 and has a capacity of 12,900 liters (3,400 gallons) per minute. The volume of unregulated effluent disposed of in 2002 was 863 million liters (227.9 million gallons). The major source of this effluent is uncontaminated cooling water and steam condensate from the 242-A evaporator, with a variety of other uncontaminated waste streams received from other Hanford facilities.

2.3.10.5 300 AREA TREATED EFFLUENT DISPOSAL FACILITY

S. S. Lowe

Industrial wastewater generated throughout the Hanford Site is collected and treated in the 300 Area Treated Effluent Disposal Facility. Laboratories, research facilities, office buildings, and former fuel fabrication facilities in the 300 Area are the primary sources of wastewater. The wastewater consists of once-through cooling water, steam condensate, and other industrial wastewater. The facility began operation in December 1994. Wastewater that is potentially contaminated is collected in the nearby 307 Retention Basins where it is monitored and released to the 300 Area process sewer for treatment by the 300 Area Treated Effluent Disposal Facility.

This facility is designed for continuous receipt of wastewater, with a storage capacity of up to 5 days at the design flow rate of 1,100 liters (300 gallons) per minute. The treatment process includes iron co-precipitation to remove heavy metals, ion exchange to remove mercury, and ultraviolet light/hydrogen peroxide oxidation to destroy organics and cyanide. Sludge from the iron co-precipitation process is dewatered and used for backfill in the low-level waste burial grounds. The treated liquid effluent is monitored and discharged through an outfall to the Columbia River under a National Pollutant Discharge Elimination System permit No. WA 002591-7 (Section 2.2.8). The volume of industrial wastewater treated and disposed of during 2002 was 163.7 million liters (43.2 million gallons). The volume of wastewater monitored and released to the 300 Area Treated Effluent Disposal Facility for treatment and disposal from the 307 Retention Basins in 2002 was 5.5 million liters (1.5 million gallons).

2.3.10.6 MISCELLANEOUS STREAMS

J. C. Sonnichsen

In February 1995, the Washington State Department of Ecology approved a *Plan and Schedule for Disposition and Regulatory Compliance for Miscellaneous Streams* (DOE/RL-93-94). This plan and schedule required that

all miscellaneous streams be permitted under WAC 173-216. Categorical permits were used to permit miscellaneous streams with similar characteristics. The permitting process was completed in 1999. All milestones identified in the plan and schedule (DOE/RL-93-94) have been fulfilled, and the annual submittal of the Hanford Site miscellaneous streams inventory report is no longer required.

In January 2000, DOE issued the *Pollution Prevention and Best Management Practices Plan for State Waste Discharge Permits ST 4508, ST 4509, and ST 4510* (DOE/RL-97-67). Preparation of this plan was a requirement of the three waste discharge permits. This plan summarized the compliance requirements in all the categorical permits and set conditions for the individual streams. The plan provides details of remediation activities to prevent further contamination of groundwater. Table 2.3.1 provides a summary of the waste streams addressed in the categorical permits.

In addition to WAC 173-216, the *Plan and Schedule for Disposition and Regulatory Compliance for Miscellaneous Streams* (DOE/RL-93-94) required registration of the underground injection control wells operated on the Hanford Site (WAC 173-218). To comply, a significant and ongoing effort to verify the location and status of all Class V underground injection control wells on the

Table 2.3.1. Permits for Miscellaneous Waste Streams on the Hanford Site

<u>Permit Number</u>	<u>Date Issued</u>	<u>What it Covers</u>	<u>2002 Activities</u>	<u>Status</u>
Permit ST 4508	May 1997	Hydrotesting, maintenance, and construction discharges.	Permit renewal application submitted to Washington State Department of Ecology in 2002 and approved on April 29, 2002.	Existing permit remains in effect until a replacement permit is issued.
Permit ST 4509	May 1998	Cooling water discharges and uncontaminated streams condensate.	Permit renewal application submitted to Washington State Department of Ecology in 2002 and approved on April 29, 2002.	Existing permit remains in effect until a replacement permit is issued.
Permit ST 4510	April 1999	Industrial stormwater discharge	Permit renewal application submitted to Washington State Department of Ecology in 2002 and approved on April 29, 2002.	Existing permit remains in effect until a replacement permit is issued.

Hanford Site began in February 2000. On the Hanford Site, Class V injection wells include the injection of stormwater and other small quantities of uncontaminated wastewater (i.e., condenser condensate). Investigators determined a large number of underground injection control wells were inactive, and they were removed from the list of active wells. In most cases, these injection wells amount to locations where small quantities of non-contaminated wastewater percolate into the soil (i.e., small percolation drains).

Registration of Hanford Site Class V Underground Injection Wells (DOE/RL-88-11) was submitted to the Washington State Department of Ecology in March 2001. During 2002, a request was received from the Washington State Department of Ecology to incorporate this information into their underground injection control database. This request was completed on September 23, 2002. Two additional underground injection control wells were added to this database on October 23, 2002.

2.3.11 REVEGETATION AND MITIGATION PLANNING

A. L. Johnson, J. Meisel, H. Newsome, and M. R. Sackschewsky

The DOE Richland Operations Office and U.S. Fish and Wildlife Service cooperatively worked on a plan to re-vegetate land on the Fitzner/Eberhardt Arid Lands Ecology Reserve to compensate for damage to the environment caused by the original construction of cells 1 and 2 at the Environmental Restoration Disposal Facility.

The Environmental Restoration Disposal Facility mitigation project includes three separate planting elements: a native grass seeding, shrub seedling planting, and native grass plug planting. The native grass seed used in the seeding project was purchased from a local seed producer and derived from local sources. In preparation for planting ~65 hectares (~160 acres) with native grass seed, an application of Roundup™ was aerial applied to the project area in mid-November 2002. Following the herbicide application, in mid-December, 9 kilograms (20 pounds) per acre of a native grass seed mix including Sandberg's bluegrass (*Poa sandbergii*), thickspike wheatgrass (*Agropyron*

dasystachyum), bottlebrush squirreltail (*Sitanion hystrix*), Indian ricegrass (*Oryzopsis hymenoides*), and needle-and-thread grass (*Stipa comata*) were planted. The grass seed was aerial broadcast then harrowed with a tractor drawn implement to increase seed to soil contact. An additional Roundup™ application was applied in mid-February to reduce cheatgrass (*Bromus tectorum*) competition to seeded species.

Approximately 139,000 shrubs were planted across ~125 hectares (~310 acres) during early December 2002. The shrubs planted included 10,300 ~164-cubic-centimeter (~10-cubic-inch) plants, 28,100 65.5-cubic-centimeter (4-cubic-inch) plants, and 93,000 bare root sagebrush (*Artemisia tridentata*) plants; 6,000 green rabbitbrush (*Chrysothamnus viscidiflorus*) plants; and 2,000 gray rabbitbrush (*Chrysothamnus nauseosus*) plants. The bare root plants were dipped in mycorrhizal root gel just prior to planting to provide the plant nutrients required for plant establishment. The shrubs were planted in three separate areas and will be monitored for survival.

Additional Environmental Restoration Disposal Facility mitigation planting is planned for 2003 and 2004. In 2002, grass and shrub seeds were collected from Indian rice grass, needle-and-thread grass, thickspike wheatgrass, antelope bitterbrush (*Purshia tridentata*), and gray and green rabbitbrush and sent to a native plant nursery for propagation into 65.5-cubic-centimeter (4-cubic-inch) plugs that will be planted over an area of ~8.1 hectares (~20 acres) during fall and winter 2003 and 2004.

All of the Environmental Restoration Disposal Facility mitigation planting efforts will be monitored by the river corridor contractor to document the planting success, plant establishment, and shrub survival with the data collections provided in an annual revegetation monitoring report such as BHI-01659.

Monitoring of the new transmission line that was installed to provide electrical power to the vitrification plant revealed that sagebrush and Sandberg's bluegrass were becoming established on nearly all of the tower pads. Both of these species were broadcast seeded in February 2001. Monitoring will continue through 2004.

Monitoring of survival and growth continued for ~90,000 sagebrush seedlings that were planted on about

90 hectares (222 acres) at nine locations on the Fitzner/Eberhardt Arid Lands Ecology Reserve during December 2000. Survival averaged about 55%, with values along individual transects ranging from a low of 3% to a high of 91%. This effort was the last phase of sagebrush transplanting as compensatory mitigation for the disturbance of sagebrush habitat resulting from the development of the site and infrastructure for the planned waste vitrification facility. Monitoring of these plants will continue through 2004.

2.3.12 ENVIRONMENTAL RESTORATION PROJECT

DOE selected an environmental restoration contractor in 1994 to perform environmental restoration projects at the Hanford Site. The Environmental Restoration Project includes characterization and remediation of contaminated soil, decontamination and decommissioning of facilities, surveillance and maintenance of inactive waste sites, and the transition of facilities into the surveillance and maintenance program.

2.3.12.1 ENVIRONMENTAL RESTORATION DISPOSAL FACILITY

M. A. Casbon

The Environmental Restoration Disposal Facility is located near the 200-West Area. The facility began operations during July 1996 and serves as the central disposal site for contaminated waste removed during cleanup operations conducted under CERCLA on the Hanford Site. To provide a barrier to contaminant migration from the facility, the Environmental Restoration Disposal Facility was constructed to RCRA Subtitle C Minimum Technology Requirements including a double liner and leachate collection system. Remediation waste disposed in the facility include soil, rubble, or other solid waste materials contaminated with hazardous, low-level radioactive or mixed (combined hazardous and radioactive) waste.

During 2000, waste was first placed into the first of two new cells (cells 3 and 4) that were constructed in 1999. Later in 2000, an interim cover was placed over portions of cells 1 and 2 that had been filled to their final configuration.

Waste placement in lower levels of cells 3 and 4 was completed during 2002. Waste disposal operations then moved to the partially completed upper level of cell 2. As of the end of 2002, the facility had received over 3.62 million metric tons (3.98 million tons) of contaminated soil and other waste.

2.3.12.2 WASTE SITE REMEDIATION

J. G. April, J. W. Donnelly, A. K. Smet, R. D. Belden, J. A. Lerch, and D. F. Obenauer

Full-scale remediation of waste sites began in the 100 Areas in 1996. Remediation and backfill activities continued through 2002 at several liquid waste disposal sites in the 100-B/C and 100-F Areas. Remediation of the treatment, storage, and disposal units at 100-N Area continued through 2002, and remediation activities were initiated in the 100-K Area. Figure 1.0.1 shows the former reactor areas along the Columbia River.

There were no soil excavation activities at the 100-H Area in 2002. However, from 1996 through 2001, 413,000 metric tons (455,000 tons) of contaminated soil were removed and shipped to the Environmental Restoration Disposal Facility.

Remediation activities were initiated in the 100-K Area during 2002. A total of 4,842 metric tons (5,321 tons) of contaminated soil was removed and disposed of at the Environmental Restoration Disposal Facility.

In 2002, over 137,000 metric tons (151,000 tons) of contaminated soil and 3,100 linear meters (11,800 linear feet) of pipeline in the 100-B/C Area were removed and shipped to the Environmental Restoration Disposal Facility. The cumulative amount of contaminated soil removed and shipped to the facility through December 2002 was 870,000 metric tons (957,000 tons) and 5,200 linear meters (17,100 linear feet) of pipeline.

Remediation in the 100-F Area continued with the removal of 279,000 metric tons (307,000 tons) of contaminated soil in 2002. A total of 749,000 metric tons (824,000 tons) of contaminated soil has been removed from the 100-F Area and disposed of at the Environmental Restoration Disposal Facility.

Remediation continued at the 116-N-3 and the 116-N-1 treatment, storage, and disposal facilities, which are both located within the 100-NR-1 Operable Unit in the 100-N Area. Remediation of these facilities is being completed as required by the Hanford Sitewide RCRA Permit. In 2002, 6,338 metric tons (6,965 tons) of contaminated soil were removed from 116-N-3 and 116,267 metric tons (127,766 tons) of contaminated soil were removed from 116-N-1. The total amount of contaminated soil removed through 2002 from the 100-NR-1 Operable Unit is 259,855 metric tons (285,853 tons), all of which was disposed of at the Environmental Restoration Disposal Facility.

The interim record of decision for the 100 Areas burial grounds, issued September 16, 2000, specified a cleanup remedy to remove/treat/dispose contaminated soil, structures, and debris from the 100 Areas burial ground sites. A 90% design package for the 100-B/C Area burial grounds was completed in 2002 and issued for review.

Remediation work at the 300-FF-1 Operable Unit began in the 300 Area in 1997 (Figure 1.0.1). Historically, both chemical and radiological materials were disposed of at the 300-FF-1 waste sites. During 2002, excavation operations were completed at the 618-4 burial ground. Between excavation operations performed at the site in 1998 and 2002, 510,000 metric tons (560,000 tons) of contaminated material and debris have been transported to Environmental Restoration Disposal Facility. Closure of the 618-4 burial ground is scheduled to be complete in 2003.

An interim action record of decision for the 300-FF-2 Operable Unit (EPA 2001) was issued in 2001. Implementation of the remedy prescribed by the record of decision consists of removal of contaminated soil and debris, treatment as necessary, and disposal at the Environmental Restoration Disposal Facility or other approved facility. Excavation of the 618-5 burial ground began in 2002, with 10,349 metric tons (11,373 tons) of contaminated soil removed and disposed of at the Environmental Restoration Disposal Facility. Excavation operations and site closeout of the 618-5 burial ground are scheduled to be completed in 2003.

2.3.12.3 FACILITY DECOMMISSIONING PROJECT

R. R. Nielson

Decontamination and decommissioning activities continued during 2002 in the 100-D/DR, 100-H, and 100-F Areas. These activities are conducted to support the interim safe storage of the four reactor buildings (D, DR, F, and H) for up to 75 years. Interim safe storage minimizes potential risks to the environment, workers, and the public and reduces surveillance and maintenance costs. These activities are conducted as non-time-critical removal actions under CERCLA.

During 2002, interim safe storage of the DR Reactor was completed. Characterization sampling of the associated 117-DR Exhaust Filter Building was completed in preparation for demolition. This facility is part of the large sodium fire facility, a permitted treatment, storage, and disposal facility undergoing RCRA closure. Demolition activities at the F and D Reactors were completed, and activities to backfill the fuel storage basin areas are in progress.

Demolition work at the H Reactor was initiated during 2002 and progressed through two areas (control room/lunchroom and fuel storage basin areas). A system was installed in the fuel storage basin to remove the remaining water. Wastewater is being shipped to the Effluent Treatment Facility for treatment and disposal. A remote-controlled excavator is being deployed in the fuel storage basin to assist in sample collection and removal of high contamination areas within the remaining 1 meter (3.3 feet) of fill. A small number of spent nuclear fuel elements are expected to be located and will be removed and shipped to the 100-K Area fuel storage basins.

Preparations are also being made to initiate demolition activities at the 118-C-4 horizontal control rod storage cave in the 100-B/C Area and at the 100-N Area ancillary facilities. Engineering documents (e.g., work plan, air monitoring plan, sampling plans, etc.) are being developed in preparation for this work.

2.3.12.4 SURVEILLANCE/ MAINTENANCE AND TRANSITION PROJECT

J. W. Golden

The activities of the Surveillance/Maintenance and Transition Project maintain and watch over inactive facilities and waste sites prior to and following final disposition. Currently, the project performs surveillance and maintenance of the N, B, C, KE, and KW Reactors (excluding the fuel storage basins) and the 308 Building.

2.3.13 GROUNDWATER PROTECTION PROGRAM

R. T. Wilde

DOE established the Groundwater/Vadose Zone Integration Project (Integration Project) in 1997 as its centerpiece for water resources protection for the Hanford Site. On July 1, 2002, the project was transferred from the environmental restoration contractor to Fluor Hanford, Inc. and re-designated the Groundwater Protection Program. Specifically, the Groundwater Protection Program coordinates all projects at Hanford involved in characterizing, monitoring, and remediating groundwater and the vadose zone, with the objective of protecting the Columbia River.

The Groundwater Protection Program team includes staff from Fluor Hanford Inc., CH2M HILL Hanford Group, Inc., and Pacific Northwest National Laboratory, as well as support from other national laboratories and universities. The Hanford Groundwater Monitoring Project is under the umbrella of the Groundwater Protection Program.

During 2002, the Groundwater Protection Program team compiled an array of accomplishments that span its key focus areas – groundwater remediation, soil zone remediation, waste site investigations, assessment of Hanford impact, science and technology, and integration management. The efforts within these focus areas directly supports DOE's plan for the Hanford Site.

2.3.13.1 GROUNDWATER REMEDICATION

L. C. Swanson

The overall objectives of groundwater remediation at sites adjacent to the Hanford Reach are to protect aquatic receptors in the river bottom substrate from contaminants in the groundwater entering the Columbia River, reduce levels of contamination in the areas of highest concentration, prevent further movement of contamination, and protect human health and the environment. Summary descriptions of the groundwater remediation activities are discussed in the following paragraphs.

Chromium. Groundwater contaminated with chromium underlies portions of the 100-D, 100-H, and 100-K Areas (the 100-HR-3 and 100-KR-4 Operable Units). Chromium is of concern because of its potential to affect the Columbia River ecosystem. Low levels of chromium are toxic to aquatic organisms, particularly those that use the riverbed sediment as habitat (DOE/RL-94-102; DOE/RL-94-113). The relevant standard for protection of freshwater aquatic life is 10 µg/L (0.01 ppm) of chromium (WAC 173-201A). Chromium concentrations exceeding 600 µg/L (0.6 ppm) have been measured in the porewater of riverbed sediment adjacent to the 100-D Area (BHI-00778). Background chromium concentrations are usually <1 µg/L (0.001 ppm) in the river.

During 1994, a groundwater extraction system was installed in the 100-D Area to test chromium removal from groundwater using ion exchange technology. Following the record of decision during 1996 (EPA 1996), full-scale pump-and-treat systems were constructed in the 100-D, 100-H, and 100-K Areas. The objective of these systems is to remove hexavalent chromium contamination from the groundwater and, thus, prevent or reduce the movement of chromium to the Columbia River.

During 2002, the total amount of groundwater treated by pump-and-treat systems in the 100-D and 100-H Areas was 350.5 million liters (92.6 million gallons), with the removal of ~32 kilograms (~70.6 pounds) of hexavalent chromium. Since 1997, more than 1.53 billion liters (404.1 million gallons) of groundwater have been treated, with 161 kilograms (354.9 pounds) of chromium removed (DOE/RL-2003-09). Treated groundwater is re-injected

into the aquifer upgradient from the 100-H Area extraction wells. Groundwater from both the 100-D and 100-H Areas is treated in the 100-H Area using separate treatment systems.

During 2002, the 100-KR pump-and-treat system treated 445.7 million liters (117.7 million gallons) of groundwater and removed 35.3 kilograms (77.8 pounds) of chromium. Total chromium removed since operations began in 1997 is 184.1 kilograms (405.9 pounds) through treatment of 1.69 billion liters (446.4 million gallons) of water (DOE/RL-2003-09). Treated groundwater is re-injected into the aquifer upgradient from the 100-KR-4 extraction wells.

In addition to pump-and-treat remediation, in situ redox manipulation technology continues to be demonstrated in the southwestern 100-D Area to address hexavalent chromium contamination in groundwater. This technology immobilizes hexavalent chromium by reducing the soluble, more toxic, chromate ion to highly-insoluble, less toxic, chromic hydroxide or a chromic-ferrous hydroxide complex. This is accomplished by injecting a chemical-reducing agent into closely spaced wells to form a permeable reactive barrier. Following reduction, the reagent and reaction products are pumped out of the wells. Chromium is immobilized as groundwater naturally flows through the barrier. This groundwater cleanup technique was tested during 1997 through 1999 in five injection wells and then expanded to include additional injection wells in 2000, 2001, and 2002. During 2002, the treatment zone was expanded by injecting the chemical reducing agent into 17 new wells.

The loss of reducing conditions in the aquifer at six wells was identified in early 2001. Five of the six wells were originally treated during 1997 or 1998, while the sixth well was originally treated during 2000. The wells were all re-treated in late 2002 to re-establish the reactive barrier.

Chromium concentrations in wells along the barrier axis and west of the northern and southern ends of the barrier are generally low ($<20 \mu\text{g/L}$ [0.02 ppm]), except in three barrier wells where concentrations are as high as $230 \mu\text{g/L}$ (0.23 ppm). A few wells to the west of the central part of the barrier still have high concentrations ranging from 99 to $542 \mu\text{g/L}$ (0.099 to 0.542 ppm).

Barrier construction continued during 2002 and is expected to be completed during 2003. By the end of 2002,

17 additional wells had been constructed and treated, increasing the barrier length to 630 meters (2,067 feet) (DOE/RL-2003-05). The barrier is ~15 meters (~48 feet) wide. The final barrier should be over 680 meters (2,230 feet) long. The barrier will intercept and neutralize chromium-contaminated groundwater moving from the aquifer to the Columbia River. The current pump-and-treat systems will also continue to operate.

Strontium-90. The 100-NR-2 (N Springs) pump-and-treat system began operating during September 1995 north of N Reactor and was designed to reduce the flux of strontium-90 to the Columbia River. The pump-and-treat system operates extraction wells to maintain hydraulic capture. Groundwater is pumped into a treatment system to remove the strontium-90 contamination, and treated water is re-injected upgradient into the aquifer. The system was upgraded during 1996 and has continued to operate through 2002. About 121.7 million liters (32.2 million gallons) were processed during 2002. During that period, 0.20 curies (7.4 gigabecquerels) of strontium were removed from the groundwater. Over 788.2 million liters (208.2 million gallons) of groundwater have been processed since the system began operation, removing 1.3 curies (48 gigabecquerels) of strontium (DOE/RL-2003-09).

Carbon Tetrachloride. The carbon tetrachloride plume in the 200-West Area (originating in the 200-ZP-1 Operable Unit) covers over 11 square kilometers (4.2 square miles). The 200-ZP-1 pump-and-treat system operated as a pilot-scale treatability test from 1994 to 1996, with full operation beginning in 1996. During 2002, 281 million liters (74.3 million gallons) of groundwater were treated, removing over 965.8 kilograms (2,125 pounds) of carbon tetrachloride. A total of 1.95 billion liters (516 million gallons) have been processed since startup, removing 7,049 kilograms (15,540 pounds) of carbon tetrachloride.

Uranium, Technetium-99, Carbon Tetrachloride, and Nitrates. Treatment of the groundwater plume underlying the 200-UP-1 Operable Unit in the 200-West Area continued throughout 2002. The contaminant plume contains uranium, technetium-99, carbon tetrachloride, and nitrate. A pump-and-treat system has operated since 1994 to contain the high concentration area of the uranium and technetium-99 plume. During early operations, groundwater was treated using ion-exchange resin to remove the uranium and technetium-99, and granular

activated carbon to remove carbon tetrachloride. Since 1997, contaminated groundwater has been transferred by pipeline to basin 43 at the 200 Area Effluent Treatment Facility. Sophisticated treatment technology at the Effluent Treatment Facility removes all four contaminants. Treated groundwater is then discharged north of the 200-West Area at the State-Approved Land Disposal Site.

The pump-and-treat system operated continually during 2002, with the two extraction wells pumping 79.1 million liters (20.9 million gallons) of groundwater. Treatment of groundwater removed 14.9 grams (0.0329 pound) of technetium-99, 27.6 kilograms (60.8 pounds) of uranium, 2.7 kilograms (6.0 pounds) of carbon tetrachloride, and 3,665 kilograms (8,080 pounds) of nitrate. The pump-and-treat operation made significant progress toward reducing technetium-99 concentrations to below required cleanup concentration levels, but less progress was made with uranium (DOE/RL-2002-67).

During 2002, technetium-99 concentrations as high as 99,700 pCi/L (3,687 Bq/L) were observed at S-SX Tank Farm well 299-W23-19. In response to this situation and after completing a field evaluation, a technical approach of extensively purging this well (~11,300 liters [3,000 gallons]) during quarterly sampling events was implemented (RPP-10757). Purge water from sampling is disposed of at the Effluent Treatment Facility in the 200-East Area. Further actions will depend on how concentrations change in the future.

2.3.13.2 SOIL ZONE REMEDIATION

V. J. Rohay

Soil-vapor extraction systems designed to remove carbon tetrachloride vapor from the vadose zone beneath the 200-West Area began operating during 1992 and continued through 2002. Soil-vapor extraction has been conducted in the vicinity of three historical carbon tetrachloride disposal sites: the 216-Z-1A tile field, the 216-Z-9 trench, and the 216-Z-18 crib. Extracted soil vapor is pumped through granular activated carbon, which absorbs carbon tetrachloride. The granular activated carbon is then shipped offsite for treatment.

Three soil-vapor extraction systems have operated at three different flow rates: 14.2 cubic meters (500 cubic feet) per minute, 28.3 cubic meters (1,000 cubic feet) per minute, and 42.5 cubic meters (1,500 cubic feet) per minute. However, only the 14.2 cubic meters (500 cubic feet) per minute system operated during 2002; the other two systems were maintained in standby mode. Passive soil-vapor extraction systems, which use atmospheric pressure fluctuations to pump carbon tetrachloride vapor from the vadose zone, were installed at wells near the 216-Z-1A tile field and 216-Z-18 crib during 1999. These passive systems operated throughout 2002. Since operations began, soil-vapor extraction has removed 77,798 kilograms (171,515 pounds) of carbon tetrachloride from the vadose zone.

2.3.13.3 WASTE SITE INVESTIGATIONS — OPERABLE UNITS

L. C. Hulstrom

Remedial investigation/feasibility study activities continued during 2002 at soil waste sites in the 200 Areas. Work was performed within the characterization and regulatory framework defined in the *200 Areas Remedial Investigation/Feasibility Study Implementation Plan* (DOE/RL-98-28). Work was performed at several operable units, which were at various stages of the CERCLA remedial investigation/feasibility study process. During 2002, a series of negotiations were completed with DOE and state and federal regulators that resulted in the consolidation of a number of operable units and generation of a number of new milestones for these operable units. The revised investigation approach allows for evaluation of one or more operable units in a single remedial investigation/feasibility study. This consolidation is reflected in the following summary descriptions of activities that were performed during 2002.

200-CW-1 Operable Unit. The 200-CW-1 Operable Unit consists of former ponds and ditches located within the 200-East Area and north and east of the 200-East Area. These sites received mostly cooling water from facilities such as the Plutonium-Uranium Extraction and B Plants. Preparation of a feasibility study for the operable unit continued. The feasibility study refines remedial

action objectives and remedial technologies originally identified in DOE/RL-98-28 and develops and evaluates remedial alternatives for the representative sites in the 200-CW-1 Operable Unit. The results of the evaluation of the representative sites are applied to the analogous sites in the operable unit as defined in DOE/RL-98-28. The feasibility study includes ecological screening level and baseline risk assessments. In addition to the 200-CW-1 Operable Unit waste sites, the 200-CW-3 Operable Unit and several other 200-North Area waste sites are included in the feasibility study based on negotiations with state and federal regulators on the Central Plateau Tri-Party Agreement milestones. Tri-Party Agreement Milestone M-015-38A requires the feasibility study to be submitted to the state and federal regulators by March 31, 2003. The results of the feasibility study have been summarized in a proposed plan that identifies the preferred remedial alternatives for the waste sites in these operable units. The proposed plan has the same milestone as the feasibility study. The proposed plan will undergo public review.

200-CS-1 Operable Unit. The 200-CS-1 Operable Unit consists of waste sites that received chemical sewer wastewater from major plant facilities in both the 200-West and 200-East Areas. A remedial investigation/feasibility study work plan was approved during 2000 that defines planned remedial investigation activities at four representative waste sites: 216-S-10 pond, 216-S-10 ditch, 216-B-63 trench, and 216-A-29 ditch (DOE/RL-99-44). The work conducted in 2002 included test pit characterization activities at the 216-B-63 trench and the 216-S-10 pond/ditch. The test pit characterization at the 216-A-29 ditch was completed during 2001.

200-CW-2, 200-CW-4, 200-CW-5, and 200-SC-1 Operable Units. This consolidated operable unit grouping consists of waste sites that received cooling water, steam condensate, and chemical sewer waste from facilities in the 200-West Area, including U Plant, powerhouse and laundry facilities, 242-Sevaporator, the Plutonium Finishing Plant and associated facilities, the Reduction-Oxidation Plant, T Plant, the Plutonium-Uranium Extraction Plant, and the Waste Encapsulation and Storage Facility. The 200-CW-5 remedial investigation/feasibility study work plan (DOE/RL-99-66) was approved in 2000 and defined planned remedial investigation activities at one representative waste site (216-Z-11 ditch). This work plan directed

field characterization using driven soil probes and geophysical logging to locate the area with the highest levels of transuranic contamination for subsequent borehole sampling (<http://www2.hanford.gov/ARPIR/common/findpage.cfm?AKey=D8434463>). During 2002, a review was conducted to determine if any additional characterization was required to account for the consolidated operable unit waste sites being added to the work plan. It was concluded that the additional operable unit waste sites aligned with the 200-CW-5 Operable Unit conceptual models, or with conceptual models from other 200 Areas work plans, and that no additional characterization was needed to support the remedial investigation/feasibility study process.

200-LW-1 and 200-LW-2 Operable Units. The waste sites in these operable units received two types of waste: liquid waste resulting from 300 Area process laboratory operations that supported radiochemistry metallurgical experiments and liquid waste resulting mainly from laboratory operations in the 200 Areas that supported the major chemical processing facilities and equipment decontamination from T Plant. A work plan (DOE/RL-2001-66) was approved in 2002. The work plan requires remedial investigation activities at four representative waste sites (216-T-28 crib, 216-B-58 trench, 216-S-20 crib, and 216-Z-7 crib) and includes borehole drilling, soil sampling, and geophysical logging.

200-MW-1 Operable Unit. The waste sites in this operable unit consist mainly of cribs, French drains, and trenches that received moderate- to low-volume equipment decontamination waste and ventilation system waste, plus small-volume waste streams commonly disposed to French drains. A work plan (DOE/RL-2001-65) was approved during 2002. The work plan requires remedial investigation activities at five representative waste sites (216-A-4 crib, 216-T-33 crib, 216-T-13 trench, 216-U-3 French drain, and 200-E-4 French drain). The work includes installing vadose zone boreholes and test pits to collect soil samples and conducting geophysical logging at the boreholes.

200-PW-2 and 200-PW-4 Operable Units. Waste sites in the 200-PW-2 Operable Unit received uranium-rich condensate/process waste, primarily from waste streams generated at U Plant, Reduction-Oxidation Plant, and Plutonium-Uranium Extraction Plant, as well as B Plant

and semi-works facilities. Waste sites in the 200-PW-4 Operable Unit received mostly process drainage, process distillate discharge, and miscellaneous condensates from the same facilities, including condensates from S and A Tank Farms and the 242-A evaporator. The original draft work plan (DOE/RL-2000-60) for 200-PW-2 was prepared and submitted for regulator review in December 2000. The revised work plan now proposes remedial investigation activities at six representative waste sites (216-A-19 trench, 216-B-12 crib, 216-A-10 crib, 216-A-36B crib, 216-A-37-1 crib, and 207-A South Retention Basin). The work includes installing vadose zone boreholes to collect soil samples and conduct geophysical logging. In addition, up to six drive casings will be installed and geophysically logged at the 216-A-10 crib. The geophysical log data will be used to determine the optimum location for the characterization borehole at the 216-A-10 crib.

200-TW-1 and 200-TW-2 Operable Units. The 200-TW-1 Operable Unit consists of waste sites, mostly cribs and trenches, which received waste associated with uranium recovery activities at U Plant. The 200-TW-2 Operable Unit consists of waste sites, mostly cribs and trenches, which received waste from the decontamination processes at B Plant and T Plant. The work plan (DOE/RL-2000-38) was prepared and approved. The work plan proposes remedial investigation at three representative waste sites (216-T-26 crib in the 200-TW-1 Operable Unit, and the 216-B-7A crib and 216-B-38 trench in the 200-TW-2 Operable Unit). The field efforts for these two operable units were completed in 2001 and consisted of installing, soil sampling, and geophysical logging of three vadose zone boreholes (one each at the 216-T-26 crib, the 216-B-38 trench, and the 216-B-7A crib). In addition, five drive casings were installed for geophysically logging at the 216-B-38 trench. The drive casing data were used to determine the optimum location for the borehole at that waste site. Data from the laboratory analyses were compiled into a draft remedial investigation report during 2002, which was provided to reviewers in October. The remedial investigation report (DOE/RL-2002-42) includes a human health risk assessment and screening of ecological impacts. The document will be revised during 2003, following receipt of review comments.

200-PW-1, 200-PW-3, and 200-PW-6 Operable Units.

The 200-PW-1 Operable Unit contains waste sites that received significant quantities of carbon tetrachloride and plutonium, as well as other contaminants associated with process waste from the Plutonium Finishing Plant. This operable unit also includes the carbon tetrachloride plume in the vadose zone that has migrated beyond the boundaries of the waste sites. A remedial investigation/feasibility study for this operable unit was submitted for review during 2001 (DOE/RL-2001-01). The study includes a strategy to reach final decisions for remediation of carbon tetrachloride in the 200-West Area. The study is being revised to include the 200-PW-3 and 200-PW-6 Operable Units. The 200-PW-3 Operable Unit waste sites received organic-rich process waste from separation facilities such as the Reduction-Oxidation Plant, the Plutonium-Uranium Extraction Plant, U Plant, and the C Plant. The 200-PW-6 Operable Unit waste sites received plutonium-rich process waste from the Plutonium Finishing Plant. The revised study is expected to be approved during 2003.

The remedial investigation at the 200-PW-1 Operable Unit is expected to focus on two representative waste sites, the 216-Z-1A tile field and the 216-Z-9 trench, and on other potential sources of carbon tetrachloride contamination. The first step in the carbon tetrachloride vadose zone investigation began during 2002. Soil-vapor sampling and analysis were used to explore the shallow vadose zone in the vicinity of the Plutonium Finishing Plant. The sampling was conducted at engineered structures that had the potential to release carbon tetrachloride to the vadose zone. The engineered structures included liquid waste discharge sites, the pipelines that conveyed liquid waste to those discharge sites, and solid waste burial ground trenches.

200-BP-1 Prototype Barrier. The 200-BP-1 prototype barrier is a surface barrier to reduce the infiltration of water that drives contaminants through the soil to groundwater. Monitoring the performance of the 200-BP-1 prototype barrier continued during 2002. Activities included water balance monitoring, stability surveys, and biotic surveys. A draft report to document the monitoring results was prepared during 2002.

2.3.13.4 WASTE SITE INVESTIGATIONS — VADOSE ZONE CHARACTERIZATION

R. G. McCain, P. D. Henwood, S. M. Sobczyk, A. W. Pearson, and S. E. Kos

Beginning in 2001, the method developed for the vadose zone baseline characterization around the single-shell tanks was extended to liquid waste disposal sites and burial grounds in the 200 Areas. The logging systems previously developed for detection and identification of manmade gamma-emitting radionuclides in the vadose zone are being used to support the work. The Spectral Gamma Logging System uses a detector that is capable of quantifying gamma-emitting radionuclides from background levels to several thousand picocuries per gram. A second system, the high-rate logging system, was specifically developed to measure radionuclide levels up to several hundred million picocuries per gram (cesium-137). These logging systems are collecting data in existing boreholes within and adjacent to waste disposal sites in the 200 Areas.

Approximately 860 existing boreholes have been identified in the Hanford 200 Areas Vadose Zone Characterization Plan (MAC-HGLP 1.7.1). In 2002, the characterization program completed the following:

- Spectral Gamma Logging System logs for 70 existing boreholes.
- Spectral Gamma Logging System logs for nine new boreholes drilled for ongoing remedial investigation projects.
- Spectral Gamma Logging System logs for five RCRA groundwater monitoring wells.
- Spectral Gamma Logging System logs for three boreholes at an intermediate and low-activity waste site.
- High-rate logging system logs for 23 boreholes.

During 2002, Microsoft® Excel workbooks were used for log analysis. The primary advantage of Excel is that the calculations are easily traceable and greater flexibility is provided for dealing with variable borehole conditions. Also, Excel files represent a universal format by which log data can be transmitted to others. The log plots and the log data report are converted to Adobe® Acrobat® (*.PDF) files to facilitate electronic transmittal, allowing log data to be widely distributed via electronic media.

When all available boreholes in a specific area have been logged and evaluated, a waste site summary report is prepared. These reports consolidate information from individual baseline spectral gamma logs, other available borehole logs and drillers' reports, geologic data, sample data, and operational history to summarize vadose zone contamination conditions. Where appropriate, data from the tank farms baseline studies are incorporated, and subsurface visualizations are prepared. During 2002, waste site summary reports were issued for the 216-B-35 to 216-B-42 trenches (GJO-2002-322-TAR) and the 216-B-8 crib and adjacent areas (GJO-2002-343-TAR), and a waste site summary report for the 216-B-5 reverse well and adjacent sites was in progress. Waste site summary reports are issued in paper copy and on CD-ROM. All supporting data are included as appendices on the CD-ROM. All log data, log plots, and reports are accessible at <http://www.gjo.doe.gov/programs/hanf/HTFVZ.html>.

2.3.13.5 ASSESSMENT OF HANFORD IMPACT

R. W. Bryce and C. T. Kincaid

During 1999, DOE initiated the development of an assessment tool that will enable the users to model the movement of contaminants from all waste sites at Hanford through the vadose zone, groundwater, and the Columbia River and estimate the impact of contaminants on human health, ecology, and the local cultures and economy. This tool was named the System Assessment Capability. An assessment was completed during 2002 with the System Assessment Capability that demonstrates that it is a functional assessment capability.

The results of that assessment are presented in *An Initial Assessment of Hanford Impact Performed with the System Assessment Capability* (PNNL-14027). The assessment provided the following information:

- Modeled the movement of contaminants from more than 500 locations throughout the Hanford Site representing 890 waste sites through the vadose zone, groundwater, and the Columbia River.
- Incorporated data on 10 radioactive and chemical contaminants (carbon tetrachloride, cesium-137, chromium, iodine-129, plutonium-239/240, strontium-90, technetium-99, tritium, total uranium, and uranium-238).

- Focused on subsurface transport, the Columbia River, and risks to human and ecological health, the economy, and culture.
- Included the geographic region from Rattlesnake Mountain to the Columbia River and from the Vernita Bridge to McNary Dam on the Columbia River.
- Included the cleanup actions in Hanford's cleanup plans and agreements as of October 2000.
- Consisted of a stochastic simulation for the period 1944 to 3050 using 25 realizations, thus providing an initial look at uncertainty.

The findings of the initial assessment for the Central Plateau sites and associated contaminant plumes parallel those of the composite analysis published during 1998 (PNNL-11800). The results also are consistent with concentrations in environmental media measured by the Environmental Surveillance Program (PNNL-13910) and the Hanford Groundwater Monitoring Project (PNNL-13788). Both the monitoring results and the assessment indicate that Hanford's effect on the Columbia River has peaked and is now declining if the cleanup actions currently planned are carried out. The initial assessment also identified some areas where an improvement to our understanding of the Hanford Site and how it is represented in this capability could improve the quality of our decisions. While the capabilities of System Assessment Capability are confirmed by its ability to simulate the tritium plume, further improvements are needed to better match groundwater plumes for other mobile contaminants including technetium-99, iodine-129, and total uranium. Completion of the initial assessment has provided information needed to design improvements to System Assessment Capability, a revision that will be designed to meet the requirements for the composite analysis, an assessment required by DOE Order 435.1.

While much of the emphasis on waste management at Hanford has been on isolating plutonium, strontium-90, and cesium-137 from the environment, this assessment identifies technetium-99 and uranium as the contaminants from the Central Plateau that will contribute the most to potential impact in the next 1,000 years through the groundwater pathway. The results of the assessment were considered in the development of a groundwater initiative within the *Performance Management Plan for the Accelerated Cleanup of the Hanford Site* (DOE/RL-2002-47).

Locations containing large inventories of these mobile long-lived contaminants are being considered for accelerated action. The remediation of the BC cribs located just south of 200-East Area was identified as an important action for acceleration due to the large inventory of technetium in those facilities and its potential to adversely affect groundwater predicted by the assessment.

The System Assessment Capability represents a holistic examination of the Hanford Site's radioactive and chemical waste legacy. For this reason, it can be used to examine the risk consequences of cleanup alternatives. To illustrate this, the assessment was re-run during 2002 without infiltration-reducing covers on waste sites. This action is not being considered for waste sites and was chosen only as a simple illustration of the capability. A four-fold increase in the amount of technetium-99 released to groundwater was predicted for the no cover case. It also showed that covers have the greatest impact on mobile long-lived radionuclides that did not get released with large volume discharges. This clearly points out the importance of surface barriers and covers that protect groundwater from enhanced infiltration, and provides useful information for cost-effective barrier design.

2.3.13.6 SCIENCE AND TECHNOLOGY

M. D. Freshley

The Groundwater Protection Program's science and technology focus area provides data, tools, and scientific understanding to fill information gaps to make remediation and site closure decisions. The science and technology focus area also provides data to set the stage for long-term monitoring and site stewardship. The following is a description of 2002 accomplishments.

During 2002, the science and technology "roadmap" was updated to include activities for soil and groundwater remediation (PNNL-14092). The roadmap, which is a tool used to manage work, was revised during several workshops involving DOE, Hanford contractors, regulators, stakeholders, and Tribal Nations. This revision of the roadmap aligns work with the Groundwater Protection Program's initiatives to accelerate groundwater remediation and protection.

Soil Inventory. During 2002, the soil inventory model (BHI-01496) was modified and applied. The model was revised to estimate inventories of waste disposed to sites that operated over multiple years. The soil inventory model was used to estimate waste site inventories used in the site-wide assessment, i.e., the System Assessment Capability computer model.

B-BX-BY Tank Farm Investigation. Laboratory and modeling studies were completed for the B-BX-BY Tank Farm. These studies addressed a number of scientific issues associated with the composition of tank waste that has leaked to the vadose zone. The investigations resulted in new information about how strontium-90 and uranium move through the vadose zone and provided geochemical models to predict future behavior of contaminants. Information about the investigations is summarized in an appendix of the B-BX-BY Tank Farm field investigation report (RPP-10098).

Vadose Zone Transport Field Study. The Science and Technology Project completed a field experiment at a clastic dike (a common sedimentary structure in the vadose zone at Hanford) located along Army Loop Road. The clastic dike was used in an infiltration test to evaluate the effects of varying soil properties on water flow and contaminant transport in the vadose zone (PNNL-14109; PNNL-14150).

Biological Fate and Transport. During 2002, the Science and Technology team completed laboratory experiments to determine the uptake of technetium-99 by periphyton, the brown slime on rocks in the Columbia River. Experiments were initiated for strontium-90. The results demonstrate that uptake and elimination of the contaminants are concentration-dependent. The exposure concentrations did not cause a toxicological effect for either trout (completed in 2001) or periphyton.

2.3.13.7 INTEGRATION MANAGEMENT: STRATEGIC PLANNING, PUBLIC INVOLVE- MENT, AND DATABASES

T. W. Fogwell and K. L. Nickola

The Groundwater Protection Program team members have worked closely with DOE and Hanford regulators to

characterize, protect, remediate, and monitor Hanford Site groundwater. Program staff also coordinate and perform scientific research and development to support decision-making activities at Hanford and manage Hanford's modeling and assessment capabilities aimed at cleaning up groundwater.

Strategic Planning. The Groundwater Protection Program developed a master plan of action during 2002. In short, *Hanford's Groundwater Plan: Accelerated Cleanup and Protection* (DOE/RL-2002-68) describes how and when accelerated cleanup work will be accomplished.

Public Involvement. During 2002, open meetings, held the first Monday of every month, gave the public, Tribal Nations, regulators, DOE, and other stakeholders an opportunity to discuss and resolve issues and identify upcoming events. Program staff also provided regular information to the Hanford Advisory Board and its subcommittees and held several information sessions and workshops concerning specific program events and activities. A new website with information about the program's missions, a calendar of upcoming events, and links to a variety of valuable resources was developed during 2002. The website is scheduled to be launched in 2003 at <http://www.hanford.gov/cp/gpp/>.

Databases. The Groundwater Protection Program manages several Hanford environmental databases. The Virtual Library is a database that provides a web-based resource of Hanford environmental data to Hanford staff. Through the use of stand-alone modules, users can retrieve, graph, and generate reports with data contained in the electronic library. During 2002, several additions were made to the Virtual Library, including the addition of two new modules and two "orphaned" modules. One of the new modules contains data for groundwater, soil, soil gas, air, surface water, and miscellaneous material samples captured in the Hanford Environmental Information System (HEIS 1994) database. The other new module contains data from the System Assessment Capability Rev. 0 modeling run, which helps capability developers identify issues that must be addressed in future revisions. "Orphaned" modules housed in the Virtual Library are databases that are no longer maintained by Hanford Site contractors. They contain useful information that would be lost unless given a home. Of the "orphaned" databases added during 2002, one contains data on the volume of

effluent discharged to the soil at disposal sites in the 200-East and 200-West Areas, while the other contains particle size and distribution data for soil on the Hanford Site.

In addition to the Virtual Library, the Groundwater Protection Program manages the Hanford Environmental Information System, the Hanford Well Information System, the Hanford Geographic Information System, and the Waste Information Data System. During 2002, the Hanford Environmental Information System was modified so users could more easily perform statistical analyses, the Hanford Well Information System was re-engineered to provide better quality traceable data, and the Hanford Geographic Information System was expanded to include data associated with more than 100 land survey jobs. During 2002, the Waste Information Data System documented closure of 23 waste sites, and a group of 71 individual releases in the tank farms were merged into 8 consolidated soil sites based on tank farm boundaries. Other databases supporting specific activities within the Groundwater Protection Program were also maintained during 2002, including pump-and-treat project-specific databases and the in situ redox manipulation project-specific database.

2.3.14 HANFORD WASTE TANKS RESEARCH AND TECHNOLOGY DEVELOPMENT

M. A. Showalter

Since 1994, the Tanks Focus Area, created by DOE's Office of Environmental Management, served to integrate radioactive tank waste remediation efforts across the DOE complex, including the development of technology. In September 2002, due to restructuring efforts at DOE, responsibility for the Tanks Focus Area was transferred to the Office of Environmental Management. However, before this transition, the Tanks Focus Area supported the DOE Office of River Protection during 2002 by addressing a number of high priority issues discussed in the following sections.

2.3.14.1 SAFE WASTE STORAGE

Remotely Operated Non-Destructive Examination System. The lower knuckle region of Hanford double-shell tanks (the 0.3-meter [1-foot] radius area where the vertical wall of the tank meets the tank bottom) is considered the area of greatest stress and carries the greatest potential for damage and leakage. This area of concern cannot be reached by conventional inspection techniques. To address the need for an inspection technology with the ability to provide structural integrity data from this critical region, the Remotely Operated Non-Destructive Examination System was developed in 2002. This system uses a slightly adapted off-the-shelf magnetic crawler to transport sound-emitting scanning equipment into the lower knuckle region. The scan data are then analyzed for indications of pitting, wall thinning, and corrosion.

During acceptance testing, the system was evaluated for (1) general system operability, (2) calibration and deployment, (3) flaw detection and sizing, (4) system failure modes and retrievability, and (5) system teardown and setup. The system also performed inspection of a variety of knuckle regions in a large carbon-steel simulated tank. Testing proved the system to be fully operational and paved the way for deployment of the system in tank AW-102 during January 2003.

2.3.14.2 TANK WASTE RETRIEVAL

During its 8 years of operation, the Tanks Focus Area assisted in developing methods to retrieve waste from the Hanford Site's single-shell tanks. During 2002, an independent panel of experts assessed the planning and development activities for retrieval technologies related to three single-shell tanks (tanks S-102, S-112, and C-104). The panel was also asked to review and discuss the rationale of the waste mobilization and transfer, and leak detection, monitoring, and mitigation aspects related to each tank and associated technology. The panel found that the technical and management approaches for each tank and associated technology were sound and likely to lead to successful completion. The panel recommended several technical and management enhancements that, if adopted, may further increase the probability of success regarding the

three tanks and associated technologies commissioned to retrieve waste from single-shell tanks.

Other retrieval technologies investigated by the Tanks Focus Area for the Hanford Site during 2002 are discussed in the following paragraphs.

Sonication. Large, underground storage tanks at the Hanford Site and across the DOE complex contain radioactive waste consisting of liquid and solidified materials (saltcake) that is difficult to mobilize. Conventional retrieval methods involve the use of large volumes of liquids to soften the saltcake; however, these methods may result in waste leaking into the soil. The Tanks Focus Area provided funding to Robotics Crosscutting Program staff from Pacific Northwest National Laboratory and Oak Ridge National Laboratory to identify methods for low-liquid-volume retrieval of waste from potentially leaking single-shell tanks. Sonication, a method using ultrasound, was selected for subsequent testing.

During 2002, Pacific Northwest National Laboratory staff conducted bench-scale testing on various saltcake simulants to evaluate the ability of sonication to fracture and dislodge waste simulants stored in potentially leaking single-shell tanks. Oak Ridge National Laboratory staff investigated the deployment of an array of sonicators using a small mechanical crawler.

Mobile Retrieval System. During 2002, the Tanks Focus Area, the Robotics Crosscutting Program, and CH2MHILL Hanford Group, Inc. began collaborations with industry to develop a mobile retrieval system (a technology that mixes and mobilizes sludge waste) for installation and deployment in tank C-104 (a tank that contains large quantities of high-level radioactive waste sludge). The Tanks Focus Area and Robotics Crosscutting Program organized an independent review of the planned cold testing of the retrieval system. During the review, participants discussed project status, system concept, risk analysis and mitigation, planned factory acceptance tests, future functional and operational cold testing, as well as lessons learned from Oak Ridge National Laboratory experiences. The independent review helped to determine the system's viability and provided recommendations to help reduce the risk of encountering significant field operational problems following deployment. Once the mobile retrieval

system is deployed in tank C-104, it will be the first time that the proposed components will operate in a nuclear waste environment.

Fluidic Retrieval System. The Tanks Focus Area and CH2M HILL Hanford Group, Inc. collaborated with two international partners, AEA Technologies of the United Kingdom and the Mining Chemical Combine of Russia, to design, fabricate, and test somewhat similar fluidic retrieval systems for potential removal of sludge and salt waste from Hanford Site tanks. Following full-scale proof-of-concept testing of the two fluidic retrieval technologies during 2002, both systems are currently awaiting consideration for future use.

Tank S-112 Saltcake Retrieval. An alternative technology for sluicing and retrieving saltcake waste from tank S-112 was investigated in 2002. The system consists of three manual water distribution devices and a central water distribution device located on a riser near the center of the tank. From these devices, water is distributed to the surface of the saltcake. A previously installed pump is used to remove the liquid brine. Each water distribution device contains a solid stream nozzle and a spray nozzle. The solid stream nozzle can deliver a forceful, focused stream at a range of 9 meters (30 feet), and the spray nozzle can project a broader spray pattern at a similar range. The central water distribution device turns at an angle in the tank and also oscillates at a 360-degree rotation using its own water pressure to drive movement. The system was tested in 2002 at the newly constructed Hanford Cold Test Facility. The testing verified that the manual water distribution device and central water distribution device and nozzles performed as specified and in some instances exceeded expectations. However, the vertical plane range of motion of the central water distribution device is being re-evaluated.

2.3.14.3 TANK WASTE PROCESSING

Alternative Treatment for Low-Activity Waste. Plans were developed to demonstrate several alternative treatment options for low-activity liquid waste stored in tanks at Hanford. During a workshop held to identify criteria and quantitative measures to support decision(s) on supplemental treatment technologies to accelerate Hanford tank waste treatment, participants identified six

major goals: (1) provide environmental protection comparable to the current vitrified waste disposal plan, (2) maximize schedule acceleration, (3) maximize cost-effectiveness, (4) assure worker and public safety, (5) maximize operability, and (6) minimize impacts to the overall system. From these goals, the participants determined action items such as developing trial data for each measure and performing test scoring with the identified criteria and measures; using smaller group meetings to discuss the best approach for the operability measure; and determining what information feeds a performance assessment and how that information is used. To achieve the ultimate acceleration goal of immobilizing waste by 2028, immediate identification of criteria and measures was required to help define requirements for industrial procurements and the corresponding scope for technology testing during 2003. Ultimately, this effort was incorporated into the Hanford Performance Management Plan for accelerated cleanup.

Glass Property Models. The tank waste at Hanford will be separated into high-level waste and low-activity waste fractions, which will be separately vitrified in the Waste Treatment Plant. Technical issues related to vitrification of Hanford waste were evaluated in 2002, including the solubility of troublesome components, the influence of secondary phases on glass processing and acceptability of the waste form, and expansion of glass property models for glass volume projections. Hanford Site glass property models were evaluated and updated to reflect recent changes to information about sludge composition and blending strategies. These updates encompassed the revised composition for high-level waste glasses resulting from properties that may limit waste loading, including primarily troublesome component solubilities and liquid temperature. These models generated data that will allow staff to predict the production rate of generated glass based on various processing options. The updated glass property models replace previous glass property predictions for the Hanford Site, which were incomplete and led to large differences in the prediction of high-level waste glass volumes, waste feed delivery requirements, and melter sizing. As a result of this research, a new frit (the fused, or partially fused materials used in making glass) was developed during 2002 that will provide a melt rate 20% faster than previous frits in small-scale melter tests. This frit also has features that allow more waste to be incorporated into the

glass and is expected to yield significantly higher melter throughput, which will help to significantly reduce vitrification costs.

Glass Formulations with Higher Waste Loading.

Waste streams at the Hanford Site contain a variety of chemical compounds, many of which can affect waste loading during vitrification or cause operating difficulties with melt rate, offgas, or equipment corrosion. Previous research has shown that higher melt temperatures may permit higher waste loadings (more than 60%) in the glass for facilitating handling of waste containing high refractory oxides or waste solubility limiting components, such as aluminum, zirconium, chromium, and sulfate. However, before advanced melters can be implemented in DOE radioactive waste treatment facilities, some technical issues need to be addressed, including life of melter materials; the ability to accommodate electrically conductive noble metal fission products; power requirements and control stability; the ability to meet production rate goals with liquid feed; the ability to increase waste loading; offgas emissions treatment; and the ability of the vitrified product to meet disposal requirements.

During 2002, research on advanced melter technologies focused primarily on French and Russian melters using induction cold crucible melter technology (a smaller, less expensive melter that generates much less waste for ultimate disposal). This research was supplemented by evaluating increased waste loading for the standard Joule-heated melter (suitable for a wide range of low-temperature-melting glasses). A specific Hanford waste stream from tanks C-106 and AY-102 was used, representing a blend of tanks to be processed during high-level waste vitrification efforts. As a result, researchers developed glass containing up to 70% waste loading, which meets specific criteria for induction cold crucible melter processing which requires temperatures of ~1250°C to 1350°C (2282°F to 2462°F). In addition, researchers developed glass formulations at higher (50% to 60%) waste loading that can be potentially processed through the Joule-heated melter at 1150°C (2102°F). Based on these results, sites like Hanford and the Savannah River Site may benefit from immobilization using higher temperature glass formulations in advanced melters, enabling DOE to evaluate options for future high-level waste processing that may reduce waste volumes and costs.



2.4 ENVIRONMENTAL OCCURRENCES

B. G. Fritz

Releases of radioactive and regulated materials to the environment are reported to DOE and other federal and state agencies as required by law. The specific agencies notified depend on the type, amount, and location of each event. All emergency, unusual, and off-normal occurrences at the Hanford Site are reported to the Hanford Site Occurrence Notification Center. This center is responsible for maintaining both a computer database and a hardcopy file of past event descriptions and corrective actions. Copies of occurrence reports are made available for public review in DOE's Public Reading Room located in Richland, Washington. The following sections summarize some of the off-normal environmental occurrences that happened during 2002. For each occurrence, the title and report number from the Hanford Site Occurrence Notification Center is given.

2.4.1 EMERGENCY OCCURRENCES

Emergency occurrences are defined in DOE Order 232.1A as "the most serious occurrences and require an increased alert status for onsite personnel and, in specific cases, for offsite authorities." There were no environmentally significant emergency occurrence reports filed during 2002.

2.4.2 UNUSUAL OCCURRENCES

An unusual occurrence is defined by DOE Order 232.1A as "a non-emergency occurrence that exceeds the off-normal occurrence threshold criteria and is related to safety, environment, health, security or operations." There were no environmentally significant unusual occurrence reports filed during 2002.

2.4.3 OFF-NORMAL OCCURRENCES

The DOE order describes off-normal occurrences as "abnormal or unplanned events or conditions that adversely affect, potentially affect, or are indicative of depredation in the safety, safeguards and security, environmental or health protection, performance or operation of a facility." Two off-normal occurrences with environmental impacts not discussed in other sections are discussed here.

- Spread of contamination discovered after high winds (RL-BHI-DND-2002-0002).

On Monday, January 21, 2002, a yellow radioactive-material trash bag was observed near a fence of the F Reactor in the 100-F Area. A radiation control technician removed the bag, and a cursory contamination survey revealed speck contamination and a contaminated tumbleweed near the bag. As a result, a comprehensive survey was performed of the entire F Reactor protected area. This survey revealed 36 spots of contamination that ranged from 20,000 to 380,000 disintegrations per minute per probe area. The spots were all beta-gamma radiation. At the time, excavation of the 105-F Fuel Storage Basin was occurring, and the specks were suspected to have originated from this excavation site. The excavation site was posted as a High Contamination Area. Despite the application of soil fixatives to the excavation area on Saturday, January 19, winds in excess of 15.6 meters per second (35 miles per hour) on Sunday, January 20, are suspected to have resulted in the transport of the contaminated material. The contaminated specks were removed via tape presses. After this occurrence, several measures were taken to minimize future spread of contaminated material. A radiological buffer area around the excavation site was expanded to include the entire area within the site's perimeter fence. Contamination monitoring is now required upon exiting the buffer area. Since the commercial soil fixative failed to adequately stop the spread of contaminated material, additional types of soil fixatives are now being applied to excavation sites.

- Removal of a contaminated water lance at the TX Tank Farm resulted in personnel and soil contamination (RL-CHG-TANKFARM-2002-0053).

On May 5, 2002, ~2 liters (0.5 gallon) of radioactive liquid spilled from the end of a water lance assembly in the TX Tank Farm, located in the 200-West Area. A water lance is a tool that uses a jet of water to remove saltcake and other deposits from waste storage tank walls. The liquid made contact with a worker's left arm, knee, and shoe. The remaining liquid was deposited onto the ground at the worker's feet. The spill area was marked with paint, roped off, and posted 35 minutes after the spill occurred. The

worker was undressed and decontaminated as quickly as possible. The application of a soil fixative helped to immobilize the contamination on the ground. A whole-body count of the worker identified cesium-137 as the main radionuclide in the liquid. The cause of this occurrence was determined to be a leaky O-ring in a joint on the water lance. Liquid seeped through the joint and into the end of the lance while the lance was in the tank. The liquid spilled from the lance when it was removed from the tank. To prevent similar occurrences in the future, the O-ring material will be changed, and the joint will be welded.



2.5 WASTE MANAGEMENT AND CHEMICAL INVENTORIES

L. P. Diediker and D. L. Dyekman

2.5.1 WASTE MANAGEMENT

Waste produced from Hanford Site cleanup operations is classified as either radioactive, non-radioactive, mixed, hazardous, or non-dangerous. Radioactive waste is categorized as transuranic, high-level, and low-level. Mixed waste has both radioactive and hazardous non-radioactive substances. Hazardous waste contains either dangerous waste or extremely hazardous waste or both, as defined in WAC 173-303. Hanford's hazardous waste is managed in accordance with WAC 173-303.

Radioactive and mixed waste are currently handled in several ways. High-level waste is stored in underground single- and double-shell tanks. The method used to manage low-level waste depends on the source, composition, and concentration of the waste. Low-level waste is stored in either a tank system, on storage pads, or is buried. Transuranic waste is stored in vaults or on underground and aboveground storage pads from which it can be retrieved.

Approximately 33 Hanford Site operations (WAC 173-303-040) have the capacity to produce dangerous waste during site cleanup activities. An annual report lists the dangerous waste generated, treated, stored, and disposed of onsite and offsite (DOE/RL-2003-10). Dangerous waste is treated, stored, and prepared for disposal at several Hanford Site facilities. Dangerous waste generated at the site also is shipped offsite for disposal, destruction, or recycling.

Non-dangerous waste generated at the Hanford Site historically has been buried near the 200 Areas Solid Waste Landfill. Beginning in 1999, non-dangerous waste has been disposed of at the Roosevelt Regional landfill near Goldendale, Washington, through a contract with Basin Disposal, Inc. Since 1996, medical waste has been

shipped to Waste Management, of Kennewick, Washington. Asbestos has been shipped to Basin Disposal, Inc. in Pasco, Washington, and the onsite Environmental Restoration Disposal Facility. Since 1996, non-regulated drummed waste has been shipped to Waste Management, of Kennewick, Washington.

Non-dangerous waste originates at a number of areas across the site. Examples include construction debris, office trash, cafeteria waste, and packaging materials. Other materials and items classified as non-dangerous waste are solidified filter backwash and sludge from the treatment of river water, failed and broken equipment and tools, air filters, uncontaminated used gloves and other clothing, and certain chemical precipitates such as oxalates. Non-hazardous demolition waste from 100 Areas decommissioning projects is buried in situ or in designated sites in the 100 Areas.

Annual reports document the quantities and types of radioactive solid waste generated onsite, received, shipped offsite, and disposed of at the Hanford Site (HNF-EP-0125-15). Solid waste program activities are regulated by the *Resource Conservation and Recovery Act* and *Toxic Substances Control Act*, discussed in Section 2.2. Solid waste generated onsite or received from offsite sources and disposed at the Hanford Site from 1997 through 2002 are shown in Tables 2.5.1 and 2.5.2. Quantities of hazardous waste shipped offsite from 1997 through 2002 are shown in Table 2.5.3. Table 2.5.4 provides a detailed summary by radionuclide of the radioactive solid waste stored or disposed during 2002.

The quantities of radioactive and/or mixed liquid waste generated during 2002 and stored in underground storage tanks are included in the annual dangerous waste report (DOE/RL-2003-10). Table 2.5.5 is a summary of the liquid waste generated from 1997 through 2002, which is stored in underground storage tanks.

Table 2.5.1. Quantities of Solid Waste^(a) Generated on the Hanford Site, 1997 through 2002, kg (lb)

<u>Waste Category</u>	<u>1997</u>	<u>1998</u>	<u>1999</u>	<u>2000</u>	<u>2001</u>	<u>2002</u>
Mixed	442,000 (975,000)	509,000 (1,120,000)	421,000 (928,000)	441,000 (973,000)	328,500 (724,300)	1,025,199 (2,260,564)
Radioactive	6,590,000 (14,500,000)	1,470,000 (3,240,000)	957,000 (2,110,000)	700,000 (1,544,000)	1,675,200 (3,693,800)	1,587,719 (3,500,920)

(a) Solid waste includes containerized liquid waste.

Table 2.5.2. Quantities of Solid Waste^(a) Received on the Hanford Site from Offsite Sources, 1997 through 2002, kg (lb)

<u>Waste Category</u>	<u>1997</u>	<u>1998</u>	<u>1999</u>	<u>2000</u>	<u>2001</u>	<u>2002</u>
Mixed	3,560 (7,850)	267 (589)	1,306 (2,880)	1,381 (3,045)	127,000 (280,000)	111,655 (246,199)
Radioactive	1,430,000 (3,150,000)	2,870,000 (6,330,000)	2,325,700 (5,128,000)	6,958,000 (15,343,000)	4,736,500 (10,444,000)	1,517,351 (3,345,759)

(a) Solid waste includes containerized liquid waste. Solid waste quantities do not include United States Navy reactor compartments.

Table 2.5.3. Quantities of Hazardous Waste^(a) Shipped Off the Hanford Site, 1997 through 2002, kg (lb)

<u>Waste Category</u>	<u>1997</u>	<u>1998</u>	<u>1999</u>	<u>2000</u>	<u>2001</u>	<u>2002</u>
Containerized	110,000 (243,000)	65,700 (145,000)	1,732,700 ^(b) (3,820,600)	33,200 ^(b) (73,220)	56,000 ^(b) (124,000)	78,413 ^(b) (172,901)
			70,000 ^(c) (154,000)	315,500 ^(c) (695,700)	2,600 ^(c) (5,800)	3,521 ^(c) (7,764)
Bulk Solids	335,000 (739,000)	47,500 (105,000)	402,300 ^(d) (887,000)	0	0	0
Bulk Liquids	5,025,000 (11,100,000)	41,800 (92,200)	0	0	0	50,649 (111,681)
Total	5,470,000 (12,100,000)	155,000 (342,000)	2,205,000 (4,862,000)	348,700 (768,883)	59,000 (130,000)	132,583 (292,346)

(a) Does not include *Toxic Substances Control Act* waste.

(b) Hazardous waste only.

(c) Mixed waste (radioactive and hazardous).

(d) Includes 399,875 kg (882,000 lb) of material associated with the extraction of carbon tetrachloride from soil.

Table 2.5.4. Radioactive Solid Waste Stored or Disposed of on the Hanford Site, 2002

Constituent^(b)	Quantity, Ci^(a)		
	Low-Level	Low-Level Mixed Waste	Transuranic
Tritium	971	120	0.00137
Carbon-14	0.095	0.004	(c)
Manganese-54	17.9	2.24	0.00529
Iron-55	29,300	197	(c)
Cobalt-60	299	0.0364	0.237
Nickel-63	116,000	0.0102	(c)
Strontium-90	779	10.6	2,930
Yttrium-90	779	10.6	2,930
Technetium-99	0.378	0.0163	0.897
Rhodium-106	0.142	(d)	(d)
Ruthenium-106	0.142	(d)	(d)
Iodine-129	0.0000269	0.00184	0.00216
Cesium-137	624	11.8	9,050
Barium-137m	590	11.1	8,560
Uranium-233	0.00216	0.000125	0.00000000288
Uranium-234	1.33	0.000324	0.0706
Uranium-235	0.0652	0.000232	0.00101
Uranium-236	0.0446	0.00000505	0.0158
Neptunium-237	0.000283	0.0027	0.0378
Uranium-238	2.56	0.0136	0.024
Plutonium-238	0.806	0.00985	644
Plutonium-239	1.63	0.0554	7,790
Plutonium-240	0.827	0.015	1,850
Plutonium-241	44.1	0.488	44,200
Plutonium-242	0.000565	0.0000305	0.332
Americium-241	3.02	0.135	1,220
Cerium-235	(d)	(d)	0.0792
Cerium-244	0.176	0.000682	384
Total	149,000	364	79,600

(a) 1 Ci = 37 GBq.

(b) See Appendix A, Table A.7 for radionuclide half-lives.

(c) Isotope is not typically found in waste type.

(d) Value is quantitatively insignificant relative to other waste types.

2.5.2 CHEMICAL INVENTORIES

Types, quantities, and locations of hazardous chemicals are tracked through prime contractor-specific chemical management system requirements (Section 2.2.3), which include compliance activities associated with the

Emergency Planning and Community Right-To-Know Act (Section 2.2.5). The 2002 Hanford Site Tier Two *Emergency and Hazardous Chemical Inventory* (DOE/RL-2003-07) was issued during March 2003 in compliance with Section 312 of the act. Table 2.5.6 summarizes the information reported, listing the 10 hazardous chemicals stored in greatest quantity on the Hanford Site during 2002.

Table 2.5.5. Quantities of Liquid Waste^(a) Generated and Stored Within the Tank Farm System on the Hanford Site During 2002 and During Each of the Previous 5 Years, L (gal)

Type of Waste	1997^(b,c)	1998^(b,c)	1999^(b,c)	2000^(b)	2001^(b)	2002
Volume of waste added to double-shell tanks	796,000 (210,000)	1,715,000 (453,000)	5,420,000 (1,432,000)	8,920,000 (2,357,000)	2,980,000 (788,000)	9,280,000 (2,452,000)
Total volume in double-shell tanks (year end)	69,245,000 (18,295,000)	70,969,000 (18,750,000)	73,290,000 (19,363,000)	79,630,000 (21,038,000)	79,980,000 (21,131,000)	87,683,000 (23,166,000)
Volume evaporated at 242-A evaporator	3,800,000 (1,004,000)	0	3,097,000 (818,000)	2,580,000 (682,000)	2,580,000 (682,000)	1,565,000 (417,000)
Volume pumped from single-shell tanks ^(d)	244,000 (64,000)	859,000 (227,000)	2,930,000 (774,100)	2,250,000 (595,000)	590,000 (155,000)	5,288,000 (1,397,000)

- (a) Quantity of liquid waste is defined as liquid waste sent to double-shell underground storage tanks during these years. This does not include containerized waste (e.g., barreled) included in the solid waste category.
- (b) Quantity of liquid waste is defined as shown by different categories on left-hand side of table during these years. This does not include containerized waste (e.g., barreled) included in the solid waste category.
- (c) Quantity of liquid waste shown is a corrected figure for these years.
- (d) Volume does not include dilution or flush water.

Table 2.5.6. Average Quantity of Ten Hazardous Chemicals Stored on the Hanford Site, 2002

Hazardous Chemical	Average Quantity, kg (lb)
Mineral oil	1,700,000 (3,800,000)
Sodium	1,000,000 (2,300,000)
Diesel fuel (Grades 1 and 2)	430,000 (960,000)
Ethylene glycol	260,000 (580,000)
Nitrogen	57,000 (130,000)
Propane	50,000 (110,000)
Argon	45,000 (99,000)
Sulfuric acid	37,000 (82,000)
Polychlorinated biphenyls	32,000 (71,000)
Silicon dioxide	26,000 (58,000)



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3.0 FACILITY-RELATED MONITORING

R. W. Hanf

The monitoring of effluent and contaminants at and near Hanford Site facilities is conducted to help determine the effects these materials may have on the public, workers at the site, and the environment. At the Hanford Site, facility effluent monitoring includes collecting and analyzing samples of liquid and airborne effluent to characterize and quantify contaminants released to the environment.

Near-facility environmental monitoring includes routine monitoring of environmental media near facilities that have the potential to discharge or have discharged, stored, or disposed of radioactive or hazardous contaminants. Monitoring locations are generally associated with nuclear-related installations, waste storage and disposal units, and remediation efforts.

Additional program sampling and effluent information is contained in *Hanford Site Near-Facility Environmental Monitoring Data Report for Calendar Year 2001* (PNNL-14295, APP. 2) and in *Environmental Releases for Calendar Year 2002* (HNF-EP-0527-12).

The following sections provide information about facility-related environmental monitoring programs at the Hanford Site, including facility effluent monitoring (Section 3.1) and near-facility environmental monitoring (Section 3.2). Hanford Site environmental surveillance activities are discussed in Chapter 4.



3.1 FACILITY EFFLUENT MONITORING

L. P. Diediker and D. J. Rokkan

Liquid and airborne effluent that may contain radioactive or hazardous constituents is continually monitored when released to the environment at the Hanford Site. Major facilities have their own individual effluent monitoring plans, which are part of the comprehensive Hanford Site environmental monitoring plan (DOE/RL-91-50). Facility personnel perform the monitoring mainly through collecting samples near points of release into the environment and having those samples analyzed for specified constituents. The resulting effluent monitoring data are evaluated to determine the degree of regulatory compliance for each facility and/or the entire site.

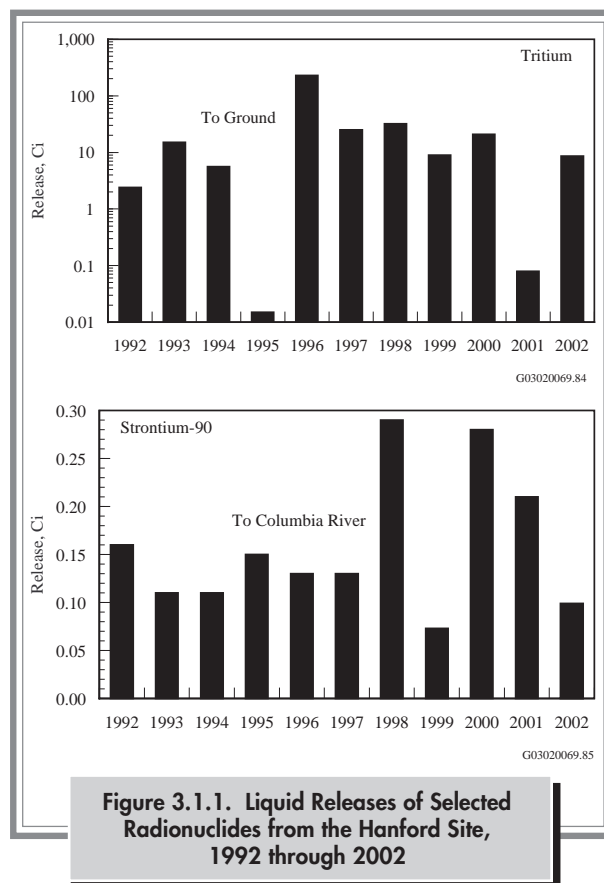
Compliance with all applicable effluent-related regulations and standards was achieved in 2002. The evaluations also demonstrated that the effects of all effluent to members of the public and to the environment were essentially negligible in comparison to effects caused, for example, by naturally occurring radioactive substances universally present in the environment.

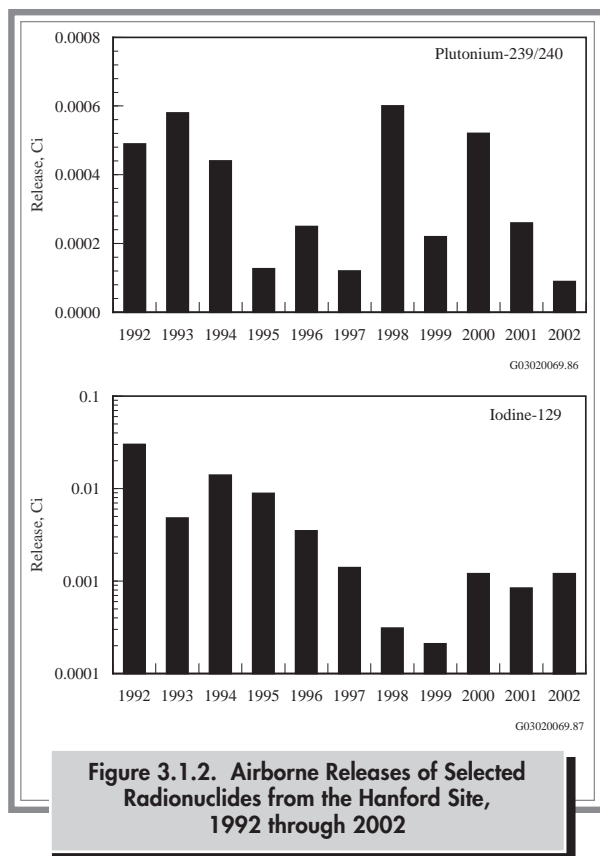
Measuring devices quantify most facility effluent flows, but some flows are calculated using process information. For most radioactive air emission units, which are primarily ventilated stacks, effluent sampling methods include continuous sampling or periodic measurements. For most liquid effluent streams, proportional sampling or grab sampling is used. Liquid and airborne effluent with a potential to contain radioactive materials at prescribed threshold levels is measured for gross alpha and gross beta concentrations, and, as warranted, specific radionuclides. Non-radioactive constituents and parameters are either monitored directly or sampled and analyzed.

Tritium, cobalt-60, strontium-90, iodine-129, cesium-137, plutonium-238, plutonium-239/240, plutonium-241, americium-241, and several other isotopes were released to the environment through state and federally permitted release points. Most of the radionuclides in effluent at the Hanford Site are nearing levels indistinguishable from

the low concentrations of radionuclides in the environment that occur naturally or originated from historical atmospheric nuclear-weapons testing. The site mission of environmental cleanup is largely responsible for the downward trend in radioactive effluent, which results in lower radiological doses to the maximally exposed member of the public. Figures 3.1.1 and 3.1.2 depict quantities of several longer-lived radionuclides released from the site over the past 11 years.

Effluent release data are documented in several reports besides this one, and all are available to the public. For instance, the U.S. Department of Energy (DOE) annually submits to the U.S. Environmental Protection Agency (EPA) and the Washington State Department of Health a





report of radioactive airborne emissions from the site (DOE/RL-2003-21), in compliance with Title 40, Code of Federal Regulations, Part 61 (40CFR 61) and Washington Administrative Code (WAC) 246-247. Data quantifying radioactive liquid and airborne effluent are reported to DOE annually in an environmental releases report (HNF-EP-0527-12). That report includes summaries of monitoring results about liquid effluent discharged to the Columbia River, which is regulated by the National Pollutant Discharge Elimination System permit and reported quarterly to the EPA; liquid effluent discharged to the soil, which is regulated by WAC 173-216 and reported quarterly to the Washington State Department of Ecology; and non-radioactive air emissions, which are also reported annually to the Washington State Department of Ecology.

3.1.1 RADIOACTIVE AIRBORNE EMISSIONS

Radioactive airborne emissions from Hanford Site activities contain particulate and volatile forms of radionuclides.

Emissions having the potential to exceed 1% of the 10 mrem (100 mSv) per year standard for public dose are monitored continuously.

The continuous monitoring of radioactive emissions involves analyzing samples collected at points of discharge to the environment, usually from a stack or vent. Samples are analyzed for gross alpha and gross beta, as well as selected radionuclides. The selection of the specific radionuclides sampled, analyzed, and reported is based on (1) an evaluation of maximum potential of unmitigated emissions hypothetically expected from known radionuclide inventories in a facility or outside activity area, (2) the sampling criteria given in contractor environmental compliance manuals, and (3) the potential each radionuclide has to contribute to the public dose. Continuous air monitoring systems with alarms are also used at selected emission points when the potential exists for radioactive emissions to exceed normal operating ranges by levels requiring immediate personnel alert.

Radioactive emission discharge points, which generally are actively ventilated stacks, are located in the 100, 200, 300, 400, and 600 Areas. The principal sources for those emissions are summarized in the following list:

- In the 100 Areas, emissions originated from normal evaporation at two water-filled storage basins (100-K East and 100-K West Fuel Storage Basins [K Basins], which contain irradiated nuclear fuel), the Cold Vacuum Drying Facility, the 105-KW Integrated Water Treatment filter backwash system, and a low-level radiological laboratory in the 1706-KE Building. During 2002, there were five radioactive emission points in the 100 Areas.
- In the 200 Areas, the primary sources of radionuclide emissions were the Plutonium Finishing Plant, T Plant, Waste Encapsulation and Storage Facility, underground tanks storing high-level radioactive waste, waste evaporators, and the inactive Plutonium-Uranium Extraction Plant. During 2002, there were 60 radioactive emission points in the 200 Areas.
- The 300 Area primarily has laboratories and research facilities. Primary sources of airborne radionuclide emissions were the 324 Waste Technology Engineering Laboratory, the 325 Applied Chemistry Laboratory, the 327 Post-Irradiation Laboratory, and the 340 Complex Vault and Tanks. During 2002, there were 24 radioactive emission discharge points in the 300 Area.

- The 400 Area has the shutdown Fast Flux Test Facility, the Maintenance and Storage Facility, and the Fuels and Materials Examination Facility. Operations and support activities at the Fast Flux Test Facility and Maintenance and Storage Facility released small quantities of radioactive material to the environment. During 2002, there were five radioactive emission points in the 400 Area.
- The 600 Area has the Waste Sampling and Characterization Facility, at which low-level radiological and chemical analyses are performed on various types of samples (e.g., particulate air filters, liquids, soil, and vegetation). This facility had two radioactive emission points during 2002. For dose-modeling purposes, emissions from the Waste Sampling and Characterization Facility, which is very close

to the eastern entrance to the 200-West Area, were grouped with emissions reported for the 200-West Area.

A summary of the Hanford Site radioactive airborne emissions in 2002 is provided in Table 3.1.1.

3.1.2 NON-RADIOACTIVE AIRBORNE EMISSIONS

Non-radioactive air pollutants emitted from power-generating and chemical processing facilities are monitored when activities at a facility are known to generate potential pollutants of concern.

Table 3.1.1. Radionuclides Discharged to the Atmosphere at the Hanford Site, 2002

Radionuclide	Half-Life	Release, Ci ^(a)					
		100 Areas	200-East Area	200-West Area ^(b)	300 Area	400 Area	Site Total
Tritium (as HT) ^(c)	12.3 yr	NM ^(d)	NM	NM	28	NM	28
Tritium (as HTO) ^(c)	12.3 yr	NM	NM	NM	88	0.019	88
Cobalt-60	5.3 yr	ND ^(e)	ND	9.3 x 10 ⁻¹⁰	ND	NM	9.3 x 10 ⁻¹⁰
Krypton-85	10.8 yr	NM	NM	NM	0.0020	NM	0.0020
Strontium-90	29.1 yr	1.2 x 10 ^{-5(f)}	0.00016 ^(f)	2.8 x 10 ^{-5(f)}	9.5 x 10 ^{-6(f)}	NM	0.00021 ^(f)
Technetium-99	213,000 yr	NM	NM	NM	ND	NM	ND
Ruthenium-106	373 d	ND	ND	2.8 x 10 ⁻⁶	ND	NM	2.8 x 10 ⁻⁶
Antimony-125	2.77 yr	ND	9.1 x 10 ⁻¹⁰	ND	ND	NM	9.1 x 10 ⁻¹⁰
Iodine-129	16,000,000 yr	NM	0.0012	NM	NM	NM	0.0012
Cesium-137	30 yr	2.2 x 10 ⁻⁵	6.2 x 10 ⁻⁵	1.1 x 10 ⁻⁵	5.4 x 10 ⁻⁷	4.9 x 10 ^{-6(g)}	0.00010 ^(g)
Europium-152	13.5 yr	ND	ND	4.7 x 10 ⁻⁸	ND	NM	4.7 x 10 ⁻⁸
Europium-155	4.8 yr	ND	1.7 x 10 ⁻⁷	ND	ND	NM	1.7 x 10 ⁻⁷
Radon-220	55.6 s	NM	NM	NM	0.50	NM	0.50
Uranium-234	240,000 yr	NM	NM	NM	1.9 x 10 ⁻¹⁰	NM	1.9 x 10 ⁻¹⁰
Uranium-235	704,000,000 yr	NM	NM	NM	5.3 x 10 ⁻¹¹	NM	5.3 x 10 ⁻¹¹
Neptunium-237	NM	NM	NM	NM	2.5 x 10 ⁻⁸	NM	2.5 x 10 ⁻⁸
Uranium-238	4,500,000,000 yr	NM	NM	NM	7.1 x 10 ⁻¹¹	NM	7.1 x 10 ⁻¹¹
Plutonium-238	87.7 yr	2.9 x 10 ⁻⁷	ND	1.5 x 10 ⁻⁶	9.9 x 10 ⁻¹⁰	NM	1.8 x 10 ⁻⁸
Plutonium-239/240	24,000 yr	2.1 x 10 ^{-6(h)}	1.4 x 10 ^{-6(h)}	8.6 x 10 ^{-5(h)}	7.1 x 10 ^{-7(h)}	2.7 x 10 ^{-7(h)}	9.0 x 10 ^{-5(h)}
Plutonium-241	14.4 yr	2.5 x 10 ⁻⁵	8.8 x 10 ⁻⁷	8.4 x 10 ⁻⁵	ND	NM	1.1 x 10 ⁻⁴
Americium-241	432 yr	1.5 x 10 ⁻⁶	1.3 x 10 ⁻⁶	1.5 x 10 ⁻⁵	2.8 x 10 ⁻⁸	NM	1.8 x 10 ⁻⁵
Americium-243	7,380 yr	NM	NM	NM	ND	NM	ND

(a) 1 Ci = 3.7 x 10¹⁰ becquerels.

(b) Emissions from the Waste Sampling and Characterization Facility in the 600 Area are included in these numbers.

(c) HT = Elemental tritium; HTO = tritiated water vapor.

(d) NM = Not measured.

(e) ND = Not detected (i.e., either the radionuclide was not detected in any sample during the year or the average of all the measurements for that given radionuclide or type of radioactivity made during the year was below background levels).

(f) This value includes gross beta release data. Gross beta and unspecified beta results were assumed to be strontium-90 in dose calculations.

(g) This value includes gross beta release data. Gross beta results were assumed to be cesium-137 in dose calculations.

(h) This value includes gross alpha release data. Gross alpha and unspecified alpha results were assumed to be plutonium-239/240 for dose calculations.

In past years, gaseous ammonia has been emitted from the Plutonium-Uranium Extraction Plant, 242-A evaporator, AP Tank Farm, and AW Tank Farm, all located in the 200-East Area. Ammonia emissions are tracked only when activities at these facilities are capable of generating them. During 2002, the 200 Areas tank farms produced reportable ammonia emissions, summarized in Table 3.1.2.

Onsite diesel-powered electrical generating plants emitted particulate matter, sulfur oxides, nitrogen oxides, volatile organic compounds, carbon monoxide, and lead. The total annual releases of these constituents are reported in accordance with the air quality standards established in WAC 173-400. Power plant emissions are calculated from the quantities of fossil fuel consumed, using EPA-approved formulas (AP-42).

Should activities result in chemical emissions in excess of quantities reportable under the *Comprehensive Environmental Response, Compensation, and Liability Act*

(CERCLA), the release totals are immediately reported to EPA. If the emissions remain stable at predicted levels, they may be reported annually with EPA's permission. Table 3.1.2 summarizes the emissions of non-radioactive pollutants discharged to the atmosphere at Hanford during 2002 (Note: the 100, 400, and 600 Areas have no non-radioactive emission sources of regulatory concern). Table 3.1.2 also includes emission estimates from the carbon tetrachloride vapor extraction work in the 200-West Area. Those emissions are accounted for in the table category of "other toxic air pollutants" and do not require reporting, because they are below the respective reportable quantity.

3.1.3 RADIOACTIVE LIQUID EFFLUENT

Liquid effluent is discharged from facilities at the Hanford Site. Effluent that normally or potentially contains radionuclides includes cooling water, steam condensates, process condensates, and wastewater from laboratories and chemical sewers. Those wastewater streams are sampled and analyzed for gross alpha and gross beta, as well as selected radionuclides.

During 2002, only facilities in the 200 Areas discharged radioactive liquid effluent to the ground, which went to a single location, the 616-A crib, also known as the State-Approved Land Disposal Site. A summary of radioactive liquid effluent is provided in Table 3.1.3. Table 3.1.4 summarizes data on radionuclides in liquid effluent released from the 100 Areas to the Columbia River, the sources of which include secondary cooling water used at the K Basins and shoreline seepage of groundwater that has passed near the retired 116-N-1 and 116-N-3 cribs in the 100-N Area.

Table 3.1.2. Non-Radioactive Pollutants Discharged to the Atmosphere at the Hanford Site, 2002

Constituent	Release, kg (lb)	
	200 Areas	300 Area
Particulate matter	750 (1,700)	640 (1,400)
Nitrogen oxides	9,200 (20,000)	3,500 (7,700)
Sulfur oxides	2,600 (5,700)	37 (82)
Carbon monoxide	17,000 (37,400)	11,000 (24,000)
Lead	0.45 (0.99)	0
Volatile organic compounds ^(a,b)	5,800 (13,000)	720 (1,600)
Ammonia ^(c)	12,000 (26,000)	NE ^(d)
Other toxic air pollutants ^(e)	2,600 (5,700)	NE

(a) The estimate of volatile organic compounds does not include emissions from laboratory operations.

(b) Produced from burning fossil fuel for steam and electrical generators, calculated estimates from the 200-East and 200-West Areas tank farms, and operation of the 242-A evaporator and the Effluent Treatment Facility (200-East Area).

(c) Ammonia releases are calculated estimates from the 200-East and 200-West Areas tank farms and operation of the 242-A evaporator and the Effluent Treatment Facility (200-East Area).

(d) NE = No emissions reported.

(e) Releases are a composite of calculated estimates of toxic air pollutants, excluding ammonia, from the 200-East and 200-West Areas tank farms and operation of the 242-A evaporator and the Effluent Treatment Facility (200-East Area).

Table 3.1.3. Radionuclides in 200 Areas Liquid Effluent Discharged to the State-Approved Land Disposal Site at the Hanford Site, 2002

<u>Radionuclide</u>	<u>Half-Life</u>	<u>Release, Ci^(a)</u>
Tritium	12.3 yr	8.6

(a) 1 Ci = 3.7×10^{10} becquerels.

3.1.4 NON-RADIOACTIVE HAZARDOUS MATERIALS IN LIQUID EFFLUENT

Non-radioactive hazardous materials in liquid effluent are monitored in the 100, 200, 300, and 400 Areas. The effluent is discharged to the State-Approved Land Disposal Site and to the Columbia River. Effluent entering the environment at designated discharge points is sampled and analyzed to determine compliance with the National Pollutant Discharge Elimination System permits and the state waste discharge permits for the site (40 CFR 122 and WAC 173-216). Should chemicals in liquid effluent exceed quantities reportable under CERCLA, the release totals are immediately reported to EPA. If effluent remains stable at predicted levels, they may, with EPA's permission, be reported annually. Section 2.2.8 provides a synopsis of the National Pollutant Discharge Elimination System and state waste discharge permit.

3.1.5 CERCLA AND WASHINGTON ADMINISTRATIVE CODE RELEASES TO THE ENVIRONMENT

Releases that are reportable to the state and/or EPA include spills or discharges of hazardous substances or

Table 3.1.4. Radionuclides in Liquid Effluent from the Hanford Site's 100 Areas Discharged to the Columbia River, 2002

<u>Radionuclide</u>	<u>Half-Life</u>	<u>Release, Ci^(a)</u>
Tritium	12.3 yr	0.013
Strontium-90	29.1 yr	0.099
Plutonium-239/240	24,000 yr	0.000011
Americium-241	432 yr	0.000023

(a) 1 Ci = 3.7×10^{10} becquerels.

dangerous waste to the environment, other than releases permitted under state or federal law. Accidents and equipment failures cause the majority of those types of releases. Releases of hazardous substances that are continuous and stable in quantity and rate but exceed specified limits must be reported as required by Section 103(f)(2) of CERCLA.

Reporting of spills or non-permitted discharges of dangerous waste or hazardous substances to the environment is required (WAC 173-303-145). That requirement applies to spills or discharges onto the ground, into the groundwater, into the surface water (e.g., Columbia River), or into the air such that human health or the environment is threatened, regardless of the quantity of dangerous waste or hazardous substance.

In accordance with both CERCLA and Washington Administrative Code (WAC 173-303-145) reporting requirements, no known CERCLA-reportable nor Washington Administrative Code-reportable releases occurred during 2002.



3.2 NEAR-FACILITY ENVIRONMENTAL MONITORING

C. J. Perkins, B. M. Markes, S. M. McKinney, and R. M. Mitchell

Near-facility environmental monitoring is conducted near facilities that have the potential to discharge, or have discharged, stored, or disposed of radioactive or hazardous contaminants. Monitoring locations are associated with nuclear facilities such as the Plutonium Finishing Plant, Canister Storage Building, and the 100-K Fuel Storage Basins; inactive nuclear facilities such as N Reactor and the Plutonium-Uranium Extraction Plant; and active and inactive waste storage or disposal facilities such as burial grounds, cribs, ditches, ponds, underground waste storage tanks, and trenches.

Much of the monitoring program consists of collecting and analyzing environmental samples and conducting radiological surveys in areas near facilities. The program also is designed to evaluate and report analytical data, determine the effectiveness of facility effluent monitoring and controls, measure the adequacy of containment at waste disposal sites, and detect and monitor unusual conditions. The program implements applicable portions of DOE Orders 435.1, 450.1 (replaced 5400.1 in January 2003), 5400.5, and 5484.1; 10 CFR 835 and 40 CFR 61; and WAC 246-247.

Near Hanford Site facilities, several types of environmental media are sampled, and various radiological and non-radiological measurements are taken. The samples and measurements taken include air, spring water, surface contamination, soil, vegetation, and external radiation fields. Samples are collected from known or expected effluent pathways, which are generally downwind of potential or actual airborne releases and downgradient of liquid discharges.

Active and inactive waste disposal sites and the terrain surrounding them are surveyed to detect and characterize radioactive surface contamination. Routine radiological survey locations include former waste disposal cribs and

trenches, retention basin perimeters, ditch banks, solid waste disposal sites (e.g., burial grounds), unplanned release sites, tank farm perimeters, stabilized waste disposal sites, roads, and firebreaks in and around the site operational areas.

Sampling and analysis results from monitoring during 2002 are summarized in the following sections. Additional data may be found in *Hanford Site Near-Facility Environmental Monitoring Data Report for Calendar Year 2002* (PNNL-14295, APP. 2). The type and general locations of samples collected for near-facility monitoring during 2002 are summarized in Table 3.2.1.

3.2.1 AIR MONITORING

During 2002, routine monitoring for radioactivity in air near Hanford Site facilities used a network of continuously operating samplers at 82 locations (Table 3.2.2) (sampling locations illustrated in PNNL-14295, APP. 2). Air samplers were located primarily at or within ~500 meters (~1,500 feet) of sites and/or facilities having the potential for, or history of, environmental releases and were predominantly located in the prevailing downwind direction. To avoid duplication of sampling, air data for the 300 and 400 Areas, some onsite remediation projects, and some offsite distant locations were obtained from Pacific Northwest National Laboratory.

Samples were collected according to a schedule established before the 2002 monitoring year. Airborne particles were sampled at each sampling location by drawing air through a glass-fiber filter. The filters were collected biweekly, field surveyed for gross radioactivity, held for at least 7 days, and then analyzed for gross alpha and beta activity. The 7-day holding period was necessary to allow for the decay of naturally occurring, short-lived radionuclides that would otherwise obscure detection of longer-lived

Table 3.2.1. Hanford Site Near-Facility Routine Environmental Monitoring Samples and Locations, 2002

Sample Type	Number of Sampling Locations	Operational Area							200/	300/
		100-B/C	100-D/DR	100-K	100-F	100-H	100-N	ERDF ^(a)	600	400
Air	82	5	4	11	6	2	5	3	41 ^(b)	5
Water	11	0	0	0	0	0	11	0	0	0
Soil	82	3	0	2	2	0	5	1	56	13
Vegetation	63	0	0	0	0	0	4	0	46	13
External radiation	135	5	0	20	5	0	14	3	67	21

(a) Environmental Restoration Disposal Facility in the 200-West Area.

(b) Includes 1 station at the Wye Barricade, 19 in the 200-East Area, and 21 in the 200-West Area.

radionuclides associated with emissions from nuclear facilities. The gross radioactivity measurements were used to indicate changes in trends in the near-facility environment.

For most specific radionuclide analyses, the amount of radioactive material collected on a single filter during a 2-week period was too small to be measured accurately. To increase the accuracy of the analysis, the samples were combined into either quarterly or semiannual composite samples for each location.

Figure 3.2.1 shows the average concentrations of selected radionuclides in the 100 and 200/600 Areas compared to DOE derived concentration guides and air concentrations measured in distant communities. The DOE derived concentration guides (DOE Order 5400.5) are reference values that are used as indexes of performance. The data indicate a large degree of variability. Air samples collected from areas located at or directly adjacent to Hanford Site facilities had higher concentrations than did those samples collected farther away. In general, analytical results for most radionuclides were at or near Hanford Site background levels, which is much less than DOE derived concentration guides but greater than those measured off the site. The data also show that concentrations of certain radionuclides were higher within different operational areas. Table 3.2.3 shows the annual average and maximum concentrations of radionuclides in near-facility air samples during 2002. A complete listing of the 2002 near-facility ambient air monitoring results can be found in PNNL-14295, APP. 2. Results for selected Pacific Northwest National Laboratory

air samples are also reported in PNNL-14295, APP. 2, as well as in Section 4.1.

At the 100-B/C Area, ambient air monitoring was conducted at five locations in 2002. Two of these locations were added in August 2002 to monitor additional cleanup activities. The radionuclides uranium-234 and uranium-238 were consistently detected. Strontium-90 was detected occasionally during 2002.

During 2002, air monitoring continued at one location at the 105-D interim safe storage site and at two locations at the 105-H interim safe storage site. Strontium-90, uranium-234, uranium-238, and plutonium-239/240 were consistently detected at all three locations. At the 105-D location, the results for strontium, uranium-234, and plutonium-239/240 were the highest measured on the Hanford Site in 2002. At the 105-H locations, air sampling results were at or near detection limits, similar to previous years.

During 2002, two samplers operated at each of the 105-DR and 105-F interim safe storage sites and, during November 2002, at one new location at the 117-DR Exhaust Filter Building decommissioning project. The quarterly analytical results from these air samples were generally similar to the results seen over the past 4 years.

At the 100-F Area remedial action site, ambient air monitoring continued at four locations during 2002. Uranium-234, uranium-238, and strontium-90 were detected consistently; plutonium-239/240 was detected occasionally.

Table 3.2.2. Hanford Site Near-Facility Air Sampling Locations and Analyses, 2002

Site	Number of Samplers	EDP Code^(a)	Analyses	
			Biweekly	Composite^(b)
100-B/C remedial action project	5	N464, N465, N466, N496, N497	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
105-D interim safe storage project	1	N523	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
105-DR interim safe storage project	2	N492, N493	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
117-DR interim safe storage project	1	N515	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
105-F interim safe storage project	2	N494, N495	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
105-F remedial action project	4	N519, N520, N521, N522	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
105-H interim safe storage project	2	N524, N525	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
100-K spent nuclear fuels	8	N401, N402, N403, N404, N476, N477, N478, N479	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso, Pu-241, Am-241
100-KR-1 remedial action project	3	N528, N529, N530	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
100-NR-1 remedial action and 100-N surveillance, maintenance/transition projects	5	N102, N103, N105, N106, N526	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
200-East Area	17	N019, N158, N498, N499, N957, N967, N968, N969, N970, N972, N973, N976, N977, N978, N984, N985, N999	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
Canister Storage Building, 200-East Area	2	N480, N481	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso, Pu-241, Am-241
200-West Area	21	N155, N161, N165, N168, N200, N304, N433, N441, N442, N449, N456, N457, N956, N963, N964, N965, N966, N974, N975, N987, N994	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
300-FF-1 and 300-FF-2 remedial action project	5	N130, N485, N486, N487, N527	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
Environmental Restoration Disposal Facility	3	N482, N517, N518	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
600 Area	1	N981	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso

(a) EDP Code = Sampler location code. See PNNL-14295, APP. 2.

(b) GEA = Gamma energy analysis; Pu-iso = isotopic plutonium-238 and plutonium-239/240; U-iso = isotopic uranium-234, uranium-235, and uranium-238.

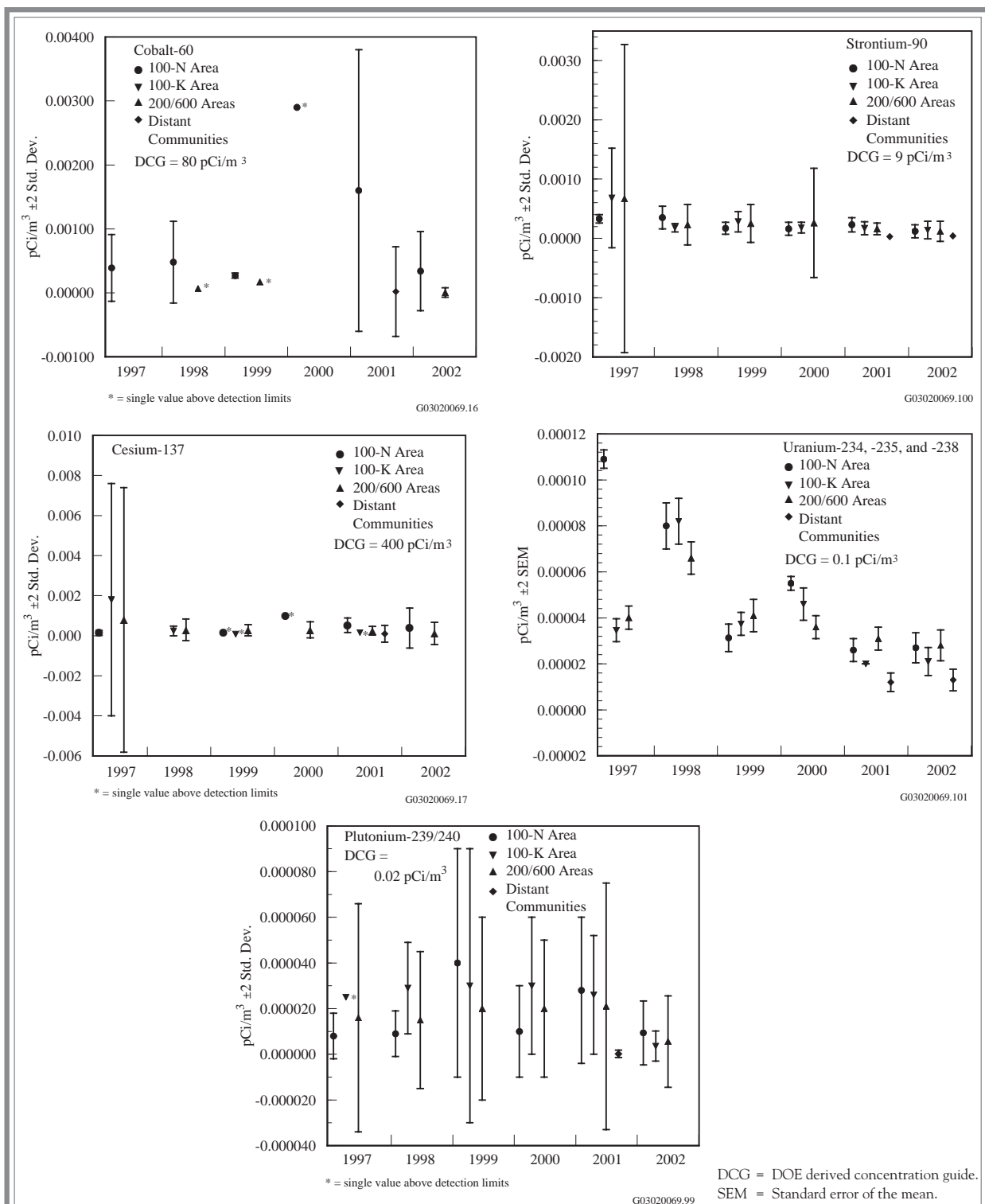


Figure 3.2.1. Average Concentrations of Selected Radionuclides in Near-Facility Air Samples Collected on the Hanford Site Compared to Those Collected in Distant Communities (PNNL-13910), 1997 through 2002. Radionuclide concentrations below analytical detection limits are not shown. As a result of figure scale, some uncertainties (error bars) are concealed by the point symbol.

Table 3.2.3. Annual Average and Maximum Concentrations (aCi/m³)^(a) of Radionuclides in Near-Facility Air Samples Collected on the Hanford Site, 2002

Cobalt-60				Uranium-235			
Site	Average^(b)	Maximum^(c)	EDP Code^(d)	Site	Average^(b)	Maximum^(c)	EDP Code^(d)
100-B/C RA ^(e)	-14 ± 14	38 ± 74	N466	100-B/C RA ^(e)	3.6 ± 9.0	7.4 ± 5.3	N465
100 Area ISS ^(f)	6.2 ± 6,200	250 ± 760	N523	100 Area ISS ^(f)	9.1 ± 15	36 ± 33	N523
100-F RA	-12 ± 24	12 ± 64	N519	100-F RA	2.5 ± 2,500	4.8 ± 4.4	N521
100-K	9.0 ± 15	63 ± 74	N402	100-K	1.9 ± 2.3	4.4 ± 3.9	N403
100-N	340 ± 620	1,000 ± 320	N526	100-N	2.9 ± 3.0	5.5 ± 4.5	N102
200-East	3.7 ± 35	110 ± 78	N985	200-East	2.7 ± 3.1	6.3 ± 5.0	N972
200-West	7.6 ± 67	80 ± 76	N964	200-West	2.9 ± 4.0	8.8 ± 6.8	N456
300-FF-1				300-FF-1			
(300 Area)	16 ± 42	120 ± 140	N486	(300 Area)	4.6 ± 5.4	9.5 ± 6.8	N485
ERDF ^(g)	50 ± 99	200 ± 100	N517	ERDF ^(g)	1.5 ± 5.3	3.4 ± 3.5	N518
Distant community ^(h)	180 ± 610	700 ± 600		Distant community ^(h)	-0.54 ± 4.1	3.1 ± 4.3	
DCG ⁽ⁱ⁾		80,000,000		DCG ⁽ⁱ⁾		100,000	
Strontium-90				Uranium-238			
Site	Average^(b)	Maximum^(c)	EDP Code^(d)	Site	Average^(b)	Maximum^(c)	EDP Code^(d)
100-B/C RA ^(e)	110 ± 190	270 ± 110	N466	100-B/C RA ^(e)	12 ± 13	28 ± 13	N465
100 Area ISS ^(f)	1,500 ± 8,300	24,000 ± 4,700	N523	100 Area ISS ^(f)	17 ± 22	47 ± 40	N523
100-F RA	180 ± 300	530 ± 200	N522	100-F RA	11 ± 4.9	16 ± 8.9	N519
100-K	140 ± 150	270 ± 120	N403	100-K	8.7 ± 11	22 ± 11	N403
100-N	120 ± 110	250 ± 120	N102	100-N	10 ± 8.0	15 ± 9.3	N105
200-East	130 ± 140	350 ± 140	N019	200-East	12 ± 11	26 ± 13	N984
200-West	110 ± 180	440 ± 160	N442	200-West	11 ± 11	35 ± 16	N457
300-FF-1				300-FF-1			
(300 Area)	140 ± 14	140 ± 87	N130	(300 Area)	26 ± 38	72 ± 29	N527
ERDF ^(g)	70 ± 190	150 ± 85	N482	ERDF ^(g)	11 ± 7.7	17 ± 9.4	N518
Distant community ^(h)	40 ± 210	300 ± 100		Distant community ^(h)	18 ± 13	28 ± 19	
DCG ⁽ⁱ⁾		9,000,000		DCG ⁽ⁱ⁾		100,000	
Cesium-137				Plutonium-238			
Site	Average^(b)	Maximum^(c)	EDP Code^(d)	Site	Average^(b)	Maximum^(c)	EDP Code^(d)
100-B/C RA ^(e)	12 ± 29	54 ± 71	N465	100-B/C RA ^(e)	1.8 ± 2.6	25 ± 11	N465
100 Area ISS ^(f)	320 ± 1,700	4,300 ± 1,300	N495	100 Area ISS ^(f)	1.5 ± 1.5	46 ± 59	N523
100-F RA	42 ± 160	330 ± 150	N522	100-F RA	2.4 ± 22	12 ± 14	N522
100-K	39 ± 33	120 ± 110	N402	100-K	-2.4 ± 8.4	21 ± 30	N401
100-N	380 ± 1,000	1,500 ± 520	N526	100-N	0.75 ± 1.1	5.6 ± 5.8	N105
200-East	150 ± 740	2,300 ± 760	N967	200-East	0.080 ± 80	11 ± 21	N481
200-West	84 ± 270	650 ± 240	N155	200-West	0.013 ± 1.5	9.4 ± 11	N994
300-FF-1				300-FF-1			
(300 Area)	2.1 ± 2.2	71 ± 74	N130	(300 Area)	5.7 ± 5,700	11 ± 15	N130
ERDF ^(g)	110 ± 170	260 ± 160	N517	ERDF ^(g)	-0.60 ± 0.62	7.1 ± 12	N517
Distant community ^(h)	100 ± 770	530 ± 520		Distant community ^(h)	-0.26 ± 0.65	0.37 ± 1.8	
DCG ⁽ⁱ⁾		400,000,000		DCG ⁽ⁱ⁾		30,000	
Uranium-234				Plutonium-239/240			
Site	Average^(b)	Maximum^(c)	EDP Code^(d)	Site	Average^(b)	Maximum^(c)	EDP Code^(d)
100-B/C RA ^(e)	17 ± 27	51 ± 21	N465	100-B/C RA ^(e)	4.0 ± 4,000	26 ± 12	N465
100 Area ISS ^(f)	28 ± 56	160 ± 80	N523	100 Area ISS ^(f)	28 ± 130	330 ± 110	N495
100-F RA	14 ± 9.8	23 ± 11	N522	100-F RA	7.7 ± 30	48 ± 20	N522
100-K	9.9 ± 6.8	17 ± 9.2	N403	100-K	3.6 ± 6.6	10 ± 11	N476
100-N	14 ± 10	24 ± 12	N526	100-N	9.4 ± 14	21 ± 10	N526
200-East	14 ± 13	28 ± 13	N999	200-East	1.9 ± 5.5	11 ± 6.7	N158
200-West	14 ± 15	50 ± 21	N457	200-West	8.7 ± 25	68 ± 26	N165
300-FF-1				300-FF-1			
(300 Area)	33 ± 23	60 ± 25	N527	(300 Area)	16 ± 32	29 ± 15	N130
ERDF ^(g)	11 ± 5.2	14 ± 8.5	N518	ERDF ^(g)	5.8 ± 9.5	12 ± 7.6	N518
Distant community ^(h)	33 ± 20	33 ± 11		Distant community ^(h)	0.46 ± 2.0	2.4 ± 3.0	
DCG ⁽ⁱ⁾		90,000		DCG ⁽ⁱ⁾		20,000	

Table 3.2.3. (contd)

Plutonium-241				Americium-241			
Site	Average ^(b)	Maximum ^(c)	EDP Code ^(d)	Site	Average ^(b)	Maximum ^(c)	EDP Code ^(d)
100-K	390 ± 910	1,100 ± 1,000	N403	100-K	4.6 ± 10	11 ± 14	N403
200-East	390 ± 390,000	990 ± 840	N481	200-East	4.9 ± 40	13 ± 13	N480
Distant community ^(h)		Not reported		Distant community ^(h)		Not reported	
DCG ⁽ⁱ⁾		1,000,000		DCG ⁽ⁱ⁾		20,000	

(a) To convert to international metric system units, multiply aCi/m³ by 0.000000037 to obtain Bq/m³.

(b) ±2 standard deviations.

(c) ± total analytical uncertainty.

(d) See PNNL-14295, APP. 2.

(e) RA = Remedial action project.

(f) ISS = Interim safe storage projects at 105-DR/F/D/H and 117-DR.

(g) ERDF = Environmental Restoration Disposal Facility.

(h) See Section 4.1.

(i) DOE derived concentration guide.

The airborne contaminant levels in the 100-K Area were similar to those measured over the previous years. Facility emissions in the 100-K Area decreased substantially during 1996 and subsequent radionuclide concentrations in the ambient air samples have been near detection limits. Strontium-90, uranium-234, and uranium-238 were detected consistently. Occasionally, plutonium-239/240 and plutonium-241 were detected also.

During October 2002, air sampling began at three locations at the 100-KR-1 remedial action site. Uranium-238 and strontium-90 were consistently detected.

Analytical results for ambient air samples from the 100-NR-1 remedial action site and 100-N surveillance and maintenance/transition site in 2002 were similar to those measured in previous years. Uranium-234, uranium-238, and plutonium-239/240 were detected consistently. Occasionally detected were cobalt-60, strontium-90, cesium-137, and uranium-238.

During 2002, radionuclide levels measured in the 200-East Area were generally similar to those measured over the previous years. Strontium-90, uranium-234, and uranium-238 were detected consistently. Occasionally, cesium-137, uranium-235, and plutonium-239/240 were detected.

Radionuclide levels measured in the 200-West Area were similar to results for previous years. Strontium-90, uranium-234, uranium-238, and plutonium-239/240 were detected consistently. Cesium-137 and uranium-235 were detected occasionally.

The air sampling network at the Environmental Restoration Disposal Facility (200-West Area) used two existing Hanford Site samplers for upwind monitoring (one near-facility sampler, N-963; one Pacific Northwest National Laboratory sampler, station #13 200 W SE [Section 4.1]) and three air samplers at the facility that provided downwind coverage. The 2002 analytical results were comparable to 2001 levels. Consistently detected were uranium-234 and uranium-238. Cobalt-60, strontium-90, cesium-137, and plutonium-239/240 were detected occasionally.

During March 2002, air sampling was re-initiated at the 300-FF-1 and 300-FF-2 remedial action site located just north of the 300 Area. Ambient air monitoring at this site included eight samplers: one near-facility monitoring upwind sampler, located at the nearby 300 Area Treated Effluent Disposal Facility; three Pacific Northwest National Laboratory upwind samplers in the 300 Area (300 Trench, 300 NE, and 300 Water Intake - Section 4.1); and four downwind, site-specific air samplers. Analytical results indicated that radionuclide concentrations in air samples collected at this site were much less than DOE derived concentration guides and were slightly lower than those measured during previous remediation activities conducted at the 300-FF-1 site during 1997 through 2000. Uranium-234, uranium-235, and uranium-238 were detected consistently and the highest concentration of uranium-238 at the Hanford Site in 2002 was measured at the air sampling location near the 618-4 burial ground (for more information regarding remediation activities at the

300-FF-1 Operable Unit in 2002, including the excavation of the 618-4 burial ground, see Section 2.3.12.2).

The remedial action, interim safe storage, and surveillance and maintenance/transition activities discussed above are described in more detail in Section 2.3.12.

3.2.2 SPRING WATER MONITORING

In the past, radioactive effluent streams from operations in the 100-N Area were sent to the 116-N-1 and 116-N-3 liquid waste disposal facilities (i.e., engineered soil columns) in the 100-N Area. After moving through the soil column to the water table, this waste migrated with the groundwater and entered the Columbia River via springs located along the adjacent riverbank region sometimes called N Springs. Groundwater springs and/or shoreline wells at the N Springs are sampled annually to verify that the reported radionuclide releases from these shoreline seeps to the Columbia River are not underreported. The amount of radionuclides entering the Columbia River at these springs is calculated based on analyses of samples collected from monitoring well 199-N-46 located near the shoreline. Analytical results and discussion of these releases may be found in Section 3.1.3 and in HNF-EP-0527-12. A groundwater pump-and-treat system designed to reduce the discharge of strontium-90 to the Columbia River in the 100-N Area was put into operation in 1995 and continued to operate in 2002. Additional discussion about this system and its effects may be found in Section 2.3.13.1.

During October 2002, samples were collected from eleven 100-N Area shoreline wells (i.e., one sample from each well). The samples were collected using a bailer carefully lowered into the water column of each well to avoid sediment suspension, and a 4-liter (1-gallon) sample was obtained. Samples were analyzed for strontium-90, tritium, and gamma-emitting radionuclides.

Strontium-90 was detected in ten of the well water samples. None of the concentrations exceeded the DOE derived concentration guide value. Tritium and

gamma-emitting radionuclide concentrations were below analytical detection limits. Tritium and strontium-90 data from 2002 riverbank springs samples are summarized in Table 3.2.4.

3.2.3 RADIOLOGICAL SURVEYS OF SURFACE CONTAMINATION

Radiological surveys are used to monitor and detect contamination on the Hanford Site. The main types of monitored areas are underground radioactive materials areas, contamination areas, soil contamination areas, high contamination areas, roads, and fence lines.

Underground radioactive materials areas are areas where radioactive materials occur below the soil surface. These areas are typically stabilized cribs, burial grounds, covered ponds, trenches, and ditches. Barriers over the contamination sources are used to inhibit radionuclide transport to the surface environs. These areas are surveyed at least annually to assess the effectiveness of the barriers.

Contamination/soil contamination areas may or may not be associated with an underground structure containing radioactive material. A breach in the surface barrier of a contaminated underground area may result in the growth of contaminated vegetation. Insects or animals may burrow into the soil and bring contamination to the surface. Vent pipes or risers from an underground structure may be a source of speck contamination (particles with a diameter less than 0.6 centimeter [0.25 inch]). Areas of contamination not related to subsurface structures can include sites

Table 3.2.4. Radionuclide Concentrations (pCi/L) in Samples Collected from Springs Along the Columbia River Shoreline in the 100-N Area of the Hanford Site, 2002

<u>Radionuclide</u>	<u>Shoreline Springs Monitoring Well 199-N-46^(a)</u>	<u>Shoreline Springs</u>		<u>DCG^(d)</u>
		<u>Maximum^(b)</u>	<u>Average^(c)</u>	
Tritium	680 ± 68	Not detected		2,000,000
Strontium-90	4,800 ± 480	82 ± 16	15 ± 3	1,000

(a) To convert to international metric system units, multiply pCi/L by 0.037 to obtain Bq/L.

(b) ± total analytical uncertainty.

(c) ±2 standard deviations.

(d) DCG = DOE derived concentration guide (DOE Order 5400.5).

contaminated with fallout from effluent stacks and sites that are the result of unplanned releases (e.g., contaminated tumbleweeds, animal feces). All contaminated areas may be susceptible to contamination migration and are surveyed at least annually to assess the current radiological status (locations of contaminated areas are illustrated in PNNL-14295, APP. 2). In addition, roadways are surveyed annually and the intersections along the Environmental Restoration Disposal Facility haul route are surveyed quarterly. During 2002, the railroads from the former 1100 Area shops to the 200-West Area were radiologically surveyed in preparation for re-opening the Hanford Site railroad for shipment of materials and supplies to the Waste Vitrification Project and possibly removing waste materials from the 300 Area.

During 2002, the Hanford Site had ~3,643 hectares (~9,002 acres) of outdoor contaminated areas (all types) and ~665 hectares (~1,643 acres) that contain underground radioactive materials not including active facilities. It was estimated that the external dose rate at 80% of the outdoor contaminated areas was <1 mrem/hour (0.01 mSv/hour), though direct dose rate readings from isolated radioactive specks could have been higher. Table 3.2.5 lists the contaminated areas and underground radioactive materials areas. Vehicles equipped with radiation detection devices and a global positioning system were again used during 2002 to more accurately measure the extent of the contamination. Area measurements are entered into the Hanford Geographical Information System, a computer database maintained by Fluor Hanford, Inc.

Though no new areas of significant size were discovered during 2002, the number and size of contaminated areas vary from year to year for several reasons: stabilization of areas of known contamination, discovery of new areas of contamination, and/or ongoing improvement of the geographical measurements of contaminated areas. Table 3.2.6 summarizes the effects of these efforts during 2002. Approximately 2.3 hectares (~6 acres) were re-classified from areas containing contamination/soil contamination to underground radioactive material areas, and ~1 hectare (~2.5 acres) was designated a contaminated area. Newly identified areas are generally the result of either contaminant migration or an increased effort to investigate outdoor areas for radiological contamination. The addition of data from a global positioning system to the base maps of the Hanford Site resulted in a change in

Table 3.2.5. Status of Outdoor Contamination at the Hanford Site, 2002

<u>Area</u>	<u>Contamination</u>		<u>Underground</u>	
	<u>Areas, ^(a) ha (acres)</u>		<u>Radioactive Materials</u>	
			<u>Areas, ^(b) ha (acres)</u>	
100-B/C	8 ^(c)	(20)	39	(96)
100-D/DR	0	(0)	39	(96)
100-F	1	(2)	33	(82)
100-H	0	(0)	14	(35)
100-K	9	(22)	62	(153)
100-N	29	(72)	12	(30)
200-East ^(d)	72	(178)	141	(348)
200-West ^(d)	27	(67)	225	(556)
300	19	(47)	45	(111)
400	0	(0)	0	(0)
600 ^(e)	3,478	(8,594)	55	(136)
Totals	3,643	(9,002)	665	(1,643)

- (a) Includes areas with contamination/soil contamination or radiologically controlled and areas that had both underground radioactive material and contamination/soil contamination.
- (b) Includes areas with only underground contamination. Does not include areas that had contamination/soil contamination as well as underground radioactive material.
- (c) The contaminated areas located at the 107-B and 107-C retention basins were remediated in 2001 and are undergoing closure and awaiting down posting.
- (d) Includes tank farms.
- (e) Includes BC controlled area, Environmental Restoration Disposal Facility, and waste disposal facilities outside the 200-East and 200-West Area boundaries.

Table 3.2.6. Status Change of Posted Contaminated Areas on the Hanford Site, 2002

<u>Areas</u>	<u>Changes^(a)</u>	<u>Area, ha (acres)</u>	
100	None to CA	8 ^(b)	(23)
100	Map changes ^(c)	1	(2)
200-East	CA to URM ^(d)	1.2	(3.1)
200-East	Not posted to CA ^(c)	3.8	(9.4)
200-West	CA to URM ^(d)	1.1	(2.8)
200-West	CA to not posted ^(c)	<10.1	(<25)
300	None to report	0	(0)
400	None to report	0	(0)
600	None to report	0	(0)

- (a) CA = Contamination/soil contamination area; URM = underground radioactive material area.
- (b) The posted contamination areas located at the 107-B and 107-C retention basins were mistakenly reported as "0" in 2001. Sites are undergoing closure and awaiting down posting.
- (c) Re-surveyed using a global positioning system.
- (d) Changes due to stabilization activities.

the sizes of the contaminated areas and the underground areas containing radioactive material.

3.2.4 SOIL AND VEGETATION MONITORING

Soil and vegetation samples were collected on, or adjacent to, waste disposal sites and from locations downwind and near or within the boundaries of operating facilities and remedial action sites. Samples were collected to evaluate long-term trends in environmental accumulation of radioactivity and to detect potential migration and deposition of facility effluent. Special samples also were collected where potential physical or biological pathway problems were identified. Contaminant movement can occur as the result of resuspension from radiologically contaminated surface areas, absorption of radionuclides by the roots of vegetation growing on or near underground and surface-water disposal units, or animal activities at the waste site. The sampling methods and locations used are discussed in detail in DFSNW-OEM-001. Radiological analyses of soil and vegetation samples included strontium-90, uranium isotopes, plutonium isotopes, and gamma-emitting radionuclides.

The number and location of soil and vegetation samples collected during 2002 are summarized in Table 3.2.1. A comprehensive presentation of the analytical data can be found in PNNL-14295, APP. 2. Only those radionuclide concentrations reported above analytical detection limits are discussed in this section.

Each 1-kilogram (2.2-pound) soil sample represented a composite of five plugs of soil, each 2.5 centimeters (1 inch) deep and 10 centimeters (4 inches) in diameter collected from each site. Each vegetation sample (~500 grams [~16.1 ounces]) consisted of new-growth leaf cuttings taken from the available species of interest at a sample location. Often, the vegetation sample consisted of a composite of several like members of the sampling site plant community to avoid decimation of any individual plant through overharvesting.

During the spring through early summer of each year, soil and vegetation samples are collected on the Hanford Site and submitted for radioanalyses. The analyses include those for radionuclides expected to occur in the areas sampled (i.e., gamma-emitting radionuclides, strontium-90, uranium

isotopes, and/or plutonium isotopes). The results are then compared to levels for selected radionuclides found at various offsite sampling locations in Yakima, Benton, and Franklin Counties. Comparison of the levels was used to determine the difference between contributions from site operations and remedial action sites and contributions from natural sources and worldwide fallout.

Soil sampling results also are compared to the “accessible soil” concentrations (WHC-SD-EN-TI-070) developed specifically for use at the Hanford Site (see PNNL-14295, APP. 2 for complete listing). These radioactive concentration values were established to assure that effective dose equivalents to the public do not exceed the established limits for any reasonable scenario, such as direct exposure, inadvertent ingestion, inhalation, and ingestion of food crops, including animal products. The accessible soil concentration values are based on a radiation dose estimate scenario where an individual would have to spend 100 hours per year in direct contact with the contaminated soil. The conservatism inherent in pathway modeling assures that the required degrees of protection are in place (WHC-SD-EN-TI-070). These concentrations apply specifically to the Hanford Site with respect to onsite disposal operations, stabilization, cleanup, and decontamination and decommissioning operations.

Some degree of variability is always associated with the collection and analysis of environmental samples. Therefore, minor variations in concentrations from year to year are expected. In general, radionuclide concentrations in soil and vegetation samples collected from, or adjacent to, waste disposal facilities were higher than the concentrations in samples collected farther away and were significantly higher than concentrations measured offsite. The data also show, as expected, that concentrations of certain radionuclides were higher within different operational areas when compared to concentrations measured in distant communities. Generally, the predominant radionuclides were activation and fission products in the 100-N Area, fission products in the 200 Areas, and uranium in the 300/400 Areas.

3.2.4.1 RADIOLOGICAL RESULTS FOR SOIL SAMPLES

In Hanford soil samples, cobalt-60, strontium-90, cesium-137, plutonium-239/240, and uranium were

detected consistently. The concentrations of these radionuclides were elevated near and within facility boundaries when compared to historical concentrations measured off the site at distant communities. Figure 3.2.2 shows average soil values for samples collected during 2002 and the preceding 5 years. The levels demonstrate a high degree of variability.

Historical results for surface soil samples collected near the 116-N-1 liquid waste disposal facility exhibited somewhat higher radionuclide concentrations than those collected at the other soil sampling locations in the 100-N Area. During 2002, however, all but one of the routine sampling locations were not accessible or had been destroyed during decommissioning activities at the site and comparative values were, therefore, not available.

Average radionuclide concentrations detected in the surface soil samples collected in the 100-N Area from 1997 through 2002 are presented in Table 3.2.7. The average values reported for 100-N Area surface soil represent a single routine sampling location. The 2002 average, distant community, and accessible soil concentrations are compared in Table 3.2.8.

Soil samples were collected from 56 sampling locations in the 200/600 Areas during 2002. Analytical results from these soil samples demonstrated a modest reduction in average radionuclide concentration levels from 2001 compared to 2002 (Table 3.2.9). The 2002 maximums, averages, offsite averages, and accessible soil concentrations are compared in Table 3.2.10. Complete listings of radionuclide concentrations and sampling location maps are provided in PNNL-14295, APP. 2.

Soil samples were collected from 13 sampling locations in the 300/400 Areas in 2002: 12 from the 300 Area and 1 from the 400 Area. Analytical results for 2002 and the preceding 5 years are summarized in Table 3.2.11. The 2002 maximums, averages, distant community average concentrations, and accessible soil concentrations are compared in Table 3.2.12. Complete listings of radionuclide concentrations and sampling location maps are provided in PNNL-14295, APP. 2. For the samples collected during 2002, average values reported for uranium isotopes were somewhat higher than the concentrations reported in 2001. Uranium concentrations were expected to be higher in the

300 Area samples than at other site locations because uranium was processed during past fuel fabrication operations in the 300 Area.

For non-routine soil sampling in support of the environmental restoration contractor projects in 2002, three soil samples were collected at the remedial action project in the 100-B/C Area, and two each at the remedial action projects in the 100-F and 100-K Areas. A total of eight samples, collected during two sampling sessions in June and October, were analyzed from the four locations at the 100-NR-1 remedial action project site. A single sample was collected from the Environmental Restoration Disposal Facility (200-West Area) to determine the effectiveness of contamination controls. Analytical results from each of these locations were comparable to those observed at other locations at Hanford. Table 3.2.13 provides a summary of the analytical results for selected radionuclides from these remedial action locations. All of the 2002 data are provided in PNNL-14295, APP. 2.

3.2.4.2 RADIOLOGICAL RESULTS FOR VEGETATION SAMPLES

In Hanford vegetation samples, cobalt-60, strontium-90, cesium-137, plutonium-239/240, and uranium were detected consistently. Concentrations of these radionuclides in vegetation were elevated near and within facility boundaries compared to concentrations measured at distant communities. Figure 3.2.3 shows the average vegetation values for samples collected during 2002 and the preceding 5 years. The results demonstrate a high degree of variability.

Average radionuclide concentrations detected in all of the vegetation samples collected in the 100-N Area from 1997 through 2002 are presented in Table 3.2.14. These concentrations were within the range of historical values. The levels of strontium-90 at the 100-N Area were higher than levels found in the 200 and 300/400 Areas. The 2002 maximum and average concentrations for vegetation samples collected at the 100-N Area are compared to distant community averages in Table 3.2.15. A complete list of radionuclide concentrations and sampling location maps are provided in PNNL-14295, APP. 2. In 2002, analytical results from vegetation samples collected from the 100-N Area were comparable to those observed in 2001. The

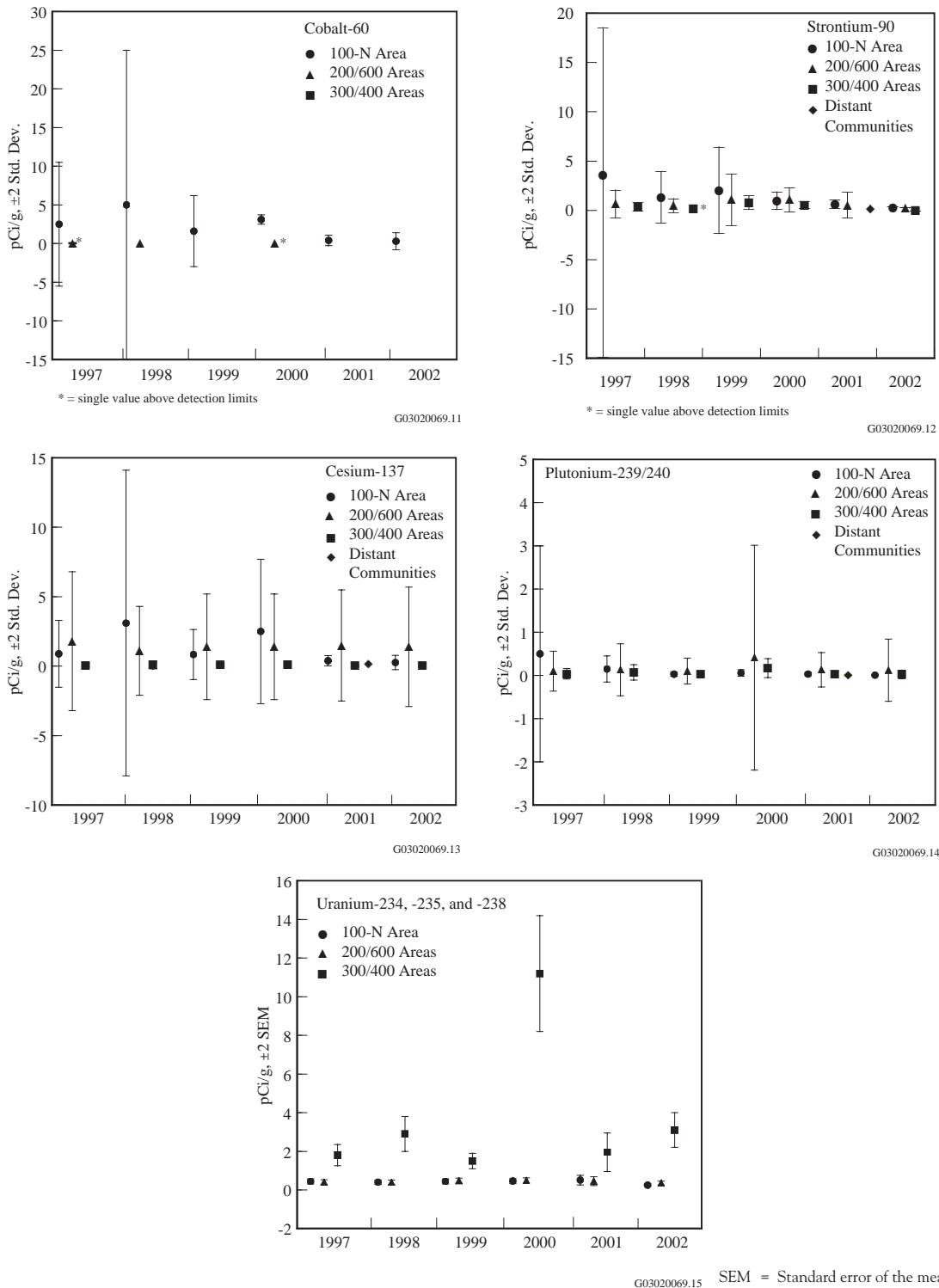


Figure 3.2.2. Average Concentrations of Selected Radionuclides in Near-Facility Soil Samples Collected on the Hanford Site Compared to Those Collected in Distant Communities (PNNL-13910), 1997 through 2002. Radionuclide concentrations below analytical detection limits are not shown. As a result of figure scale, some uncertainties (error bars) are concealed by the point symbol.

Table 3.2.7. Average Radionuclide Concentrations (pCi/g^(a) dry wt.)^(b) Detected in Surface Soil Samples Collected from the 100-N Area on the Hanford Site, 1997 through 2002

Year	⁶⁰ Co	⁹⁰ Sr	¹³⁷ Cs	²³⁴ U	²³⁵ U	²³⁸ U	^{239/240} Pu
1997	2.5 ± 8.0	3.4 ± 16	0.89 ± 2.4	0.21 ± 0.04	0.020 ± 0.002	0.207 ± 0.036	0.52 ± 2.5
1998	4.9 ± 20	1.0 ± 2.6	3.1 ± 11	0.214 ± 0.063	0.033 ± 0.008	0.166 ± 0.026	0.13 ± 0.3
1999	1.6 ± 4.6	1.9 ± 4.4	0.84 ± 1.8	0.22 ± 0.04	0.016 ± 0.004	0.20 ± 0.03	0.026 ± 0.05
2000	3.1 ± 0.6	0.84 ± 0.9	2.1 ± 5.2	0.22 ± 0.09	0.018 ± 0.007	0.22 ± 0.03	0.050 ± 0.074
2001	0.27 ± 0.68	0.20 ± 0.42	0.32 ± 0.44	0.24 ± 0.09	0.024 ± 0.01	0.25 ± 0.07	0.022 ± 0.04
2002 ^(c)	0.3 ± 1.1	0.15 ± 0.47	0.26 ± 0.51	0.13 ± 0.05	0.01 ± 0.008	0.11 ± 0.04	0.006 ± 0.006

(a) To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.

(b) ±2 standard deviations.

(c) Represents one sample site only.

Table 3.2.8. Concentrations of Selected Radionuclides (pCi/g^(a) dry wt.) in Surface Soil Samples Collected from the 100-N Area on the Hanford Site, 2002

	⁶⁰ Co	⁹⁰ Sr	¹³⁷ Cs	²³⁴ U	²³⁵ U	²³⁸ U	^{239/240} Pu
Average ^(b,c)	0.3 ± 1.1	0.15 ± 0.47	0.26 ± 0.51	0.13 ± 0.05	0.01 ± 0.008	0.11 ± 0.04	0.006 ± 0.006
Distant community ^(c,d)	NR ^(e)	0.052 ± 0.11	0.15 ± 0.32	NR	NR	0.13 ± 0.11	0.0055 ± 0.012
Accessible soil concentration (WHC-SD-EN-TI-070) ^(f)	7.1	2,800	30	630	170	370	190

(a) To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.

(b) Represents one sample site only.

(c) ±2 standard deviations.

(d) PNNL-13910.

(e) NR = Not reported.

(f) Hanford soil that is not behind security fences.

Table 3.2.9. Average Radionuclide Concentrations (pCi/g^(a) dry wt.)^(b) Detected in Surface Soil Samples Collected from the 200/600 Areas on the Hanford Site, 1997 through 2002

Year	⁶⁰ Co	⁹⁰ Sr	¹³⁷ Cs	²³⁴ U	²³⁸ U	^{239/240} Pu
1997	0.017 ± 0.02	0.42 ± 1.4	1.70 ± 5.1	0.20 ± 0.01	0.20 ± 0.01	0.07 ± 0.40
1998	0.014 ± 0.09	0.21 ± 0.67	1.00 ± 3.1	0.19 ± 0.07	0.19 ± 0.07	0.08 ± 0.49
1999	ND ^(c)	0.51 ± 1.9	1.30 ± 3.8	0.23 ± 0.13	0.22 ± 0.13	0.08 ± 0.27
2000	0.006 ± 0.006	0.99 ± 1.3	1.40 ± 3.8	0.23 ± 0.22	0.23 ± 0.22	0.29 ± 2.3
2001	ND	0.31 ± 1.1	1.50 ± 4.0	0.22 ± 0.11	0.22 ± 0.11	0.10 ± 0.37
2002	ND	0.27 ± 0.66	1.40 ± 4.30	0.17 ± 0.10	0.17 ± 0.11	0.12 ± 0.72

(a) To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.

(b) ±2 standard deviations.

(c) ND = Not detected.

Table 3.2.10. Concentrations of Selected Radionuclides (pCi/g^[a] dry wt.) in Surface Soil Samples Collected from the 200/600 Areas on the Hanford Site, 2002

	⁶⁰ Co	⁹⁰ Sr	¹³⁷ Cs	²³⁴ U	²³⁵ U	²³⁸ U	^{239/240} Pu
Maximum ^(b)	ND ^(c)	1.9 ± 0.38	12.0 ± 1.9	0.36 ± 0.08	0.033 ± 0.018	0.38 ± 0.087	2.4 ± 0.48
Average ^(d)	ND	0.27 ± 0.66	1.4 ± 4.3	0.17 ± 0.1	0.015 ± 0.014	0.17 ± 0.11	0.12 ± 0.72
Distant community ^(d,e)	NR ^(f)	0.052 ± 0.11	0.15 ± 0.32	NR	NR	0.13 ± 0.11	0.0055 ± 0.012
Accessible soil concentration limits (WHC-SD-EN-TI-070) ^(g)	7.1	2,800	30	630	170	370	190

(a) To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.

(b) ± total analytical uncertainty.

(c) ND = Not detected.

(d) ±2 standard deviations.

(e) PNNL-13910.

(f) NR = Not reported.

(g) Hanford soil that is not behind security fences.

Table 3.2.11. Average Radionuclide Concentrations (pCi/g^[a] dry wt.)^(b) Detected in Surface Soil Samples Collected from the 300/400 Areas on the Hanford Site, 1997 through 2002

Year	⁶⁰ Co	⁹⁰ Sr	¹³⁷ Cs	²³⁴ U	²³⁸ U	^{239/240} Pu
1997	ND ^(c)	0.09 ± 0.61	0.07 ± 0.12	0.90 ± 3.8	0.90 ± 3.7	0.02 ± 0.08
1998	ND	0.005 ± 0.026	0.09 ± 0.26	1.4 ± 5.3	1.4 ± 5.5	0.03 ± 0.14
1999	ND	0.85 ± 0.70	0.09 ± 0.10	0.70 ± 1.8	0.66 ± 1.8	0.03 ± 0.05
2000	ND	0.56 ± 0.40	0.09 ± 0.23	5.40 ± 24.0	5.40 ± 2.4	0.07 ± 0.21
2001	ND	ND	0.04 ± 0.08	0.94 ± 3.0	0.95 ± 3.1	0.03 ± 0.10
2002	ND	0.03 ± 0.03	0.07 ± 0.13	1.50 ± 6.40	1.50 ± 6.40	0.02 ± 0.10

(a) To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.

(b) ±2 standard deviations.

(c) ND = Not detected.

Table 3.2.12. Concentrations of Selected Radionuclides (pCi/g^[a] dry wt.) in Surface Soil Samples Collected from the 300/400 Areas on the Hanford Site, 2002

	⁶⁰ Co	⁹⁰ Sr	¹³⁷ Cs	²³⁴ U	²³⁵ U	²³⁸ U	^{239/240} Pu
Maximum	ND ^(c)	0.028 ± 0.029 ^(b,d)	0.23 ± 0.034	12.0 ± 2.3	0.65 ± 0.16	12.0 ± 2.3	0.16 ± 0.046
Average ^(c)	ND	0.028 ± 0.029 ^(b,d)	0.074 ± 0.13	1.5 ± 6.4	0.086 ± 0.34	1.5 ± 6.4	0.029 ± 0.099
Distant community ^(e,f)	NR ^(g)	0.052 ± 0.11	0.15 ± 0.32	NR	NR	0.13 ± 0.11	0.0055 ± 0.012
Accessible soil concentration limits (WHC-SD-EN-TI-070) ^(h)	7.1	2,800	30	630	170	370	190

(a) To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.

(b) ± total analytical uncertainty.

(c) ND = Not detected.

(d) Single value above detection limit.

(e) ±2 standard deviations.

(f) PNNL-13910.

(g) NR = Not reported.

(h) Hanford soil that is not behind security fences.

Table 3.2.13. Radionuclide Concentrations (pCi/g^(a) dry wt.)^(b) in Soil Samples Collected by the Environmental Restoration Contractor on the Hanford Site, 2002

Site	Sample Location ^(c)	⁶⁰ Co	⁹⁰ Sr	¹³⁷ Cs	²³⁴ U	²³⁵ U	²³⁸ U	^{239/240} Pu
ERDF ^(d)	D146	ND ^(e)	0.28 ± 0.13	0.049 ± 0.011	0.18 ± 0.05	0.011 ± 0.01	0.19 ± 0.053	0.007 ± 0.007
100-B/C	D150	ND	0.23 ± 0.12	0.2 ± 0.029	0.16 ± 0.048	0.019 ± 0.015	0.16 ± 0.048	0.02 ± 0.015
100-F	D154	0.004 ± 0.009	ND	0.6 ± 0.092	0.13 ± 0.042	0.022 ± 0.016	0.11 ± 0.036	0.031 ± 0.019
100-F	D155	ND	ND	0.23 ± 0.034	0.16 ± 0.046	0.009 ± 0.009	0.15 ± 0.045	0.01 ± 0.009
100-N	D156 (6/02)	ND	ND	0.029 ± 0.009	0.12 ± 0.036	0.014 ± 0.01	0.13 ± 0.039	ND
100-N	D156 (11/02)	ND	0.16 ± 0.14	0.014 ± 0.012	0.12 ± 0.036	ND	0.1 ± 0.032	ND
100-N	D157 (6/02)	1.8 ± 0.14	0.28 ± 0.14	0.85 ± 0.11	0.11 ± 0.036	ND	0.091 ± 0.033	0.026 ± 0.016
100-N	D157 (11/02)	0.27 ± 0.027	ND	0.29 ± 0.051	0.11 ± 0.032	0.014 ± 0.012	0.074 ± 0.025	ND
100-N	D158 (6/02)	0.043 ± 0.008	ND	0.037 ± 0.01	0.1 ± 0.031	0.012 ± 0.009	0.12 ± 0.036	ND
100-N	D158 (11/02)	0.071 ± 0.012	ND	0.15 ± 0.027	0.12 ± 0.034	ND	0.12 ± 0.035	ND
100-N	D159 (6/02)	0.24 ± 0.029	ND	0.46 ± 0.068	0.16 ± 0.043	0.015 ± 0.01	0.11 ± 0.033	ND
100-N	D159 (11/02)	0.22 ± 0.023	0.66 ± 0.2	0.35 ± 0.055	0.17 ± 0.049	ND	0.14 ± 0.042	ND
100-B/C	D160	ND	0.58 ± 0.17	0.33 ± 0.05	0.23 ± 0.062	0.03 ± 0.017	0.18 ± 0.052	0.015 ± 0.011
100-B/C	D161	ND	0.18 ± 0.11	0.065 ± 0.017	0.19 ± 0.053	ND	0.22 ± 0.057	0.009 ± 0.008
100-KR-1	D162	ND	ND	0.12 ± 0.021	0.12 ± 0.038	ND	0.13 ± 0.039	ND
100-KR-1	D163	ND	ND	0.41 ± 0.067	0.16 ± 0.046	0.014 ± 0.011	0.16 ± 0.046	0.029 ± 0.016
Distant community ^(f,g)		NR ^(h)	0.066 ± 0.06	0.0022 ± 0.034	NR	NR	ND	0.0008 ± 0.002
Accessible soil concentration ⁽ⁱ⁾ (WHC-SD-EN-TI-070)		7.1	2,800	30	630	170	370	190

(a) To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.

(b) ± total analytical uncertainty.

(c) Sampling location code. See PNNL-14295, APP. 2. Sampling dates in parentheses indicate multiple sampling events at the same location.

(d) ERDF = Environmental Restoration Disposal Facility.

(e) ND = Not detected.

(f) ±2 standard error of the mean.

(g) See PNNL-13910.

(h) NR = Not reported.

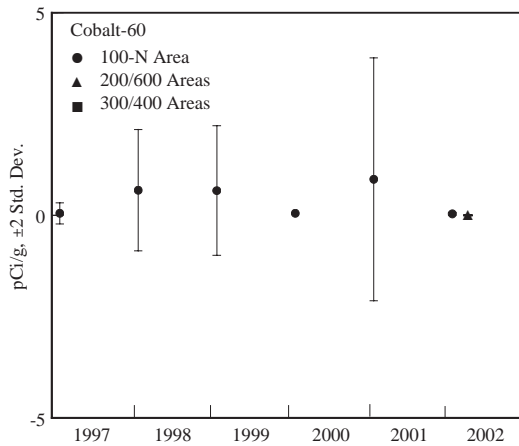
(i) Hanford soil that is not behind security fences.

radionuclide levels measured in 100-N Area vegetation were greater than those measured at distant communities.

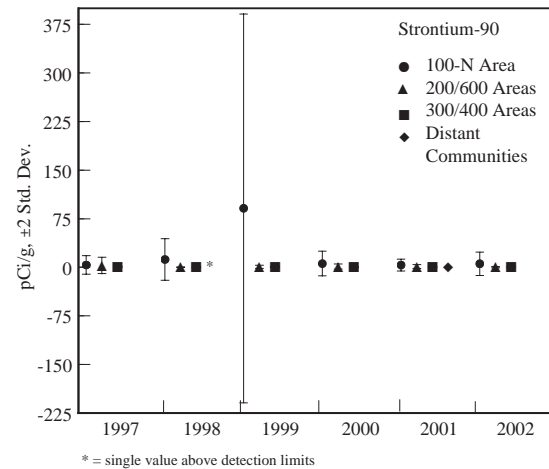
Vegetation samples from 46 sampling locations were collected in the 200/600 Areas during 2002. Concentrations of selected radionuclides reported for 1997 through 2002 are summarized in Table 3.2.16. Analytical results from vegetation samples taken in 2002 from the 200/600 Areas were comparable to those observed in previous years. Radionuclide levels for strontium-90, cesium-137, and plutonium-239/240 were greater than those measured off the Hanford Site. The 2002 maximum and average concentrations for selected radionuclides are compared to offsite averages in Table 3.2.17. A complete list of radionuclide concentrations and sampling location maps are provided in PNNL-14295, APP. 2.

Thirteen vegetation samples were collected from the 300/400 Areas in 2002. Table 3.2.18 provides a summary of the 300/400 Areas results from vegetation samples collected from 1997 through 2002. The levels of most radionuclides measured in the 300 Area were greater than those measured off the Hanford Site, and uranium levels were higher than levels measured in either the 100 and 200 Areas. The higher uranium levels were expected because uranium was released to the environment during past fuel fabrication operations in the 300 Area. In the 400 Area, the concentrations recorded for most radionuclides were higher than those measured at the distant communities.

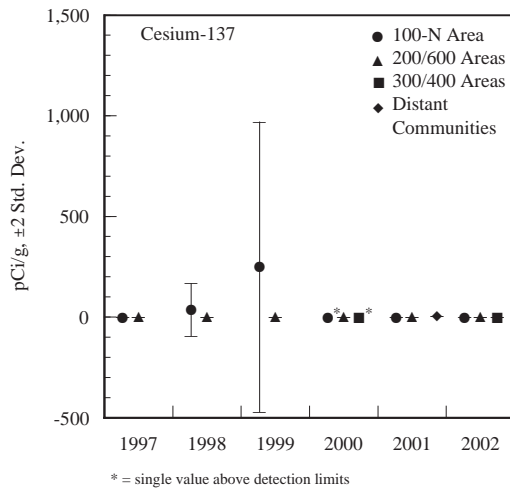
The 2002 maximum, average, and distant community average concentrations for 300/400 Areas samples are



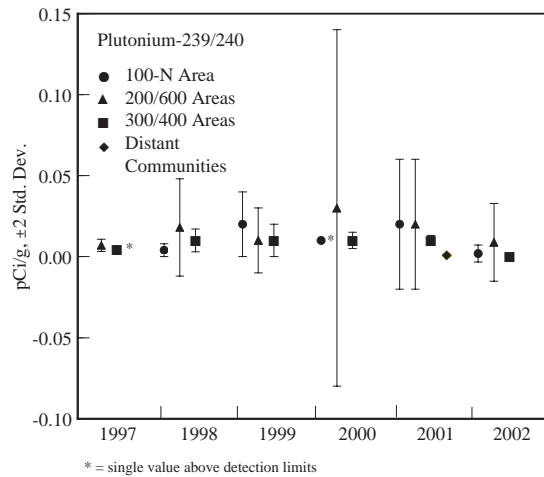
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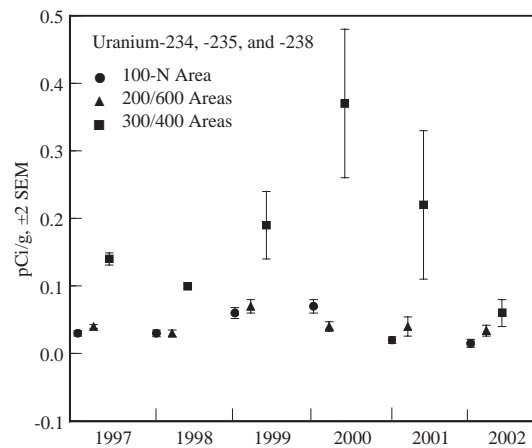
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Figure 3.2.3. Average Concentrations of Selected Radionuclides in Near-Facility Vegetation Samples Collected on the Hanford Site Compared to Those Collected in Distant Communities (PNNL-13910), 1997 through 2002. Radionuclide concentrations below analytical detection limits are not shown. As a result of figure scale, some uncertainties (error bars) are concealed by the point symbol.

Table 3.2.14. Average Radionuclide Concentrations (pCi/g^(a) dry wt.)^(b) Detected in Vegetation Samples Collected from the 100-N Area on the Hanford Site, 1997 through 2002

<u>Year</u>	<u>⁶⁰Co</u>	<u>⁹⁰Sr</u>	<u>¹³⁷Cs</u>	<u>^{239/240}Pu</u>
1997	0.06 ± 0.26	2.6 ± 12	0.10 ± 0.19	ND ^(c)
1998	0.62 ± 1.3	12 ± 32	38 ± 94	0.002 ± 0.004
1999	0.61 ± 1.4	91 ± 300	250 ± 670	0.01 ± 0.02
2000	0.05 ± 0.09	5.7 ± 16	0.2 ^(d) ± 0.2	0.0004 ± 0.04
2001	0.89 ± 2.3	3.5 ± 8.4	0.38 ± 0.44	0.024 ± 0.03
2002	0.004 ± 0.037	5.4 ± 18.0	0.002 ± 0.008	0.002 ± 0.005

(a) To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.

(b) ±2 standard error of the mean.

(c) ND = Not detected.

Table 3.2.15. Concentrations of Selected Radionuclides (pCi/g^(a) dry wt.) in Vegetation Samples Collected from the 100-N Area on the Hanford Site, 2002

	<u>⁶⁰Co</u>	<u>⁹⁰Sr</u>	<u>¹³⁷Cs</u>	<u>²³⁴U</u>	<u>²³⁵U</u>	<u>²³⁸U</u>	<u>^{239/240}Pu</u>
Maximum	0.0037 ± 0.037 ^(b,c)	21.6 ± 2.9	0.0024 ± 0.0089 ^(c)	0.013 ± 0.0083	ND	0.0073 ± 0.0059	0.0019 ± 0.0053 ^(c)
Average ^(d)	0.0037 ± 0.037 ^(b,c)	5.4 ± 18.0	0.0024 ± 0.0084	0.0098 ± 0.0045	ND	0.0051 ± 0.0029	0.0019 ± 0.0053
Distant community ^(d,e)	NR ^(f)	0.066 ± 0.059	0.0022 ± 0.034	NR	NR	ND ^(g)	0.00078 ± 0.0016

(a) To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.

(b) ± total analytical uncertainty.

(c) Single value above detection limit.

(d) ±2 standard deviations.

(e) PNNL-13910.

(f) NR = Not reported.

(g) ND = Not detected.

Table 3.2.16. Average Radionuclide Concentrations (pCi/g^(a) dry wt.)^(b) Detected in Vegetation Samples Collected from the 200/600 Areas on the Hanford Site, 1997 through 2002

<u>Year</u>	<u>⁶⁰Co</u>	<u>⁹⁰Sr</u>	<u>¹³⁷Cs</u>	<u>²³⁴U</u>	<u>²³⁸U</u>	<u>^{239/240}Pu</u>
1997	ND ^(c)	1.80 ± 10.0	0.07 ± 0.21	0.015 ± 0.015	0.011 ± 0.014	0.0033 ± 0.0063
1998	ND	0.14 ± 0.50	0.051 ± 0.18	0.016 ± 0.002	0.010 ± 0.009	0.007 ± 0.024
1999	ND	0.79 ± 2.3	0.13 ± 0.18	0.033 ± 0.004	0.023 ± 0.003	0.009 ± 0.017
2000	ND	1.30 ± 3.3	0.16 ± 0.21	0.020 ± 0.02	0.014 ± 0.002	0.033 ± 0.06
2001	ND	1.00 ± 2.3	0.17 ± 0.24	0.019 ± 0.002	0.018 ± 0.018	0.021 ± 0.03
2002	0.0003 ± 0.0018	0.32 ± 1.10	0.089 ± 0.42	0.016 ± 0.016	0.014 ± 0.015	0.009 ± 0.024

(a) To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.

(b) ±2 standard deviations.

(c) ND = Not detected.

Table 3.2.17. Concentrations of Selected Radionuclides (pCi/g^(a) dry wt.) in Vegetation Samples Collected from the 200/600 Areas on the Hanford Site, 2002

	⁶⁰ Co	⁹⁰ Sr	¹³⁷ Cs	²³⁴ U	²³⁵ U	²³⁸ U	^{239/240} Pu
Maximum	0.00032 ± 0.0018 ^(b,c)	3.2 ± 0.64	1.5 ± 0.23	0.038 ± 0.014	0.015 ± 0.0078	0.039 ± 0.014	0.052 ± 0.017
Average ^(d)	0.00032 ± 0.0018 ^(b,c)	0.32 ± 1.1	0.089 ± 0.42	0.016 ± 0.016	0.0039 ± 0.0067	0.014 ± 0.015	0.0088 ± 0.024
Distant community ^(d,e)	NR ^(f)	0.066 ± 0.059	0.0022 ± 0.034	NR	NR	ND ^(g)	0.00078 ± 0.0016

(a) To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.

(b) ± total analytical uncertainty.

(c) Single value above detection limit.

(d) ±2 standard deviations.

(e) PNNL-13910.

(f) NR = Not reported.

(g) ND = Not detected.

Table 3.2.18. Average Radionuclide Concentrations (pCi/g^(a) dry wt.)^(b) Detected in Vegetation Samples Collected from the 300/400 Areas on the Hanford Site, 1997 through 2002

Year	⁶⁰ Co	⁹⁰ Sr	¹³⁷ Cs	²³⁴ U	²³⁸ U	^{239/240} Pu
1997	ND ^(c)	0.13 ± 0.64	ND	0.069 ± 0.64	0.062 ± 0.18	0.001 ± 0.002
1998	ND	0.17 ± 0.09	ND	0.046 ± 0.12	0.044 ± 0.12	0.003 ± 0.011
1999	ND	0.45 ± 0.25	ND	0.094 ± 0.20	0.890 ± 0.19	0.005 ± 0.008
2000	ND	0.21 ± 0.15	ND	0.018 ± 0.72	0.017 ± 0.73	0.004 ± 0.008
2001	ND	0.26 ± 0.39	ND	0.098 ± 0.33	0.110 ± 0.33	0.003 ± 0.004
2002	ND	0.21 ± 0.47	0.011 ± 0.079	0.032 ± 0.055	0.029 ± 0.33	-0.0004 ± 0.0007 ^(d)

(a) To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.

(b) ±2 standard deviations.

(c) ND = Not detected.

(d) Negative value indicates a result at or below background levels of radioactivity.

listed in Table 3.2.19. Complete listings of radionuclide concentrations and sampling location maps are provided in PNNL-14295, APP. 2.

3.2.5 EXTERNAL RADIATION

External radiation fields were monitored near facilities and waste handling, storage, and disposal sites to measure and assess the impact of operations. Thermoluminescent dosimeters were used at numerous fixed locations to gather dose rate information over longer periods of time. Thermoluminescent dosimeter results were used individually or averaged to determine dose rates in a given area for a particular sampling period. A summary of the 2001 and 2002 thermoluminescent dosimeter results for waste

handling facilities can be found in Table 3.2.20. Individual thermoluminescent dosimeter results and locations are provided in PNNL-14295, APP. 2. Specific information regarding external radiation sampling methods and locations can be found in DFSNW-OEM-001. Dose rate information for Hanford perimeter locations can be found in Section 4.6.

Environmental thermoluminescent dosimeters measure dose rates from all types of external radiation sources. These sources include cosmic radiation, naturally occurring radioactivity in air and soil, and fallout from past nuclear weapons testing, as well as any contribution from Hanford Site activities. These outside radiation sources are not constant and may cause an estimated 20% deviation in thermoluminescent dosimeter results.

Table 3.2.19. Concentrations of Selected Radionuclides (pCi/g^(a) dry wt.) in Vegetation Samples Collected from the 300/400 Areas on the Hanford Site, 2002

	⁶⁰ Co	⁹⁰ Sr	¹³⁷ Cs	²³⁴ U	²³⁵ U	²³⁸ U	^{239/240} Pu
Maximum	ND ^(c)	0.88 ± 0.18	0.011 ± 0.079 ^(b,d)	0.12 ± 0.03	0.0087 ± 0.006	0.13 ± 0.032	-0.00036 ± 0.00072 ^(b,d)
Average ^(e)	ND	0.21 ± 0.47	0.011 ± 0.079 ^(b,d)	0.032 ± 0.055	0.0038 ± 0.0065	0.029 ± 0.058	-0.00036 ± 0.00072 ^(b,d)
Distant community ^(e,f)	NR ^(g)	0.066 ± 0.059	0.0022 ± 0.034	NR	NR	ND	0.00078 ± 0.0016

- (a) To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.
(b) ± total analytical uncertainty.
(c) ND = Not detected.
(d) Single value above detection limit.
(e) ±2 standard deviations.
(f) PNNL-13910.
(g) NR = Not reported.

Table 3.2.20. Thermoluminescent Dosimeter Results (mrem/yr)^(a) for Waste Handling Facilities on the Hanford Site, 2001 and 2002, Based on 24 hours/day

Area	No. of Locations, 2002	2001		2002		% Change ^(c)
		Maximum	Mean ^(b)	Maximum	Mean ^(b)	
100-B/C	5	93	87 ± 8.0	93	86 ± 9.0	0
100-F	5	90	85 ± 6.0	93	86 ± 8.8	1
100-K	11	410	125 ± 200	440	129 ± 210	5
100-KR-1	5	NA ^(d)	NA	110	96 ± 19	NA
100-N	14	980	310 ± 480	1,042	274 ± 540	-12
200-East	42	400	120 ± 120	290	113 ± 96	-1
200-West	24	173	100 ± 50	220	108 ± 64	5
212-R						
(200-North)	1	2,500	2,300 ± 870	3,400	3,200 ± 800	38
300	8	170	110 ± 64	130	99 ± 38	-7
300 TEDF ^(e)	6	90	85 ± 5.8	88	85 ± 4.0	1
400	7	83	81 ± 2.6	86	82 ± 5.0	1
CVDF ^(f)	4	80	77 ± 5.0	83	79 ± 5.6	3
ERDF ^(g)	3	110	100 ± 23	95	90 ± 10	-10

- (a) To convert to international metric system units, multiply mrem/yr by 0.01 to obtain mSv/yr.
(b) ±2 standard deviations.
(c) Numbers indicate a decrease (-) or increase from the 2001 mean.
(d) NA = Not applicable.
(e) TEDF = 300 Area Treated Effluent Disposal Facility.
(f) CVDF = Cold Vacuum Drying Facility.
(g) ERDF = Environmental Restoration Disposal Facility.

Near-facility monitoring uses the Harshaw thermoluminescent dosimeter system, which includes the Harshaw 8807 dosimeter and the Harshaw 8800 reader. The packaging, which uses an O-ring seal, protects the dosimeter from light, heat, moisture, and dirt. The thermoluminescent dosimeters were placed 1 meter (3.3 feet) above the ground near facilities, active and inactive surface-water disposal sites, and remedial action projects. The dosimeters were exchanged and analyzed

each calendar quarter. The Radiological Calibration Facility in the 318 Building (300 Area) calibrates the response of the chips; results are reported in terms of external dose.

In 2002, there were 135 near-facility thermoluminescent dosimeter locations collecting external radiation information. At three of the operational areas, the dosimeter results showed a decrease of 7% or more in external radiation from 2001 levels. At one location (212-R Railroad

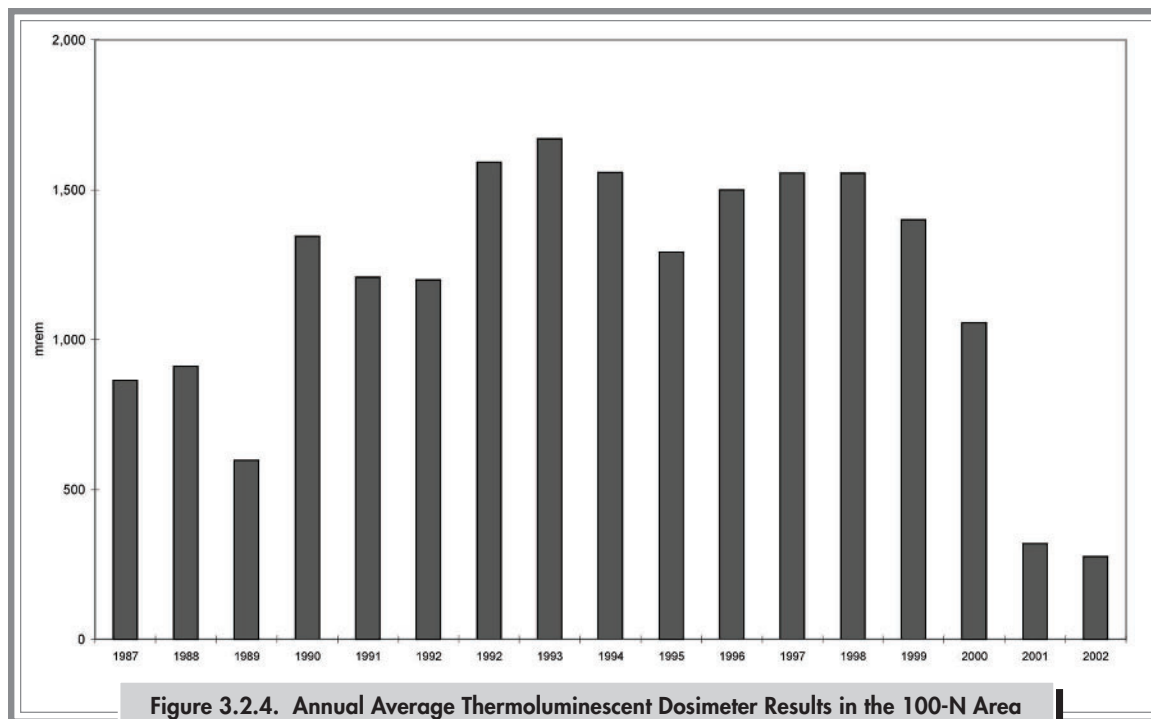
Car Disposition Area in the 200-North Area), there was a 38% increase in the amount of radiation detected due to the receipt and/or re-arrangement of contaminated railroad cars in the vicinity. At the remaining operational areas, changes in the external radiation levels were 5% or less.

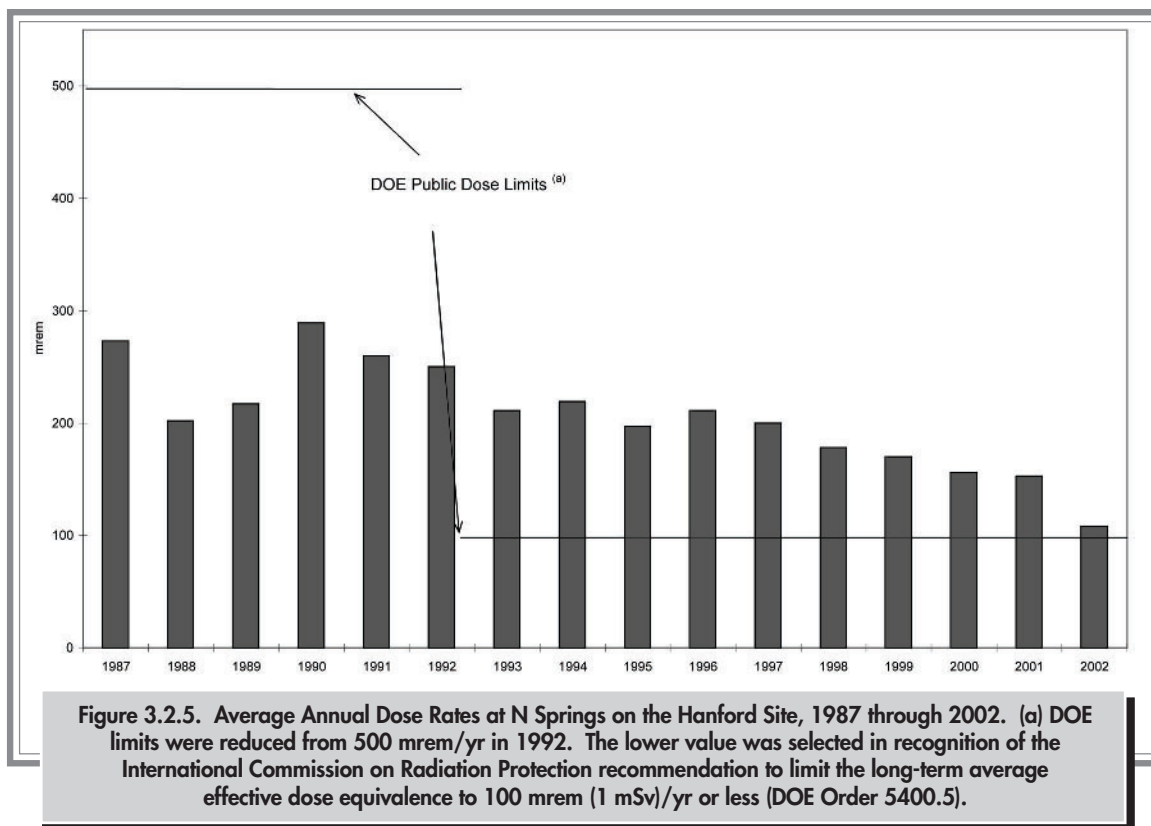
At the former 116-B-11 and 116-C-1 liquid waste disposal facilities (located in the 100-B/C Area), five thermoluminescent dosimeter sites monitored dose rates in 2002. In the 100-F Area, five thermoluminescent dosimeter monitoring sites were used. During 2002, dose rates measured in these areas were comparable to those measured in 2001.

Cleanup activities at the 100-K Fuel Storage Basins and adjacent retired reactor buildings in the 100-K Area continue to be monitored. Dose rates in this area in 2002 slightly increased by 5% relative to 2001 values. For the same reason, the four thermoluminescent dosimeter monitoring sites around the Cold Vacuum Drying Facility also showed an annual dose rate increase of 3% in 2002. Five new thermoluminescent dosimeters were installed during the fourth quarter of 2002 to monitor activities at the 100-KR-1 remedial action site.

The 2002 results for the 100-N Area indicate that direct radiation levels are highest near facilities that contained or received liquid effluent from N Reactor. These facilities primarily include the retired 116-N-1 and 116-N-3 liquid waste disposal facilities. The results for these two facilities were noticeably higher than those for other 100-N Area thermoluminescent dosimeter locations, but were significantly lower than dose levels measured at these locations in 2001. This reduction was directly attributable to the removal of source material from the facilities by the environmental restoration contractor. Overall, the average dose rate measured in the 100-N Area in 2002 was ~12% lower than that measured in 2001 and ~75% lower than that measured in 2000. Annual average thermoluminescent dosimeter results for the entire 100-N Area from 1987 through 2002 are presented in Figure 3.2.4.

Dose rates were measured at the N Springs shoreline to determine potential external radiation doses to the public as well as to onsite workers. Because of the cleanup at the liquid waste disposal facilities, the “skyshine” effect (i.e., radiation reflected by the atmosphere back to the earth’s surface) at the N Springs shoreline continued to decrease during 2002 (see Figure 3.2.5 for annual averages since 1987).





The highest dose rates in the 200 Areas were measured near waste handling facilities. The location within the 200 Areas exhibiting the highest dose rate was at the AZ Tank Farm in the 200-East Area. The average annual dose rate measured in 2002 in the 200 Areas was slightly lower than the average 2001 measurement. The annual average thermoluminescent dosimeter results from 1987 through 2002 are presented in Figure 3.2.6.

This is the seventh year that thermoluminescent dosimeters have been placed at the Environmental Restoration Disposal Facility to evaluate dose rates during ongoing activities. Dose rates measured in 2002 were ~10% lower than the 2001 results.

The highest dose rates in the 300 Area in 2002 were measured near the retired 316-3 process trench. The average dose rates measured in 2002 in the 300 Area, at the 300 Area Treated Effluent Disposal Facility, and in the 400 Area were similar to those measured in 2001. The annual average thermoluminescent dosimeter results for the 300 and 400 Areas from 1991 through 2002 are presented in Figure 3.2.7.

One thermoluminescent dosimeter monitoring site is located in the 200-North Area at the (contaminated) 212-R Railroad Car Disposition Area. This thermoluminescent dosimeter location was established in 2000 to monitor expected high radiation levels emitted from contaminated railroad cars staged in the immediate vicinity. The annual average dose rate at 212-R Railroad Car Disposition Area in 2002 showed an increase of 38% compared to 2001. Dose rates measured at this location exceed the DOE annual external dose limit to the members of the public; however, no member of the public, or Hanford worker, would conceivably spend an entire year at this location.

3.2.6 INVESTIGATIVE SAMPLING

Investigative sampling was conducted in the operational areas to monitor the presence or movement of radioactive and/or hazardous materials around areas of known or suspected contamination or to verify radiological conditions at specific project sites. Investigative sampling took place

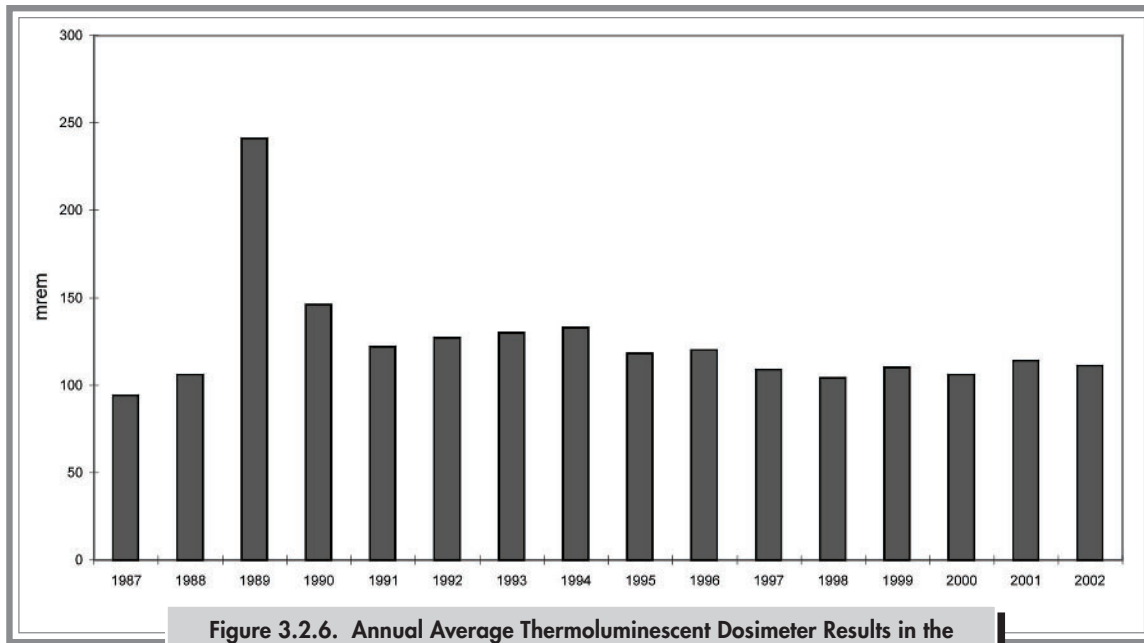


Figure 3.2.6. Annual Average Thermoluminescent Dosimeter Results in the 200 Areas on the Hanford Site, 1987 through 2002

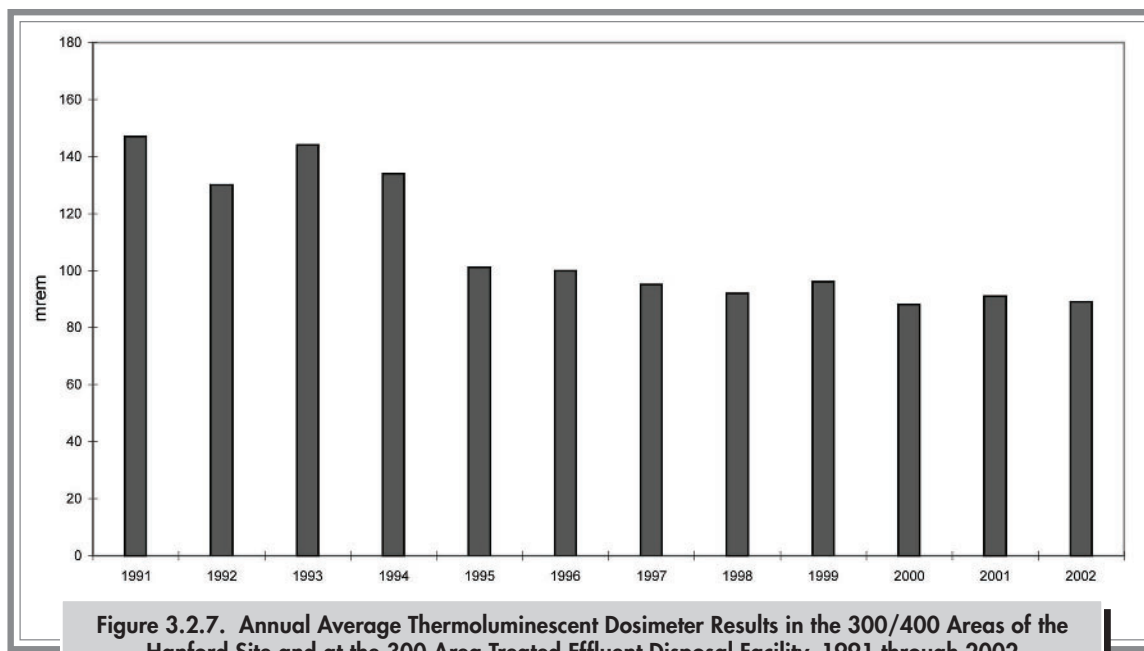


Figure 3.2.7. Annual Average Thermoluminescent Dosimeter Results in the 300/400 Areas of the Hanford Site and at the 300 Area Treated Effluent Disposal Facility, 1991 through 2002

near facilities such as storage and disposal sites for at least one of the following reasons:

- to follow up radiological surface surveys that had indicated radioactive contamination was present
- to conduct pre-operational surveys to characterize the radiological/chemical conditions at a site before facility construction, operation, or ultimate remediation
- to determine if biotic intrusion (e.g., animal burrows or deep-rooted vegetation) had created a potential for contaminants to spread
- to determine the integrity of waste containment systems

Generally, the predominant radionuclides discovered during these efforts were strontium-90, cesium-137, and

plutonium-239/240 in the 100 and 200 Areas and uranium-234, uranium-235, and uranium-238 in the 300 Area.

Investigative samples collected in 2002 included soil, vegetation, animals, animal feces, and water. Methods for collecting investigative samples are described in DFSNW-OEM-001. Field monitoring was conducted to detect beta/gamma and alpha radiation from samples before they were submitted for analysis. Field monitoring results are expressed as disintegrations per minute per 100 square centimeters. Beta/gamma radiation field surveys were conducted with a Geiger-Müller detector, while alpha radiation field surveys were performed with a portable alpha meter.

In 2002, investigative samples were analyzed for radionuclides at either the 222-S laboratory in the 200-West Area or at the Severn Trent Laboratories, Inc. in Richland, Washington. See Table 3.2.21 for a summary of historical investigative sample collections. Typically, there are numerous contaminated investigative environmental samples that are field screened and disposed of without isotopic analyses each year. In 2002, there were 55 of these. Laboratory analyses results and field readings are provided in PNNL-14295, APP. 2, Chapter 7.

During 2002, there were 22 instances of radiological contamination in investigative soil samples. Of the 22, 16 were identified as speck or soil speck contamination.

None of the investigative soil samples were submitted for radioisotopic analysis. Thirteen of the 16 locations were cleaned up, and the contaminated soil was disposed of in low-level burial grounds. At the remaining sites, the contamination levels did not exceed limitations of the posting and the soil was left in place.

The number of investigative soil contamination incidents, range of radiation dose levels, and radionuclide concentrations in 2002 were generally within historical values (WHC-MR-0418). Areas of special soil sampling that were found outside radiological control areas and that had dose rate levels greater than radiological control limits were cleaned up or posted as surface contamination areas.

During 2002, there were 16 instances of radiological contamination in investigative vegetation samples. All were identified as tumbleweeds (Russian thistle [*Salsola kali* var. *tenuifolia*] or tumbleweed fragments and none were analyzed for radionuclide activity. One sample, collected on the Liquid Effluent Retention Facility transfer line at the 242-A evaporator in the 200-East Area, exhibited elevated field readings. Investigative vegetation samples not sent to the laboratory for analysis were disposed of in low-level burial grounds.

Tumbleweed and gray rabbitbrush (*Chrysothamnus nauseosus*) are deep-rooted species and become radiologically contaminated by the uptake of below ground contaminants through their root systems. Herbicide application is intended to halt vegetation growth before this uptake occurs. During 2002, application techniques were improved, and administrative procedures were implemented to improve vegetation management. The reduced number of incidents (16) during 2002 appears to reflect these improvements. Nevertheless, contaminated vegetation continued to be identified by radiological surveys. However, as "old" contaminated vegetation from past years is identified and cleaned up, subsequent years should show the results of program improvements.

Investigative wildlife samples were collected directly from or near facilities to monitor and track the effectiveness of measures designed to deter animal intrusion. Samples were collected either as part of an integrated pest management program designed to limit the access of animals to radioactive materials, or as a result of finding radiologically

Table 3.2.21. Investigative Samples Collected on the Hanford Site, 1994 through 2002^(a)

<u>Year</u>	<u>Sample Type</u>		
	<u>Soil</u>	<u>Vegetation</u>	<u>Wildlife^(b)</u>
1994	94	39	27
1995	73	39	25
1996	37	21	41
1997	51	46	30
1998	41	51	55
1999	42	85	16
2000	25	66	12
2001	20	31	10
2002	22	16	10

(a) Annual number of samples collected.

(b) May include wildlife-related materials (e.g., feces, nests, etc.)

contaminated wildlife-related material (e.g., feces, nests) during radiation surveys.

Radiological surveys were performed after the collection of wildlife to determine whether an animal was radioactively contaminated. If a live animal was found to be free of contamination, it was taken to an area of suitable habitat, still in a controlled area, and released. If an animal was contaminated, a decision was made based on the level of contamination, location, and frequency of occurrence either to collect the animal as a sample or to dispose of the animal in a low-level burial ground. The number of contaminated animals discovered during 2002, and their levels and ranges of radioactivity were within historical levels (WHC-MR-0418).

In 2002, ten contaminated wildlife and wildlife-related incidents were investigated and from these, three wildlife specimens were surgically transitioned into nine samples that were submitted for laboratory analysis. The analytical results obtained from each of these can be found in PNNL-14295, APP. 2, Table 7-1. The number of samples submitted for analysis depended on opportunity (i.e., resulting from the pest control activities), the technical merits of having isotopic analyses results, and the analytical budget, rather than prescheduled sampling at established sampling points.

In February 2002, a contaminated starling carcass was found in the ductwork in the 222-S laboratory. Contaminants included strontium-89/90 and cesium-137.

In March 2002, a feral canine that had been seen entering several radiologically-controlled waste sites was captured at the 100-N Area. Contaminants included strontium-89/90 and uranium.

In August 2002, near a metal storage building at the 212-R Railroad Car Disposition Area in the 200-North Area, a contaminated bushy-tailed wood rat and its nest were discovered in a Manitowoc Crane. Significant levels of strontium-89/90 and cesium-137 were measured in the wood rat samples. No samples from the nest were collected. The wood rat samples represented the maximum radionuclide concentrations observed in investigative wildlife samples during 2002.

During December 2002, the Manitowoc Crane was moved to the 218-W-3AE burial ground to offload incoming waste for disposal. While stored in the adjacent radiological material storage area, feces from the contaminated wood rat were discovered. The feces were collected and sent in for laboratory analysis. Contaminants included strontium-89/90 and cesium-137.

During 2002, there was one water sample collected and submitted to the laboratory for analysis. The sample was identified while investigating the source of contamination for the wood rat, and standing water was discovered in a cut off pipe at the abandoned 212-R pumphouse. Although no contamination was evident in the water using field instruments, the laboratory gamma energy analysis of the sample revealed a measurable level of cesium-137.

There were seven cases of contaminated wildlife or related samples found during cleanup operations that were not submitted to a laboratory for analysis. These samples included a beetle, housefly, mouse, and mouse feces.

Special characterization projects conducted or completed during 2002 to ascertain the radiological status, and in some cases, physical condition of specific sites or operations included the projects listed below:

- Deep-rooted vegetation, big sagebrush and rabbitbrush were collected on top of and along the perimeter of the State-Approved Land Disposal Site structure (616-A crib in the 200-West Area) to determine the concentrations of tritium being transported through the plant medium. The results of this sampling can be found in PNNL-14295, APP. 2, Table 7-1.
- A pre-operational monitoring plan (RPP-6877) was developed to support the Waste Vitrification Initiative. As part of this plan, a survey is being conducted on the proposed location for the Integrated Disposal Site in the 200-East Area. Tasks completed in 2002 included radiological and ground penetrating radar surveys and surface and subsurface soil sampling to a depth of 15 meters (50 feet). These tasks were performed at three locations within the footprint of disposal trench 1. Following the completion of all the tasks outlined in the monitoring plan, the obtained data will be published in a final report.



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4.0 ENVIRONMENTAL SURVEILLANCE INFORMATION

R. W. Hanf and L. E. Bisping

The following sections describe results of the Hanford Site Surface Environmental Surveillance and Drinking Water Surveillance Projects for 2002 and include, where applicable, information on both radiological and non-radiological constituents. The objectives, criteria, design, and description of these projects are summarized below and provided in detail in the Hanford Site environmental monitoring plan (DOE/RL-91-50). Radiological doses associated with the surveillance results are discussed in Chapter 5. The quality assurance and quality control programs developed to assure the value of surveillance data are described in Chapter 9.

Many samples are collected and analyzed for the Hanford Site environmental surveillance project, and the resulting data are compiled in a large database (Hanford Environmental Information System [HEIS 1994]). Only summary information is reported here emphasizing those radionuclides and chemicals of Hanford Site origin that are important to the environment or human health and safety. Supplemental data for some sections can be found in Appendix B. More detailed results for specific surface environmental surveillance sampling locations are contained in *Hanford Site Environmental Surveillance Data Report for Calendar Year 2002* (PNNL-14295, APP. 1). The intent of these sections (4.1 through 4.6) is to provide current surveillance data, to compare 2002 data to past data and appropriate standards, and to present a general overview of Hanford Site surveillance activities.

In addition to Hanford Site environmental surveillance, environmental monitoring is conducted at or near facilities on the site. These near-facility monitoring efforts are discussed in Section 3.2 of this report.

4.0.1 SURFACE ENVIRONMENTAL SURVEILLANCE

The Pacific Northwest National Laboratory's Surface Environmental Surveillance Project measures the concentrations of radionuclides and chemicals in environmental media and assesses the potential effects of these materials on the environment and the public. Samples of agricultural products, air, fish, sediment, soil, surface water, vegetation, and wildlife are collected routinely or periodically. The samples are then analyzed for radionuclides, at very low environmental levels, and chemicals, including metals and anions. In addition, ambient external radiation is measured.

The project focuses on routine releases from U.S. Department of Energy (DOE) facilities on the Hanford Site; however, the project also responds to unplanned releases and releases from non-DOE operations on and near the site. Surveillance results are provided to DOE and the public annually through this report series. Unusually high results are reported to the DOE Richland Operations Office and the appropriate facility managers when they occur. Whereas effluent and near-facility environmental monitoring are conducted by the facility operating contractor or designated subcontractor, environmental surveillance is conducted under an independent program that reports directly to the DOE Richland Operations Office, Closure Division.

4.0.1.1 SURVEILLANCE OBJECTIVES

The general requirements and objectives for environmental surveillance are to monitor routine and non-routine

releases to the environment from DOE facilities, to assess doses to members of the public, and to monitor potential impacts to biota (DOE Orders 450.1 and 5400.5; DOE/EH-0173T).

The surveillance objectives include the following:

- Determining compliance with applicable environmental quality standards, public exposure limits, and applicable laws and regulations; the requirements of DOE Orders; and the environmental commitments made in environmental impact statements, environmental assessments, safety analysis reports, or other official DOE documents. Additional objectives include conducting pre-operational assessments, assessing radiological doses to the public and environment, assessing doses from other local sources, reporting alarm levels and potential doses exceeding reporting limits.
- Determining background levels and site contributions of contaminants in the environment.
- Determining long-term accumulation of site-related contaminants in the environment and predict trends.
- Characterizing and defining trends in the physical, chemical, and biological conditions of environmental media.
- Determining the effectiveness of treatment and controls in reducing effluent and emissions.
- Determining the validity and effectiveness of models to predict concentrations of pollutants in the environment.
- Detecting and quantifying unplanned releases.
- Identifying and quantifying new environmental quality problems.

Subsidiary objectives for surveillance should also be considered (DOE/EH-0173T). Subsidiary objectives applicable to the site include the following:

- Obtaining data and maintaining the capability to assess the consequence of accidents.
- Providing public assurance; addressing issues of concern to the public, stakeholders, regulators, and business community.
- Enhancing public understanding of site environmental issues, primarily through public involvement and by providing public information.
- Providing environmental data and assessments to assist the DOE in environmental management of the site.

4.0.1.2 SURVEILLANCE DESIGN

The DOE Orders require that the content of surveillance programs be determined on a site-specific basis by the DOE site offices. The surveillance programs must reflect facility characteristics; applicable regulations; hazard potential; quantities and concentrations of materials stored or released; extent and use of affected air, land, and water; and specific local public interests and concerns. Environmental surveillance at the Hanford Site is designed to meet the listed objectives while considering the environmental characteristics of the site and potential and actual releases from site operations, surface contamination areas, former waste disposal sites, current waste disposal and storage facilities, and ongoing remediation efforts. Knowledge gained from more than 50 years of environmental surveillance and studies at the Hanford Site provides valuable technical background information for planning the surveillance design and managing the site.

The Hanford Site environmental surveillance project historically focused on radionuclides in various media and non-radiological water quality parameters. However, surveillance for non-radiological constituents, including hazardous chemicals, in selected media is also conducted. A detailed chemical pathway and exposure analysis for the Hanford Site was completed during 1995 (PNL-10714). The analysis helped guide the selection of chemical surveillance media, sampling locations, and chemical constituents.

Each year, a radiological pathway analysis and exposure assessment is performed. The 2002 pathway analysis was based on 2002 source-term data and on the comprehensive pathway and dose assessment methods included in the Generation II (GENII) computer code (PNL-6584) used to estimate radiation doses to the public from Hanford Site operations. The Radiological-Biota Concentration Guide (RAD-BCG) Calculator, a spreadsheet program developed by DOE, was used to screen doses to animals. The results of the pathway analysis and exposure assessment (discussed in Chapter 5) serve as a basis for future years' surveillance program design.

Exposure is defined as the interaction of an organism with a physical or chemical agent of interest. Thus, exposure can be quantified as the amount of chemical or physical agent available for absorption or uptake at the organism's exchange boundaries (i.e., skin contact, lungs, gut). An exposure pathway is identified based on (1) examination of the types, location, and sources (contaminated soil, raw effluent) of contaminants; (2) principal release mechanisms; (3) probable environmental fate and transport (including persistence, partitioning, and intermediate transfer) of contaminants of interest; and, most important, (4) location and activities of the potentially exposed populations. Mechanisms that influence the fate and transport of a chemical through the environment and influence the amount of exposure a person might receive at various receptor locations are listed below.

Once a radionuclide or chemical is released into the environment, it may be:

- Transported (e.g., migrate downstream in solution or on suspended sediment, travel through the atmosphere, or be carried off the site by wildlife).
- Physically or chemically transformed (e.g., deposition, precipitation, volatilization, photolysis, oxidation, reduction, hydrolysis, or radionuclide decay).
- Biologically transformed (e.g., biodegradation).
- Accumulated in the receiving media (e.g., sorbed strongly in the soil column, stored in organism tissues).

The primary pathways for movement of radioactive materials and chemicals from the site to the public are the atmosphere and surface water. Figure 4.0.1 illustrates these and other potential routes and exposure pathways to humans.

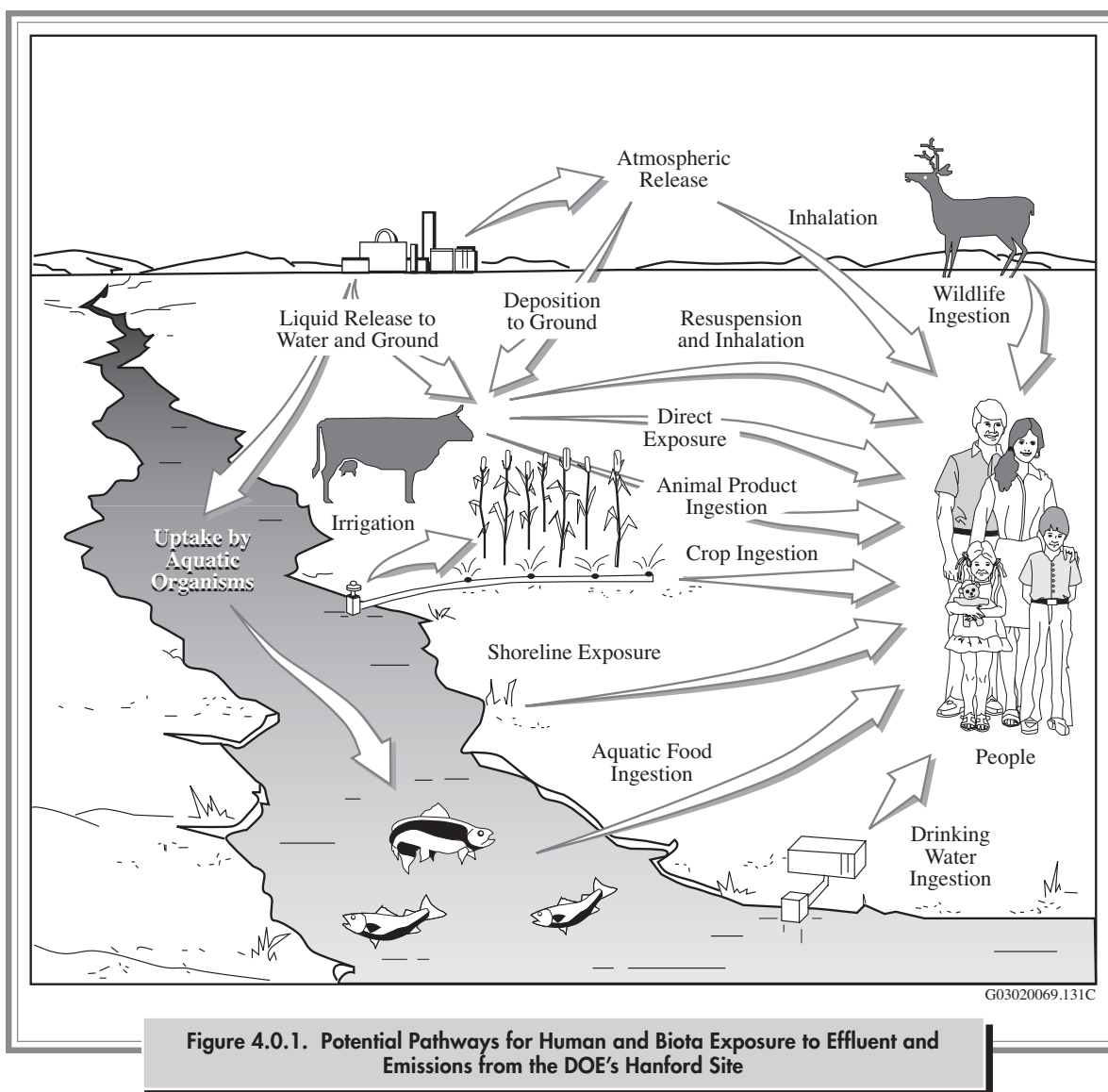
The significance of each pathway was determined from measurements and calculations that estimated the amount of radioactive material or chemical transported along each pathway and by comparing the concentrations or potential radiological doses to environmental and public health protection standards or guides. Pathways were also evaluated based on prior studies and observations of radionuclide and chemical movement through the environment and food chains. Calculations based on effluent data showed the expected concentrations off the Hanford Site, for all Hanford-produced radionuclides and chemicals, to be frequently below the levels that could be detected by

monitoring technology. To assure that radiological and chemical analyses of samples were sufficiently sensitive, minimum detectable concentrations of key radionuclides and chemicals were established at levels well below applicable health standards.

Environmental pathways were monitored near site facilities, locations, or operations with the potential to release contaminants. Food chain pathways were monitored at potential offsite receptor locations. Samples were collected, and radionuclide and chemical concentrations were measured in three general surveillance zones that extended from onsite facilities and operations to the offsite environs.

The first surveillance zone extended from near operational areas to the site perimeter. Environmental concentrations of contaminants released from facilities and fugitive sources (those released from other than monitored sources such as contaminated soil) generally would be the highest and, therefore, most easily detected in this zone. The second surveillance zone consisted of a series of perimeter sampling stations positioned near or just inside the site boundary, along State Highway 240, which runs through the site from Richland to the Yakima Barricade, and along the Columbia River (Figure 1.0.1). The third surveillance zone consisted of locations in and between communities within an 80-kilometer (50-mile) radius of the industrial areas on the site. Surveillance was conducted in communities to obtain measurements at locations where a large number of people potentially could be exposed to Hanford Site releases and to document that contaminant levels were well below standards established to protect public health. Table 4.0.1 lists the sample types and measurement locations in all three zones for 2002. A summary of the number and types of samples collected during 2002, and the number of analytical results obtained from those samples is provided in Table 4.0.2. Except for special studies, soil and vegetation samples are only collected every 3 to 5 years. Routine soil and vegetation samples were last collected in 2001.

Background concentrations were measured at distant locations and compared with concentrations measured on the site and at perimeter and community locations. Background locations were essentially unaffected by Hanford Site operations (i.e., these locations could be used to measure ambient environmental levels of chemicals and radionuclides). Comparing concentrations at these background



locations to concentrations measured on or near the site indicated the impact, if any, of Hanford Site operations.

To the extent possible, radiological dose assessments should be based on direct measurements of dose rates and radionuclide activities in environmental media. However, the amount of most radioactive materials released from operations on the Hanford Site in recent years generally have been too small to be measured directly once dispersed in the offsite environment. For the measurable radionuclides, often it was not possible to distinguish levels resulting from worldwide fallout and natural sources from those

associated with Hanford Site releases. Therefore, offsite doses during 2002 were estimated using the following methods:

- Doses from monitored air emissions and liquid effluent released to the Columbia River were estimated by applying environmental transport and dose calculation models to measured effluent monitoring data and selected environmental measurements.
- Doses from fugitive air emissions (e.g., from unmonitored, resuspended, contaminated soil) were estimated from measured airborne concentrations at site perimeter locations.

Table 4.0.1. Routine Environmental Surveillance Sample Types and Measurement Locations on and Around the Hanford Site in Washington State, 2002

<u>Type</u>	<u>Total Number</u>	<u>Sample Locations</u>						
		<u>Onsite^(a)</u>	<u>Site Perimeter^(b)</u>	<u>Nearby^(c)</u>	<u>Distant^(c)</u>	<u>Columbia River</u>		
						<u>Upstream^(c)</u>	<u>Hanford Reach^(b)</u>	<u>Downstream^(c)</u>
Air	45	24	11	8 ^(d)	2 ^(d)			
Spring water	8						8	
Spring sediment	6						6	
Columbia River water	7					2	4	1
Irrigation water	2		2					
Drinking water	4	4						
River sediment	6					1	3	2
Ponds	2	2						
Pond sediment	1	1						
Foodstuffs	7			5	2			
Wildlife	12	7				1	4	
External dose	80	33	38	7	2			
External shoreline radiation	14		14					
Exposure rate	4			3	1			

(a) Surveillance Zone 1 (near operational areas to the site perimeter).

(b) Surveillance Zone 2 (near or just inside the site boundary).

(c) Surveillance Zone 3 (in and between communities within an 80-kilometer (50-mile) radius of the site's industrial areas).

(d) Includes community-operated environmental surveillance stations.

Table 4.0.2. Samples Collected for the Hanford Site Surface Environmental Surveillance Project and Analytical Results Obtained, 2002

<u>Media</u>	<u>Number of Samples Collected</u>	<u>Number of Analytical Results Obtained</u>
Air	1,658	4,312
Biota	370	3,004
Soil and sediment	71	936
Surface water	426	4,039
Drinking water	20	69
External radiation	314	314
Totals	2,859	12,674

- Doses from unmonitored groundwater seeping into the Columbia River were estimated by evaluating differences in measured concentrations in Columbia River water upstream and downstream from the Hanford Site.

The surveillance design is reviewed annually based on the above considerations as well as an awareness of planned waste management and environmental restoration activities. The final sampling design and schedule are documented annually in the environmental surveillance master sampling schedule (e.g., PNNL-13749).



4.1 AIR SURVEILLANCE

B. G. Fritz

Atmospheric releases of radioactive material from the Hanford Site to the surrounding region are a potential source of human exposure. Radioactive constituents in air are monitored at a network of air sampling locations on and around the Hanford Site. Detailed descriptions of all routine radiological sampling and analytical techniques are provided in DOE, Richland Operations Office's environmental monitoring plan (DOE/RL-91-50). Comparing measured radionuclide concentrations from locations on and around the Hanford Site to upwind sites assumed to be uninfluenced by Hanford Site operations provides an evaluation of the impact of radionuclide air emissions from the Hanford Site on surrounding ambient air. A complete listing of all radiological analytical results summarized in this section is reported separately (PNNL-14295, APP. 1). Non-radiological, particulate air monitoring data are also summarized in Section 4.1.3.

4.1.1 COLLECTION OF AIR SAMPLES AND ANALYTES TESTED

Airborne radionuclide samples were collected at 45 continuously operating samplers. The sampling stations are grouped into four distance classes: onsite (24 stations), perimeter (11 stations), community (8 stations), and distant (2 stations) (Figure 4.1.1 and Table 4.1.1). Four of the stations were community-operated environmental surveillance stations (Section 8.4) that were managed and operated by local school teachers as part of an ongoing DOE-sponsored program to promote public awareness of Hanford Site environmental monitoring programs. Air samplers on the Hanford Site were located primarily around major operational areas to maximize the ability to detect radiological 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 (Section 8.1). Samplers located in

Basin City, Benton City, Kennewick, Mattawa, Othello, Pasco, and Richland, Washington, provided data for the nearest population centers. Samplers in Toppenish and Yakima, Washington, provided background data for communities essentially unaffected by Hanford Site operations.

Samples were collected according to a schedule established before the monitoring year (PNNL-13749). The air sampling locations and the analytes tested for at each location are given in Table 4.1.1. Airborne particle samples were collected biweekly at each of these locations by continuously drawing air through a high efficiency glass-fiber filter. The samples were transported to an analytical laboratory and stored for at least 72 hours. The storage period was necessary to allow for the decay of short-lived, naturally occurring radionuclides (e.g., radon gas decay products) that would otherwise obscure detection of longer-lived radionuclides potentially present from Hanford Site emissions. The filters were then analyzed for gross beta radiation. Selected filters were also analyzed for gross alpha radiation.

Historically, for most radionuclides, the amount of radioactive material collected on a filter during a 2-week period has been too small for accurate analysis. In order to increase the sensitivity and accuracy of the analysis, biweekly samples were combined into quarterly composite samples. The quarterly composite samples were analyzed for specific gamma-emitting radionuclides (Appendix F). Most composite samples were also analyzed for strontium-90, plutonium isotopes, and uranium isotopes.

Samples were collected for iodine-129 analysis at four locations by drawing air through a chemically treated, low-background petroleum-based charcoal adsorbent cartridge. Samples were collected monthly and combined to form quarterly composite samples for each location.

Atmospheric water vapor was collected for tritium analysis at 21 locations by continuously drawing air through columns containing adsorbent silica gel. The silica gel columns were

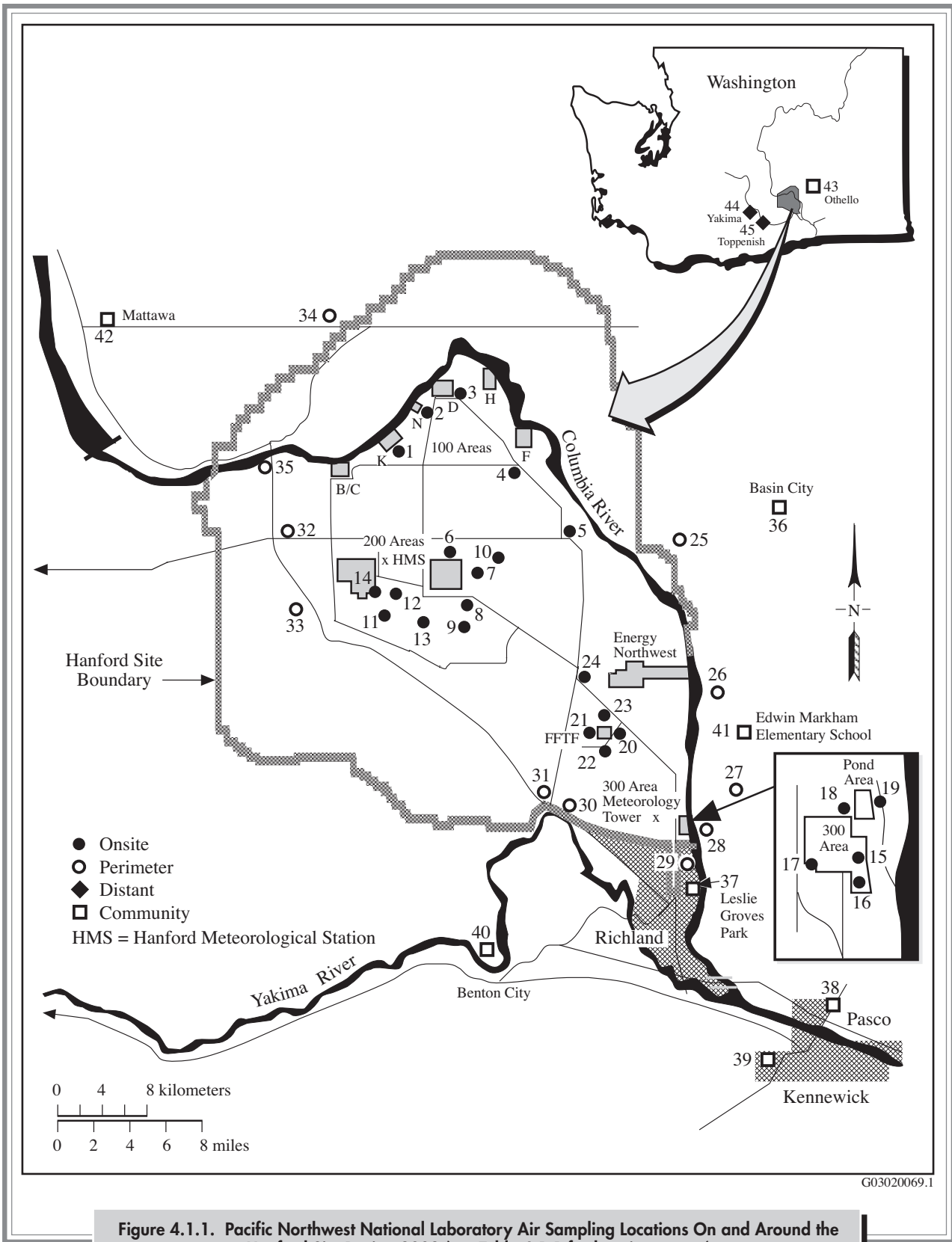


Figure 4.1.1. Pacific Northwest National Laboratory Air Sampling Locations On and Around the Hanford Site During 2002 (see Table 4.1.1 for location names)

Table 4.1.1. Pacific Northwest National Laboratory Air Sampling Locations On and Around the Hanford Site, Sample Composite Groups, and Analytes, 2002

<u>Map^(a) Location</u>	<u>Sampling Location</u>	<u>Analytes^(b)</u>	<u>Composite Group</u>	<u>Analytes^(c)</u>
Onsite				
1	100 K Area	Alpha, Beta, ³ H	100 Areas	Gamma, Sr, Pu
2	100 N-1325 Crib	Alpha, Beta, ³ H		
3	100 D Area	Alpha, Beta		
4	100 F Met Tower	Alpha, Beta	Hanford Townsite	Gamma, Sr, Pu
5	Hanford Townsite	Alpha, Beta		
6	N of 200 E	Beta	N of 200 E	Gamma
7	E of 200 E	Alpha, Beta	E of 200 E	Gamma, Sr, Pu, U
8	200 ESE	Alpha, Beta, ³ H, ¹²⁹ I	200 E Area	Gamma, Sr, Pu, U
9	S of 200 E	Alpha, Beta		
10	B Pond	Alpha, Beta	B Pond	Gamma, Sr, Pu, U
11	Army Loop Camp	Alpha, Beta	200 W South East	Gamma, Sr, Pu, U
12	200 Tel. Exchange	Alpha, Beta, ³ H		
13	SW of B/C Crib	Alpha, Beta		
14	200 W SE	Alpha, Beta	200 West	Gamma, Sr, Pu, U
15	300 Water Intake	Alpha, Beta, ³ H	300 Area	Gamma, Sr, Pu, U
16	300 South Gate	Alpha, Beta, ³ H		
17	300 South West	Alpha, Beta, ³ H		
18	300 Trench	Alpha, Beta, ³ H U, Gamma	300 NE	Sr, Pu
19	300 NE	Alpha, Beta, ³ H U, Gamma		
20	400 E	Alpha, Beta, ³ H	400 Area	Gamma, Sr, Pu
21	400 W	Alpha, Beta		
22	400 S	Alpha, Beta		
23	400 N	Alpha, Beta		
24	Wye Barricade	Alpha, Beta	Wye Barricade	Gamma, Sr, Pu, U
Perimeter				
25	Ringold Met Tower	Alpha, Beta, ³ H, ¹²⁹ I	Ringold Met Tower	Gamma, Sr, Pu
26	W End of Fir Road	Alpha, Beta	W End of Fir Road	Gamma, Sr, Pu, U
27	Dogwood Met Tower	Alpha, Beta, ³ H	Dogwood Met Tower	Gamma, Sr, Pu, U
28	Byers Landing	Alpha, Beta, ³ H, ¹²⁹ I	Byers Landing	Gamma, Sr, Pu, U
29	Battelle Complex	Alpha, Beta, ³ H	Battelle Complex	Gamma
30	Horn Rapids Substation	Alpha, Beta	Prosser Barricade	Gamma, Sr, Pu, U
31	Prosser Barricade	Alpha, Beta, ³ H		
32	Yakima Barricade	Alpha, Beta	Yakima Barricade	Gamma, Sr, Pu
33	Rattlesnake Springs	Alpha, Beta		
34	Wahluke Slope	Alpha, Beta, ³ H	Wahluke Slope	Gamma, Sr, Pu
35	S End Vernita Bridge	Alpha, Beta		

Table 4.1.1. (contd)

Map^(a) Location	Sampling Location	Analytes^(b)	Composite Group	Analytes^(c)
Nearby Communities				
36	Basin City School ^(d)	Alpha, Beta, ³ H	Basin City School	Gamma, Sr, Pu, U
37	Leslie Groves-Rchlnd ^(d)	Alpha, Beta, ³ H	Leslie Groves-Rchlnd	Gamma, Sr, Pu, U
38	Pasco	Beta	Tri-Cities	Gamma, Sr, Pu
39	Kennewick	Alpha, Beta		
40	Benton City	Beta	Benton City	Gamma
41	Edwin Markham School ^(d)	Alpha, Beta, ³ H	Edwin Markham School	Gamma, Sr, Pu, U
42	Mattawa	Beta	Mattawa	Gamma
43	Othello	Beta	Othello	Gamma
Distant Communities				
44	Yakima	Alpha, Beta, ³ H, ¹²⁹ I	Yakima	Gamma, Sr, Pu, U
45	Toppenish ^(d)	Alpha, Beta, ³ H	Toppenish	Gamma, Sr, Pu, U

(a) See Figure 4.1.1.

(b) Alpha (gross) and beta (gross) samples are collected and analyzed every 2 weeks, ³H samples are collected and analyzed every 4 weeks, and ¹²⁹I samples are collected every 4 weeks, combined into a quarterly composite sample and analyzed for each location.

(c) Gamma spectroscopy, strontium-90, isotopic plutonium (²³⁸Pu, ^{239/240}Pu), and isotopic uranium (²³⁴U, ²³⁵U, ²³⁸U) analyses are performed on quarterly composite samples.

(d) A community-operated environmental surveillance station.

exchanged every 4 weeks to prevent loss of sample as a result of breakthrough. The collection efficiency of the silica gel adsorbent is discussed in Patton et al. (1997). The collected water was distilled from the silica gel and analyzed for its tritium content.

The samples collected at the community-operated environmental surveillance stations were submitted to the analytical laboratory and treated the same as all other submitted samples.

4.1.2 RADIOLOGICAL RESULTS FOR AIR SAMPLES

Radiological air sampling results for onsite, site perimeter, nearby communities, and distant communities for gross alpha, gross beta, and specific radionuclides are summarized in Table 4.1.2.

A detectable value is defined in this section as a value reported above the minimum detectable level and above the total propagated analytical uncertainty. A nominal detection limit is defined as the average total propagated analytical uncertainty of the population of reported values.

During 2002, the average onsite gross alpha concentration was higher than the average concentration measured at the distant location. However, the difference was not statistically significant. The highest average gross alpha concentration was observed at the community locations. Again, there was no statistically significant difference between the average concentrations observed at the community and distant locations. The average gross alpha concentrations from 1997 through 2001 were slightly higher than the average concentrations observed during 2002 (Table 4.1.2).

Gross beta concentrations in air peaked during the winter months of 2002 (Figure 4.1.2), repeating a pattern of natural radioactivity fluctuations (Eisenbud 1987). The annual average gross beta concentration during 2002 was slightly

Table 4.1.2. Airborne Radionuclide Concentrations in the Environs of the Hanford Site, 2002 Compared to Previous Years

Radionuclide	Location Group ^(a)	2002				1997-2001				Derived Concentration Guide ^(e)
		No. of Samples	No. of Detections ^(b)	Maximum ^(c)	Average ^(d)	No. of Samples	No. of Detections ^(b)	Maximum ^(c)	Average ^(d)	
				pCi/m ^{3(f)}	pCi/m ^{3(f)}			pCi/m ^{3(f)}	pCi/m ^{3(f)}	
Tritium	300 Area	75	75	15 ± 2.2	5.1 ± 5.1	321	272	25 ± 3.0	3.9 ± 7.5	100,000
	Onsite	65	60	15 ± 1.3	3.3 ± 5.3	318	184	13 ± 1.9	1.8 ± 3.0	
	Perimeter	77	66	23 ± 2.1	4.4 ± 8.9	333	173	36 ± 3.6	2.1 ± 6.1	
	Nearby communities	39	35	33 ± 2.9	4.1 ± 11	186	107	15 ± 1.3	2.2 ± 5.1	
	Distant communities	25	15	6.4 ± 1.5	2.2 ± 3.4	127	47	7.9 ± 1.1	1.3 ± 2.6	
Gross beta	Onsite	631	631	0.069 ± 0.011	0.016 ± 0.021	2,855	2,848	0.084 ± 0.014	0.015 ± 0.017	No standard
	Perimeter	290	289	0.074 ± 0.012	0.015 ± 0.021	1,214	1,214	0.070 ± 0.011	0.015 ± 0.016	
	Nearby communities	208	208	0.056 ± 0.0094	0.015 ± 0.021	1,050	1,049	0.053 ± 0.0088	0.016 ± 0.017	
	Distant communities	53	53	0.054 ± 0.0093	0.015 ± 0.022	282	281	0.059 ± 0.010	0.014 ± 0.016	
				aCi/m ^{3(g)}	aCi/m ^{3(g)}			aCi/m ^{3(g)}	aCi/m ^{3(g)}	
Gross alpha	Onsite	631	374	2,600 ± 1,100	490 ± 790	3,332	2,181	5,500 ± 1,300	600 ± 880	No standard
	Perimeter	290	182	1,900 ± 790	470 ± 750	1,430	985	5,100 ± 1,300	600 ± 880	
	Nearby communities	104	63	1,800 ± 1,000	500 ± 780	663	457	6,300 ± 1,700	670 ± 1,000	
	Distant communities	53	27	1,600 ± 680	400 ± 860	333	200	5,500 ± 1,900	570 ± 1,000	
Strontium-90	Onsite	44	9	1,300 ± 280	44 ± 410	139	34	340 ± 130	26 ± 110	9,000,000
	Perimeter	28	0	58 ± 41	-4.4 ± 59	98	15	390 ± 79	17 ± 99	
	Nearby communities	16	0	54 ± 67	3.5 ± 71	56	7	220 ± 190	23 ± 98	
	Distant communities	8	1	300 ± 100	40 ± 210	28	2	79 ± 37	0.16 ± 88	
Iodine-129	Onsite	4	4	2.2 ± 2.5	18 ± 6.4	20	20	32 ± 2.9	20 ± 12	70,000,000
	Perimeter	8	8	0.87 ± 0.096	0.40 ± 0.63	40	40	1.5 ± 0.12	0.64 ± 0.72	
	Distant communities	4	4	0.059 ± 0.0081	0.048 ± 0.016	20	20	0.22 ± 0.015	0.058 ± 0.090	
Plutonium-238	Onsite	44	3	4.3 ± 7.1	0.19 ± 1.8	139	5	5.3 ± 1.7	-0.038 ± 1.6	30,000
	Perimeter	28	0	1.6 ± 1.6	-0.023 ± 1.2	98	1	1.9 ± 1.4	-0.18 ± 0.85	
	Nearby communities	16	0	2.2 ± 3.2	0.010 ± 1.8	56	0	1.5 ± 1.8	-0.15 ± 1.1	
	Distant communities	8	0	0.37 ± 1.8	-0.26 ± 0.65	28	0	0.31 ± 1.8	-0.36 ± 0.72	
Plutonium-239/240	Onsite	44	7	8.7 ± 2.8	1.1 ± 4.6	139	48	36 ± 6.4	1.5 ± 7.8	20,000
	Perimeter	28	0	1.1 ± 1.8	0.025 ± 1.2	98	10	5.2 ± 2.5	0.48 ± 1.9	
	Nearby communities	16	2	2.1 ± 1.2	0.43 ± 1.6	56	4	1.7 ± 2.3	0.35 ± 1.1	
	Distant communities	8	0	2.4 ± 3.0	0.46 ± 2.0	28	1	3.2 ± 2.9	0.29 ± 1.8	

Table 4.1.2. (contd)

Radionuclide	Location Group ^(a)	2002				1997-2001				Derived Concentration Guide ^(e)
		No. of Samples	No. of Detections ^(b)	Maximum ^(c)	Average ^(d)	No. of Samples	No. of Detections ^(b)	Maximum ^(c)	Average ^(d)	
				aCi/m ^{3(g)}	aCi/m ^{3(g)}			aCi/m ^{3(g)}	aCi/m ^{3(g)}	
Uranium-234	Onsite	36	36	150 ± 44	30 ± 56	113	107	85 ± 21	21 ± 32	90,000
	Perimeter	16	16	87 ± 16	32 ± 37	56	56	140 ± 32	29 ± 43	
	Nearby communities	12	12	58 ± 18	27 ± 25	42	41	54 ± 17	25 ± 26	
	Distant communities	8	8	33 ± 11	33 ± 20	28	27	41 ± 15	17 ± 17	
Uranium-235	Onsite	36	0	4.0 ± 4.7	0.40 ± 3.4	113	8	3.7 ± 2.7	0.44 ± 2.3	100,000
	Perimeter	16	0	3.8 ± 3.8	0.56 ± 2.5	56	4	6.0 ± 6.0	0.77 ± 2.9	
	Nearby communities	12	0	4.6 ± 6.4	0.64 ± 3.9	42	3	6.2 ± 5.6	0.63 ± 3.8	
	Distant communities	8	0	3.1 ± 4.3	-0.54 ± 4.1	28	0	7.0 ± 9.3	0.41 ± 3.7	
Uranium-238	Onsite	36	36	120 ± 47	27 ± 46	113	102	92 ± 27	20 ± 32	100,000
	Perimeter	16	16	74 ± 20	31 ± 38	56	54	140 ± 32	27 ± 42	
	Nearby communities	12	12	46 ± 14	27 ± 18	42	40	56 ± 18	24 ± 26	
	Distant communities	8	8	28 ± 19	18 ± 13	28	28	33 ± 15	16 ± 15	
Cobalt-60	Onsite	52	0	1,700 ± 2,700	67 ± 680	238	1	3,800 ± 2,500	100 ± 890	80,000,000
	Perimeter	32	0	610 ± 690	90 ± 560	163	0	1,000 ± 530	0.62 ± 840	
	Nearby communities	28	0	1,100 ± 690	210 ± 610	130	0	1,800 ± 3,600	33 ± 920	
	Distant communities	8	0	700 ± 600	180 ± 610	44	0	650 ± 490	84 ± 530	
Cesium-137	Onsite	52	0	450 ± 540	-44 ± 810	238	1	710 ± 530	3.4 ± 490	400,000,000
	Perimeter	32	0	810 ± 530	60 ± 460	163	0	1,200 ± 2,000	27 ± 630	
	Nearby communities	28	0	500 ± 460	27 ± 530	130	0	2,100 ± 3,100	26 ± 700	
	Distant communities	8	0	530 ± 520	100 ± 770	44	0	400 ± 510	9.0 ± 520	

(a) Location groups are identified in Table 4.1.1.

(b) Detection is defined as a value reported above the minimum detectable activity and above the total propagated analytical uncertainty.

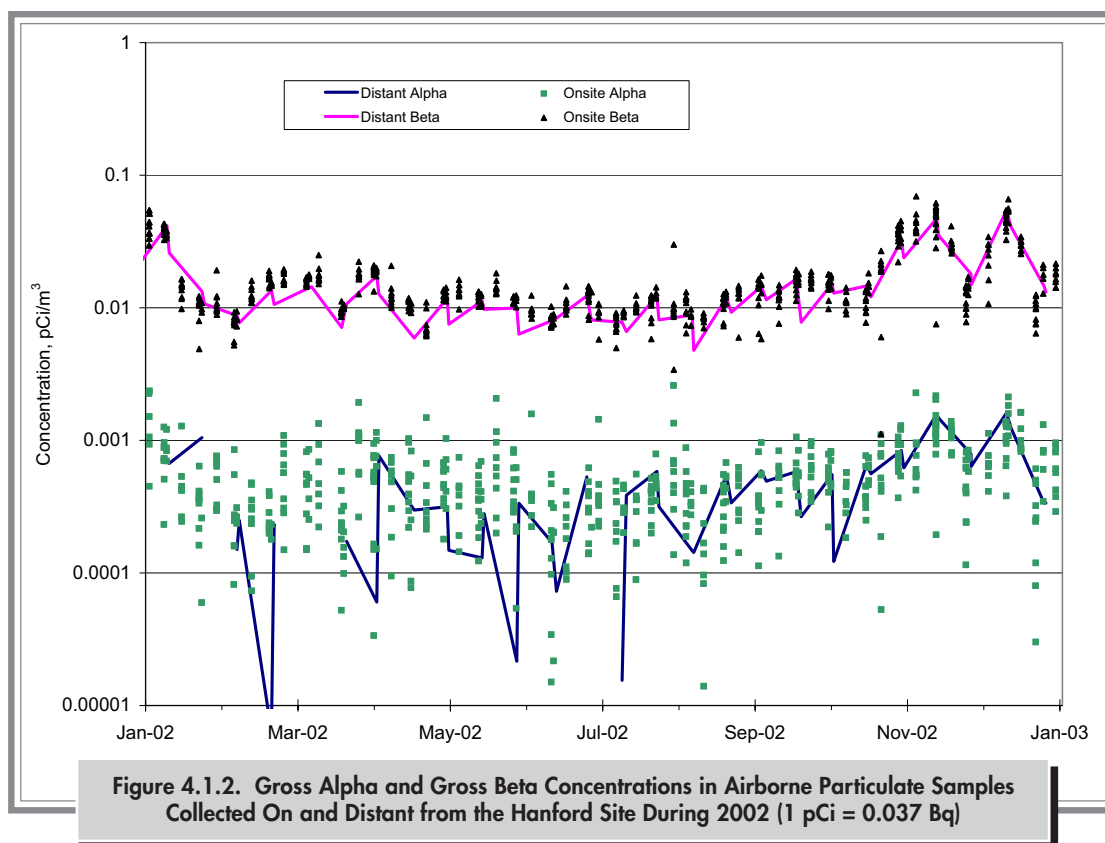
(c) Maximum single sample result ± total analytical uncertainty. Negative concentration values are explained in Appendix A.

(d) Average of all samples ± 2 times the standard deviation.

(e) DOE derived concentration guide (see Appendix D, Table D.5).

(f) 1 pCi = 0.037 Bq.

(g) There are 1 million attocuries (aCi) in 1 picocurie (pCi).

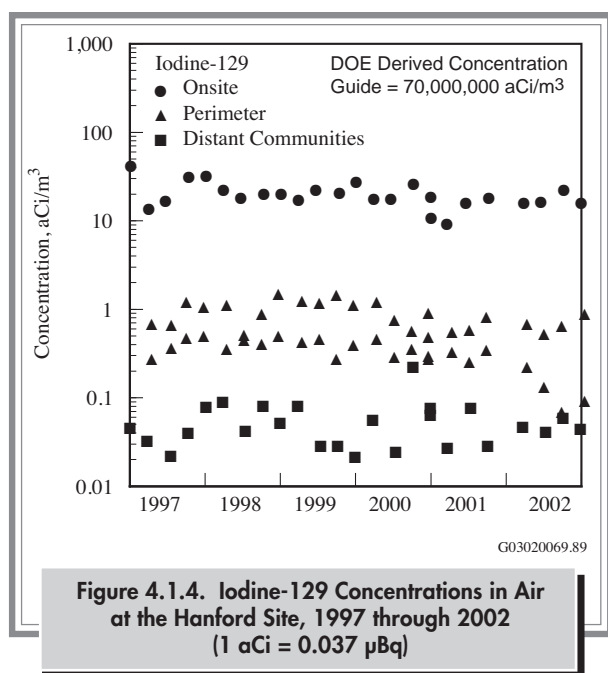
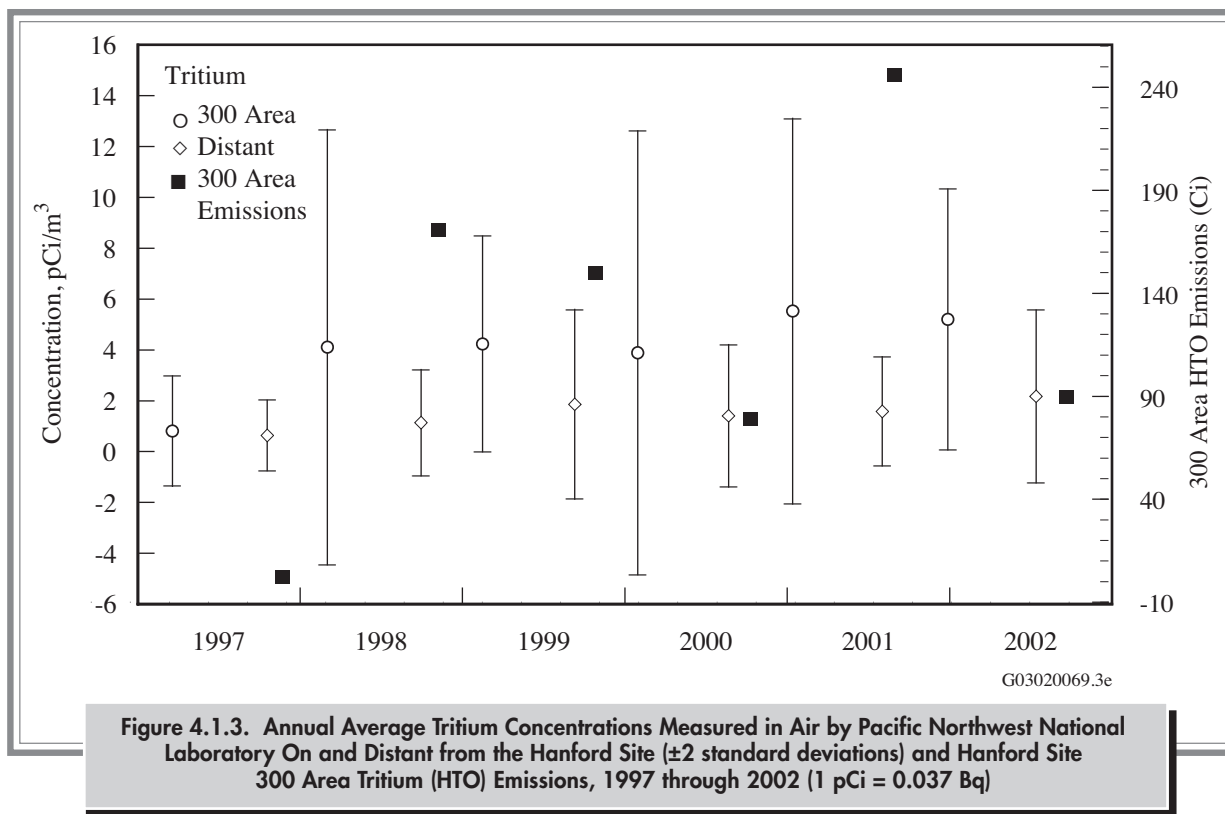


higher onsite than at the distant locations. The difference, however, was not statistically significant (two-sample means t-test, 95% confidence level). The average gross beta concentrations reported for 2002 were similar to concentrations reported from 1997 through 2001 (Table 4.1.2).

Average tritium concentrations measured during 2002 were slightly higher than average values reported for 1997 through 2001 (Table 4.1.2 and Figure 4.1.3). For non-300 Area samples in 2002, ~85% contained detectable amounts of tritium (the analytical method is capable of detecting concentrations below 3 pCi/m³ [0.11 Bq/m³]). All 300 Area tritium results in 2002 were above the minimum detectable concentration. Tritium releases in the 300 Area (associated with research and development activities [Table 3.1.1]) resulted in average 300 Area tritium concentrations that were higher than at distant sampling locations. The difference between 300 Area perimeter and community average concentrations was statistically significant relative to the distant location. The sample with the highest tritium concentration measured during 2002 (33 pCi/m³ [1.2 Bq/m³]) was collected at Leslie Groves Park in Richland (location 37 in Figure 4.1.1) during the month of April. This

concentration was only 0.033% of the DOE derived concentration guide (Appendix D, Table D.5). For an evaluation of longer term trends in tritium concentrations on the Hanford Site, see PNNL-13909.

Iodine-129 analyses were performed on samples collected onsite at a location downwind of the Plutonium-Uranium Extraction Plant, at two downwind perimeter locations, and at a distant location (Yakima) in 2002 (Table 4.1.1). Concentrations measured onsite during 2002 were elevated compared to those measured at the site perimeter, and perimeter levels were higher than those measured at the distant location, Yakima (Figure 4.1.4 and Table 4.1.2). Concentration differences between these locations were statistically significant and indicated a Hanford source. Onsite and perimeter air concentrations have remained at their respective levels from 1997 through 2002 (Figure 4.1.4). Onsite air concentrations of iodine-129 were influenced by minor emissions (0.0012 curie [44 MBq]; Table 3.1.1) from the Plutonium-Uranium Extraction Plant and possible releases from waste storage tanks and cribs. The annual average iodine-129 concentration (0.40 ± 0.63 aCi/m³ [0.015 ± 0.023 μBq/m³]) at the downwind



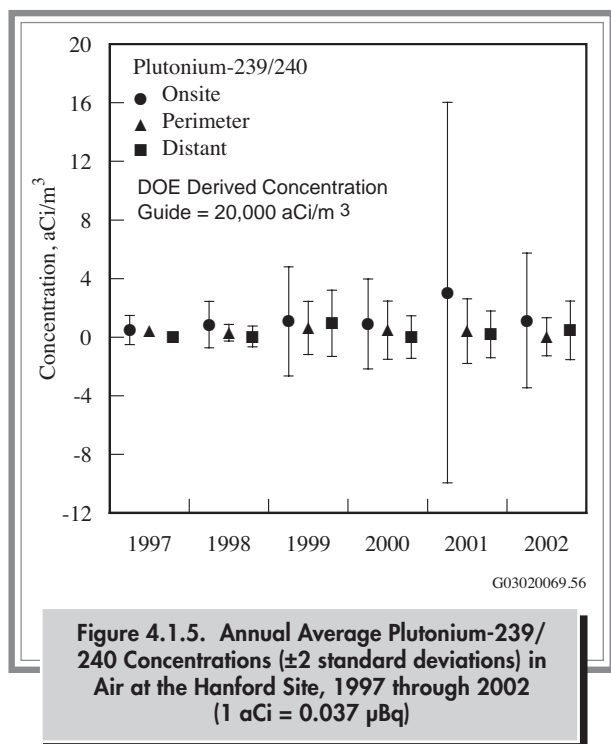
perimeter in 2002 was $<0.0000006\%$ of the DOE derived concentration guide (70 million aCi/m³ [2.6 Bq/m³]).

Plutonium-238 was detected in three of the onsite composite samples during 2002 (nominal detection limit of

1.8 aCi/m³ [0.067 μ Bq/m³]). The three detected samples were all from the 100 Areas composite sample group. The maximum reported plutonium-238 concentration in 2002 was 4.3 ± 7.1 aCi/m³ (0.15 ± 0.26 μ Bq/m³), or 7,000 times less than the DOE derived concentration guide for plutonium-238 (30,000 aCi/m³ [1.1 mBq/m³]).

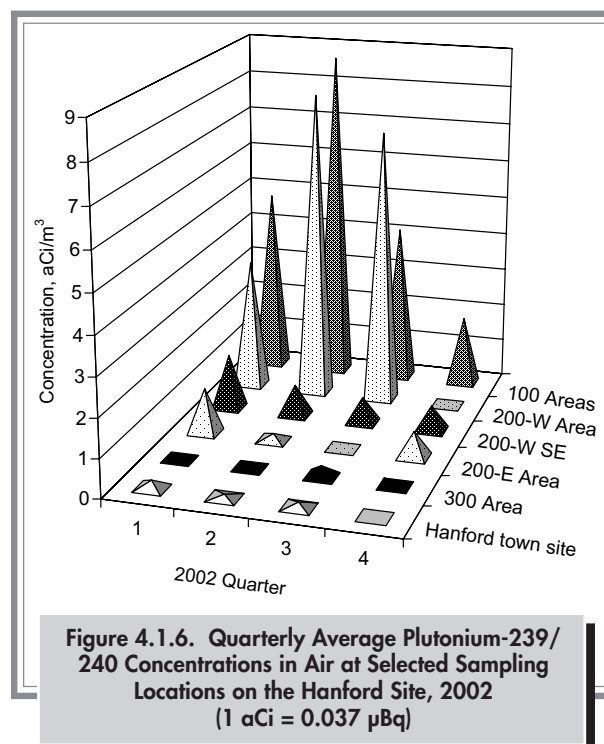
The annual average plutonium-239/240 concentrations measured in air samples for 2002 are given in Table 4.1.2 and Figure 4.1.5. The annual average air concentration of plutonium-239/240 at onsite locations was 1.1 ± 4.6 aCi/m³ (0.04 ± 0.17 μ Bq/m³) during 2002. The annual average air concentrations were higher for the onsite locations than the distant locations; however, the difference was not statistically significant. The maximum Hanford Site plutonium-239/240 air concentration (8.7 ± 2.8 aCi/m³ [0.32 ± 0.1 μ Bq/m³]) was observed for the 100 Areas second quarter composite sample (locations 1, 2, and 3 on Figure 4.1.1). This maximum reported concentration was $<0.05\%$ of the DOE derived concentration guide (20,000 aCi/m³ [0.73 mBq/m³]) for plutonium-239/240.

The 100 Areas and the 200-West Area had statistically significant higher plutonium-239/240 concentrations than other selected onsite locations. Figure 4.1.6



illustrates plutonium-239/240 results for 2002 quarterly composite samples from selected onsite locations. The concentrations measured for the 200-West Area composite samples are presumed to be from stack emissions in the 200-West Area (Section 3.1.1), while the plutonium-238 and plutonium-239/240 detected in the 100 Areas are likely related to cleanup activities in the 100 Areas. The reported plutonium-239/240 stack emissions from the 200-West Area in 2002 were ten times larger than the stack emissions from the 100 Areas. However, average concentrations of plutonium-239/240 in air were similar in the 200-West Area and the 100 Areas (Figure 4.1.6). Cleanup activities in the 100 Areas likely led to increased dust suspension, and subsequently an increase in airborne radioactive particulates in the vicinity of the 100 Areas, resulting in detectable concentrations of plutonium-238, and concentrations of plutonium-239/240 slightly higher than at other onsite locations. For a summary of activities in the 100 Areas, refer to Section 2.3. For an account of an occurrence of radioactive soil being blown off of a cleanup site in the 100-F Area during 2002, refer to Section 2.4.

Average isotopic uranium concentrations (uranium-234, uranium-235, and uranium-238) in airborne particulate matter in 2002 were similar to average concentrations between 1997 and 2001 for all distance classes (Table 4.1.2). The 2002 annual average uranium-238 concentration for



the site perimeter was 31 ± 38 aCi/m³ (1.1 ± 1.4 μ Bq/m³), which is 0.03% of the DOE derived concentration guide (100,000 aCi/m³ [3.7 mBq/m³]). There were no statistical differences observed between average concentrations of each measured uranium isotope at different distance classes (two-sample means t-test, 95% confidence level). This implies that the measured concentrations of the different uranium isotopes are from background material in the air, and not from Hanford emissions.

A total of 96 samples were analyzed for strontium-90 in 2002 (Table 4.1.2). Only 9% (9 of 96) samples analyzed were above the detection limit (~ 90 aCi/m³ [3 μ Bq/m³]). Comparison of the average reported concentration at different distance classes was considered meaningless due to the low number of detected sample results, and the large variability in concentrations. The highest measured strontium-90 concentration ($1,300 \pm 280$ aCi/m³ [48 ± 10 μ Bq/m³]) was from the 400 Area and was only 0.014% of the DOE derived concentration guide (9 million aCi/m³ [0.33 Bq/m³]).

Quarterly composite samples were analyzed by gamma spectroscopy. Naturally occurring beryllium-7 and potassium-40 were routinely identified. The potential Hanford-origin gamma-emitting radionuclides of cobalt-60 and cesium-137 were of particular interest. Cobalt-60 and

cesium-137 results for 2002 samples are included in Table 4.1.2. None of the 120 samples analyzed by gamma spectroscopy had concentrations of cobalt-60 or cesium-137 above their respective minimum detectable concentrations ($\sim 1,000$ and 800 aCi/m^3 [~ 37 and $30 \text{ }\mu\text{Bq/m}^3$]).

4.1.3 AIR PARTICULATE MONITORING

Airborne particulate matter (dust) is one of the U.S. Environmental Protection Agency's (EPA) criteria pollutants. EPA classifies particulate matter by particle size. PM_{10} is defined as a particle having an aerodynamic diameter <10 micrometers. Similarly, $\text{PM}_{2.5}$ is defined as a particle having an aerodynamic diameter <2.5 micrometers (a sample of PM_{10} includes $\text{PM}_{2.5}$, since particles smaller than 2.5 micrometers are also smaller than 10 micrometers). The EPA's National Ambient Air Quality Standard (Title 40, Code of Federal Regulations, Part 50 [40 CFR 50]) for PM_{10} requires a 24-hour average concentration of $<150 \text{ }\mu\text{g/m}^3$, and an annual average concentration $<50 \text{ }\mu\text{g/m}^3$. There is currently no enforced EPA standard for $\text{PM}_{2.5}$, although proposed standards are $65 \text{ }\mu\text{g/m}^3$ 24-hour average concentration and $15 \text{ }\mu\text{g/m}^3$ annual average concentration. Health risk studies have shown a positive correlation between increases in concentrations of airborne particulate matter and increased hospital admissions for pulmonary and heart conditions (Schwartz 1994; Morgan et al. 1998; Ostro et al. 1999). Studies have indicated that a $100 \text{ }\mu\text{g/m}^3$ increase in PM_{10} concentrations has a relative risk^(a) of ~ 1.17 for hospital admissions for pneumonia and chronic obstructive pulmonary disorder (Schwartz 1994). Similar relationships were found between PM_{10} concentrations and daily human mortality in areas where windblown dust was the main contributor to high PM_{10} concentrations (similar to the Hanford Site) (Ostro et al. 1999).

During February 2001, monitoring of particulate matter mass concentrations in air on the Hanford Site began. The motivation for this was the decrease in vegetative cover on a large portion of the site after the 24 Command Wildland Fire in 2000 (PNNL-13487), as well as information requests from the public. It was theorized that the decrease

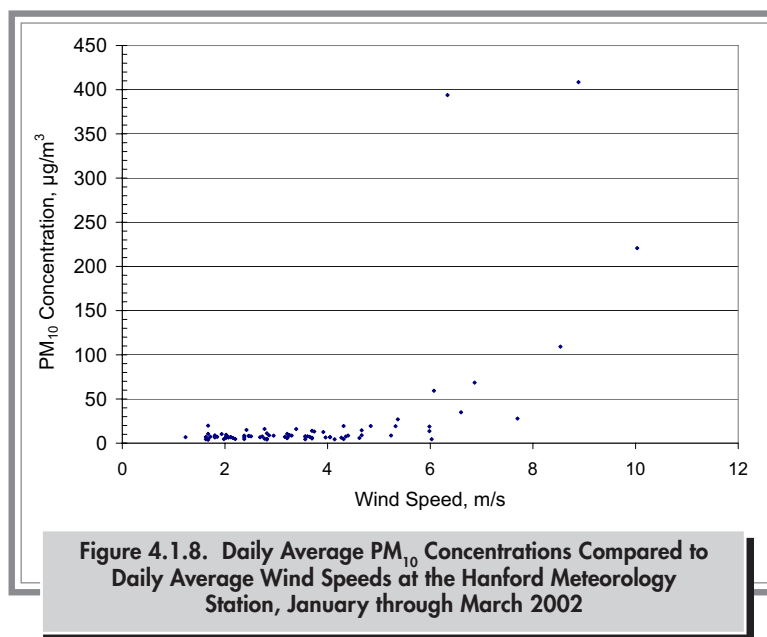
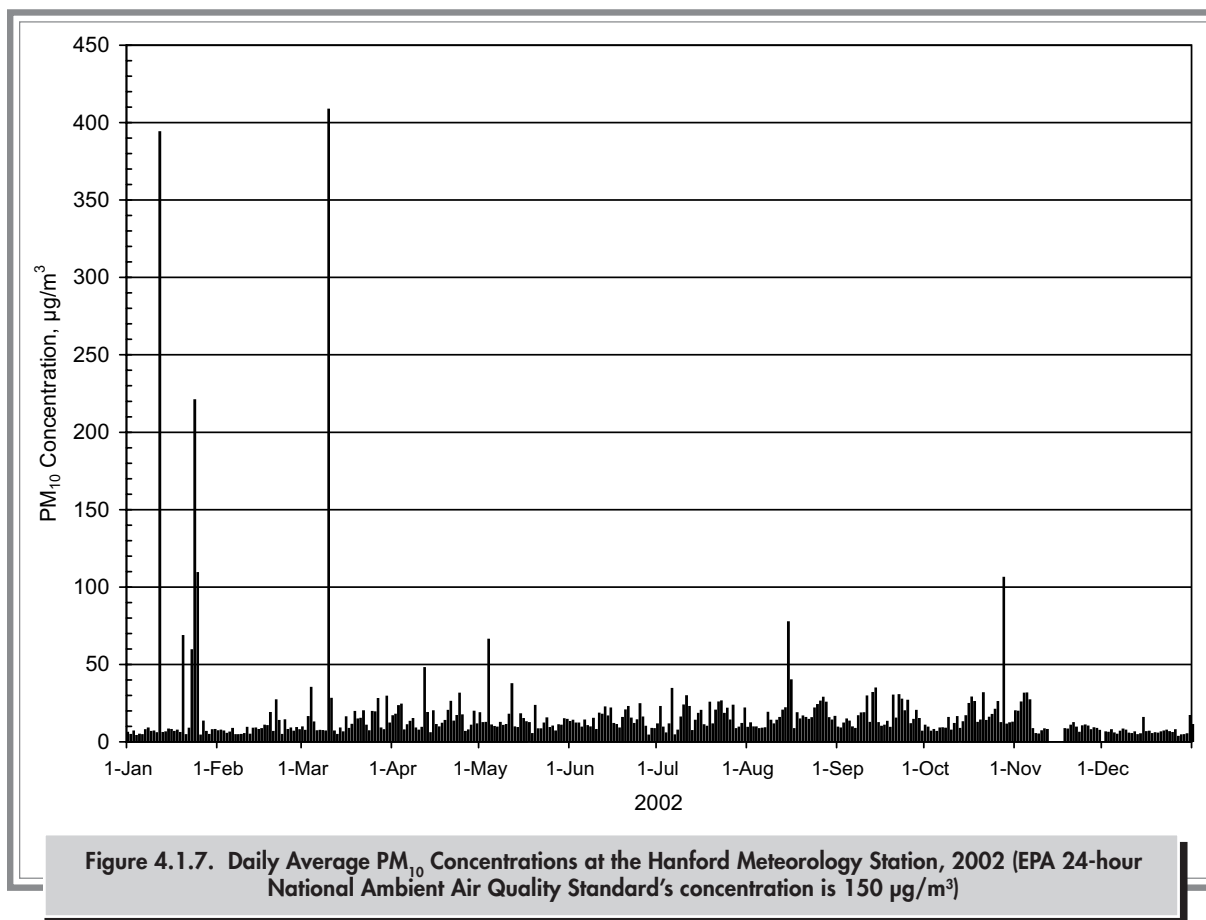
in vegetative cover would result in increased wind erosion, and subsequently, increased particulate matter concentrations in air. Particulate monitoring was done using tapered element oscillating microbalances. The unique design of the tapered element oscillating microbalance instrument measures the difference in mass collected on a filter by measuring the change in frequency of oscillation of the filter. The instruments record hourly average concentrations, but daily average concentration data were calculated for this report. PM_{10} data have been collected at the Hanford Meteorology Station since February 2001, while $\text{PM}_{2.5}$ data collection began at the Hanford Meteorology Station in October of 2001.

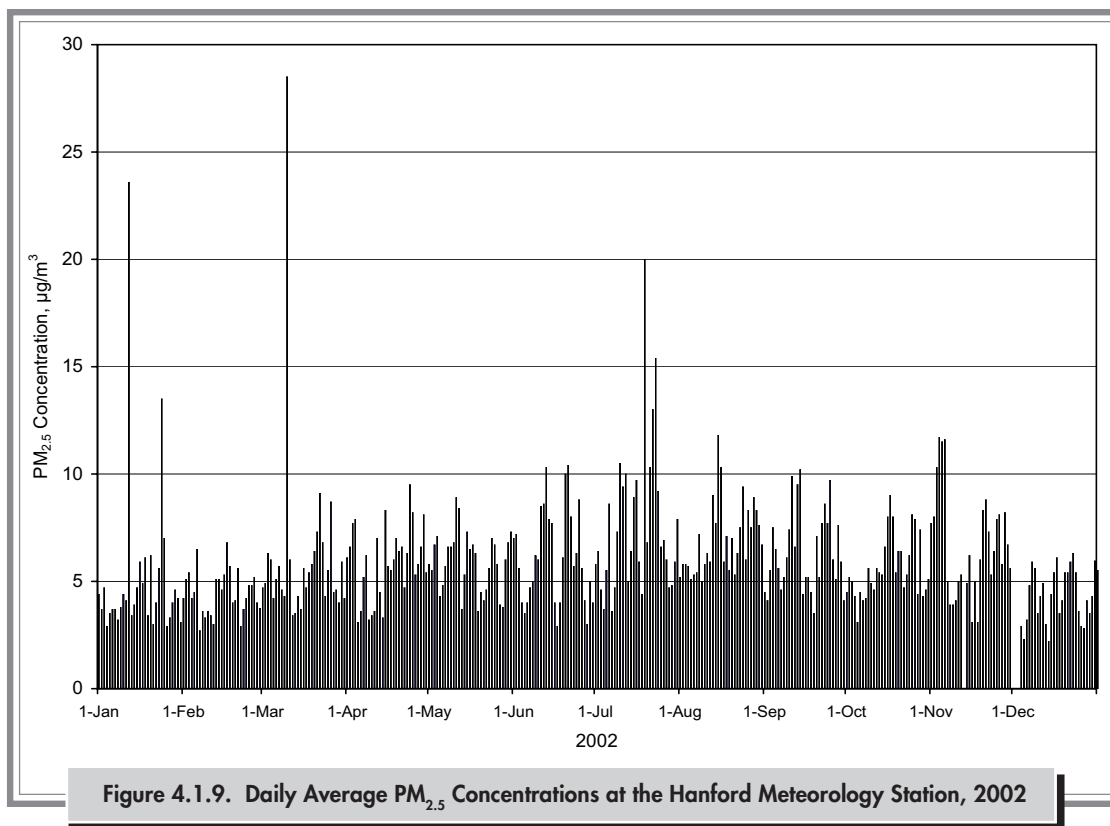
Figure 4.1.7 shows the daily average PM_{10} concentrations recorded at the Hanford Meteorology Station during 2002. Daily average PM_{10} concentrations on the Hanford Site were higher than the EPA 24-hour average standard for PM_{10} ($150 \text{ }\mu\text{g/m}^3$) three times during 2002 (January 12, January 24, and March 11). The observed annual average PM_{10} concentration at the Hanford Meteorology Station during 2002 ($17 \text{ }\mu\text{g/m}^3$) was well below the EPA annual average standard ($50 \text{ }\mu\text{g/m}^3$). Hanford Site measurements are not used by the Benton Clean Air Authority to determine compliance with air quality standards. EPA policy allows exemptions for natural events that result in high particulate matter concentrations, such as windstorms. All of the elevated PM_{10} concentrations observed on the Hanford Site in 2002 appeared to be a result of high winds (Figure 4.1.8).

There is currently no enforced EPA concentration standard for $\text{PM}_{2.5}$. However, the $\text{PM}_{2.5}$ concentrations measured at the Hanford Meteorology Station during 2002 (Figure 4.1.9) were well below the proposed EPA health-based standards for $\text{PM}_{2.5}$ ($15 \text{ }\mu\text{g/m}^3$ annual average, $65 \text{ }\mu\text{g/m}^3$ 24-hour average). The measured annual average $\text{PM}_{2.5}$ concentration at the Hanford Meteorology Station during 2002 was $6 \text{ }\mu\text{g/m}^3$, while the highest 24-hour average concentration observed was $28.5 \text{ }\mu\text{g/m}^3$.

During 2002, Hanford Site particulate monitoring was also conducted at the 300 Area meteorology tower, on the peak of Rattlesnake Mountain, at Rattlesnake Springs, and at the 100-F Area meteorological station. These samples were collected over periods of several months for special studies and projects, and the data are not discussed here.

(a) Relative risk here refers to the increase in hospital admissions after PM_{10} levels rise. When 24-hour average PM_{10} increased by $100 \text{ }\mu\text{g/m}^3$, a 17% increase in hospital admissions for pneumonia and chronic obstructive pulmonary disorder occurred.







4.2 SURFACE WATER AND SEDIMENT SURVEILLANCE

G. W. Patton

Samples of surface water and sediment on and near the Hanford Site were collected and analyzed to determine the potential impact to the public and to the aquatic environment from radiological and chemical contaminants that originated at Hanford. Surface-water bodies included in routine surveillance were the Columbia River and associated riverbank springs, onsite ponds, and irrigation sources (Figure 4.2.1). Sediment surveillance was conducted for the Columbia River and riverbank springs. Tables 4.2.1 and 4.2.2 summarize the sampling locations, types, frequencies, and analyses included in surface water and sediment surveillance during 2002. This section describes the surveillance efforts and summarizes the results for these aquatic environments. Detailed analytical results are reported in PNNL-14295, APP. 1.

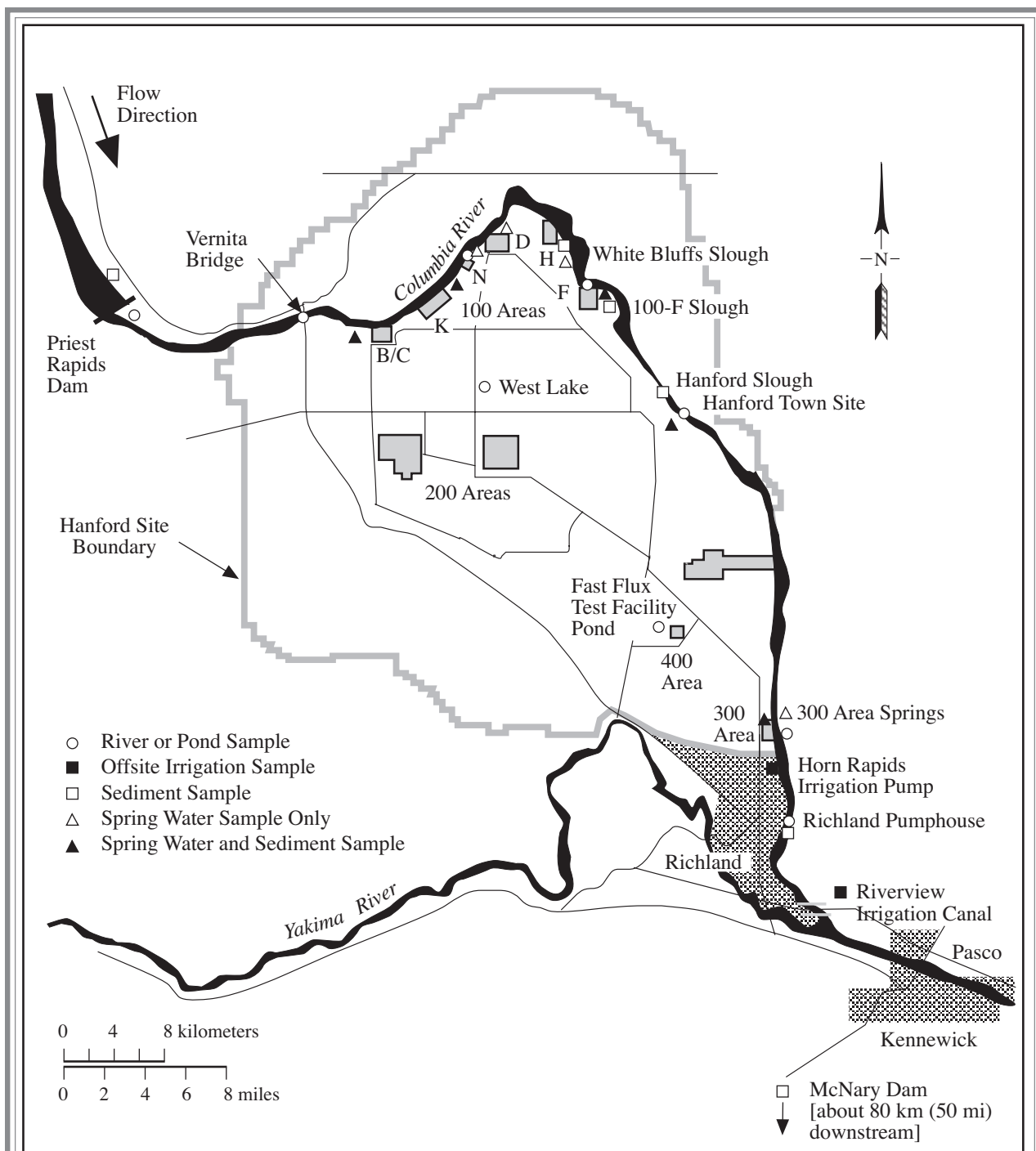
4.2.1 COLUMBIA RIVER WATER

The Columbia River is the second largest river in the continental United States in terms of total flow and is the dominant surface-water body on the Hanford Site. The original selection of the Hanford Site for plutonium production was based, in part, on the abundant water supply offered by the river. The river flows through the northern edge of the site and forms part of the site's eastern boundary. The river is used as a source of drinking water for onsite facilities and communities located downstream from the Hanford Site. Water from the river downstream of the site also is used for crop irrigation. In addition, the Hanford Reach of the Columbia River is used for a variety of recreational activities, including hunting, fishing, boating, water-skiing, and swimming.

Originating in the mountains of eastern British Columbia, the Columbia River and its tributaries drain an area of ~670,000 square kilometers (260,000 square miles) en route to the Pacific Ocean. The flow of the river is regulated by

three dams in Canada and eleven dams in the United States, seven upstream and four downstream of the Hanford Site. Priest Rapids Dam is the nearest upstream dam and McNary Dam is the nearest downstream dam from the site. The Hanford Reach of the Columbia River extends from Priest Rapids Dam to the head of Lake Wallula (created by McNary Dam) near Richland, Washington. The Hanford Reach is the last stretch of the Columbia River in the United States upstream of Bonneville Dam that remains unimpounded.

River flow through the Hanford Reach fluctuates significantly and is controlled primarily by operations at Priest Rapids Dam. Annual average flows of the Columbia River downstream of Priest Rapids Dam are usually around 3,400 cubic meters (120,000 cubic feet) per second (WA-94-1). In 2002, the Columbia River had normal flows; the average daily flow rate downstream of Priest Rapids Dam was 3,340 cubic meters (118,000 cubic feet) per second. The peak monthly average flow rate occurred during June (6,220 cubic meters [220,000 cubic feet] per second) (Figure 4.2.2). The lowest monthly average flow rate occurred during March (2,080 cubic meters [73,400 cubic feet] per second). Daily flow rates varied from 1,320 to 7,620 cubic meters (46,700 to 269,000 cubic feet) per second during 2002. As a result of fluctuation in discharges, the depth of the river varies significantly over time. River stage (water surface level) may change along the Hanford Reach by up to 3 meters (10 feet) within a few hours (see Section 3.3.7 in PNL-10698). Seasonal changes of approximately the same magnitude are also observed. River-stage fluctuations measured at the 300 Area are approximately half the magnitude of those measured near the 100 Areas because of the effect of the pool behind McNary Dam (PNL-8580) and the relative distance of each area from Priest Rapids Dam. The width of the river varies from ~300 to 1,000 meters (~980 to 3,300 feet) through the Hanford Site.



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Figure 4.2.1. Hanford Site Environmental Surveillance Project Sampling Locations for Water and Sediment, 2002

Table 4.2.1. Surface Water Surveillance On and Near the Hanford Site, 2002

<u>Location</u>	<u>Sample Type</u>	<u>Frequency^(a)</u>	<u>Analyses</u>
Columbia River - Radiological			
Priest Rapids Dam and Richland Pumphouse	Cumulative	M Comp ^(b) Q Comp ^(e)	Alpha, beta, lo ³ H, ^(c) ⁹⁰ Sr, ⁹⁹ Tc, U ^(d) ¹²⁹ I
	Particulate (filter)	M Cont ^(f) Q Cont ^(g)	Gamma energy analysis Pu ^(h)
	Soluble (resin)	M Cont Q Cont	Gamma energy analysis Pu
Vernita Bridge and Richland Pumphouse	Grab (transects)	Quarterly	lo ³ H, ⁹⁰ Sr, U
100-F, 100-N, 300, and Hanford town site	Grab (transects)	Annually	lo ³ H, ⁹⁰ Sr, U
Columbia River - Chemical			
Vernita Bridge and Richland Pumphouse ⁽ⁱ⁾	Grab	Quarterly	Temperature, dissolved oxygen, turbidity, pH, alkalinity, anions, suspended solids, dissolved solids, specific conductance, hardness (as CaCO ₃), Ca, P, Cr, Mg, N-Kjeldahl, Fe, NH ₃ , NO ₃ + NO ₂ , ICP ^(j) metals (filtered and unfiltered), anions
	Grab (transects)	Quarterly	VOA ^(k)
	Grab (transects)	Annually	
100-F, 100-N, 300, and Hanford town site	Grab (transects)	Annually	ICP metals (filtered and unfiltered), anions
Onsite Ponds			
West Lake	Grab	Quarterly	Alpha, beta, ³ H, ⁹⁰ Sr, ⁹⁹ Tc, U, gamma energy analysis
Fast Flux Test Facility pond	Grab	Quarterly	Alpha, beta, ³ H, gamma energy analysis
Offsite Irrigation Water			
Riverview irrigation canal	Grab	3/year	Alpha, beta, ³ H, ⁹⁰ Sr, U, gamma energy analysis
Horn Rapids	Grab	Annually	Alpha, beta, ³ H, ⁹⁰ Sr, U, gamma energy analysis
Riverbank Springs			
100-H Area	Grab	Annually	Alpha, beta, ³ H, ⁹⁰ Sr, ⁹⁹ Tc, U, gamma energy analysis, ICP metals (filtered and unfiltered), anions
100-F Area	Grab	Annually	Alpha, beta, ³ H, ⁹⁰ Sr, U, gamma energy analysis, ICP metals (filtered and unfiltered), anions, VOA
100-B Area	Grab	Annually	Alpha, beta, ³ H, ⁹⁰ Sr, ⁹⁹ Tc, gamma energy analysis, ICP metals (filtered and unfiltered), anions, VOA
100-D, 100-K, and 100-N Areas	Grab	Annually	Alpha, beta, ³ H, ⁹⁰ Sr, gamma energy analysis, ICP metals (filtered and unfiltered), anions, VOA (100-K Area only)
Hanford town site	Grab	Annually	Alpha, beta, ³ H, ¹²⁹ I, ⁹⁰ Sr, ⁹⁹ Tc, U, gamma energy analysis, ICP metals (filtered and unfiltered), anions
300 Area	Grab	Annually	Alpha, beta, ³ H, ¹²⁹ I, ⁹⁰ Sr, U, gamma energy analysis, ICP metals (filtered and unfiltered), anions, VOA

(a) M = Monthly; Q = Quarterly; Comp = Composite; Cont = Continuous.

(b) M Comp indicates river water was collected hourly and composited monthly for analysis.

(c) lo ³H = Low-level tritium analysis (10-pCi/L detection limit), which includes an electrolytic preconcentration.

(d) U = Isotopic uranium-234, uranium-235, and uranium-238.

(e) Collected weekly and composited for quarterly analysis.

(f) M Cont = River water was sampled for 2 wk by continuous flow through a filter and resin column and multiple samples were composited monthly for analysis.

(g) Q Cont = River water was sampled for 2 wk by continuous flow through a filter and resin column and multiple samples were composited quarterly for analysis.

(h) Pu = Isotopic plutonium-238 and plutonium-239/240.

(i) Numerous water quality analyses are performed by the U.S. Geological Survey under contract to Pacific Northwest National Laboratory.

(j) ICP = Inductively coupled plasma analysis method.

(k) VOA = Volatile organic compounds.

Table 4.2.2. Columbia River Sediment Surveillance from Priest Rapids Dam to McNary Dam, 2002

<u>Location</u> ^(a)	<u>Frequency</u>	<u>Analyses</u>
River		All river sediment analyses included gamma energy analysis, ⁹⁰ Sr, U ^(b) , Pu ^(c) , ICP ^(d) metals, SEM/AVS ^(e)
Priest Rapids Dam: 2 locations near the dam	Annually	
White Bluffs Slough	Annually	
100-F Slough	Annually	
Hanford Slough	Annually	
Richland	Annually	
McNary Dam: 2 locations near the dam	Annually	
Springs ^(f)		All springs sediment analyses included gamma energy analysis, ⁹⁰ Sr, U, ICP metals
100-B Area	Annually	
100-K Area	Annually	
100-N Area	Annually	
100-F Area	Annually	
Hanford town site springs	Annually	
300 Area	Annually	

(a) See Figure 4.2.1.

(b) U = Uranium-235 and uranium-238 analyzed by low-energy photon analysis.

(c) Pu = Isotopic plutonium-238 and plutonium-239/240.

(d) ICP = Inductively coupled plasma analysis method.

(e) SEM/AVS = Simultaneously extracted metals and acid-volatile sulfide.

(f) Sediment is collected when available.

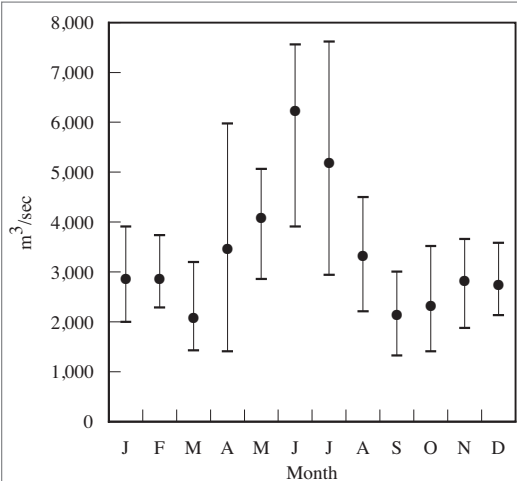


Figure 4.2.2. Mean, Maximum, and Minimum Monthly Columbia River Flow Rates at Priest Rapids Dam, Washington, 2002

Hanford pollutants, both radiological and chemical, enter the Columbia River along the Hanford Reach. Effluent from each direct discharge point is monitored routinely and reported by the responsible operating contractor (Section 3.1). Direct discharges are identified and regulated for non-radiological constituents under the National Pollutant Discharge Elimination System in compliance with the *Clean Water Act* (Section 2.2.8). In addition to permitted direct discharges of liquid effluent from Hanford facilities, contaminants in groundwater from past operational discharges to the ground seep into the river (DOE/RL-92-12; PNL-5289; PNL-7500; WHC-SD-EN-TI-006).

Washington State 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 (WAC 173-201A). Water quality criteria and

water use guidelines have been established in conjunction with this designation and are provided in Appendix D (Table D.1).

4.2.1.1 COLLECTION OF RIVER-WATER SAMPLES AND ANALYTES OF INTEREST

During 2002, samples were collected from fixed-location monitoring stations at Priest Rapids Dam and the Richland Pumphouse and from Columbia River transects and near-shore locations near the Vernita Bridge, 100-N Area, 100-F Area, Hanford town site, 300 Area, and Richland Pumphouse (Figure 4.2.1). Samples were collected upstream from Hanford Site facilities at Priest Rapids Dam and Vernita Bridge to provide background data from locations unaffected by site operations. Samples were collected from all other locations to identify any increase in contaminant concentrations attributable to Hanford operations. The Richland Pumphouse is the first downstream point of Columbia River water withdrawal for a municipal drinking water supply.

The fixed-location monitoring stations at Priest Rapids Dam and the Richland Pumphouse consisted of both an automated sampler and a continuous flow system. Using the automated sampler, unfiltered samples of Columbia River water (cumulative samples) were obtained hourly and collected weekly. Weekly samples were combined into monthly composite samples for radiological analyses (Table 4.2.1). Using the continuous flow system, particulate and soluble constituents in Columbia River water were collected by passing water through a filter and then through a resin column. Filter and resin samples were exchanged approximately every 14 days and were combined into quarterly composite samples for radiological analyses. The river sampling locations and the methods used for sample collection are discussed in detail in DOE/RL-91-50.

Radionuclides of interest were selected for analysis based on

- their presence in effluent discharged from site facilities or in near-river groundwater underlying the Hanford Site
- their importance in determining water quality, verifying effluent control and monitoring systems, and determining compliance with applicable standards

Analytes of interest in water samples collected from Priest Rapids Dam and the Richland Pumphouse included gross

alpha, gross beta, selected gamma emitters, tritium, strontium-90, technetium-99, iodine-129, uranium-234, uranium-235, uranium-238, plutonium-238, and plutonium-239/240. Gross alpha and beta measurements are indicators of the general radiological quality of the river and provide a timely indication of change. Gamma energy analysis provides the ability to detect numerous specific radionuclides (Appendix F). Sensitive radiochemical analyses were used to determine the concentrations of tritium, strontium-90, technetium-99, iodine-129, uranium-234, uranium-235, uranium-238, plutonium-238, and plutonium-239/240 in river water during the year. Analytical detection levels for all radionuclides were <12% of their respective water quality criteria levels (Appendix D, Tables D.1 and D.2). Unless otherwise noted in this section, the statistical tests for differences are paired sample comparisons and two-tailed t-tests, 5% significance level.

Transect sampling (multiple samples collected along a line across the Columbia River) was initiated as a result of findings of a special study conducted during 1987 and 1988 (PNL-8531). That study concluded that, under certain flow conditions, contaminants entering the river from the Hanford Site are not completely mixed when sampled at routine monitoring stations located downriver. Incomplete mixing results in a slightly conservative (high) bias in the data generated using the routine, single-point, sampling system at the Richland Pumphouse. During 1999, the transect sampling strategy was modified, with some of the mid-river sampling points shifted to near-shore locations in the vicinity of the transect. For example, at the 100-N Area instead of collecting ten evenly-spaced cross-river transect samples, only six cross-river samples were collected, and the other four samples were obtained at near-shore locations. This sampling pattern was used during 2002 and allowed the cross-river concentration profile to be determined and also provided information over a larger portion of the Hanford shoreline where the highest contaminant concentrations would be expected. The Vernita Bridge and the Richland Pumphouse transects and near-shore locations were sampled quarterly during 2002. Annual transect and near-shore sampling were conducted at the 100-N Area, 100-F Area, Hanford town site, and 300 Area locations in late summer when river flows were low.

Columbia River transect water samples collected during 2002 were analyzed for both radiological and chemical contaminants (Table 4.2.1). Metals and anions were selected for analysis following reviews of existing surface-water and groundwater data, various remedial investigation/feasibility study work plans, and preliminary Hanford Site risk assessments (DOE/RL-92-67; PNL-8073; PNL-8654; PNL-10400; PNL-10535). All radiological and chemical analyses of transect samples were performed on grab samples of unfiltered water, except for metals analyses, which were performed on both filtered and unfiltered samples.

In addition to radiological monitoring conducted, water quality monitoring was performed by the U.S. Geological Survey for the Pacific Northwest National Laboratory. Samples were collected along Columbia River transects quarterly at the Vernita Bridge and the Richland Pump-house (Appendix B, Table B.5). Sample analyses were performed at the U.S. Geological Survey laboratory in Denver, Colorado, for numerous physical parameters and chemical constituents.

4.2.1.2 RADIOLOGICAL RESULTS FOR RIVER-WATER SAMPLES

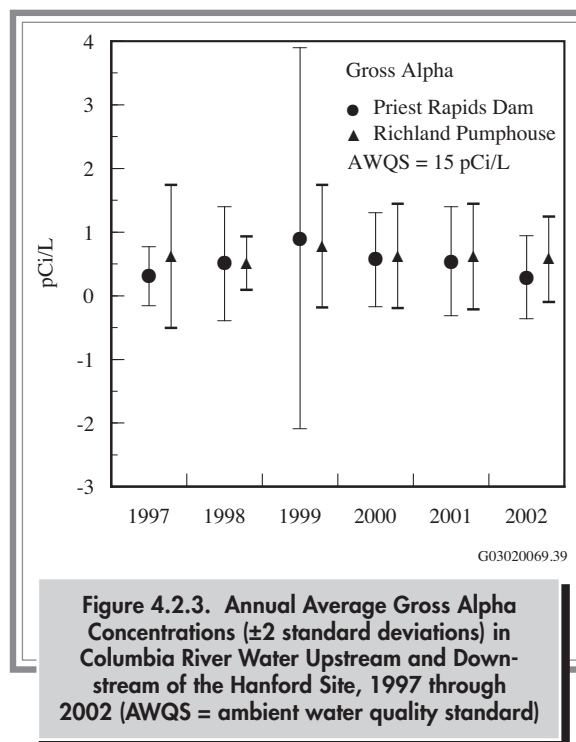
Fixed Location Sampling. Results of the radiological analyses of Columbia River water samples collected at Priest Rapids Dam and the Richland Pump-house during 2002 are reported in PNNL-14295, APP. 1 and summarized in Appendix B (Tables B.1 and B.2). These tables also list the maximum and average concentrations of selected radionuclides detected in Columbia River water in 2002 and during the previous 5 years. All radiological contaminant concentrations measured in Columbia River water during 2002 were less than DOE derived concentration guides (DOE Order 5400.5) and Washington State ambient surface-water quality criteria (WAC 173-201A and 40 CFR 141; Appendix D, Tables D.2, D.3, and D.5). Significant results are discussed in the following paragraphs, and comparisons to previous years are provided.

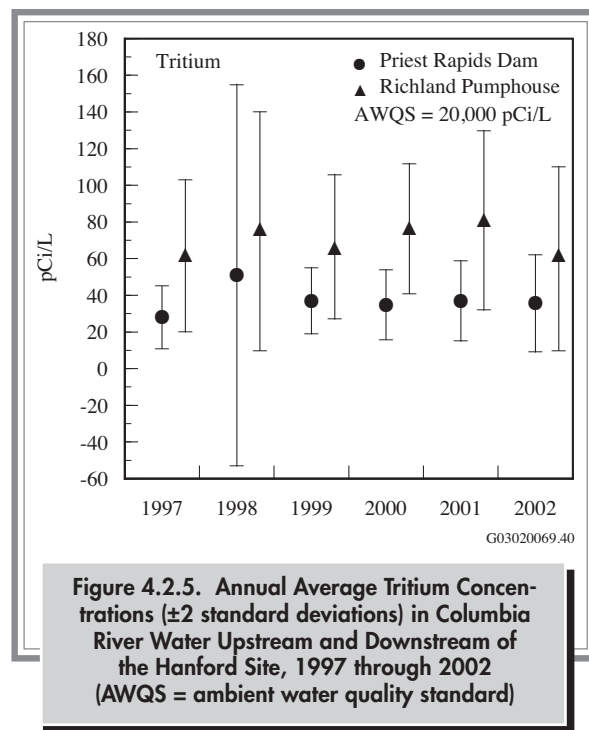
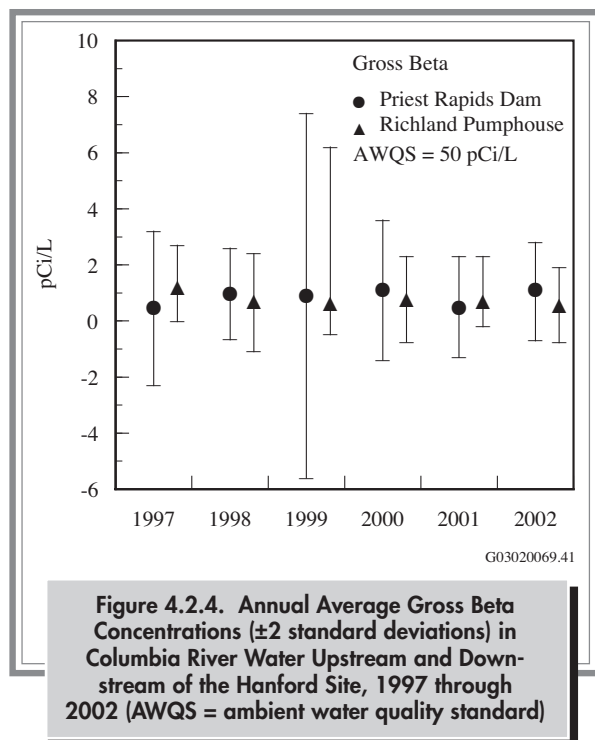
Radionuclide concentrations monitored in Columbia River water were low throughout the year. During 2002, the radionuclides tritium, strontium-90, iodine-129, uranium-234, uranium-238, plutonium-239/240, and naturally occurring beryllium-7 and potassium-40 were

consistently detected in river water at levels greater than two times their associated total propagated analytical uncertainty. The concentrations of all other radionuclides were typically below detection limits. Tritium, strontium-90, iodine-129, and plutonium-239/240 exist in worldwide fallout from historical nuclear-weapons testing, as well as in effluent from Hanford facilities. Tritium and uranium occur naturally in the environment, in addition to being present in Hanford Site effluent.

The 2002 average gross alpha and gross beta concentrations measured upstream and downstream of the Hanford Site were similar to those observed during recent years. Statistical comparisons for gross alpha and gross beta concentrations at Priest Rapids Dam and the Richland Pump-house were not performed because the majority of the concentrations were below the 1 pCi/L (0.037 Bq/L) detection limit (Figures 4.2.3 and 4.2.4). The average alpha concentration in Columbia River water at the Richland Pump-house during 2002 was less than the state ambient surface-water quality criteria level of 15 pCi/L (0.56 Bq/L).

The 2002 annual average tritium concentrations measured upstream and downstream of the Hanford Site were similar to concentrations measured in previous years. Statistical analyses indicated that monthly tritium



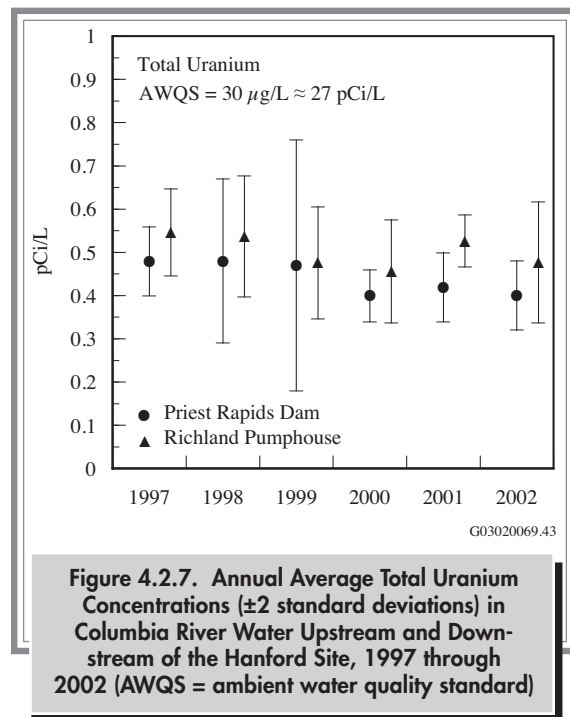
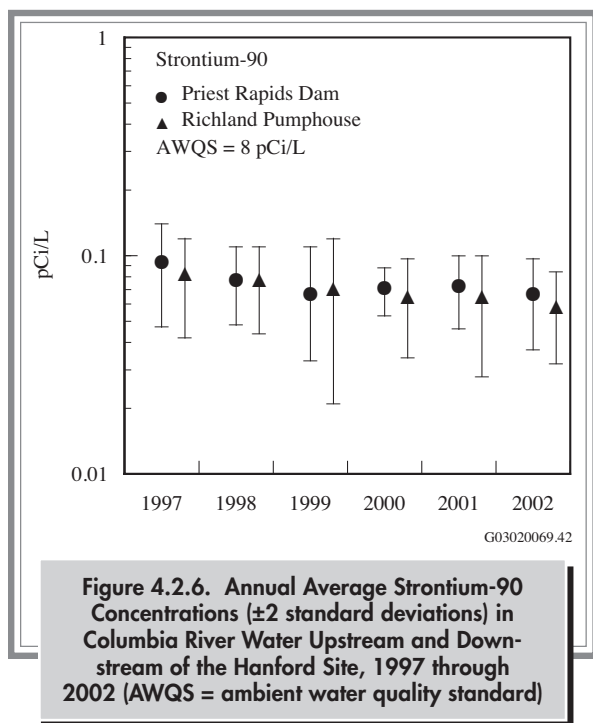


concentrations in river water samples at the Richland Pumphouse were higher than concentrations in samples from Priest Rapids Dam (Figure 4.2.5). However, 2002 average tritium concentrations in Columbia River water collected at the Richland Pumphouse were only 0.3% of the state ambient surface-water quality criteria level of 20,000 pCi/L (740 Bq/L). Onsite sources of tritium entering the river include groundwater seepage and direct discharge from the 100-K Area permitted outfall (Sections 3.1 and 7.1). Tritium concentrations measured at the Richland Pumphouse, while representative of river water used by the city of Richland for drinking water, tend to overestimate the average tritium concentrations across the river at this location (PNL-8531). This bias is attributable to the contaminated 200 Areas' groundwater plume entering the river along the portion of shoreline extending from the Hanford town site to below the 300 Area, which is relatively close to the Richland Pumphouse sample intake. This plume is not completely mixed within the river at the Richland Pumphouse. Sampling along cross-river transects at the pumphouse during 2002 confirmed the existence of a concentration gradient in the river under certain flow conditions and is discussed subsequently in this section. The extent to which samples taken from the Richland Pumphouse overestimate the average tritium concentrations in the Columbia River at this location is variable

and appears to be related to the flow rate of the river just before and during sample collection.

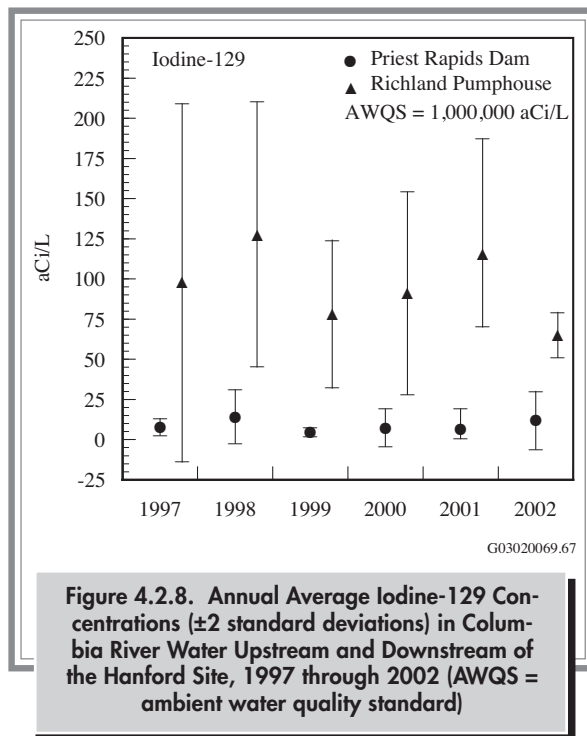
Strontium-90 levels measured in Columbia River water collected upstream and downstream of the Hanford Site during 2002 were similar to those reported previously (Figure 4.2.6). Groundwater plumes containing strontium-90 enter the Columbia River throughout the 100 Areas (Section 6.2). Some of the highest strontium-90 levels that have been found in onsite groundwater are the result of past discharges to the 100-N Area liquid waste disposal facilities. Despite the Hanford Site source, there was no statistical difference between monthly strontium-90 concentrations at Priest Rapids Dam and the Richland Pumphouse during 2002. Average strontium-90 concentrations in Columbia River water at the Richland Pumphouse were less than 0.7% of the state ambient surface-water quality criteria level (8 pCi/L [0.30 Bq/L]).

Annual average total uranium concentrations (i.e., the sum of uranium-234, uranium-235, uranium-238) observed in water samples collected upstream and downstream of the Hanford Site during 2002 were similar to those observed during recent years (Figure 4.2.7). Monthly total uranium concentrations measured at the Richland Pumphouse during 2002 were statistically higher than those measured



at Priest Rapids Dam. Although there is no direct process discharge of uranium to the river, uranium is present in the groundwater beneath the 300 Area as a result of past Hanford operations (Section 6.2). Groundwater contaminants have been detected at elevated levels in riverbank springs at the 300 Area (Section 4.2.3 and PNNL-13692). Uranium is also known to enter the river across from the Hanford Site via irrigation return water and groundwater seepage associated with extensive irrigation north and east of the Columbia River (PNL-7500). There are no ambient surface-water quality criteria levels directly applicable to uranium. However, total uranium levels in the river during 2002 were well below the EPA drinking water standard of 30 µg/L (~ 27 pCi/L [1.0 Bq/L], Appendix D, Table D.2).

The average iodine-129 concentration in Columbia River water measured downstream of the Hanford Site at the Richland Pumphouse was extremely low during 2002 (0.007% of the state ambient surface-water quality criteria level of 1 pCi/L [0.037 Bq/L]) and similar to levels observed during recent years (Figure 4.2.8). The onsite source of iodine-129 to the Columbia River is the discharge of contaminated groundwater along the portion of shoreline downstream of the Hanford town site (Section 6.2). The iodine-129 plume originated in the 200 Areas from past

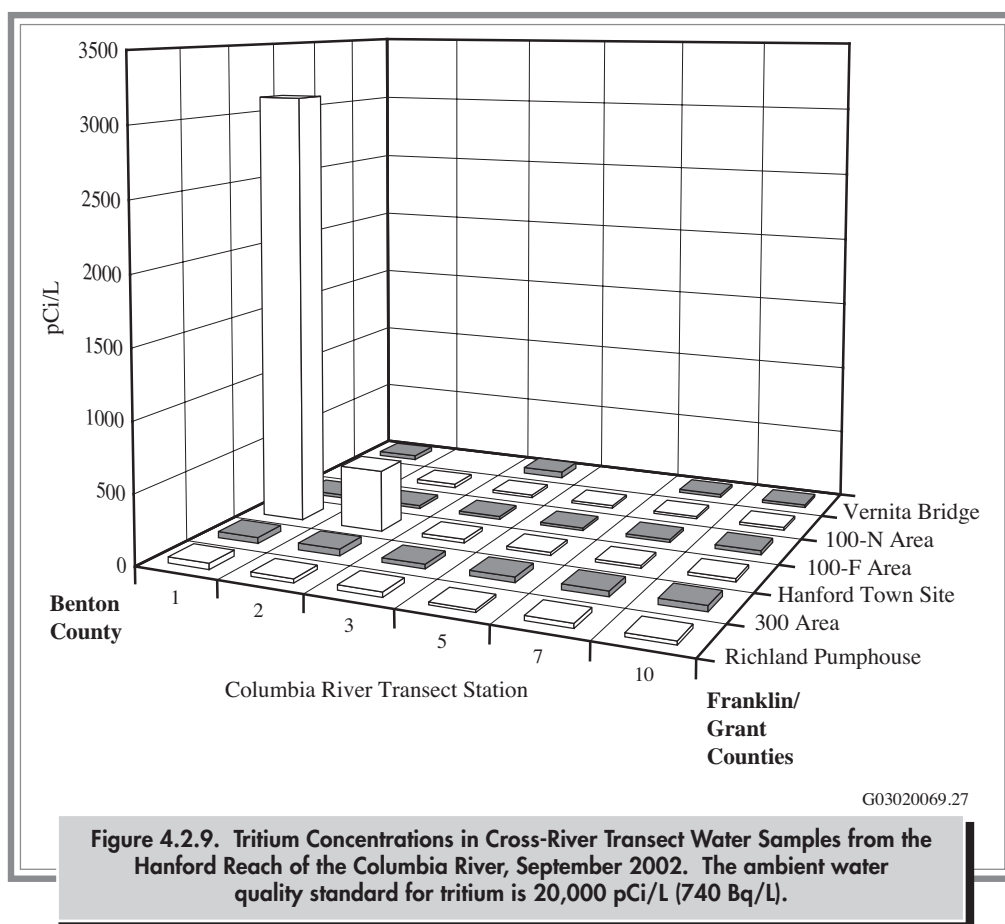


waste disposal practices. Quarterly iodine-129 concentrations in Columbia River water at the Richland Pumphouse were statistically higher than those at Priest Rapids Dam.

Plutonium-239/240 concentrations were at or near the detection limit for some filter (particulate) and all resin (dissolved) components. Average plutonium-239/240 concentrations on filter samples at Priest Rapids Dam and the Richland Pumphouse were 0.000022 ± 0.000024 pCi/L ($0.00000081 \pm 0.00000089$ Bq/L) and 0.000011 ± 0.000015 pCi/L ($0.00000041 \pm 0.00000056$ Bq/L), respectively. Plutonium was only detected for the particulate fraction of the continuous water sample (i.e., detected on the filters but not detected on the resin column). All concentrations were below the DOE derived concentration guide of 30 pCi/L (1.1 Bq/L) (Appendix D, Table D.5). No state ambient surface-water quality criteria level exists for plutonium-239/240. Results for filter samples for plutonium-239/240 were statistically higher at Priest Rapids Dam compared to the Richland Pumphouse; thus, there was no observed Hanford Site contribution. Statistical comparisons for dissolved plutonium concentrations at Priest Rapids Dam and the Richland Pumphouse were not performed because the majority of the concentrations were below the detection limit.

River Transect and Near-Shore Sampling. Radiological results from samples collected along Columbia River transects and at near-shore locations near the Vernita Bridge, 100-N Area, 100-F Area, Hanford town site, 300 Area, and Richland Pumphouse during 2002 are presented in Appendix B (Tables B.3 and B.4) and PNNL-14295, APP. 1. Sampling locations were documented using a global positioning system. Radionuclides consistently detected at concentrations greater than two times their associated total propagated analytical uncertainty included tritium, strontium-90, uranium-234, and uranium-238. All measured concentrations of these radionuclides were less than applicable state ambient surface-water quality criteria levels.

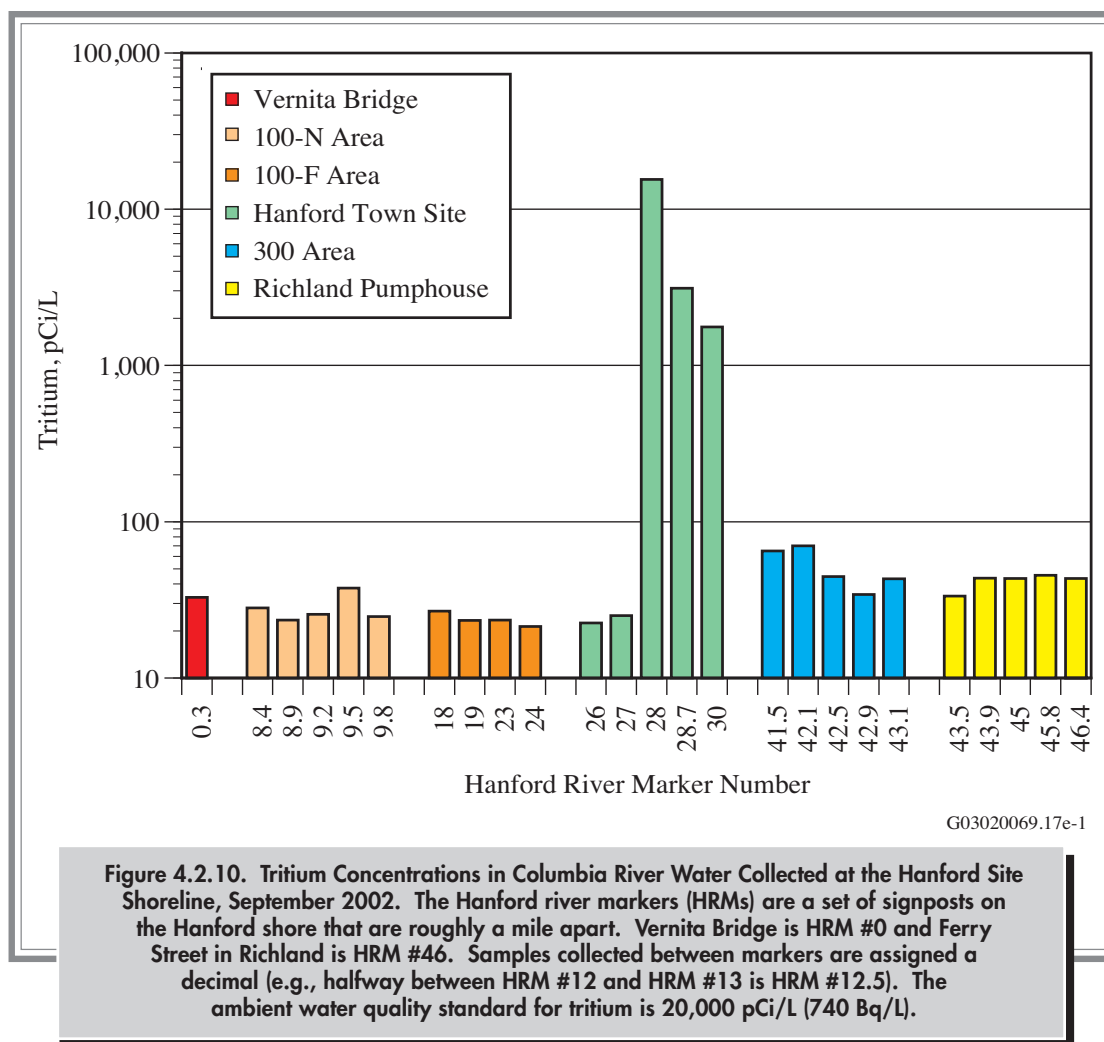
Tritium concentrations measured along Columbia River transects during September 2002 are depicted in Figure 4.2.9. The results are displayed such that the observer's view is upstream from the Richland Pumphouse. Vernita Bridge is the most upstream transect. Stations 1 and 10 are located along the Benton County and Franklin/Grant Counties



Counties shorelines, respectively. The 100-N Area, Hanford town site, 300 Area, and Richland Pumphouse transects have higher tritium concentrations at the Hanford (Benton County) shore compared to the opposite shore. The presence of a tritium concentration gradient in the Columbia River at the Richland Pumphouse supports previous conclusions made in HW-73672 and PNL-8531 that contaminants in the 200 Areas' groundwater plume entering the river at, and upstream of, the 300 Area are not completely mixed at the Richland Pumphouse. The gradient is most pronounced during periods of relatively low river flow. Since transect sampling began during 1987, the average tritium concentration measured along the Richland Pumphouse transect has been less than that measured in monthly composited samples from the pump-house, illustrating the conservative bias (i.e., overestimate) of the fixed-location monitoring station. The highest tritium concentration detected in 2002 samples of cross-river

transect water was $3,100 \pm 160$ pCi/L (120 ± 5.9 Bq/L) (Appendix B, Table B.3), which was detected along the shoreline of the Hanford town site. This is a location where groundwater containing tritium levels over the state ambient surface-water quality criterion (20,000 pCi/L [740 Bq/L]) is known to discharge to the river (Section 6.2).

Tritium concentrations for near-shore water samples collected at the Hanford (Benton County) shoreline during September 2002 are shown in Figure 4.2.10. The near-shore sampling locations are identified according to Hanford river markers, which are a series of signpost markers (~1.6 kilometers [~1 mile] apart) that originate at Vernita Bridge (Hanford river marker #0) and end just upriver from the Richland Pumphouse (Hanford river marker #46). The concentrations of tritium in near-shore water samples collected at the 100-N Area, Hanford town site, and 300 Area were elevated compared to concentrations in



samples collected near the Vernita Bridge. There was a wide range of tritium concentrations measured for the shoreline samples with the concentrations increasing near discharge points for the groundwater tritium plume (Chapter 6, Figures 6.1.11, 6.1.12, and 6.1.19). The tritium concentrations in near-shore samples collected from the Richland shore were only slightly higher than those measured at Vernita Bridge. During 2002, the highest tritium concentration observed in near-shore water samples was $16,000 \pm 490$ pCi/L (590 ± 18 Bq/L) (Appendix B, Table B.4), which was detected along the shoreline of the Hanford town site at Hanford river marker #28. This location is roughly 1 kilometer (0.6 mile) upriver from the cross-river transect sampling location where the maximum tritium level was $3,100 \pm 160$ pCi/L (120 ± 5.9 Bq/L).

During 2002, strontium-90 concentrations in Hanford Reach river water for both transect and near-shore samples were similar to background concentrations for all locations, except for the 100-N Area. The 100-N Area had elevated strontium-90 concentrations in some samples obtained at near-shore locations. The average strontium-90 concentration found during transect sampling at the Richland Pump house was similar to those measured in monthly composite samples from the pump house, indicating that strontium-90 concentrations in water collected from the fixed-location monitoring station are representative of the average strontium-90 concentrations in the river at this location.

Total uranium concentrations in Hanford Reach water during 2002 were elevated along the Franklin County shoreline in both the 300 Area and Richland Pump house transects. The highest total uranium concentration was measured in March near the Franklin County shoreline of the Richland Pump house transect (1.5 ± 0.21 pCi/L [0.056 ± 0.0078 Bq/L]) (Appendix B, Table B.3) and likely resulted from groundwater seepage and water from irrigation return canals on the Franklin County side of the river that contained naturally occurring uranium (PNL-7500).

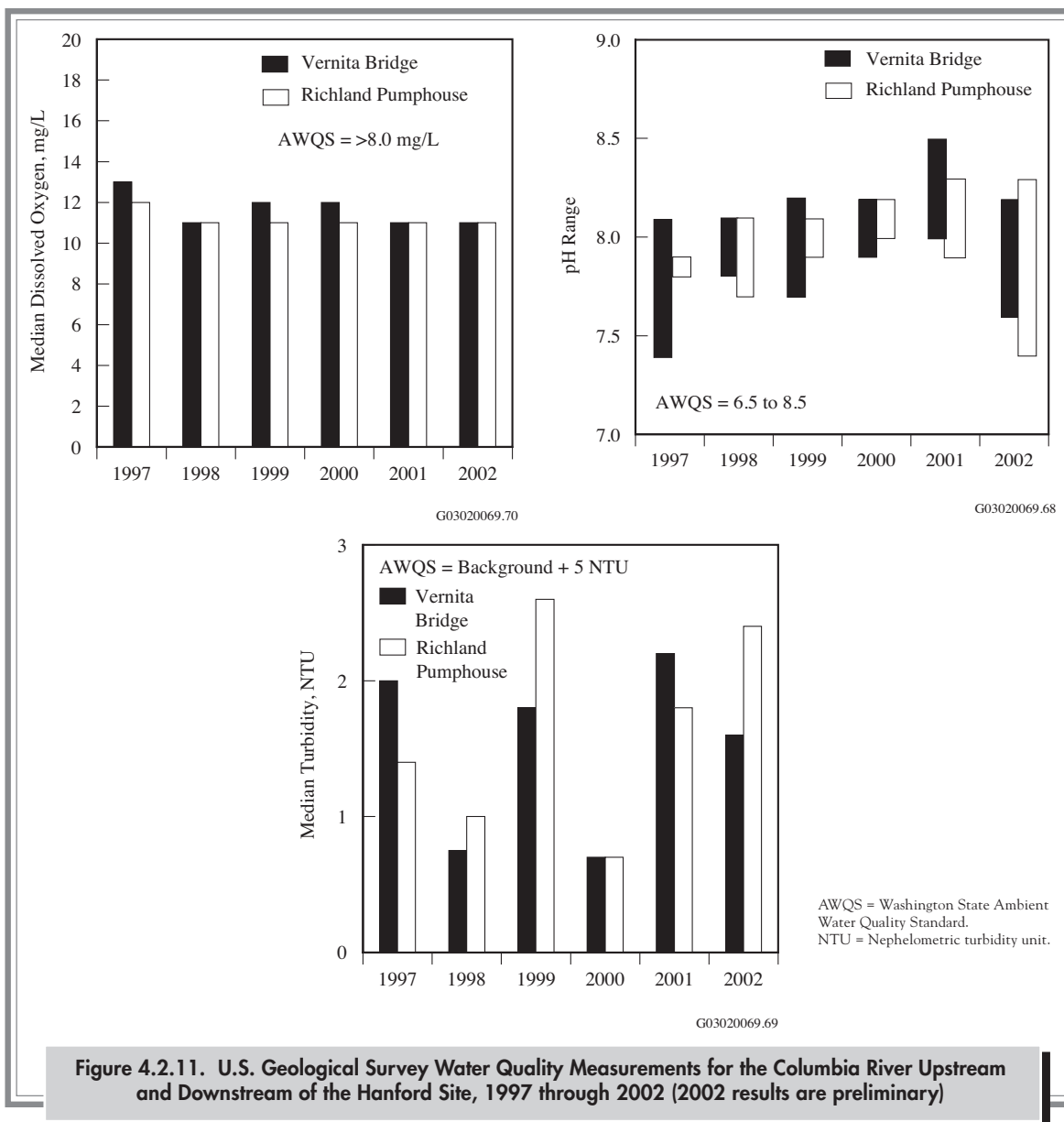
4.2.1.3 CHEMICAL AND PHYSICAL RESULTS FOR RIVER-WATER SAMPLES

The U.S. Geological Survey and Pacific Northwest National Laboratory compiled chemical and physical

water quality data for the Columbia River during 2002. A number of the parameters measured have no regulatory limits; however, they are useful as indicators of water quality and contaminants of Hanford origin. Potential sources of pollutants not associated with Hanford include irrigation return water and groundwater seepage associated with extensive irrigation north and east of the Columbia River (PNL-7500).

U.S. Geological Survey. Figure 4.2.11 shows U.S. Geological Survey results for the Vernita Bridge and Richland Pump house for 1997 through 2002 (2002 results are preliminary) for several water quality parameters with respect to their applicable standards. The complete list of preliminary results obtained through the U.S. Geological Survey National Stream Quality Accounting Network program is documented in PNNL-14295, APP. 1 and is summarized in Appendix B (Table B.5). Final results are published annually by the U.S. Geological Survey (e.g., WA-99-1). The 2002 U.S. Geological Survey results were comparable to those reported during the previous 5 years. Applicable standards for a Class A-designated surface-water body were met. During 2002, there was no indication of any deterioration of water quality resulting from site operations along the Hanford Reach of the Columbia River (Appendix D, Table D.1).

River Transect and Near-Shore Samples. Results of chemical sampling conducted by Pacific Northwest National Laboratory along transect and near-shore locations of the Columbia River in 2002 at the Vernita Bridge, 100-F Area, 100-N Area, Hanford town site, 300 Area, and Richland Pump house are provided in PNNL-14295, APP. 1. The concentrations of metals and anions observed in river water during 2002 were similar to those observed in the past and remain below regulatory limits. Several metals and anions were detected in Columbia River transect samples both upstream and downstream of the Hanford Site. Arsenic, antimony, cadmium, chromium, lead, nickel, thallium, and zinc were detected in the majority of samples, with similar levels at most locations. Beryllium, selenium, and silver were detected occasionally. Nitrate concentrations for water samples from the Benton County shoreline near the Richland Pump house were similar to mid-river samples. Nitrate, sulfate, and chloride concentrations were slightly elevated, compared to mid-river samples, along the Franklin County shoreline at the Richland Pump house and 300 Area transects and likely resulted from



groundwater seepage associated with extensive irrigation north and east of the Columbia River. Nitrate contamination of some Franklin County groundwater has been documented by the U.S. Geological Survey (1995) and is associated with high fertilizer and water usage in agricultural areas. Numerous wells in western Franklin County exceed the EPA maximum contaminant level for nitrate (40 CFR 141; USGS Circular 1144). Average chloride, nitrate, and sulfate results were slightly higher for quarterly concentrations at the Richland Pumphouse transect compared to the Vernita Bridge transect. The only apparent

concentration gradients near the Hanford shoreline for anions measured in transect samples were at the Hanford town site.

Washington State ambient surface-water quality criteria for cadmium, copper, lead, nickel, silver, and zinc are total-hardness dependent (WAC 173-201A; Appendix D, Table D.3). Criteria for Columbia River water were calculated using a total hardness of 47 mg/L as calcium carbonate, the limiting value based on U.S. Geological Survey monitoring of Columbia River water near Vernita Bridge and the Richland Pumphouse over the past years. The total

hardness reported by the U.S. Geological Survey at those locations from 1992 through 2002 ranged from 47 to 77 mg/L as calcium carbonate. All metal and anion concentrations in river water were less than the state ambient surface-water quality criteria levels for the protection of aquatic life from both acute and chronic toxicity levels (Appendix B, Table B.6 and Appendix D, Table D.3). Arsenic concentrations exceeded the EPA standard for the protection of human health for the consumption of water and organisms; however, this EPA value is ~10,500 times lower than the state chronic toxicity value and similar concentrations were found at the Vernita Bridge and the Richland Pumphouse (Appendix D, Table D.3). The concentrations of volatile organic compounds in Columbia River water samples (e.g., chlorinated solvents, benzene) were below detection limits in most samples, with no indication of a Hanford source.

4.2.2 RIVERBANK SPRING WATER

The Columbia River is the primary discharge area for the unconfined aquifer underlying the Hanford Site (Section 6.1.2). Groundwater provides a means for transporting Hanford-associated contaminants, which have leached into groundwater from past waste disposal practices, to the Columbia River (DOE/RL-92-12; PNL-5289; PNL-7500; WHC-SD-EN-TI-006). Contaminated groundwater enters the Columbia River via surface and subsurface discharge. Discharge zones located above the water level of the river are identified in this report as riverbank springs. Routine monitoring of riverbank springs offers the opportunity to characterize the quality of groundwater being discharged to the river and to assess the potential human and ecological risk associated with the spring water.

The seepage of groundwater into the Columbia River has occurred for many years. Riverbank springs were documented along the Hanford Reach long before Hanford Site operations began during World War II (Jenkins 1922). During the early 1980s, researchers walked the 66-kilometer (41-mile) stretch of the Benton County shoreline of the Hanford Reach and identified 115 springs (PNL-5289). They reported that the predominant areas of groundwater discharge at that time were in the vicinity of the 100-N

Area, Hanford town site, and 300 Area. The predominance of the 100-N Area may no longer be valid because of declining water-table elevations in response to the cessation of liquid waste discharges to the ground from Hanford Site operations and the pump-and-treat operations to decontaminate groundwater at the 100-N Area. In recent years, it has become increasingly difficult to locate riverbank springs in the 100-N Area.

The presence of riverbank springs also varies with river stage. Groundwater levels in the 100 and 300 Areas are heavily influenced by river stage fluctuations (Section 6.2). Water levels in the Columbia River fluctuate greatly on annual and daily cycles and are controlled by the operation of Priest Rapids Dam upstream of the site. Water flows into the aquifer (as bank storage) as the river stage rises and then flows in the opposite direction as the river stage falls. Following an extended period of low river flow, groundwater discharge zones located above the water level of the river may cease to exist once the level of the groundwater comes into equilibrium with the level of the river. Thus, springs are most readily identified immediately following a decline in river stage. Bank storage of river water also affects the contaminant concentration of the springs. Spring water discharge immediately following a river stage decline generally consists of river water or a mixture of river water and groundwater. The percentage of groundwater in the spring water discharge is believed to increase over time following a drop in river stage. Measuring the specific conductivity of the spring water discharge provides an indicator of the extent of bank storage because Hanford Site groundwater has a higher specific conductivity than Columbia River water.

Because of the effect of bank storage on groundwater discharge and contaminant concentration, it is difficult to estimate the volume of contaminated groundwater discharged to the Columbia River within the Hanford Reach. Studies of riverbank springs conducted during 1983 (PNL-5289), 1988 (PNL-7500), and a near-shore study (PNNL-11933) noted that discharges from the springs had only localized effects on river contaminant concentrations. These studies reported that the volume of groundwater entering the river at these locations was very small compared to the flow of the river and that the impact of groundwater discharges to the river was minimal.

4.2.2.1 COLLECTION OF WATER SAMPLES FROM RIVERBANK SPRINGS AND ANALYTES OF INTEREST

Routine monitoring of selected riverbank springs was initiated during 1988. Currently, riverbank spring water samples are collected for environmental surveillance and to support groundwater operable unit investigations (Figure 4.2.1; DOE/RL-91-50). Analytes of interest for samples from riverbank springs were selected based on findings of previous investigations, reviews of contaminant concentrations observed in nearby groundwater monitoring wells, and results of preliminary risk assessments. Sampling is conducted annually when river flows are low, typically in late summer or early fall.

All samples collected during 2002 were analyzed for gamma-emitting radionuclides, gross alpha, gross beta, and tritium. Samples from selected springs were analyzed for strontium-90, technetium-99, iodine-129, and uranium-234, uranium-235, and uranium-238. All samples were analyzed for metals and anions, with volatile organic compounds analyzed at selected locations. All analyses were conducted on unfiltered samples, except for metals analyses, which were conducted on both filtered and unfiltered samples (Appendix B, Table B.9; PNNL-14295, APP. 1).

Hanford-origin contaminants continued to be detected in water from riverbank springs entering the Columbia River along the Hanford Site during 2002. The locations and extent of contaminated discharges were consistent with recent groundwater surveys. Tritium, strontium-90, technetium-99, iodine-129, uranium-234, uranium-235, and uranium-238, metals, and anions (chloride, fluoride, nitrate, and sulfate) were detected in spring water. Volatile organic compounds were near or below the detection limits for most samples. The contaminant concentrations in water from riverbank springs are typically lower than those found in near-shore groundwater wells because of bank storage effects. In the following discussion, radiological and chemical results are addressed separately. Contaminant concentration trends are illustrated for selected locations.

4.2.2.2 RADIOLOGICAL RESULTS FOR WATER SAMPLES FROM RIVERBANK SPRINGS

All radiological contaminant concentrations measured in riverbank springs during 2002 were less than the DOE derived concentration guides (DOE Order 5400.5; Appendix D, Table D.5). However, the spring near well 199-N-8T at the 100-N Area that has historically exceeded the DOE derived concentration guide for strontium-90 only had observed flow during one (1997) sampling attempt in the last 6 years; thus, an alternative spring was sampled in the 100-N Area.

Gross beta concentrations in riverbank spring water at the 100-H Area, Hanford town site, and 300 Area were elevated compared to other riverbank spring water locations.

Tritium concentrations varied widely with location. The highest tritium concentration detected in riverbank springs was at the Hanford town site ($58,000 \pm 1,900$ pCi/L [$2,100 \pm 70$ Bq/L]), which exceeded the state ambient surface-water quality criterion of 20,000 pCi/L (740 Bq/L) (WAC 173-201A; 40 CFR 141), followed by the 300 Area ($8,100 \pm 690$ pCi/L [300 ± 26 Bq/L]), and the 100-N Area ($7,100 \pm 320$ pCi/L [260 ± 12 Bq/L]). Tritium concentrations in all riverbank spring samples were elevated compared to the 2002 average Columbia River concentration at Priest Rapids Dam (35 ± 26 pCi/L [1.3 ± 0.96 Bq/L]).

Samples from riverbank springs in the 100-B, 100-K, 100-H Areas, and the Hanford town site were analyzed for technetium-99. All results for technetium-99 were below the EPA drinking water standard of 900 pCi/L (33 Bq/L) (Appendix D, Table D.2). The highest technetium-99 concentration was found in riverbank spring water from the Hanford town site (75 ± 4.7 pCi/L [2.8 ± 0.17 Bq/L]), which was higher than the observed gross beta concentrations (24 ± 4.4 pCi/L [0.89 ± 0.16 Bq/L]).

Samples from riverbank springs at the Hanford town site and 300 Area were analyzed for iodine-129. The highest concentration was measured in a water sample from the Hanford town site spring (0.19 ± 0.019 pCi/L [0.007 ± 0.0007 Bq/L]). This value was elevated compared to the

2002 average measured at Priest Rapids Dam (0.000012 ± 0.000018 pCi/L [$0.00000044 \pm 0.00000067$ Bq/L]) but was below the 1-pCi/L (0.037-Bq/L) surface-water quality criteria level (Appendix D, Table D.2).

Uranium was sampled in riverbank spring water in the 100-H Area, 100-F Area, Hanford town site, and 300 Area in 2002. The highest total uranium level was found in 300 Area spring water (99 ± 11 pCi/L [3.7 ± 0.41 Bq/L]), which was collected from a spring located downgradient from the retired 300 Area process trenches. The total uranium concentration in this spring exceeded the EPA drinking water standard of 30 $\mu\text{g/L}$ (~ 27 pCi/L [~ 1.0 Bq/L]). The 300 Area spring had an elevated gross alpha concentration (81 ± 19 pCi/L [3.0 ± 0.70 Bq/L]), which paralleled that of uranium. The gross alpha level in 300 Area spring water also exceeded the state ambient surface-water quality criterion of 15 pCi/L (0.56 Bq/L) (Appendix D, Table D.2).

Samples from riverbank springs were analyzed for strontium-90 in the 100-B, 100-K, 100-N, 100-D, 100-H, and 100-F Areas. The highest strontium-90 concentration detected in riverbank spring water was at the 100-H Area (3.3 ± 0.71 pCi/L [0.12 ± 0.026 Bq/L]). This value was 41% of the ambient surface-water quality criterion of 8 pCi/L (0.30 Bq/L).

Concentrations of selected radionuclides in riverbank spring water near the Hanford town site (spring 28-2) from 1997 through 2002 are provided in Figure 4.2.12. Annual fluctuations in these values may reflect the influence of bank storage during the sampling period.

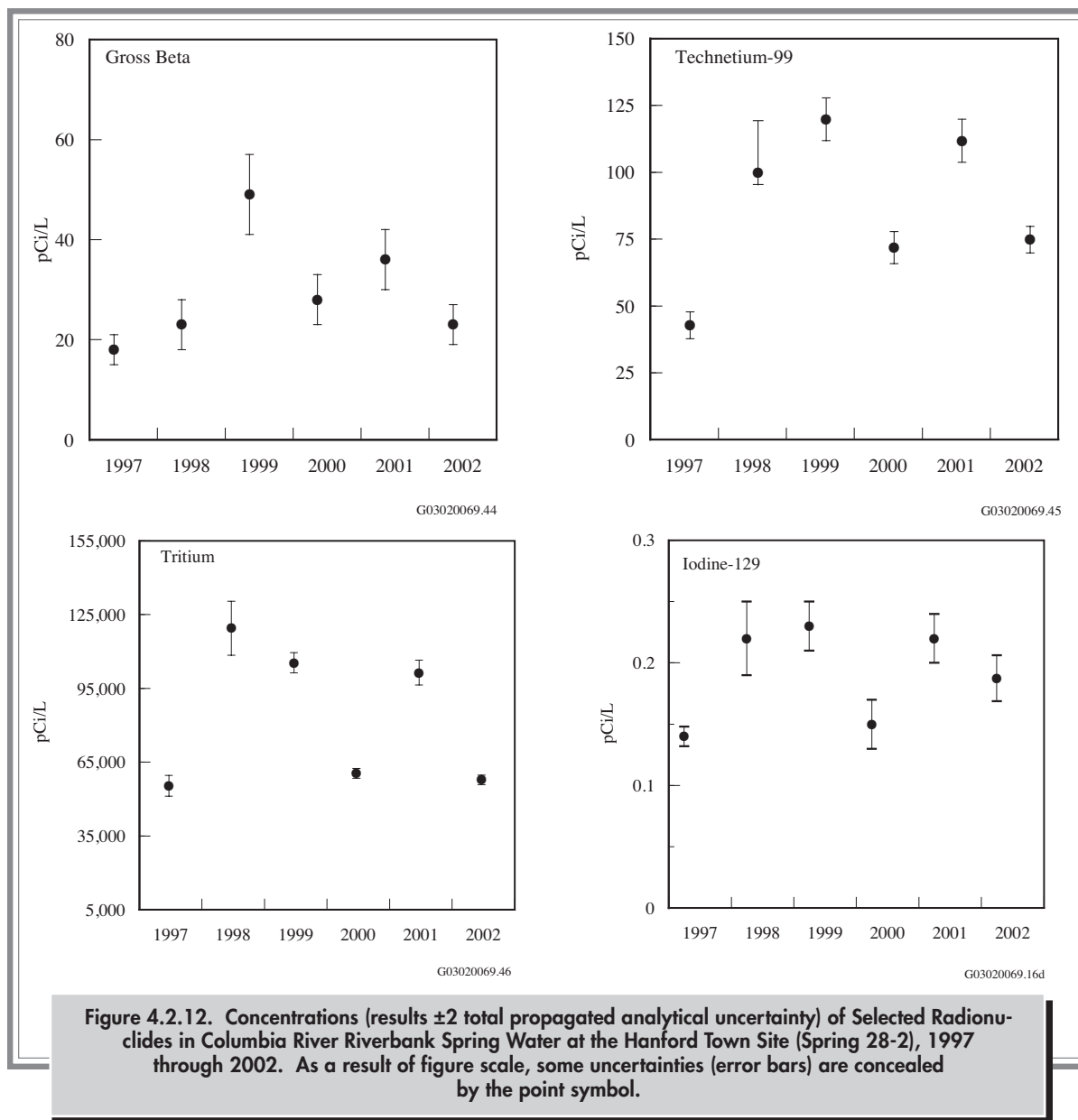
Figure 4.2.13 depicts concentrations of selected radionuclides in the 300 Area riverbank spring water (spring 42-2 and spring DR 42-2) from 1997 through 2002. The elevated tritium levels measured in the 300 Area riverbank springs are indicators of the contaminated groundwater plume from the 200 Areas (Section 5.9 in PNL-10698). Elevated uranium concentrations exist in the unconfined aquifer beneath the 300 Area in the vicinity of the former uranium fuel fabrication facilities and inactive waste sites. The gross alpha and gross beta concentrations in 300 Area riverbank springs water from 1997 through 2002 parallel uranium and are likely associated with its presence.

Historically, riverbank seepage in the 100-N Area has been monitored for contaminants by sampling from well

199-N-8T, which is located close to the river; well 199-N-46 (caisson), which is slightly inland from well 199-N-8T (see PNNL-11795, Figure 3.2.4); or riverbank springs. Since 1993, 100-N Area seepage samples for the Surface Environmental Surveillance Project have been collected only from riverbank springs. The Near-Facility Environmental Monitoring Program (Section 3.2.2) also collects water samples along the 100-N shoreline at monitoring well 199-N-46 and at shoreline seepage wells. The Near-Facility Environmental Monitoring Program reported all strontium-90 concentrations during 2002 samples from shoreline seepage wells located near monitoring well 199-N-46 were below the 1,000-pCi/L (37-Bq/L) DOE derived concentration guide (Table 3.2.4). From 1993 to 2002, there were no visible riverbank springs directly adjacent to wells 199-N-8T or 199-N-46 during the Surface Environmental Surveillance Project sampling periods, with the exception of one sample collected during 1997. The samples collected from 100-N Area riverbank springs during those years were, therefore, collected from a downstream riverbank spring. Contaminant concentrations measured in water from the downstream spring were distinctly different from concentrations in the springs located near the shoreline wells (Table 4.2.3). Historically, the concentrations of strontium-90 and gross beta were considerably higher in the riverbank spring directly adjacent to well 199-N-8T than for the downstream spring. Tritium levels in water from riverbank springs are typically elevated at both locations, and the 2002 tritium result for the 100-N riverbank spring was similar to those seen in previous years at the same location (Table 4.2.3). Tritium was the only specific radionuclide detected in 100-N Area riverbank spring water during 2002.

4.2.2.3 CHEMICAL RESULTS FOR WATER SAMPLES FROM RIVERBANK SPRINGS

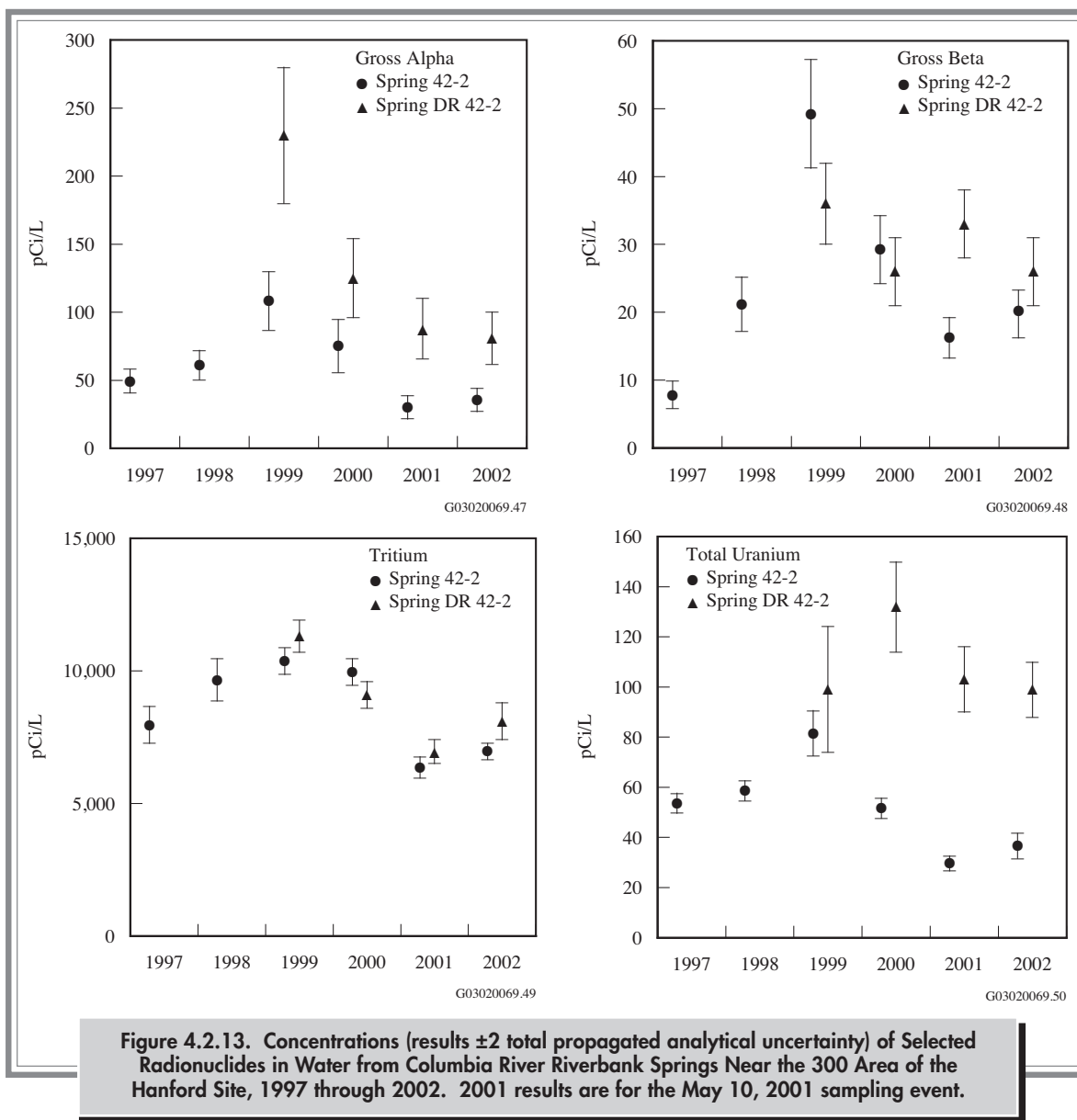
Concentration ranges of selected chemicals measured in riverbank springs water during 1999 through 2002 are presented in Table 4.2.4. For most locations, the 2002 chemical sample results were similar to those reported previously (PNNL-12088). Nitrate concentrations were highest in the 300 Area. Chromium concentrations were generally highest in the 100-K, 100-D, and 100-H Areas' riverbank springs. Hanford groundwater monitoring



results for 2002 indicated similar contaminant concentrations in shoreline areas (Section 6.2).

The ambient surface-water quality criteria for cadmium, copper, lead, nickel, silver, and zinc are total-hardness dependent (WAC 173-201A; Appendix D, Table D.3). For comparison purposes, spring water criteria were calculated using the same 47-mg calcium carbonate per liter hardness given in Appendix D, Table D.3. Most metal concentrations measured in water collected from riverbank springs along the Hanford Site shoreline during 1999 through 2002 were below ambient surface-water acute

toxicity levels (WAC 173-201A). However, concentrations of chromium in 100-B, 100-K, 100-N, 100-D, 100-H, and 100-F, and 300 Areas spring water were above state ambient surface-water acute toxicity levels (Appendix D, Table D.3). Arsenic concentrations in riverbank spring water were well below state ambient surface-water chronic toxicity levels, but concentrations in all samples (including upriver Columbia River water samples) exceeded the federal limit for the protection of human health for the consumption of water and organisms; however, this EPA value is more than 10,500 times lower than



the state chronic toxicity standard (40 CFR 141; Appendix D, Table D.3). Nitrate concentrations at all spring water locations were below the drinking water standard (Appendix D, Table D.2).

4.2.3 COLUMBIA RIVER AND RIVERBANK SPRINGS SEDIMENT

Upon release to the Columbia River, radioactive and non-radioactive materials were dispersed rapidly, sorbed onto detritus and inorganic particles, incorporated into aquatic

biota, deposited on the riverbed as sediment (particularly in upstream areas of a dam), or flushed out to sea. The concentrations of the radioactive material decreased as it underwent radioactive decay. Fluctuations in the river flow, as a result of the operation of hydroelectric dams, annual spring freshets, and occasional floods, have resulted in the resuspension, relocation, and subsequent redeposition of the sediment (DOE/RL-91-50). Sediment in the Columbia River contains low concentrations of radionuclides and metals of Hanford Site origin as well as radionuclides from nuclear weapons testing fallout (Beasley et al. 1981; BNWL-2305; PNL-8148; PNL-10535). Potential public exposure is well below the level at which

Table 4.2.3. Selected Radionuclide Concentrations in 100-N Area Riverbank Spring Water at the Hanford Site, 1997 through 2002

Year	Concentration, pCi/L ^(a)		
	Tritium	Gross Beta	Strontium-90
1997 ^(b)	19,000 ± 1,500	3.5 ± 1.6	0.59 ± 0.13
1997 ^(c)	14,000 ± 1,100	16,000 ± 1,400	9,900 ± 1,800
1998 ^(b)	24,000 ± 1,900	2.3 ± 2.1	^(d)
1999 ^(b)	14,000 ± 670	2.9 ± 1.7	0.026 ± 0.034 ^(e)
2000 ^(b)	18,000 ± 800	5.9 ± 2.1	-0.0026 ± 0.037 ^(e)
2001 ^(b)	17,000 ± 800	3.7 ± 1.8	0.013 ± 0.043 ^(e)
2001 ^(b)	6,500 ± 430	5.5 ± 2.0	0.039 ± 0.044 ^(e)
2002 ^(b)	7,100 ± 320	4.8 ± 1.7	0.0042 ± 0.0034 ^(e)

- (a) Concentrations are ±2 total propagated analytical uncertainty. To convert to international metric system, multiply pCi/L by 0.037 to obtain Bq/L.
- (b) Sample collected from riverbank spring downstream of well 199-N-8T (Spring 8-13).
- (c) Samples collected from spring below well 199-N-8T (see PNNL-11795, Figure 3.2.4).
- (d) Sample was lost during processing at the analytical laboratory.
- (e) Value below the detection limit.

routine surveillance of Columbia River sediment is required (PNL-3127; Wells 1994). However, periodic sampling is necessary to confirm the low concentrations and to assure that no significant changes have occurred for this pathway. The accumulation of radioactive materials in sediment can lead to human exposure by ingestion of aquatic organisms associated with the sediment, sediment resuspension into drinking water supplies, or as an external radiation source irradiating people who are fishing, wading, sunbathing, or participating in other recreational activities associated with the river or shoreline (DOE/EH-0173T).

Since the shutdown of the last single-pass reactor at Hanford during 1971, the contaminant concentrations in the surface sediment have been decreasing as a result of radioactive decay and the subsequent deposition of uncontaminated material (Cushing et al. 1981). However, discharges of some pollutants from the Hanford Site to the Columbia River still occur via permit-regulated liquid effluent discharges at the 100-K Area (Section 3.1) and via contaminated groundwater seepage (Section 4.2.3).

Several studies have been conducted on the Columbia River to investigate the difference in sediment grain-size composition and total organic carbon content at routine monitoring sites (Beasley et al. 1981; PNL-10535; PNNL-13417). Physical and chemical sediment characteristics were found to be highly variable among monitoring sites along the Columbia River. Samples containing the highest percentage of silts, clays, and total organic carbon were generally collected from the upstream pools at the dams and from White Bluffs Slough.

4.2.3.1 COLLECTION OF SEDIMENT SAMPLES AND ANALYTES OF INTEREST

During 2002, samples of the surface layer of Columbia River sediment were collected at depths of 0 to 15 centimeters (0 to 6 inches) from six river locations that were permanently (some Hanford Reach sampling locations may not be submerged during extremely low river stage) submerged and six riverbank springs that were periodically inundated (Figure 4.2.1 and Table 4.2.2). Sediment sampling locations were documented using a global positioning system.

Samples were collected upstream of Hanford Site facilities from the Priest Rapids Dam pool (the nearest upstream impoundment) to provide background data from an area unaffected by site operations. Samples were collected downstream of the Hanford Site above McNary Dam (the nearest downstream impoundment) to identify any increase in contaminant concentrations. Any increases in contaminant concentrations found in sediment above McNary Dam compared to that found above Priest Rapids Dam do not necessarily reflect a Hanford Site source. The confluences of the Columbia River with the Yakima, Snake, and Walla Walla Rivers lie between the Hanford Site and McNary Dam. Several towns, irrigation water returns, and factories in these drainages also may contribute to the contaminant load found in McNary Dam sediment; thus, sediment samples are periodically taken at Ice Harbor Dam (the first dam on the Snake River upstream of the river mouth) to assess Snake River inputs (the most recent samples were collected during 2001). Sediment samples also were collected along the Hanford Reach of the Columbia River from areas close to contaminant discharges (e.g., riverbank springs), from

Table 4.2.4. Concentration Ranges for Selected Chemicals in Water from Columbia River Springs at the Hanford Site, 1999 through 2002

Ambient Water Quality Criterion Level ^(a)		Concentration, µg/L							
		100-B Area	100-K Area	100-N Area	100-D Area	100-H Area	100-F Area	Hanford Town Site	300 Area
No. of Samples		6	8	5	6	12	5	6	7
Dissolved Metals (µg/L)									
Antimony	NA	0.081 - 0.28	0.14 - 0.24	0.16 - 0.24	0.18 - 0.22	0.23 - 0.42	0.096 - 0.23	0.13 - 0.39	0.20 - 0.36
Arsenic	190	0.93 - 1.6	0.32 - 2.1	1.4 - 3.4	0.66 - 1.3	0.30 - 3.0	1.5 - 2.6	2.6 - 4.8	0.95 - 2.9
Cadmium	0.59	0.010 - 0.021	0.0044 - 0.051	0.011 - 0.031	0.017 - 0.093	0.0044 - 0.034	0.0091 - 0.023	0.010 - 0.089	0.012 - 0.078
Chromium	10 ^(b)	7.5 - 20	2.1 - 82	5.6 - 12	24 - 150	4.0 - 88	14 - 22	1.8 - 4.6	2.2 - 3.9
Copper	6	0.20 - 2.1	0.38 - 1.1	0.25 - 0.40	0.38 - 1.4	0.29 - 5.6	0.32 - 0.45	0.20 - 0.62	0.38 - 0.60
Lead	1.1	0.011 - 0.16	0.0078 - 0.016	0.0050 - 0.016	0.0073 - 0.020	0.0050 - 0.57	0.0078 - 0.033	0.0049 - 0.075	0.0050 - 0.062
Nickel	83	0.028 - 1.6	0.12 - 1.7	0.027 - 1.0	0.22 - 1.8	0.070 - 1.2	0.070 - 2.2	0.62 - 1.7	0.055 - 2.1
Silver	0.94 ^(c)	0.0012 - 0.021	0.0012 - 0.021	0.0012 - 0.021	0.0043 - 0.021	0.0050 - 0.021	0.0012 - 0.042	0.0043 - 0.053	0.0049 - 0.021
Thallium	NA	0.0035 - 0.020	0.0035 - 0.023	0.0071 - 0.016	0.026 - 0.098	0.0059 - 0.026	0.0035 - 0.011	0.013 - 0.028	0.013 - 0.038
Zinc	55	0.94 - 5.0	0.76 - 3.7	1.5 - 3.7	1.7 - 12	0.35 - 5.0	1.1 - 2.5	1.3 - 3.1	1.7 - 3.0
No. of Samples		7	8	5	6	11	5	10	7
Total Recoverable Metals (µg/L)									
Chromium	96 ^(d)	7.2 - 20	2.2 - 93	7.6 - 14	24 - 190	4.0 - 99	17 - 33	1.8 - 5.4	1.9 - 24
Mercury	0.012	0.00048 - 0.0013 ^(e)	0.00098 - 0.014 ^(f)	0.00044 - 0.0062 ^(g)	0.00086 - 0.020 ^(e)	0.00056 - 0.002 ^(h)	0.0017 - 0.0038 ^(g)	0.00079 - 0.0028 ⁽ⁱ⁾	0.00074 - 0.0047 ^(e)
Selenium	5	0.60 - 2.2	0.11 - 2.2	0.41 - 0.96	0.67 - 2.7	0.39 - 2.9	0.94 - 2.3	0.56 - 2.3	1.7 - 4.1
No. of Samples		8	7	4	10 ^(j)	12	5	8	7
Anions (mg/L)									
Nitrate	45 ^(k)	1.5 - 3.4	0.29 - 4.9	2.0 - 4.9	0.84 - 6.3	0.10 - 20	0.58 - 33	3.0 - 8.1	3.2 - 6.4

(a) Ambient Water Quality Criteria Values (WAC 173-201A-040) for chronic toxicity unless otherwise noted.

(b) Value for hexavalent chromium.

(c) Value for acute toxicity; chronic value not available.

(d) Value for trivalent chromium.

(e) n=5.

(f) n=4.

(g) n=3.

(h) n=7.

(i) n=8.

(j) One nitrate result of 295 mg/L for riverbank spring (SD-110-2) on October 17, 2000 was not included in the range because it was considered an anomalously high value.

(k) Drinking water standard (WAC 246-290).

NA = Not available.

slackwater areas where fine-grained material is known to deposit (e.g., the White Bluffs, 100-F Area, and Hanford Sloughs), and from the publicly accessible Richland shoreline that lies within the influence of the McNary Dam impoundment.

Monitoring sites at McNary and Priest Rapids Dams consisted of two stations spaced equidistant (approximately) on a transect line crossing the Columbia River; the samples were collected near the boat exclusion buoys at each dam. All other monitoring sites consisted of a single sampling location. Samples of permanently inundated river sediment were collected using a clam-shell style sediment dredge. Samples of periodically inundated (covered by water) river sediment (riverbank springs sediment) were collected using a large plastic spoon, immediately following the collection of riverbank springs water samples. Sampling methods are discussed in detail in DOE/RL-91-50. All sediment samples were analyzed for gamma-emitting radionuclides (Appendix F), strontium-90, uranium-234, uranium-235, uranium-238, and metals (DOE/RL-91-50). Selected river sediment samples were also analyzed for plutonium-238 and plutonium-239/240. The specific analytes selected for sediment samples were based on findings of previous Columbia River sediment investigations, reviews of past and present effluent discharged from site facilities, and reviews of contaminant concentrations observed in groundwater monitoring wells near the river.

4.2.3.2 RADIOLOGICAL RESULTS FOR SEDIMENT SAMPLES FROM COLUMBIA RIVER

Radionuclides consistently detected in river sediment adjacent to and downstream of the Hanford Site during 2002 included potassium-40, cesium-137, uranium-238, plutonium-238, and plutonium-239/240 (Appendix B, Table B.7). The concentrations of all other radionuclides were below detection limits for most samples (PNNL-14295, APP. 1). Cesium-137 and plutonium isotopes exist in worldwide fallout, as well as in effluent from Hanford Site facilities. Potassium-40 and uranium occur naturally in the environment, and uranium is also present in Hanford Site effluent. No federal or state freshwater sedi-

ment criteria are available to assess the sediment quality of the Columbia River (EPA 822-R-96-001).

Radionuclide concentrations reported in river sediment during 2002 were similar to those reported for previous years (Appendix B, Table B.7). Cesium-137, plutonium-239/240, and uranium isotopes were the only radionuclides detected in sediment samples, and there were no obvious differences between locations. Median, maximum, and minimum concentrations of selected radionuclides measured in Columbia River sediment (1996 through 2001) are presented in Figure 4.2.14.

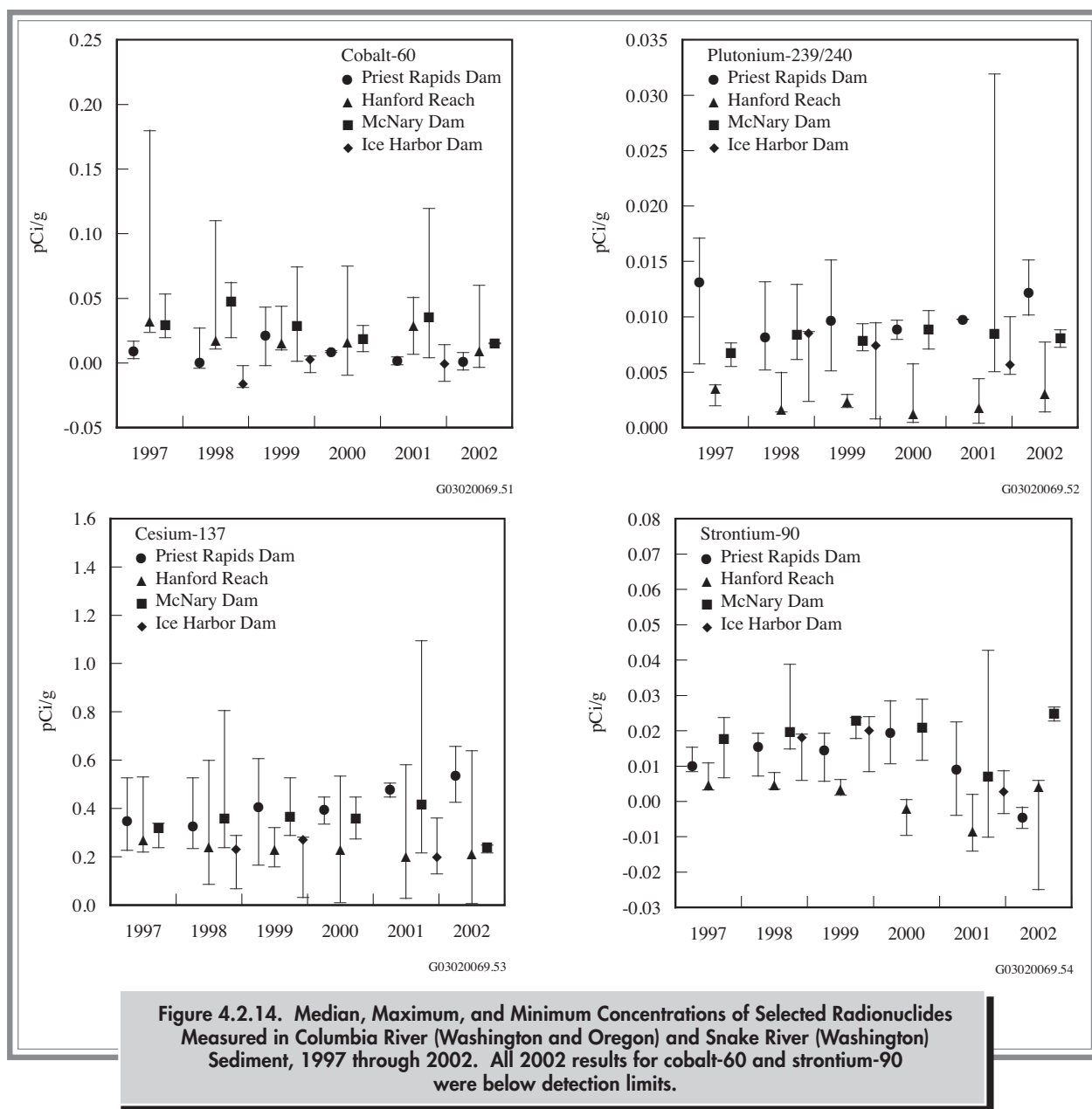
4.2.3.3 RADIOLOGICAL RESULTS FOR SEDIMENT SAMPLES FROM RIVERBANK SPRINGS

Sampling of sediment from riverbank springs began during 1993 at the Hanford town site and the 300 Area. Sampling of the riverbank springs in the 100-B, 100-K, and 100-F Areas began during 1995. Substrates at riverbank springs sampling locations in the 100-N, 100-D, and 100-H Areas consist of predominantly large cobble and are unsuitable for sample collection.

During 2002, sediment samples were collected at riverbank springs in the 100-B, 100-F, and 300 Areas. No sediment was available for sampling at the 100-K and 100-N Area locations. Results for 2002 samples were similar to those observed for previous years (PNNL-14295; APP. 1; Appendix B, Table B.7). Cesium-137 and uranium isotopes were the only radionuclides reported above the detection limits. During 2002, radionuclide concentrations in riverbank spring sediment were similar to those observed in river sediment, with the exception of the 300 Area where elevated uranium concentrations were observed (PNNL-13692).

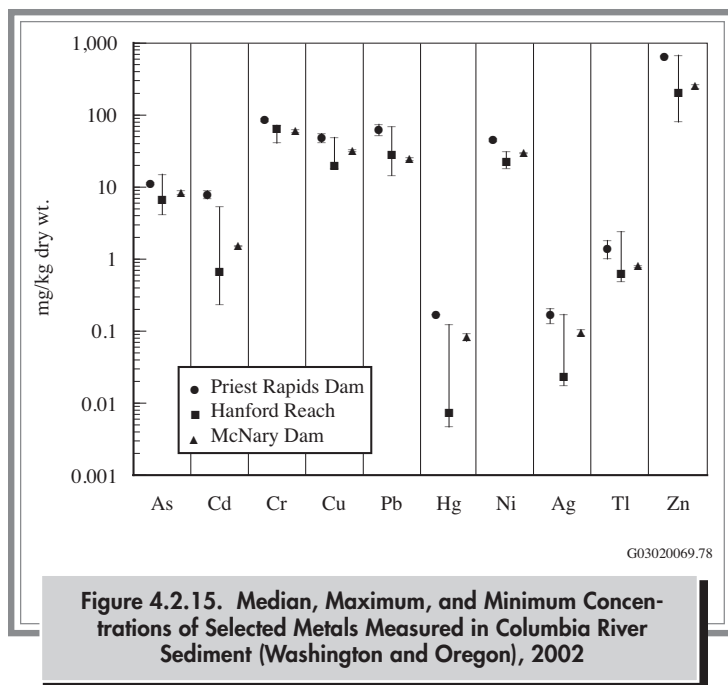
4.2.3.4 CHEMICAL RESULTS FOR SEDIMENT SAMPLES FROM THE COLUMBIA RIVER AND RIVERBANK SPRINGS

Detectable amounts of most metals were found in all river sediment samples (Figure 4.2.15; Appendix B, Table B.8;



PNNL-14295, APP. 1). Maximum and median concentrations of most metals were higher for sediment collected at Priest Rapids Dam compared to either Hanford Reach or McNary Dam sediment. The concentrations of cadmium, mercury, silver, and zinc had the largest differences between locations. Metal concentrations in riverbank spring sediment samples during 2002 were similar to concentrations in Hanford Reach Columbia River sediment samples. Currently, there are no Washington State freshwater sediment quality criteria for comparison to the measured values.

From 1997 to 2000 and for 2002, Columbia River sediment was analyzed for simultaneously extracted metals/acid volatile sulfide (SEM/AVS). This analysis involves a cold acid extraction of the sediment followed by analysis for sulfide and metals. The SEM/AVS ratios are an indicator of potential sediment toxicity (DeWitt et al. 1996; Hansen et al. 1996; PNNL-13417). Acid volatile sulfide is an important binding phase for divalent metals (i.e., metals with a valence state of 2+, such as Pb^{2+}) in sediment. Metal sulfide precipitates are typically very insoluble, and this limits the amount of dissolved metal available in the



sediment porewater. For an individual metal, when the amount of acid volatile sulfide exceeds the amount of the metal (i.e., the SEM/AVS molar ratio is below 1), the dissolved metal concentration in the sediment porewater will be low because of the limited solubility of the metal sulfide. For a suite of divalent metals, the sum of the simultaneously extracted metals must be considered, with the assumption that the metal with the lowest solubility will be the first to combine with the acid volatile sulfide.

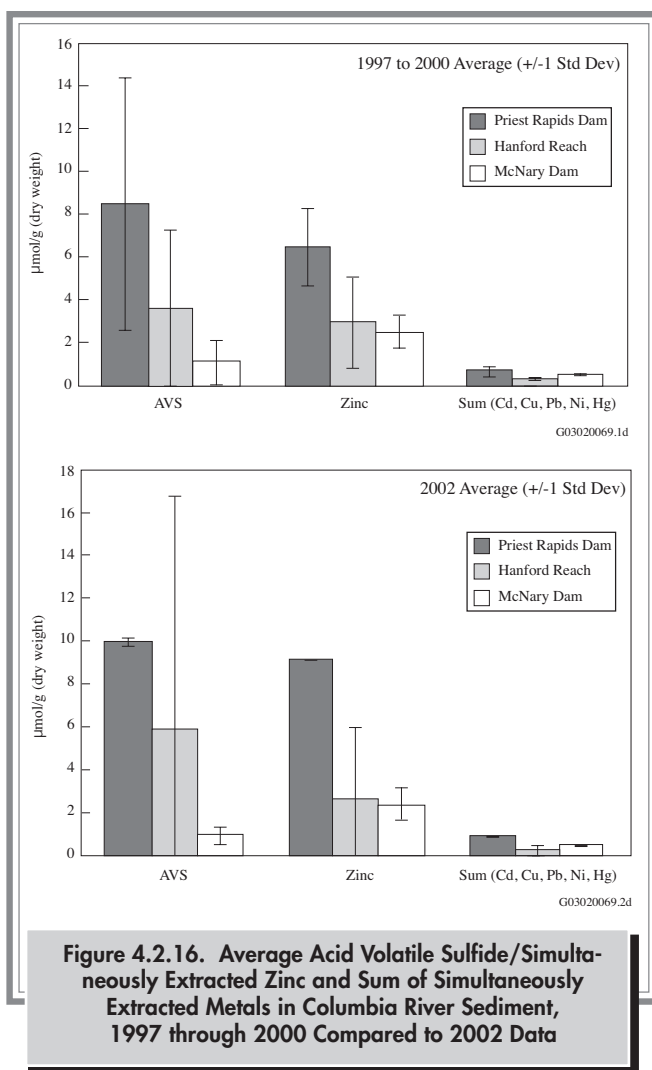
The SEM/AVS results for the sediment collected during 2002 near Priest Rapids Dam and McNary Dam were similar to previous years (Figure 4.2.16). The average SEM/AVS results for the Hanford Reach sediment collected during 2002 were similar but the concentrations varied over a wider range (0.024 to 22 $\mu\text{mol/g}$). The sediment deposition locations in the Hanford Reach are more subject to annual variations in sediment parameters that can influence SEM/AVS results (e.g., sediment deposition rate, scouring by floods, changes in total organic carbon concentrations, and potential exposure to air during dry periods) than the sediment deposition areas upstream of the dams. For 2002, the acid volatile sulfide values in sediment from the Priest Rapid Dam reservoir had concentrations ranging from 9.8 to 10 $\mu\text{mol/g}$. Sediment from the Hanford Reach and McNary Dam reservoir had lower concentrations of acid volatile sulfide, with values ranging from 0.024 to 1.2 $\mu\text{mol/g}$, excluding the White

Bluffs Slough result of 22 $\mu\text{mol/g}$. For 2002, the SEM/AVS molar ratios were near 1.0 for Priest Rapids Dam. For 2002, SEM/AVS molar ratios for sediment from the Hanford Reach and McNary Dam were above 1.0, indicating a potential for some dissolved metals to be present in the sediment porewater; excluding the White Bluffs Slough that had SEM/AVS molar ratio below one (i.e., low potential for dissolved metals in sediment porewater). For all locations, zinc was the primary SEM metal present.

These results reveal an apparent difference in the acid volatile sulfide concentrations in sediment from Priest Rapids Dam reservoir, which had higher concentrations than Hanford Reach and McNary Dam. An apportionment of acid volatile sulfide by divalent metals according to solubility values revealed that sufficient acid volatile sulfide should exist in all locations to limit the porewater concentrations of cadmium, copper, lead, and mercury. In Priest Rapids Dam sediment, average zinc values were of similar magnitude as the average acid volatile sulfide concentrations. In Hanford Reach and McNary Dam sediment, the average zinc concentrations were higher than the available mean acid volatile sulfide pool, indicating the potential for zinc and possibly other dissolved metals to be present in the sediment porewater.

4.2.4 ONSITE POND WATER AND SEDIMENT

Two onsite ponds (Figure 4.2.1), located near operational areas, were sampled periodically during 2002. The ponds are inaccessible to the public and, therefore, did not constitute a direct offsite environmental impact during 2002. However, they were accessible to migratory waterfowl and deer, creating a potential biological pathway for the dispersion of contaminants (PNL-10174). The Fast Flux Test Facility pond is a disposal site for process water (primarily cooling water drawn from groundwater wells). West Lake, the only naturally occurring pond on the site, is located north of the 200-East Area (ARH-CD-775). West Lake has not received direct effluent discharges from Hanford Site facilities but is influenced by changing water-table elevation as a result of previous discharge of water to the ground in the 200 Areas.



4.2.4.1 COLLECTION OF POND WATER AND SEDIMENT SAMPLES AND ANALYTES OF INTEREST

During 2002, grab samples were collected quarterly from the Fast Flux Test Facility pond (water) and from West Lake (water and sediment). All water samples were analyzed for tritium. Water samples from the Fast Flux Test Facility pond were also analyzed for gross alpha and gross beta concentrations, and gamma-emitting radionuclides. The groundwater table in the 200-East Area has decreased in recent years (Section 6.1) and this has decreased the size of West Lake and caused the suspended sediment loading to increase. During 2002, it was no longer practical for the analytical laboratory to process West Lake water

samples for gross alpha, gross beta, strontium-90, technetium-99, and uranium-234, uranium-235, and uranium-238 because of the high sediment load; thus, sediment samples were submitted for these analytes. Constituents were chosen for analysis based on their known presence in local groundwater, effluent discharged, and their potential to contribute to the overall radiation dose to biota that frequent the ponds.

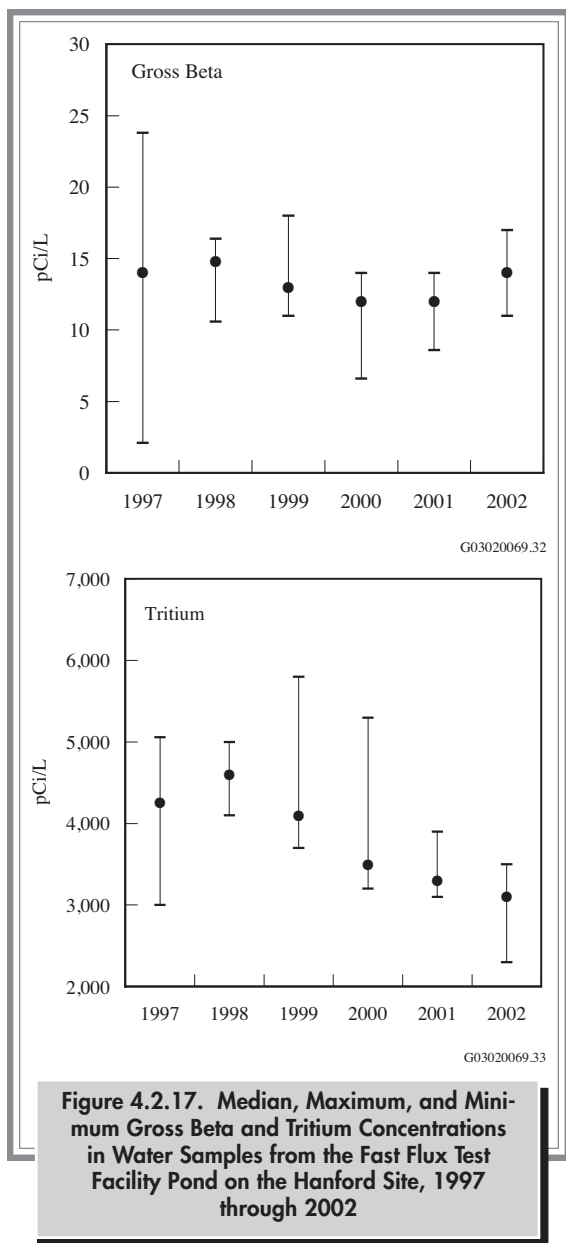
4.2.4.2 RADIOLOGICAL RESULTS FOR POND WATER AND SEDIMENT SAMPLES

All radionuclide concentrations in onsite pond water were less than applicable DOE derived concentration guides (DOE Order 5400.5; Appendix D, Table D.5) and state ambient surface-water quality criteria levels (WAC 173-201A; 40 CFR 141; PNNL-14295, APP. 1; Appendix D, Tables D.1 and D.2).

Figure 4.2.17 shows the annual gross beta and tritium concentrations in Fast Flux Test Facility pond water from 1997 through 2002. Median levels of both constituents have remained stable in recent years. The median tritium concentration in Fast Flux Test Facility pond water during 2002 was 15% of the state ambient surface-water quality criterion of 20,000 pCi/L (740 Bq/L).

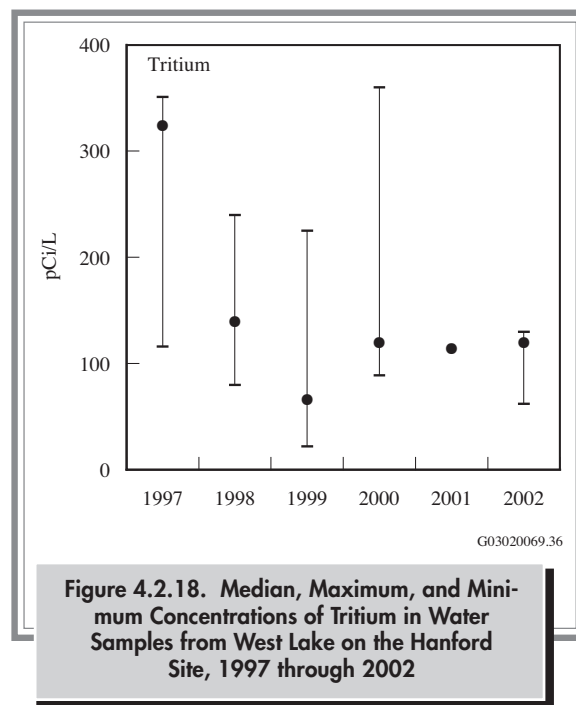
Median tritium concentrations in West Lake water during 2002 were similar to those observed in the past (Figure 4.2.18). The median concentration of tritium in West Lake water in 2002 was 0.6% of the state ambient surface-water quality criterion level (20,000 pCi/L [740 Bq/L]) and reflected local groundwater concentrations.

Samples of West Lake sediment in 2002 had detectable values for gross alpha (2.6 to 11 pCi/g [0.096 to 0.41 Bq/g]), gross beta (24 to 34 pCi/g [0.89 to 1.3 Bq/g]), potassium-40 (14 to 19 pCi/g [0.52 to 0.70 Bq/g]), strontium-90 (0.11 to 0.70 pCi/g [0.0041 to 0.026 Bq/g]), cesium-137 (0.28 to 1.8 pCi/g [0.010 to 0.067 Bq/g]), uranium-234 (0.29 to 4.8 pCi/g [0.011 to 0.16 Bq/g]), uranium-235 (0.0099 to 0.18 pCi/g [0.00037 to 0.0067 Bq/g]), and uranium-238 (0.29 to 4.3 pCi/g [0.011 to 0.16 Bq/g]). These levels of radionuclides are similar to previous measurement (PNL-7662) and are believed to result from high levels of naturally occurring uranium in the surrounding soil (BNWL-1979).



4.2.5 IRRIGATION WATER

During 2002, water samples were collected from an irrigation canal located across the Columbia River and downstream from the Hanford Site at Riverview, and from an irrigation water supply on the Benton County shoreline near the southern boundary of the Hanford Site (Horn Rapids irrigation pumping station). As a result of public concerns about the potential for Hanford-associated contaminants in offsite water, sampling was conducted to document the levels of radionuclides in water used by



the public. Consumption of vegetation irrigated with Columbia River water downstream of the site has been identified as one of the primary pathways contributing to the potential dose to the hypothetical maximally exposed individual and any other member of the public (Chapter 5).

COLLECTION, ANALYSIS, AND RESULTS FOR IRRIGATION WATER

Water from the Riverview irrigation canal and the Horn Rapids irrigation pumping station was sampled three times during 2002 during the irrigation season. Unfiltered samples were analyzed for gross alpha, gross beta, gamma emitters, tritium, strontium-90, and uranium-234, uranium-235, and uranium-238. During 2002, radionuclide concentrations measured in irrigation water were at the same levels detected in the Columbia River (PNNL-14295, APP. 1). All radionuclide concentrations were below their respective DOE derived concentration guides and state ambient surface-water quality criteria levels (DOE Order 5400.5; WAC 173-201A; 40 CFR 141). Strontium-90 levels in all irrigation water samples during 2002 ranged from 0.055 ± 0.028 to 0.077 ± 0.034 pCi/L (0.0020 ± 0.0010 to 0.0028 ± 0.0013 Bq/L).



4.3 RADIOLOGICAL SURVEILLANCE OF HANFORD SITE DRINKING WATER

R. W. Hanf and L. M. Kelly

The quality of drinking water at the Hanford Site is monitored by routinely collecting and analyzing drinking water samples and comparing the resulting analytical data with established drinking water standards and guidelines (WAC 246-290; 40 CFR 141; EPA-570/9-76-003; EPA 822-R-96-001; Appendix D, Tables D.2 and D.5). During 2002, Pacific Northwest National Laboratory conducted radiological surveillance of drinking water supplied to Hanford Site facilities by DOE-owned pumps and water treatment facilities. Fluor Hanford, Inc. conducted routine chemical and microbiological monitoring of these drinking water systems.

The community drinking water standards of the *Safe Drinking Water Act* apply to the drinking water supplies at the Hanford Site (DOE Order 5400.5). In Washington State, adherence to these standards is enforced by the Washington State Department of Health. Washington Administrative Code (WAC 246-290) requires that all drinking water analytical results be reported routinely to the Washington State Department of Health. Radiological results for the Hanford Site are reported to the state through this annual environmental report and through an annual supplemental data compilation (PNNL-14295, APP. 1). Non-radiological data are reported to the state by Fluor Hanford, Inc. but are not published.

All DOE-owned drinking water systems on the Hanford Site were in compliance with community drinking water standards for radiological contaminant levels during 2002. Contaminant concentrations measured during the year were similar to those observed in recent years (see Section 4.3 in PNNL-13487; PNNL-13910).

4.3.1 HANFORD SITE DRINKING WATER SYSTEMS

During 2002, drinking water was supplied to DOE facilities on the site by nine DOE-owned, contractor-operated, water

treatment and distribution systems (Table 4.3.1), and one system owned and operated by the city of Richland. Eight of these systems (including Richland's system) used water pumped from the Columbia River. One system used groundwater pumped from the unconfined aquifer beneath the site. Fluor Hanford, Inc. operated most of the systems. Bechtel Hanford, Inc. operated one system in the 100-N Area that was supplied with water from a pumping station operated by Fluor Hanford, Inc. The city of Richland provided drinking water to the 300 Area, Richland North Area, and Hazardous Materials Management and Emergency Response Training and Education Center (HAMMER) facility.

4.3.2 HANFORD SITE DRINKING WATER SUPPLY FACILITIES

During 2002, radionuclide concentrations in onsite drinking water were monitored at four DOE-owned water supply facilities (Figure 4.3.1). The 100-B Area pumphouse continued to serve as the primary Columbia River pumping station for many areas on the site (100-B and 100-N Areas, 200-West Area, 251 Building, and 100 Areas Fire Station). The 181-KE pumphouse supplied water (Columbia River) for the 100-K Area. Water for the 200-East Area, which formerly came from the 283-E water treatment plant located in the 200-East Area, was supplied by the 283-W water treatment plant (located in the 200-West Area). Water for this treatment plant was obtained from the Columbia River via the 100-B or 100-D raw water export lines. The 283-E treatment plant was designated as an emergency supply facility in 1999 and was maintained in a standby mode during 2002. The 181-D pumphouse in the 100-D Area continues to operate and supply water to the 100-D raw water export line. This line was used as a backup to the 100-B raw water export line during 2002.

Table 4.3.1. DOE-Owned Drinking Water Systems^(a) on the Hanford Site, 2002

<u>Location</u>	<u>Source of Supply</u>	<u>Notes</u>
100-D	Columbia River via 181-B or D raw water export	The 100-D water treatment facility was permanently removed from service on July 12, 2000, but the pumping facility remains operational.
100-B	Columbia River via 181-B pump-house and 100-B raw water export line or via the 181-D pumphouse and 100-D raw water export line	Filtered and chlorinated at 182-B Reservoir pumphouse.
100-K	Columbia River via 181-KE pumphouse	Filtered and chlorinated at 185-KE Water Treatment Plant.
100-N	Columbia River via 181-B pump-house and 100-B raw water export line or via the 181-D pumphouse and 100-D raw water export line	Filtered and chlorinated at 186-N Water Treatment Plant. This is a small skid-mounted package plant that contains three banks of various sized filters and a sodium hypochlorite system for disinfection.
200-East	Normally from the Columbia River via the 283-W Water Treatment Plant. In emergencies, supplied via 181-B or D raw water export and 283-E Water Treatment Plant.	Filtered and chlorinated at 283-W Water Treatment Plant. The clearwells at 283-E serve as reservoirs that supply the 200-East Area distribution system. Under normal conditions, the clearwells are supplied from the 283-W Water Treatment Plant. The 283-E Water Treatment Plant is maintained in standby mode for emergencies.
200-West	Columbia River via 181-B pump-house and 100-B raw water export line or via the 181-D pumphouse and 100-D raw water export line	Filtered and chlorinated at 283-W Water Treatment Plant.
251 Building (electrical switching)	Columbia River via 181-B pump-house and 100-B raw water export line or via the 181-D pumphouse and 100-D raw water export line	Filtered and chlorinated at 251 Building.
609 Building (100 Areas Fire Station)	Columbia River via 181-B pump-house and 100-B raw water export line or via the 181-D pumphouse and 100-D raw water export line	Filtered and chlorinated at 609 Building.
400 Area	Wells 499-S1-8J, 499-S0-8, and 499-S0-7	Supplied from well 499-S1-8J (P-16); wells 499-S0-8 (P-14) and 499-S0-7 (P-15) are the dire emergency supplies. Whichever well has the lowest tritium levels, as demonstrated by sampling and analysis, is considered the primary backup well. Well P-15 was not used in 2002. Chlorination only.
300 Area	Treated Columbia River water via city of Richland	300 Area distribution system.

(a) The system in the 100-N Area was operated by Bechtel Hanford, Inc. All other systems were operated by Fluor Hanford, Inc.

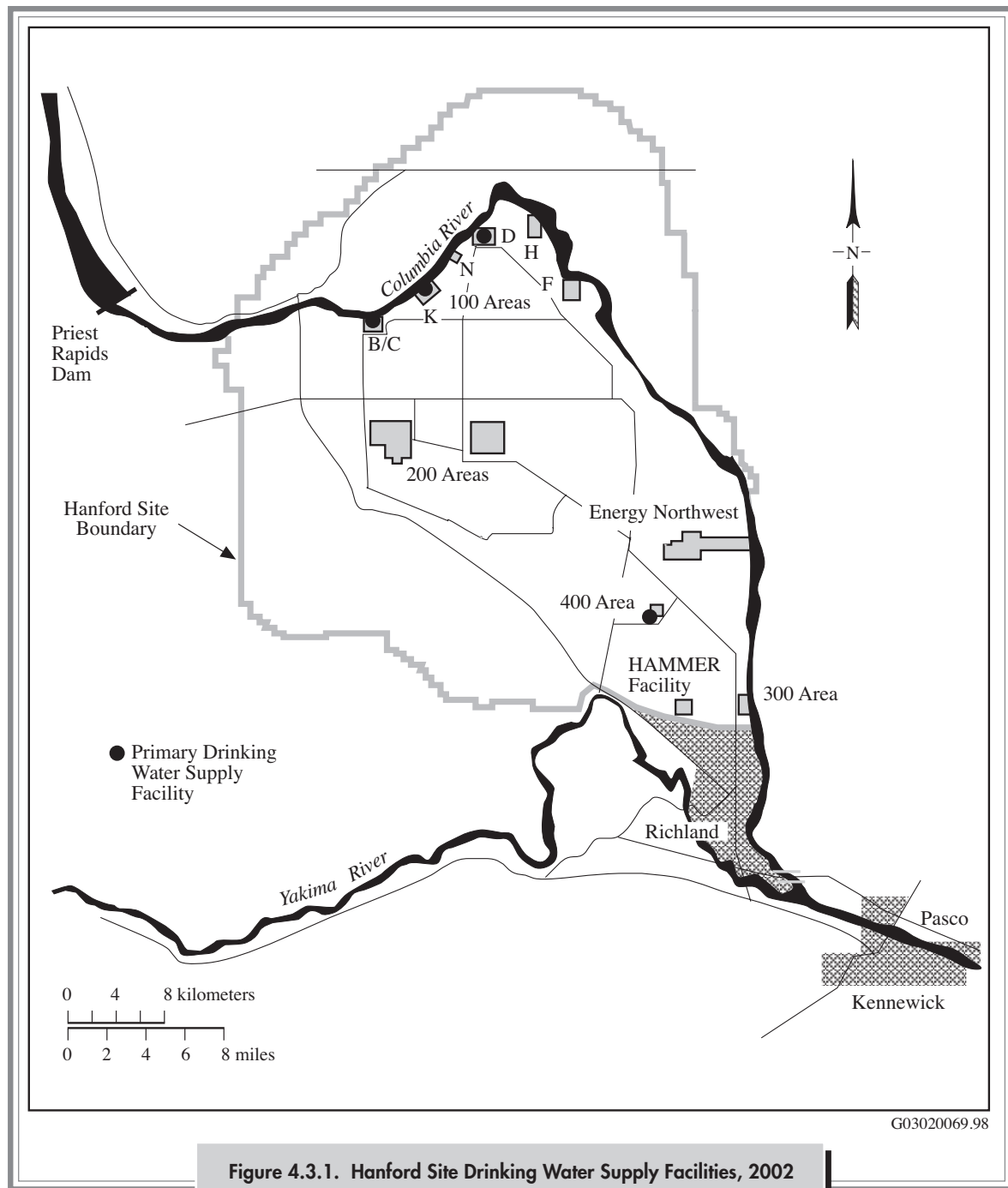


Figure 4.3.1. Hanford Site Drinking Water Supply Facilities, 2002

The 400 Area continued to use well 499-S1-8J (P-16) as the primary drinking water supply well, with wells 499-S0-8 (P-14) and 499-S0-7 (P-15) serving as backup supplies. The backup well with the lowest tritium level, as demonstrated by sampling and analysis, is considered the primary backup water supply. Well 499-S0-7 was not used as a drinking water source during 2002. Well 499-S0-8 supplied 2.13 million liters (564,000 gallons) to the distribution system in

March, 154,000 liters (40,800 gallons) in May, and 1.5 million liters (399,600 gallons) in August. At these times, the primary supply well (499-S1-8J) was off-line due to an electrical outage and scheduled maintenance, an electrical outage, and an unscheduled maintenance, respectively. In addition to supplying drinking water, these three wells were also important for maintaining fire suppression capabilities within the 400 Area, where they are located.

4.3.3 COLLECTION OF DRINKING WATER SAMPLES AND ANALYTES OF INTEREST

Drinking water samples were collected for radiological analyses according to a schedule established at the beginning of the calendar year (PNNL-13749). Samples at all of the locations were collected and analyzed quarterly. All were samples of treated water collected prior to distribution to facilities.

The Hanford Groundwater Monitoring Project collected samples of raw well water from each of the 400 Area drinking water wells four times during the first half of the calendar year. Beginning in April 2002, collection frequency changed from monthly to quarterly, with collections occurring during the first month of each quarter. The samples for the last quarter of the calendar year were scheduled for collection during October but, because of facility problems, were not obtained.

Drinking water samples obtained from the 400 Area during May were co-sampled with the Washington State Department of Health. The analytical results from the state's samples help to verify the quality of the drinking water data reported herein and in PNNL-14295, APP. 1.

Water from the city of Richland's system was not monitored for radiological contaminants in the 300 and Richland North Areas and at the HAMMER facility, through the site drinking water surveillance project; however, personnel from Pacific Northwest National Laboratory's Surface Environmental Surveillance Project routinely collected water samples from the Columbia River at the Richland Pump House, which is the city of Richland's drinking water intake. The analytical results (radiological) for these raw river water samples can be found in Appendix B (Table B.2). The city of Richland also monitored its water for radiological and chemical contaminants, and for general water quality and reported those data in its annual newsletter to consumers (City of Richland 2003), and on its web page (<http://www.ci.richland.wa.us/UPS/waterquality.html>).

Sampling of 300 Area drinking water for non-radiological analyses was conducted routinely by Fluor Hanford, Inc. to

monitor the DOE-owned, contractor-operated water distribution system within the area. However, as stated earlier, non-radiological data are reported directly to the state and are not discussed in this report.

All 2002 drinking water samples collected for radiological analysis were analyzed for gross alpha, gross beta, tritium, strontium-90, iodine-131, radium-226, and radium-228.

4.3.4 RADIOLOGICAL RESULTS FOR HANFORD SITE DRINKING WATER SAMPLES

Results for radiological monitoring of Hanford Site drinking water during 2002 are summarized in Table 4.3.2. Individual analytical results are reported in PNNL-14295, APP. 1. The maximum amount of beta-gamma radiation from manmade radionuclides allowed in drinking water by Washington State and the EPA is an annual average concentration that will not produce an annual dose equivalent to the whole body or any internal organ >4 mrem (>0.04 mSv). If two or more radionuclides are present, the sum of their annual dose equivalent to the total body or to any internal organ must not exceed 4 mrem (0.04 mSv). Maximum contaminant levels for gross alpha (excluding uranium and radon), and radium-226 and radium-228 (a combined total) are 15 pCi/L (0.56 Bq/L) and 5 pCi/L (0.18 Bq/L), respectively. The maximum allowable limit for tritium is 20,000 pCi/L (740 Bq/L) (40 CFR 141; WAC 246-290). During 2002, annual average concentrations of all monitored radionuclides in Hanford Site drinking water were well below state and federal maximum contaminant levels. All iodine-131 and gross alpha results were below their respective analytical detection limits (that is, concentrations were so low that they could not be measured) and concentrations of gross beta, tritium, and radium-228 in half of the samples analyzed during the year were also below their respective detection limits (Table 4.3.2).

The Hanford Groundwater Monitoring Project collected and analyzed raw water samples from all three 400 Area drinking water wells. Results from these samples show that tritium levels are lowest in wells 499-S1-8J and 499-S0-8 and consistently highest in well 499-S0-7 (Table 4.3.3;

Table 4.3.2. Concentrations (pCi/L)^(a) of Selected Radiological Constituents in Hanford Site Drinking Water, 2002

Constituent	No. of Samples^(b)	Systems				Standards
		100-K Area	100-N Area	200-West Area	400 Area	
Gross alpha ^(c)	4	-0.02 ± 0.58 ^(d)	0.40 ± 1.09 ^(d)	0.51 ± 0.66 ^(d)	0.48 ± 1.19 ^(d)	15 ^(e,f)
Gross beta ^(c)	4	0.47 ± 2.22 ^(d)	1.11 ± 4.15	0.49 ± 1.04 ^(d)	6.93 ± 1.90	50 ^(f)
Tritium ^(c)	3 ^(g)	44.2 ± 88.4 ^(d)	78.4 ± 105.9 ^(d)	154.7 ± 257.6	3,160 ± 311	20,000 ^(f)
Strontium-90 ^(c)	3	0.08 ± 0.04	0.07 ± 0.03	0.07 ± 0.03	0.006 ± 0.03 ^(d)	8 ^(e,f)
Iodine-131 ^(h)	1	1.05 ± 6.2 ⁽ⁱ⁾	-1.87 ± 5.3 ⁽ⁱ⁾	-2.27 ± 4.7 ⁽ⁱ⁾	1.91 ± 5.9 ⁽ⁱ⁾	3 ⁽ⁱ⁾
Radium-226 ^(h)	1	0.05 ± 0.01	0.03 ± 0.01	0.08 ± 0.02	0.03 ± 0.01	combined
Radium-228 ^(h)	1	0.29 ± 0.24 ⁽ⁱ⁾	0.67 ± 0.29	0.62 ± 0.30	0.52 ± 0.31 ⁽ⁱ⁾	

- (a) Multiply pCi/L by 0.037 to convert to Bq/L.
(b) Grab samples collected and analyzed quarterly.
(c) Annual average ±2 standard deviations.
(d) Analytical results for all samples were below the detection limit.
(e) WAC 246-290.
(f) 40 CFR 141.
(g) Four samples at the 400 Area.
(h) Single result ±2 total propagated analytical error.
(i) Below the detection limit.
(j) EPA-570/9-76/003.

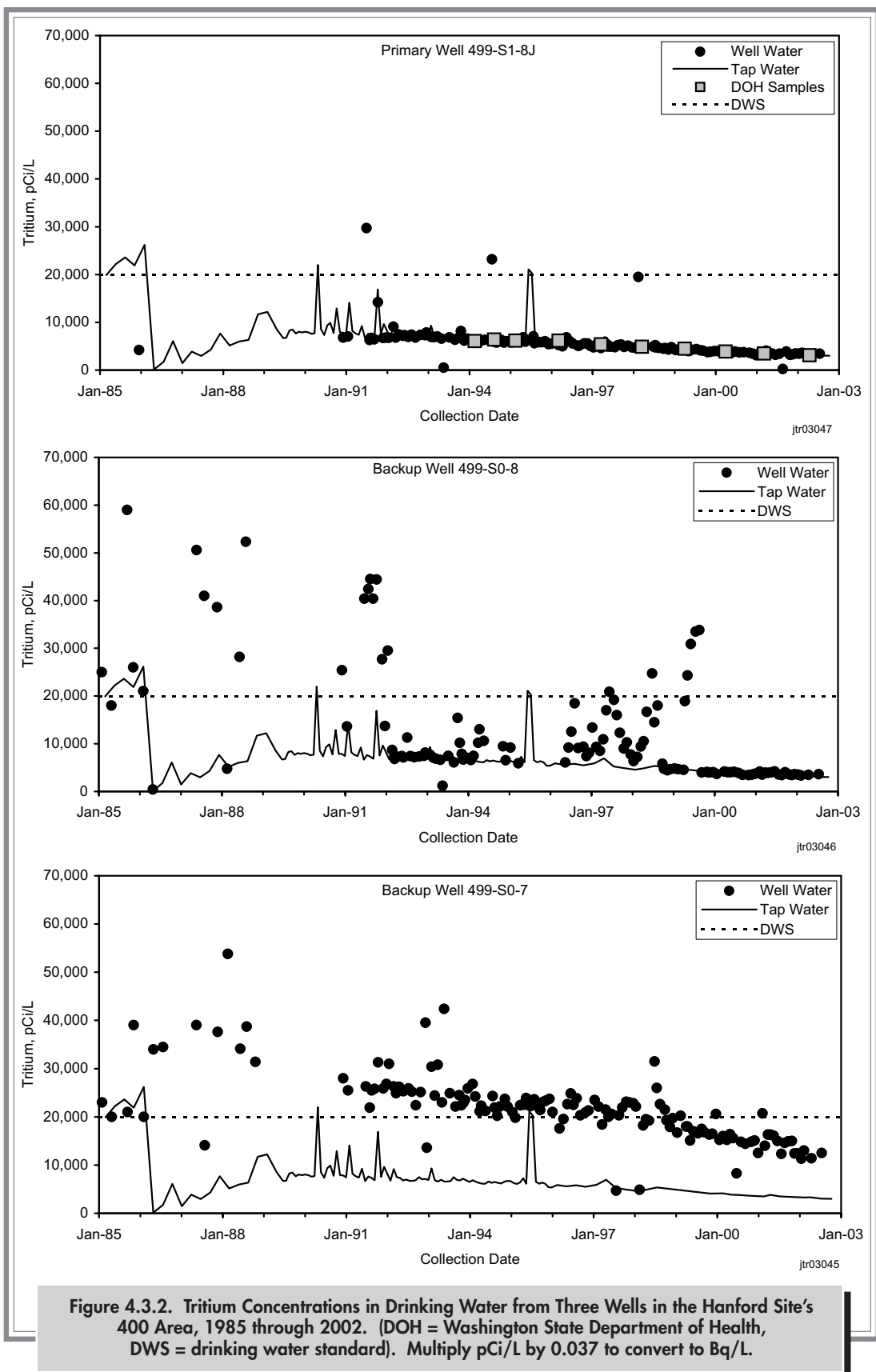
Table 4.3.3. Tritium Concentrations (pCi/L)^(a) in Hanford Site 400 Area Drinking Water Wells, 2002^(b)

Sampling Date	Primary Drinking Water	Backup Drinking Water	Backup Drinking Water
	Well 499-S1-8J (P-16)	Well 499-S0-8 (P-14)	Well 499-S0-7 (P-15)
January 15, 2002	3,420 ± 450	3,510 ± 460	11,300 ± 860
February 8, 2002	3,610 ± 410	3,340 ± 390	13,000 ± 850
April 15, 2002	3,170 ± 430	3,480 ± 450	11,400 ± 850
July 16, 2002	3,420 ± 390	3,590 ± 400	12,500 ± 820

- (a) Multiply pCi/L by 0.037 to convert to Bq/L.
(b) Reported concentration ±2 total propagated analytical error.

Figure 4.3.2). A tritium plume that originates in the 200-East Area extends under the 400 Area and has historically affected tritium concentrations in wells 499-S0-7 and 499-S0-8 (Figure 4.3.2). During 2002,

annual average tritium concentrations in all three wells were below the 20,000 pCi/L (740 Bq/L) state and federal annual average drinking water standard.





4.4 FOOD AND FARM PRODUCT SURVEILLANCE

B. L. Tiller

Food products, including fruits, leafy vegetables, milk, potatoes, and wine, were collected routinely during 2002 at several locations surrounding the Hanford Site (Figure 4.4.1). Routine samples were collected primarily from locations in the prevailing downwind directions (south and east of the site) where airborne effluent or fugitive dust from the Hanford Site could be deposited. Samples were collected also in generally upwind directions and at locations somewhat distant from the site to provide information on reference radiation levels in foodstuff.

Routine food and farm product sampling assesses the potential influence of Hanford Site releases in three ways:

- Through the comparison of results reported from the same regions over long periods of time.
- Through the comparison of results from downwind locations to those from generally upwind or distant locations.
- Through the comparison of results from locations irrigated with Columbia River water withdrawn downstream from the Hanford Site to results from locations irrigated with water from other sources.

The food and farm product sampling schedule was modified during 1996 by establishing a 2- or 3-year rotation to sample certain farm products (DOE/RL-91-50; PNNL-13749). Analyses for some radionuclides that (1) historically have not been detected in food or farm products and (2) are not likely to increase have been discontinued (Table 4.4.1).

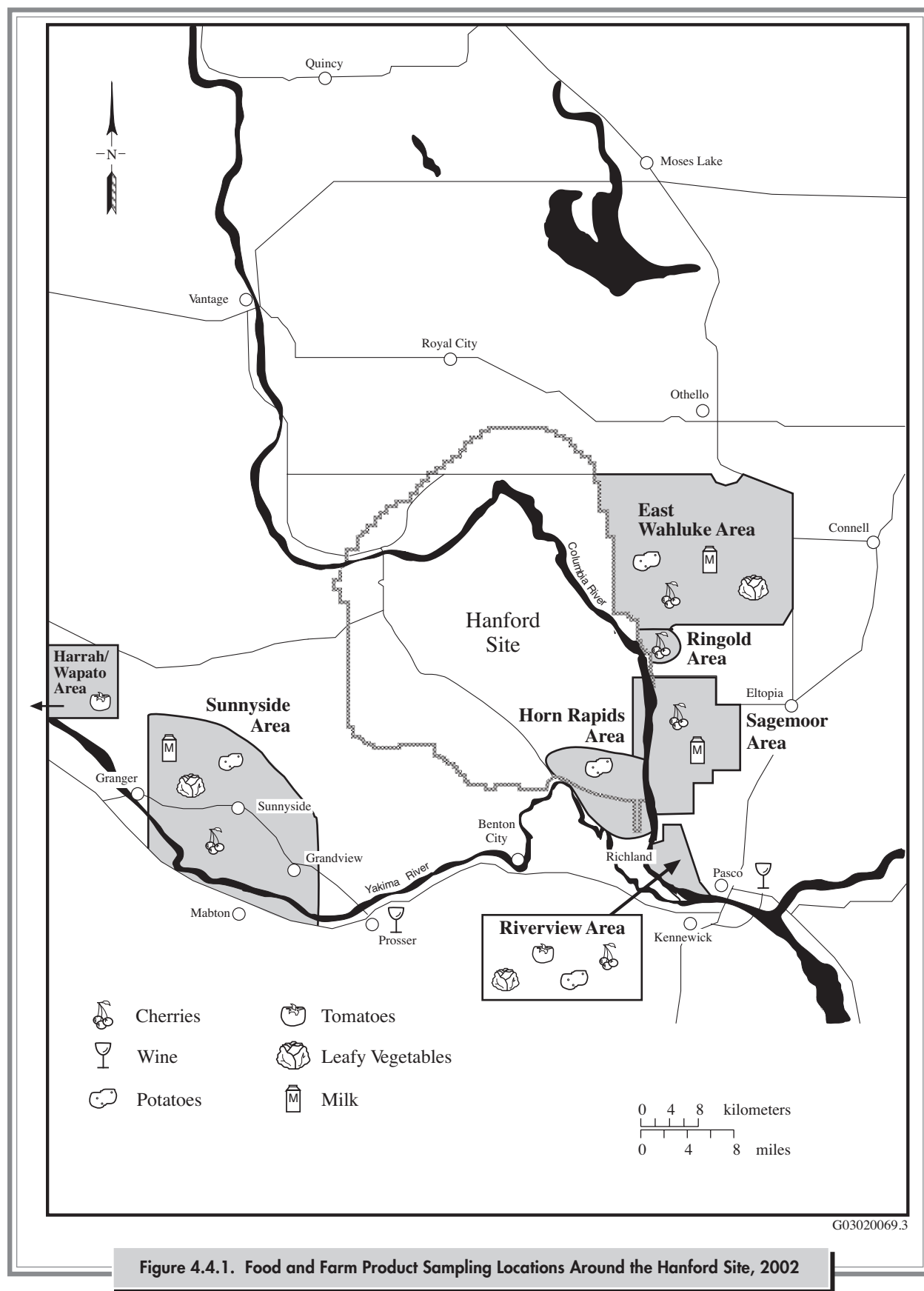
Gamma scans (cobalt-60, cesium-137, and other radionuclides; Appendix F) and strontium-90 analyses were performed for nearly all products. Milk was analyzed for iodine-129 and tritium; wine also was analyzed for tritium. Results for fruits and vegetables are reported in picocuries per gram (pCi/g) wet weight. Results for tritium are reported in picocuries per liter (pCi/L). Most tritium is found as water, and very little tritium is organically bound to other constituents present in food products.

Tritium and iodine-129 from site facilities are released to the atmosphere and to the Columbia River via riverbank springs. Strontium-90 from Hanford is released to the Columbia River through riverbank springs. Cesium-137 is present in atmospheric fallout from weapons testing and is found in Hanford Site radiological waste sites.

For many radionuclides, concentrations in farm produce are below levels that can be detected by the analytical laboratory. When this occurs for an entire group of samples, a nominal detection limit is estimated by using two times the total propagated analytical uncertainty. This value from a group of samples is used as an estimate of the lower level of detection for that analyte and particular food product. This value is then used to estimate the relatively low dose received to consumers of the produce (Chapter 5). The total propagated analytical uncertainty includes all sources of analytical error associated with the analysis (e.g., counting errors and errors associated with weight and volumetric measurements). Theoretically, re-analysis of the sample should yield a result that falls within the range of the uncertainty 95% of the time. Results and uncertainties not given in this report may be found in PNNL-14295, APP. 1. Radiological dose considerations were calculated and reported in Chapter 5.

4.4.1 MILK SAMPLES AND ANALYTES OF INTEREST

Composite samples of raw, whole milk were collected during 2002 from three dairy farms in the East Wahluke area and from three dairy farms in the Sagemoor area. These sampling areas are located near the site perimeter in the prevailing downwind direction (Figure 4.4.1). Milk samples also were collected from three dairy farms in the



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Table 4.4.1. Sampling Locations, Frequencies, and Analyses Performed for Food and Farm Products Routinely Sampled Around the Hanford Site, 2002^(a)

Product	Number of Locations		Sampling Frequency ^(b)	Number of Samples Analyzed			
	Upwind	Downwind		³ H	Gamma	⁹⁰ Sr	¹²⁹ I
Milk	1	2	Q or SA	12	12	12	6
Vegetables	2	3	A	2	7	7	0
Fruit	1	4	A	0	7	7	0
Wine	2	2	A	8	8	0	0

(a) Products may include multiple varieties for each category.

(b) Q = quarterly, SA = semiannually, A = annually.

Sunnyside area to represent reference radionuclide concentrations at a generally upwind region.

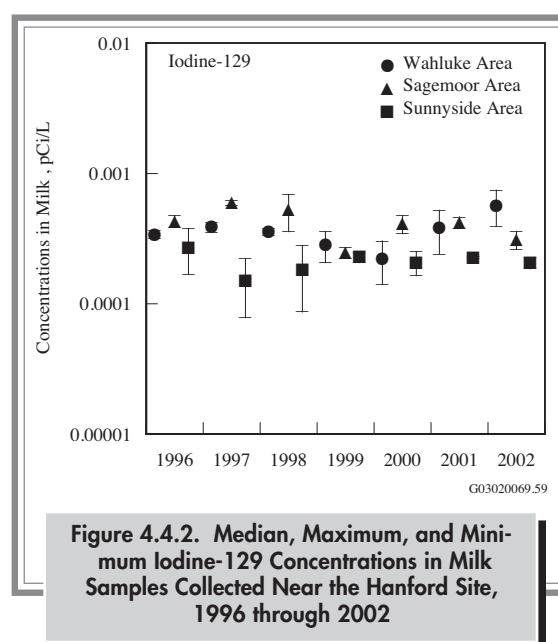
Samples of milk were analyzed for strontium-90, iodine-129, tritium, and gamma emitters such as cesium-137 because these radionuclides have the potential to move through the air-pasture-cow-milk or water-pasture-cow-milk food chains to humans.

Worldwide fallout radionuclides in feed and/or drinking water may be a significant source of radionuclides in milk products; however, measured levels of radionuclides in milk from private dairies near the Hanford Site are usually near levels considered to be background. During 2002, gamma scans and strontium-90 analyses of milk samples were conducted quarterly, and iodine-129 analyses were conducted on two semiannual composite samples. Since 1995, tritium concentrations have been below the detection level of standard liquid scintillation counting methods. During 1998, another analytical technique (DOE/RL-91-50) was instituted to measure low levels of tritium in milk samples. The technique has a detection limit of ~10 pCi/L (~0.37 Bq/L) of water distilled from milk as compared to ~180 pCi/L (~6.66 Bq/L) for the analytical technique used prior to 1996. The protection guideline for human consumption of tritiated water is 20,000 pCi/L (740 Bq/L) (Appendix D, Table D.2).

Strontium-90 was not detected in 12 milk samples analyzed in 2002. The results reported during 2002 appear consistent with results reported in previous years. Only 6 of 36 results were reported above the analytical detection limit in 1999, 2000, and 2001 combined. While there is no strontium-90 standard for milk, the drinking water

standard (based on a 2-liter [0.5-gallon] per day consumption rate) is 8 pCi/L (0.3 Bq/L) (40 CFR 141). The maximum milk consumption rate for estimating dose is ~270 liters (~71 gallons) per year (Appendix E, Table E.2).

Iodine-129 concentrations were determined by high-resolution mass spectrometry in six milk samples. In recent years, the levels of iodine-129 in milk collected from generally downwind dairies in the Sagemoor and East Wahluke areas have persisted at concentrations greater than levels measured upwind in Sunnyside (Figure 4.4.2). Iodine-129 concentrations have declined with the end of nuclear materials production at the Hanford Site. While there is no iodine-129 standard for milk, the drinking water standard is 1.0 pCi/L (0.037 Bq/L), one thousand times



greater than results reported for milk samples from these three areas over the past 4 years (EPA-570/9-76-003).

No manmade gamma emitters (including cesium-137) were detectable in 2002 milk samples (PNNL-14295, APP. 1).

Tritium was analyzed in quarterly composite milk samples from the East Wahluke, Sagemoor, and Sunnyside areas (Figure 4.4.1) during 2002. The results indicate Sagemoor area milk had higher (approximately four times) median and maximum tritium concentrations when compared to milk from both the Sunnyside and the East Wahluke areas (Figure 4.4.3). Elevated tritium concentrations in milk from the Sagemoor area are consistent with results in previous years (Figure 4.4.3). Tritium concentrations in Sagemoor area milk appear to decline at a rate consistent with radiological decay. Dilution of the groundwater (PNNL-13230) in the aquifer used by Sagemoor area dairies may also reduce tritium levels.

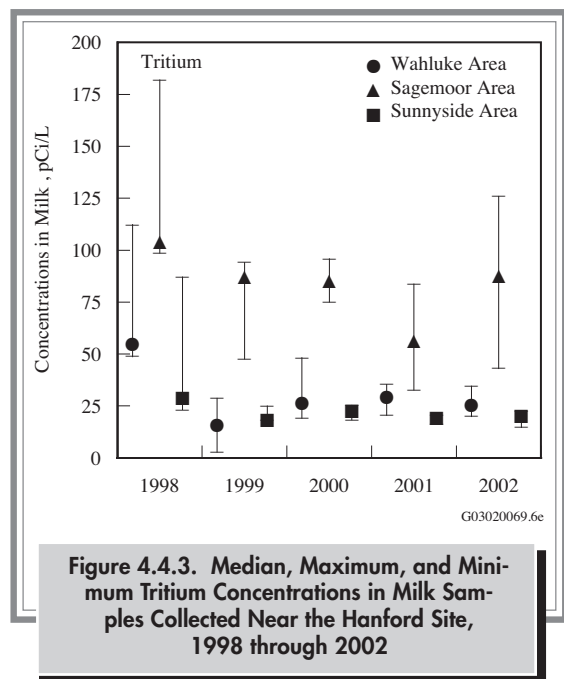
In the 1999 Hanford Site environmental report (PNNL-13230, Section 4.4), tritium concentrations in dairy water were reported in conjunction with the milk samples and illustrated the ability to predict tritium concentrations in dairy milk from tritium concentrations in the well water used by the dairies. The dairies in all three of the areas sampled during 2001 used well water. The Franklin County aquifers used by the dairies in the Sagemoor and East

Wahluke areas have historically been recharged by Columbia River water brought into the areas by the Columbia Basin Irrigation Project. Water for the Columbia Basin Irrigation Project is obtained from the Columbia River upstream of the Grand Coulee Dam. Tritium levels in Columbia River water in the 1960s ranged from 800 to 5,540 pCi/L (30 to 205 Bq/L). These concentrations were influenced by fallout from worldwide aboveground nuclear-weapons testing (Wyerman et al. 1970). Irrigation water from the Columbia River containing these comparatively high tritium levels entered the groundwater aquifers in Franklin County as a result of over application and leaking canals.

Over the past 30 years, tritium levels in the aquifer have slowly decreased as a result of radiological decay and possible dilution caused by subsequent recharge with reduced levels of tritium in irrigation water. Based on a 12.3-year half-life, if we assume an aquifer having a tritium concentration of 1,000 pCi/L (37 Bq/L) during 1963 (assumes some dilution with natural groundwater), the estimated level after three half-lives in 2002 would be ~111 pCi/L (~4.1 Bq/L). While the relationships between tritium in milk and groundwater used by the dairies are interesting, the actual levels of tritium in milk are a minor contributor to the radiological dose received by those who consume milk (Chapter 5). There is no tritium standard for milk; however, the standard for drinking water is 20,000 pCi/L (740 Bq/L), over 100 times greater than values reported in Sagemoor area dairy milk over the past 4 years (Figure 4.4.3).

4.4.2 VEGETABLE SAMPLES AND ANALYTES OF INTEREST

Leafy vegetables are routinely sampled to monitor airborne contaminants. Samples of leafy vegetables (i.e., beets and cabbage) and vegetables (i.e., potatoes and tomatoes) were obtained during the summer from gardens and farms located within selected sampling areas (Figure 4.4.1). The Riverview area also was sampled because of its exposure to potentially contaminated irrigation water withdrawn from the Columbia River downstream of the Hanford Site. All vegetable samples from all sampling areas were analyzed for gamma-emitting radionuclides and strontium-90.



Measurements of cesium-137 in vegetable and leafy vegetable samples collected in 2002 were all less than their detection limit (0.02 pCi/g [0.0007 Bq/g]) and were consistent with results seen in recent years (PNNL-14295, APP. 1). Strontium-90 was not detected in potato, tomato, or leafy vegetable samples collected during 2002. Strontium-90 concentrations in vegetable samples obtained from the Riverview area also fell below the analytical detection limit (<0.006 pCi/g [<0.00022 Bq/g]). Tritium was not detected in tomato samples obtained from the Riverview or Harrah/Wapato areas. In recent years, few vegetable samples have had measurable concentrations of strontium-90 or cesium-137. Consequently, it is not possible to discern upwind or downwind distribution patterns of these radionuclides in vegetables.

4.4.3 FRUIT SAMPLES AND ANALYTES OF INTEREST

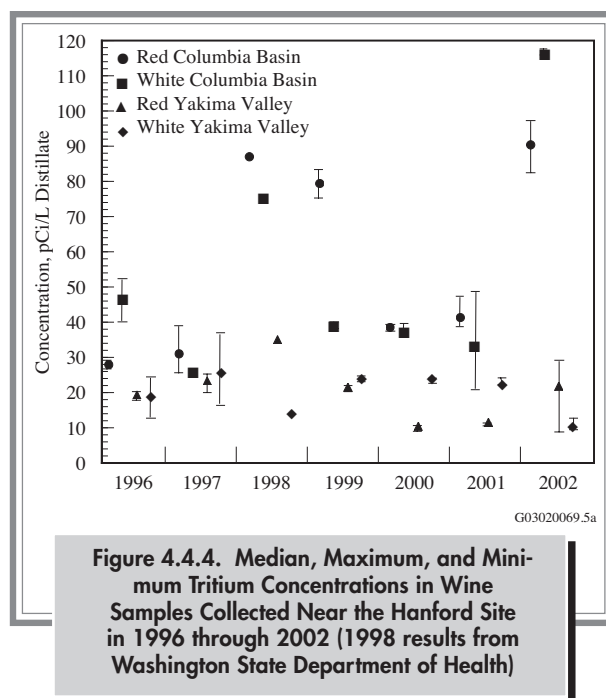
Cherry samples were analyzed for gamma-emitting radionuclides and strontium-90 (Figure 4.4.1). Measurable levels of cesium-137 were reported in cherries collected from the Riverview area (0.007 ± 0.004 pCi/g [0.00026 ± 0.00015 Bq/g]). No other radionuclides were detected in cherries in 2002. These results are consistent with measurements in grapes, cherries, and melons over recent years (PNL-10575; PNNL-11140; PNNL-11473; PNNL-11796; PNNL-12088; PNNL-13230; PNNL-13910). The nominal level of detection for cesium-137 was ~ 0.01 pCi/g (~ 0.00037 Bq/g) wet weight and strontium-90 was 0.002 to 0.05 pCi/g (0.000074 to 0.0019 Bq/g) dry weight.

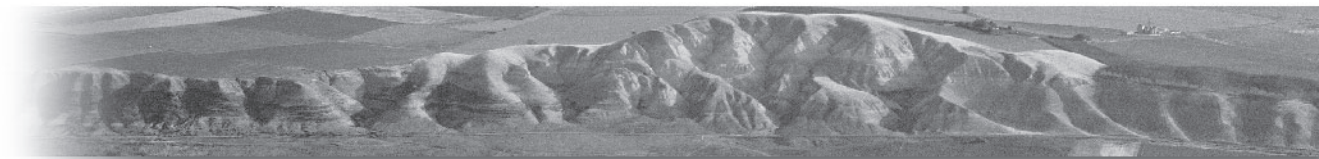
4.4.4 WINE SAMPLES AND ANALYTES OF INTEREST

Locally produced red and white wines (2002 vintage grapes) were analyzed for gamma-emitting radionuclides and tritium. The wines were made from grapes grown at

individual vineyards downwind of the site and at an upwind location in the lower Yakima Valley. Two samples each of red and white wine were obtained from each location and analyzed. An electrolytic enrichment method was used for tritium analysis in water distilled from the wine.

Tritium levels in 2002 wine samples were consistent with past results. While there is no tritium standard for wine, the drinking water standard is 20,000 pCi/L (740 Bq/L), ~ 430 times greater than maximum concentrations reported in wines from these two areas in 2002 (EPA-570/9-76-003). Tritium concentrations were higher in Columbia Basin wines when compared to Yakima Valley wines (Figure 4.4.4). Red wine from the Columbia Basin contained similar levels of tritium as those found in white wine sampled from the same region. The observed differences between wines and/or regions are consistent with past results and are likely related to irrigation/well water sources as discussed with tritium in milk (Section 4.4.1). Gamma spectroscopy did not indicate the presence of cesium-137 or any other gamma-emitting manmade radionuclide in any of the 2002 wine samples.





4.5 FISH AND WILDLIFE SURVEILLANCE

B. L. Tiller

Contaminants in fish and wildlife that inhabit the Columbia River and Hanford Site are monitored for several reasons. Wildlife have access to areas of the site containing radioactive or chemical contamination, and aquatic organisms can be exposed to contamination entering the river along the shoreline. Fish and some wildlife species exposed to Hanford contaminants might be harvested for food and may potentially contribute to offsite public exposure. In addition, detection of contaminants in wildlife may indicate that wildlife are entering contaminated areas (e.g., burrowing in waste burial grounds) or that materials are moving out of contaminated areas (e.g., through blowing dust or food-chain transport). Consequently, fish and wildlife samples are collected at selected locations annually (Figure 4.5.1).

Fish and wildlife species are collected on a 2- to 3-year rotation. Routine background sampling is conducted approximately every 5 years at locations believed to be unaffected by Hanford releases. Additional background data also may be collected during special studies.

Wildlife species were selected for sampling based on recommendations provided by a review committee during the early 1980s. Primary consideration for species selection included their likelihood to accumulate contaminants in their tissue, their likelihood of being consumed by people, and their likelihood of being found at the monitoring sites identified in Figure 4.5.1. For each species of fish or wildlife, radionuclides are selected for analysis based on their potential to be found at the sampling site and to accumulate in the organism (Table 4.5.1). At the Hanford Site, strontium-90 and cesium-137 have been historically the most frequently measured radionuclides in fish and wildlife.

Strontium-90 is chemically similar to calcium; consequently, it accumulates in hard tissues rich in calcium such as bone, antlers, and eggshells. Strontium-90 has a biological half-life in hard tissue of 14 to 600 days (PNL-9394). Hard-tissue concentrations may profile an organism's

lifetime exposure to strontium-90. However, strontium-90 generally does not contribute much to human dose because it does not accumulate in edible portions of fish and wildlife. Contaminated groundwater that enters the Columbia River via shoreline springs in the 100-N and 100-H Areas is the primary source of strontium-90 from Hanford to the river; however, current contaminant contribution relative to historical fallout from atmospheric weapons testing is small (<2%) (PNL-8817).

Cesium-137 is particularly important because it is chemically similar to potassium and is found in the muscle tissues of fish and wildlife. Having a relatively short biological half-life (<200 days in muscle; <20 days in the gastrointestinal tract [PNL-9394]), cesium-137 is an indicator of more recent exposure to radioactive materials and is also a major constituent of historical worldwide fallout.

Heavy metals have the potential to accumulate in certain fish and wildlife tissue and have been identified in the Hanford Site environment as contaminants of concern (e.g., chromium, copper, lead, and mercury), particularly in areas where groundwater enters the Columbia River.

Fish and wildlife samples were analyzed by gamma spectrometry to detect a number of gamma emitters (Appendix F). However, gamma spectrometry results for most radionuclides are not discussed here because levels were too low to measure or measured concentrations were considered artifacts of low-background counts. Low-background counts occur at random intervals during sample counting and can produce occasional spurious false-positive results.

For many radionuclides, concentrations are below levels that can be detected by the analytical laboratory. When this occurs for an entire group of samples, two times the total propagated analytical uncertainty is used as an estimate of the nominal detection level for that analyte and particular medium. Results and propagated uncertainties for all results may be found in PNNL-14295, APP. 1.

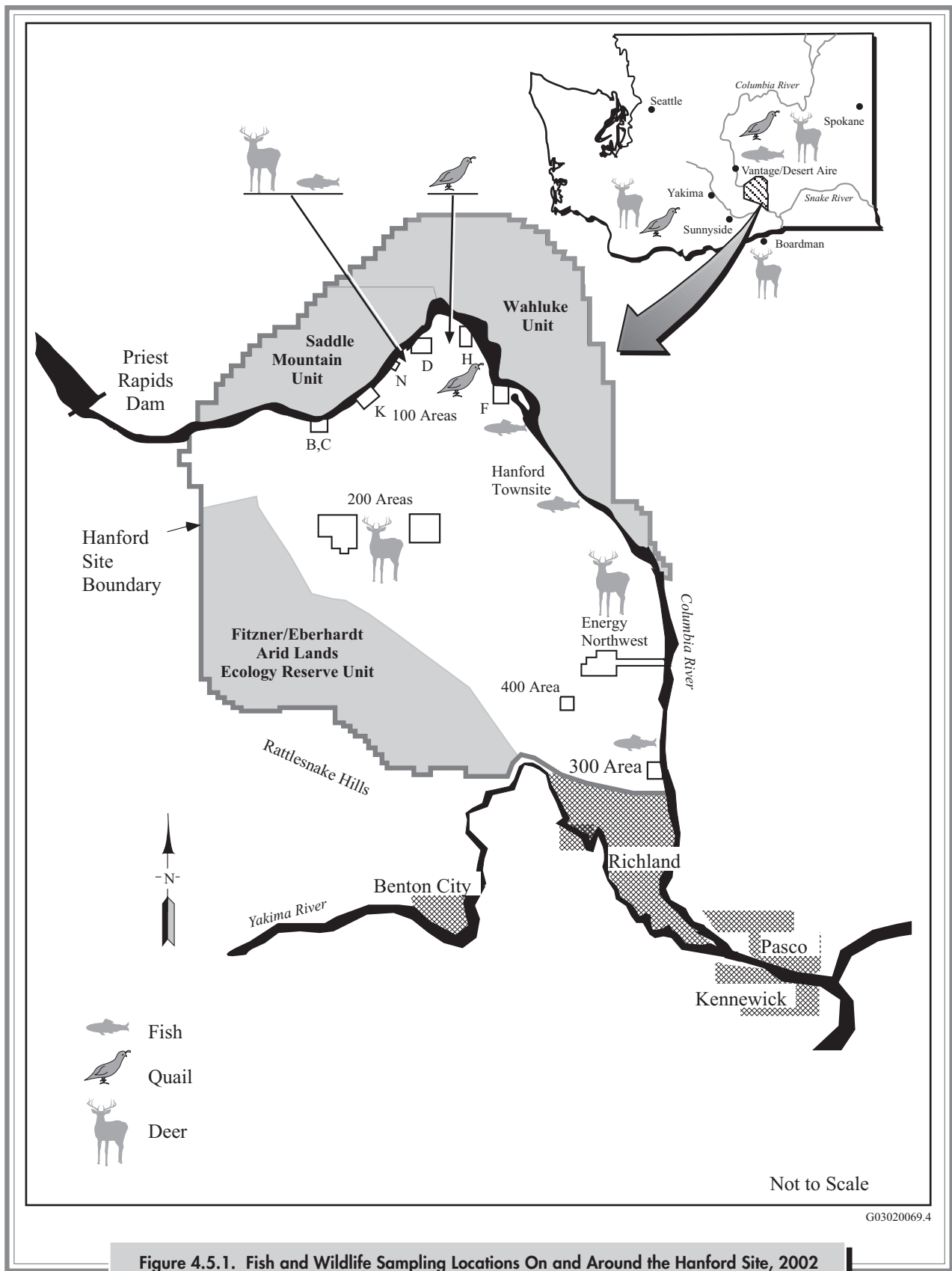


Figure 4.5.1. Fish and Wildlife Sampling Locations On and Around the Hanford Site, 2002

Table 4.5.1. Hanford Site Fish and Wildlife Sampling Locations and Analyses, 2002

Biota	No. of Reference Locations	No. of Onsite Locations	No. of Analyses		
			Gamma	Strontium-90	Isotopic Plutonium
Fish (carp)	1	2	15	15	0
(bass)	1	3	13	13	0
Upland game (California quail)	0	2	10	10	0
Big game (mule deer)	1	3	9	9	1

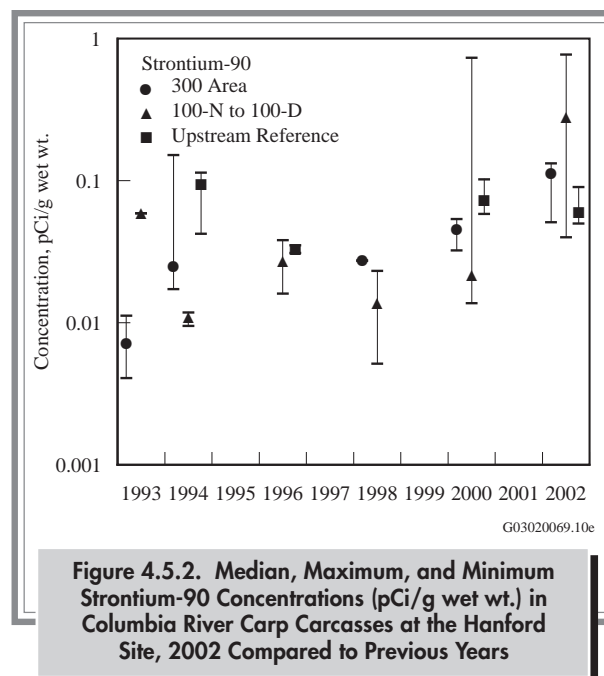
4.5.1 FISH SAMPLES AND ANALYTES OF INTEREST

The amount of radiological contamination measured in fish samples has consistently been well below levels that are thought to cause adverse biological effects and contributes only a small proportion of the radiation dose to the maximally exposed individual (Chapter 5). However, monitoring fish and other organisms for uptake and exposure to radionuclides at both nearby and distant locations continues to be important to track the extent and long-term trends of contamination in the Columbia River environment. During 2002, 15 carp (*Eyprinus cyprinus*) were collected from three locations on the Columbia River: near the 100-N Area, near the 300 Area, and from an upstream reference site near Vantage, Washington (Figure 4.5.1). Thirteen smallmouth bass (*Micropterus dolomieu*) were also collected in 2002 from two major backwater areas along the Hanford Reach, near the 300 Area, and from an upstream reference area near Vantage, Washington (Figure 4.5.1). Fillets and the eviscerated remains (carcass) of fish were analyzed for a variety of radiological contaminants and results from the nearby and distant locations were compared and are discussed in the following paragraphs. During 2002, fillet (muscle) samples were analyzed with gamma spectrometry for cesium-137 and other gamma-emitting radionuclides (PNNL-14295, APP. 1).

Cesium-137 results were below the analytical detection limit (0.04 pCi/g [0.0015 Bq/g] wet weight) in 10 carp fillet samples collected near the 100-N and 300 Areas during 2002. All five samples collected from the upriver reference area (Vantage, Washington) during 2002 also fell below

the analytical detection limit as compared to 19 of 30 (53%) reference area fish tissue levels reported below the analytical detection limit in 2000, 1996, and 1992 (PNNL-11472; PNNL-12088). Cesium-137 was also not detected in any of the 13 bass fillets analyzed during 2002. These results are consistent with results reported throughout the 1990s that indicated a gradual decline in cesium-137 levels in fish found both near to and distant from the Hanford Site.

Strontium-90 was found in 13 of 15 carp carcass samples collected and analyzed during 2002. The median level of strontium-90 in carcass tissues collected from the 100-N to 100-D region during 2002 was slightly higher than levels observed in fish from the 300 Area and in fish from the upstream reference site (Figure 4.5.2). However, results



reported during 2002 are consistent with samples collected over the preceding 8 years. The strontium-90 concentration in one of the five carp samples collected between 100-N and 100-D Areas was over six times greater than the median concentrations from all three sampling regions, and eight times greater than the highest value reported from the reference areas. This result (0.77 ± 0.22 pCi/g [0.03 ± 0.008 Bq/g]) was the highest reported over the preceding 8-year period. Elevated amounts have been consistently measured in carp and other bottom-feeding fishes (suckers and whitefish) collected near the 100-N Area in the past. The five results reported during 2002 are all greater than 17 of 18 results reported for carp carcass tissues throughout the 1990s. The median and maximum-result pattern near the 100-N Area may indicate some of the fish have consumed items containing elevated amounts of strontium-90 from Hanford sources and have incorporated some strontium into their tissues. Strontium-90 concentrations in carcass tissue would have to be around 600 pCi/g (22.2 Bq/g) wet weight (in the absence of other radionuclides and external exposure) to be near the DOE dose limit of 1.0 rad (10 mGy) per day established for aquatic organisms (Section 5.6). The hypothetical dose associated with the consumption of Hanford Reach fish is found in Chapter 5.

Liver tissue samples from all bass and carp collected in 2002 were analyzed for a number of heavy metals using inductively-coupled plasma gas chromatography analytical techniques (EPA 1994, 1998). Concentrations of most metals (antimony, beryllium, lead, nickel, silver, thallium, thorium, and uranium [PNNL-14295, APP. 1]) were found to be near or below their analytical detection limits. The highest chromium concentrations (PNNL-14295, APP. 1) were reported from bass samples collected at the upstream reference locations (Figure 4.5.1). Tissue residue levels of metals did not appear to differ between each sampling location; however, copper and zinc concentrations in carp samples were generally 10 times higher than concentrations in bass samples.

4.5.2 WILDLIFE SAMPLING

The amount of radiological contamination measured in wildlife samples under this project has been well below levels that are estimated to cause adverse health effects

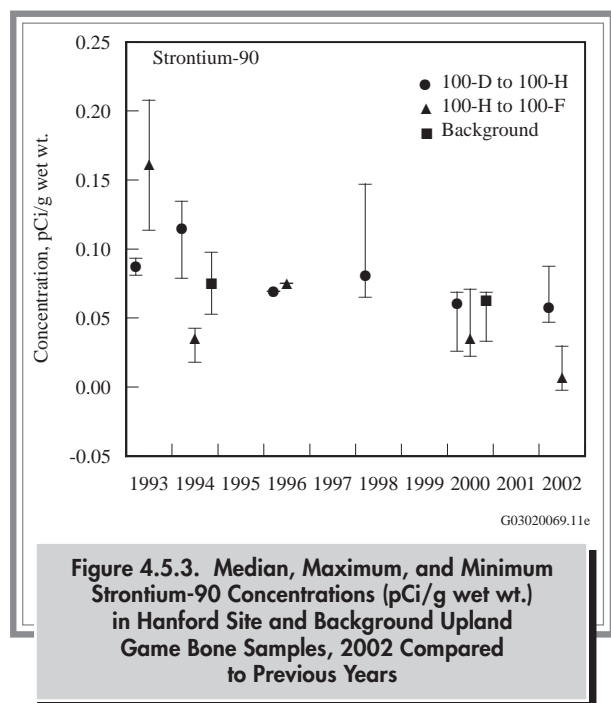
(Section 5.6). Monitoring various biota for uptake and exposure to radionuclides both near and distant from Hanford Site operations continues to assure that consumption of wildlife does not pose a threat to humans. This work is also intended to provide long-term trends of contamination in the selected components of the ecosystem. Wildlife sampled and analyzed during 2002 for radioactive constituents included mule deer (*Odocoileus hemionus*) and upland game (California quail [*Callipepla californica*]). Wildlife samples were analyzed for gamma emitters, strontium-90, and isotopic plutonium.

4.5.2.1 UPLAND GAME SAMPLES AND ANALYTES OF INTEREST

Fifteen California quail were collected from two selected sampling areas on Hanford in the fall of 2002 (Figure 4.5.1). Radionuclide levels found in ten samples analyzed during 2002 were compared to levels in samples collected onsite during the previous 8-year period and were also compared to levels found in samples collected from two background locations near Sunnyside, Washington, and Kimberly, Oregon. Quail samples were provided to the Washington State Department of Health for comparative purposes.

Analyses for gamma-emitting radionuclides (cesium-137) in muscle tissue typically require more mass than what is available on a single quail. For this reason, quail collected on the Hanford Site were often composited into a single sample for the gamma-scan analysis. Samples of bone analyzed for strontium-90 were also composited in a similar fashion as muscle tissue samples. Cesium-137 was not detected (at or below ~ 0.04 pCi/g [~ 0.001 Bq/g] wet weight) in any of the six quail muscle samples collected between the 100-H and 100-F Areas nor in any of the four samples collected between the 100-D and 100-H Areas. These results were consistent with those reported in 1998 and 2000 as 18 of 18 samples were reported below the analytical detection limit (PNNL-13487). The number of samples reported at or below the analytical detection limit during 1998, 2000, and 2002 (24 of 24 collectively) reflects the continued downward trend in worldwide levels of cesium-137 fallout due to atmospheric dispersion of radionuclides during the weapons testing era (1950s through the 1970s).

None (0 of 10) of the quail bone samples collected and analyzed for strontium-90 during 2002 had concentrations above the analytical detection limit (0.04 pCi/g [0.001 Bq/g] wet weight). Although upland game samples were not obtained from a reference area during 2002, the onsite results are consistent with results obtained from the background areas in past years and do not indicate elevated levels of strontium-90 in upland game (Figure 4.5.3).



4.5.2.2 DEER SAMPLES AND ANALYTES OF INTEREST

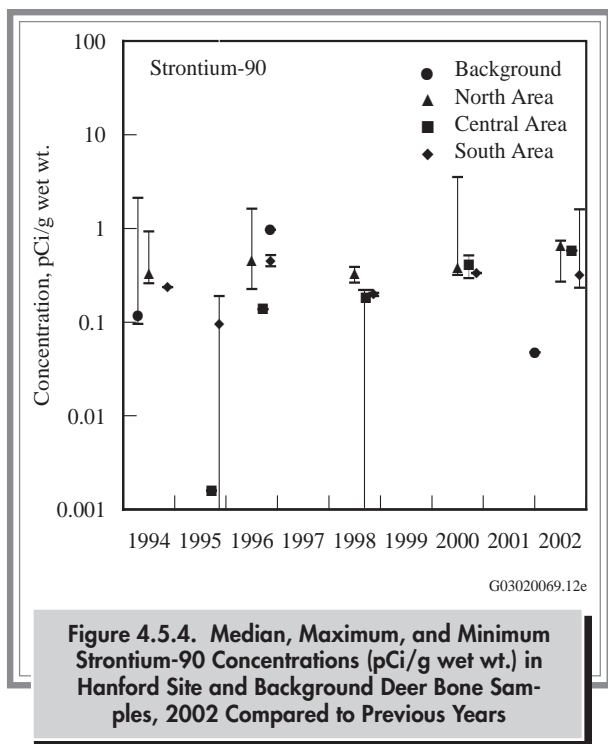
Studies of mule deer populations residing on the central portions of the Hanford Site indicate their division into three relatively distinct groups (Tiller and Poston 2000): (1) deer that inhabit land around the retired reactors in the 100 Areas are designated the north area population; (2) deer that reside from the Hanford town site south to the 300 Area are designated the south area population; and (3) by default, deer living around the 200 Areas, away from the river, are designated the central area population (Figure 4.5.1).

Radionuclide levels in nine deer collected onsite in 2002 were compared to levels in deer collected distant from the site and to results reported for the preceding 8-year period. One deer was from the central population (200 Areas),

four were from the north population (100 Areas), and four were from the south population (300 Area). Background samples were collected between 1992 and 1995 near Boardman, Oregon and in Stevens County, Washington (see PNNL-11472, Section 4.5). During 2000, one background deer sample was obtained from the lower Yakima Valley, near Sunnyside, Washington (see PNNL-13487, Section 4.5). Additionally, levels in onsite mule deer were compared to levels in a white-tailed deer that was co-sampled with the Washington State Department of Health during 1996 from Vail, Washington (see PNNL-12088, Section 4.5). These comparisons with samples from distant locations are useful in evaluating Hanford's relative contribution of radionuclides in deer. The deer collected in Stevens County and Vail, Washington, inhabited mountain regions that received more rainfall (and more atmospheric fallout) than Hanford, increasing background levels of fallout radionuclides there (Tiller and Poston 2000). The climate and precipitation of the Boardman, Oregon, and the Sunnyside, Washington, regions are similar to Hanford.

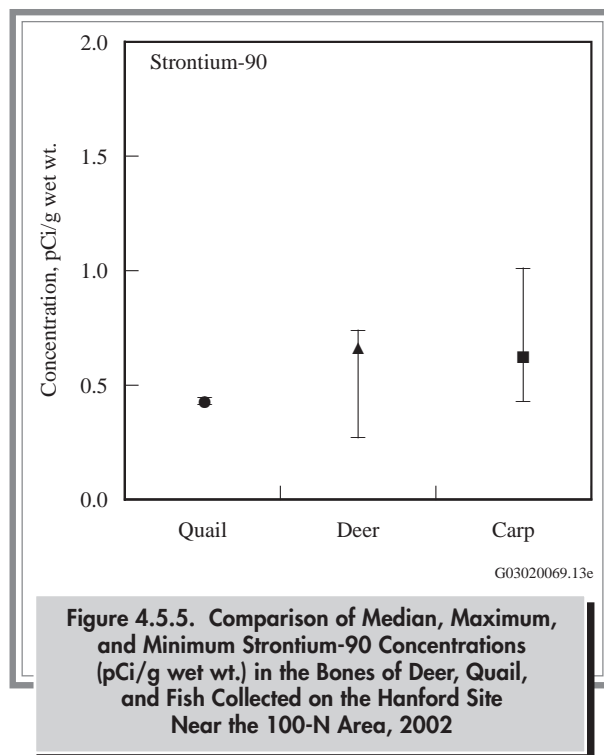
Radiological Results for Deer Samples. Cesium-137 was not detected (at or <0.02 pCi/g [0.007 Bq/g] wet weight) in all nine deer muscle samples analyzed during 2002. These results are consistent with a decline in cesium-137 levels in all wildlife examined from 1983 through 1992 (PNL-10174) and with data obtained over the preceding 8 years. In this time period, the levels of cesium-137 in more than 60 Hanford Site deer muscle samples were less than the background levels measured in deer samples collected from 1991 through 1995 from Stevens County, Washington, and, during 1996, from Vail, Washington.

Strontium-90 was detected in all nine deer bone samples collected and analyzed in 2002 and continues to demonstrate the utility of this organism to accumulate and depict trends of strontium-90 contamination in the environment. The lower results found in deer bone from the south and central areas populations are consistent with strontium-90 levels found in deer antlers (Tiller and Poston 2000). Median levels of strontium-90 found in deer bone in 2002 were similar between the three sampling areas onsite (Figure 4.5.4). The highest concentration of strontium-90 (1.51 ± 0.5 pCi/g [0.05 ± 0.02 Bq/g] wet weight) obtained onsite during 2002 was obtained from the south area.



However, these results do not indicate excessive exposure of strontium-90 to mule deer. Elevated levels of strontium-90 in samples from the north area typically occurred in about one of three deer samples collected there throughout the preceding 8-year period, with the highest concentration (20.8 ± 5.2 pCi/g [0.77 ± 0.19 Bq/g] wet weight) reported during 1992 (see PNNL-13487, Section 4.5). Background samples of deer bone indicate strontium-90 concentrations can be as high as 2.06 ± 0.4 pCi/g (0.08 ± 0.01 Bq/g) wet weight. The apparently higher concentrations reported in deer bone from the north area may indicate some exposure to localized, low-level contamination near the N Reactor.

Levels of strontium-90 found in deer bone samples collected between 1992 and 2000 have been consistently higher than levels found in quail bone collected from the same general vicinity (Figure 4.5.5). The diet of quail primarily includes insects and dry-land grass seeds, whereas



deer generally consume riparian and woody plants. Deep-rooted riparian plants can contain higher levels of Hanford-produced contaminants if their roots are deep enough to reach contaminated groundwater. Strontium-90 concentrations measured in carp and other bottom-feeding fishes (i.e., suckers and whitefish) near the 100-N Area in previous years also indicate some of the aquatic organisms have consumed items containing elevated amounts of strontium-90 from Hanford sources and have incorporated a portion of the contamination into their tissues.

Plutonium-238 and plutonium-239/240 were not found above the analytical detection limit (0.00004 pCi/g [0.0000015 Bq/g] wet weight) in the one deer liver sample obtained during 2002 near the 200 Areas. The result is consistent with results reported through the 1990s. Less than 6% (2 of 35) of the deer livers analyzed since 1992 have contained plutonium at concentrations above the analytical detection limit.



4.6 EXTERNAL RADIATION SURVEILLANCE

E. J. Antonio

External radiation is defined as radiation originating from a source external to the body. External radiation fields consist of a natural component and a manmade component. The natural component can be divided into (1) cosmic radiation; (2) primordial radionuclides, primarily potassium-40, thorium-232, and uranium-238; and (3) an airborne component, primarily radon and its progeny. The manmade component consists of radionuclides generated for or from nuclear medicine, power, research, waste management, and consumer products containing nuclear materials. Environmental radiation fields may be influenced by the presence of radionuclides deposited as worldwide fallout from atmospheric testing of nuclear weapons or those produced and released to the environment during the production or use of nuclear fuel. During any year, external radiation levels can vary from 15% to 25% at any location because of changes in soil moisture and snow cover (National Council on Radiation Protection and Measurements 1987).

The interaction of radiation with matter results in energy being deposited in that matter. This is why your hand feels warm when exposed to a light source (e.g., sunlight, flame). Ionizing radiation energy deposited in a mass of material is called radiation absorbed dose. A special unit of measurement, called the rad, was introduced for this concept during the early 1950s. The rad is equal to 100 ergs of ionizing energy deposited in one gram of material. The International System of Units introduced the Gray and is defined as follows: 1 Gray = 1 Joule per kilogram and is numerically equivalent to 100 rad (American Society for Testing and Materials 1993).

One device for measuring radiation absorbed dose is the thermoluminescent dosimeter (i.e., “dose meter”) that absorbs and stores energy of ionizing radiation within the dosimeter’s crystal lattice. By heating the dosimeter material under controlled laboratory conditions, the stored energy is released in the form of light, measured and related

to the amount of ionizing radiation energy stored in the material. Thermoluminescence, or light output exhibited by dosimeters when heated, is proportional to the energy absorbed, which by convention is related to the amount of radiation exposure (X), which is measured in units of roentgen (R). The exposure is multiplied by a factor of 0.98 to convert to a dose (D) in rad to soft tissue (Shleien 1992). This conversion factor relating R to rad is, however, assumed to be unity (1) throughout this report for consistency with past reports. This dose is further modified by a quality factor, $Q = 1$, for beta and gamma radiation and the product of all other modifying factors (N). N is assumed to be unity to obtain dose equivalence (H) measured in rem. The international unit, the sievert (Sv), is equivalent to 100 rem.

$$D (\text{rad}) = X (\text{R}) * 1.0$$

$$H (\text{rem}) = D * N * Q$$

For a point of reference, a radiological dose of 100 rem (1 Sv) beta/gamma to an 8-ounce (0.227 L) cup of water will deposit enough energy in the water to increase the temperature of the water by about 1°F (0.55°C).

During 2002, environmental external radiation exposure was measured at 33 locations on the Hanford Site, 11 locations around the perimeter of the site, 9 locations in surrounding communities including 2 at distant locations, and 27 locations along the Columbia River shoreline using thermoluminescent dosimeters and pressurized ionization chambers. The dosimeter exposure was converted to dose rates by the process described above, then the dose rates were divided by the length of time the dosimeter was in the field. Annual results for 2002 were compared to results obtained during the previous 5 years. External radiation and surface contamination surveys at specified locations were performed with portable radiation survey instruments.

4.6.1 EXTERNAL RADIATION MEASUREMENTS

The Harshaw 8800-series environmental dosimeter consists of two TLD-700 (LiF) chips and two TLD-200 (CaF₂:Dy) chips and provides both shallow and deep dose measurement capabilities. The two TLD-700 chips were used to determine the average total environmental dose at each location. The average dose rate was computed by dividing the average total environmental dose by the number of days the dosimeter was in the field. Quarterly dose equivalent rates (millirem per day) at each location were converted to annual dose equivalent rates (millirem per year) by averaging the quarterly dose rates and multiplying by 365 days per year. The two TLD-200 chips were included only to determine doses in the event of a radiological emergency and were not needed during 2002.

Thermoluminescent dosimeters were positioned ~1 meter (~3.3 feet) above the ground at 33 onsite locations (Figure 4.6.1). This is an increase of four onsite locations compared to 2001. Figure 4.6.2 shows the 11 locations around the site perimeter, 7 locations in nearby communities, and 2 distant locations. One community location (Leslie Groves Park) was moved due to continued vandalism and was re-classified as a shoreline location (N. Richland, location number 26 on Figure 4.6.3). Figure 4.6.3 shows the 27 locations along the Columbia River shoreline. All thermoluminescent dosimeters were collected and read quarterly.

To determine the maximum dose rate for each distance classification, the annual average dose rates, as calculated above for each location, were compared and the highest value was reported. The uncertainties associated with the maximum dose rates were calculated as two standard deviations of the quarterly dose rates then corrected to annual rates.

All community and most of the onsite and perimeter thermoluminescent dosimeter locations were collocated with air-monitoring stations. The onsite and perimeter locations were selected based on determinations of the highest potentials for public exposure (i.e., access areas, downwind population centers) from past and current Hanford Site operations. The two background stations in Yakima and Toppenish were chosen because they are generally upwind and distant from the site.

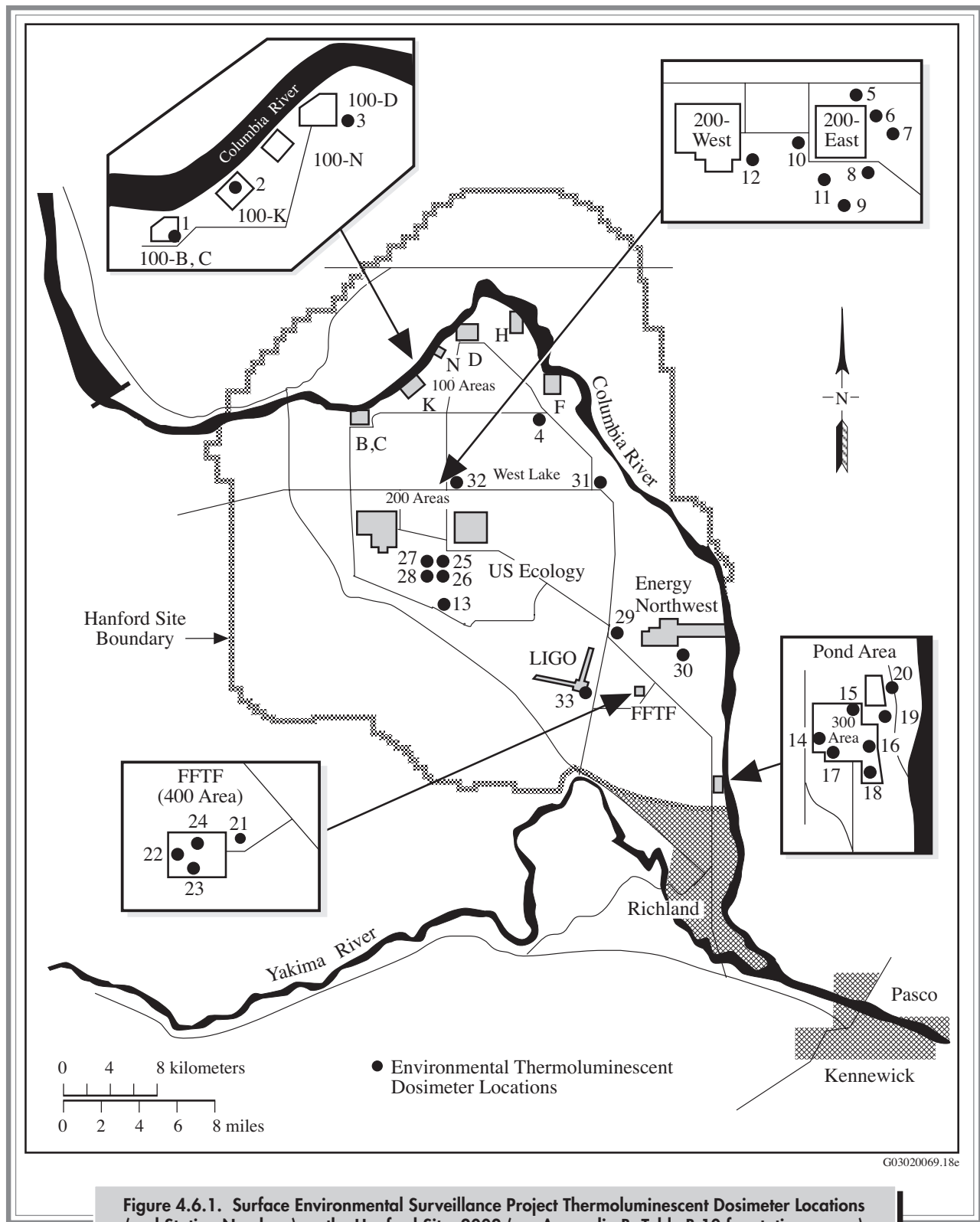
The shoreline of the Columbia River in the Hanford Reach was monitored by a series of 27 thermoluminescent dosimeters located in the area from Vernita Bridge to downstream of Bateman Island at the mouth of the Yakima River. Ground contamination surveys also were conducted quarterly at 13 shoreline locations. These measurements are made to estimate radiation exposure levels attributed to sources on the Hanford Site, to estimate background levels along the shoreline, and to help assess exposures to onsite personnel and offsite populations. Ground contamination surveys were conducted using Geiger-Müller meters (Geiger counters) and Bicron® Microrem meters. Results are reported in counts per minute and microrem per hour, respectively. Geiger counter measurements were made within 2.54 centimeters (1 inch) of the ground and covered a 1-square-meter (10-square-foot) area. The Bicron® measurements were taken 1 meter (3.3 feet) above the ground surface and at least 10 meters (33 feet) away from devices or structures which may have contributed to the ambient radiation levels.

Pressurized ionization chambers were situated at four community-operated monitoring stations (Section 4.6.3). These instruments provided a way to measure ambient exposure rates near and downwind of the site and at locations distant and upwind of the site. Real-time exposure-rate data are displayed at each station to provide information to the public and to serve as an educational tool for the teachers who manage the stations.

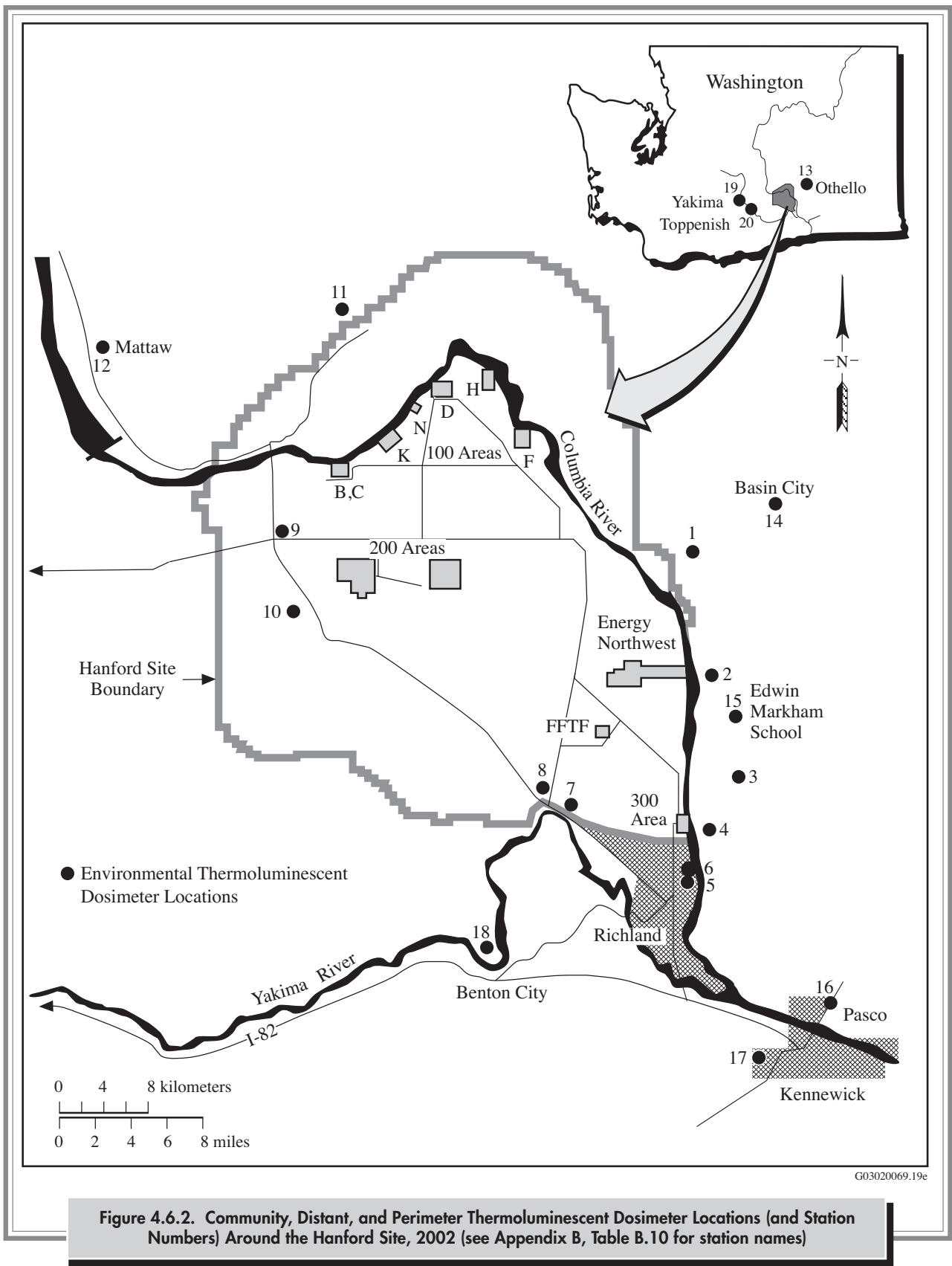
EXTERNAL RADIATION RESULTS

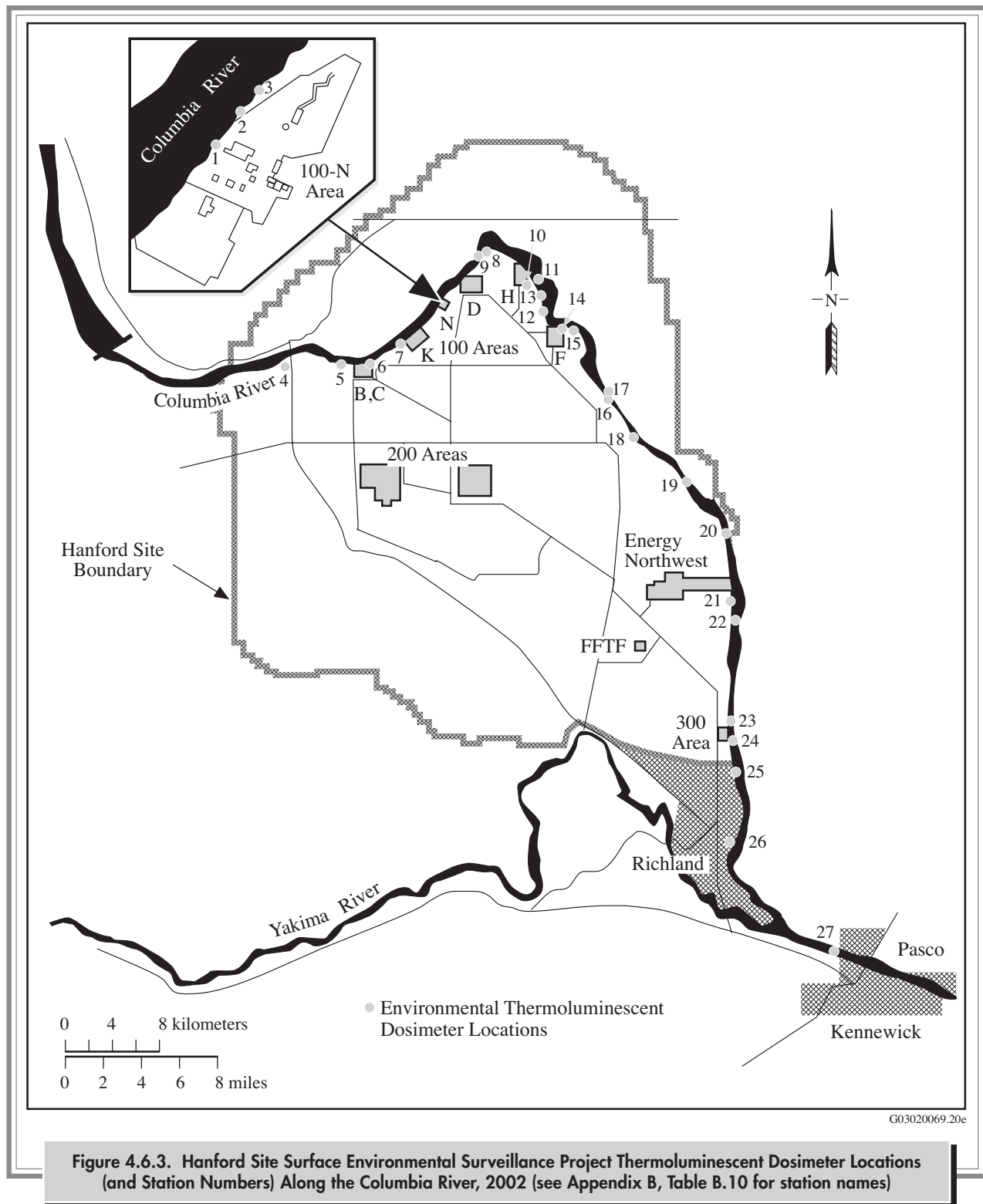
Thermoluminescent dosimeter readings were converted to annual dose equivalent rates by the process described above. External dose rates reported in Tables 4.6.1 through 4.6.3 include the maximum annual dose rate (± 2 standard deviations) for all locations within a given surveillance zone and the average dose rate (± 2 standard error of the mean) for each distance class. Locations were classified (or grouped) based on their location on or near the Hanford Site.

Onsite Results. Table 4.6.1 summarizes the results of 2002 onsite measurements, which are grouped by operational area. The average dose rates in all operational areas were higher than average dose rates measured at distant locations. The highest annual average dose rate measured



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G03020069.20e

Table 4.6.1. Dose Rates (mrem/yr^(a)) Measured by Thermoluminescent Dosimeters on the Hanford Site, 2002 Compared to Previous 5 Years

<u>Location</u>	<u>Map Location^(b)</u>	<u>2002</u>		<u>No. of Samples</u>	<u>1997-2001</u>	
		<u>Maximum^(c)</u>	<u>Mean^(d)</u>		<u>Maximum^(c)</u>	<u>Mean^(d)</u>
100 Areas	1 - 4	87 ± 7	83 ± 5	13	88 ± 8	81 ± 3
200 Areas	5 - 13	95 ± 6	87 ± 3	41	98 ± 6	88 ± 2
300 Area	14 - 20	107 ± 6	87 ± 6	30	89 ± 7	82 ± 1
400 Area	21 - 24	88 ± 5	84 ± 2	20	89 ± 7	83 ± 1
600 Area	25 - 33	99 ± 7	86 ± 4	32	137 ± 31	91 ± 5
Combined onsite	1 - 33	107 ± 6	86 ± 2	136	137 ± 31	86 ± 1

(a) Multiply by 10 to convert to $\mu\text{Sv/yr}$.

(b) All station locations are shown on Figure 4.6.2 and are described in Appendix B, Table B.10.

(c) Maximum annual average dose rate for all locations within a given distance classification (± 2 standard deviations).

(d) Means computed by averaging annual means for each location within distance class (± 2 standard error of the mean).

Table 4.6.2. Dose Rates (mrem/yr^(a)) Measured by Thermoluminescent Dosimeters at Perimeter and Offsite Locations of the Hanford Site, 2002 Compared to Previous 5 Years

<u>Location</u>	<u>Map Location^(b)</u>	<u>2002</u>		<u>No. of Samples</u>	<u>1997-2001</u>	
		<u>Maximum^(c)</u>	<u>Mean^(d)</u>		<u>Maximum^(c)</u>	<u>Mean^(d)</u>
Perimeter	1 - 11	104 ± 32	93 ± 4	48	106 ± 8	90 ± 2
Community	12 - 18	87 ± 9	80 ± 3	40	90 ± 9	79 ± 2
Distant	19 - 20	72 ± 5	72 ± 1	10	75 ± 9	71 ± 1

(a) Multiply by 10 to convert to $\mu\text{Sv/yr}$.

(b) All station locations are shown on Figure 4.6.2 and are described in Appendix B, Table B.10.

(c) Maximum annual average dose rate for all locations within a given distance classification (± 2 standard deviations).

(d) Means computed by averaging annual means for each location within distance class (± 2 standard error of the mean).

by Pacific Northwest National Laboratory dosimeters on the Hanford Site during 2002 (107 ± 6 mrem [1.07 ± 0.06 mSv] per year) was detected at the newly established (2002) location on the north side of the 300 Area (location 17 in Figure 4.6.1). The 5-year maximum onsite dose rate (137 ± 31 mrem [1.37 ± 0.31 mSv] per year) was measured during 1997 near the US Ecology low-level waste disposal facility.

Offsite Results. Table 4.6.2 shows the maximum and average dose rates for perimeter and offsite locations

measured in 2002 and the previous 5 years. The average perimeter dose rate was 93 ± 4 mrem (0.93 ± 0.04 mSv) per year in 2002; the maximum was 104 ± 32 mrem (1.04 ± 0.32 mSv) per year. The 5-year perimeter average dose rate was 90 ± 2 mrem (0.90 ± 0.02 mSv) per year and the 5-year maximum was 106 ± 8 (1.06 ± 0.08 mSv) per year. The location of this year's maximum perimeter dosimeter result was Rattlesnake Springs (location number 10 on Figure 4.6.2). The variation in dose rates may be partially attributed to changes in natural background radiation that can occur as a result of changes in annual cosmic radiation

Table 4.6.3. Dose Rates (mrem/yr^(a)) Measured by Thermoluminescent Dosimeters Along the Hanford Reach of the Columbia River, 2002 Compared to Previous 5 Years

<u>Location</u>	<u>Map Location^(b)</u>	<u>2002</u>		<u>No. of Samples</u>	<u>1997-2001</u>	
		<u>Maximum^(c)</u>	<u>Mean^(d)</u>		<u>Maximum^(c)</u>	<u>Mean^(d)</u>
100-N Area shoreline	1 - 3	100 ± 7	92 ± 8	18	153 ± 61	115 ± 14
Typical shoreline	4 - 27	98 ± 13	86 ± 3	107	102 ± 15	86 ± 2
All shoreline	1 - 27	100 ± 7	87 ± 3	125	153 ± 61	90 ± 3

(a) Multiply by 10 to convert to $\mu\text{Sv/yr}$.

(b) All station locations are shown on Figure 4.6.2 and are described in Appendix B, Table B.10.

(c) Maximum annual average dose rate for all locations within a given distance classification (± 2 standard deviations).

(d) Means computed by averaging annual means for each location within distance class (± 2 standard error of the mean).

(up to 10%) and terrestrial radiation (15% to 25%) (National Council on Radiation Protection and Measurements 1987). Other factors possibly affecting the annual dose rates reported here have been described in PNL-7124.

The average background dose rate (measured in distant communities) in 2002 was 72 ± 1 mrem (0.72 ± 0.01 mSv) per year compared to the previous year's average of 72 ± 2 mrem (0.72 ± 0.02 mSv) per year (PNNL-13910) and the 5-year average of 71 ± 1 mrem (0.71 ± 0.01 mSv) per year.

Figure 4.6.4 displays a comparison of dose rates between onsite, perimeter, and distant thermoluminescent dosimeter locations from 1997 through 2002.

Columbia River Shoreline Results. During 2002, dose rates along the Columbia River shoreline near the 100-N Area were about the same as the typical shoreline dose rates (Table 4.6.3). Higher dose rates historically measured along the 100-N Area shoreline were attributed to waste management practices in that area (PNL-3127). The shoreline location of the highest average thermoluminescent dosimeter reading was along the 100-N Area shoreline. The 2002 maximum annual 100-N Area shoreline dose rate was 100 ± 7 mrem (1.00 ± 0.07 mSv) per year, which is significantly different from the maximum of 129 ± 6 mrem (1.29 ± 0.06 mSv) per year measured in 2001 (PNNL-13910), but is not significantly different than the 5-year maximum of 153 ± 61 mrem (1.53 ± 0.61 mSv) per year measured during 1997. They are not considered different because of the overlap between the two distributions. The 5-year maximum was measured along the 100-N Area shoreline. Over the past 5 years, the maximum dose rates along the 100-N Area shoreline have decreased as a result of cleanup efforts in the 100-N Area (Figure 4.6.5). The general public does not have legal access to the 100-N Area shoreline above the high water line but does have access to the adjacent Columbia River and to the shoreline below the high water line. The dose implications associated with this access are discussed in Chapter 5.

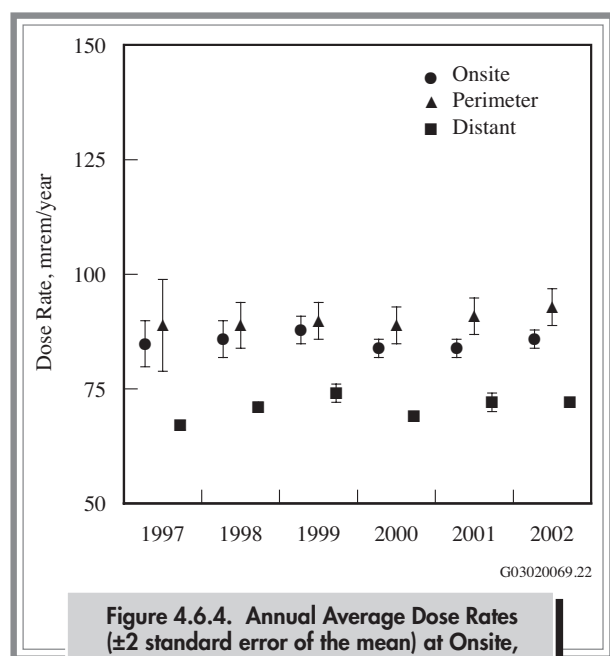
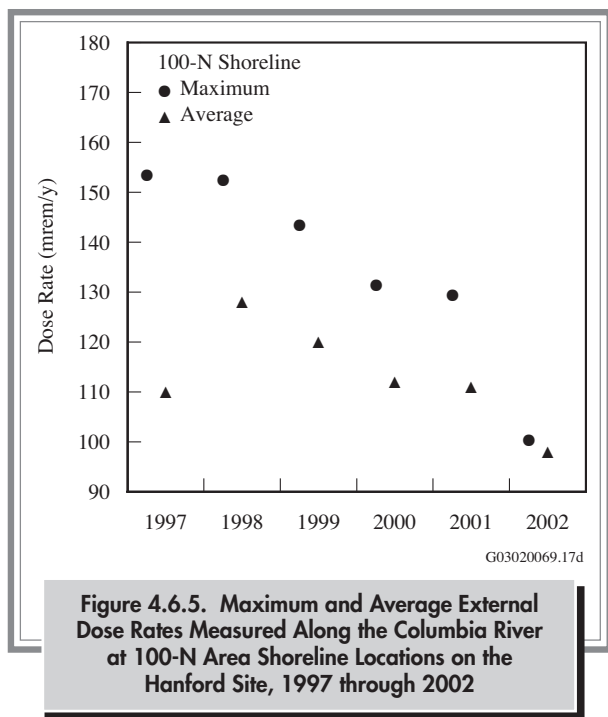


Figure 4.6.4. Annual Average Dose Rates (± 2 standard error of the mean) at Onsite, Perimeter, and Distant Locations of the Hanford Site, 1997 through 2002



4.6.2 RADIOLOGICAL SURVEY RESULTS

During 2002, Bicron® Microrem meters and Geiger counters were used to perform radiological surveys at selected Columbia River shoreline locations. These surveys provide a coarse screening for elevated radiation fields. The highest dose rate measured with the Bicron® Microrem meter (70 μrem [0.7 μSv] per hour) was measured in September along the 100-N Area shoreline; the lowest dose rate measured with the Bicron® Microrem meter was 0.4 μrem (0.004 μSv) per hour and was recorded at the south end of Vernita Bridge (location 4 on Figure 4.6.3) in June. The 70 μrem (0.7 μSv) per hour is abnormally high, ~350% higher than the maximum shoreline survey result reported last year and 700% higher than any other shoreline recorded Bicron® Microrem meter measurement made during 2002. The thermoluminescent dosimeter result for the quarter at the 100-N Area shoreline did not corroborate the high Bicron® Microrem meter reading. Likewise, the lowest Bicron® Microrem meter reading, 0.4 μrem per hour, did not agree with the thermoluminescent dosimeter reading obtained at the Vernita Bridge Station. The highest reported count rate measured with the Geiger counter in ground level surveys (100 counts per minute) was measured at various locations and in multiple yearly quarters. The

lowest ground level count rate (50 counts per minute) was recorded at the several locations throughout the year.

4.6.3 PRESSURIZED IONIZATION CHAMBER RESULTS

Gamma radiation levels were monitored with pressurized ionization chambers at four community-operated air-monitoring stations during 2002 (Section 8.4). These stations were located in Leslie Groves Park in Richland, at Edwin Markham Elementary School in north Franklin County, at Basin City Elementary School in Basin City, and at Heritage College in Toppenish (locations 37 on Figure 4.1.1 and 15, 14, and 20, respectively, on Figure 4.6.2). Measurements were collected to determine ambient gamma radiation levels near and downwind of the site and upwind and distant from the site, to display real-time exposure rate information to the public living near the station, and for educational information for the teachers who manage the stations.

Data collection systems consist of computers, data loggers, and modems or radiotelemetry instruments. The computers at Leslie Groves Park and Heritage College are accessed using telephone modems and data are obtained directly from the station. The computers at Edwin Markham Elementary School and Basin City Elementary School are connected by radiotelemetry to a computer at the Hanford Meteorology Station (near the 200-West Area). These data are summarized and posted on the Internet (Section 8.4).

Readings at the Leslie Groves Park and Heritage College stations were collected every 5 seconds and an average reading was recorded every hour. Data at Basin City and Edwin Markham School were collected every second and averaged every 15 minutes. The 15-minute averages were then used to generate a 60-minute average. The measurements at all four locations were made with Reuter-Stokes Model RSS-121 pressurized ionization chambers (Table 4.6.4).

Average hourly exposure rates ranged from a maximum of 41.9 μR per hour (88.4 pW/kg per second) at Edwin Markham School during September to a minimum of 1.0 μR per hour (2.1 pW/kg per second) in Leslie Groves Park in

Table 4.6.4. Average Exposure Rates^(a) Measured by Pressurized Ionization Chambers at Four Locations Around the Hanford Site,^(b) 2002

		Exposure Rate, $\mu\text{R}/\text{h}^{(\text{c})}$ (number of hourly averages)							
Month		Leslie Groves Park ^(d)		Basin City ^(e)		Edwin Markham ^(e)		Toppenish ^(d)	
January	Mean	8.5	(744)	7.7	(713)	7.7	(743)	7.9	(662)
	Maximum	9.3		10.8		39.3		8.4	
	Minimum	4.1		7.4		7.2		6.8	
February	Mean	8.7	(672)	7.8	(648)	7.8	(652)	8.0	(672)
	Maximum	10.3		8.8		9.2		9.8	
	Minimum	5.7		7.3		6.6		7.4	
March	Mean	8.1	(500)	7.9	(625)	7.8	(743)	8.0	(81)
	Maximum	9.4		9.7		9.2		8.7	
	Minimum	7.7		7.6		5.8		7.7	
April	Mean	ND ^(f)		7.7	(692)	7.8	(720)	8.2	(530)
	Maximum	ND		9.8		9.0		9.2	
	Minimum	ND		7.3		7.4		7.7	
May	Mean	8.5	(607)	ND		7.7	(745)	8.1	(744)
	Maximum	9.0		ND		8.7		10.0	
	Minimum	3.4		ND		7.5		7.6	
June	Mean	8.4	(720)	ND		7.8	(700)	8.0	(720)
	Maximum	10.0		ND		9.3		9.9	
	Minimum	2.3		ND		7.0		7.6	
July	Mean	8.4	(654)	7.8	(682)	7.7	(622)	7.9	(744)
	Maximum	9.1		10.1		12.5		9.8	
	Minimum	7.6		7.4		7.0		7.5	
August	Mean	8.4	(616)	7.8	(737)	7.6	(745)	8.1	(744)
	Maximum	9.1		8.4		8.2		10.0	
	Minimum	3.2		7.4		7.4		7.6	
September	Mean	8.6	(720)	7.8	(738)	7.8	(751)	8.6	(719)
	Maximum	9.2		8.5		41.9		10.7	
	Minimum	5.3		7.1		7.2		7.6	
October	Mean	8.8	(744)	7.7	(320)	7.9	(695)	8.7	(744)
	Maximum	9.7		8.3		9.7		10.0	
	Minimum	1.0		7.4		7.3		7.8	
November	Mean	8.7	(720)	7.9	(644)	8.0	(628)	8.6	(720)
	Maximum	10.0		9.0		9.2		10.1	
	Minimum	1.0		7.1		7.4		7.7	
December	Mean	8.6	(744)	8.0	(693)	8.1	(702)	8.5	(730)
	Maximum	11.0		9.6		10.4		10.2	
	Minimum	1.0		7.5		7.5		7.9	

(a) Maximum and minimum values are hourly averages. Means are monthly means.

(b) Measurement locations are illustrated in Figure 4.1.1.

(c) To convert to international metric system units (picowatts per kilogram), multiply exposure rates by 2.109.

(d) Readings are stored every 60 minutes. Each 60-minute reading is an average of as many as 720 individual measurements collected at 5-second intervals.

(e) Readings were collected every second and averaged every 15 minutes. Fifteen-minute averages were used to compute 60-minute averages (as many as 3,600 individual measurements per hour).

(f) ND = No data collected; instrument problems.

October, November, and December (Table 4.6.4). Monthly mean readings were consistently between 7.3 and 8.8 μR per hour (15.4 and 18.6 pW/kg per second) at the stations near Hanford, and ranged between 7.9 and 8.7 μR

per hour (16.7 and 18.3 pW/kg per second) at the distant station (Heritage College). These mean exposure rates were similar to exposure rates measured by thermoluminescent dosimeters at these locations (Table 4.6.5).

Table 4.6.5. Quarterly Average Exposure Rates ($\mu\text{R}/\text{h}^{[a,b]}$) Measured by Thermoluminescent Dosimeters at Four Locations Around the Hanford Site,^[c] 2002

<u>Quarter Ending</u>	<u>Leslie Groves Park^(d)</u>	<u>Basin City</u>	<u>Edwin Markham</u>	<u>Toppenish</u>
March	8.83 \pm 0.00	8.79 \pm 0.04	8.88 \pm 0.04	7.96 \pm 0.13
June	8.42 \pm 0.25	8.63 \pm 0.08	8.46 \pm 0.00	8.00 \pm 0.17
September	8.50 \pm 0.25	9.00 \pm 0.00	8.54 \pm 0.08	7.71 \pm 0.04
December	8.79 \pm 0.00	9.00 \pm 0.25	9.33 \pm 0.17	9.00 \pm 0.54

(a) \pm counting error.

(b) To convert to international metric system units (picowatts per kilogram), multiply exposure rates by 2.109.

(c) Sampling locations shown on Figure 4.1.1.

(d) Thermoluminescent dosimeter located ~1 kilometer (0.6 mile) north of Leslie Groves Park at location 26.



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5.0 POTENTIAL RADIOLOGICAL DOSES FROM 2002 HANFORD SITE OPERATIONS

E. J. Antonio and K. Rhoads

During 2002, potential radiological doses to the public and biota from Hanford Site operations were evaluated in detail to determine compliance with pertinent regulations and limits. The potential sources of radionuclide contamination included gaseous emissions from stacks and ventilation exhausts, liquid effluent from operating wastewater treatment facilities, and contaminated groundwater seeping into the Columbia River. Other potential sources included fugitive emissions from contaminated soil areas and facilities. The methods used to calculate the potential doses are detailed in Appendix E.

The radiological impact of 2002 Hanford Site operations was assessed in terms of the:

- Dose to a hypothetical, maximally exposed individual at an offsite location using a multimedia pathway assessment (U.S. Department of Energy [DOE] Order 5400.5; Section 5.0.1).
- Collective dose to the population residing within 80 kilometers (50 miles) of Hanford Site operating areas (Section 5.0.2).
- Dose for air pathways, using U.S. Environmental Protection Agency (EPA) methods, for comparison to the *Clean Air Act* standards in Title 40, Code of Federal Regulations, Part 61 (40 CFR 61), Subpart H (Section 5.0.3).
- Maximum dose rate from external radiation at a publicly accessible location at or just within the site boundary (Section 5.0.4.1).
- Dose to an avid sportsman who consumes wildlife that may have been contaminated with radionuclides originating on the site (Section 5.0.4.2).
- Inhalation dose associated with measured radionuclide concentrations in air (Section 5.0.4.3).
- Absorbed dose received by animals exposed to radionuclide releases to the Columbia River and to radionuclides in onsite surface water bodies (Section 5.0.6).

It is generally accepted that radiological dose assessments should be based on direct measurements of radiation dose rates and radionuclide concentrations. However, the amount of most radioactive materials released during 2002 from Hanford Site sources was generally too small to be measured directly once it was dispersed in the offsite environment. For many of the radionuclides present in measurable amounts, it was difficult to separate the contributions from Hanford sources from the contributions from fallout and from naturally occurring uranium and its decay products. Therefore, in nearly all instances, offsite doses were estimated using *GENII - The Hanford Environmental Radiation Dosimetry Software System*, Version 1.485 (PNL-6584) and the Hanford Site-specific parameters listed in Appendix E and in PNNL-14295, APP. 1. As a comparison, air surveillance data were used to assess the maximum inhalation doses at onsite and offsite monitoring stations.

Radiological doses from the water pathway were calculated based on the differences in radionuclide concentrations between upstream and downstream sampling points on the Columbia River. During 2002, tritium, technetium-99, iodine-129, and uranium isotopes were found in the Columbia River downstream of Hanford at greater levels than predicted based on direct discharges from the 100-K Area (Section 4.2 and Appendix B). All other radionuclide concentrations were lower than those predicted from known releases. Riverbank spring water, containing radionuclides, is known to enter the river along the portion of shoreline extending from the 100-B/C Area downstream to the 300 Area (Sections 4.2 and 6.2). No direct discharge of radioactive materials from the 300 Area to the Columbia River was reported during 2002.

5.0.1 MAXIMALLY EXPOSED INDIVIDUAL DOSE (OFFSITE RESIDENT)

The maximally exposed individual is a hypothetical person who lives at a particular location and has a lifestyle that makes it unlikely that any other member of the public would have received a higher radiological dose from Hanford releases during 2002. This individual's exposure pathways were chosen to maximize the combined doses from all reasonable environmental routes of exposure to radionuclides in Hanford Site effluent and emissions using a multimedia pathway assessment (DOE Order 5400.5). In reality, such a combination of maximized parameters is highly unlikely to apply to any single individual.

The location of the hypothetical maximally exposed individual varies from year to year, depending on the relative contributions of the several sources of radioactive effluent released to the air and to the Columbia River from Hanford facilities (Figure 5.0.1). During 2002, the dose assessment determined that the maximally exposed individual was located across the Columbia River (east of the

Hanford Site), at Riverview (Figure 5.0.1). For the calculation, it was assumed that this individual:

- Inhaled and was submersed in airborne radionuclides.
- Received external exposure to radionuclides deposited on the ground.
- Ingested locally grown food products that had been irrigated with water from the Columbia River.
- Used the Columbia River for recreational purposes, resulting in direct exposure from water and radionuclides deposited on the shoreline.
- Ingested locally caught fish.

Doses were calculated using Hanford Site effluent data (Tables 3.1.1 and 3.1.4) and the calculated quantities of radionuclides assumed to be present in the Columbia River from riverbank spring discharges. The estimated releases to the river from these sources were derived from the difference between the upstream and downstream concentrations in Columbia River water. These radionuclides were assumed to enter the river through shoreline groundwater seeps between the 100-B/C Area and the 300 Area.

During 2002, the total dose to the maximally exposed individual at Riverview was calculated to be 0.02 mrem (0.2 μ Sv) per year (Table 5.0.1). This dose was 0.02 mrem

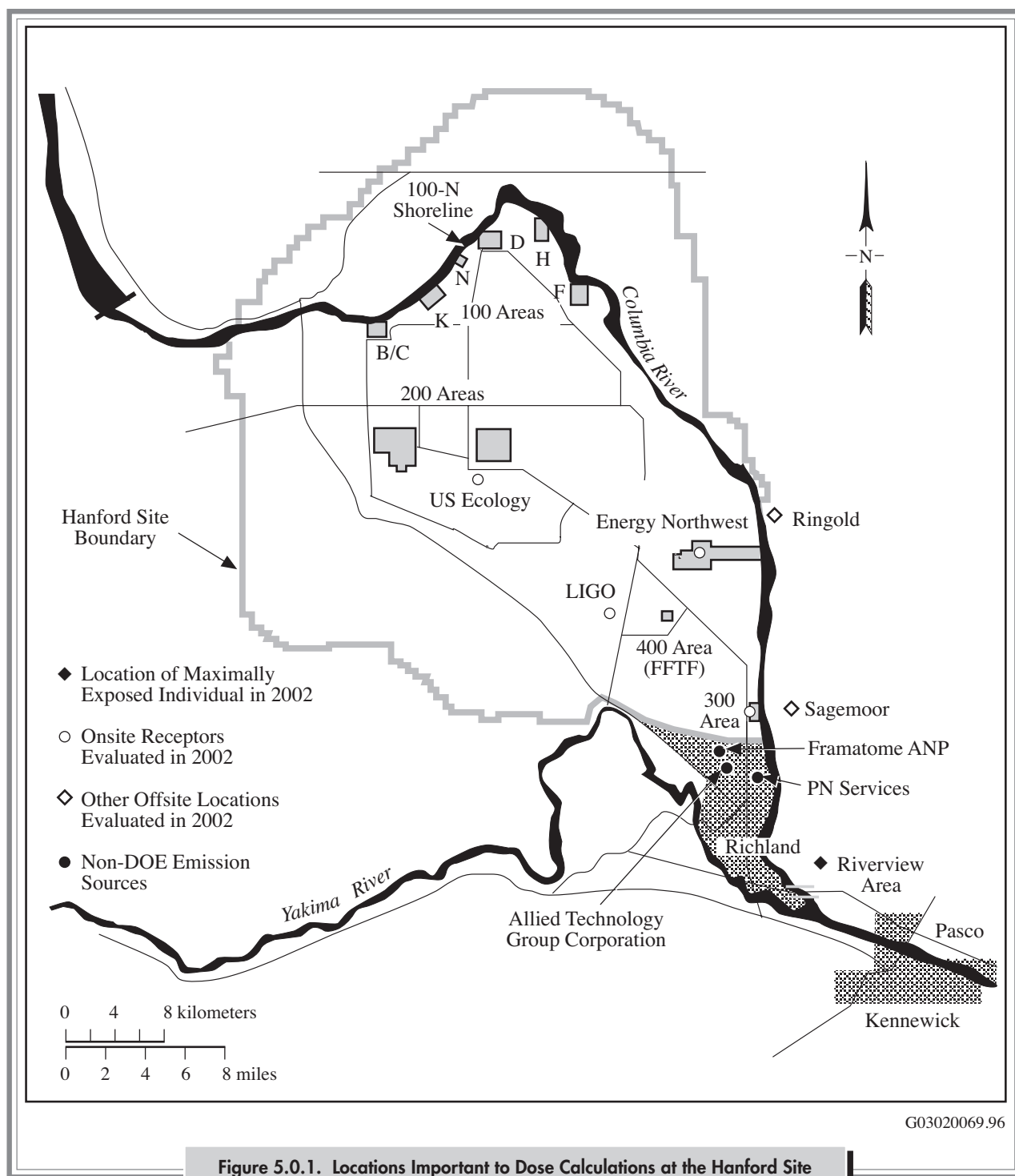
Historically at Hanford, there has been one primary expression of radiological risk to an offsite individual – this is the maximally exposed individual dose. However, the maximally exposed individual dose is currently calculated by two different methods in response to two different requirements:

- One maximally exposed individual dose computation is required by DOE Order 5400.5 and is calculated using the GENII computer code. This calculation considers all reasonable environmental pathways (e.g., air, water, food) that maximize a hypothetical individual offsite exposure to Hanford's radiological effluent and emissions.
- A second estimate of maximally exposed individual dose is required by the *Clean Air Act* and is calculated using an EPA dose modeling computer code (CAP-88) or other methods accepted by EPA for estimating offsite exposure. This offsite dose is based solely on an airborne radionuclide emissions pathway and considers Hanford's stack emissions and emissions from diffuse and unmonitored sources (e.g., windblown dust).

Because the DOE and EPA computer codes use different input parameters, the location and predicted dose of each agency's maximally exposed individual may be different. However, the estimated dose from both methods has historically been significantly lower than health-based exposure criteria.

Recently, DOE has allowed private businesses to locate their activities and personnel on the Hanford Site. This has created the need to calculate a maximum onsite occupational dose for an individual who is employed by a non-DOE business and works within the boundary of the Hanford Site. This dose is based on a mix of air emission modeling data, the individual's exposure at an onsite work location, and the individual's potential offsite exposure.

Another way to estimate risk is to calculate the collective dose. This dose is based on exposure to Hanford radiological contaminants through the food, water, and air pathways and is calculated for the population residing within 80 kilometers (50 miles) of the Hanford Site operating areas. The collective dose is reported in units of person-rem (person-sievert), which is the average estimated individual dose multiplied by the total number of people in the population.



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Table 5.0.1. Dose to the Hypothetical, Maximally Exposed Individual Residing at Riverview from 2002 Hanford Site Operations

<u>Effluent</u>	<u>Pathway</u>	<u>Dose Contributions from Operating Areas, mrem</u>				<u>Pathway Total</u>
		<u>100 Areas</u>	<u>200 Areas</u>	<u>300 Area</u>	<u>400 Area</u>	
Air	External	1.7×10^{-9}	9.7×10^{-8}	1.5×10^{-8}	4.7×10^{-9}	1.2×10^{-7}
	Inhalation	8.7×10^{-7}	1.6×10^{-5}	1.7×10^{-4}	5.9×10^{-7}	1.9×10^{-4}
	Foods	4.2×10^{-8}	6.5×10^{-5}	1.6×10^{-3}	1.5×10^{-7}	1.7×10^{-3}
	Subtotal air	9.1×10^{-7}	8.1×10^{-5}	1.8×10^{-3}	7.4×10^{-7}	1.9×10^{-3}
Water	Recreation	5.6×10^{-7}	8.1×10^{-5}	0.0 ^(a)	0.0	8.2×10^{-5}
	Foods	2.8×10^{-4}	7.4×10^{-3}	0.0	0.0	7.7×10^{-3}
	Fish	2.4×10^{-4}	7.6×10^{-3}	0.0	0.0	7.8×10^{-3}
	Drinking water	1.8×10^{-5}	4.2×10^{-3}	0.0	0.0	4.2×10^{-3}
	Subtotal water	5.4×10^{-4}	1.9×10^{-2}	0.0	0.0	2.0×10^{-2}
Combined total		5.4×10^{-4}	1.9×10^{-2}	1.8×10^{-3}	7.4×10^{-7}	2.2×10^{-2}

(a) Zeros indicate no dose contribution to maximally exposed individual through water pathway.

or 0.02% of the DOE limit of 100 mrem (1 mSv) per year specified in DOE Order 5400.5 (Figure 5.0.2.). The primary pathways (Appendix E, Tables E.1, E.2, and E.4) contributing to this dose (and the percentage of all pathways) were

- the consumption of fish from the Columbia River (35%), foods irrigated with water withdrawn downstream of Hanford (35%), and water (19%) withdrawn from the Columbia River containing principally uranium-234, uranium-238, and tritium
- the inhalation of air downwind of Hanford (1%) and the consumption of food products grown downwind of Hanford (7%), due principally to airborne releases of tritium from the 300 Area

5.0.2 COLLECTIVE DOSE

The regional collective dose from 2002 Hanford Site operations was estimated by calculating the radiological dose to the population residing within an 80-kilometer (50-mile) radius of the onsite operating areas. Collective dose is defined as the sum of doses to all individual members of the public within 80 kilometers (50 miles) of the operating areas at Hanford. During 2002, the collective dose calculated for the population was 0.3 person-rem (0.003 person-Sv) per year, slightly lower than the 2001 collective dose (0.4 person-rem [0.004 person-Sv]) per year (Table 5.0.2) (Appendix E, Tables E.5 to E.9).

Primary pathways contributing to the 2002 collective dose included

- the consumption of water withdrawn from the Columbia River (52%) and containing principally tritium, uranium-234, and uranium-238
- the consumption of foodstuffs (35%) contaminated with radionuclides, principally tritium from 300 Area stacks
- the inhalation of radionuclides (9%) that were released to the air, principally tritium from 300 Area airborne releases

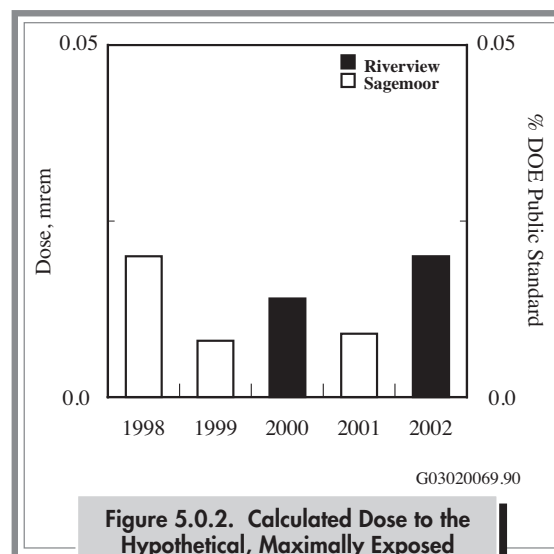


Figure 5.0.2. Calculated Dose to the Hypothetical, Maximally Exposed Individual at the Hanford Site, 1998 through 2002

Table 5.0.2. Collective Dose to the Population from 2002 Hanford Site Operations

Effluent	Pathway	Dose Contributions from Operating Areas, person-rem				Pathway Total
		100 Areas	200 Areas	300 Area	400 Area	
Air	External	6.2×10^{-7}	1.3×10^{-5}	1.4×10^{-6}	6.7×10^{-7}	1.6×10^{-5}
	Inhalation	4.6×10^{-4}	3.4×10^{-3}	2.1×10^{-2}	1.3×10^{-4}	2.5×10^{-2}
	Foods	1.3×10^{-5}	9.8×10^{-3}	1.1×10^{-1}	2.0×10^{-5}	1.2×10^{-1}
	Subtotal air	4.7×10^{-4}	1.3×10^{-2}	1.3×10^{-1}	1.5×10^{-4}	1.4×10^{-1}
Water	Recreation	4.2×10^{-6}	4.6×10^{-4}	0.0 ^(a)	0.0	4.6×10^{-4}
	Foods	2.9×10^{-4}	8.1×10^{-3}	0.0	0.0	8.4×10^{-3}
	Fish	8.8×10^{-5}	2.9×10^{-3}	0.0	0.0	3.0×10^{-3}
	Drinking water	7.3×10^{-4}	1.8×10^{-1}	0.0	0.0	1.8×10^{-1}
	Subtotal water	1.1×10^{-3}	1.9×10^{-1}	0.0	0.0	1.9×10^{-1}
Combined total		1.6×10^{-3}	2.0×10^{-1}	1.3×10^{-1}	1.5×10^{-4}	3.4×10^{-1}

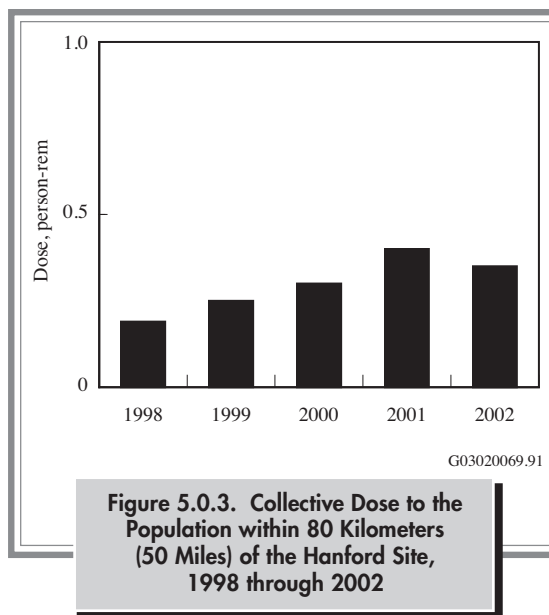
(a) Zeros indicate no dose contribution to the population through the water pathway.

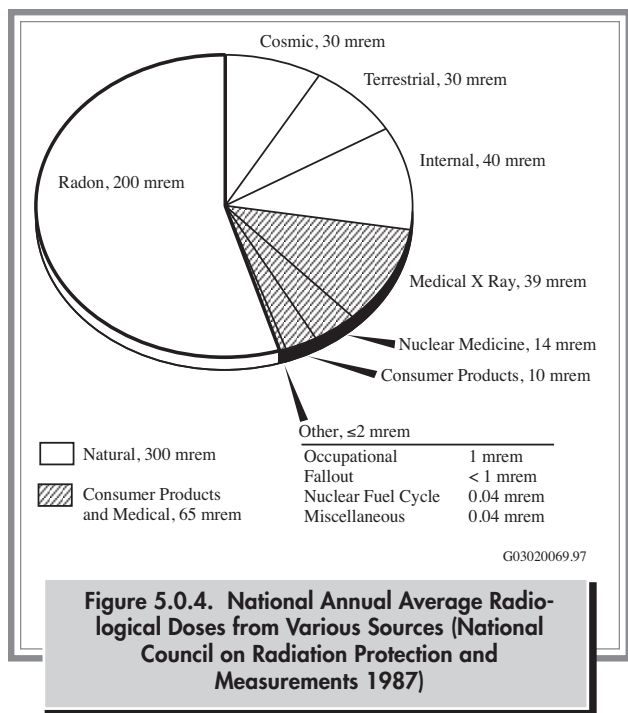
Collective doses reported for 2002 are based on population data from the 2000 census, whereas doses for 1997 to 2001 were based on the 1990 census (Figure 5.0.3). The collective dose is reported in units of person-rem (person-sievert), which is the average estimated individual dose multiplied by the total number of people in the population. Between 1990 and 2000, the population within 80 kilometers (50 miles) of the major operating areas on the Hanford Site increased by 24% to 29%.

The average individual dose from 2002 Hanford Site operations based on a population of 486,000 within 80 kilometers (50 miles) was 0.7 mrem (7 nSv) per year. To place this estimated dose into perspective, it may be compared with doses received from other routinely encountered sources of radiation such as natural terrestrial and cosmic background radiation, medical treatment and x-rays, natural radionuclides in the body, and inhalation of naturally occurring radon (Figure 5.0.4). The estimated annual average individual dose to members of the public from Hanford Site sources during 2002 was ~0.0002% of the estimated annual individual dose received from natural background sources (300 mrem). The calculated radiological doses from Hanford Site operations in 2002 were a small percentage of the standards and of doses from natural background sources (Table 5.0.3).

5.0.3 COMPLIANCE WITH CLEAN AIR ACT STANDARDS

In addition to complying with the all-pathways dose limits established by DOE Order 5400.5, DOE facilities are required to demonstrate that they comply with standards established by the EPA for airborne radionuclide emissions under the *Clean Air Act* in 40 CFR 61, Subpart H. This





regulation specifies that no member of the public shall receive a dose greater than 10 mrem (0.1 mSv) per year from exposure to airborne radionuclide emissions, other than radon, released at DOE facilities. Whereas DOE uses the GENII computer code at Hanford to determine dose to the all-pathways maximally exposed individual, EPA requires the use of CAP-88 (EPA 402-R-00-004) or other EPA-approved models to demonstrate compliance with the requirements in 40 CFR 61, Subpart H. The assumptions embodied in the CAP-88 code differ slightly from standard assumptions used with the GENII code. Therefore, air pathway doses calculated by the two codes may differ somewhat. In addition, the maximally exposed individual for air pathways

may be evaluated at a different location from the all-pathways maximally exposed individual because of the relative contributions from each exposure pathway (Section 5.0.1).

The EPA regulation also requires that each DOE facility submit an annual report to EPA that supplies information about atmospheric emissions for the preceding year and their potential offsite dose. For more detailed information about 2002 air emissions on the Hanford Site, refer to DOE's report to EPA (DOE/RL-2002-20).

Maximum Dose to Non-DOE Workers on the Site.

The DOE Richland Operations Office received guidance from EPA Region 10 and the Washington State Department of Health that, in demonstrating compliance with the 40 CFR 61 standards, it should evaluate potential doses to non-DOE employees who work on the Hanford Site, but who are not under direct DOE control. Accordingly, the doses to members of the public employed at non-DOE facilities that were outside access-controlled areas on the Hanford Site were evaluated for the 2002 EPA air emissions report (DOE/RL-2002-20). These locations included the Columbia Generating Station operated by Energy

Table 5.0.3. Comparison of Doses to the Public from Hanford Site Effluent to Federal Standards and Natural Background Levels

Standard	Hanford Dose ^(a)	Hanford Dose Percent of Standard
DOE - 100 mrem/yr all pathways MEI ^(b,c)	0.02 mrem/yr	0.02
EPA - 10 mrem/yr air pathway MEI ^(d)	0.023 mrem/yr	0.23
Background Dose		
300 mrem/yr average U.S. individual ^(e)	0.02 mrem/yr	0.007
110,000 person-rem/yr to population within 80 km (50 mi)	0.3 person-rem/yr	0.0003

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

(b) DOE Order 5400.5.

(c) MEI = Maximally exposed individual.

(d) 40 CFR 61.

(e) National Council on Radiation Protection and Measurements (1987).

Northwest, the Laser Interferometer Gravitational Wave Observatory (LIGO) operated by the University of California, and a research laboratory on the west side of the 300 Area leased to Washington State University through late March, 2002 (Figure 5.0.1). Because 300 Area emissions accounted for the majority of the air pathway dose during 2002, a person working in the Washington State University research laboratory 25% of the year received the highest dose for non-DOE employees who worked on the Hanford Site. The dose calculated using the CAP-88 code was 0.014 mrem (0.0012 mSv) per year, assuming full-time occupancy for the first quarter of the year. After the first quarter, the facility was no longer occupied by non-DOE workers.

EPA guidance does not currently permit adjustment of doses calculated using the CAP-88 code to account for less than full-time occupancy at locations within the site boundary. However, if a selected occupancy period of 2,000 hours per year were assumed for workers at onsite non-DOE facilities, the doses to individuals at any of the locations evaluated would be lower than the dose to the maximally exposed offsite individual that has historically been evaluated for compliance with the EPA standard. Methods to estimate doses to individuals within the site boundary are currently under discussion by DOE and EPA.

Maximum Dose to an Offsite Maximally Exposed Individual. During 2002, the maximally exposed offsite individual for air pathways using EPA specified methods was determined to be at a location in the Sagemoor area of Franklin County, ~1.5 kilometers (~1 mile) directly across the Columbia River from the 300 Area (Figure 5.0.1). The potential air pathway dose from stack emissions to a maximally exposed individual at that location was calculated by using the CAP-88 code to be 0.023 mrem (0.00023 mSv) per year, which represented <0.3% of the EPA standard. This is similar to the dose for offsite individuals calculated for previous annual air emission reports to EPA.

Dose from Diffuse and Fugitive Sources of Airborne Radionuclides. The December 15, 1989, revisions to the *Clean Air Act* (40 CFR 61, Subpart H) required DOE facilities to estimate the dose to a member of the public for radionuclides released from all potential sources of airborne radionuclides. DOE and EPA interpreted the regulation to include diffuse and fugitive sources as well as

monitored point sources (i.e., stacks). EPA has not specified or approved methods to estimate air emissions from diffuse sources, and standardization has been difficult because of the wide variety of such sources at DOE sites. The method developed at Hanford to estimate potential diffuse source emissions is based on environmental surveillance measurements of airborne radionuclides at the site perimeter (DOE/RL-2002-20). During 2002, the estimated dose to a maximally exposed individual at a location in the Sagemoor area from diffuse sources was calculated using the CAP-88 code to be 0.44 mrem (0.0044 mSv) per year. The dose to a non-DOE worker in the 300 Area from diffuse and fugitive sources would be similar to, or lower than, the dose at the site perimeter. Therefore, the potential combined dose from stack emissions and diffuse sources during 2002 was well below the EPA 10 mrem (0.1 mSv) per year standard for either onsite or offsite members of the public.

5.0.4 SPECIAL CASE DOSE ESTIMATES

The parameters used to calculate the dose to the maximally exposed individual were selected to provide a scenario yielding a reasonable upper (or bounding) estimate of the dose. However, such a scenario may not have necessarily resulted in the highest conceivable radiological dose. Other low-probability exposure scenarios existed that could have resulted in somewhat higher doses. Four scenarios that could have potentially led to larger doses included (1) an individual who spent time at the site boundary location with the maximum external radiological dose rate, (2) a sportsman who consumed contaminated wildlife that migrated from the site, (3) a person who drank water at the Fast Flux Test Facility in the 400 Area, and (4) an individual at various locations who breathed the measured radionuclide concentrations in air for an entire year. The potential doses resulting from these scenarios are examined in the following sections.

5.0.4.1 MAXIMUM “BOUNDARY” DOSE RATE

The boundary radiological dose rate is the external radiological dose rate measured at publicly accessible locations at or near the Hanford Site boundary. The maximum boundary dose rate was determined from radiation

exposure measurements using thermoluminescent dosimeters at locations where elevated dose rates might be expected on the site and at representative locations off the site. These boundary dose rates were not used to calculate annual doses to the general public because no one could actually reside at any of these boundary locations. However, these rates were used to determine the dose to a specific individual who might have spent some time at that location.

External radiological dose rates measured during 2002 were made along the 100-N Area shoreline (Figure 5.0.1) (Section 4.6). The measurements were consistently above background levels and represented the highest measured boundary dose rates. The Columbia River allows public access to within ~100 meters (~330 feet) of the N Reactor and supporting facilities at this location.

The highest dose rate along the 100-N Area shoreline during 2002 was about 0.011 mrem (0.11 μ Sv) per hour, or 10% higher than the average dose rate of 0.01 mrem (0.1 μ Sv) per hour normally observed at other shoreline locations. Therefore, for every hour someone spent near the 100-N Area shoreline during 2002, the external radiological dose received from Hanford operations was ~0.001 mrem (~0.01 μ Sv) above the average shoreline dose rate. If an individual had spent 2 hours at that location, he or she would have received a dose comparable to the annual dose calculated for the hypothetical maximally exposed individual at Riverview. Members of the public could reach the 100-N Area shoreline by boat and could have legally occupied the shoreline area below the high water line. However, the topography of the shoreline below the high water line near the N Reactor area is very rocky and visitors are not likely to remain on shore for extended periods.

5.0.4.2 SPORTSMAN DOSE

Wildlife have access to areas of the Hanford Site that are contaminated with radioactive materials. Sometimes wildlife acquire radioactive contamination and migrate off the site. Wildlife sampling was conducted on the site to estimate the maximum contamination levels that might have existed in animals from Hanford that were hunted off the site. Because this scenario had a relatively low probability of occurrence, this pathway was not considered in the maximally exposed individual calculation.

Uranium isotopes were detected in bass and carp muscle samples collected from the Columbia River near the 300 Area (Section 4.5). The radiological dose to a person consuming 1 kilogram (2.2 pounds) of the bass containing the maximum measured concentrations of uranium was calculated to be ~3 μ rem (~0.03 μ Sv). It should be noted that the ratios of the uranium isotopes found in the sample were not those of natural uranium and were higher in uranium-235.

The radiological dose to a person consuming 1 kilogram (2.2 pounds) of carp containing the maximum measured concentrations of uranium was calculated to be ~0.6 μ rem (~0.006 μ Sv). Strontium-90 was the only other radionuclide, possibly of Hanford origin, detected in wildlife samples during 2002 and was only found in bone or offal samples. Because bone or offal are not normally consumed by humans, a dose to a sportsman from this pathway was viewed as relatively implausible and was not included in this report.

5.0.4.3 ONSITE DRINKING WATER

During 2002, groundwater was used as drinking water by workers at the Fast Flux Test Facility in the 400 Area, and Columbia River water was used as a drinking water source in the 100-B, 100-D, 100-K, and 200 Areas. Therefore, these water supplies were sampled and analyzed throughout the year in accordance with applicable drinking water regulations (40 CFR 141). All annual average radionuclide concentrations measured during 2002 were below applicable drinking water standards. However, tritium in the Fast Flux Test Facility groundwater wells was detected at levels greater than typical background values (Section 4.3 and Appendix E).

Based on the measured concentrations, the potential annual dose to Fast Flux Test Facility workers (an estimate derived by assuming a consumption of 1 liter [0.26 gallon] per day for 240 working days) would be ~0.02 mrem (~0.2 μ Sv). This dose is well below the drinking water dose limit of 4 mrem (40 μ Sv) per year for public drinking water supplies.

5.0.4.4 INHALATION DOSES FOR ENTIRE YEAR

A nominal inhalation rate of 23 cubic meters (812 cubic feet) per day of air and an exposure period of 8,766 hours (365 days) were assumed for all offsite calculations (Tables 4.1.2 and 4.1.3). For onsite locations, the exposure period was reduced to 2,000 hours (250 8-hour work-days) to simulate a typical work year, and the breathing rate was increased to 28.8 cubic meters (1,017 cubic feet) per day to account for light duty work.

Radiological inhalation doses to hypothetical offsite individuals modeled to be in the same location for the entire year and to onsite individuals located near air surveillance stations during their workday are presented in Table 5.0.4. The maximum air concentrations (Table 4.1.2) were used in the calculations and assumed to be constant for the year-long evaluation period. Inhalation doses calculated

using this method ranged from 0.079 mrem (0.00079 mSv) at onsite and distant locations to 0.21 mrem (0.0021 mSv) at the site perimeter. These were comparable to doses calculated using CAP-88 code and reported for various air pathways (Section 5.0.3).

5.0.5 DOSES FROM NON-DOE SOURCES

DOE Order 5400.5, Section II, paragraph 7, has a reporting requirement for combined DOE and other manmade doses exceeding 100 mrem (1 mSv) per year. During 2002, various non-DOE industrial sources of public radiation exposure existed on or near the Hanford Site. These included a commercial low-level radioactive waste burial ground at Hanford operated by US Ecology; a nuclear power-generating station at Hanford operated by Energy Northwest; a nuclear-fuel production plant operated near

Table 5.0.4. Inhalation Doses On and Around the Hanford Site Based on 2002 Air Surveillance Data^(a)

Radionuclide	Location	Dose Based on Maximum Air Data (mrem/yr) ^(b,c)	Radionuclide	Location	Dose Based on Maximum Air Data (mrem/yr) ^(b,c)
Tritium	300 Area	1.81×10^{-3}	Plutonium-239/240	Onsite	5.50×10^{-3}
	Onsite	1.81×10^{-3}		Perimeter	3.05×10^{-3}
	Perimeter	1.22×10^{-2}		Nearby communities	5.82×10^{-3}
	Nearby communities	1.75×10^{-2}		Distant communities	6.65×10^{-3}
	Distant communities	1.59×10^{-7}	Uranium-234	Onsite	3.74×10^{-2}
Cobalt-60	Onsite	4.89×10^{-4}		Perimeter	9.49×10^{-2}
	Perimeter	2.14×10^{-3}		Nearby communities	6.33×10^{-2}
	Nearby communities	1.39×10^{-3}		Distant communities	3.60×10^{-2}
	Distant communities	8.81×10^{-4}	Uranium-235	Onsite	9.20×10^{-4}
Strontium-90	Onsite	3.24×10^{-3}		Perimeter	3.83×10^{-3}
	Perimeter	1.42×10^{-2}		Nearby communities	4.63×10^{-3}
	Nearby communities	5.89×10^{-4}		Distant communities	3.12×10^{-3}
	Distant communities	3.27×10^{-3}	Uranium-238	Onsite	2.76×10^{-2}
Iodine-129	Onsite	7.72×10^{-6}		Perimeter	7.45×10^{-2}
	Perimeter	1.32×10^{-6}		Nearby communities	4.63×10^{-2}
	Distant communities	8.92×10^{-8}		Distant communities	2.82×10^{-2}
Cesium-137	Onsite	2.76×10^{-5}	Totals	Onsite	7.9×10^{-2}
	Perimeter	1.21×10^{-4}		Perimeter	2.1×10^{-1}
	Nearby communities	1.34×10^{-4}		Nearby communities	1.5×10^{-1}
	Distant communities	1.42×10^{-4}		Distant communities	7.9×10^{-2}
Plutonium-238	Onsite	2.47×10^{-3}			
	Perimeter	4.03×10^{-3}			
	Nearby communities	5.54×10^{-3}			
	Distant communities	9.32×10^{-4}			

(a) Onsite inhalation dose calculations were based on 2,000-hour exposure period and 1.2 m³/h breathing rate; all offsite inhalation dose calculations were based on a 8,766-hour exposure period and a 0.958 m³/h breathing rate.

(b) Includes contributions from DOE activities as well as contributions from atmospheric fallout, naturally occurring radionuclides, and non-DOE facilities on and near the site.

(c) To convert to international metric system units (mSv/yr), divide reported values by 100.

the site by Framatome ANP Richland, Inc.; a commercial, low-level, radioactive waste treatment facility operated near the site by Allied Technology Group Corporation; and a commercial decontamination facility operated near the site by PN Services (Figure 5.0.1).

DOE maintains an awareness of these other sources of radiation, which, if combined with the DOE sources, might have the potential to cause a dose exceeding 10 mrem (0.1 mSv) per year to any member of the public. With information gathered from these companies (via personal communication and annual reporting), it was conservatively estimated that the total 2002 individual dose from their combined activities was on the order of 0.05 mrem (0.0005 mSv) per year. Therefore, the combined dose from Hanford area non-DOE and DOE sources to a member of the public for 2002 was well below any regulatory dose limit.

5.0.6 DOSE RATES TO ANIMALS

Upper estimates have been made of the radiological dose to aquatic organisms in accordance with the DOE Order 5400.5 interim requirement for management and control of liquid discharges. The current dose limit for aquatic biota is 1 rad (10 mGy) per day. The proposed limit for terrestrial biota is 0.1 rad (1 mGy) per day. Surveillance data from soil, Columbia River shoreline spring water, the Fast Flux Test Facility pond water, and West Lake sediment and water were evaluated using the RAD-BCG Calculator (a screening method to estimate radiological doses to aquatic and terrestrial biota). The RAD-BCG Calculator^(a) is a Microsoft® Excel spreadsheet that initially compares radionuclide concentrations in soil, water, or sediment measured by routine surveillance programs to a set of biota concentration guides (i.e., soil or water concentrations that result in a dose rate of 1 rad [10 mGy] per day for aquatic biota or 0.1 rad [1 mGy] per day for terrestrial organisms). The process involves two screening tiers. Tier 1 is a screening assessment based on maximum measured radionuclide concentrations, and Tier 2 is a screening assessment based on average measured radionuclide concentrations.

For soil and water samples containing multiple radionuclides, a sum of fractions is calculated to account for the contribution to dose from each radionuclide relative to its corresponding dose guideline. If the sum of fractions for the maximum radionuclide concentrations exceeds 1.0 (Tier 1), the dose guideline has been exceeded and the screening assessment has failed. Tier 2 screening, where mean radionuclide concentrations are employed, is then conducted.

The biota concentration guides are very different from the DOE derived concentration guides that are used to assess radiological doses to humans. If the estimated screening value exceeds the guideline (Tiers 1 and 2 sum of fractions >1.0), additional calculations are performed to more accurately evaluate exposure of the biota to the radionuclides. The process may culminate in a site-specific assessment requiring additional sampling and study of exposure. During 2002, biota dose assessments were conducted by operational areas (Table 5.0.5) and for special situations.

Maximum concentrations of radionuclides in Columbia River sediment, onsite pond sediment, riverbank spring water, and pond water were evaluated using the RAD-BCG Calculator. Riverbank springs carry groundwater contaminants into the Columbia River at greater concentrations than observed in river water and provide another level of conservatism in the biota dose assessment process. The results indicate that all spring data from the 100 Areas, Hanford town site, and 300 Areas resulted in doses below the guidelines in the Columbia River (sum of fractions <1.0) (Table 5.0.5). The Tier 1 West Lake evaluation produced a total sum of fraction greater than unity and was consistent with past assessments (PNNL-13910, APP. 1). Tier 2 West Lake evaluations using average sediment data provided a more realistic sum of fractions (0.54) using a more representative assessment of average exposure levels over time and space at West Lake.

For the terrestrial evaluations, the screening assessments were based on radionuclide concentrations in soil collected between 1997 and 2001 by the Surface Environmental Surveillance Project. At locations where a body of water is located near the soil collection location and radiological

(a) Memorandum from Dr. David Michaels (Assistant Secretary for Environmental, Safety, and Health) to Distribution, *Availability of DOE Technical Standard, "A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota (Project ENVR-0011)," for use in DOE Compliance and Risk Assessment Activities*, dated July 19, 2000.

Table 5.0.5. Results of RAD-BCG Calculator^(a) Screenings at the Hanford Site, 2002

<u>Location</u>	<u>Tier 1 Screen Sum of Fraction</u>	<u>Pass or Fail</u>	<u>Tier 2 Screen Sum of Fraction</u>	<u>Pass or Fail</u>
100 Areas				
Aquatic	0.002-0.07			
100-B Area	0.040	Pass	NA ^(b)	
100-F Area	0.018	Pass	NA	
100-F Area Spring	0.024	Pass	NA	
100-H Area Springs	0.021	Pass	NA	
100-K Area Springs	0.072	Pass	NA	
100-N Area	0.002	Pass	NA	
Terrestrial	0.03-0.10			
100-K Area	0.097	Pass	NA	
100-N Area	0.053	Pass	NA	
100-D Area	0.049	Pass	NA	
100-F Area	0.026	Pass	NA	
200 Areas				
Terrestrial				
200-East and 200-West Areas	0.73	Pass	NA	
300 and 400 Areas				
Aquatic	0.00015-0.48			
300 Area	0.023	Pass	NA	
300 Area Springs	0.48	Pass	NA	
400 Area Pond	0.00015	Pass	NA	
Terrestrial	0.06			
300 and 400 Areas Combined	0.063	Pass	NA	
600 Area				
Aquatic	0.017-1.05			
Hanford Town Site	0.017	Pass	NA	
Hanford Town Site Springs	0.018	Pass	NA	
West Lake	1.05	Fail	0.54	Pass
Terrestrial	0.07			
600 Area with Hanford Town Site Water	0.071	Pass	NA	

(a) A screening method to estimate radiological doses to aquatic and terrestrial biota.

(b) NA = Not applicable.

analyses have been performed for that water, the water data was used for the terrestrial screening evaluation. For example, in the 100-F Area terrestrial evaluation, the water data from the 100-F Area spring were imported into the calculation to account for aquatic pathways. All biota assessments of terrestrial locations passed the Tier 1 screening sum of fraction.

5.0.7 RADIOLOGICAL DOSE IN PERSPECTIVE

Two scientific studies (National Research Council 1980, 1990; United Nations Science Committee on the Effects of Atomic Radiation 1988) were performed to estimate the possible risk from exposure to low levels of radiation. These studies provided information to government and scientific organizations and recommend radiological dose limits and standards for public and occupational safety.

Although no increase in the incidence of health effects from low doses of radiation has actually been confirmed by the scientific community, regulatory agencies cautiously assume that the probability of these types of health effects at low doses (down to zero dose) is the same per unit dose as the health effects observed at much higher doses (e.g., in atomic bomb survivors, individuals receiving medical exposure, or radium dial painters). This concept is known as the linear no threshold hypothesis. Under these assumptions, even natural background radiation, which is hundreds of times greater than radiation from current Hanford Site releases, increases each person's probability or chance of developing a detrimental health effect.

Scientists do not agree on how to translate the available data on health effects into the numerical probability (risk) of detrimental effects from low-level radiological doses. Some scientific studies have indicated that low radiological doses result in beneficial effects (Sagan 1987). Because cancer and hereditary diseases in the general population are caused by many sources (e.g., genetic defects, sunlight, chemicals, background radiation), some scientists doubt that the risk from low-level radiation exposure can ever be proven conclusively. In developing *Clean Air Act* regulations, EPA uses a probability value of ~ 4 per 10 million

(0.0004) for the risk of developing a fatal cancer after receiving a dose of 1 mrem (0.01 mSv) (EPA 520/1-89-005). Additional data (National Research Council 1990) support the reduction of even this small risk value, possibly to zero, for certain types of radiation when the dose is spread over an extended time.

Government agencies are trying to determine what level of risk is safe for members of the public exposed to pollutants from industrial operations (e.g., DOE facilities, nuclear power plants, chemical plants, hazardous waste sites). All of these industries are considered beneficial to people in some way such as providing electricity, national defense, waste disposal, and consumer products. Government agencies have a complex task to establish environmental regulations that control levels of risk to the public without unnecessarily reducing needed benefits from industry.

One perspective on risks from industry is to compare them to risks involved in other typical activities. For instance, two risks that an individual experiences when flying on an airplane are added radiological dose (from a stronger cosmic radiation field that exists at higher altitudes) and the possibility of being in an aircraft accident. The estimated risks from various radiological doses to the risks of some activities encountered in everyday life (Table 5.0.6).

Table 5.0.6. Estimated Risk from Various Activities and Exposure^(a)

<u>Activity or Exposure Per Year</u>	<u>Risk of Fatality</u>
Smoking 1 pack of cigarettes per day (lung/heart/other diseases)	$3,600 \times 10^{-6}$
Home accidents	$100 \times 10^{-6(b)}$
Taking contraceptive pills (side effects)	20×10^{-6}
Drinking 1 can of beer or 0.12 L (4 oz) of wine per day (liver cancer/cirrhosis)	10×10^{-6}
Firearms, sporting (accidents)	$10 \times 10^{-6(b)}$
Flying as an airline passenger (cross-country roundtrip - accidents)	$8 \times 10^{-6(b)}$
Eating approximately 54 g (4 tbsp) of peanut butter per day (liver cancer)	8×10^{-6}
Pleasure boating (accidents)	$6 \times 10^{-6(b)}$
Drinking chlorinated tap water (trace chloroform - cancer)	3×10^{-6}
Riding or driving in a passenger vehicle (483 km [300 mi])	$2 \times 10^{-6(b)}$
Eating 41 kg (90 lb) of charcoal-broiled steaks (gastrointestinal tract cancer)	1×10^{-6}
Natural background radiological dose (300 mrem [3 mSv])	0 to 120×10^{-6}
Flying as an airline passenger (cross-country roundtrip - radiation)	0 to 5×10^{-6}
Dose of 1 mrem (0.01 mSv) for 70 yr	0 to 0.4×10^{-6}
Dose to the maximally exposed individual living near Hanford	0 to 0.008×10^{-6}

(a) These values are generally accepted approximations with varying levels of uncertainty; there can be significant variation as a result of differences in individual lifestyle and biological factors (Atallah 1980; Dinman 1980; Ames et al. 1987; Wilson and Crouch 1987; Travis and Hester 1990).

(b) Real actuarial values. Other values are predicted from statistical models. For radiological dose, the values are reported in a possible range from the least conservative (0) to the currently accepted most conservative value.

Table 5.0.7. Activities Comparable in Risk to the 0.02-mrem (0.002-mSv) Dose Calculated for the Hanford Site's 2002 Maximally Exposed Individual

Driving or riding in a car 2 km (1.2 mi)
Smoking less than 1/50 of a cigarette
Flying approximately 5 km (3 mi) on a commercial airliner
Eating approximately 5 tsp of peanut butter
Eating one 0.4-kg (12-oz) charcoal-broiled steak
Drinking 2 L (approximately 66 oz) of chlorinated tap water
Being exposed to natural background radiation for 35 min in a typical terrestrial location
Drinking approximately 0.07 L (1.2 oz) of wine or 0.2 L (3.5 oz) of beer

Some activities are considered approximately equal in risk to that from the dose received by the maximally exposed individual from monitored Hanford effluent during 2002 (Table 5.0.7).

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6.0 HANFORD SITE GROUNDWATER MONITORING

D. R. Newcomer

The strategy for managing and protecting groundwater at the Hanford Site is to protect the Columbia River, human health, and the environment; treat groundwater contamination; and limit the migration of contaminants from the 200 Areas (see DOE/RL-98-48 and DOE/RL-98-56). To support this strategy, the Hanford Groundwater Monitoring Project continues to monitor the quality of groundwater. The project, which is conducted by staff of the Pacific Northwest National Laboratory, is designed to detect and characterize new groundwater contamination and to document the distribution and movement of existing contaminant plumes. Monitoring provides the historical baseline to evaluate current and future risk from exposure to groundwater contamination and to decide on remedial options. The Hanford Groundwater Monitoring Project includes site-wide groundwater monitoring mandated by U.S. Department of Energy (DOE) Orders and near-field groundwater monitoring conducted to assure that operations in and around specific waste disposal facilities comply with applicable regulations.

Most of the groundwater contamination at the Hanford Site resulted from discharge of wastewater from reactor operations, reactor fuel fabrication, and processing of spent reactor fuel. Table 6.0.1 lists the principal contaminants found in each operational area and the type of operation that generated them. In the 100 Areas, discharges included

reactor cooling water, fuel storage basin water, filter backwash, and smaller amounts of waste from a variety of other processes. In the 200 Areas, large quantities of wastewater from fuel reprocessing were discharged to the ground. Other contamination sources in the 200 Areas included plutonium purification waste and decontamination waste. The plutonium purification process resulted in the discharge of large amounts of liquid organic chemicals in addition to aqueous solutions. This has produced widespread contaminant plumes. Non-aqueous liquid may also be present, and this would result in a continuing source of contamination that is very difficult to clean up. Groundwater contamination in the 300 Area resulted mainly from discharge of waste from fuel fabrication and laboratory operations.

Collection and analysis of groundwater samples to determine the distribution of radiological and chemical constituents were major parts of the groundwater monitoring effort. In addition, hydrogeologic characterization and modeling of the groundwater flow system were used to assess the monitoring network and to evaluate potential effects of Hanford Site groundwater contamination. Other work included data management, interpretation, and reporting.

The purpose of this chapter is to provide an overall summary of groundwater monitoring during 2002. A

Table 6.0.1. Chemical and Radiological Groundwater Contaminants and Their Link to Areas and Facilities on the Hanford Site

<u>Areas</u>	<u>Facilities Type</u>	<u>Contaminants Generated</u>
100	Reactor operations	Tritium, ⁶⁰ Co, ⁹⁰ Sr, hexavalent chromium, sulfate
200	Irradiated fuel processing chromium, fluoride, nitrate	Tritium, ⁹⁰ Sr, ⁹⁹ Tc, ¹²⁹ I, ¹³⁷ Cs, Pu, U, cyanide, hexavalent
200	Plutonium purification	Pu, carbon tetrachloride, chloroform, nitrate
300	Fuel fabrication	⁹⁹ Tc, U, hexavalent chromium, trichloroethene

conceptual model describing the general groundwater hydrogeology of the Hanford Site is included in Section 6.0.1. A description of groundwater transport at the Hanford Site is discussed in Section 6.0.2. Summary results for groundwater monitoring during 2002 are discussed in Section 6.2. Additional details concerning the Hanford Groundwater Monitoring Project are available in PNNL-14187, *Hanford Site Groundwater Monitoring for Fiscal Year 2002*.

Groundwater monitoring was conducted to accomplish the following tasks:

- Assess the impact of radiological and hazardous chemicals on groundwater as a result of Hanford Site operations.
- Evaluate potential offsite effects from the groundwater pathway.
- Verify compliance with applicable environmental laws and regulations.
- Evaluate effectiveness of groundwater remediation.
- Identify and characterize new or existing groundwater quality problems.
- Evaluate the potential human exposure to contaminants in groundwater.

Background conditions, or the quality of groundwater on the site unaffected by operations, must be known to assess the effect of Hanford Site operations on groundwater quality. Data on the concentration of contaminants of concern in groundwater that existed before site operations began are not available. Therefore, concentrations of naturally occurring chemical and radiological constituents in groundwater sampled from wells located in areas unaffected by site operations, including upgradient locations, provide the best estimate of pre-Hanford groundwater quality. Summaries of background conditions are tabulated in several reports (PNL-6886; PNL-7120; DOE/RL-96-61; and Appendix A of WHC-EP-0595).

During 2002, groundwater samples were collected from both the unconfined and upper confined aquifers beneath the Hanford Site. The unconfined aquifer was monitored extensively because it contains contaminants from Hanford Site operations (PNNL-14187) and provides a potential pathway for contaminants to reach points of human exposure (e.g., water supply wells, Columbia River). The upper confined aquifer was monitored, though

less extensively and less frequently than the unconfined aquifer, because it also provides a potential pathway for contaminants to migrate off the site. Some sampling also was conducted at the request of the Washington State Department of Health.

Site-wide groundwater monitoring is designed to meet the project objectives stated in DOE Order 5400.1^(a) and the tasks described in the preceding paragraphs. The effects of Hanford Site operations on groundwater have been monitored for more than 50 years under this project and its predecessors. Near-field monitoring of groundwater around specific waste facilities was performed to meet the requirements of the *Resource Conservation and Recovery Act* (RCRA) (40 CFR 265) and Washington Administrative Codes (WAC 173-216; WAC 173-303; WAC 173-304) as well as applicable DOE Orders (e.g., 435.1, 5400.1, 5400.5). Groundwater monitoring was also performed in conjunction with cleanup investigations under the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) and 40 CFR 300.

To evaluate the effect of remediation efforts on groundwater, groundwater within the contaminant plumes must be monitored to characterize and define flow patterns and trends in the concentrations of radiological or chemical constituents. Monitoring is required to quantify existing groundwater quality and to provide a baseline of environmental conditions against which future changes can be assessed.

Areas that potentially could be a source of contamination also were monitored to characterize and define trends in the condition of the groundwater. These areas were monitored to identify and quantify changes in groundwater quality. Potential source areas included active waste disposal facilities or facilities that had generated or received waste in the past. Most of these facilities are located within the 100, 200, and 300 Areas. However, some sources, such as the 618-11 burial ground, are located outside these operational areas.

Water supplies on and near the Hanford Site potentially provide the most direct route for human exposure to contaminants in groundwater. During 2002, one of the site's ten DOE-owned, contractor-operated drinking water systems provided groundwater for human consumption on

(a) DOE Order 5400.1, applicable for calendar year 2002, was replaced by DOE Order 450.1 in January 2003.

the site. This system supplied water at the Fast Flux Test Facility (Section 4.3). Wells used for supplemental water supply by the city of Richland are located near the site's southern boundary. Monitoring wells near these water systems were sampled routinely to assure that any potential water quality changes would be identified long before regulatory limits were reached.

6.0.1 HYDROGEOLOGY

Both confined and unconfined aquifers are present beneath the Hanford Site. An aquifer is a water-saturated geologic interval or unit that has a high permeability, meaning it can transmit significant quantities of water. A confined aquifer is bounded above and below by low-permeability materials that restrict the vertical movement of water. The confining layers may be dense rock, such as the central parts of basalt flows, silt, clay, or well-cemented sediment (i.e., caliche). Extensive, confined aquifers at the site are found primarily within interflows and interbeds of the Columbia River basalts.

An unconfined aquifer, or water-table aquifer, is overlain by unsaturated sediment. The upper surface of the saturated zone in an unconfined aquifer, which is called the water table, rises and falls in response to changes in the volume of water stored in the aquifer. The unconfined aquifer is bounded below either by the basalt surface or, in places, by relatively impervious clays and silts. Laterally, the unconfined aquifer is bounded by basalt ridges and by the Yakima and Columbia Rivers. The basalt ridges have a low permeability and act as a barrier to the lateral flow of groundwater where they rise above the water table (RHO-BWI-ST-5, p. II-116).

The unconfined aquifer, which forms the uppermost groundwater zone, has been directly affected by wastewater disposal at the Hanford Site. The unconfined aquifer discharges primarily into the Columbia River and is the most thoroughly monitored aquifer beneath the site. Confined aquifers beneath the Hanford Site are generally isolated from the unconfined aquifer by dense rock that forms the interior of the basalt flows. However, interflow between the unconfined aquifer and the confined aquifer system is known to occur at faults that bring a water-bearing interbed in contact with other sediments or where the overlying basalt has been eroded to reveal an interbed (Newcomb et al. 1972; RHO-RE-ST-12 P; WHC-MR-0391).

6.0.2 TRANSPORT

The history of contaminant releases and the physical and chemical principles of mass transport control the distribution of radionuclides and chemicals in groundwater. Processes that control the movement of these contaminants at the Hanford Site are discussed in the following paragraphs.

Liquid effluent discharged to the ground at Hanford Site facilities percolated down through the unsaturated zone toward the water table. Radionuclide and chemical constituents move through the soil column and, in some cases, enter the groundwater. In some locations, sufficient water was discharged to saturate the soil column to the surface. Not all contaminants move at the same rate as the water in the subsurface. Chemical processes such as adsorption onto soil particles, chemical precipitation, and ion exchange slow the movement of some constituents such as strontium-90, cesium-137, and plutonium-239/240. However, these processes may be affected by the chemical characteristics of the waste such as high ionic strength, acidity, or presence of chemical complexants. Other radionuclides, such as technetium-99, iodine-129, and tritium, and chemicals, such as nitrate, are not as readily retained by the soil and move vertically through the soil column at a rate nearly equal to the infiltrating water. When the contaminants reach the water table, their concentrations are reduced by dilution with groundwater. As these dissolved constituents move with the groundwater, many radionuclides and chemicals adhere to sediment particle surfaces (adsorption) or diffuse into the particles (absorption). Radionuclide concentrations are also reduced by radioactive decay.

Outside the source areas (i.e., liquid disposal sites), there is typically little or no downward gradient (driving force or head), so contamination tends to remain in the upper part of the aquifer. In the source areas, where large volumes of wastewater were discharged, a large vertical hydraulic gradient developed that moved contaminants downward in the aquifer. Layers of low-permeability silt and clay within the unconfined aquifer also limit the vertical movement of contaminants. Flow in the unconfined aquifer is generally toward the Columbia River, which acts as a drainage area for the groundwater flow system at Hanford (Section 6.2.4). Contamination that reaches the river is further diluted by river water.



6.1 GROUNDWATER MONITORING

D. R. Newcomer and M. J. Hartman

Groundwater monitoring at the Hanford Site is an integral part of the *Hanford Site Ground-Water Protection Management Plan* (DOE/RL-89-12). That plan assures that monitoring at active waste disposal facilities complies with requirements of RCRA and Washington State regulations, as well as requirements for operational monitoring around inactive reactor and chemical processing facilities and environmental surveillance monitoring. Pacific Northwest National Laboratory staff manages these monitoring efforts to assess the distribution and movement of existing groundwater contamination, to identify and characterize potential and emerging changes in groundwater contamination, and to integrate the various groundwater projects to minimize redundancy.

The FY 2002 *Integrated Monitoring Plan for the Hanford Groundwater Monitoring Project* (PNNL-13698) describes how DOE will implement the groundwater monitoring requirements outlined in DOE/RL-89-12 and DOE/RL-91-50. The purpose of the integrated monitoring plan is to (1) describe the monitoring well networks, constituents, sampling frequencies, and criteria used to design the monitoring program; (2) identify federal and state groundwater monitoring requirements and regulations; and (3) provide a list of wells, constituents, and sampling frequencies for groundwater monitoring conducted on the Hanford Site. Federal and state regulations include RCRA, CERCLA, and Washington Administrative Codes (Section 2.2).

Information on contaminant distribution and transport are integrated into a site-wide evaluation of groundwater quality, which is documented in an annual groundwater monitoring report (e.g., PNNL-14187 for fiscal year 2002). Groundwater monitoring is also carried out during CERCLA cleanup investigations. These investigations, managed by Bechtel Hanford, Inc. and subsequently transferred to Fluor Hanford, Inc. during 2002, are documented in annual summary reports (e.g., DOE/RL-2002-05 for calendar year 2001).

6.1.1 GROUNDWATER MONITORING NETWORK

Groundwater samples were collected from 658 wells for all monitoring programs during 2002. A summary that accounts for the number of all groundwater wells monitored during 2002 according to geographic area and monitoring purpose is provided in Tables 6.1.1 and 6.1.2, respectively. The number of wells in Table 6.1.1 is subdivided by geography into the 100, 200, 300, 400, and 600 Areas (Figure 1.0.1). The purposes for which monitoring was conducted are divided into restoration, waste management, and environmental surveillance (Table 6.1.2). Restoration refers to wells associated with groundwater remediation activities, including pump-and-treat systems and innovative technology demonstrations. Waste management refers to wells sampled to determine impacts, if any, of a waste management unit (e.g., RCRA facility) on groundwater. Environmental surveillance refers to wells sampled to detect impacts, if any, of site operations on groundwater over the entire Hanford Site and adjacent offsite areas. The numbers of wells installed and removed from service during 2002 are also shown in each of the tables.

Well names are indicated only for those wells specifically discussed in the text (Figures 6.1.1 and 6.1.2). Because of the density of unconfined aquifer wells in the operational areas, well names in these areas are also shown on detailed maps. Figure 6.1.3 shows the locations of facilities where groundwater monitoring was conducted to comply with RCRA (see Appendix A in PNNL-14187). Wells at the Hanford Site generally follow a naming system that indicates the approximate location of the well. The prefix of the well name indicates the area of the site (Table 6.1.3). The names for 600 Area wells follow a local coordinate system in which the numbers indicate the distance relative to an arbitrary datum location in the south-central part of the site.

Table 6.1.1. Summary of the Hanford Site Groundwater Monitoring Program by Geographic Area, Calendar Year 2002

	<u>Hanford Site</u>	<u>100 Areas^(a)</u>	<u>200 Areas</u>	<u>300 Area</u>	<u>400 Area</u>	<u>600 Area^(b)</u>
Number of wells monitored	658	254	227	36	3	138
Number of sampling events	1,781	739	719	73	12	238
Number of analyses performed	23,556	7,984	11,080	597	106	3,789
Number of results	61,441	15,414	30,159	2,425	207	13,236
Percent of non-detectable results	42	27	43	66	39	52
Number of installed wells	28	21	7	0	0	0
Number of wells removed from service	88	0	0	0	0	88

(a) Includes aquifer tubes.

(b) Includes the former 1100 and 3000 Areas.

Table 6.1.2. Summary of the Hanford Site Groundwater Monitoring Program by Monitoring Purpose,^(a) Calendar Year 2002

	<u>Restoration</u>	<u>Waste Management</u>	<u>Environmental Surveillance</u>
Number of wells monitored	589	239	413
Number of sampling events	1,172	672	646
Number of analyses performed	12,913	12,727	7,149
Number of results	31,711	35,775	19,119
Percent of non-detectable results	39	44	41
Number of installed wells	22	6	0
Number of wells removed from service	0	0	88

(a) Because of co-sampling between groundwater monitoring programs, the wells monitored, sampling events, analyses, results, and non-detectable results overlap between monitoring purposes.

sampled more than four times during 2002. The sampling frequency is every 3 years for several wells that have consistently shown contaminant concentrations at steady historical levels. Wells showing larger variability are sampled more frequently (annually or more often). Wells that monitor groundwater source areas are sampled more frequently than wells that do not monitor groundwater source areas. Groundwater containing the more mobile contaminants (e.g., tritium) may be sampled more frequently than groundwater that does not contain very mobile contaminants (e.g., strontium-90).

Most groundwater monitoring wells on the Hanford Site are 10 to 20 centimeters (4 to 8 inches) in diameter. Monitoring wells for the unconfined aquifer are constructed with well screens or perforated casing generally in the upper 3 to 6 meters (10 to 20 feet) of the unconfined aquifer, with the open interval extending across the water table. This construction allows sample collection at the top of the aquifer, where maximum concentrations of radionuclides and maximum concentrations of chemicals tend to be found. Wells monitoring the shallowest of the basalt-confined aquifers have screens, perforated casing, or an open hole within the monitored

The monitoring frequency for the wells was selected based on regulatory requirements, variability of historical data, proximity to waste sources (PNL-6456), and characteristics of the groundwater flow system at the sampling location. Of the 658 wells sampled, 234 were sampled once, 162 twice, 68 three times, 153 four times, and 41 wells were

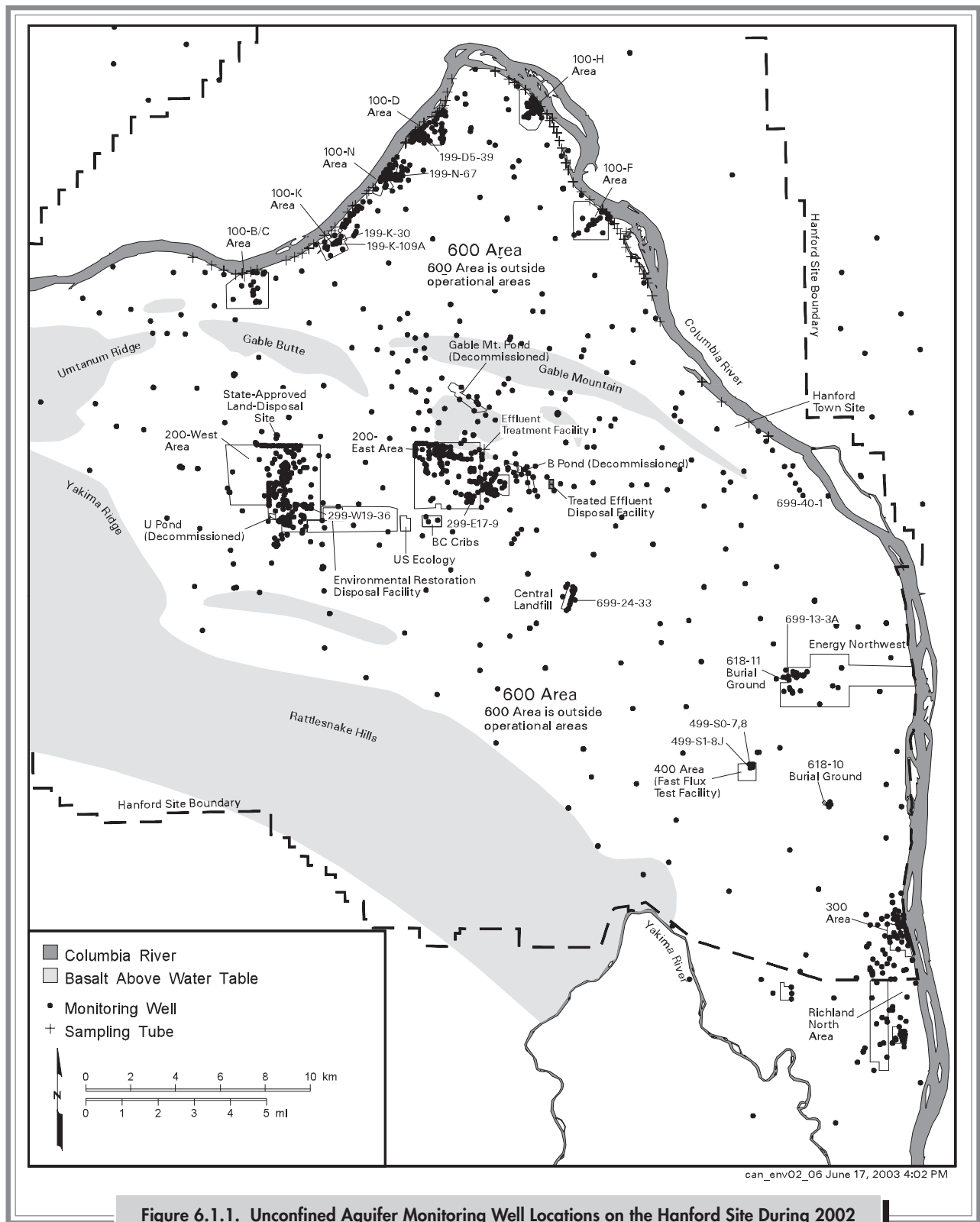


Figure 6.1.1. Unconfined Aquifer Monitoring Well Locations on the Hanford Site During 2002

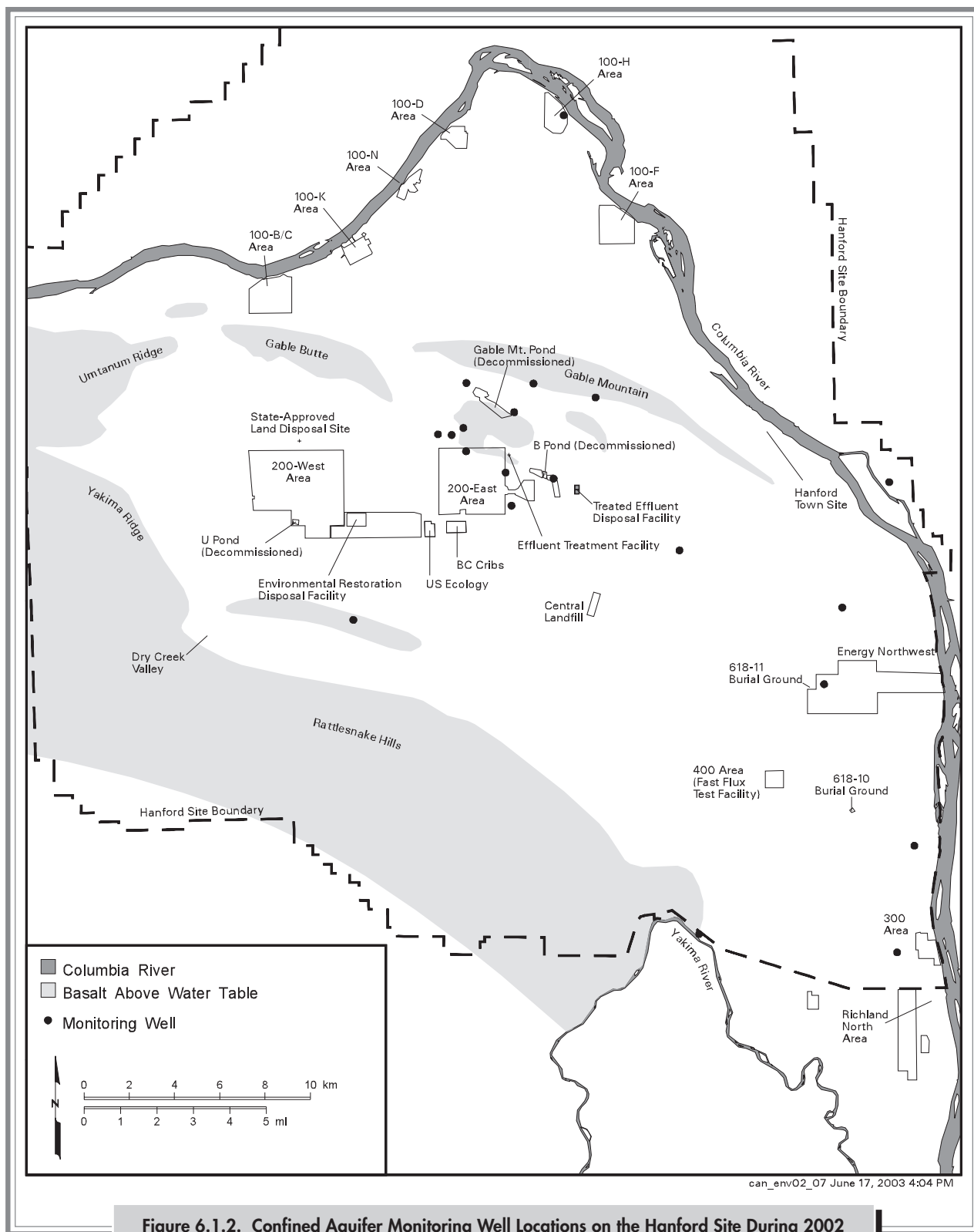
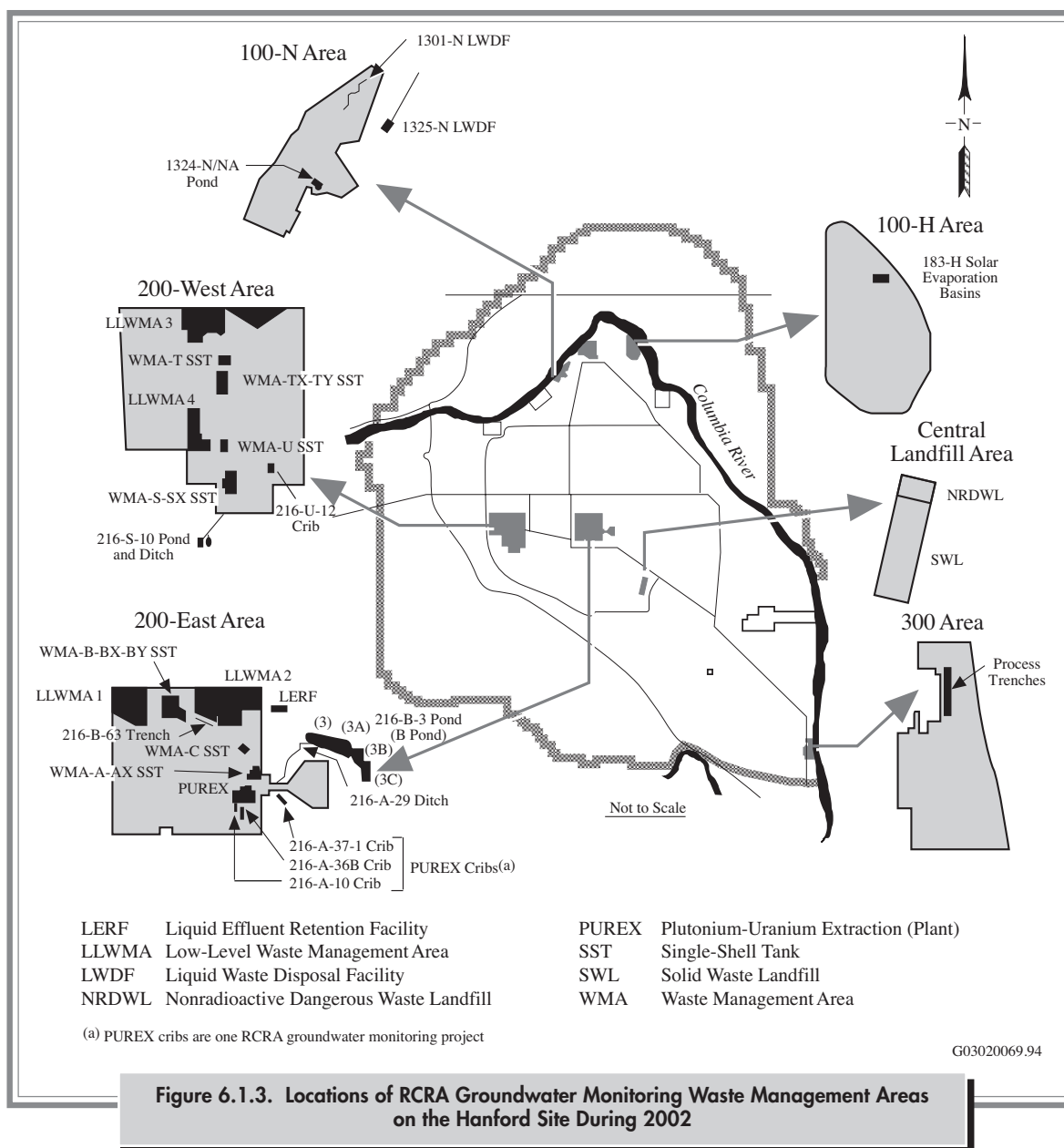


Figure 6.1.2. Confined Aquifer Monitoring Well Locations on the Hanford Site During 2002



aquifer. Wells drilled before 1985 were generally constructed with carbon steel casing. Since 1985, RCRA monitoring wells and CERCLA characterization wells have been constructed with stainless steel casing and screens. Most monitoring wells on the site are sampled using either submersible or Hydrostar™ pumps (a registered trademark of Instrumentation Northwest, Inc., Redmond, Washington), though some wells are sampled with bailers or airlift systems.

6.1.2 SAMPLING AND ANALYTICAL METHODS

Samples were collected for all programs following documented sampling procedures that conform to U.S. Environmental Protection Agency (EPA) guidelines (EPA 1986), or other EPA methods, and ASTM standards (American Society for Testing and Materials 1986). The methods used for radiochemical analyses were developed by the

Table 6.1.3. Hanford Site Well Naming System

<u>Example Well Name</u>	<u>Area</u>	<u>Example Well Name</u>	<u>Area</u>
199-	100 Areas	399-	300 Area
199-B3-47	100-B/C Area	399-1-17A	300 Area
199-D5-12	100-D Area	499-	400 Area
199-F8-3	100-F Area	499-S1-8J	400 Area
199-H4-3	100-H Area	699-	600 Area
199-K-30	100-K Area	699-50-53A	600 Area north and west of datum
199-N-67	100-N Area	699-42-E9A	600 Area north and east of datum
299-	200 Areas	699-S19-11	600 Area south and west of datum
299-W19-3	200-West Area	699-S19-E13	600 Area south and east of datum
299-E28-4	200-East Area		

Note: Letters at end of well names distinguish either multiple wells located close together or multiple intervals within a single well bore.

analytical laboratory and are recognized as acceptable within the technical radiochemistry industry (PNNL-13080 and CERCLA work plans). The samples were analyzed for ~30 different radiological constituents and ~280 different chemical and biological parameters during 2002 (Table 6.1.4).

The number of sampling events, analyses performed, and results in 2002 is summarized in Table 6.1.1 by geographic area and in Table 6.1.2 by monitoring purpose. A sampling event refers to a groundwater sample collected from a single well at a distinct point in time for the purpose of one or more field or laboratory analyses. An analysis refers to a field or laboratory method used to determine the concentration of one or more constituents in a sample. A result refers to a concentration value associated with a constituent whether it is detected or not. Tables 6.1.1 and 6.1.2 also show the percentage of results where the concentration values were less than the minimum levels of detection. Concentration values less than the minimum levels of detection indicate that no constituents were found.

The percentage of non-detectable results can vary, depending on the analytical method used or constituents analyzed. Some constituents can be analyzed by different methods that yield different minimum levels of detection. A constituent detected using a method capable of low minimum levels of detection may not be detected using a method with a higher minimum level of detection. Different analytical methods have a wide range in the number of constituents analyzed. A method capable of analyzing for a

large number of constituents, such as volatile organic analyses, can often yield a high number of non-detectable results. This is because most of the constituents associated with the method are not targeted for analysis. The percents of non-detectable results (Tables 6.1.1 and 6.1.2) are largely attributed to analysis of gamma-emitting radionuclides, metals, and volatile organic compounds. Some constituents, such as chloride, are rarely non-detectable because ambient concentrations are typically greater than the minimum level of detection.

Co-sampling efforts occur between different groundwater monitoring programs to increase monitoring efficiency at the Hanford Site (Table 6.1.2). Co-sampling accounts for all wells monitored, sampling events, analyses performed, results, and non-detectable results by each monitoring purpose. A co-sample is defined as a single sample, collected from a well, that is used by more than one monitoring program, regardless of the types or number of analyses performed by each monitoring program (Table 6.1.2). Thus, many of the wells monitored, sampling events, analyses performed, results, and non-detectable results are associated with more than one monitoring purpose.

Of the radionuclides, samples for tritium analyses were collected most often during 2002. Selected samples were collected for other radionuclide analyses. Analytical results for radionuclides are generally presented in picocuries (becquerels) per liter; however, the results for total uranium, which is usually measured by laser fluorescence, are given in micrograms per liter.

Table 6.1.4. Radionuclides, Water Quality Parameters, Metals, Anions, and Other Contaminants Analyzed for in Hanford Site Groundwater Samples During 2002

<u>Radionuclides</u>	<u>Water Quality Parameters (contd)</u>
Americium-241	Oxidation reduction potential
Antimony-125	pH (field)
Beryllium-7	Temperature
Carbon-14	Total dissolved solids
Cesium-134	Total inorganic carbon
Cesium-137	Total organic carbon
Cobalt-58	Total organic halogens
Cobalt-60	Turbidity
Europium isotopes	
Gross alpha	
Gross beta	
Iodine-129	
Iron-59	
Neptunium-237	
Nickel-63	
Plutonium isotopes	
Potassium-40	
Radium isotopes	
Ruthenium-106	
Strontium-90	
Technetium-99	
Thorium isotopes	
Tritium	
Uranium isotopes	
Uranium (total)	
<u>Water Quality Parameters</u>	<u>Metals</u>
Alkalinity	Al, As, Be, Co, K, Mg, Na, Se, Si, Ti
Biochemical oxygen demand	Ca, Cr, Fe, Hg, Mn, Ni, P, Pb, V
Chemical oxygen demand	Ag, Ba, Cd, Cu, Mo, S, Sb, Sn, Sr, silica, Tl, Zn
Conductance (field and laboratory)	Hexavalent chromium
Dissolved oxygen (field)	
Hardness	
	<u>Anions</u>
	Br ⁻ , Cl ⁻ , F ⁻ , NO ₂ ⁻ , NO ₃ ⁻ , PO ₄ ³⁻ , SO ₄ ²⁻
	CN ⁻ , NH ₃
	<u>Other Contaminants</u>
	Pesticides
	Polychlorinated biphenyls
	Semivolatile organic compounds
	Volatile organic compounds
	Herbicides
	Coliform bacteria
	Oil and grease
	Phenols
	Sodium dithionite
	Total petroleum hydrocarbons
	Total petroleum hydrocarbons - diesel range
	Total petroleum hydrocarbons - gasoline range

Of the chemicals, samples for filtered chromium analyses were collected most often during 2002. A large portion of the samples for filtered chromium analyses was associated with remediation and monitoring in the 100 Areas. Nitrate analyses were performed on many samples collected during 2002 because of the extensive portions of the unconfined aquifer containing detectable nitrate concentrations. Nitrate contamination of the unconfined aquifer originates from onsite and offsite sources (Section 6.2.2). However, nitrate concentrations were less than the EPA 45-mg/L drinking water standard (40 CFR 141) for most of the affected areas. Selected monitoring wells were used for additional chemical surveillance.

6.1.3 DATA QUALITY

Data quality is assessed primarily by evaluating accuracy, precision, and detection of field and laboratory analytical measurements. Representativeness, completeness, and comparability are also parameters used to evaluate overall data quality. Laboratory quality control checks, replicate sampling and analysis, analysis of blind standards and blanks, and interlaboratory comparisons are used to evaluate these parameters (see PNNL-14187, Section 9.0 and Appendix B).

6.1.4 DATA INTERPRETATION

The chemical composition of groundwater may fluctuate because of differences in the contaminant source, recharge, or groundwater flow rate and direction. The range of fluctuation in concentration can be estimated by taking many samples, but there are limits to the number that can be practicably taken. Comparison of results through time helps interpret this variability.

Overall sample uncertainties may be factored into data evaluations by considering concentration trends in a given well over time. This often helps identify gross errors; overall, long-term trends can be distinguished from short-term variabilities. The interpretation of concentration trends depends on an understanding of chemical properties as well as site hydrogeology. The trend analyses, in turn, aid in refining the conceptual chemical transport models.

Plume maps presented in Section 6.2 illustrate site groundwater chemistry. Although analytical data are available only at specific points where wells were sampled, contours are drawn to join the approximate locations of equal chemical concentrations or radionuclide activity levels.

The contour maps are simplified representations of plume geometry because of map scale, the lack of detailed information, and the fact that plume depth and thickness cannot be fully represented on a two-dimensional map. Plume maps are powerful tools because knowledge of concentrations in surrounding wells, groundwater flow, site geology, and other available information are factored into their preparation.

6.1.5 DATA MANAGEMENT

Groundwater data are accessed through a common database, the Hanford Environmental Information System (HEIS 1994). This database contains 1,826,577 groundwater monitoring records as of the end of 2002. The majority of data are loaded into the database from electronic files provided by the analytical laboratories. After the data are verified and/or validated, they are made available to federal and state regulators for retrieval and study.



6.2 GROUNDWATER MONITORING RESULTS

D. R. Newcomer

The following sections summarize the distribution of radioactive and chemical contaminants detected in Hanford Site groundwater during 2002. These discussions are followed by a summary of groundwater monitoring results for RCRA sites (Section 6.4). Detailed information on groundwater monitoring, including listings of analysis results for each monitoring well in electronic format, is available in the Hanford Site annual groundwater report, PNNL-14187. The Hanford Site annual groundwater report covers the fiscal year (October 2001 through September 2002) and does not include results from the last 3 months of 2002. This report includes a summary of results for January through December 2002.

One way to assess the potential impact of radionuclides and chemicals to groundwater is to compare their concentrations to EPA's drinking water standards and DOE's derived concentration guides (40 CFR 141 and DOE Order 5400.5; Appendix D, Tables D.2 and D.5). The drinking water standards were established to protect public drinking water supplies. The DOE derived concentration guides were established to protect the public from radionuclides resulting from DOE operations. Specific drinking water standards have been defined for only a few radiological constituents. Drinking water standards have been calculated for other radionuclides, using an annual dose limit of 4 mrem (0.04 mSv). Calculations of these standards consider their half-life, the energy and nature of the radioactive decay, and the physiological factors such as its buildup in particular organs. Drinking water standards are more restrictive than derived concentration guides because the standards are based on an annual dose of 4 mrem (0.04 mSv) to the affected organ. The guides are based on an effective dose equivalent of 100 mrem (1 mSv) per year (Appendix D, Tables D.2 and D.5). Primary and secondary drinking water standards are given for some chemical

constituents; secondary standards are based on aesthetic (e.g., odor, taste) rather than health considerations.

The total area of contaminant plumes with concentrations exceeding drinking water standards was estimated to be ~196 square kilometers (76 square miles) during 2002. This area occupies ~13% of the total area of the Hanford Site. The most widespread contaminants within these plumes were tritium, iodine-129, nitrate, carbon tetrachloride, trichloroethene, chromium, strontium-90, technetium-99, and uranium. The area of contaminant plumes for these constituents at levels above drinking water standards are summarized in Table 6.2.1. Most of the contaminant plume area, represented by tritium, lies southeast of the 200-East Area extending to the Columbia River (Figure 6.2.1). Contaminant plumes with concentrations exceeding DOE derived concentration guides

Table 6.2.1. Areas of Contaminant Plumes on the Hanford Site at Levels Above Drinking Water Standards, 2002 (adapted from PNNL-14187)

<u>Constituent</u>	<u>Drinking Water Standard</u>	<u>Area (km²)</u>
Tritium	20,000 pCi/L	142
Iodine-129	1 pCi/L	79.4
Nitrate	45 mg/L	35.7
Carbon tetrachloride	5 µg/L	9.9
Trichloroethene	5 µg/L	3.4
Filtered chromium	100 µg/L	2.6
Strontium-90	8 pCi/L	2.7
Technetium-99	900 pCi/L	2.3
Total uranium	30 µg/L	1.5
Combined plumes	--	196 ^(a)

(a) Total reflects some overlap of contaminant plumes.

1 pCi/L = 0.037 Bq/L.

1 µg/L = 0.001 ppm.

1 mg/L = 1 ppm.

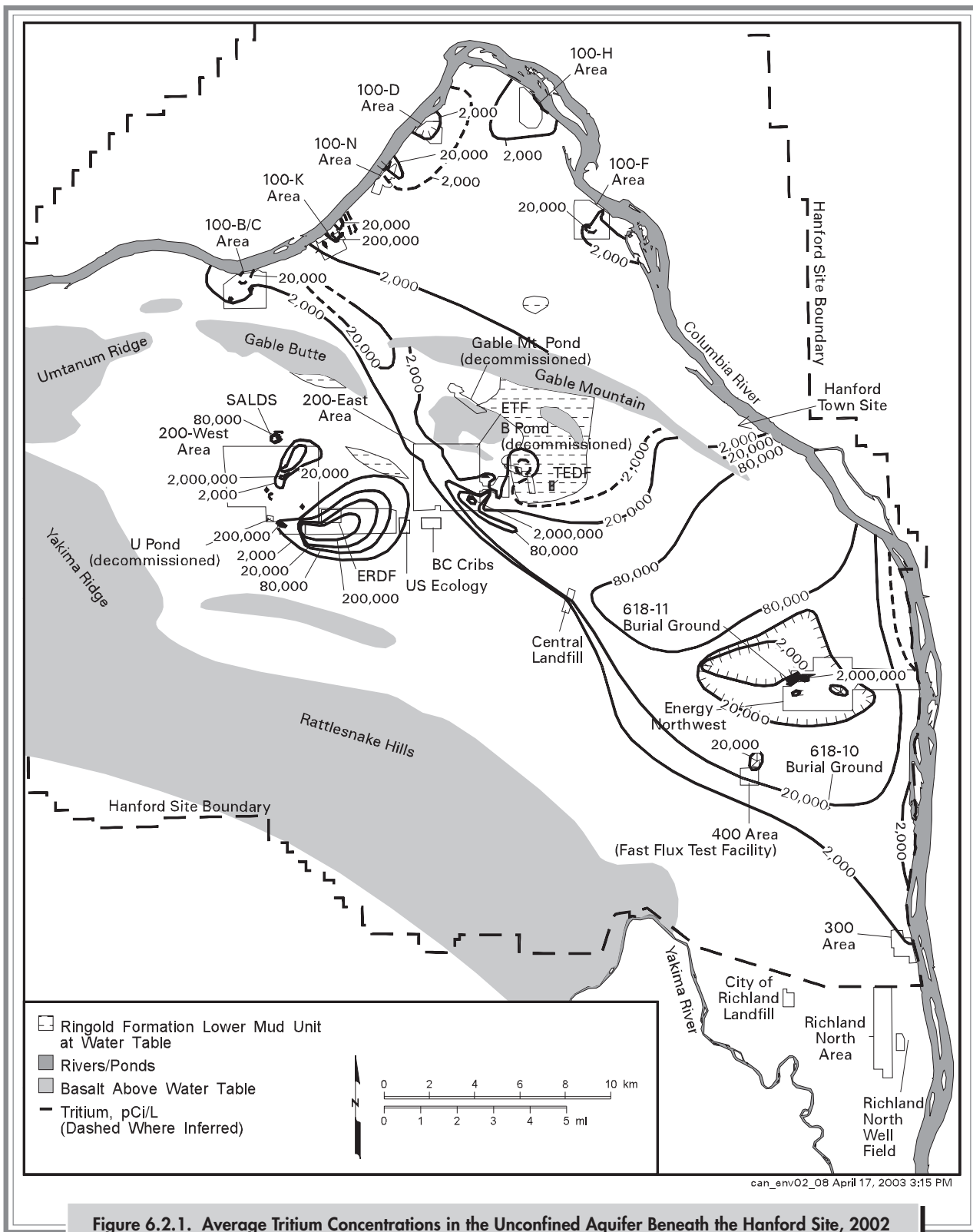


Figure 6.2.1. Average Tritium Concentrations in the Unconfined Aquifer Beneath the Hanford Site, 2002

occur in isolated areas. The only contaminants at levels above DOE derived concentration guides during 2002 were strontium-90, tritium, and uranium.

Summaries of maximum concentrations for the most widespread contaminants are presented in Table 6.2.2 and by monitoring purpose in Table 6.2.3. As expected, most of the maximum concentrations were detected in the 100 and 200 Areas because these areas contain the largest number of waste sites that have affected groundwater quality (Table 6.2.2). Some contaminants were not detected or not analyzed for in some of the areas. For each monitoring purpose, the maximum concentrations detected were greater than the drinking water standards for all of the most widespread contaminants listed in Table 6.2.3. A list of drinking water standards for these contaminants is provided in Table D.2 in Appendix D.

6.2.1 RADIOLOGICAL MONITORING RESULTS FOR THE UNCONFINED AQUIFER

Hanford Site groundwater was analyzed for several radionuclides (Table 6.1.4). The distribution of tritium, iodine-129, technetium-99, uranium, strontium-90, carbon-14, cesium-137, cobalt-60, and plutonium are

discussed in the following sections. Tritium and iodine-129 are the most widespread radiological contaminants associated with past site operations. Technetium-99 and uranium plumes are extensive in the 200 Areas and adjacent 600 Area. Strontium-90 plumes exhibit high concentrations in the 100 Areas but are of relatively smaller extent. Strontium-90 also occurs in the 200 Areas and near the former Gable Mountain Pond in the 600 Area. Carbon-14 is present in two small plumes in the 100-K Area. Cesium-137, cobalt-60, and plutonium contamination occurs in isolated areas in the 200 Areas. Gross alpha and gross beta results are used as indicators of radionuclide distribution and are not discussed in detail because the specific radionuclides contributing to these measurements are discussed individually. Several other radionuclides, including ruthenium-106, antimony-125, and americium-241, are associated with waste from Hanford Site operations. Because of their low concentrations in groundwater, they are not discussed in this section. Half-lives of the radionuclides are presented in Appendix A, Table A.7.

Tritium. Tritium, which is present in irradiated nuclear fuel, was released in process condensates associated with decladding and dissolution of the fuel. Tritium also was manufactured as part of the Hanford mission by irradiating targets containing lithium in several reactors from 1949 to 1952 (DOE/EIS-0119F; WHC-SD-EN-RPT-004).

Table 6.2.2. Summary of Maximum Contaminant Concentrations in Hanford Site Groundwater, 2002

Constituent	Hanford Site	100 Areas	200 Areas	300 Area	400 Area	600 Area ^(a)
Tritium (pCi/L)	5,570,000	588,000	5,570,000	8,910	13,000	4,230,000
Iodine-129 (pCi/L)	31.6	Not detected	31.6	Not detected	Not detected	29.9
Nitrate (mg/L)	2,090	474	2,090	89.9	3.4	188
Carbon tetrachloride (µg/L)	6,900	Not detected	6,900	Not detected	Not detected	35
Trichloroethene (µg/L)	16	11	16	4.3 J	Not detected	3.5 J
Filtered chromium (µg/L)	6,250	5,300	6,250	4.6 B	Not detected	112
Strontium-90 (pCi/L)	18,500	18,500	53.6	3.4	Not detected	2.7
Technetium-99 (pCi/L)	99,700 ^(b)	986	99,700	Not analyzed	Not detected	164
Total uranium (µg/L)	2,100	119	2,100	235 B	0.025	16.3

(a) Includes the former 1100 and 3000 Areas.

B = Detected at a value less than the contract required detection limit.

J = Reported value is an estimate.

1 pCi/L = 0.037 Bq/L.

1 µg/L = 0.001 ppm.

1 mg/L = 1 ppm.

Table 6.2.3. Summary of Maximum Contaminant Concentrations in Hanford Site Groundwater by Monitoring Purpose, 2002

Constituent	Restoration	Waste	
		Management	Surveillance
Tritium (pCi/L)	4,230,000	5,570,000	4,230,000
Iodine-129 (pCi/L)	29.9	31.6	5.8
Nitrate (mg/L)	2,090	2,090	735
Carbon tetrachloride (µg/L)	6,900	3,400	3,300
Trichloroethene (µg/L)	16	16	13
Filtered chromium (µg/L)	5,300	6,250	5,300
Strontium-90 (pCi/L)	18,500	1,240	18,500
Technetium-99 (pCi/L)	22,400	99,700	10,600
Total uranium (µg/L)	2,100	391	329

(a) Maximum concentrations may be the same between monitoring purposes because of co-sampling between groundwater monitoring programs.

1 pCi/L = 0.037 Bq/L.

1 µg/L = 0.001 ppm.

During the late 1960s, tritium production took place in N Reactor (WHC-MR-0388).

Tritium was present in many historical waste streams at the Hanford Site and is highly mobile, essentially moving at the same velocity as the groundwater. Consequently, the extent of groundwater contamination from site operations is generally reflected by tritium distribution. For this reason, tritium is the most frequently monitored radionuclide at the Hanford Site (Figure 6.2.1). Tritium is one of the most widespread contaminants in groundwater across the Hanford Site and exceeded the drinking water standard (20,000 pCi/L [740 Bq/L]) in portions of the 100, 200, and 600 Areas. Of these areas, tritium levels exceeded the DOE derived concentration guide (2 million pCi/L [74,000 Bq/L]) in portions of the 200 and 600 Areas. The highest tritium concentration measured at the Hanford Site in 2002 was 5.57 million pCi/L (206,300 Bq/L) near the Plutonium-Uranium Extraction Plant in the 200-East Area. Tritium levels are expected to decrease because of dispersion and radioactive decay (half-life is 12.35 years).

During 2002, the State-Approved Land Disposal Site was the only site at Hanford where liquid effluent containing a radionuclide was discharged to the soil column. The State-Approved Land Disposal Site received a total of 8.6 curies (319 billion becquerels) of tritium during 2002. This facility, which began operating in 1995, is located just north of the 200-West Area.

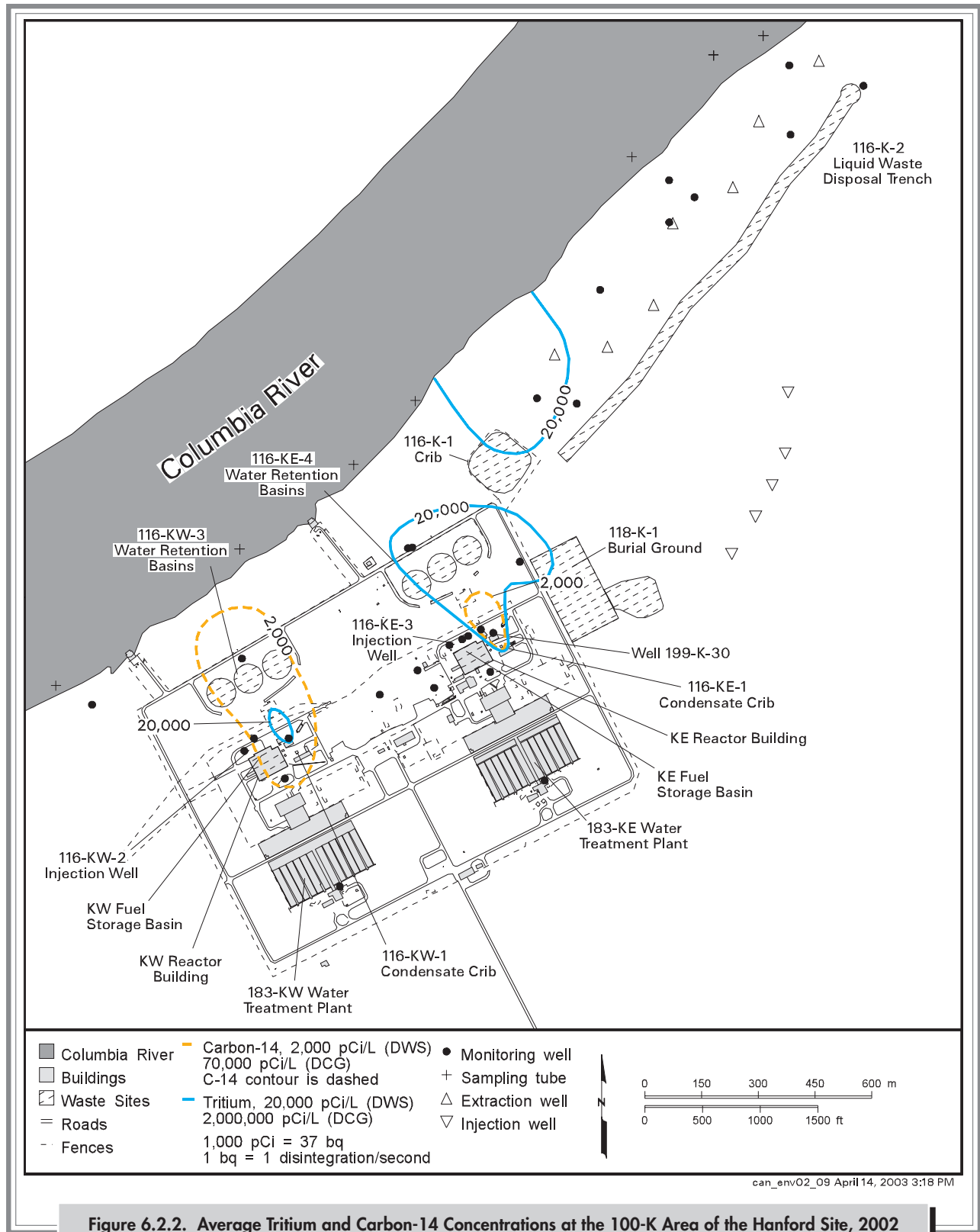
Tritium in the 100 Areas. During 2002, there was no waste containing tritium discharged in the 100 Areas. All the tritium detected here comes from past activities at Hanford. Tritium concentrations greater than the drinking water standard were detected in groundwater beneath portions of the 100-B/C, 100-K, 100-N, and 100-D Areas. The largest tritium plume in the 100 Areas, with concentrations above the drinking water standard, occurs along the Columbia River in the northeast part of the 100-N Area.

Tritium concentrations in groundwater beneath most of the 100-B/C Area declined during 2002. However, tritium concentrations continued to exceed the drinking water standard in two wells in

the northern and southwestern parts of the 100-B/C Area. Most of the tritium contamination is associated with past liquid disposal practices at 100-B/C retention basins and trenches near the Columbia River. In 2002, the maximum tritium concentration measured was 30,600 pCi/L (1,133 Bq/L) in a sample from the northern part of the 100-B/C Area.

In the 100-K Area, tritium contamination in groundwater is associated with the KE and KW Reactor complexes and the 116-K-2 liquid waste disposal trench. Sources of tritium contamination at the KE and KW Reactor complexes are the 116-KE-1 and 116-KW-1 cribs where condensate from earlier discharges continues to migrate downward through the soil column. Carbon-14 is a co-contaminant with tritium in the effluent disposed to these cribs and in the groundwater. Potential sources of tritium contamination beneath the 116-K-2 liquid waste disposal trench include vadose zone moisture beneath the trench, and leakage from the KE Fuel Storage Basin, the 116-KE-1 crib, and the 118-K-1 burial ground.

The tritium plume near the KE Reactor continued to contain the highest tritium concentrations within the 100 Areas. The maximum concentration measured was 588,000 pCi/L (21,800 Bq/L) in a well located immediately downgradient of the 116-KE-1 crib (Figure 6.2.2). Tritium concentrations in groundwater at this location (well 199-K-30) are most likely the result of downward



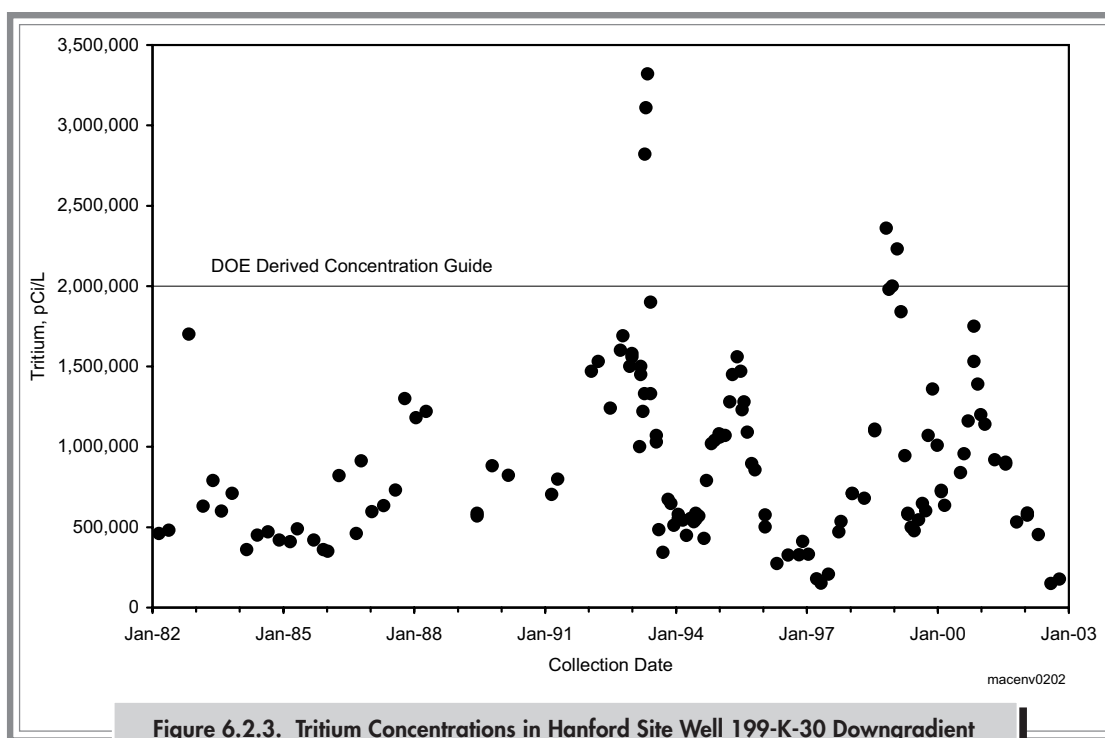
movement of vadose zone moisture containing tritium (Figure 6.2.3). A second source of this plume is past leakage from the KE Fuel Storage Basin, with the latest leakage occurring in 1993. Tritium concentrations in a plume farther downgradient of the 116-KE-1 crib rose during 2001 and then began to decline during 2002. This rise and fall most likely indicates the arrival of a plume originating from leakage of the KE Fuel Storage Basin in 1993 (Figure 6.2.4). In the northwestern corner of the 118-K-1 burial ground, tritium concentrations increased rapidly to levels above the drinking water standard from late 2000 through 2001 and then began to decline in 2002. The maximum concentration measured during 2001 was 98,100 pCi/L (3,630 Bq/L). By the end of 2002, the maximum level had declined to 62,400 pCi/L (2,310 Bq/L). The elevated tritium in this area is from a previously unidentified plume to the east or southeast and circumstantial evidence suggests the burial ground is the source. Various investigations to identify the source of tritium in the northwestern corner of the 118-K-1 burial ground are currently underway (PNNL-14031).

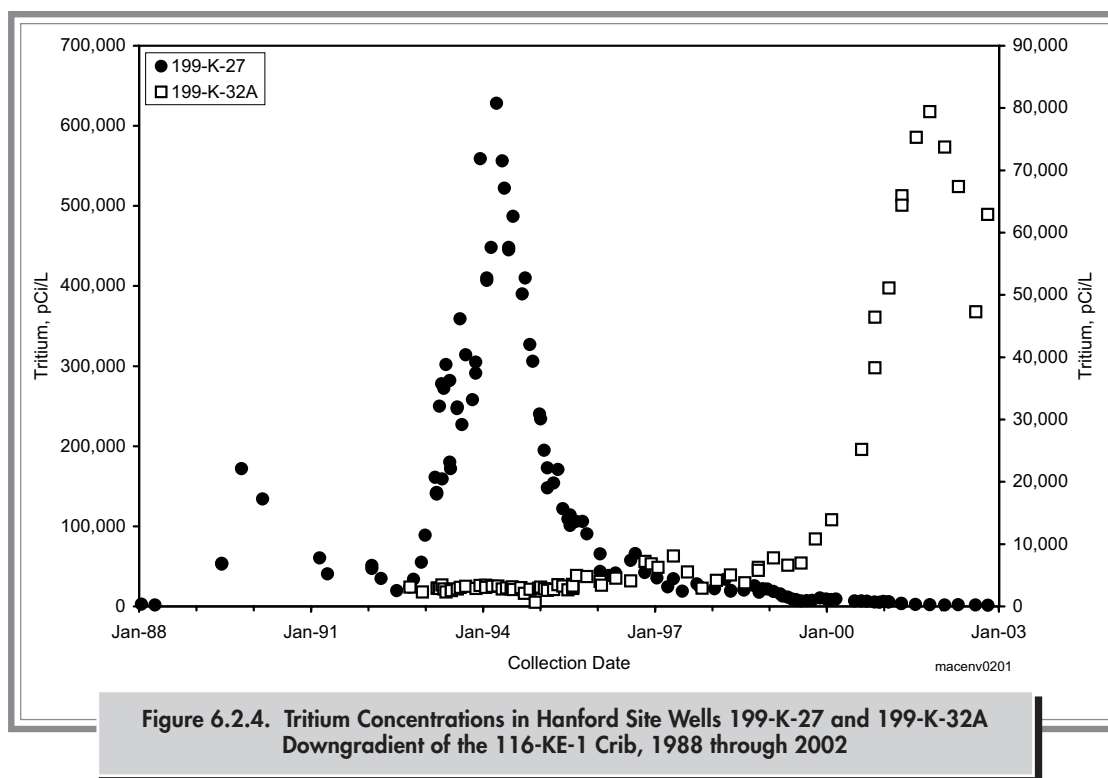
Near the KW Reactor Building, tritium concentrations exceeding the drinking water standard were measured in one well in 2002. Tritium levels in this well increased to a

maximum of 280,000 pCi/L (10,370 Bq/L) in early 2002 and then began to decline during the middle to latter part of 2002. Tritium levels greater than the drinking water standard, but much less than the DOE derived concentration guide, continued to occur during 2002 in a small area near a pump-and-treat extraction well between the 116-K-1 liquid waste disposal trench and the Columbia River.

A tritium plume at levels exceeding the drinking water standard occurs in the northern part of the 100-N Area. This plume, which generally occurs in the same area as the strontium-90 plume, is associated with past liquid disposal to the 116-N-1 and 116-N-3 liquid waste disposal facilities. The size of the tritium plume at levels above the drinking water standard continued to decrease during 2002 because of dispersion and radioactive decay. The portion of the tritium plume containing the highest concentrations, formerly beneath the 116-N-3 facility, migrated to the northwest toward the Columbia River. The maximum tritium level measured in the 100-N Area during 2002 was 39,300 pCi/L (1,456 Bq/L) in a well near the Columbia River.

Tritium concentrations rose above the drinking water standard in one well in the western part of the 100-D Area.





Tritium reached a maximum level of 23,700 pCi/L (878 Bq/L) during 2002 and most likely migrated from the 100-N Area.

Tritium in the 200-East and 600 Areas. The highest tritium concentrations in the 200-East Area continued to be measured in wells near cribs that received effluent from the Plutonium-Uranium Extraction Plant. Tritium levels are decreasing slowly in most wells in this area because of dispersion and radioactive decay. However, levels greater than the DOE derived concentration guide were detected in one well (299-E17-9) near the 216-A-36B crib in the southeastern part of the 200-East Area. The maximum tritium level detected in this well was 5.57 million pCi/L (206,000 Bq/L) in 2002, which is greater than the maximum detected in this well in 2001. Tritium concentrations continued to exceed the drinking water standard in many wells monitoring the cribs near the Plutonium-Uranium Extraction Plant.

In a plume that extends from the southeastern portion of the 200-East Area, tritium concentrations above 200,000 pCi/L (7,400 Bq/L) were measured in a small area downgradient of the Plutonium-Uranium Extraction Plant and were not found beyond the 200-East Area boundary.

The plume area at levels above 200,000 pCi/L (7,400 Bq/L) had extended at least as far southeast as the Central Land-fill in the past (PNL-8073).

A widespread tritium plume extends from the southeastern portion of the 200-East Area to the Columbia River (Figure 6.2.1). In the western part of this tritium plume, a control in the movement of the plume to the southeast is the presence of a low permeability Ringold Formation unit at the water table east of the 200-East Area (PNNL-12261). Flow to the southeast also appears to be controlled by a zone of highly permeable sediment, stretching from the 200-East Area toward the 400 Area (PNL-7144). Near Energy Northwest, an area of lower tritium concentration is a result of a higher degree of cemented Ringold Formation sediment in the unconfined aquifer. The shape of the tritium plume indicates that tritium discharges to the Columbia River between the Hanford town site and the 300 Area. The highest tritium concentrations in groundwater discharging to the river occurred near the Hanford town site (Figure 6.2.1).

Separate tritium pulses associated with the two episodes of Plutonium-Uranium Extraction Plant operations can be distinguished in the plume. A trend plot (Figure 6.2.5) of

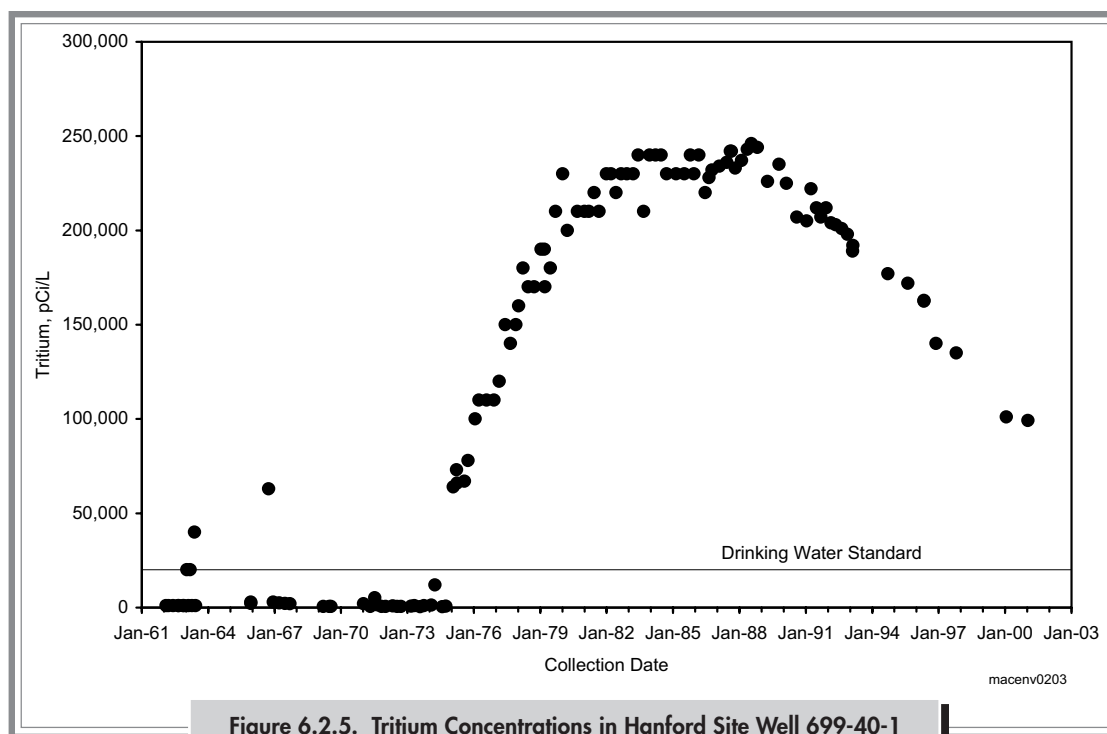


Figure 6.2.5. Tritium Concentrations in Hanford Site Well 699-40-1 Near the Columbia River, 1961 through 2002

the tritium concentrations in well 699-40-1 near the Hanford town site near the Columbia River clearly shows the arrival of a pulse in the mid-1970s. High tritium concentrations near the Columbia River result from discharges to the ground during the operation of the Plutonium-Uranium Extraction Plant from 1956 to 1972. Following an 11-year shutdown, plant operation resumed during 1983 and ceased in December 1988. This resulted in elevated tritium levels measured in several wells downgradient from the 200-East Area. Movement of the leading edge of this later pulse shows arrival near the Central Landfill during early 1987 (Figure 6.2.6). Tritium concentrations from the earlier pulse (Figure 6.2.5) were higher than the maximum concentrations in the later pulse. The effects of the 1983 to 1988 operational period have not been detected near the Columbia River.

The tritium plume, which has been monitored since the 1960s, provides information on the extent of groundwater contamination over time. Figure 6.2.7 shows the distribution of tritium in selected years from 1964 through 2002. This figure was created from maps in BNWL-90, BNWL-1970, PNL-5041, PNL-6825 (Section 5.0), PNNL-11141, and PNNL-14187. The contours in the

original references were re-calculated and interpreted to provide uniform contour intervals. Tritium at levels greater than the drinking water standard reached the Columbia River near the Hanford town site in approximately the mid-1970s (Figure 6.2.7). By the late 1980s, tritium at these levels was discharging to the Columbia River several kilometers south of the Hanford town site. The tritium plume continued to expand in the southeastern part of the Hanford Site. By 1995, tritium at concentrations exceeding 20,000 pCi/L (740 Bq/L) was entering or very near the Columbia River along greater portions of the shoreline extending between the Hanford town site and the 300 Area. Tritium levels did not change significantly between 1995 and 2002.

Tritium in groundwater also is found at levels above the drinking water standard in the northwestern part of the 200-East Area (Figure 6.2.1). This plume appears to extend to the northwest through the gap between Gable Mountain and Gable Butte where a pulse of tritium also occurs at levels above the drinking water standard. Waste sites in the vicinity of B Plant in the 200-East Area are the sources of tritium contamination in groundwater in the Gable Mountain/Gable Butte area. The tritium distribution to

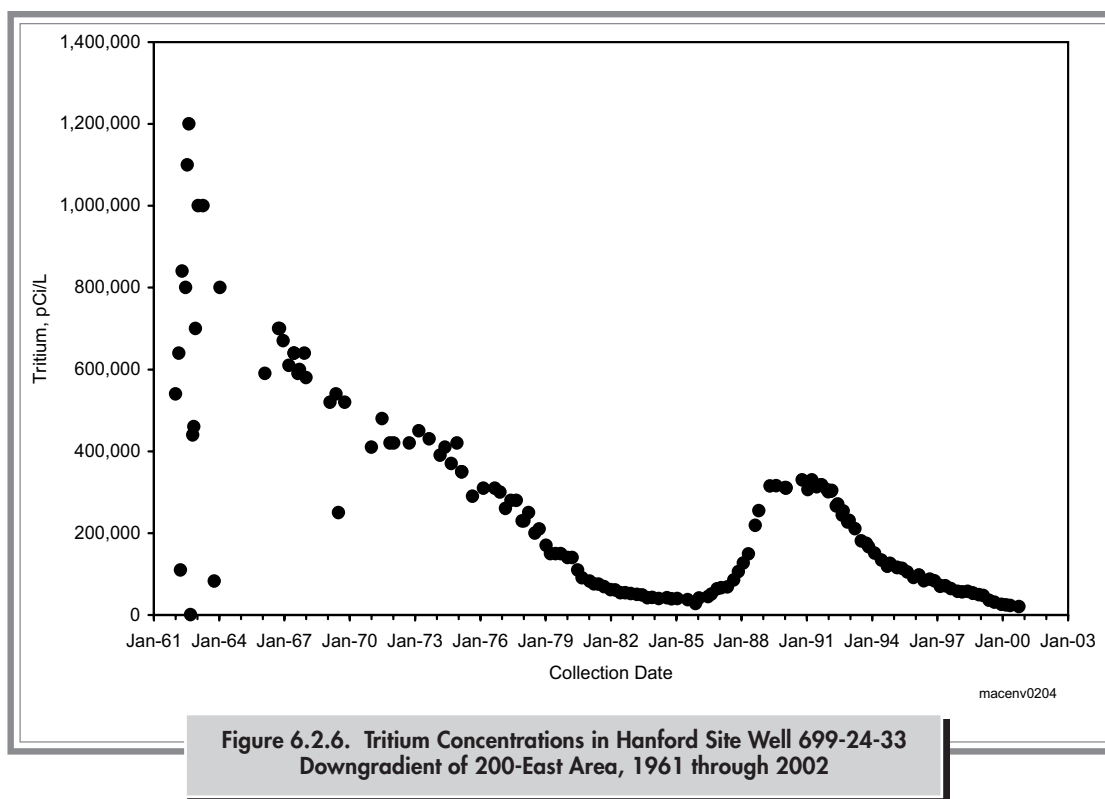


Figure 6.2.6. Tritium Concentrations in Hanford Site Well 699-24-33 Downgradient of 200-East Area, 1961 through 2002

the northwest and southeast of the 200-East Area indicates a divide in groundwater flow direction across the 200-East Area.

Tritium in the 200-West Area. Tritium from sources near the Reduction-Oxidation Plant forms the most extensive tritium groundwater plume associated with the 200-West Area. The Reduction-Oxidation Plant is located in the southeastern part of the 200-West Area and operated from 1951 through 1967. This plume extends into the 600 Area east of the 200-West Area to US Ecology's facility, and the eastern part of the plume curves to the north (Figure 6.2.1). This plume continues to decrease in size because of radioactive decay. The movement of plumes in the 200-West Area is expected to be slow because the Ringold Formation sediment that underlies the area has low permeability and restricts flow. Movement of the plumes in the 200-West Area also is slowing further because of declining hydraulic gradients. The maximum concentration detected in this plume during 2002 was 914,000 pCi/L (33,850 Bq/L) east of the Reduction-Oxidation Plant. Tritium concentrations exceeded the drinking water standard in much of the plume, including a small area near the former 216-S-25 crib and the S and SX Tank Farms upgradient of the Reduction-Oxidation

Plant. The maximum tritium concentration measured near these facilities during 2002 was 300,000 pCi/L (11,110 Bq/L) in a well adjacent to the former 216-S-25 crib.

A smaller tritium plume occurs in the northern part of the 200-West Area and extends to the northeast (Figure 6.2.1). This plume is associated with former T Plant waste sites, including the TY Tank Farm, the 242-T evaporator, T Pond, and inactive disposal cribs and trenches. The highest tritium concentration detected in the 200-West Area was 1.77 million pCi/L (65,560 Bq/L) just east of the TX and TY Tank Farms near the 216-T-26 crib. The area where the drinking water standard was exceeded extends northeast past the northern boundary of the 200-West Area.

Tritium concentrations in the top of the unconfined aquifer near the State-Approved Land Disposal Site (an active tritium discharge site) just north of the 200-West Area exceeded the drinking water standard during 2002. The maximum tritium concentration detected in the top of the unconfined aquifer was 240,000 pCi/L (8,890 Bq/L). In the deeper portion of the unconfined aquifer, tritium concentrations continued to decrease during 2002 after reaching a peak of 980,000 pCi/L (36,300 Bq/L) in 2001. Tritium

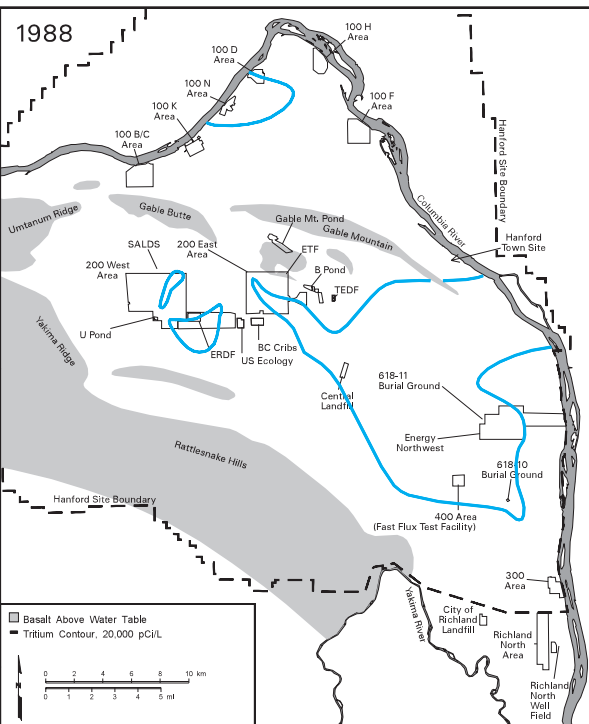
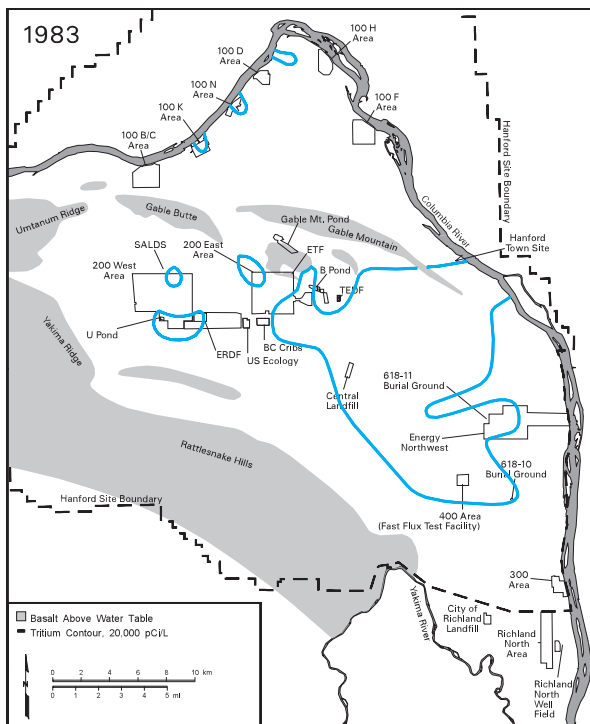
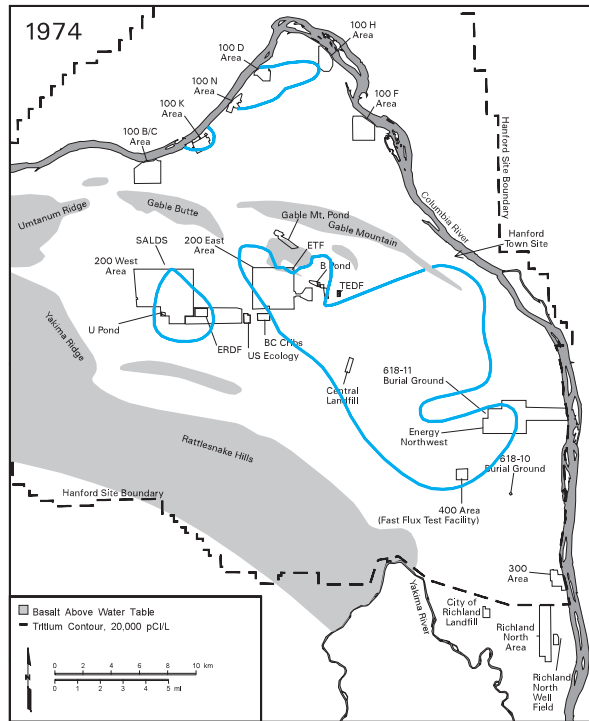
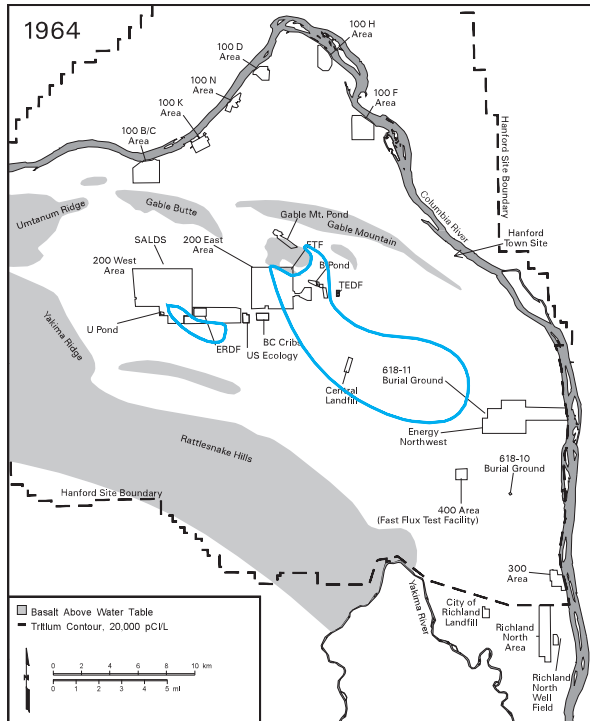


Figure 6.2.7. Current and Historical Tritium Concentrations in Hanford Site Groundwater

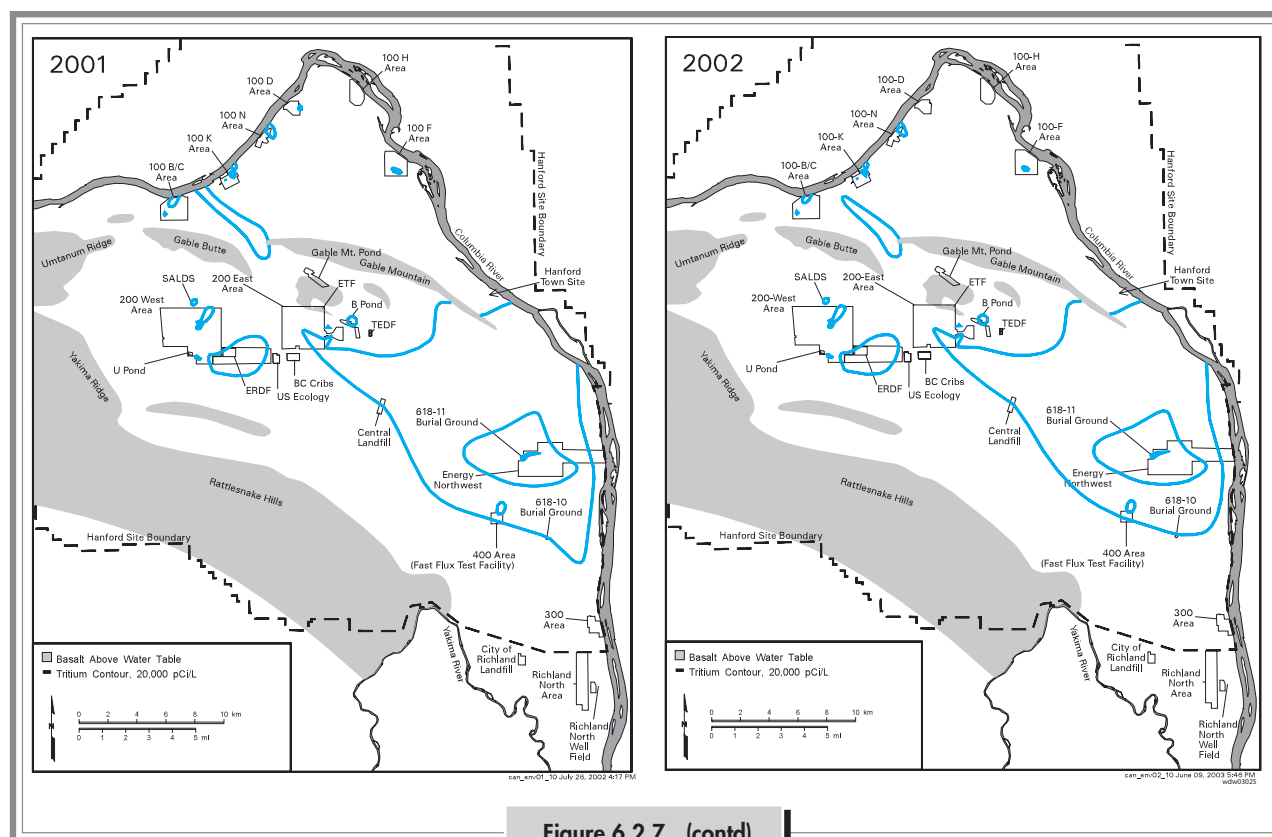


Figure 6.2.7. (contd)

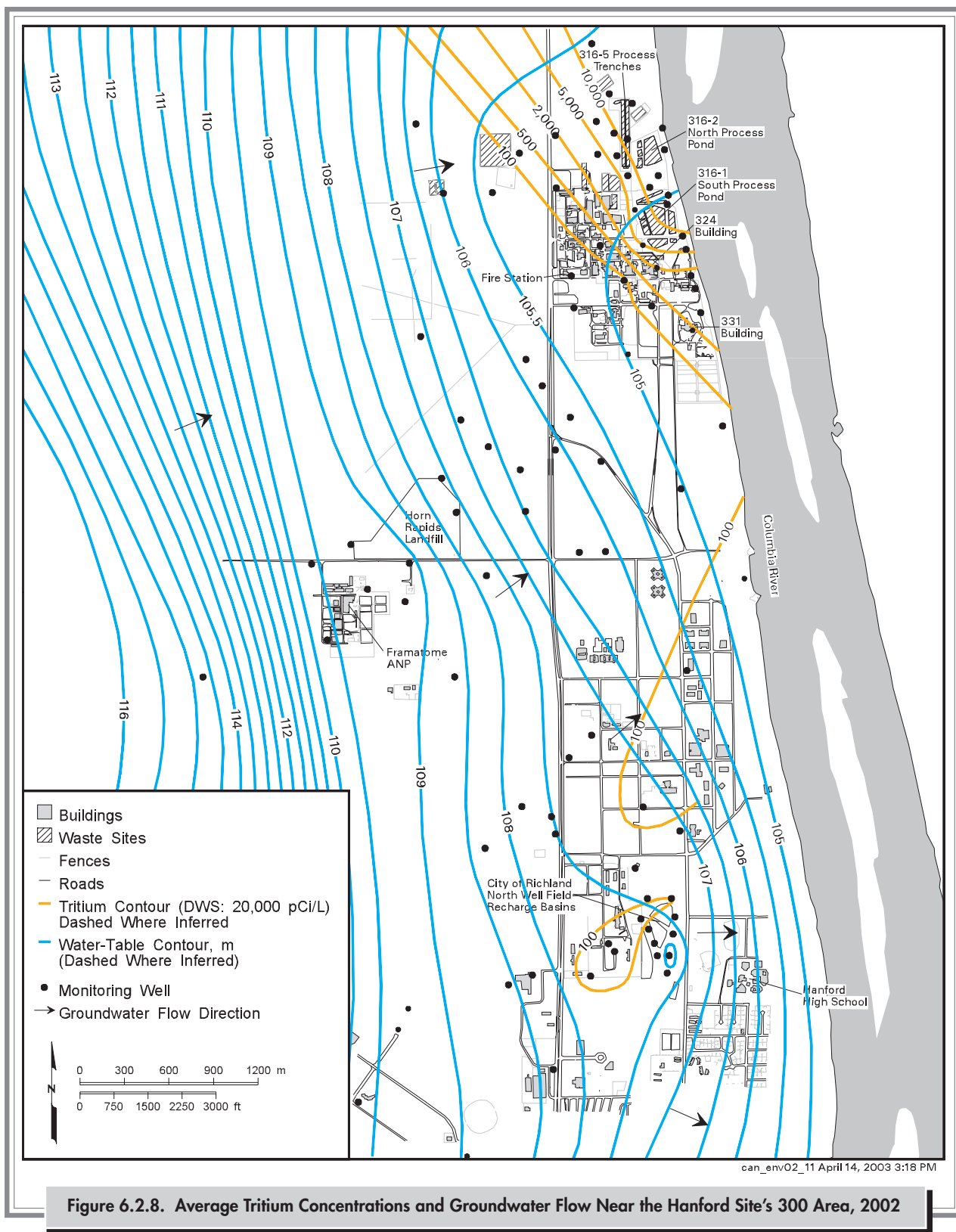
concentrations in the deeper portion of the unconfined aquifer decreased to 490,000 pCi/L (18,150 Bq/L) by July 2002. This rise and fall in the tritium concentrations is related to effluent from earlier discharges containing tritium prior to April 1999. Approximately 8.6 curies (~319 billion becquerels) of tritium were discharged to this facility during 2002. By the end of December 2002, ~333 curies (~12.33 trillion becquerels) of tritium and ~556 million liters (~147 million gallons) of treated effluent containing tritium had been discharged to this facility since operations began during 1995.

Tritium in the 300 Area and 618-11 Burial Ground.

The eastern portion of the groundwater tritium plume that emanates from the 200-East Area continues to move to the east-southeast and discharge into the Columbia River (Figure 6.2.1). The southern edge of the tritium plume extends into the 300 Area (Figure 6.2.8). Tritium concentrations decrease from >10,000 pCi/L (>370 Bq/L) in the northeastern part of the 300 Area to <100 pCi/L (<3.7 Bq/L) in the southwestern part of the 300 Area (Figure 6.2.8). The tritium contours shifted slightly to the northeast, indicating that the tritium plume in the 300 Area

decreased in size between 2001 and 2002. Although tritium in the 300 Area is at levels (a maximum of 8,910 pCi/L [330 Bq/L]) less than the drinking water standard, a concern has been the potential migration of tritium to a municipal water supply to the south. The municipal water supply consists of the city of Richland's well field and recharge ponds (Figure 6.2.8). The highest tritium level detected south of the 300 Area was 727 pCi/L (27 Bq/L) ~300 meters (~980 feet) from the well field. Monitoring data indicate that the Hanford Site tritium plume has not reached the municipal water supply.

The tritium plume is not expected to affect the well field because of the influence of groundwater flow from the Yakima River, recharge from agricultural irrigation, and recharge from infiltration ponds at the well field (Figure 6.2.8). The Yakima River is at a higher elevation than the water table and recharges the groundwater in this area. Groundwater flows from west to east (Figure 6.2.8), minimizing the southward movement of the regional tritium plume from the Hanford Site. Recharge from agricultural irrigation occurs south of the Hanford Site boundary and contributes to eastward flow. The recharge ponds are



supplied with Columbia River water, which infiltrates to the groundwater. The amount of recharge water exceeded the amount pumped at the well field by a factor of at least 2:1 during 2002, resulting in groundwater flow away from the well field. Recharge creates a mound that further assures that tritium-contaminated groundwater will not reach the well field.

Some of the highest tritium concentrations measured in Hanford Site groundwater in 2002 were in one well (699-13-3A) immediately downgradient of the 618-11 burial ground. The maximum tritium concentration at this well was 4.23 million pCi/L (156,670 Bq/L) in 2002. The 618-11 burial ground is located west of the Energy Northwest reactor complex in the eastern portion of the 600 Area (Figure 6.2.9). The burial ground was active from 1962 to 1967 before the Energy Northwest reactor complex was constructed and received a variety of low- and high-level waste from the 300 Area. A special investigation during 2000 determined that the burial ground was the likely source of the tritium contamination after an unexpected discovery of high tritium concentrations up to several million picocuries per liter in early 1999 (PNNL-13228).

However, potential tritium source materials and locations within the burial ground have not been identified.

The investigation continued during 2001 to define the lateral and vertical extent of contamination. The 2001 study defined a tritium plume that is narrow and extends ~900 meters (~2,950 feet) east-northeast of the burial ground (Figure 6.2.10). The vertical extent of the plume was throughout the unconfined aquifer above a silt layer that is ~14 meters (46 feet) below the water table. Based on this extent, the plume is estimated to contain between 190 and 235 curies (7.03 and 8.70 trillion becquerels) of tritium. In 2001, the travel time for the tritium plume to reach the Columbia River was estimated to be between 43 and 166 years. During 2002, additional methods using alternative assumptions provided a range of 43 to 129 years for the travel time to reach the Columbia River (PNNL-14187). These calculations indicate that the tritium in this plume will most likely decay to levels less than the drinking water standard before it reaches the river.

Tritium in the 400 Area. The tritium plume that originated in the 200-East Area extends under the 400 Area.

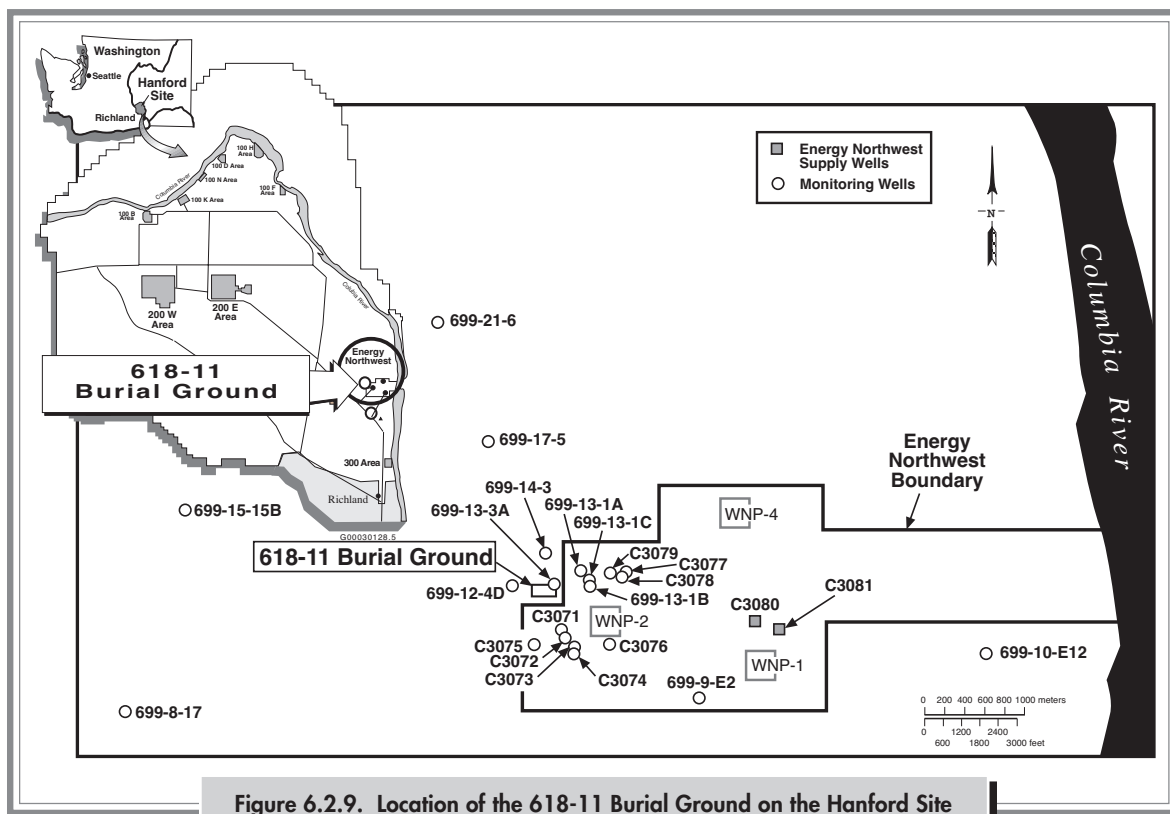


Figure 6.2.9. Location of the 618-11 Burial Ground on the Hanford Site

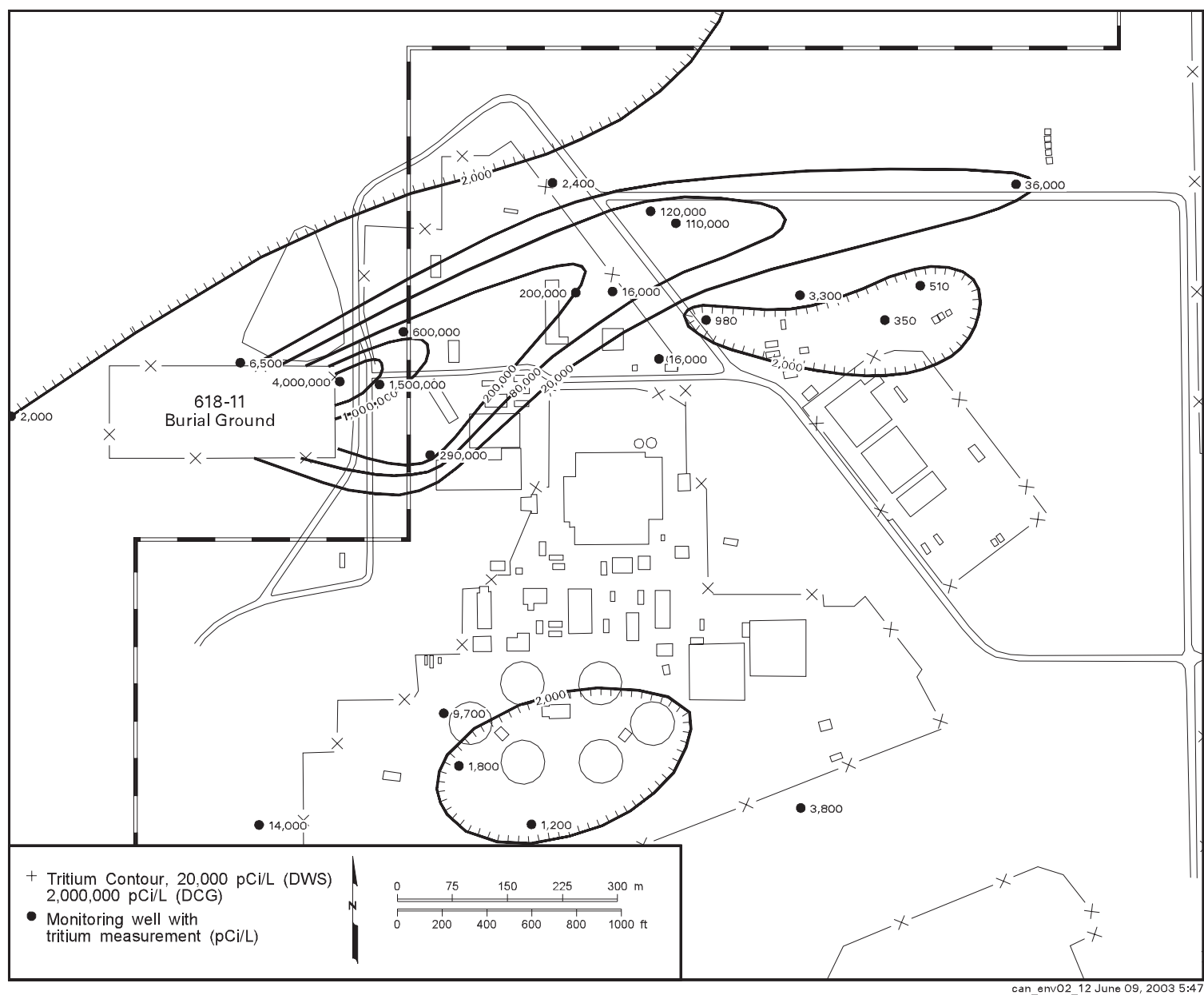


Figure 6.2.10. Average Tritium Concentrations in the Unconfined Aquifer at the Hanford Site's 618-11 Burial Ground, 2002

The maximum concentration detected in this area during 2002 was 19,900 pCi/L (737 Bq/L) near the 4608 B/C process ponds. The water supply wells are located in the northern part of the 400 Area. Tritium levels in the primary (499-S1-8J) and backup (499-S0-7 and 499-S0-8) water supply wells did not exceed the annual average drinking water standard of 20,000 pCi/L (740 Bq/L) during 2002. Tritium levels in the 400 Area are slowly declining because of dispersion and radioactive decay. Additional information on the 400 Area water supplies is provided in Section 4.3.

Iodine-129. Iodine-129 has a relatively low drinking water standard (1 pCi/L [0.037 Bq/L]), has the potential to accumulate in the environment as a result of long-term releases from nuclear fuel reprocessing facilities (Soldat 1976), and has a long half-life (16 million years). An iodine-129 plume at levels exceeding the drinking water standard is extensive in the 200 and 600 Areas. No groundwater samples showed iodine-129 concentrations above the 500-pCi/L (18.5-Bq/L) DOE derived concentration guide during 2002. Iodine-129 may be released as a vapor during fuel dissolution and during other elevated temperature processes and, thus, may be associated with process condensate waste. At the Hanford Site, the main contributor of iodine-129 to groundwater is past-practice liquid discharges to cribs in the 200 Areas. Iodine-129 has essentially the same high mobility in groundwater as tritium. The highest level of iodine-129 detected in groundwater during 2002 on the Hanford Site was 31.6 pCi/L (1.2 Bq/L) in a well sample collected near the TX and TY Tank Farms in the 200-West Area.

Iodine-129 in the 200-East Area. The highest iodine-129 concentrations in groundwater in the 200-East Area are near the Plutonium-Uranium Extraction Plant and in the vicinity of B Plant (Figure 6.2.11). The maximum level of iodine-129 detected during 2002 in the 200-East Area was 11.2 pCi/L (0.41 Bq/L) in a well located south of the Plutonium-Uranium Extraction Plant near the 216-A-36B crib. Iodine-129 concentrations near this crib are declining slowly or are stable. This iodine-129 plume extends from the Plutonium-Uranium Extraction Plant area southeast into the 600 Area and appears coincident with the tritium plumes (Figure 6.2.11). The iodine-129 plume likely had the same sources as the tritium plume. The iodine-129 plume appears smaller than

the tritium plume because of the lower initial concentration of iodine-129. Iodine-129 also is present in groundwater at levels above the drinking water standard in the northwestern portion of the 200-East Area and extends northwest into the gap between Gable Mountain and Gable Butte.

Iodine-129 in the 200-West Area. The distribution of iodine-129 in Hanford Site groundwater is shown in Figure 6.2.11. The highest level detected in groundwater in the 200-West Area during 2002 was 31.6 pCi/L (1.2 Bq/L) in a well near the TX and TY Tank Farms. This level occurs in a plume that extends northeast toward T Plant. This iodine-129 plume, which is generally coincident with the technetium-99 and tritium plumes in this area, most likely originates from the 242-T evaporator facility located between the TX and TY Tank Farms. A much larger iodine-129 plume occurs in the southeastern part of the 200-West Area. This plume originates near the Reduction-Oxidation Plant, with a possible contribution from cribs to the north near U Plant, and extends east into the 600 Area. This plume is essentially coincident with the tritium plume in that area. During 2002, the maximum concentration detected in this plume was 29.9 pCi/L (1.1 Bq/L) measured in a well at the 600 Area east of the Reduction-Oxidation Plant. Iodine-129 levels in this plume have not changed significantly in the last several years.

Technetium-99. Technetium-99, which has a half-life of 210,000 years, was produced as a high-yield fission byproduct and was present in waste streams associated with fuel reprocessing. Past reactor operations also may have resulted in the release of some technetium-99 associated with fuel element breaches. Technetium-99 is typically associated with uranium through the fuel processing cycle, but uranium is less mobile in groundwater. Under the chemical conditions that exist in Hanford Site groundwater, technetium-99 is normally present in solution as anions that sorb poorly to sediments. Therefore, technetium-99 is very mobile in site groundwater.

The DOE derived concentration guide for technetium-99 is 100,000 pCi/L (3,700 Bq/L) and the interim drinking water standard is 900 pCi/L (33 Bq/L). Technetium-99 was found at concentrations greater than the interim drinking water standard (900 pCi/L [33 Bq/L]) in the 200-East, 200-West, and 100-H Areas. The highest level

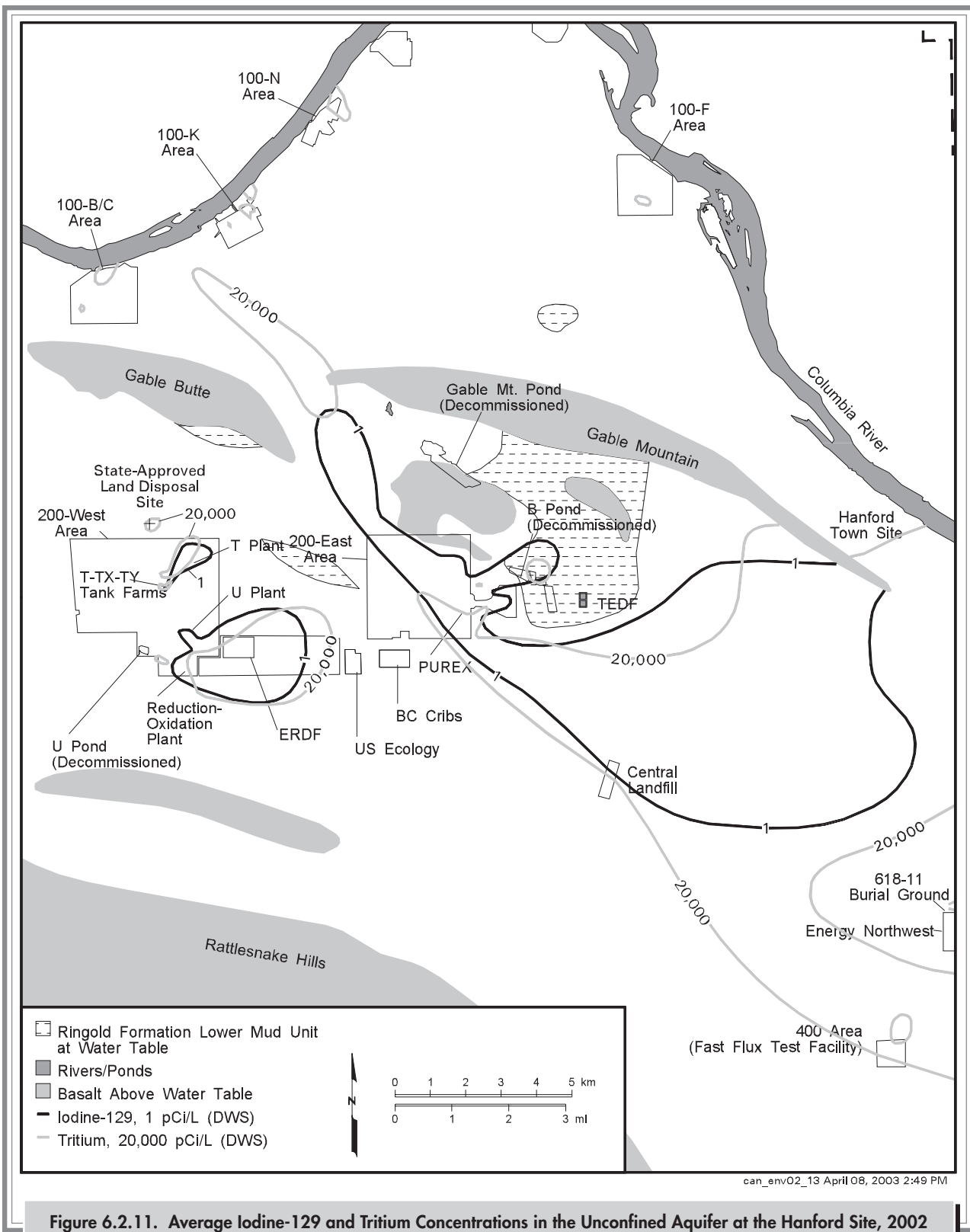


Figure 6.2.11. Average Iodine-129 and Tritium Concentrations in the Unconfined Aquifer at the Hanford Site, 2002

measured on the Hanford Site during 2002 was 99,700 pCi/L (3,690 Bq/L) in a well near the SX Tank Farm in the 200-West Area.

Technetium-99 in the 200-East Area. Groundwater in the northwestern part of the 200-East Area and a part of the 600 Area north of the 200-East Area contains technetium-99 at concentrations above the interim drinking water standard (Figure 6.2.12). The primary source of the technetium contamination was apparently the BY cribs (Section 2.9.1 in PNNL-13116). However, some of this contamination is also believed to originate from B, BX, and BY Tank Farms (PNNL-11826). The maximum concentration (10,600 pCi/L [393 Bq/L]) in groundwater in the 200-East Area during 2002 was measured in a well at the BY cribs. During 2002, technetium-99 concentrations near B, BX, and BY Tank Farms generally decreased from 2001 technetium-99 levels. Technetium-99 levels near the tank farms reached maximum concentrations in late 2000 and early 2001. The extent of technetium-99 contamination in groundwater north of the 200-East Area is uncertain. This larger portion of the plume to the north appears to be moving north through the gap between Gable Mountain and Gable Butte. Increasing technetium-99 concentrations southeast of the BX and BY Tank Farms in recent years indicate that part of the technetium-99 plume is moving to the south.

Technetium-99 in the 200-West Area. The largest technetium-99 plume in the 200-West Area originates from cribs that received effluent from U Plant and extends into the 600 Area to the east (Figure 6.2.13). The technetium plume is approximately in the same location as the uranium plume because technetium-99 and uranium, which are typically associated with the same fuel reprocessing cycle, were disposed to the same 216-U-1, 216-U-2, and 216-U-17 cribs. A pump-and-treat system reduced technetium-99 concentrations in the central part of the plume during 2001 (Section 2.3.13). Technetium-99 concentrations have generally declined in the central part of the plume since pump-and-treat operations began in 1997. The maximum technetium-99 level detected in this plume during 2002 was 22,400 pCi/L (829 Bq/L).

Several wells that monitor T, TX, and TY Tank Farms consistently showed technetium-99 concentrations above the interim drinking water standard in recent years (Figure 6.2.13). In 2002, the highest measured concentration

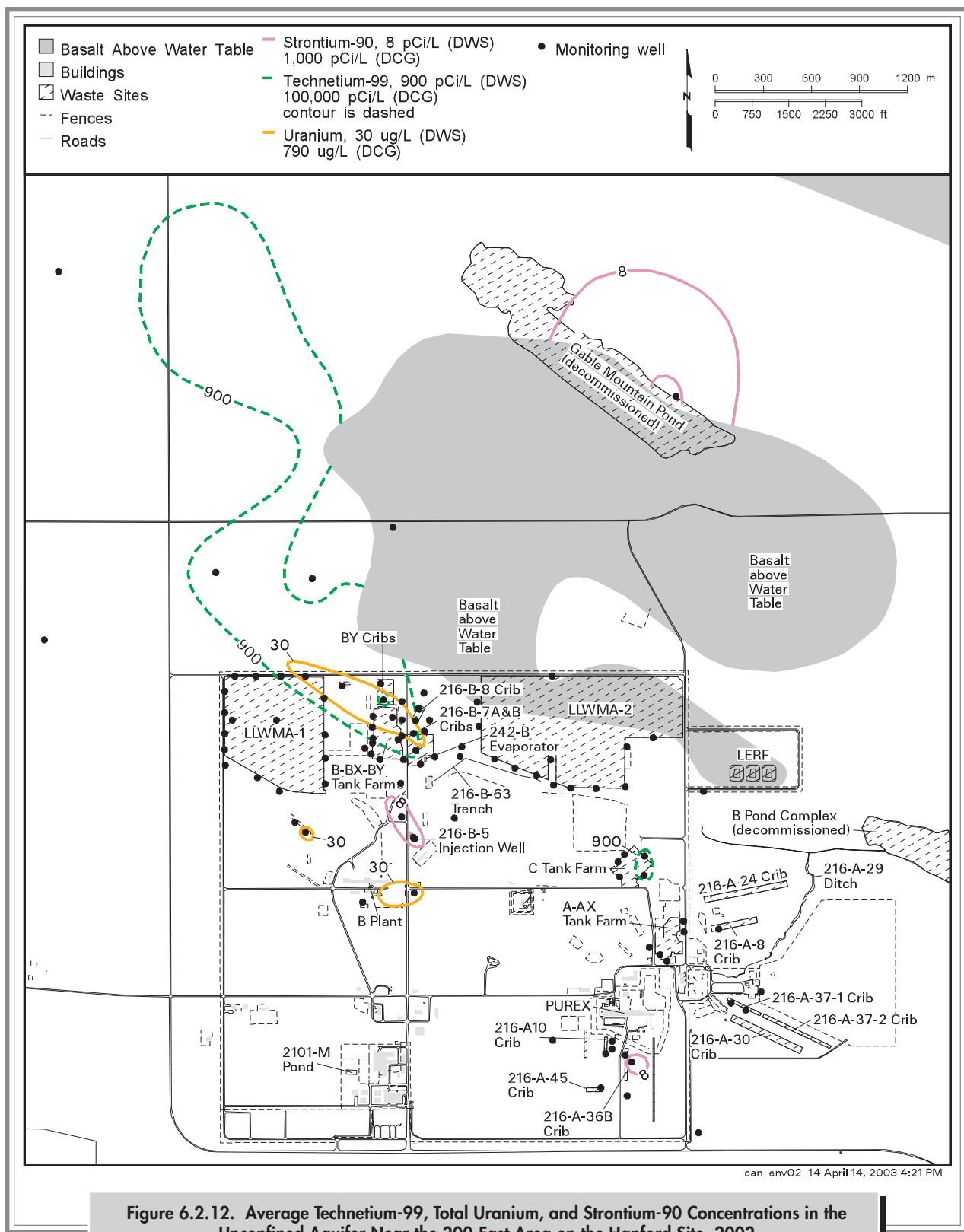
was 6,510 pCi/L (241 Bq/L) in a well east of T Tank Farm. The 200-ZP-1 pump-and-treat operation immediately to the south of the TX and TY Tank Farms is having a significant influence on the distribution of contaminants beneath the TX and TY Tank Farms. A large cone of depression in the water table is resulting in the movement of groundwater contaminants from beneath the tank farms toward the pump-and-treat system.

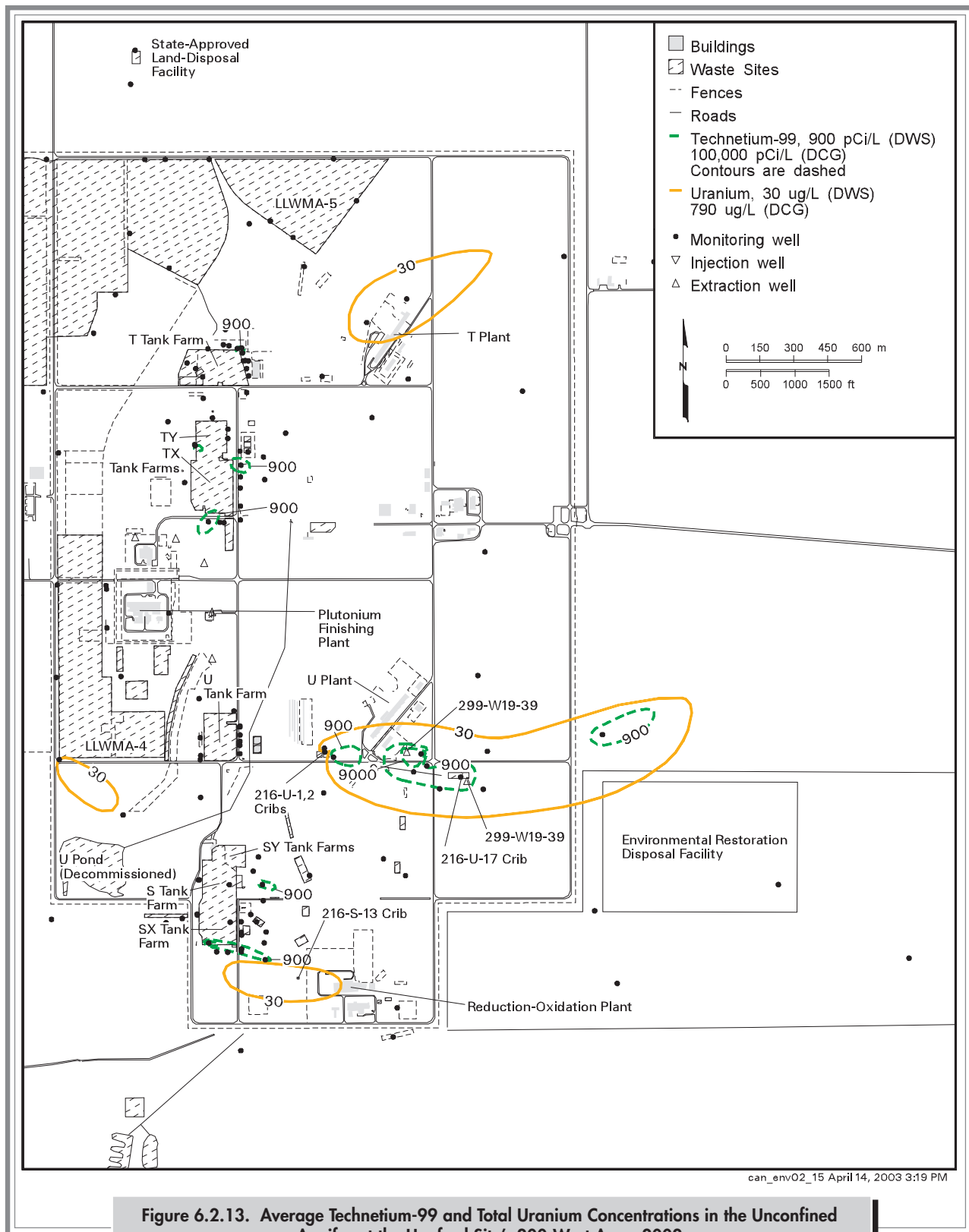
Technetium-99 levels in groundwater were above the interim drinking water standard near the T Tank Farm. The maximum technetium-99 concentration in this area during 2002 was 6,790 pCi/L (251 Bq/L). Technetium-99 concentrations generally increased near T Tank Farm during 2002. The sources of the technetium-99 contamination include T, TX, and TY Tank Farms (PNNL-11809).

Technetium-99 contamination in two small areas in the southern part of the 200-West Area originates near S and SX Tank Farms and the 216-S-13 crib. Multiple sources of technetium-99 contribute to groundwater contamination in this area (PNNL-13441; PNNL-13801). One plume containing technetium-99 has migrated east of the S Tank Farm, where the maximum technetium-99 concentration was 4,670 pCi/L (173 Bq/L) in 2002. A second small, but narrow plume containing technetium-99 located south of the SX Tank Farm changed significantly on the downgradient margin during 2002. The downgradient margin of the plume moved through and beyond the farthest downgradient well southeast of the SX Tank Farm. The maximum level detected in this plume was 99,700 pCi/L (3,690 Bq/L) in the southwestern corner of SX Tank Farm. This was the highest technetium-99 concentration detected on the Hanford Site during 2002.

Technetium-99 in the 100-H Area. Technetium-99 exceeded the interim drinking water standard in one well near the 116-H-6 evaporation basins in 2002 for the first time. The technetium-99 concentration was 986 pCi/L (36.5 Bq/L) in this well.

Total Uranium. There were numerous possible contributors of uranium released to the groundwater at the Hanford Site in the past, including fuel fabrication, fuel reprocessing, and uranium recovery operations. Uranium may exist in several states, including elemental uranium or uranium oxide as well as tetravalent and hexavalent cations. Only the hexavalent form has significant mobility in groundwater,





largely by forming dissolved carbonate species. Uranium mobility is, thus, dependent on oxidation state, pH, and the presence of carbonate. Uranium is observed to migrate in site groundwater but is retarded relative to more mobile species such as technetium-99 and tritium. The EPA's drinking water standard for uranium^(a) is 30 µg/L (0.03 ppm), which protects against both chemical toxicity and cancer risk. The DOE derived concentration guide, which represents an annual effective dose equivalent of 100 mrem (1 mSv), is 790 µg/L (0.79 ppm) for uranium. Total uranium has been detected in groundwater at concentrations greater than the drinking water standard in portions of the 100, 200, and 300 Areas. The highest levels detected at the Hanford Site during 2002 were in the 200-West Area near U Plant, where uranium levels were 2,100 µg/L (2.1 ppm) and exceeded the DOE derived concentration guide.

Total Uranium in the 100 Areas. Uranium was detected at levels exceeding the 30-µg/L (0.03 ppm) drinking water standard in a small area in the 100-H Area. The maximum level detected during 2002 was 119 µg/L (0.119 ppm) between the 116-H-6 evaporation basins and the Columbia River. Concentrations of uranium (and associated technetium-99) in the 100-H Area have generally fluctuated in response to changes in groundwater levels in the past several years. Near the river, low groundwater levels are usually associated with higher concentrations. Past leakage from the 116-H-6 evaporation basins is the source of the 100-H Area uranium contamination.

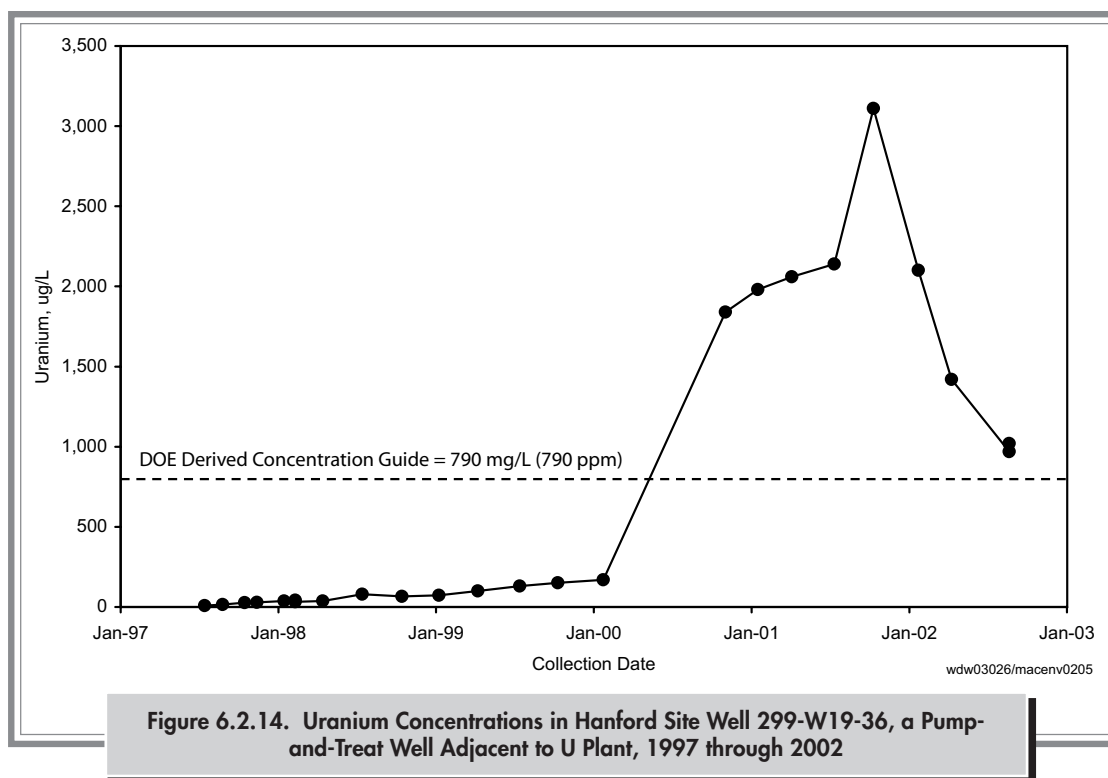
Total Uranium in the 200-East Area. In the 200-East Area, uranium contamination at levels greater than the drinking water standard is limited to isolated areas associated with B Plant (Figure 6.2.12). The uranium distribution during 2002 indicates the highest concentrations were in the vicinity of B, BX, and BY Tank Farms; the BY cribs; and the 216-B-5 injection well, which has been inactive since 1947. The highest concentration detected was 391 µg/L (0.391 ppm) at the BY Tank Farm (south of the BY cribs). The uranium plume, which is associated with technetium-99 at the BY Tank Farm, has a narrow northwest-southeast shape. Though unclear, a likely source of the uranium contamination is the tank farm.

Total Uranium in the 200-West Area. The highest uranium concentrations in Hanford Site groundwater occurred near U Plant (Figure 6.2.13). The 216-U-1 and 216-U-2 cribs are the major sources of the uranium. The maximum concentration detected in this area and on the Hanford Site during 2002 was 2,100 µg/L (2.1 ppm) in a well (299-W19-36) adjacent to U Plant (Figure 6.2.14). This former pump-and-treat well was converted to an extraction well in early 2002. Uranium concentrations in this well declined during most of 2002 after uranium levels in this well peaked in late 2001, just prior to the start of extraction. The uranium plume, which extends into the 600 Area to the east, is approximately in the same location as the technetium-99 plume discussed above. Uranium and technetium-99 were typically associated with the same fuel reprocessing cycle and were disposed to the same cribs. However, uranium is less mobile than technetium-99 because of its stronger sorption to the sediment. A greater proportion of the uranium contamination remains at or near the source area. The general configuration of the uranium plume during 2002 was similar to past years. The high concentrations exceeded the DOE derived concentration guide for uranium. A pump-and-treat system continued to operate in the 200-West Area in 2002 to remove uranium from groundwater (Section 2.3.13).

In the northern part of the 200-West Area, a localized area of uranium contamination in groundwater occurs near T Plant, where concentrations were above the drinking water standard at a maximum level of 411 µg/L (0.411 ppm).

Total Uranium in the 300 Area. A plume of uranium contamination exists near former uranium fuel fabrication facilities and inactive waste sites known to have received uranium waste. The plume extends downgradient from inactive liquid waste disposal facilities to the Columbia River (Figure 6.2.15). The major source of the contamination is the inactive 316-5 process trenches, as indicated by the distribution of the uranium concentrations downgradient from these trenches. The maximum concentration detected at this area during 2002 was 235 µg/L (0.235 ppm) northeast of the North Process Pond near the Columbia River. Because wastewater is no longer discharged to the 316-5 process trenches, elevated concentrations at the

(a) The final rule for the uranium drinking water standard was promulgated on December 7, 2000, and becomes effective on December 8, 2003 (40 CFR Parts 9, 141, and 142).



south end of the process trenches indicate that the soil column contributes uranium contamination to the groundwater. Uranium levels in 300 Area groundwater fluctuate annually but show an overall decline in recent years. The annual fluctuations in uranium levels are caused by river stage changes, which mobilize more uranium during high river stages in spring months and less uranium during low river stages in fall and early winter months. This is consistent with the results of a recent study of uranium leaching and adsorption in the 300 Area (PNNL-14022).

Strontium-90. Strontium-90 was produced as a high-yield fission product and was present in waste streams associated with past fuel reprocessing. Reactor operations also resulted in the release of some strontium-90 associated with fuel element breaches. Strontium-90 mobility in Hanford Site groundwater is reduced by adsorption onto sediment particles. However, strontium-90 is moderately mobile in groundwater because its adsorption is much weaker than for other radionuclides such as cesium-137 and plutonium. Because of sorption, a large proportion of the strontium-90 in the subsurface is not present in solution. The half-life of strontium-90 is 29.1 years.

During 2002, strontium-90 concentrations greater than the 8-pCi/L (0.3-Bq/L) drinking water standard were found

in one or more wells in each of the 100 and 200 Areas. Levels of strontium-90 were greater than the DOE derived concentration guide (1,000 pCi/L [37 Bq/L]) in the 100-K and 100-N Areas. The 100-N Area had the widest distribution detected at the Hanford Site during 2002. The maximum concentration detected in groundwater at the Hanford Site during 2002 was 18,500 pCi/L (685 Bq/L) in the 100-N Area.

Strontium-90 in the 100 Areas. Strontium-90 concentrations in groundwater at levels greater than the drinking water standard extend from the B Reactor to the Columbia River in the northeastern part of the 100-B/C Area. The highest concentration was found near the inactive 116-C-1 trench at a level of 39.3 pCi/L (1.5 Bq/L) during 2002. Strontium-90 concentrations in 100-B/C Area groundwater are generally declining. Sources for the strontium-90 appear to be inactive liquid waste disposal sites near B Reactor and inactive liquid overflow trenches near the Columbia River (DOE/EIS-0119F).

A small plume of strontium-90 with levels exceeding the drinking water standard occurs near the 116-F-14 retention basins and 116-F-2 and 116-F-9 trenches in the eastern part of the 100-F Area. The maximum concentration detected during 2002 was 27.8 pCi/L (1.0 Bq/L) between the

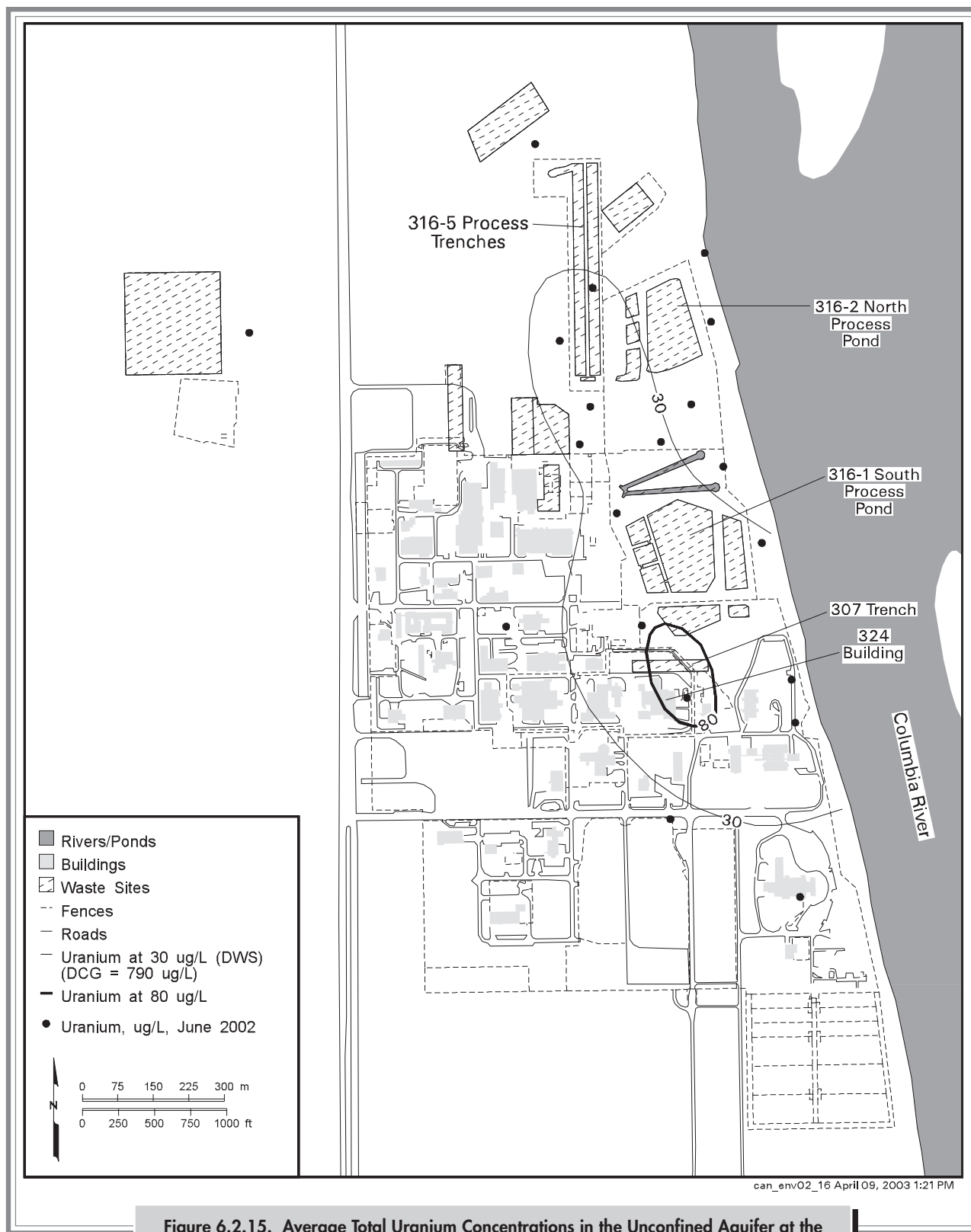


Figure 6.2.15. Average Total Uranium Concentrations in the Unconfined Aquifer at the Hanford Site's 300 Area, 2002

116-F-2 trench and the Columbia River. Strontium-90 levels in groundwater fluctuate with changing river levels in the 100-F Area.

In the 100-H Area, strontium-90 contamination levels greater than the drinking water standard were present in wells in an area adjacent to the Columbia River near the 116-H-7 retention basin. The maximum concentration detected during 2002 was 23.2 pCi/L (0.86 Bq/L) in a pump-and-treat well adjacent to the retention basin. The source of the contamination is past disposal of reactor coolant containing strontium-90 to the 116-H-7 retention basin, the 116-H-1 liquid waste trench, and the 116-H-5 sludge burial trench in the 100-H Area. Contaminated soil was excavated from the upper portion of the vadose zone at these facilities and disposed of to the Environmental Restoration Disposal Facility during 1999 and 2000. Strontium-90 levels in groundwater are generally stable in the 100-H Area.

Strontium-90 at levels greater than the drinking water standard continues to be found in wells in isolated areas of the 100-K Area. These areas include fuel storage basin drain fields/injection wells associated with the KE and KW Reactors and the area between the inactive 116-K-2 liquid waste disposal trench and the Columbia River. The maximum concentration detected during 2002 was 2,440 pCi/L (90 Bq/L) at well 199-K-109A, the only well in the 100-K Area where strontium-90 levels were above the DOE derived concentration guide. Strontium-90 concentrations in this well decreased to a level below the DOE derived concentration guide by mid-2002, but increased above the DOE derived concentration guide by late 2002. The original source of the strontium-90 in this well was identified as past-practice disposal to the 116-KE-3 drain field/injection well near KE Reactor (PNNL-12023). Strontium-90 is a co-contaminant with chromium in the groundwater, which is being treated with a pump-and-treat system. However, strontium-90 is not removed by the treatment system that removes chromium from the extracted groundwater. Therefore, strontium-90 is returned to the aquifer via the pump-and-treat injection wells. Strontium-90 concentrations measured in the returned groundwater have been less than the drinking water standard since the pump-and-treat system began operating in 1997. The maximum strontium-90 concentration measured in groundwater near the inactive 116-K-2 liquid waste disposal trench during 2002 was

39.5 pCi/L (1.5 Bq/L). Near the KW Reactor, strontium-90 is elevated above the drinking water standard. The maximum strontium-90 concentration measured in groundwater near the KW Reactor during 2002 was 35.6 pCi/L (1.3 Bq/L).

The general distribution of strontium-90 in the 100-N Area has not changed significantly in the past 10 years or more (Figure 6.2.16). Strontium-90 was detected at concentrations greater than the DOE derived concentration guide in several wells located between the 116-N-1 liquid waste disposal facility, a source of the strontium-90, and the Columbia River. A pump-and-treat system is operating in this area to remove strontium-90 from groundwater. The 116-N-3 liquid waste disposal facility is also a source of strontium-90 in groundwater. The maximum level detected in the 100-N Area during 2002 was near the head end of the 116-N-1 liquid waste facility (well 199-N-67), where concentrations ranged between 4,490 and 18,500 pCi/L (166 and 685 Bq/L). The concentration 18,500 pCi/L (685 Bq/L) was the highest strontium-90 concentration detected in Hanford Site groundwater during 2002.

In the 100-N Area, strontium-90 enters the Columbia River via springs along the shoreline (Sections 3.2 and 4.2). Because of high strontium-90 concentrations in wells near the river, it was expected that strontium-90 concentrations would exceed the drinking water standard at the interface between the groundwater and the river (DOE/RL-96-102). The highest strontium-90 concentration measured in a near-river well during 2002 was 4,810 pCi/L (178 Bq/L). Strong, positive correlations between increases in groundwater levels and high strontium-90 concentrations in wells near the shoreline indicate that strontium-90 is remobilized during periods of high water levels. A pump-and-treat system continued to operate in the 100-N Area during 2002 to reduce the amount of strontium-90 to the Columbia River in that area (Section 2.3.13).

Strontium-90 in the 200-East Area. Strontium-90 distribution in the 200-East Area is shown in Figure 6.2.12. In the past, strontium-90 concentrations in the 200-East Area have been detected above the DOE derived concentration guide in two wells near the inactive 216-B-5 injection well. However, monitoring wells near the injection well were not sampled during 2002 because waste management documentation in support of CERCLA sampling needed to be developed. The former injection well received

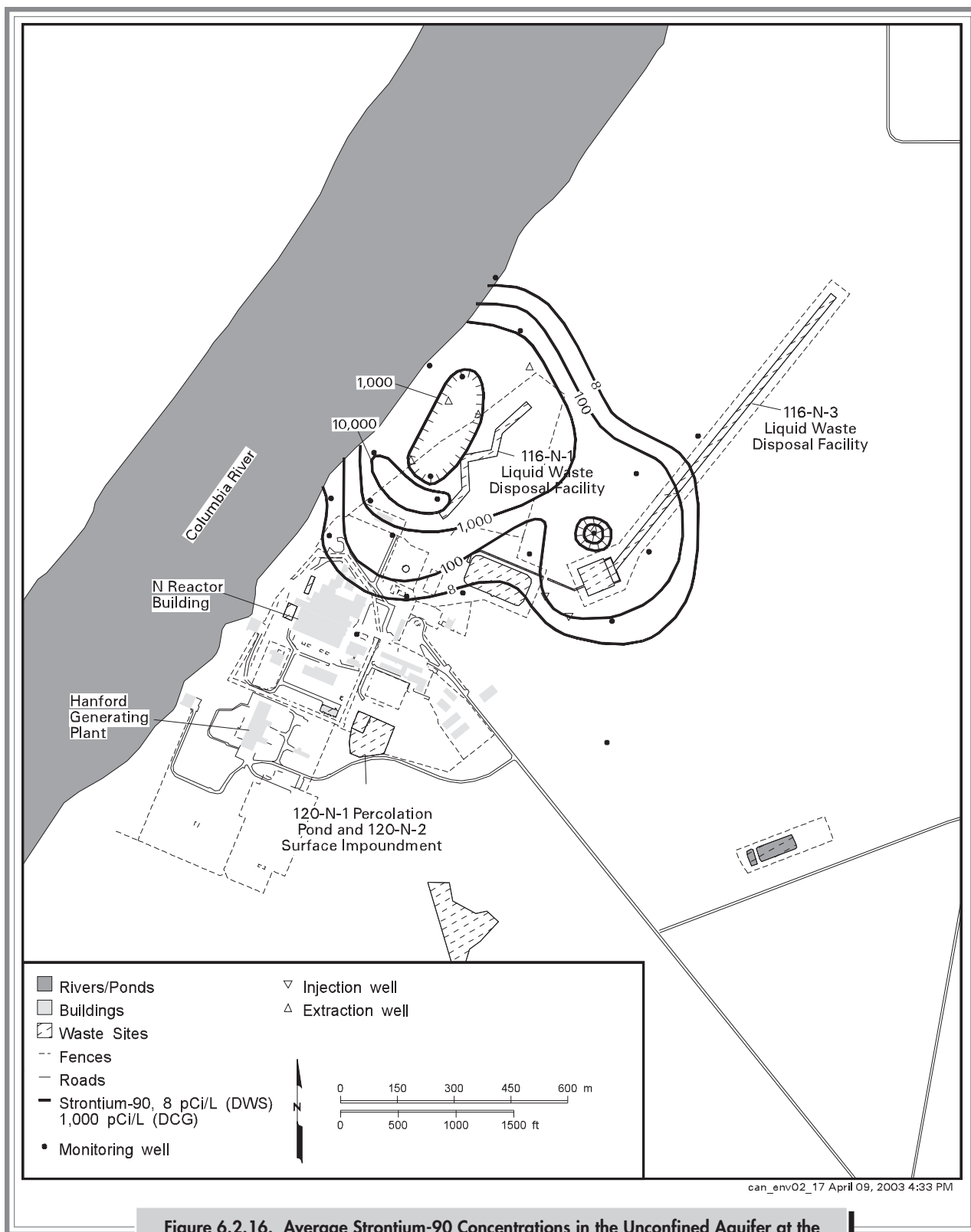


Figure 6.2.16. Average Strontium-90 Concentrations in the Unconfined Aquifer at the Hanford Site's 100-N Area, 2002

an estimated 27.9 curies (1.03 trillion becquerels) of strontium-90 during 1945 and 1946 (PNL-6456). Elsewhere in the 200-East Area, strontium-90 was detected above the drinking water standard in one well near the Plutonium-Uranium Extraction Plant cribs. The maximum strontium-90 level measured in this well during 2002 was 21.4 pCi/L (0.79 Bq/L).

Carbon-14. Carbon-14 contamination occurs in the 100-K Area and groundwater concentrations exceeded the interim drinking water standard (2,000 pCi/L [74 Bq/L]) in two small plumes near the KE and KW Reactors (Figure 6.2.2). The sources of the carbon-14 were the 116-KE-1 and 116-KW-1 cribs. Waste disposal to these cribs ended during 1971. Carbon-14 was included with tritium in the condensate wastewater disposed to these cribs. However, the distribution of carbon-14 in groundwater is not the same as for tritium because carbon-14 sorbs onto sediment and is less mobile than tritium (PNNL-12023). Carbon-14 concentrations in 100-K Area groundwater were lower in 2002 than in previous years. The maximum concentration measured during 2002 was 20,900 pCi/L (774 Bq/L) in a well near the 116-KW-1 crib. The DOE derived concentration guide for carbon-14 is 70,000 pCi/L (2,590 Bq/L). Carbon-14 has a relatively long half-life of 5,730 years, which suggests that some of the carbon-14 will reach the Columbia River before the carbon-14 decays away. A portion of the carbon-14 will likely remain fixed on soil particles.

Cesium-137. Cesium-137, which has a half-life of 30 years, was produced as a high-yield fission product and was present in historical waste streams associated with fuel processing. Former reactor operations also may have resulted in the release of some cesium-137 associated with fuel element breaches. Normally, cesium-137 is strongly sorbed on soil and, thus, is not very mobile in Hanford Site groundwater. The interim drinking water standard for cesium-137 is 200 pCi/L (7.4 Bq/L); the DOE derived concentration guide is 3,000 pCi/L (110 Bq/L).

In the past, cesium-137 has been detected at levels above the 200-pCi/L (7.4-Bq/L) interim drinking water standard near the inactive 216-B-5 injection well in the 200-East Area. However, monitoring wells near the injection well were not sampled in 2002 because waste management documentation in support of CERCLA sampling needed to

be developed. The injection well received waste containing cesium-137 from 1945 to 1947. It is estimated that this well received 81 curies (2,997 gigabecquerels) of cesium-137 (RHO-CD-673). Cesium-137 appears to be restricted to the immediate vicinity of the former injection well.

Cobalt-60. Cobalt-60 in groundwater is typically associated with waste generated by reactor effluent disposed to the ground in the past. Cobalt-60 is normally present as a divalent transition metal cation and, as such, tends to be immobile in groundwater. However, complexing agents may mobilize it. All cobalt-60 levels in groundwater samples analyzed during 2002 were less than the interim drinking water standard (100 pCi/L [3.7 Bq/L]). The DOE derived concentration guide for cobalt-60 is 5,000 pCi/L (185 Bq/L).

Cobalt-60 was detected in groundwater in the northwestern part of the 200-East Area. This is the same area where the technetium-99 contamination associated with the BY cribs is found. Apparently, cobalt in this plume is mobilized by reaction with cyanide or ferrocyanide in the waste stream, forming a dissolved cobalt species. The maximum cobalt-60 concentration measured in groundwater during 2002 was 48.4 pCi/L (1.8 Bq/L) at the BY cribs. Because of its relatively short half-life (5.3 years), much of the cobalt-60 in groundwater in this area has decayed to low concentrations.

Plutonium. Plutonium was released to the soil column in the past at several locations in both the 200-West and 200-East Areas. Plutonium is generally considered to sorb strongly to sediment, which limits its mobility in the aquifer. The DOE derived concentration guide for both plutonium-239 and plutonium-240 is 30 pCi/L (1.1 Bq/L). Radiological analysis is incapable of distinguishing between plutonium-239 and plutonium-240; therefore, the results are expressed as a concentration of plutonium-239/240. There is no explicit drinking water standard for plutonium-239/240; however, the gross alpha drinking water standard of 15 pCi/L (0.56 Bq/L) would be applicable at a minimum. However, if the DOE derived concentration guide based on a 100-mrem (1-mSv) dose standard is converted to the 4-mrem (40-mSv) dose equivalent used for the drinking water standard, 1.2 pCi/L (0.04 Bq/L) would be the relevant guideline. The half-lives of plutonium-239 and plutonium-240 are 24,000 and 6,500 years, respectively.

The only location where plutonium isotopes were detected at levels above the 30-pCi/L (1.1-Bq/L) DOE derived concentration guide in groundwater on the Hanford Site in the past was near the inactive 216-B-5 injection well in the 200-East Area. This well was not sampled during 2002 because waste management documentation in support of CERCLA sampling needed to be developed. Plutonium levels near the injection well have not changed significantly since monitoring for plutonium began during the 1980s. Because plutonium is strongly adsorbed to sediment and may have been injected into the aquifer as suspended particles, it is likely that the values measured result in part from solid rather than dissolved material. The injection well received an estimated 244 curies (9.03 trillion becquerels) of plutonium-239/240 during its operation from 1945 to 1947 (PNL-6456).

6.2.2 CHEMICAL MONITORING RESULTS FOR THE UNCONFINED AQUIFER

Chemical analyses performed for various monitoring programs at the Hanford Site have identified several hazardous chemicals in groundwater at concentrations greater than their respective drinking water standards. Nitrate, chromium, and carbon tetrachloride are the most widely distributed of these hazardous chemicals and have the highest concentrations in groundwater at the Hanford Site. Hazardous chemicals that are less widely distributed and have lower concentrations in groundwater include chloroform, trichloroethene, tetrachloroethene, cis-1,2-dichloroethene, cyanide, fluoride, and arsenic.

A number of parameters such as pH, specific conductance, total carbon, total organic carbon, and total organic halides are used as indicators of contamination (Section 6.4). Other chemical parameters (Table 6.1.4) are indicators of the natural chemical composition of groundwater and are usually not considered contaminants from operations at the Hanford Site. These include alkalinity, aluminum, calcium, iron, magnesium, manganese, potassium, silica, and sodium. Chloride and sulfate occur naturally in groundwater. However, these constituents also have been introduced as contaminants from site operations. There are no primary drinking water standards for chloride or sulfate. The secondary standard for each is 250 mg/L (250 ppm) and is based on aesthetic rather than health

considerations; therefore, they will not be discussed in detail. The analytical technique used to determine the concentration of metals in groundwater provides results for a number of constituents. These trace metal constituents, rarely observed at greater than background concentrations, include antimony, barium, beryllium, boron, cadmium, copper, nickel, silver, vanadium, and zinc.

The following presents a summary of the chemical constituents in groundwater at concentrations greater than existing or proposed drinking water standards (40 CFR 141 and EPA 822-R-96-001; Appendix D).

Nitrate. Many groundwater samples collected during 2002 were analyzed for nitrate (Figure 6.2.17). The distribution of nitrate on the Hanford Site is similar to previous evaluations. Nitrate is the most widespread chemical contaminant in Hanford Site groundwater because of its mobility in groundwater and the large volumes of liquid waste containing nitrate discharged to the ground. However, the areas affected by levels greater than the drinking water standard are small. Nitrate was measured in groundwater at concentrations greater than the drinking water standard (45 mg/L [45 ppm] as nitrate ion) in portions of the 100, 200, 300, 600, and former 1100 Areas. The maximum nitrate concentration measured on the Hanford Site was 2,090 mg/L (2,090 ppm) in a well in the 200-West Area. Nitrate contamination in the unconfined aquifer reflects the extensive use of nitric acid in decontamination and chemical reprocessing operations. Nitrate is associated primarily with process condensate liquid waste, though other liquids discharged to the ground also contained nitrate. However, additional sources of nitrate, primarily associated with agriculture, occur off the site to the south, west, and southwest.

Nitrate in the 100 Areas. Nitrate in groundwater was measured at concentrations exceeding the drinking water standard in all of the 100 Areas except the 100-B/C Area. Nitrate concentrations have generally been rising in many 100 Areas wells.

Nitrate in groundwater is found at levels greater than the drinking water standard in two separate plumes in the 100-D Area. These two nitrate plumes generally coincide with the chromium plumes. The highest nitrate level found during 2002 was 107 mg/L (107 ppm) in a well in the southwestern part of the 100-D Area. Levels of nitrate in groundwater are generally declining in the 100-D Area.

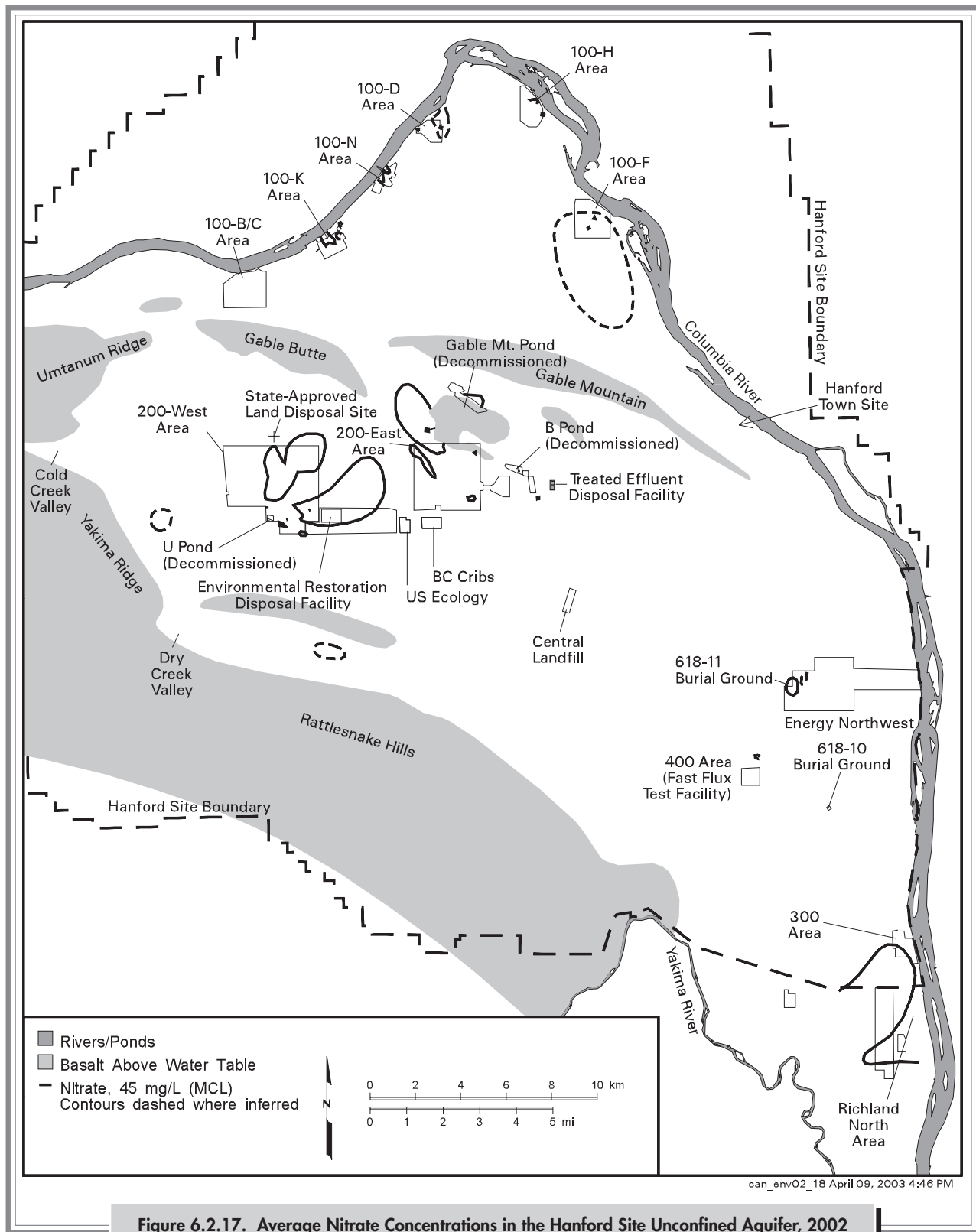


Figure 6.2.17. Average Nitrate Concentrations in the Hanford Site Unconfined Aquifer, 2002

Nitrate continues to be widely distributed in groundwater in the 100-F Area and the adjacent 600 Area to the south. Groundwater in the central and southern portions of the 100-F Area and the adjacent 600 Area contains nitrate at levels greater than the drinking water standard. A nitrate plume extends to the south and southeast into the 600 Area from upgradient sources near F Reactor. In the southern part of the 100-F Area, groundwater flow is to the southeast. The maximum nitrate concentration detected in the 100-F Area during 2002 was 177 mg/L (177 ppm) in a well in the southwestern part of the 100-F Area, where nitrate concentrations are increasing. The wide distribution of nitrate in the 100-F Area suggests multiple sources of nitrate in the 100-F Area or the adjacent 600 Area.

A nitrate plume with concentrations above the drinking water standard lies in the eastern portion of the 100-H Area adjacent to the Columbia River. The highest concentrations are restricted to a small area downgradient of the former 116-H-6 evaporation basins. The maximum nitrate concentration detected in 2002 was 474 mg/L (474 ppm) in a well located between the basins and the river.

Nitrate is widely distributed in the 100-K Area and has multiple sources, including septic system drain fields and past-practice disposal to the soil column. The drinking water standard for nitrate was exceeded in a number of 100-K Area wells during 2002. Nitrate concentration trends vary in the 100-K Area. The maximum nitrate concentration detected in 100-K Area groundwater during 2002 was 94.3 mg/L (94.3 ppm) in a well near the southwestern end of the 116-K-2 liquid waste disposal trench.

Although detected over most of the 100-N Area, nitrate contamination above the drinking water standard occurs at isolated locations in the 100-N Area. The maximum concentration measured in the 100-N Area during 2002 was 60 mg/L (60 ppm) in a well located between the 116-N-1 liquid waste disposal facility and the Columbia River.

Nitrate in the 200-East Area. The nitrate plume in the 200-East Area covers a nearly identical area to that of the tritium plume. However, the area with nitrate exceeding the drinking water standard is smaller than the area with tritium exceeding its drinking water standard. Nitrate concentrations exceed the drinking water standard in the northern part of the 200-East Area and adjacent 600 Area

to the northwest and near the Plutonium-Uranium Extraction Plant in the southeastern part of the 200-East Area. In the northern part of the 200-East Area, the plume has two parts, a western plume that extends from B Plant to the northwest and an eastern portion that extends from the BY and surrounding cribs to the south and to the northwest. The two portions of the plume join northwest of the 200-East Area and extend through the gap between Gable Butte and Gable Mountain (see Figure 2.9-9 of PNNL-14187.)

Past disposal practices related to the BY cribs is a major contributor to the high nitrate concentrations in the northern part of the 200-East Area and adjacent 600 Area. Some nitrate may also be associated with past releases from the B, BX, and BY Tank Farms. During 2002, the highest 200-East Area nitrate concentrations were measured in several wells near the BY and 216-B-8 cribs, where nitrate concentrations continue to increase. The maximum concentration measured during 2002 was 735 mg/L (735 ppm) in a well located at the BY cribs. Nitrate originating from the BY cribs is a co-contaminant with cobalt-60, cyanide, and technetium-99.

High nitrate concentrations continued to be found near liquid waste disposal facilities that received effluent from Plutonium-Uranium Extraction Plant operations. Nitrate concentrations in wells near the inactive 216-A-10 and 216-A-36B cribs have decreased in the past few years but remained greater than the drinking water standard, though these cribs were removed from service during 1987. The maximum nitrate concentration detected near the Plutonium-Uranium Extraction Plant during 2002 was 170 mg/L (170 ppm) in a well adjacent to the 216-A-36B crib.

Nitrate is known to be elevated above the drinking water standard in a few wells near the former Gable Mountain Pond, north of the 200-East Area. However, these wells were not sampled during 2002 because they are sampled on a triennial schedule.

Nitrate in the 200-West Area. Nitrate concentrations greater than the drinking water standard were widespread in groundwater beneath the 200-West Area and adjacent parts of the 600 Area. The major nitrate plumes were found in wells east of U Plant and wells in the north-central part of the 200-West Area. The widespread distribution of

nitrate reflects multiple sources in the 200-West Area (see Figures 2.8-8 and 2.8-39 of PNNL-14187).

Near U Plant, widespread nitrate contamination in groundwater is associated with the tritium and iodine-129 plumes. The nitrate contamination in this area is attributed to multiple sources, including the 216-U-1 and 216-U-2 cribs southwest of U Plant, and the 216-U-17 crib southeast of U Plant. The 216-U-1 and 216-U-2 cribs received more than 1 million kilograms (2.2 million pounds) of chemicals containing nitrate during their operation from 1951 to 1967 (PNL-6456). The highest nitrate concentration measured in the plume east of U Plant during 2002 was 236 mg/L (236 ppm) in a well located near the inactive 216-U-17 crib. Nitrate concentrations continued to decrease near this crib during 2002. A pump-and-treat system continued to operate in this area during 2002 (Section 2.3.13). However, nitrate is not the primary target of the pump-and-treat system. The primary targets of the pump-and-treat system are uranium and technetium-99.

Nitrate concentrations in groundwater continued to be elevated above the drinking water standard near other inactive cribs to the south of U Plant that are associated with the U Plant and Reduction-Oxidation Plant. These elevated levels represent nitrate plumes that merge with the plume from the U Plant area. The maximum nitrate concentration measured in this merged area of the groundwater plume during 2002 was 72.6 mg/L (72.6 ppm) near the 216-S-20 crib southeast of the Reduction-Oxidation Plant.

A small, isolated plume of elevated nitrate occurs west of the Reduction-Oxidation Plant near the inactive 216-S-25 crib and S and SX Tank Farms, where the maximum measured concentration was 1,000 mg/L (1,000 ppm) during 2002. Nitrate concentrations, which increased in this plume during 2002, appear to be associated with technetium-99.

A large area, encompassing much of the northern half of the 200-West Area, contains nitrate in groundwater at concentrations much greater than the drinking water standard. Wells showing the highest concentrations are located near several inactive liquid waste disposal facilities (cribs) that received waste from early T Plant operations. A large amount of nitrate was disposed to these cribs (e.g., ~2.3 million kilograms [~5.1 million pounds] to the

216-T-7 crib). Maximum concentrations in these wells in 2002 ranged up to 2,090 mg/L (2,090 ppm) in wells located just south of the T Tank Farm. These are the highest nitrate concentrations measured on the Hanford Site during 2002 and concentrations continued to increase during the year.

A smaller area of elevated nitrate concentrations in groundwater above the drinking water standard is located in vicinity of the Plutonium Finishing Plant, which is in the central part of the 200-West Area. One source of this nitrate is the 216-Z-9 trench, which received ~1.3 million kilograms (~2.9 million pounds) of chemicals containing nitrate from 1955 to 1962. Waste sites near the Plutonium Finishing Plant have contributed to the large nitrate plume in the northern half of the 200-West Area. The highest measured concentration during 2002 at the Plutonium Finishing Plant was 333 mg/L (333 ppm) in a pump-and-treat extraction well adjacent to the 216-Z-9 trench, which is located east of the Plutonium Finishing Plant.

Nitrate in the 300, 600, and Former 1100 Areas.

Nitrate contamination in groundwater occurs near the city of Richland in the former 1100 Area, Richland North Area, and adjacent parts of the 600 Area along the southern boundary of the Hanford Site. This contamination is apparently affected by nitrate sources off the Hanford Site. These sources may include agriculture, food processing, and nuclear fuel manufacturing at offsite commercial facilities. The part of this plume with nitrate concentrations greater than the drinking water standard extends south of the Hanford Site and northeast to the 300 Area. Nitrate concentrations generally continued to increase in the southern part of the Hanford Site and the adjacent area south of the Hanford Site during 2002. The maximum nitrate concentration measured in groundwater wells just south of the Hanford Site boundary during 2002 was 280 mg/L (280 ppm) (EMF-1865, Addendum 30). This nitrate contamination is likely the result of agricultural activities to the west and southwest. The maximum nitrate concentration measured in 300 Area groundwater during 2002 was 89.9 mg/L (89.9 ppm) (see Figure 2.12-13 in PNNL-14187).

Nitrate was detected at levels exceeding the drinking water standard in a well downgradient of the 4608 B/C process ponds. These levels, which declined during 2002, were attributed to a former sanitary sewage lagoon west and upgradient of the process ponds and later to a drainfield

associated with septic tanks southwest of the ponds. The maximum concentration measured in this well during 2002 was 71.3 mg/L (71.3 ppm).

Chromium. Use of chromium on the Hanford Site has been extensive. In the 100 Areas, sodium dichromate was added to cooling water as a corrosion inhibitor, and some residual chromium in soil and groundwater remains from that use. Chromium was used for decontamination in the 100, 200, and 300 Areas and for oxidation state control in the Reduction-Oxidation Plant process. In the hexavalent form, chromium is present in a soluble anionic state. Thus, hexavalent chromium is freely mobile in the groundwater. The drinking water standard for chromium is 100 µg/L (0.1 ppm).

Both filtered and unfiltered samples were collected from several onsite wells for analyses of chromium and other metals. Unfiltered samples may contain metals present as particulate matter, whereas filtered samples are representative of the more mobile, dissolved metals. Filtered samples also may contain some colloidal particles that are fine enough to pass through the filter. In general, filtered samples provide the best indication of groundwater contamination levels for chromium because unfiltered samples are subject to greater variability introduced by the sampling process. Chromium concentrations in filtered samples, which are considered representative of dissolved hexavalent chromium, will be used to describe the level of contamination in the discussion below.

Chromium in the 100 Areas. Chromium was detected in groundwater above the drinking water standard during 2002 in 100-D, 100-H, 100-K, and 100-N Area wells. The maximum detected concentration was 5,300 µg/L (5.3 ppm) in the 100-D Area. Groundwater pump-and-treat systems continued to operate during 2002 to reduce the amount of hexavalent chromium entering the Columbia River at the 100-D, 100-H, and 100-K Areas (Section 2.3.13). The purpose of the pump-and-treat systems is to prevent discharge of hexavalent chromium into the Columbia River at concentrations exceeding 11 µg/L (0.011 ppm), which is the EPA's standard for protection of freshwater aquatic life (EPA 822-Z-99-001).

Chromium contamination in 100-D Area groundwater at levels greater than the drinking water standard is defined by two plumes that appear to be merging (Figure 6.2.18).

The chromium plume in the southwestern part of the 100-D Area has expanded in size to the north, where chromium concentrations have been increasing in recent years. The source of this chromium plume has not been identified with certainty, but is suspected to be past use of sodium dichromate at the 183-DR water treatment facility or at a transfer station. Vadose zone studies in these areas failed to locate source areas of high chromium contamination in the vadose zone (PNNL-13486; PNNL-13107). The maximum measured chromium concentration from filtered samples collected in 2002 was 5,300 µg/L (5.3 ppm) in the southwestern plume near the Columbia River, where concentrations continued to increase during 2002 (Figure 6.2.19). The southwestern plume contained the highest concentrations of hexavalent chromium on the Hanford Site during 2002.

The source of the chromium plume in the northern part of the 100-D Area is sodium dichromate released to the ground at former facilities near D Reactor. Leakage from inactive retention basins and liquid waste disposal trenches north of D Reactor may also have contributed to this chromium plume. The maximum measured chromium concentration in the northern plume was 792 µg/L (0.792 ppm) during 2002. The area of low chromium concentrations between the plumes is suspected to be a result of past leakage of clean water from the 182-D reservoir. Leakage of clean water from the reservoir is suspected to mix with chromium contaminated groundwater, thereby lowering the chromium concentrations.

A small chromium plume in the northeastern part of the 100-H Area contains chromium levels greater than the drinking water standard (Figure 6.2.18). During 2002, the maximum chromium concentration from filtered samples collected from the shallow parts of the unconfined aquifer was 81 µg/L (0.081 ppm) between the former 116-H-6 evaporation basins and the Columbia River. Chromium levels at this location are known to fluctuate in response to changing water-table conditions. Potential chromium sources include past disposal of sodium dichromate near H Reactor, disposal to the inactive 116-H-1 liquid waste disposal trench, and chromium in acid waste stored in the former 116-H-6 evaporation basins (Peterson and Connelly 1992). Upgradient sources also include waste sites in the 100-D Area. Chromium was also found at levels above the drinking water standard in one well monitoring a deeper

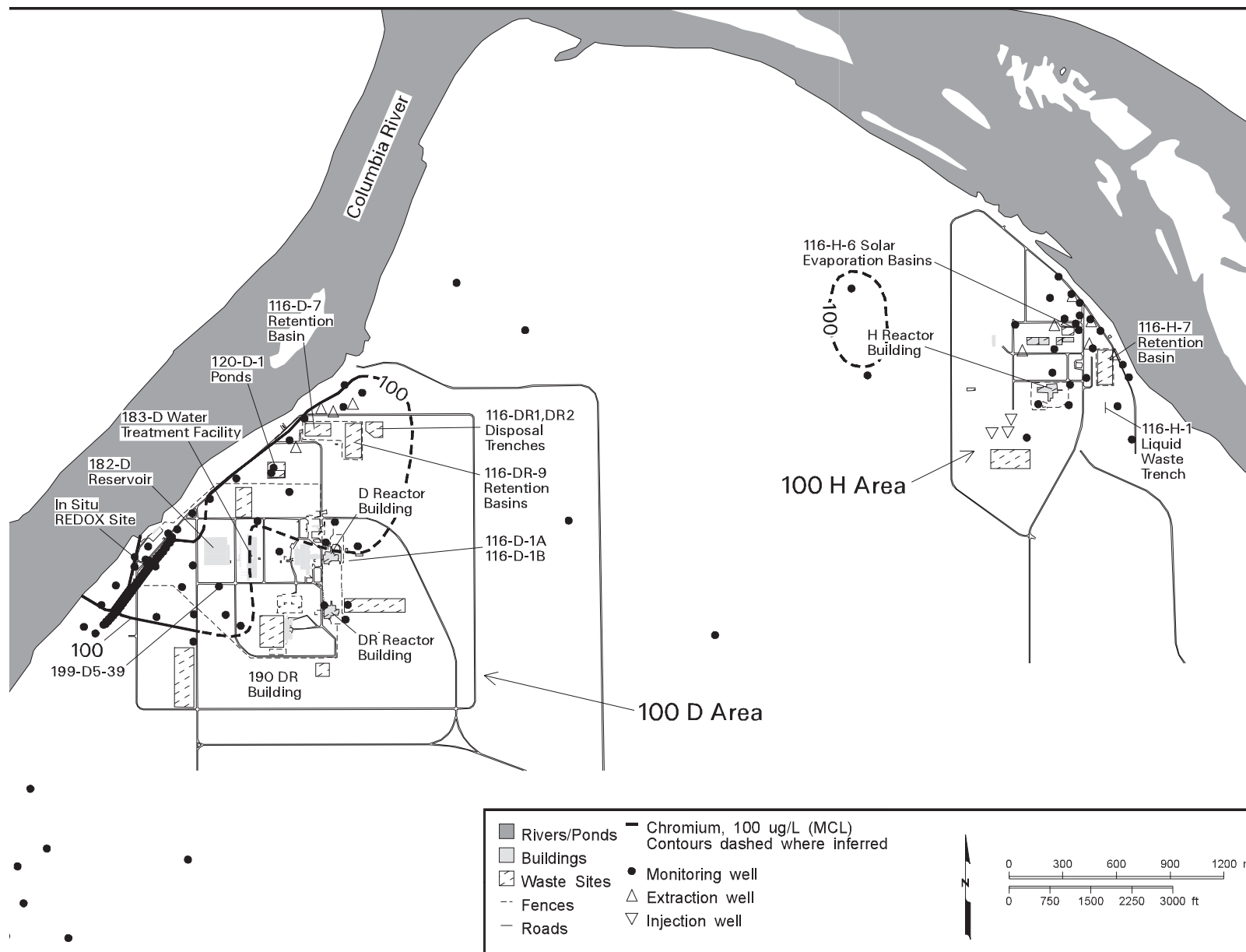
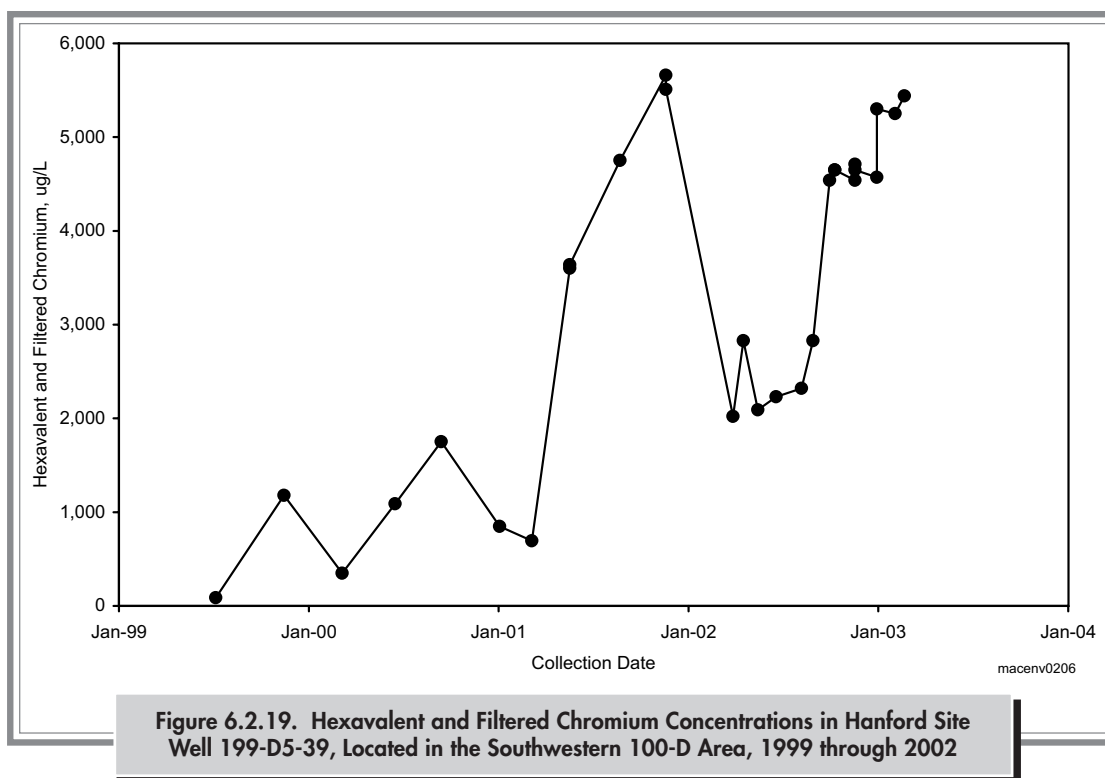


Figure 6.2.18. Average Filtered Chromium Concentrations at the Hanford Site's 100-D and 100-H Areas, 2002



part of the unconfined aquifer. Filtered samples from this well, located near the former 116-H-6 evaporation basins, contained 154 µg/L (0.154 ppm) of chromium during 2002. Chromium levels in this well have been decreasing in recent years, but increased during 2002. Chromium concentrations exceeded the drinking water standard in one 600 Area well west of the 100-H Area. The maximum chromium concentration in this well in 2002 was 112 µg/L (0.112 ppm).

Chromium in the 100-K Area occurs in groundwater at levels greater than the drinking water standard in three areas (Figure 6.2.20). Two localized areas of chromium contamination occur near the KW Reactor and the water treatment basins southeast of the KE Reactor. The maximum concentration measured near the KW Reactor during 2002 was 707 µg/L (0.707 ppm). Chromium concentrations in the plume near the KW Reactor were stable or decreased during 2002. Potential sources of the chromium plume near the KW Reactor are the railcar transfer station and storage tanks southeast of the 183-KW water treatment plant.

The other small chromium plume occurs near the 183-KE water treatment basins. The most likely sources of this chromium are sodium dichromate storage tanks or the railcar transfer station near the area. The maximum chromium

concentration measured in this plume during 2002 was 735 µg/L (0.735 ppm) in a well adjacent to the treatment basins. Chromium concentrations in this plume decreased during 2002 after rising during 2001.

A much wider area of chromium contamination is found in vicinity of the former 116-K-2 liquid waste disposal trench to the northeast of the reactor areas. The maximum concentration in this area in 2002 was 149 µg/L (0.149 ppm).

In the 100-N Area, chromium contamination is not widespread in groundwater. However, filtered samples in one well that monitors a locally confined unit within the Ringold Formation have consistently shown concentrations at steady levels greater than the drinking water standard. This well is northwest of the 116-N-1 liquid waste disposal facility. The maximum chromium concentration measured at this location during 2002 was 168 µg/L (0.168 ppm). Chromium was disposed to the 116-N-1 liquid waste disposal facility until the early 1970s (DOE/RL-96-39).

Chromium in the 200 Areas. Chromium at concentrations greater than the drinking water standard in the 200-East Area was found in two wells on the southern

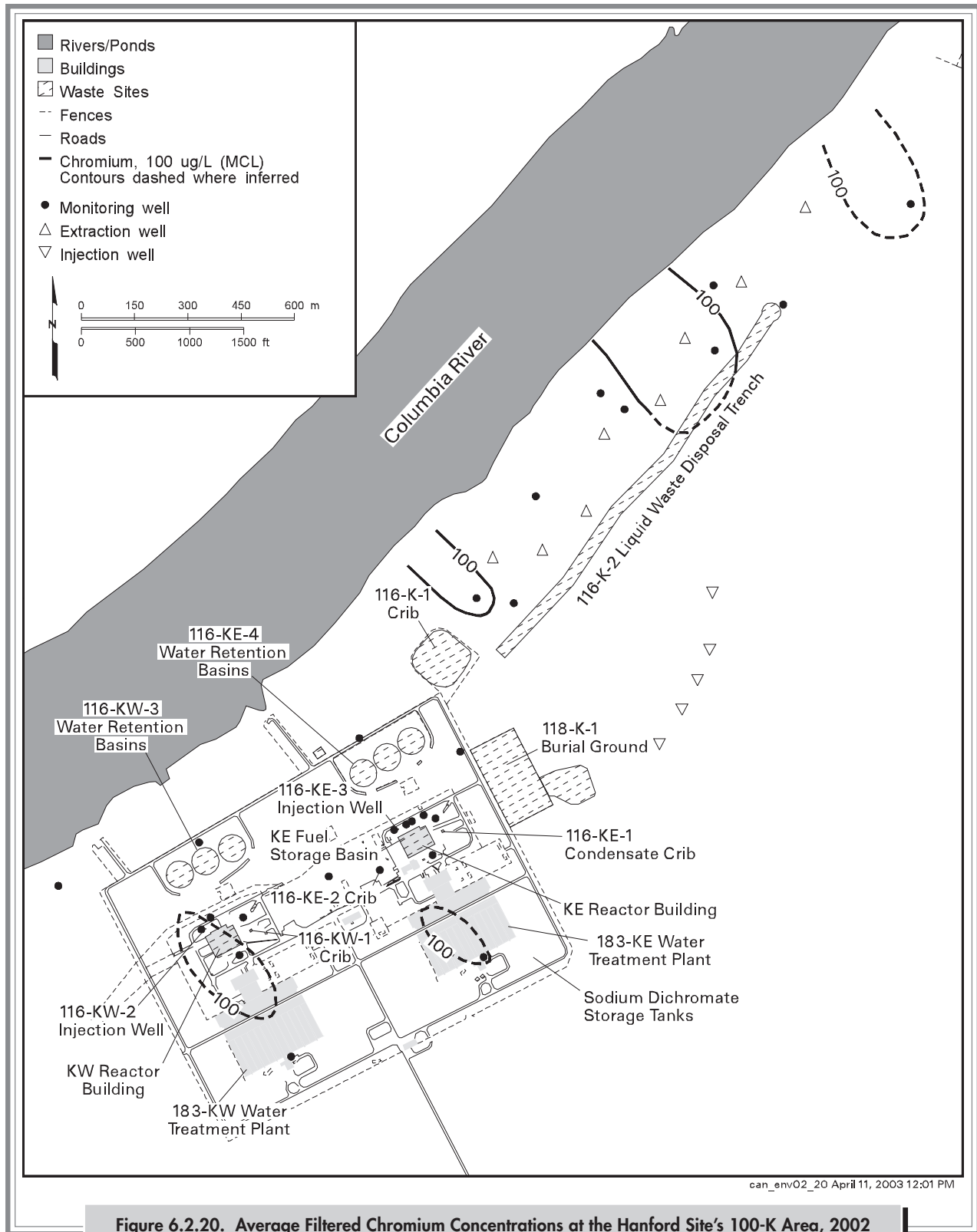


Figure 6.2.20. Average Filtered Chromium Concentrations at the Hanford Site's 100-K Area, 2002

boundary of A and AX Tank Farms. The maximum concentration detected in samples collected from one of these wells during 2002 was 6,250 µg/L (6.25 ppm).

Chromium contamination in groundwater has been found in small areas in the 200-West Area. Areas where concentrations exceeded the drinking water standard during 2002 include the T, TX, and TY Tank Farms, the former 216-S-10 pond, and near the Reduction-Oxidation Plant. Filtered samples from a well east of TX and TY Tank Farms showed a maximum concentration of 427 µg/L (0.427 ppm), which is the highest filtered chromium concentration measured in the 200-West Area during 2002. Chromium concentrations have generally been increasing near TX and TY Tank Farms. In 2002, a small chromium plume in the vicinity of T Tank Farm showed a maximum chromium concentration of 307 µg/L (0.307 ppm). Chromium concentrations generally increased near T Tank Farm during 2002. The 216-T-36 crib and pipes leading to the crib are suspected of being sources of the chromium contamination at T Tank Farm. Chromium concentrations near the former 216-S-10 pond increased to levels above the drinking water standard during 2002. Chromium concentrations near this facility reached a maximum of 204 µg/L (0.204 ppm). Near the Reduction-Oxidation Plant, chromium concentrations have shown an increasing trend since 1997 and increased to 381 µg/L (0.381 ppm) during 2002.

Chromium in Other Areas. Filtered chromium concentrations have consistently exceeded the drinking water standard in groundwater just southwest of the 200-East Area. This area was not sampled for filtered chromium during 2001 and 2002 because the sampling frequencies for these wells were changed from annual to every 3 years. The maximum concentration detected in filtered samples in this area during 2000 was 201 µg/L (0.201 ppm). Filtered chromium will be sampled again in this area in 2003. The extent of chromium contamination in this area is poorly defined, and the source has not been determined.

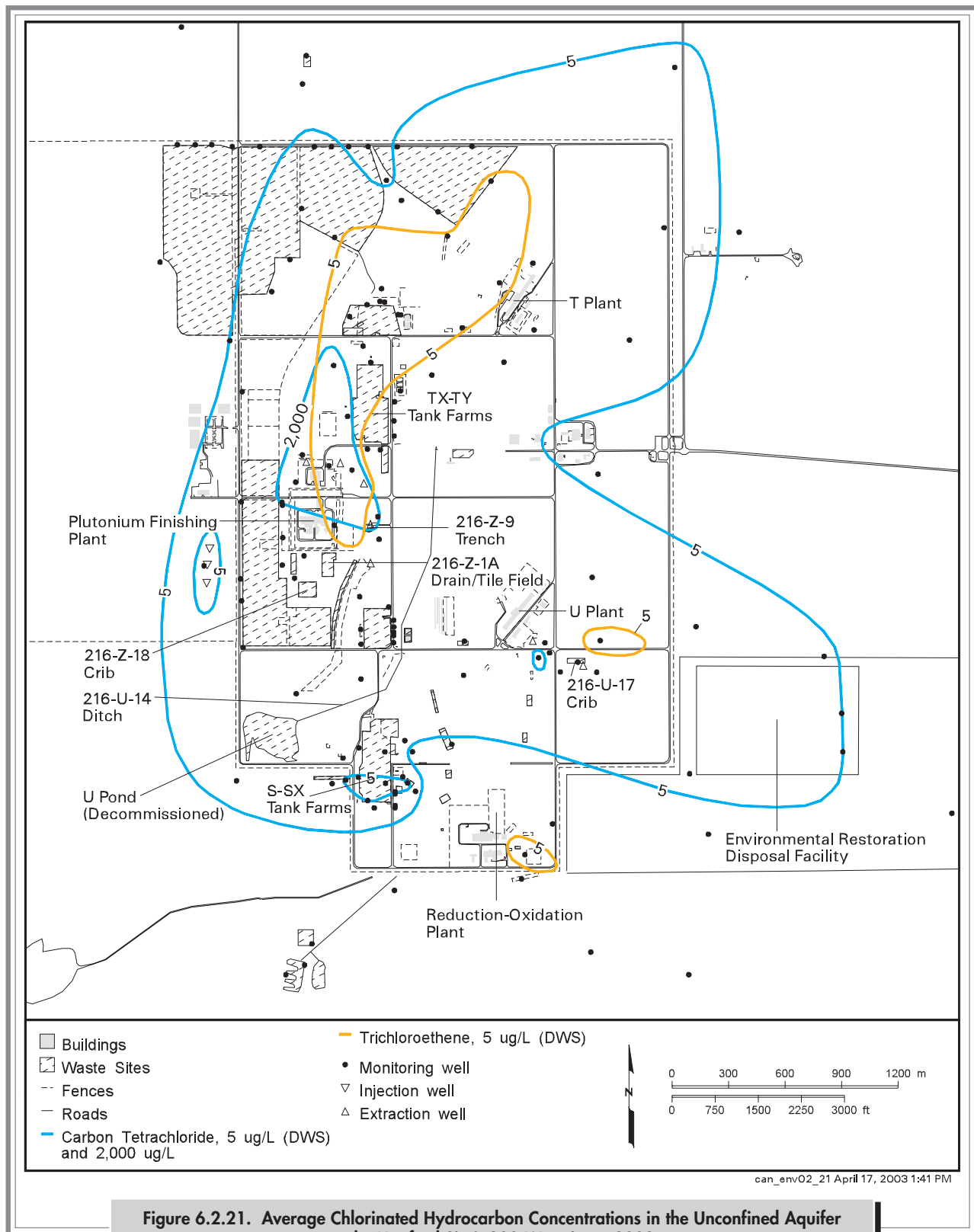
Carbon Tetrachloride. Carbon tetrachloride occurs at levels exceeding its drinking water standard (5 µg/L [0.005 ppm]) in much of the 200-West Area and represents one of the most significant contaminant plumes at the Hanford Site (Figure 6.2.21). The plume, which covers an area of more than 11 square kilometers (4 square miles), extends past the 200-West Area boundary into the 600 Area. The maximum detected concentration in this plume during

2002 was 6,900 µg/L (6.9 ppm) in a pump-and-treat well north of the Plutonium Finishing Plant.

The bulk of the contamination is believed to be from pre-1973 waste disposal operations associated with the Plutonium Finishing Plant in the west-central part of the 200-West Area. Major sources identified in this area include the 216-Z-9 trench, the 216-Z-1A drain/tile field, and the 216-Z-18 crib. Carbon tetrachloride was used as the carrier solvent for tributyl phosphate in the final purification of plutonium. Carbon tetrachloride was also used in the same facility as a non-flammable thinning agent while machining plutonium. A minor source of carbon tetrachloride is a former waste disposal crib near T Plant. Carbon tetrachloride is immiscible in water but exhibits a relatively high solubility (805,000 µg/L [804 ppm] at 20°C [68°F]). Carbon tetrachloride has been found to have a relatively high degree of mobility in groundwater. Mobilization above the water table can also occur through vapor transport. Monitoring and soil-gas extraction of carbon tetrachloride in the vadose zone are discussed in Section 7.2.

Wells in vicinity of the Plutonium Finishing Plant showed the highest concentrations in the plume. The maximum concentration measured during 2002 was 6,900 µg/L (6.9 ppm) in a pump-and-treat extraction well just north of the plant. Pump-and-treat operations, which began during 1994, have influenced the distribution of carbon tetrachloride in the vicinity of the operations. The purpose of the pump-and-treat system is to contain the portion of the carbon tetrachloride plume where concentrations are >2,000 µg/L (>2 ppm), which extends to the north reaching an area west of TX and TY Tank Farms (Section 2.3.13). The extraction wells are located north and east of the Plutonium Finishing Plant. Carbon tetrachloride concentrations generally were stable in the center part of the plume during 2002. Carbon tetrachloride concentrations continued to be below the minimum detection limit in the pump-and-treat injection wells southwest of the plant during 2002. Concentrations in these injection wells have declined because of injections of the treated water.

The carbon tetrachloride plume is divided into two major lobes, one in the northern half and one in the southern half of the 200-West Area. In the northern lobe, an area of increasing carbon tetrachloride concentrations has moved



slowly beyond the northeastern 200-West Area boundary since 1997. This area is the greatest concern for transport of carbon tetrachloride from the 200-West Area. The highest concentration detected in this northern lobe during 2002 was 1,500 µg/L (1.5 ppm) near T Plant in the 200-West Area. In the southern lobe of the carbon tetrachloride plume, carbon tetrachloride concentrations increased in wells near S and SX Tank Farms from levels less than the drinking water standard during 1995 to a maximum of 290 µg/L (0.29 ppm) during 2002.

The extent of carbon tetrachloride contamination in deeper parts of the aquifer is uncertain because of the limited amount of concentration data collected from depths below the water table. The available data indicate that concentrations are highest at the top of the aquifer and decline with depth at most locations within the plume. During 2002, carbon tetrachloride concentrations ranging between 130 and 180 µg/L (0.13 and 0.18 ppm) were detected at depths of greater than 19 meters (62 feet) below the water table near U Plant. These concentrations indicate that carbon tetrachloride contamination has moved into deeper parts of the unconfined aquifer at locations considerably distant from and downgradient of the source area.

Changes in groundwater flow since 216-U-10 pond (U Pond) was decommissioned in 1984 may have influenced the plume configuration and the concentrations at particular locations. Another potential influence is the continued spreading of carbon tetrachloride in the vadose zone above the water table, in either a liquid or a vapor phase. Carbon tetrachloride in the liquid phase above and possibly below the water table may provide a continuing source of groundwater contamination, in which case, lateral expansion of the carbon tetrachloride plume will continue.

Chloroform. A chloroform plume appears to be associated with, but not exactly coincident with, the carbon tetrachloride plume in the 200-West Area. The highest chloroform concentrations were measured in a new well near the Plutonium Finishing Plant, where the maximum level measured during 2002 (January) was 680 µg/L (0.68 ppm). However, chloroform concentrations at this well decreased to levels less than the drinking water standard one month later. The drinking water standard for chloroform was reduced from 100 µg/L (0.1 ppm) (total trihalomethanes) to

80 µg/L (0.08 ppm) during January 2002 (EPA 822-F-02-013). The origins of the chloroform are suspected to be the chlorination of organic matter during purification of potable water or the biodegradation of carbon tetrachloride.

Trichloroethene. A commonly used organic solvent, trichloroethene has a drinking water standard of 5 µg/L (0.005 ppm). In 2002, trichloroethene was detected at levels greater than the drinking water standard in several wells in the 100 and 200 Areas. The most widespread area of groundwater contamination occurred in the 200-West Area.

Trichloroethene in the 100 Areas. Trichloroethene was detected in groundwater at levels greater than the drinking water standard in the southwestern corner of the 100-F Area. Trichloroethene concentrations in this area showed increases during 2002. The maximum concentration detected in the 100-F Area during 2002 was 9.8 µg/L (0.0098 ppm). No specific sources of this contamination have been identified.

In the 100-K Area, a localized area of trichloroethene contamination occurs near the KW Reactor complex. This area of contamination resulted from the past disposal/spillage of organic solvents. One well downgradient of the KW Reactor showed a maximum trichloroethene concentration above the drinking water standard at a level of 11 µg/L (0.011 ppm). Trichloroethene concentrations in groundwater near the KW Reactor complex are gradually declining with time.

Trichloroethene in the 200 Areas. Trichloroethene was detected at levels greater than the drinking water standard in wells in several parts of the 200-West Area (Figure 6.2.21). The most significant area extends from the Plutonium Finishing Plant northeast to an area west of T Plant. Sources of the contamination are presumably disposal facilities near the plant. The highest concentration measured during 2002 was 16 µg/L (0.016 ppm) in a well west of TX and TY Tank Farms. A smaller, isolated area of trichloroethene contamination occurs downgradient of the U Plant cribs, where the maximum concentration measured during 2002 was 8.8 µg/L (0.0088 ppm). Another localized area of trichloroethene contamination occurs east of the Reduction-Oxidation Plant in the southern part of the 200-West Area. The maximum concentration in this area during 2002 was 15 µg/L (0.015 ppm).

cis-1,2-Dichloroethene. Concentrations of cis-1,2-dichloroethene remain elevated in one well near the former process trenches and ponds in the 300 Area. This well is completed in the bottom of the unconfined aquifer and is the only well on the site where this constituent is found at levels above its drinking water standard (70 µg/L [0.07 ppm]). During 2002, a maximum concentration of 160 µg/L (0.16 ppm) was measured in this well. The source of the cis-1,2-dichloroethene is the inactive 316-5 process trenches.

Cyanide. Waste fractionation performed in the late 1950s used large quantities of sodium and nickel ferrocyanide to recover cesium-137. Large volumes of aqueous supernatant waste containing excess ferrocyanide were disposed to the ground in both the northern and southern portions of the 200-East Area. Smaller quantities were also disposed to former cribs in the 200-West Area. Procedures used to analyze for cyanide do not distinguish between ferrocyanide and free cyanide. Cyanide results reported here are assumed to be residual ferrocyanide associated with the discharges from the waste fractionation activities performed more than 30 years ago. A chemical speciation study performed in 1988 indicated that approximately one-third of the cyanide in groundwater is present as free cyanide and the rest may be present as ferrocyanide (Section 4.1 in PNL-6886 and Section 3.2.2 in PNL-7120). The drinking water standard for cyanide is 200 µg/L (0.2 ppm).

The highest cyanide levels measured in groundwater during 2002 were detected in samples collected from wells in the northwestern part of the 200-East Area. Samples collected from two wells near the inactive BY cribs in 2002 showed concentrations above the drinking water standard. The maximum concentration near the cribs was 299 µg/L (0.299 ppm). Cyanide levels near the cribs generally remained stable during 2002. Although cobalt-60 is normally immobile in the subsurface, it appears to be chemically complexed by cyanide or ferrocyanide. The complexed chemical species is more soluble and more mobile in groundwater (Peterson et al. 2002).

Fluoride. At this time, fluoride has a primary drinking water standard of 4 mg/L (4 ppm) and a secondary standard of 2 mg/L (2 ppm). Secondary standards are based primarily on aesthetic rather than health considerations. Fluoride

was detected above the primary drinking water standard near T Tank Farm in the 200-West Area during 2002. The maximum fluoride concentration measured in 2002 was 4.4 mg/L (4.4 ppm) in a well located on the east side of T Tank Farm. A few other wells near T Tank Farm showed concentrations above the secondary standard. Aluminum fluoride nitrate, used in past 200-West Area processes, is the probable source of the fluoride contamination.

Arsenic. During 2002, arsenic exceeded the 10-µg/L (0.01-ppm)^(b) final drinking water standard in three unfiltered groundwater samples from wells within the in situ redox manipulation zone in the 100-D Area. The reducing environment of the treatment zone increases the solubility of arsenic, which occurs naturally in the aquifer sediments.

6.2.3 RADIOLOGICAL AND CHEMICAL MONITORING RESULTS FOR THE UPPER BASALT-CONFINED AQUIFER

Monitoring the upper basalt-confined aquifer is important because of the potential for the downward migration of contaminants from the overlying unconfined aquifer. Contaminants that reach the upper basalt-confined aquifer have the potential to migrate off the Hanford Site through the upper basalt-confined aquifer. The upper basalt-confined aquifer is also monitored to assess the potential migration of contaminants onto the Hanford Site from offsite sources.

The upper basalt-confined aquifer is monitored by ~20 wells of which most are sampled on a triennial schedule. Most of these wells are located near the 200 Areas in the central part of the Hanford Site (Figure 6.1.2). During 2002, two upper basalt-confined aquifer wells were sampled for tritium, iodine-129, nitrate and other anions, cations, gross alpha, gross beta, and gamma-emitters. Tritium, iodine-129, and nitrate are the most widespread contaminants in the overlying unconfined aquifer, are the most mobile in groundwater, and provide an early warning of potential contamination in the upper basalt-confined aquifer (Figure 6.2.22).

(b) The drinking water standard for arsenic was changed from 50 to 10 µg/L (0.05 to 0.01 ppm) on January 22, 2001 (40 CFR Parts 9, 141, and 142).

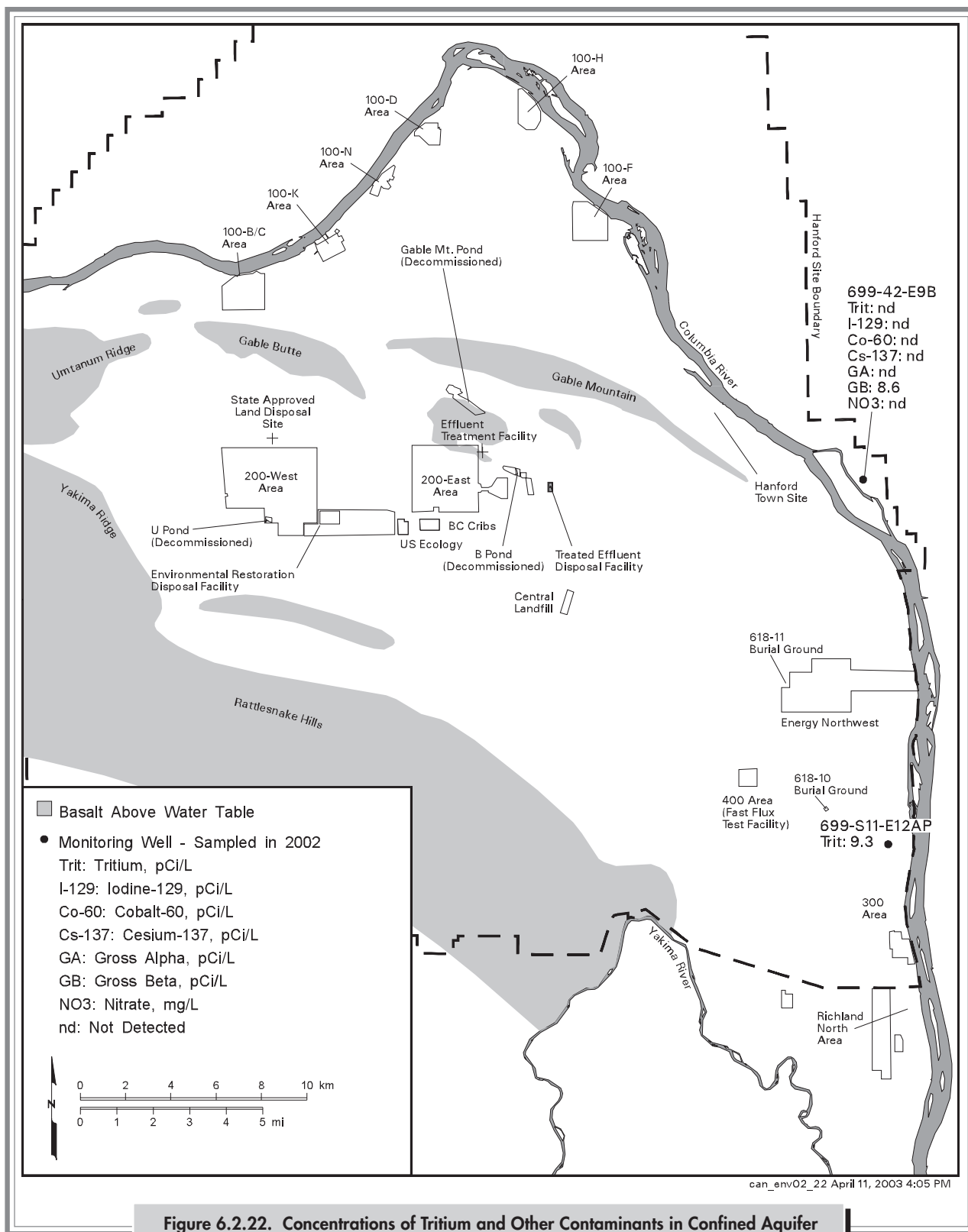


Figure 6.2.22. Concentrations of Tritium and Other Contaminants in Confined Aquifer Wells on the Hanford Site, 2002

6.2.4 GROUNDWATER FLOW

The water-table elevation contours for the Hanford Site unconfined aquifer indicate the direction of groundwater flow and the magnitude of the hydraulic gradient (Figure 6.2.23). Groundwater flow is generally perpendicular to the water-table contours from areas of higher elevation to areas of lower elevation. Areas where the contours are closer together are high-gradient areas, where the driving force for groundwater flow is greater. However, because sediment with low permeability inhibits groundwater flow, producing steeper gradients, a high gradient does not necessarily mean high groundwater velocity. Lower permeability and steeper gradients are often associated with areas where the water table is below the bottom of the Hanford formation and the aquifer is entirely within the less permeable Ringold sediment. Additional information on aquifer hydraulic properties at Hanford is presented in DOE/RW-0164 (Vol. 2) and PNL-8337.

Recharge of water within the unconfined aquifer (RHO-ST-42) comes from several sources. Natural recharge occurs from infiltration of precipitation along the mountain fronts, run-off from intermittent streams such as Cold and Dry Creeks on the western margin of the site, and limited infiltration of precipitation on the site. The Yakima River, where it flows along the southern boundary of the site, also recharges the unconfined aquifer. The Columbia River is the primary discharge area for the unconfined aquifer. However, the Columbia River also recharges the unconfined aquifer for short periods during high-river stage, when river water is transferred into the aquifer along the riverbank. Recharge from infiltration of precipitation is highly variable on the Hanford Site both spatially and temporally. The rate of natural recharge depends primarily on soil texture, vegetation, and climate (Gee et al. 1992; PNL-10285). Natural recharge rates range from near zero, where fine-grained soil and deep-rooted vegetation are present, to greater than 10 centimeters (4 inches) per year in areas where soil is coarse textured and bare of vegetation.

Large-scale, artificial recharge to the Hanford Site unconfined aquifer occurred because of past liquid waste disposal

in the operating areas and offsite agricultural irrigation to the west and south of the site. Discharge of wastewater caused the water table to rise over most of the Hanford Site. Since the peak discharge in 1984, discharge of wastewater to the ground at Hanford has been significantly reduced and, in response, the water table subsequently declined over most of the site. The water-table elevation declined up to 0.25 meter (0.8 foot) over most of the site between 2001 and 2002. The water-table elevation declined by an average of 0.19 meter (0.6 foot) in the 200-East Area and 0.36 meter (1.2 feet) in the 200-West Area. A result of the declining water table is that 52 wells have gone dry at the Hanford Site, including 45 in the 200 Areas, since 1997.

A large decline in the water table between 2001 and 2002 was 1.19 meter (3.9 feet) near the Richland North Well Field and Recharge Basins south of the Hanford Site. This decline is a response to a change in the net volume of recharge at the recharge basins.

The decline in the water table has altered the flow pattern of the unconfined aquifer on the site, which is generally from the recharge areas in the west to the discharge areas (primarily the Columbia River) in the east and north. Water levels in the unconfined aquifer have continually changed as a result of variations in the volume and location of wastewater discharge. Consequently, the movement of groundwater and its associated constituents has also changed with time (Sections 6.2.1 and 6.2.2).

In the past, two major groundwater mounds formed near the 200-East and 200-West Areas in response to wastewater discharges. The first of these mounds was created by disposal at the U Pond in the 200-West Area. After U Pond was decommissioned in 1984, the mound slowly dissipated. The water table continues to decline in this area. The second major mound was created by discharge to the decommissioned, or former, 216-B-3 pond (B Pond), east of the 200-East Area. After discharge to B Pond ceased in August 1997, the decline in the water-table elevation accelerated. Groundwater mounding related to wastewater discharges also occurred in the 100 and 300 Areas in the past. However, groundwater mounding in these areas was not as great as in the 200 Areas primarily because of lower discharge volumes.

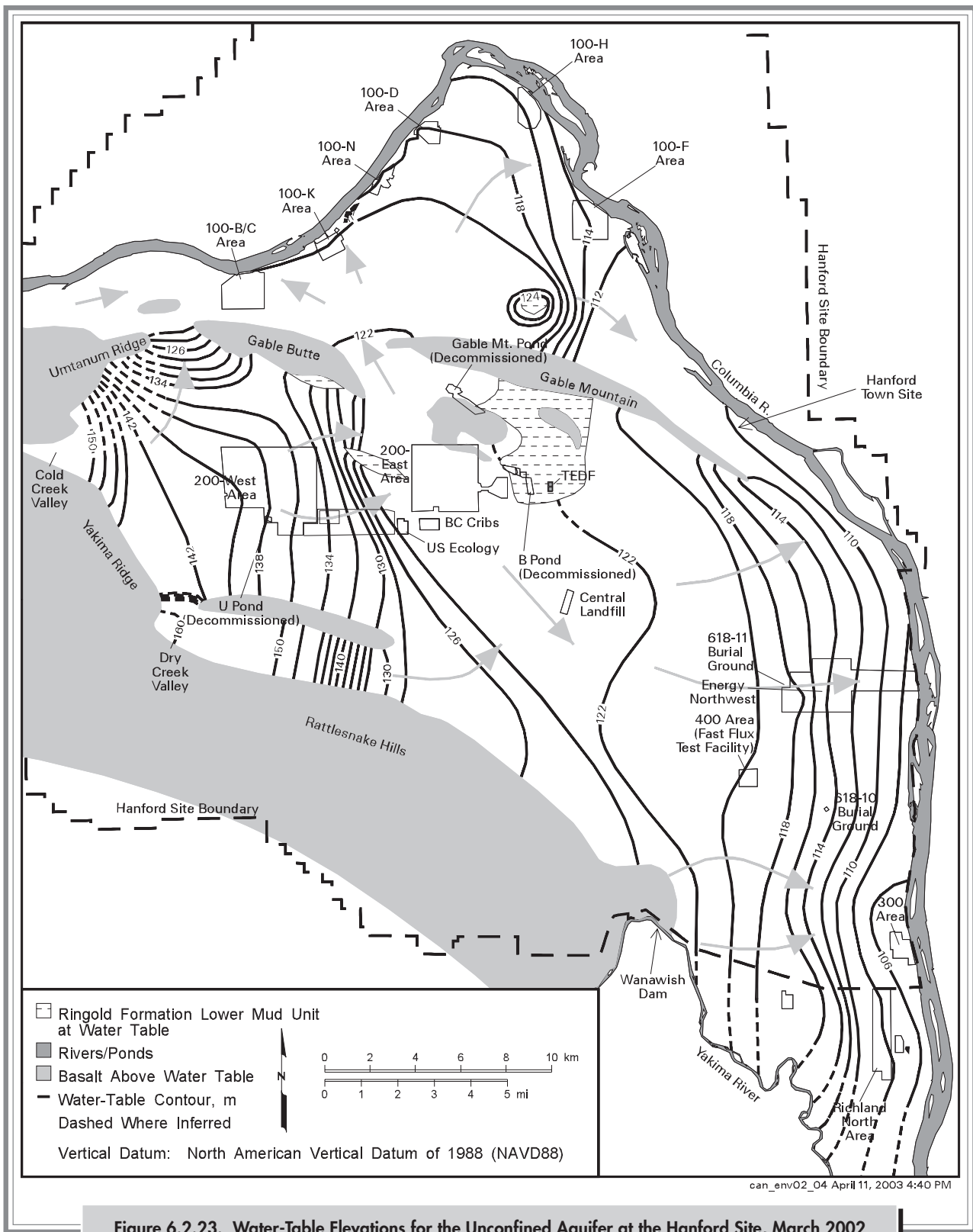


Figure 6.2.23. Water-Table Elevations for the Unconfined Aquifer at the Hanford Site, March 2002



6.3 GROUNDWATER MODELING

P. D. Thorne

Computer models are used to predict the movement of contaminants in groundwater beneath the Hanford Site. These predictions are important for planning waste management and cleanup activities. For large-scale problems, such as contaminant movement from the Central Plateau to the Columbia River, a three-dimensional site-wide model was developed. This model is being improved to represent groundwater flow more realistically and to quantify the uncertainty in model predictions. Other groundwater models are used for problems at a local scale (i.e., $< \sim 10$ kilometers [$< \sim 6.2$ miles]), such as the design and evaluation of pump-and-treat systems for groundwater. Groundwater modeling for 2002 included the following activities:

- Continuing development of a site-wide groundwater model.
- Completing the System Assessment Capability initial assessment.
- Creating a site-wide model for the Hanford Site Solid Waste Environmental Impact Statement.
- Modeling potential releases from each of the tank farm areas.
- Evaluating groundwater pump-and-treat systems

6.3.1 DEVELOPMENT OF THE SITE-WIDE GROUNDWATER MODEL

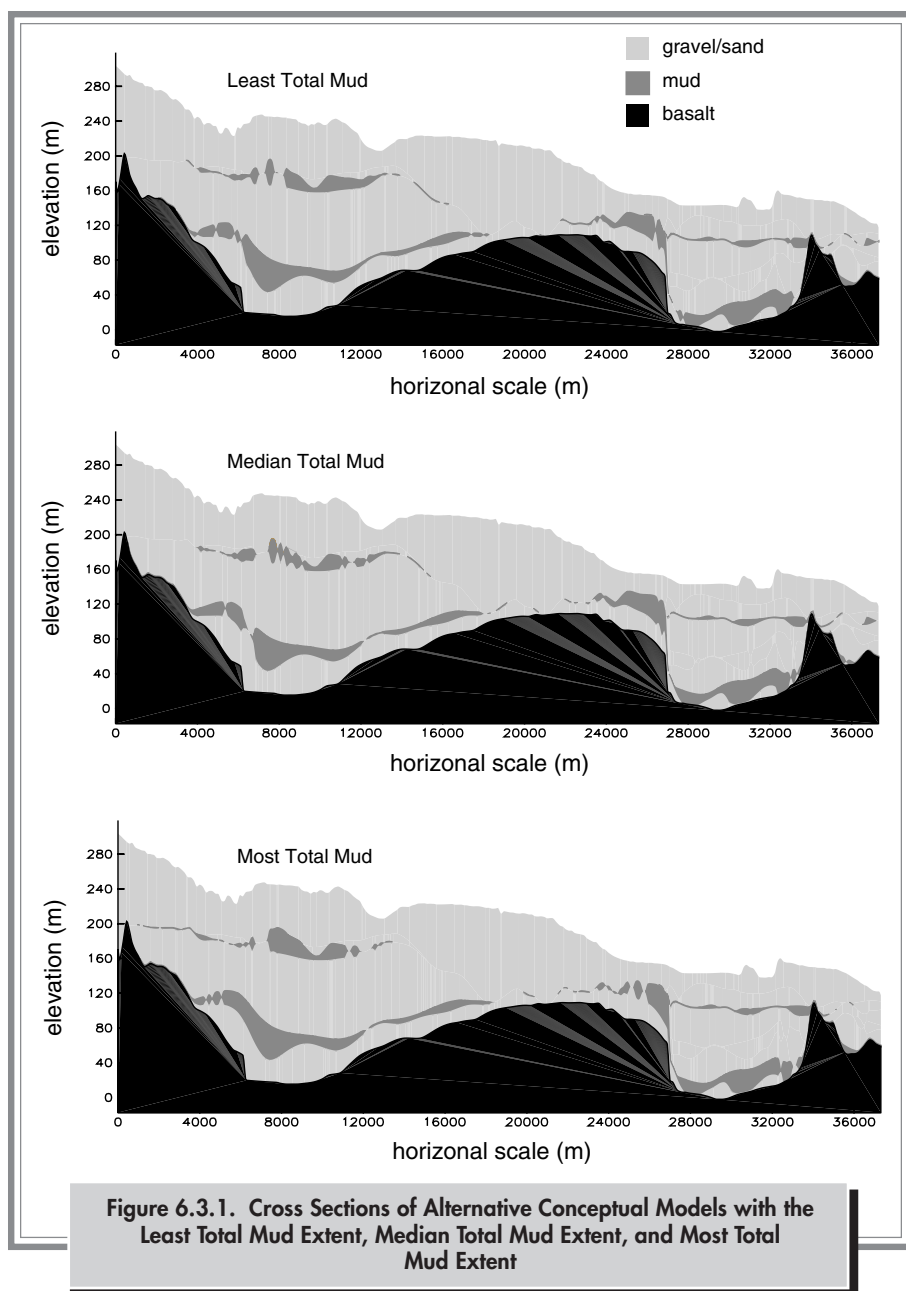
The site-wide groundwater model was developed from information about the hydrogeologic structure of the aquifer, spatial distributions of hydraulic and transport properties, aquifer boundary conditions, and the distribution and movement of contaminants. Model results are uncertain because of incomplete knowledge of the groundwater flow system and because the calculations used in groundwater models only approximate the processes of groundwater flow and transport. Quantifying the uncertainties in model results is a major objective of the consolidated groundwater-modeling task. Understanding and

quantifying the uncertainties in model predictions will strengthen the technical defensibility of groundwater transport predictions and lead to a better basis for waste management and cleanup decisions.

As described in PNNL-13641, uncertainty in the site-wide groundwater model is being quantified through both sensitivity analysis and uncertainty analysis. Sensitivity analysis involves developing alternative conceptual models that encompass identified uncertainties, then calibrating each model based on historical observations of water-level changes and contaminant movement. Results of the different calibrated models will then span the range of results expected based on different assumptions. Uncertainty analysis uses a probability distribution rather than a single value for selected model input parameters. The model then produces a range of results reflecting the uncertainty in the input parameters.

During 2002, alternative conceptual models were developed that address (1) uncertainty in the extent and distribution of major mud units (low-permeability layers) within the unconfined aquifer system, and (2) uncertainty in the distribution of hydraulic conductivity zones within the Hanford formation. The distribution of mud units within the aquifer affects vertical migration of contaminants and also affects lateral movement, particularly where mud units exist at the water table. Three major mud units have been identified at boreholes, but their extent and continuity are uncertain. The Hanford formation is important in transport of groundwater contaminants to the Columbia River because of its relatively high hydraulic conductivity. Therefore, within the groundwater model, the distribution of Hanford formation zones that have unique values of hydraulic conductivity may have a large effect on contaminant movement from the Central Plateau on the Hanford Site to the Columbia River.

Advanced geostatistical techniques were applied to develop the new alternative conceptual models, partially



through a cooperative project between Pacific Northwest National Laboratory and the Russian Academy of Sciences Institute for Nuclear Safety. To address uncertainty in the extent and continuity of mud units, a stochastic simulation method was applied to create a set of 100 realizations that span the range of likely extent/distribution for each of the three mud units. Each realization is an equally probable spatial configuration of the mud unit based on the available borehole data. The realizations for each of the units were merged to create a set of 10,000 different possible combinations. The merged

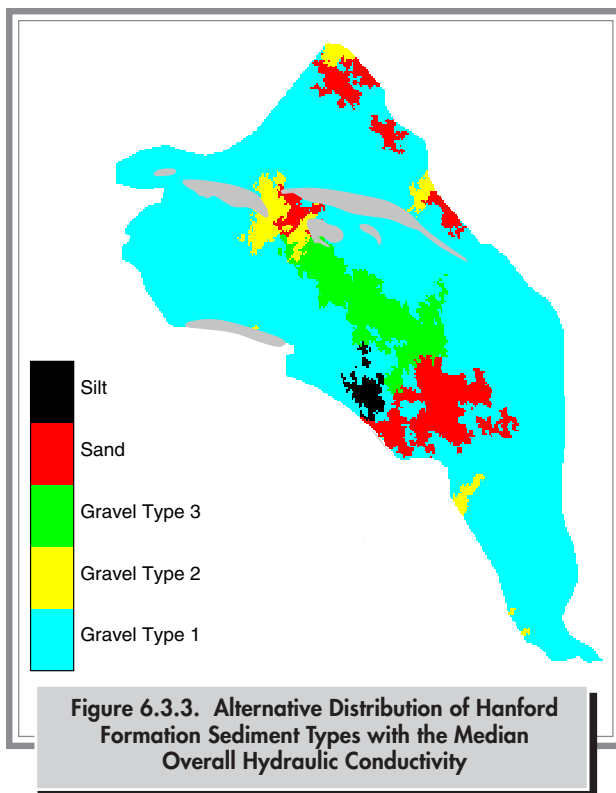
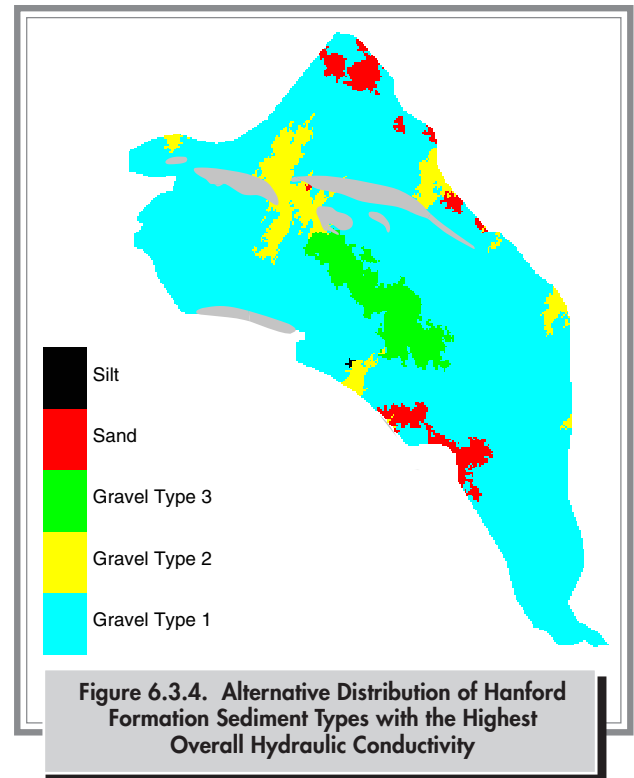
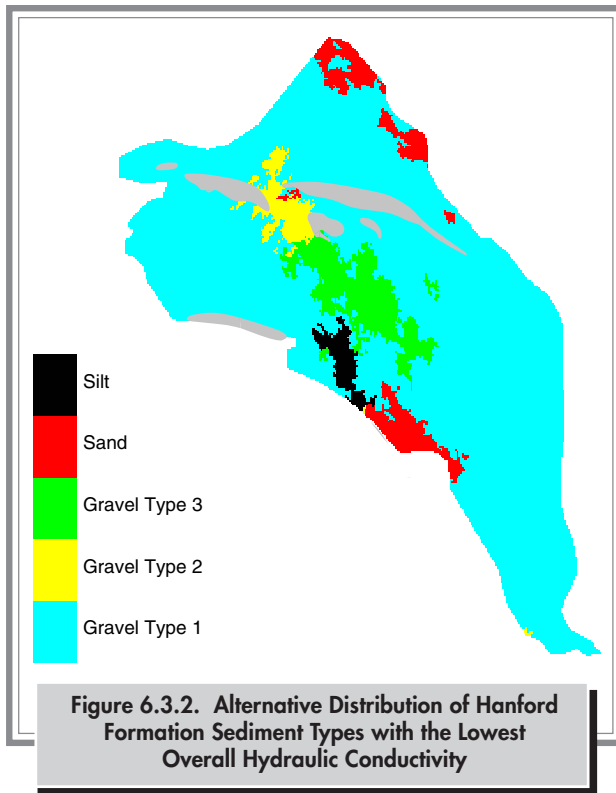
realizations were ranked according to the total area of mud present and the tortuosity (a measure of continuity) for each mud unit. Ranking provided a range of cases to select from for model calibration. Figure 6.3.1 shows cross sections of alternative conceptual models generated from the extreme (least mud and most mud) and median cases. These and other cases will be used in the inverse model calibration to create calibrated alternative conceptual models. The calibrated models will then produce a range of results for hydraulic head and contaminant transport that can be compared to historical measurements.

To address uncertainty in the distribution of hydraulic conductivity zones for the Hanford formation, 100 different realizations were created that span the range of likely sediment-type distributions. The realizations were ranked according to overall hydraulic conductivity and tortuosity. Figures 6.3.2 through 6.3.4 show the distribution of different sediment types for the extreme (lowest and highest) and median conductivity realizations. These and other realizations will be calibrated to create alternative models. The calibrated models will produce a range of results for hydraulic

head and contaminant transport that can then be compared to historical measurements. Additional details of the geostatistical methods and results are available in PNNL-14187.

Improvements were also made during 2002 to the site-wide model with the objective of producing more realistic hydraulic parameter estimates and better fits to historical water-level data. The following changes were included in the model:

- Accounting for delay of discharged wastewater caused by transit-time through the vadose zone.



- Creating a separate hydrogeologic unit composed of gravels deposited on top of the Ringold Formation but prior to the Missoula floods. These gravels are found in the east-central portion of the Hanford Site and were previously lumped with Hanford formation (Missoula flood) sediments to form model unit 1.
- Adjusting contacts between layers representing different hydrogeologic sediment types in the area southeast of 200-East Area to make the model more consistent with well data and to create a channel where saturated Hanford formation sediments exist below the water table.
- Adjusting the extent of hydraulic conductivity zones used in the model to represent different sediment types within the Hanford formation.

Significant improvement to the model calibration, compared to an earlier calibration, resulted from the above modifications. However, refinement of the model is continuing, particularly with regard to the distribution of hydraulic conductivity zones within the Hanford formation (model unit 1).

6.3.2 SYSTEM ASSESSMENT CAPABILITY

An initial assessment performed using the System Assessment Capability was completed during 2002. Results including those for the groundwater module are presented in PNNL-14027.

The System Assessment Capability is an integration of several linked computer models that simulates the movement of contaminants from waste sites through the vadose zone, groundwater, and Columbia River. It then assesses the impact of the contaminant releases on human health, other living organisms, the local economy, and cultures. The assessment uses a stochastic analysis, which means that selected parameters are represented by probability distributions from which values are selected.

The initial System Assessment Capability assessment met its primary objectives. The original scope of the effort was to develop and successfully test a site-wide assessment capability addressing composite risks from a suite of representative Hanford contaminants for subsurface and surface water pathways over a 1,000-year period. For the initial assessment, the transport of 10 different radionuclide and chemical contaminants released from 890 waste sites from 1944 through 3050 was simulated. Completion of the initial assessment demonstrates that a site-wide analysis can be accomplished.

6.3.3 MODELING TO SUPPORT THE RECEPTOR RISK MODEL FOR TANK FARMS

The site-wide groundwater model was applied to determine the flow path and travel time to the Columbia River for potential contaminant releases at each of the tank farms located in the 200-East or 200-West Areas. Eighteen tank farms were assessed in this evaluation. Because of the model grid spacing (~375 meters [~1,230 feet]) in the Central Plateau area, releases from some tank farms were

combined at single locations, resulting in consolidation of the 18 tank farms to 8 different combined locations, 5 in the 200-East Area and 3 in the 200-West Area.

The groundwater simulations were performed using the base-case site-wide groundwater model that had been calibrated to water-level changes from 1944 to 1996. Because of the long-term nature of the simulations being made, the flow system was assumed to reflect natural steady-state conditions after the effect of Hanford operational discharges have ceased. The simulations were based on a unit release at each tank farm location for five discrete sorption coefficient (K_d) classes at each location. The sorption coefficient classes applied were 0, 0.2, 0.5, 0.8, 1, and 3. The K_d (Appendix C) classes represent contaminants with different degrees of adsorption to sediments in the aquifer. The 0 K_d class represents a contaminant that moves with the groundwater flow (no adsorption). A K_d class of 3 represents an upper limit at which the contaminant is strongly adsorbed to the sediment and does not move with groundwater in a reasonable amount of time.

Simulated results showed that for all sites, the majority of the contaminant plumes move to the north, through the gap between Gable Mountain and Gable Butte toward the Columbia River. A lesser component of the plumes move to the east toward the Columbia River south of Gable Mountain. Earlier groundwater modeling by Cole et al. (PNNL-11801) suggested that as the water table drops in the central part of the Hanford Site and the saturated thickness of the unconfined aquifer decreases, groundwater flow northward from the 200 Areas may be cutoff by relatively impermeable basalt in the area just north of the 200-East Area. The water table is within a few meters of the currently interpreted basalt surface in this area. However, there is uncertainty in both the elevation of the basalt surface and in the natural recharge and boundary fluxes that control predictions of future water-table elevation. Therefore, the potential for movement of contaminants northward through the gap between Gable Butte and Gable Mountain is also uncertain. These issues are currently being investigated as part of the site-wide groundwater modeling task.

6.3.4 MODELING FOR THE SOLID WASTE ENVIRONMENTAL IMPACT STATEMENT

A version of the site-wide model described in PNNL-11801 was applied to predict transport from low-level burial grounds located in the 200-West and 200-East Areas. This version of the model utilizes a distribution of hydraulic conductivity based on a steady-state calibration of the model. The contaminant source terms for the modeling included both low-level waste that have been previously placed in the burial grounds and waste that are forecast to be placed in the burial grounds before 2046. Results are presented in DOE/EIS-0286D.

6.3.5 LOCAL-SCALE MODELING OF PUMP-AND- TREAT OPERATIONS

The Hanford environmental restoration contractor has performed local-scale modeling during the past several years to design and evaluate pump-and-treat systems for groundwater. Capture and injection zones of extraction and injection wells were determined, and the areas affected by the pump-and-treat systems over time were estimated. During 2002, these models were only updated to reflect the changing water-table elevation in the aquifer and changes in pumping rates. Additional information on these models is provided in DOE/RL-99-79 and DOE/RL-2000-01.



6.4 RCRA SUMMARY

M. J. Hartman

More than 60 treatment, storage, and disposal units are recognized under the RCRA permit for the Hanford Site. The units that required groundwater monitoring are grouped into 24 waste management areas. Locations of these sites were given in Figure 6.1.3. Table 6.4.1 provides a summary of groundwater monitoring activities and

results for these sites during 2002. Additional information, including complete listings of constituents measured in monitoring wells from October 2001 through September 2002, is available in PNNL-14187. Radionuclides are not regulated under RCRA, but are monitored under the *Atomic Energy Act of 1954*.

Table 6.4.1. Summary of Hanford Site RCRA Monitoring Results in 2002

<u>RCRA Unit</u>	<u>Monitoring Status</u>	<u>Highlights in 2002</u>
116-N-1 facility	Indicator evaluation	No contamination indicator parameter exceedance. Revised monitoring plan.
116-N-3 facility	Indicator evaluation	No contamination indicator parameter exceedance. Revised monitoring plan.
120-N-1 and 120-N-2 facilities	Indicator evaluation	No contamination indicator parameter exceedance. Revised monitoring plan.
116-H-6 basins	Corrective action	Corrective-action monitoring continued during operation of the 100-HR-3 chromium pump-and-treat system. Leakage from basins in past contaminated groundwater with chromium, nitrate, technetium-99, and uranium. CERCLA program directs corrective action.
216-A-29 ditch	Indicator evaluation	No contamination indicator parameter exceedance.
216-B-3 pond	Indicator evaluation	Revised monitoring plan to initiate 2-year demonstration of alternative statistical method.
216-B-63 trench	Indicator evaluation	No contamination indicator parameter exceedance. Revised monitoring plan.
216-S-10 pond and	Indicator evaluation	No contamination indicator parameter exceedance. One useable, shallow, down-gradient well, and one upgradient well.
216-U-12 crib	Assessment	Nitrate plume from various sources, including crib. Monitoring network contains just two useable downgradient wells and no upgradient wells.
316-5 process trenches	Corrective action	Trenches and other sources contaminated groundwater with cis-1,2-dichloroethene, trichloroethene, and uranium. Corrective action deferred to CERCLA; involves monitored natural attenuation of contaminants. Trichloroethene below 5 µg/L maximum contaminant level. Implementing 2-year demonstration of alternative statistical method.
LERF	Indicator evaluation	One useable downgradient well. In 2001, Washington State Department of Ecology directed DOE to suspend statistical evaluations.
LLWMA 1	Indicator evaluation	No contamination indicator parameter exceedance.
LLWMA 2	Indicator evaluation	No contamination indicator parameter exceedance. Additional dry well.
LLWMA 3	Indicator evaluation	No contamination indicator parameter exceedance. Wells going dry. Poor down-gradient coverage.
LLWMA 4	Indicator evaluation	No contamination indicator parameter exceedance. Wells going dry. Only two downgradient wells.
NRDWL	Indicator evaluation	No contamination indicator parameter exceedance.
PUREX cribs	Assessment	Nitrate plume from various sources, including PUREX cribs.

Table 6.4.1. (contd)

<u>RCRA Unit</u>	<u>Monitoring Status</u>	<u>Highlights in 2002</u>
SST WMA A-AX	Indicator evaluation	No contamination indicator parameter exceedance. Revised monitoring plan.
SST WMA B-BX-BY	Assessment	Tanks may have contributed to nitrate and nitrite plumes. Other major sources (e.g., BY cribs, 216-B-8 crib) produced most contamination.
SST WMA C	Indicator evaluation	Directions of groundwater flow re-interpreted. Revised monitoring plan. Ceased statistical evaluation until new background established.
SST WMA S-SX	Assessment	Sources within tank farms contaminated groundwater with chromium and nitrate. Revised monitoring plan. New assessment report.
SST WMA T	Assessment	Chromium and nitrate had source within tank farm. New assessment report.
SST WMA TX-TY	Assessment	Nearby pump-and-treat system affects groundwater flow, may have impact on distribution of contaminants. Technetium-99 may be drawn from beneath WMA into pump-and-treat. Plume containing chromium and nitrate originated within WMA. New assessment report.
SST WMA U	Assessment	Nitrate elevated.

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act.*
 DOE = U.S. Department of Energy.
 LERF = Liquid Effluent Retention Facility.
 LLWMA = Low-Level Waste Management Area.
 NRDWL = Nonradioactive Dangerous Waste Landfill.
 PUREX = Plutonium-Uranium Extraction Plant.
 SST = Single-shell tank.
 WMA = Waste management area.



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7.0 VADOSE ZONE

S. P. Reidel and D. G. Horton

The vadose zone is the area between the ground surface and the water table. Radioactive and hazardous waste in the soil from past intentional liquid waste disposals, unplanned leaks, solid waste burial grounds, and underground tanks at the Hanford Site are sources of continuing and future vadose zone contamination. During 2002, subsurface source characterization, vadose zone monitoring, and soil-gas monitoring were conducted to better understand the distribution of subsurface contaminants and to track the movement of vadose zone contamination. Also, vadose zone remediation and associated characterization to assess post-remediation contamination were conducted during 2002 as part of cleanup efforts at the Hanford Site.

This chapter summarizes the results of vadose zone studies associated with reactor operations, past single-shell tank leaks, and liquid disposals from spent fuel processing. This chapter contains the results of several technical studies, which could lead to new understanding of moisture and contaminant movement in the vadose zone, contaminant interactions with the soil column, and new and improved methods to characterize and monitor the vadose zone. Information is included about how vadose zone contamination could affect groundwater in the future.



7.1 VADOSE ZONE CHARACTERIZATION

S. P. Reidel and D. G. Horton

This section describes significant vadose zone characterization activities that occurred during 2002. These characterization activities were done to further the understanding of physical and chemical properties of the vadose zone and vadose zone contamination and to help determine the extent of existing vadose zone contamination. During the year, vadose zone characterization activities were completed to evaluate the effectiveness of the remedial actions related to the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) and to characterize existing vadose zone contaminant plumes to help plan future CERCLA remedial actions.

Also during the year, several characterization efforts were performed at single-shell tank waste management areas. At Waste Management Area TX-TY in the 200-West Area, three new characterization boreholes were drilled and sampled to learn more about contaminant distribution, particularly uranium, and contaminant transport mechanisms. The results of extensive geochemical characterization of core samples from Waste Management Area B-BX-BY in the 200-East Area became available during 2002. These data allow comparison of contaminated vadose zone sediment with uncontaminated sediment. In addition, the data are used to determine the leading edge of contaminant plumes beneath single-shell tanks in the waste management area. The same drill cores were used for several laboratory studies to determine the geochemical characteristics of strontium and uranium in the vadose zone at Waste Management Area B-BX-BY.

Finally, characterization of the vadose zone at the location of the proposed Integrated Disposal Site in the 200-East

Area continued during 2002 to support the 2005 U.S. Department of Energy (DOE) performance assessment of the site.

7.1.1 VADOSE ZONE CHARACTERIZATION FOR REMEDIATION AT PAST-PRACTICE DISPOSAL FACILITIES

Vadose zone characterization was completed at five operable units in the 200 Areas to support remediation of sites that received waste from past-practice spent-fuel processing. Characterization was completed at the 200-PW-1, 200-TW-1, 200-TW-2, 200-ZP-1, and 200-CS-1 Operable Units. The results of the characterization provide needed information to plan remedial activities in those areas. Characterization also was completed at one site in the 100-F Area to assess the effectiveness of remediation in the reactor areas.

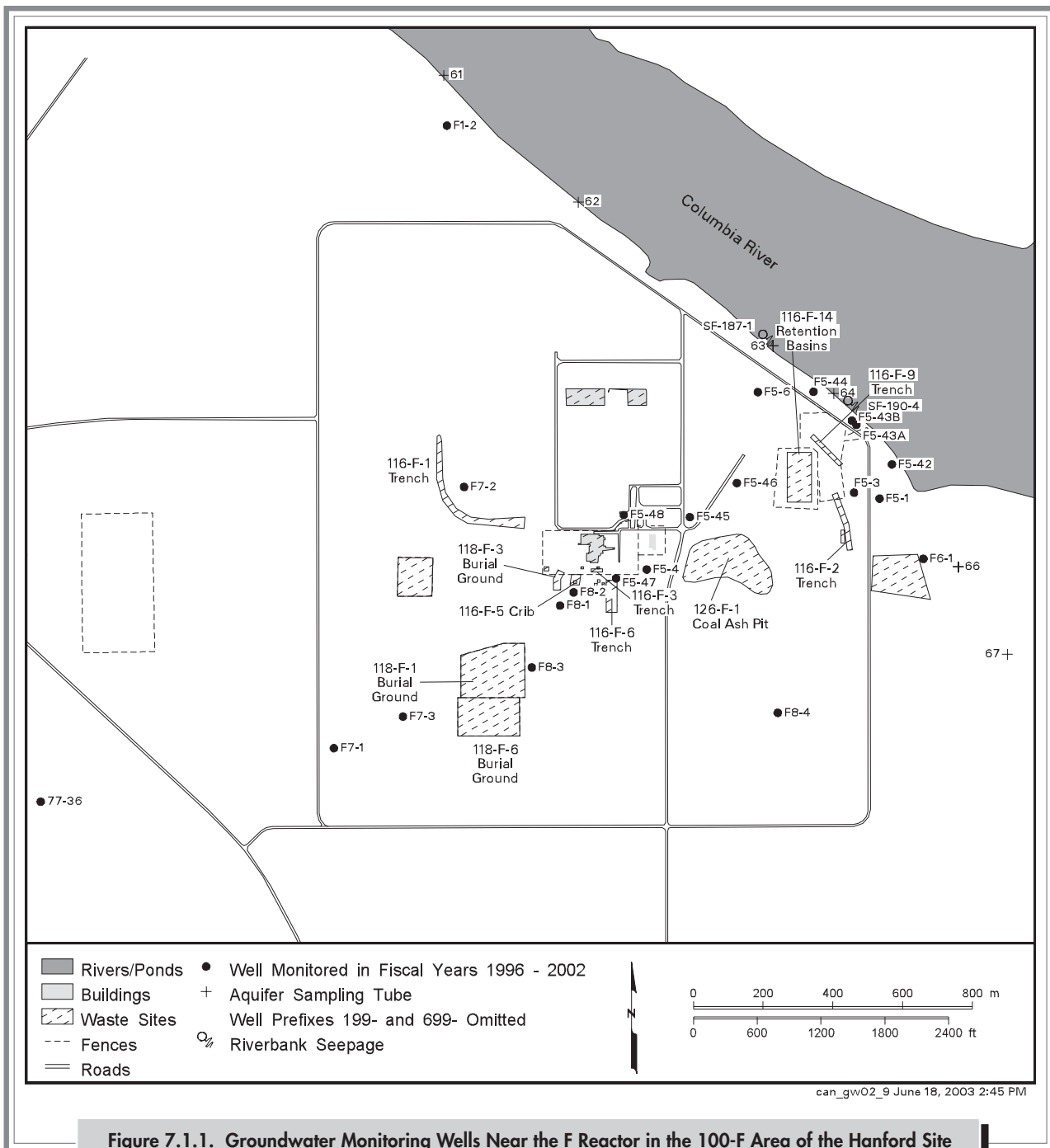
7.1.1.1 CHARACTERIZATION AT 116-F-14 RETENTION BASIN

S. W. Clark

Bechtel Hanford, Inc. excavated a test pit in the 116-F-14 retention basins at the 100-FR-1 Operable Unit, 100-F Area during 2000 and 2001. The results of analyses from the excavated sediment became available during 2002. Figure 7.1.1 shows the location of the 116-F-14 retention basins. The full description of the activities can be found in BHI-01613.

The 116-F-14 retention basins received essentially all cooling water effluent from F Reactor when the reactor was operating from 1945 to 1965. The retention basin was

A characterization borehole is a boring into the earth where sediment is collected and examined to address a specific question. In addition, the open borehole can then be used as an access way for instruments that can examine the sediment surrounding the borehole.



made of reinforced concrete and was divided lengthwise into two chambers to hold the cooling water for a brief period of time, allowing radioactive decay and thermal cooling to occur before the water was discharged to the Columbia River. Numerous instances of retention basin leakage and overflows contaminated the sediment in the immediate vicinity of the basin, including the sediment beneath the basins.

The objective of the excavation and sampling of the test pit was to determine the extent and distribution of contaminants within the vadose zone between the base of the basin and the water table. The test pit was dug in a depression that was the former location of a sump used to transfer process effluent and had formerly been a small, localized zone of contamination.

The sediment data indicate that concentrations of cobalt-60, nickel-63, cesium-137, europium-152, and europium-154, total chromium, hexavalent chromium, lead, and mercury decrease with increasing depth. However, arsenic concentrations were found to increase with depth. The highest concentrations of contaminants were found immediately below the bottom of the retention basin. The same general residual contamination profile has been observed for other remedial action excavations throughout the 100 Areas.

7.1.1.2 CHARACTERIZATION OF THE 200-TW-1 OPERABLE UNIT

M. E. Todd and C. A. Kahler-Royer

Bechtel Hanford, Inc. drilled a borehole through the 216-T-26 crib in the 200-West Area during 2001 to characterize the nature and extent of contamination as part of the remedial investigation for the 200-TW-1 Operable Unit (BHI-01606). The site received waste from uranium recovery and ferrocyanide processes between August 1955 and November 1956 when the crib was deactivated. Data from field screening, geophysical logging, and analytical results from sediment samples became available during 2002 (Figure 7.1.2 shows the location of the crib).

The data indicate that contaminant distribution is influenced by the contacts between sedimentary layers where significant changes in texture (i.e., grain size) occur. These texture changes result in retardation of many contaminants including cobalt-60, cesium-137, and europium-154. Contaminants that typically are not retarded by sediment, including chloride, hexavalent chromium, and nitrate, are able to reach the water table.

7.1.1.3 CHARACTERIZATION AT THE 200-PW-1 AND 200-ZP-1 OPERABLE UNITS

V. J. Rohay and D. G. Horton

Investigations were conducted in the 200-West Area at the Plutonium Finishing Plant and 216-Z-9 trench during 2002 to support carbon tetrachloride remediation efforts (BHI-01631). Near the Plutonium Finishing Plant, a

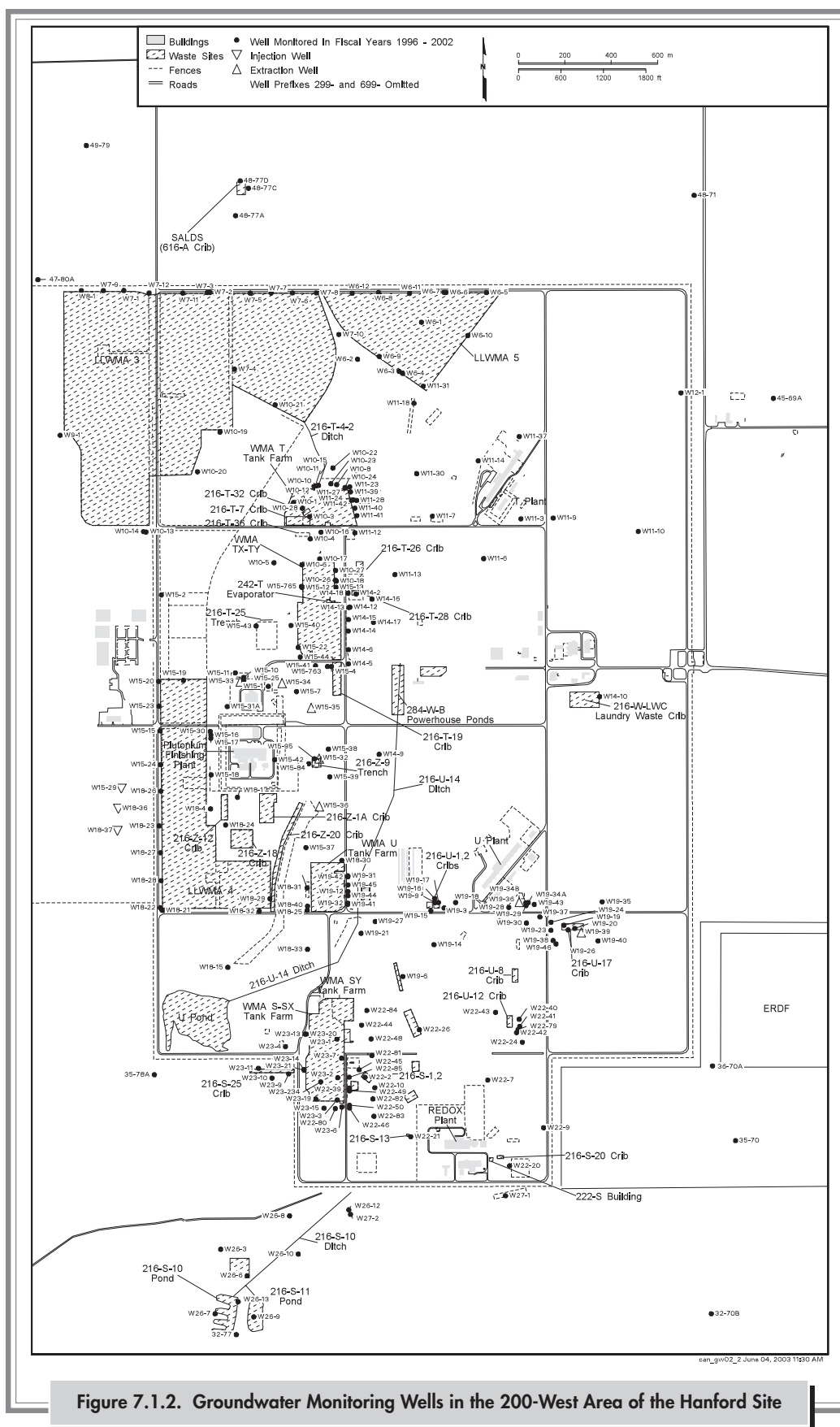
groundwater extraction/monitoring well (299-W15-42) was installed as part of the 200-ZP-1 Operable Unit investigations to evaluate the distribution of carbon tetrachloride and potentially to enhance the work being done for the existing groundwater remediation system (Figure 7.1.2 shows the location of well 299-W15-42). At the 216-Z-9 trench, two existing wells (299-W15-84 and 299-W15-95, Figure 7.1.2) were deepened as part of 200-PW-1 Operable Unit investigations to characterize the distribution of carbon tetrachloride in the vadose zone and groundwater. The deepened wells were completed as soil-vapor extraction wells to enhance vadose zone remediation activities.

Sediment sampling also was conducted at the 200-PW-1 Operable Unit to further characterize the carbon tetrachloride plume.

The results of characterization at the Plutonium Finishing Plant concluded that it is unlikely there is a source of carbon tetrachloride and co-contaminants near well 299-W15-42. Relatively low carbon tetrachloride concentrations in groundwater suggest that the vadose zone is not contaminating the aquifer here. Results suggest that the 216-Z-9 trench or 216-Z-1A tile field at the Plutonium Finishing Plant are the more likely vadose zone sources of groundwater contamination. Furthermore, the data suggest that the two effluent pipelines that carried waste from the Plutonium Finishing Plant to the 216-Z-9 trench had not leaked near the boreholes.

In the 216-Z-9 trench area, carbon tetrachloride was detected in both sediment and soil-gas samples from the Cold Creek unit, a deep sediment layer. However, no artificially produced radionuclides were detected in the sediment samples. The relatively low concentrations of carbon tetrachloride in soil gas suggest that the vapor phase is not a source of groundwater contamination at this location. The data indicate that in 2002 the distribution of carbon tetrachloride is consistent with a conceptual model that suggests the Cold Creek unit would retain more carbon tetrachloride than the overlying and underlying sand and gravel at the well locations.

Soil-Gas Sampling. Characterization of the carbon tetrachloride vadose zone plume was conducted during 2002 as part of the remedial investigation for the 200-PW-1 Operable Unit. The 200-PW-1 Operable Unit waste sites received plutonium-rich and organic-rich waste from the



Plutonium Finishing Plant complex. A primary component of the organic-rich waste was carbon tetrachloride. The objective of the vadose zone investigation was to locate and characterize the sources of carbon tetrachloride contamination that presently affect groundwater, as well as known and suspected release sites with the potential to affect groundwater in the future.

Soil-gas sampling and analysis were used to explore the upper vadose zone in the vicinity of the Plutonium Finishing Plant as Step I of the remedial investigation into the dispersed carbon tetrachloride plume in the vadose zone at that location. The sampling was conducted at engineered structures (e.g., liquid waste discharge pipelines, liquid waste discharge sites, and solid waste burial ground trenches) that had the potential to release carbon tetrachloride to the vadose zone.

- **Liquid waste discharge pipelines.** Soil-gas samples were collected along six liquid discharge pipelines to investigate potential leaks of carbon tetrachloride-bearing waste from the pipelines. The six pipelines connected the 234-5Z and 231-Z Buildings with various disposal facilities.

Low concentrations of carbon tetrachloride were detected in some samples collected along the waste discharge pipelines leading to cribs and ditches that are known to have received carbon tetrachloride in liquid waste. The low concentrations detected along the pipelines suggest that any pipeline leaks were small or were naturally remediated (e.g., by diffusion or evaporation) since the pipelines were last used. Carbon tetrachloride was not detected in samples collected along a pipeline to the 216-Z-9 trench, which is known to have received large volumes of carbon tetrachloride.

- **Liquid waste discharge sites.** Soil-gas samples were collected at eleven liquid waste discharge sites to investigate discharge of waste containing carbon tetrachloride to the sediment column at those sites. Low concentrations of carbon tetrachloride were detected in some samples collected at liquid waste discharge sites. Carbon tetrachloride was not detected in samples collected at the 216-Z-9 trench or 216-Z-18 crib, which are both known to have received large volumes of waste containing carbon tetrachloride.
- **218-W-4C Burial Ground.** Sampling in the 218-W-4C burial ground was conducted in three phases. During the first phase, vapor samples were collected from 27 vent risers generally aligned with the centers of the trenches. During the second phase, the GeoProbe® was used to collect samples at 12 locations in the vadose zone. During the third

phase, a cone penetrometer was used to collect samples at 5 of the 12 locations sampled using the GeoProbe®.

During the first phase of the investigation, carbon tetrachloride was detected at all but one of the 27 vent risers sampled. During the second phase, carbon tetrachloride was detected in soil-gas samples collected at 5 of the 12 locations. During the third phase, carbon tetrachloride samples were collected near the location of the highest concentration measured from the second phase.

7.1.1.4 CHARACTERIZATION OF THE 200-TW-2 OPERABLE UNIT

M. E. Todd and C. Trice

Boreholes were drilled through the 216-B-38 trench and 216-B-7A crib during 2001 by Bechtel Hanford, Inc. to characterize the nature and vertical extent of contamination as part of the remedial investigation for the 200-TW-2 Tank Waste Group Operable Unit, 200-East Area (BHI-01607). The results of the investigation became available during 2002. The 200-TW-2 waste sites received tank waste from first- and second-cycle decontamination processes associated with the bismuth-phosphate process at the B and T Plants. The locations of the 216-B-38 trench and the 216-B-7A crib are shown in Figure 7.1.3.

The 216-B-38 trench is located north of B Plant and west of the BX Tank Farm. The trench received 1.43 million liters (378,000 gallons) of high-salt, neutral/basic waste from tanks 241-B-110, 241-B-111, and 241-B-112. The trench was deactivated in October 1982.

To determine the best location for a characterization borehole at the 216-B-38 trench, five test holes were drilled in the areas of greatest contamination. The test holes were installed along the length of the trench. They were logged with both spectral gamma and neutron-moisture tools to identify the area of highest radiological contamination and moisture content. The test holes were then backfilled and decommissioned.

The geophysical logs from the test holes showed the greatest contamination occurred in the test hole closest to the head end of the trench where the characterization borehole ultimately was drilled.

The analytical results and the geophysical logs at the 216-B-38 trench show that most of the radionuclides occur in the original backfill of the crib and immediately below it. Cesium-137, plutonium, and uranium appear to be concentrated just below the backfill but chemical constituents (e.g., ammonium, cadmium, chromium, copper, lead, nickel, and sulfate) did not penetrate deeper than the backfill.

The 216-B-7A and 216-B-7B cribs are located north of the B Tank Farm. The cribs operated from September 1946 to May 1967 and received a total volume of 43.6 million liters (11.5 million gallons) of waste. The waste included liquid from the 221-B Building from tanks 241-B-202 through 241-B-204, lanthanum/fluoride process waste, cell drainage, and other liquid waste from cells 5 and 6 in the 221-B Building. The cribs were deactivated during 1967, and the area was covered with clean backfill.

The radionuclides (cesium-137, americium-241, and plutonium) observed in the characterization borehole at the 216-B-7A crib are concentrated in the original backfill and immediately below it. The anions and some metals (chromium, copper, and lead) show a bimodal distribution with depth; they occur in the backfill and in the underlying sediments. Metals and anions appear to have reached the water table at this location.

7.1.1.5 CHARACTERIZATION OF THE 200-CS-1 OPERABLE UNIT TEST PITS

C. S. Cearlock and D. L. Bowers

Test pits were excavated by Bechtel Hanford, Inc. during 2002 to characterize the vadose zone at the 216-A-29 ditch and the 216-B-63 trench, 200-East Area (Figure 7.1.3 shows the locations of the facilities). Both waste sites are *Resource Conservation and Recovery Act* (RCRA) treatment, storage, and disposal units and part of the 200-CS-1 Operable Unit.

The primary manmade radionuclides detected were strontium-90, cesium-137, and plutonium-239/240. Cesium-137 was detected at the 216-A-29 ditch and at the 216-B-63 trench. Strontium-90 was detected at the 216-A-29 ditch along with plutonium-239/240, americium-241, and uranium.

All observed metals, anions, organic compounds, semi-volatile organic compounds, and volatile organic compounds exceeding background concentrations were well below the Washington State *Model Toxics Control Act* (WAC 173-340) Method C direct exposure cleanup values.

7.1.2 VADOSE ZONE CHARACTERIZATION AND TECHNICAL STUDIES AT SINGLE-SHELL TANK FARMS

New characterization boreholes were drilled and sampled at Waste Management Area TX-TY (200-West Area) and the results of geochemical characterization of core samples from boreholes at Waste Management Area B-BX-BY (200-East Area) became available during 2002. Results from the analysis of core samples allow comparison of contaminated and uncontaminated sediment in the area, which helps delineate the leading edge of vadose zone plumes beneath the B, BX, and BY Tank Farms. These results are summarized in this section.

7.1.2.1 TANK FARM VADOSE ZONE PROJECT – DRILLING AND SAMPLING

D. A. Myers

The Tank Farm Vadose Zone Project conducted characterization activities in the TX Tank Farm during 2002. Three boreholes were drilled, sampled, and then decommissioned. The location of one borehole was based on a potentially large metal-waste contamination zone between tanks TX-101 and TX-105. Vadose zone monitoring equipment was installed during decommissioning of the borehole to provide information on the behavior of infiltrating water in the tank farm environment. The location for a second borehole was based on an extensive and fairly well-defined contaminant zone from a past leak. The third borehole was drilled to define the leading edge of contamination released from tank TX-107 and/or tank TX-104 (RPP-7578). Analyses of samples from these boreholes are scheduled to be completed during 2003.

7.1.2.2 CHARACTERIZATION AT WASTE MANAGEMENT AREA B-BX-BY

R. J. Serne, B. N. Bjornstad, G. W. Gee, H. T. Schaef, D. C. Lanigan, C. W. Lindenmeier, R. D. Orr, V. L. Legore, R. E. Clayton, M. J. Lindberg, I. V. Kutnyakov, S. R. Baum, K. N. Geiszler, M. M. Valenta, T. S. Vickerman, and L. J. Royack

Geochemical examination of drill cores from three boreholes (RCRA well 299-E33-338, borehole 299-E33-45, and borehole 299-E33-46) at Waste Management Area B-BX-BY was completed during 2002 to characterize vadose zone contamination. Well 299-E33-338, was located southeast of the B Tank Farm in an uncontaminated area. Characterization data from this well are thought to represent natural background in the area of Waste Management Area B-BX-BY. A second borehole, 299-E33-45, was located east of tanks BX-101 and BX-102, and drilled through a uranium plume. This borehole was drilled to evaluate concentrations of mobile contaminants, primarily technetium-99 and nitrate, assumed to co-exist with uranium. A third borehole, 299-E33-46, was located northeast of tank B-110. This borehole was drilled to characterize contamination from a leak in a transfer line to tank B-110.

All three boreholes encountered essentially the same stratigraphy and were sampled for moisture content and logged with a neutron-moisture tool. High moisture zones were found to occur in finer grained sands, at the contact between sands underlying gravel, and within the Cold Creek unit, a deep sediment layer.

An extensive set of chemistry analyses of water extracts was completed on samples from natural background borehole 299-E33-338 and serves as a baseline against which to compare results of analyses of contaminated samples from the other two boreholes.

In the contaminated boreholes, elevated pH and increases in electrical conductivity above background were found at selected depths. In addition, a primary indicator of tank waste is the occurrence of elevated nitrate. Elevated nitrate was found in both contaminated boreholes.

Among the cations, elevated sodium concentrations are primary indicators of tank fluid in the sediment column.

Sodium concentrations are elevated in both contaminated boreholes. Calcium, magnesium, and potassium show a distinct concentration pattern with depth in both contaminated boreholes that indicates sodium in the sediment was exchanged for the other natural cations in the sediment. The high sodium fluids push the other cations deeper in the sediment column.

Analyses of selected radionuclides and trace metals also were done on samples from the two contaminated boreholes. The dominant radionuclides in the first contaminated borehole were technetium-99 and uranium. The radionuclides identified in the second were uranium, strontium-90, and technetium-99. Strontium-90 was the primary radionuclide released from tank B-110 transfer lines. The uranium concentrations suggest that there is process uranium from Hanford Site activities at low concentrations in the sediment.

7.1.2.3 STRONTIUM ADSORPTION, DESORPTION, AND TRANSPORT IN PRISTINE AND CONTAMINATED SEDIMENT

J. M. Zachara

The Hanford Science and Technology Project was initiated during 1998 as part of the Groundwater Protection Program (formerly the Groundwater/Vadose Zone Integration Project). The project's goal was to coordinate and perform scientific research to support decision making for environmental cleanup at the Hanford Site. The results of the Science and Technology Project's investigation of strontium-90 geochemistry and transport at single-shell tank B-110 were to support the Waste Management Area B-BX-BY Field Investigation Report (RPP-10098). The key results from 2002 that are summarized here are from four separate but related studies by several principal investigators from Pacific Northwest National Laboratory, Los Alamos National Laboratory, and Lawrence Livermore National Laboratory. Some of key findings as described in the field investigation report (RPP-10098) are listed below:

- The vadose zone strontium-90 plume currently appears stable and immobile.

- The primary mechanism for holding strontium-90 in Hanford sediment is isotopic exchange with stable isotopic strontium.
- Bicarbonate solutions enhanced ion exchange adsorption of Sr^{2+} .
- Approximately 75% of the sorbed strontium-90 is present in an ion exchangeable state and 25% was precipitated in a high magnesium-calcite. Re-wetting of the sediment can remobilize ion exchangeable strontium-90.

7.1.2.4 URANIUM SPECIATION AND DISSOLUTION FROM BX-102 SEDIMENT

J. M. Zachara

Uranium speciation and dissolution in sediment from Waste Management Area B-BX-BY was investigated during 2002. The results of those investigations provide insights into uranium distribution and future migration of the vadose zone plumes, and support decision making for environmental cleanup at Waste Management Area B-BX-BY. The key results summarized here are from five separate but related studies by several principal investigators from Pacific Northwest National Laboratory, Los Alamos National Laboratory, Argonne National Laboratory, and Stanford University. The following are some of the key findings from those studies as described in the field investigation report (RPP-10098):

- Uranium exists as uranium(VI) in samples and as a uranium silicate phase within the uranophane – boltwoodite mineral series.
- The precipitated uranium(VI) can dissolve from the sediment if water is added and the pH is above 8.5.
- The amount of precipitated uranium(VI) that will dissolve appears predictable, and is most dependent on pH, bicarbonate/carbonate concentration ratio, and water content.
- The precipitated uranium(VI) phases in the sediment are sufficiently soluble and reactive to function as long-term source terms to infiltrating waters if allowed. Water management will be key to limiting further contamination.

7.1.3 CHARACTERIZATION FOR INTEGRATED DISPOSAL SITE

D. G. Horton

Waste from plutonium production and separation processes is currently stored underground in 149 single-shell tanks and 28 double-shell tanks. DOE plans to retrieve tank waste, separate it into low- and high-activity fractions, and immobilize it using a vitrification process. The low-activity waste will then be disposed in near-surface burial facilities at the Hanford Site 200-East Area.

The results of geochemical and mineralogical characterization of borehole samples from the vadose zone at the location of the proposed Integrated Disposal Site became available during 2002. The information from that characterization effort will support the Integrated Disposal Site performance assessment during 2005.

A study of iodide sorption onto sediment from the proposed Integrated Disposal Site was completed during 2002.

7.1.3.1 BOREHOLE 299-E24-21 GEOCHEMISTRY

D. G. Horton, H. T. Schaef, R. J. Serne, M. M. Valenta, T. S. Vickerman, I. V. Kutnyakov, S. R. Baum, K. N. Geiszler, and K. E. Parker

Borehole 299-E24-21 was drilled at the northeast corner of proposed Integrated Disposal Site during 2001. Near-continuous core was collected from the borehole from below ground surface to the water table. The purpose of the borehole was to obtain characterization data to support the Integrated Disposal Site performance assessment during 2005 and to serve as a groundwater monitoring well for future RCRA monitoring. Details of the drilling and sampling can be found in BHI-01531 and in PNNL-13652.

The data collected included particle size distribution data, moisture content, bulk composition (as measured by x-ray fluorescence), total carbon content, inorganic carbon, and organic carbon (by difference), x-ray diffraction analysis, major cations and anions in 1:1 water extracts. These data are similar to other data collected from the sand-dominated portion of the Hanford formation.

7.1.3.2 SORPTION LINEARITY AND REVERSIBILITY OF IODIDE

W. Um and R. J. Serne

A performance assessment of the proposed Integrated Disposal Site investigated the effects of the planned disposal on long-term environmental conditions and human health. The investigation showed that technetium-99, iodine-129, uranium-233, uranium-235, neptunium-237, and uranium-238 pose the most potential health risks at the proposed disposal site. Because of its long half-life and high mobility in the subsurface environment, the sorption/desorption characteristics of radioactive iodine were

investigated. During 2002, sorption onto sediment and reversibility were determined using iodine-125 as a radioactive tracer for iodine-129 on a typical Hanford formation sand from the second Integrated Disposal Site borehole in 200-East Area. Because iodine-129 is one of the key risk drivers at the Hanford Site, predictions for the fate of iodine-129 using simple transport models are technically defensible. However, since iodide desorption is slower than adsorption and only partially reversible, the concentration of iodide will not drop as fast as predicted and the time for iodide to leave the system may be longer than the time predicted by simple transport theory.



7.2 VADOSE ZONE MONITORING

S. P. Reidel and D. G. Horton

Vadose zone monitoring continued at the Hanford Site in 2002. Leachate and soil-gas were sampled and analyzed as part of monitoring of the Solid Waste Landfill and the Environmental Restoration Disposal Facility. Soil-gas monitoring continued at the carbon tetrachloride expedited-response site and geophysical borehole monitoring continued at single-shell tank farms to detect leaks and subsurface migration of contaminants. Borehole geophysical monitoring (or characterization) of drywells at past-practice liquid disposal sites began during 2002. The first monitoring events at each of these sites were designed to provide results that will serve as a baseline to compare subsequent logging events to detect any subsurface contaminant movement.

7.2.1 TANK FARMS VADOSE ZONE MONITORING PROJECT

P. D. Henwood, A. W. Pearson, and R. G. McCain

A project was established during 2001 to monitor the movement of radioactive contaminants in the vadose zone using boreholes in single-shell tank farms (MAC-HGLP 1.8.1). During 2002, 384 new logs were completed in wells and boreholes. A new geophysical logging detection system, the Radionuclide Assessment System, was used because it was simpler to use, faster than the previous systems, and more cost-effective for routine monitoring than other systems available at the Hanford Site. The previous system, the Spectral Gamma Logging System, was used between 1995 and 2000 to establish a baseline record of existing radionuclide contamination in the vadose zone. Measurements using the new system can easily be compared to the baseline data acquired by the older system. When routine monitoring by the new system

identifies anomalies relative to the baseline, a more detailed examination of the anomaly may be required using the older system, which was designed specifically for such detailed work. A significant cost-savings is achieved by using the older systems only when necessary.

Monitoring is performed from quarterly to once during 5 years, depending on the location of a borehole with respect to known or potential contaminant plumes. The intent of the program is to log (i.e., to measure the distribution of gamma-emitting radionuclides) in each borehole at least once during a 5-year period. A list prioritizing the boreholes was developed based on proximity to known or suspected contaminant plumes, proximity to tanks known to be leaking, and proximity to tanks containing relatively large volumes of drainable liquid. All high-priority boreholes in tank farms have been monitored at least once since June 2001.

Comparisons that were made between earlier geophysical logs and subsequent logs suggest there is a possibility of contaminant movement in 25 boreholes from seven tank farms; however, only two boreholes show confirmed contaminant movement. One borehole was in C Tank Farm in the 200-East Area, and the other was in TY Tank Farm in the 200-West Area. Cobalt-60 and processed uranium (uranium-235 and uranium-238) were the main contaminants detected in these boreholes. Borehole geophysical logs are included in the quarterly reports available at <http://www.gjo.doe.gov/programs/hanf/HTFVZ.html>.

A special investigation of boreholes around tank U-107 in the U Tank Farm, 200-West Area, was started during 2001 to support pending waste retrieval operations. No significant changes in contaminant profiles were observed at that tank during the five monitoring events that were conducted there during 2001 and 2002.

7.2.2 GEOPHYSICAL LOGGING AT PAST-PRACTICE DISPOSAL FACILITIES

S. M. Sobczyk, P. D. Henwood, R. G. McCain, and S. E. Kos

Geophysical logging (i.e., the measurement of radioactive contaminants using geophysical methods) of boreholes began at liquid waste disposal sites and solid waste burial grounds at the 200-East and 200-West Areas during 2001. The purpose of this work is to determine concentrations of naturally occurring and manmade radionuclides in the vadose zone; this work is an extension of the baseline characterization work at single-shell tank farms. In addition, geophysical logging also was done to support remedial investigation projects and the RCRA Groundwater Monitoring Project. The newly acquired data establish a baseline for future comparisons to determine contaminant mobility.

During 2002, geophysical logging for vadose zone characterization was completed in 70 boreholes. Nine of these boreholes were new boreholes and were logged to support remedial investigation projects. Five boreholes were new RCRA groundwater monitoring wells and three new wells were drilled for the Integrated Disposal Site in the 200-East Area. Geophysical data from each borehole were analyzed to determine concentrations of naturally occurring radionuclides (potassium-40, thorium-232, uranium-238, and associated decay products) and manmade radionuclides (e.g., cobalt-60, antimony-125, cesium-137, europium-152, europium-154, uranium-235, and uranium-238).

Waste site summary reports were issued for the results from geophysical logging in the following 200-East Area sites: 216-B-8 crib and adjacent areas (GJO-2002-343), 216-B-35 to 216-B-42 trenches (GJO-2002-322), and 216-B-5 injection well and 216-B-9 crib (GJO-2002-358-TAC).

Geophysical logging of 19 vadose zone boreholes and 13 groundwater wells northeast of Waste Management Area B-BX-BY, in the 200-East Area, detected cobalt-60, cesium-137, europium-154, uranium-235, and uranium-238. Cobalt-60 and cesium-137 were detected in the vadose zone and in the uppermost part of the aquifer; however, this

was only observed in older wells (1950s) and not in newer stainless steel casings. The resulting apparent distribution of contamination is probably related to radioactive metals that were sorbed onto or into iron alteration minerals from the rusted casing. Rust can easily sorb trace metals, whereas the newer stainless steel casings are designed to prevent this. Thus, the contaminant concentrations in the groundwater could be small; however, over time concentrations in the rusting casings increase. Uranium contamination originating from the BX Tank Farm was detected east of its presumed source at tank BX-102 (Figure 7.2.1). This contamination had reached borehole 299-E33-41 (Figure 7.2.2) and well 299-E33-18 between 1991 and 1997 and the logging results suggest that the amount of manmade uranium has increased in well 299-E33-18 since 1997.

Eleven boreholes were logged at trenches located west of Waste Management Area B-BX-BY, in the 200-East Area (GJO-2002-322; Figure 7.1.3 shows the location of the trenches). Cesium-137 was detected in all boreholes. A comparison between data collected during 2002 and data collected during the 1990s shows good agreement indicating contaminants have not migrated during the last 10 years.

7.2.3 CARBON TETRACHLORIDE MONITORING AND REMEDIATION

V. J. Rohay

Carbon tetrachloride was disposed of in the 200-West Area. This section summarizes activities related to determining its distribution in the subsurface and its remediation as part of a CERCLA expedited response action.

7.2.3.1 SOIL-VAPOR EXTRACTION

Soil-vapor extraction technology is being used to remove carbon tetrachloride from the vadose zone in the 200-West Area. The U.S. Environmental Protection Agency (EPA) and the Washington State Department of Ecology authorized DOE to initiate this technology during 1992 as a CERCLA expedited response action.

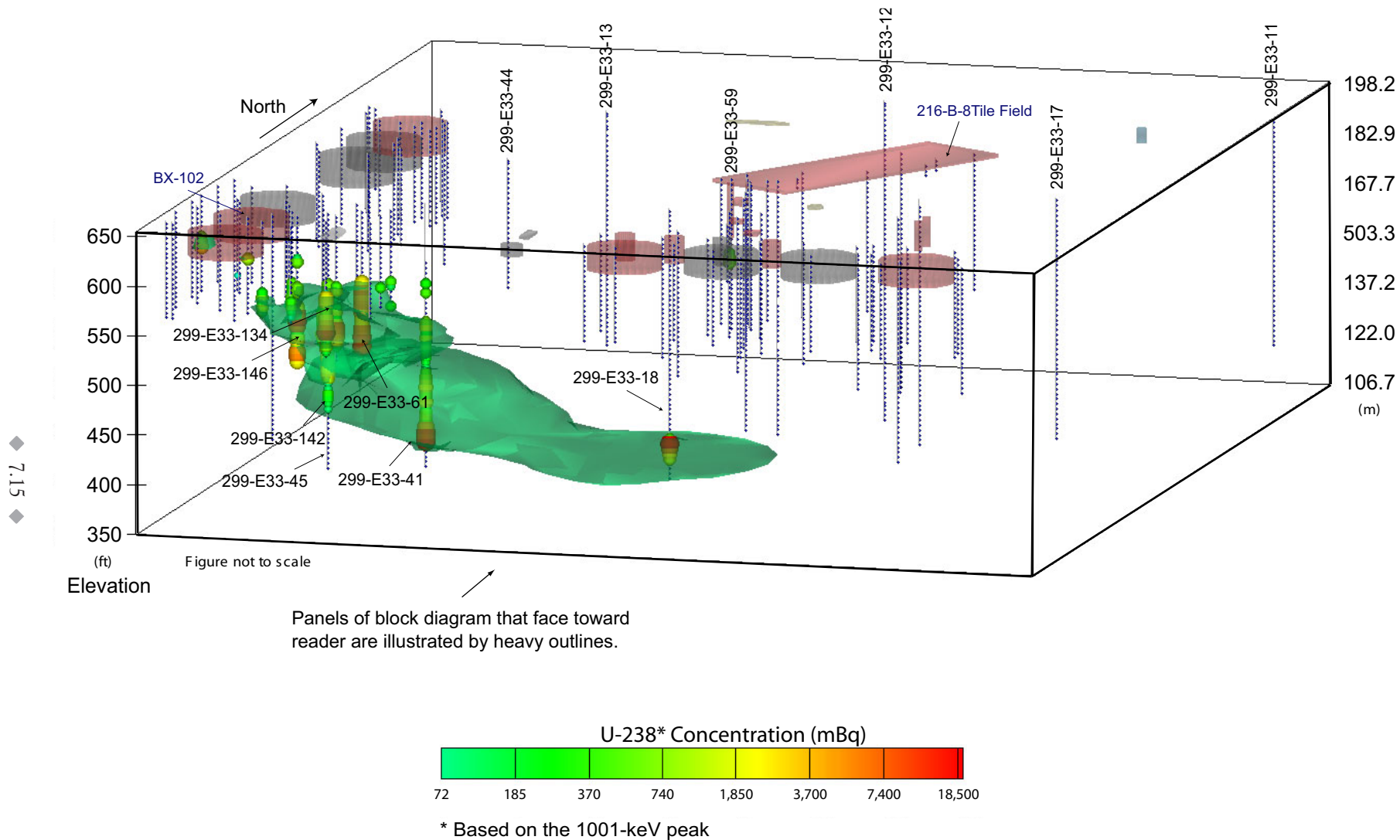
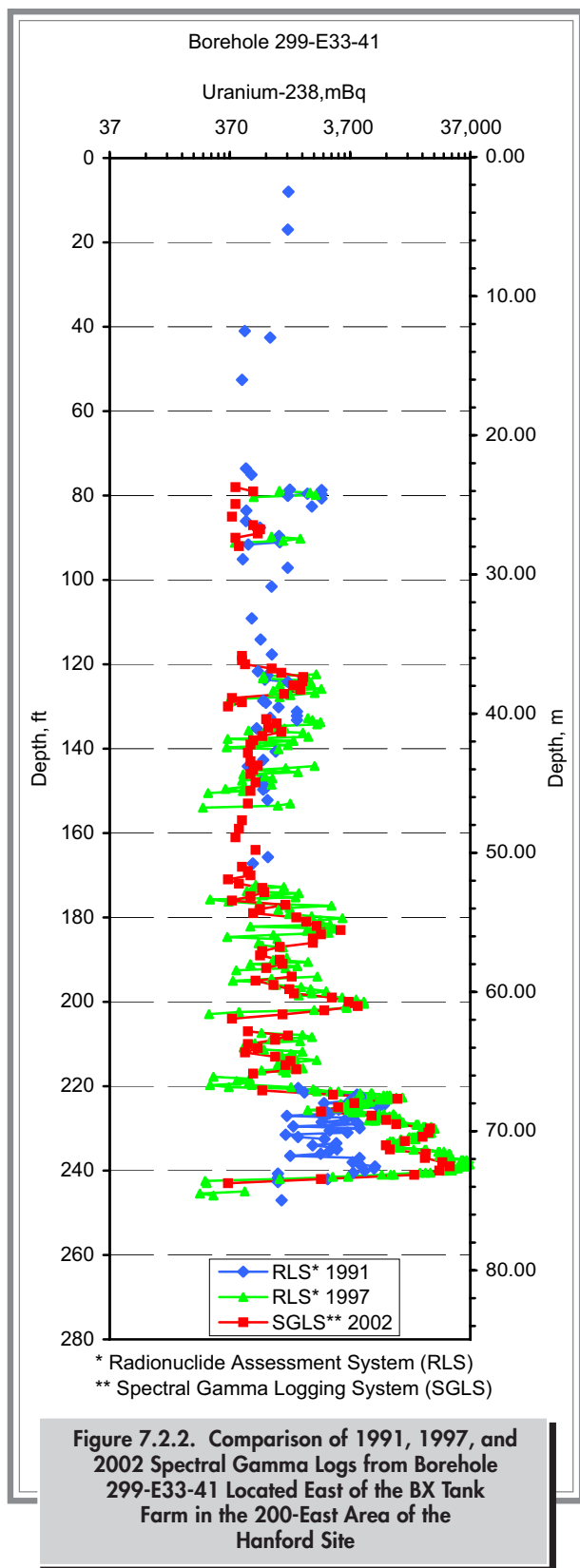


Figure 7.2.1. Uranium-238 Contamination North of the BX Tank Farm in the 200-East Area of the Hanford Site. Wells and boreholes are shown as dashed blue lines. Also shown are projections of tanks (cylinders) and the 216-B-8 tile field.

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A soil-vapor extraction system operated at the 216-Z-9 well field in the 200-West Area from April 1 through July 22, 2002, and at the combined 216-Z-1A/216-Z-12/216-Z-18 well field in the 200-West Area from July 24 through September 30, 2002. The system had been in standby mode from October 1, 2001, through March 31, 2002.

To track the effectiveness of the remediation effort, soil-gas concentrations of carbon tetrachloride were monitored during the 6-month operating period. Results were reported in 2002 (BHI-00720; WHC-SD-EN-TI-101).

As of September 2002, ~77,800 kilograms (171,549 pounds) of carbon tetrachloride had been removed from the vadose zone since startup in 1991. The extraction systems are estimated to have removed 7% of the residual mass at 216-Z-1A/216-Z-12/216-Z-18 well field and 22% of the mass at the 216-Z-9 well field.

7.2.3.2 MONITORING AT OFF-LINE WELLS AND PROBES

During 2002, soil-gas concentrations of carbon tetrachloride also were monitored near the ground surface, near the Cold Creek unit (a sediment layer ~40 meters [131 feet] below ground surface), and near groundwater (~66 meters [216 feet] below ground surface). This monitoring was done to evaluate whether non-operation of the soil-vapor extraction system would adversely affect carbon tetrachloride concentrations in the atmosphere or groundwater near the extraction site.

The suspension of soil-vapor extraction activities appears to have had minimal impact on the movement of carbon tetrachloride through the sediment to the atmosphere. This is supported by data that show carbon tetrachloride concentrations did not increase significantly near the ground surface or in the groundwater.

7.2.3.3 PASSIVE SOIL-VAPOR EXTRACTION

Passive soil-vapor extraction is a remediation technology that uses changes in atmospheric pressure to move carbon tetrachloride vapor from the subsurface to the surface. In

general, falling atmospheric pressure causes subsurface vapor to move to the atmosphere through wells, whereas rising atmospheric pressure causes atmospheric air to move into the subsurface.

Passive soil-vapor extraction systems were installed during 1999 at eight wells that are open near the vadose-groundwater interface at the 216-Z-1A/216-Z-12/216-Z-18 well field in the 200-West Area. The passive systems are outfitted with check valves that only allow soil vapor to flow out of the borehole (i.e., one-way movement), and canisters with granular activated carbon that adsorbs carbon tetrachloride from the vapor before it is vented to the atmosphere. The check valve prohibits flow of atmospheric air into the borehole when barometric pressure increases, which would allow air to dilute and spread carbon tetrachloride vapors in the subsurface. The concentrations measured at four of the wells during 2002 indicate that the passive system has the capability to remove carbon tetrachloride from the sediment.

7.2.4 LEACHATE MONITORING AT THE ENVIRONMENTAL RESTORATION DISPOSAL FACILITY

C. W. Miller, C. S. Wright, and R. S. Edrington

Bechtel Hanford, Inc. operates the Environmental Restoration Disposal Facility landfill to dispose of radioactive, hazardous or dangerous, and mixed waste generated during waste management and remediation activities at the Hanford Site. The facility began operating during July 1996 and is located between the 200-East and 200-West Areas (ERDF on Figure 6.1.1). The facility is currently operating its second set of two disposal cells since June 2000. The initial cells received waste until September 2000. Each of the four cells is lined to collect leachate resulting from natural precipitation and water added as a dust suppressant.

During 2002, Bechtel Hanford, Inc. published the results of groundwater monitoring and sampling at the Environmental Restoration Disposal Facility during 2001 (BHI-01641). The purpose of the data was to provide a

contaminant inventory for the Effluent Treatment Facility, where the leachate is disposed.

Composite leachate samples were collected during June and December 2001 and reported in 2002. Leachate samples contained detectable concentrations of common metals, anions, and mobile radionuclides. The constituents detected in leachate samples were compared to the groundwater monitoring constituent list to determine if additional constituents should be added to the groundwater monitoring program. Results indicated that the target constituents for the groundwater monitoring program were consistent with the leachate monitoring program. At this time, no additional constituents will be added to the groundwater monitoring program at the Environmental Restoration Disposal Facility landfill.

7.2.5 LEACHATE AND SOIL-GAS MONITORING AT THE SOLID WASTE LANDFILL

R. A. Del Mar

The Solid Waste Landfill is a land disposal facility in the center of the Hanford Site (Figure 6.1.1). It began operating in 1973 to receive non-hazardous, non-radioactive sanitary waste generated from Hanford Site operations. The Solid Waste Landfill stopped receiving waste during 1996, and an interim cover was placed over all trenches. Current monitoring at the Solid Waste Landfill consists of quarterly sampling of groundwater, soil gas, and leachate.

The Solid Waste Landfill consists of ~70 single disposal trenches and 14 double disposal trenches. One of the double trenches overlies a lined, basin lysimeter designed to collect leachate that infiltrates through the overlying refuse. A discharge pipe continuously drains leachate by gravity flow from the basin to a nearby collection pump. However, because the lysimeter only collects leachate from 1 of 84 trenches, it may not be representative of leachate drainage throughout the entire landfill area but it does provide some indication of the rate of infiltration and contaminants that may be entering the vadose zone from the landfill.

Between 3.8 and 7.6 liters (1 and 2 gallons) of leachate per day are produced at the site, which are then collected from the basin lysimeter every 10 to 14 days. These volumes are consistent with expectations based on precipitation, sediment type, and vegetative cover. Some of the contaminants in the leachate (most notably arsenic, manganese, nickel, and 1,4-dioxane) continue to be found in concentrations exceeding groundwater quality criteria (WAC 173-200) and/or maximum contaminant levels (WAC 246-290). In addition, some of the indicator parameters exceeded groundwater quality criteria and/or maximum contaminant thresholds, including conductivity, chloride, and total dissolved solids. The most notable change that occurred during 2002 was an increase in several non-chlorinated organic constituents, including acetone, 2-butanone, 2-hexanone, and 2-pentanone.

Soil-gas monitoring at the Solid Waste Landfill uses eight shallow monitoring stations located around the perimeter of the landfill. Soil gas is monitored quarterly to determine concentrations of oxygen, carbon dioxide, methane, and several key volatile organic compounds. No contaminants of concern in concentrations above reporting limits were discovered during 2002.

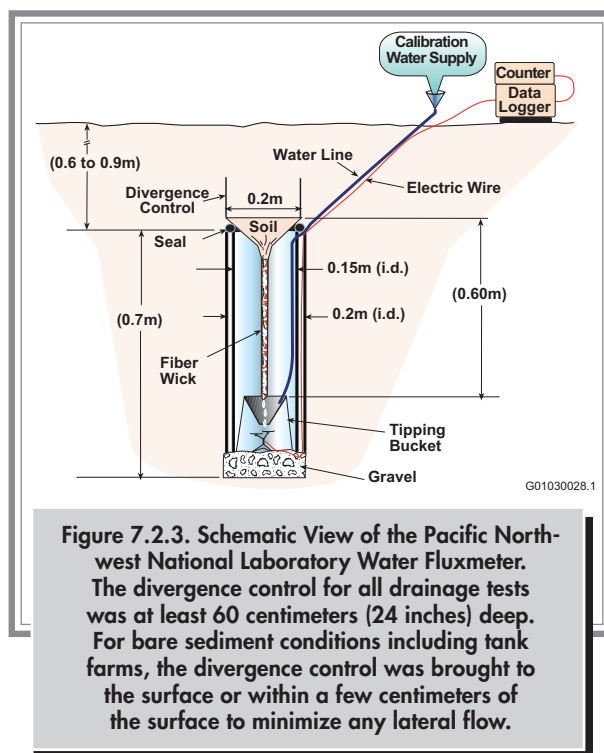
7.2.6 HYDROLOGIC CHARACTERIZATION USING VADOSE ZONE MONITORING TOOLS AT HANFORD

G. W. Gee, A. L. Ward, J. B. Sisson, J. M. Hubbell, D. A. Myers, and H. A. Sydnor

Characterization of the vadose zone is needed to assess contaminant migration from buried waste. In addition, data from vadose zone monitoring provide direct measures of sediment-water pressures, temperatures, and water fluxes or rates of infiltration. Vadose zone monitoring can document waste site responses to changes in precipitation (rain and snowmelt), the occurrence of water-line leaks at a site, or help detect tank leaks during waste retrieval operations. Since most flow rates (flux) in the vadose zone are relatively low and changes generally occur slowly, most results will not be instantaneous. Meaningful data sets will require an extended monitoring period (several years or more).

The Pacific Northwest National Laboratory, in collaboration with CH2M HILL Hanford Group, Inc., Idaho National Engineering and Environmental Laboratory, and Duratek Federal Services, deployed a suite of vadose-zone instruments for characterization and monitoring at the Hanford Site. Several new instruments were tested. One instrument, the advanced tensiometer developed at Idaho National Engineering and Environmental Laboratory, measures sediment-water pressures in the vadose zone and was tested successfully at the Hanford Site. Another new instrument, the water fluxmeter (Figure 7.2.3) directly measures rates at which water drains through the sediment. It also was deployed and successfully tested to obtain in situ hydrologic characterization data, to verify drainage potential, and to obtain estimates of current water recharge rates under a range of surface conditions.

A series of tests to confirm performance and longevity of vadose zone monitoring sensors has been ongoing since 1999 (<http://vadose.pnl.gov>). A nearly continuous record that has been maintained since sensor installation indicates that the instruments have been reliable and have required little or no maintenance for periods up to 3 years or longer. The sensor site contains a set of instruments designed to simulate waste burial ground conditions. The data confirm that drainage persists at the site in spite of the arid climate



and water pulses from infiltration of winter rain and snow do not appear to penetrate much below 2 meters (6.5 feet) depth. The top 1 meter (3.3 feet) of sediment appears to capture most of the transient water. Measured drainage for the past 3 years has averaged about 55 millimeters (2.16 inches) per year, similar to predictions using measurements from past experiments.

Two instrument packages were deployed within the Hanford Site tank farms during the past 2 years. During 2001, a sensor package containing eight instruments was placed in the vadose zone inside an uncased borehole (C3360) located adjacent to tank B-110 in the 200-East Area. The instruments are part of the Vadose Zone Monitoring System for the Hanford Site tank farms and include advanced tensiometers, heat dissipation units, water content reflectometers, thermal probes, and vadose zone solution samplers. A water fluxmeter was deployed within the top meter (3.3 feet) of the surface to directly measure net infiltration of meteoric water (rain and snowmelt). In addition, a rain gage was located within the tank farm to document onsite precipitation.

Tensiometer data from 2002 show that steady-state conditions have persisted at the B Tank Farm since installation of

the instruments more than a year ago (Figure 7.2.4) and indicate continued drainage at this site. The coarse gravel at the surface and the lack of vegetation at the tank farm promote drainage conditions. The data show that drainage is occurring, but do not provide a direct measure of drainage rates. The water fluxmeter provides data on net infiltration of meteoric water but does not indicate how much lateral spreading of water is occurring in the subsurface. Thermal profiles from the instrument packages appear normal and show heating due to radioactivity has had little effect in the subsurface (Figure 7.2.5).

During 2002, four instrument sets were placed in an uncased borehole (C3830) located between tank TX 101 and tank TX 105 in the TX Tank Farm, 200-West Area. Data collected from the TX Tank Farm are similar to those at the B Tank Farm in the 200-East Area and indicate that the vadose zone beneath the tank farm is draining. Water-fluxmeter data collected over the course of the next 3 years will be used to estimate vadose zone drainage rates within the TX Tank Farm.

Based on current observations, however, data from the tensiometers indicate that drainage is occurring at the TX and B Tank Farms. Similar drainage conditions are

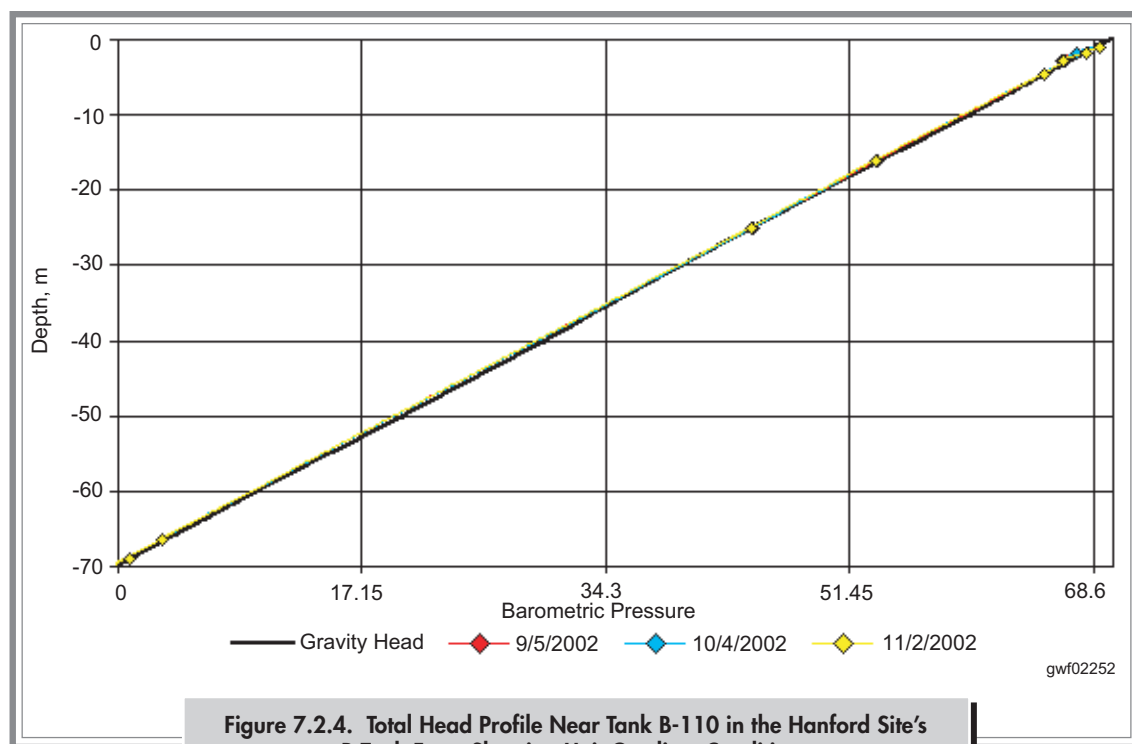
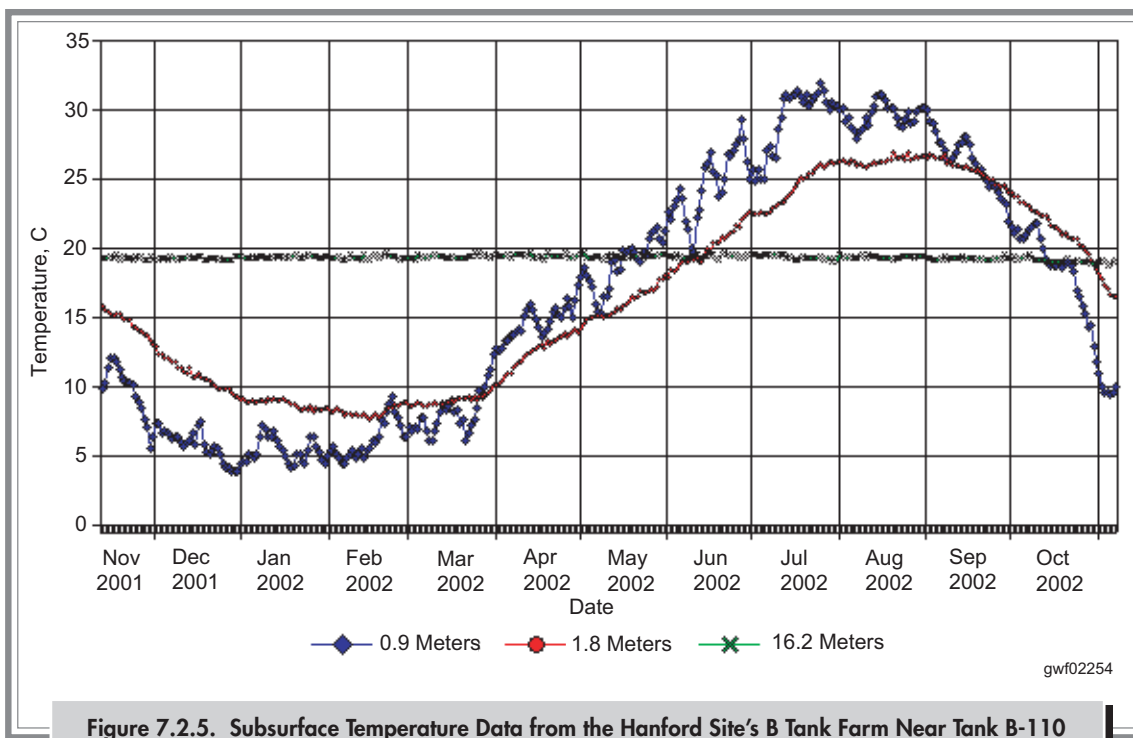


Figure 7.2.4. Total Head Profile Near Tank B-110 in the Hanford Site's B Tank Farm Showing Unit Gradient Conditions



expected at other tank farms at Hanford, where surfaces are similar. As multiple years of data are collected, vadose zone field monitoring systems with water fluxmeters will be able to provide a direct measure of annual recharge

within tank farms and other waste sites, thus providing an early warning to potential future groundwater contamination.



7.3 OTHER VADOSE ZONE ACTIVITIES

D. G. Horton and S. P. Reidel

This section summarizes the activities and results of several technical studies done at the Hanford Site during 2002 to better understand the vadose zone sediment, hydrology, and contamination. These studies were designed to develop new, innovative methods for cleanup and monitoring at the Hanford Site. The studies included the application of various geophysical methods to vadose zone monitoring, infiltration studies at a monitored prototype surface barrier site, and laboratory studies of immobilization of chromium, technetium-99, and uranium.

7.3.1 CORRELATION OF STRONTIUM-90 CONCENTRATION AND GAMMA LOG RESPONSE

R. G. McCain and C. Koizumi

Anomalous gamma-ray radioactivity detected in the subsurface during routine borehole geophysical logging at a region northeast of tank B-110 in the 200-East Area suggests a zone of subsurface strontium-90 contamination. However, there was no other evidence for any gamma-emitting radionuclide contaminants in the area (GJO-99-113-TAR, GJO-HAN-28). One possible source for the anomalous gamma-ray activity is a special type of radiation called bremsstrahlung radiation, which results when beta particles (positively charged electrons emitted from the nucleus of an atom) from strontium-90/yttrium-90 strike the steel casing of a well or borehole.

Borehole 299-E33-46 was drilled during 2001 to investigate Waste Management Area B-BX-BY and to collect samples for laboratory analysis to investigate subsurface contamination. Analyses from the samples showed high concentrations of strontium-90 that appeared to correlate with anomalous zones of gamma-ray activity, thus making the borehole a good place to test for bremsstrahlung radiation.

During 2002, a technique called spectral shape factor analysis was used to test this concept. Spectral shape factor analysis compares the shape of energy peaks produced by gamma-ray producing radionuclides to the shape produced by the background measurements recorded for the same interval in the borehole. Using this technique, the energy peak for strontium-90 will have a specific shape due to bremsstrahlung radiation. The results of this test showed that there appears to be a spectral shape factor correlation between laboratory-measured strontium-90 concentrations and the gamma-ray count rate. This suggests that bremsstrahlung radiation may be the source of anomalous gamma-ray radioactivity observed in that borehole. The results of this investigation may lead to a method for quantitative measurement of strontium-90 in the subsurface.

7.3.2 TEST OF HANFORD SITE 1,000-YEAR SURFACE BARRIER DESIGN

G. W. Gee, A. L. Ward, and C. D. Wittreich

DOE has been investigating technologies that can be used to develop surface barriers at the Hanford Site (RHO-CD-1142; Wing and Gee 1994; Ward and Gee 2000; BHI-01551; Link et al. 1995). A prototype surface barrier was constructed in 1994 that was designated to be used at waste sites in arid climates for at least 1,000 years. A report was issued in 1999 (PNNL-13116) on the first 4 years of data monitoring. This section updates that report with information that was collected through 2002.

Because a barrier must last for at least 1,000 years without maintenance, natural construction materials (e.g., fine soil, sand, gravel, cobble, basalt riprap) and asphalt were selected for its design. Most of these are available in large quantities on the Hanford Site. The barrier consists of a fine-soil layer overlying other layers of coarser materials,

such as sands, gravels, and basalt riprap (Figure 7.3.1). Asphalt provides an impermeable layer at the base of the barrier. Natural vegetation was then established on the surface of the barrier.

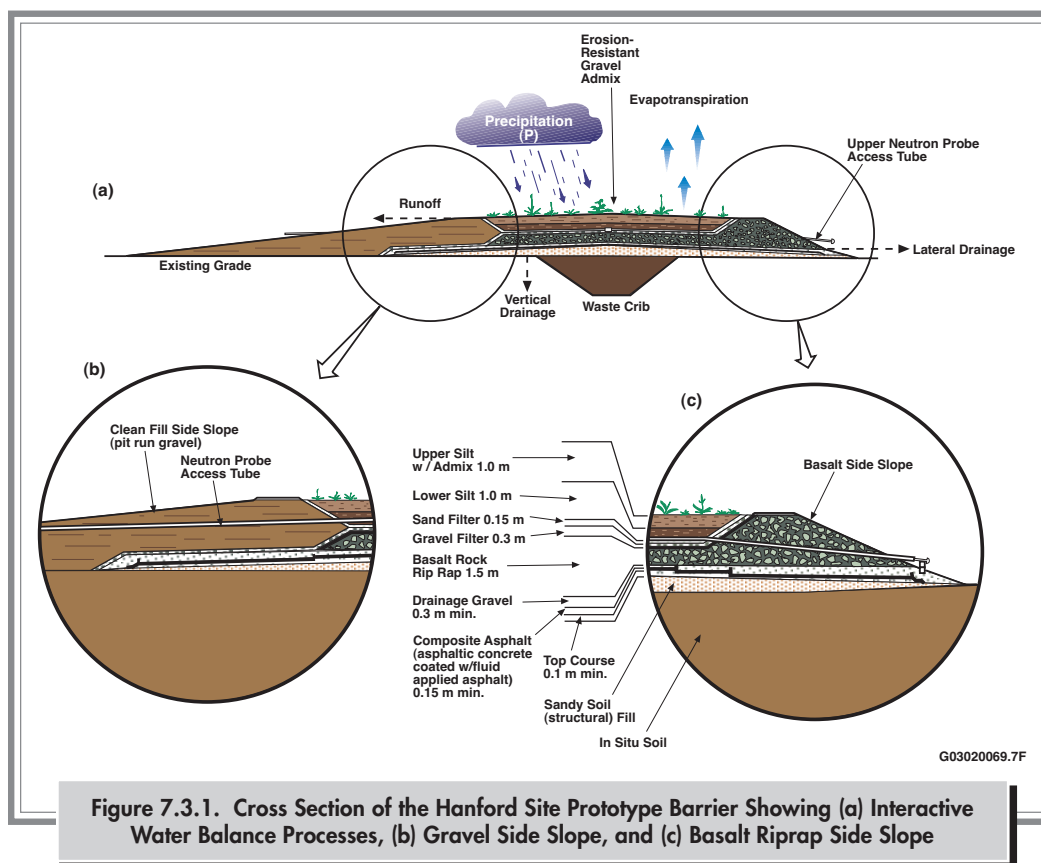
The primary purpose of a surface barrier is to prevent water from passing through it. Infiltrating water (usually as precipitation) is the main driving force that will move waste downward to the groundwater. Therefore, it is important to know the water balance; that is, how much precipitation is diverted away and out of the soil cover by asphalt, how much water gets past the asphalt layer, how much water is surface runoff, how much water is stored in the soil, and how much water is lost by evapotranspiration. Evapotranspiration is the only component not directly measured at the Hanford Site prototype barrier, but it can be calculated from the other variables just mentioned.

In order to determine the water balance, the north half of the prototype barrier was irrigated from November 1994 through October 1997 with water equivalent to three times the long-term average annual precipitation. Water-balance

monitoring of the surface barrier was carried out using rain gages to measure irrigation and precipitation, neutron probes for soil water content (water storage), and pan or basin-type lysimeters for drainage collection. Piping carried the drainage water from collection zones to basins where it was monitored.

Monitoring results from September 1994 through September 2002 indicated that evapotranspiration was the most important process for water removal. All irrigation water and natural precipitation plus all plant-available stored soil water were removed by evapotranspiration over the years the barrier was monitored. There was no monitoring at the barrier between September 1998 and May 2000; however, so no data are available for that time period.

The results suggest that extreme winter precipitation, the prime cause of recharge and drainage of the vadose zone at the Hanford Site, is stored in the surface barrier until spring when it is removed from the soil by evapotranspiration. This supports the case for designing a surface barrier with sufficient capacity to store water so that even under extreme conditions, the surface barrier will still perform adequately.



The ability of the barrier to remove water and limit drainage demonstrates the benefits of having vegetation on the surface. Evapotranspiration for the irrigated part was nearly double that for the non-irrigated part, suggesting that vegetation is capable of adjusting to differing amounts of water. This indicates that the combination of vegetation and soil storage capacity is more than sufficient to remove all applied water under the test conditions. Neutron logging confirmed that no water got under the asphalt pad.

The rapid establishment of the natural vegetation cover on the surface was thought to have at least three positive benefits to the performance of the surface barrier. First, the vegetation was the main process responsible for removing water from the surface soil. Second, the surface was stabilized against water erosion and runoff. Third, it helped control wind erosion. After a plant community established itself during November 1994, there were no measurable soil losses by wind erosion from the surface of the prototype barrier.

Eight years of testing provided important but limited information for long-term barrier-performance estimates. Because only a finite amount of time was available to test a barrier that was intended to function for a considerably longer period of time, the testing program was designed to stress the prototype so that barrier performance could be determined within a reasonable period of time. To date, the results are very encouraging and support the premise that a barrier can be subjected to extreme stresses, for example, 1,000-year storms, and still perform successfully. It is desirable to continue to monitor the performance of the prototype barrier for an extended period because the succession of vegetation types, the full development of root profiles, and the natural colonization of the barrier surface by burrowing animals will occur over a longer time period.

Test results obtained to date show that in the Hanford Site's arid climate, a well-designed barrier limits drainage to near-zero amounts. Data collected under extreme conditions (excess precipitation) provides confidence that the surface barrier has the capability to meet performance objectives for its 1,000-year design life.

7.3.3 USE OF ELECTRO-MAGNETIC INDUCTION AND GROUND-PENETRATING RADAR TO MONITOR SEDIMENT-WATER STORAGE IN A PROTOTYPE SURFACE BARRIER

A. L. Ward, W. P. Clement, and G. W. Gee

A barrier-development program was started at the Hanford Site during 1985 to develop, test, and evaluate the effectiveness of various surface barrier designs (Section 7.3.2). However, the lack of cost-effective technologies for long-term monitoring and the difficulty in projecting barrier performance from the short term to the long term were major challenges to barrier deployment. For this reason, two non-invasive geophysical techniques, electromagnetic induction and ground-penetrating radar, were investigated as techniques for measuring sediment-water content and storage in a surface barrier. The objective this study was to investigate how electromagnetic induction and ground-penetrating radar responded to spatial and temporal variations in soil-water storage in a surface barrier. The study was conducted during 2002 on the prototype surface barrier discussed in Section 7.3.2.

Electromagnetic induction measures the electrical conductivity of the ground; that is, it is a measure of the amount of electrical current that can move through the sediment. Water or moisture in sediment may dissolve substances that can make it easier for electric current to pass through the sediment, thus providing a method to determine the location of water or moisture and the amount present. This technique is effective as far as 6 meters (20 feet) below the ground surface. This study used two surveys that were designed to penetrate 0.75 and 1.5 meters (2.5 and 5 feet). The data from these two surveys were compared to neutron probe measurements of water content as a function of depth.

The ground-penetrating radar surveys use radar to probe the subsurface. Radar waves are similar to radio waves but with slightly different properties. Radar waves generated at the surface are reflected back by materials in the subsurface. Water or soil moisture can reduce the amount of

signal reflected back or the velocity of the reflection providing a method for determining the location of sediment-water and the amount present. Metallic objects at and below the surface can negatively affect the results of both techniques because metals conduct electricity and are good reflectors of radar waves.

Electromagnetic induction conductivity maps suggest that irrigation on the north end of the barrier between November 1994 and September 1997 might have caused an increase in conductivity (moisture) from the initial condition during 1994. An analysis of the data shows a linear relationship for water stored in the sediment that was measured by a neutron probe and apparent electrical conductivity. The small size of the data set may limit the use of this relationship for predicting sediment-water storage from electrical conductivity measurements; however, it does suggest that the method may hold promise for field-scale monitoring of water storage. The mobility of these instruments, the speed with which measurements can be made, and the ability to do this with aerial electromagnetic induction surveys in mapping large areas makes this method an attractive option for monitoring large field-scale surface barriers.

Ground-penetrating radar surveys showed slower velocities (more moisture) for surveys during January and March 2001 than for surveys during May and October 2001. These velocity differences reflected differences in water content in the upper layer of the barrier, with the highest water content occurring in the winter and spring, and the lowest in the summer and fall. Similar differences were seen also in the electromagnetic induction measurements. As with the electromagnetic induction measurements, the data set for ground-penetrating radar is quite limited. Nevertheless, the data show a linear relationship between ground-penetrating radar measurements and neutron probe measurements.

In summary, these investigations showed relationships between results from electromagnetic induction and ground-penetrating radar surveys and the spatial and temporal variations of sediment-water storage in the surface barrier. Electromagnetic measurements showed some anomalous values due to metallic components in the Hanford surface barrier, but the data could be used to develop reasonable relationships between water content,

water storage, and electrical conductivity. Ground-penetrating radar also showed considerable promise for high-resolution mapping of sediment-water content and storage distributions in surface barriers. Changes in the ground-penetrating radar response correlated well with changes in soil moisture over time.

Non-invasive geophysical techniques offer significant advantages over traditional monitoring methods including high speed data acquisition, lower costs, high sampling resolution, and integration of multiple spatial scales. Furthermore, the non-intrusive nature minimizes damage to barrier integrity from instrument installation or degradation. The potential for the airborne deployment of electromagnetic induction and ground-penetrating radar make these methods attractive for monitoring large field-scale barriers. The improved understanding of the non-linear dependence of large-scale processes on local-scale water content that can be gained from these data is an important step toward the use of remote sensing for monitoring barrier performance.

7.3.4 EVALUATION OF ELECTRICAL LEAK-DETECTION METHODS

D. B. Barnett, M. D. Sweeney, M. D. Johnson, and G. W. Gee

The Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement; Ecology et al. 1998) requires removal of waste from single-shell tanks and other miscellaneous underground tanks for storage in the double-shell tank system. CH2M HILL Hanford Group, Inc. is demonstrating several retrieval methods to dislodge, mobilize, and remove the waste from the tanks. During retrieval operations, conditions beneath and in the single-shell tanks may be monitored as an additional precaution to protect the vadose zone beneath the tanks.

From mid-July through early November 2002, Pacific Northwest National Laboratory and CH2M HILL Hanford Group, Inc. evaluated two electrical geophysical methods at the 105-A mock tank facility in the 200-East Area of the Hanford Site. These two geophysical methods were designed to detect leaks beneath buried tanks. The techniques tested were electrical resistivity tomography

designed by Lawrence Livermore National Laboratory and a high-resolution steel-casing resistivity technique designed by HydroGEOPHYSICS, Inc. The two techniques were initially tested during 2001 and were selected for further evaluation during an appraisal/elimination process completed during January 2002 (PNNL-13818). The possible leak events that were tested involved a series of blind, leak/no leak events and continuous monitoring. Only preliminary results are presented here; detailed analysis of the collected data is still in progress.

Preliminary results indicate that the methods performed within the expected ranges of sensitivity for leak detection. Early indications from the high-resolution steel-casing resistivity technique suggested that equipment configurations in contact with the tank (as a receiver or transmitter) appear to be very sensitive to both leak detection and estimation of the leak volume. Final results from this testing are expected to be available during 2003.

7.3.5 TANK FARM VADOSE ZONE PROJECT — CORRECTIVE MEASURES

D. A. Myers

The Tank Farm Vadose Zone Project under CH2M HILL Hanford Group, Inc. took a series of major interim corrective measures in the 200-East and 200-West Areas during 2002. In the 200-East Area, actions were taken to protect the tank farms from surface water runoff that could flow onto a tank farm. Measures were taken to protect all single-shell tank farms from the nominal 30-year storm and from potential leaks from pressurized water lines that are within the tank farms. Of particular note was the re-working of Baltimore Avenue that runs north-south between B Tank Farm and the BX and BY Tank Farms in the 200-East Area (Figure 7.1.2). When a transfer line between B and BX Tank Farms was built during the 1970s, the construction left a berm that resulted in water ponding upstream of the transfer line and west of Baltimore Avenue. Since the transfer line was built, a total of six rapid snow-melt events have taken place that provided a potential source of recharge that could mobilize vadose zone contamination resulting in groundwater contamination. A culvert system was designed and installed during 2002 to carry the water away from this area to the north fence line

of the 200-East Area. Berms were constructed to direct water runoff away from the farms.

Water lines servicing the 200-East Area single-shell tank farms were tested to ascertain their integrity; all lines passed the pressure tests. Those lines for which no future use was found were cut and capped outside the waste management area boundaries to prevent any inadvertent release of water to the tank farms.

In the 200-West Area, a water line servicing the 244-TX double-contained receiver tank was cut and capped in 2002. During 2001, tests determined this line was losing water at a rate of 0.72 liter (0.19 gallon) per minute. However, the water line was needed to flush waste from the Plutonium Finishing Plant to the SY Tank Farm so this water line was not capped until after the flush was completed.

7.3.6 IMMOBILIZATION OF CHROMIUM, TECHNETIUM, AND URANIUM IN HANFORD SEDIMENT BY GASEOUS REDUCTION

E. C. Thornton, V. L. Legore, and K. B. Olsen

Chromium, technetium-99, uranium-233, uranium-234, uranium-235, uranium-236, and uranium-238 are vadose zone contaminants at the Hanford Site that could be leached from the sediment and reach groundwater by surface-water infiltration. In situ gaseous reduction appears to be a promising technology for immobilizing these contaminants. Laboratory tests were done to determine (1) if sediment contaminated with technetium and uranium can be treated effectively by exposing it to a diluted hydrogen sulfide gas and (2) if sediment treated with hydrogen sulfide can retard the migration of chromium, technetium, and uranium in solutions infiltrating through the treated zone. Results from these tests became available during 2002.

In situ gaseous reduction can be applied in two different ways to waste in the vadose zone. The first application involves immobilization of chromium, technetium, and uranium by forming coatings on existing sediment grains

or mineral precipitates that incorporate these contaminants. This stabilizes the existing contamination. The second application creates a permeable reactive barrier in vadose zone sediment by changing ferric iron to ferrous iron. This provides a way to capture contamination from possible future waste tank leaks.

7.3.6.1 GASEOUS TREATMENT OF TECHNETIUM-99 CONTAMINATED SEDIMENT

Sediment contaminated with technetium-99 was treated in laboratory tests to determine whether technetium can be changed from the +VII to +IV oxidation state and immobilized with hydrogen sulfide diluted with air or nitrogen. Treated and untreated sediment then were leached with water, and the rate of technetium-99 release was monitored. The test results indicate that ~50% of the technetium present in the contaminated sediment was immobilized by treatment with diluted hydrogen sulfide.

Treatment of the vadose zone with hydrogen sulfide in air could provide a way to partially stabilize technetium contamination beneath single-shell tanks in the vadose zone. The partial immobilization of technetium may result from incorporation of technetium in iron oxide as it formed or in the formation of a coating (e.g., elemental sulfur on sediment grains). These processes would retard technetium movement through the vadose zone and lower the amount reaching groundwater. Treatment of the vadose zone sediment with hydrogen sulfide diluted with air, however, would not be useful in generating a permeable reactive barrier.

Hydrogen sulfide diluted with nitrogen, however, may stabilize technetium contamination in the vadose zone and create a permeable reactive barrier. A permeable reactive barrier would result from reaction of nitrogen with the iron component present in vadose zone sediment, which then could immobilize technetium. The longevity of the barrier would be a function of the iron content and the rate the barrier would re-oxidize, which is related to water infiltration rates and the diffusion of oxygen through the vadose zone.

7.3.6.2 GASEOUS TREATMENT OF URANIUM-CONTAMINATED SEDIMENT

Sediment contaminated with uranium was treated in laboratory tests with air and nitrogen to determine whether uranium can be chemically changed from the mobile +VI oxidation state to the immobile +IV oxidation state by treatment with diluted hydrogen sulfide. During 2002, treated and untreated sediment was then leached with water and the rate of sediment reoxidation and uranium release was monitored.

Test results indicate that the treatment of the vadose zone with hydrogen sulfide in air would probably not provide a way to stabilize uranium contamination in Hanford Site sediment. Treatment with hydrogen sulfide with nitrogen, however, may stabilize uranium contamination present in the vadose zone to some extent and create a possible permeable reactive barrier.

7.3.6.3 EVALUATION OF THE IN SITU GASEOUS REDUCTION PERMEABLE REACTIVE BARRIER CONCEPT TO IMMOBILIZE CHROMIUM, TECHNETIUM, AND URANIUM IN THE VADOSE ZONE

During 2002, uncontaminated sand-dominated sediment from the SX Tank Farm in the 200-West Area was used in laboratory experiments to test the potential of using an in situ reactive barrier to immobilize chromium, technetium, and uranium. The testing involved packing two columns with the uncontaminated sediment. One column was an untreated control sample and a hydrogen sulfide gas mixture was passed through the second column. Air and nitrogen gas were individually mixed with the hydrogen sulfide gas. A mixture of chromium (VI), technetium (VII), and uranium (VI) then was pumped through both columns. The concentrations of the three contaminants in the effluent from the treated column were compared to that of the untreated column to determine the degree of immobilization associated with gas treatment.

The results suggest that a permeable reactive barrier generated by a hydrogen sulfide/nitrogen gas mixture would be very effective at immobilizing chromium (VI) in the vadose zone because once chemically changed from chromium (VI) to chromium (III), chromium is not readily re-mobilized. However, the barrier would no longer be effective for immobilizing additional chromium (VI) once infiltrating water that was carrying oxygen re-oxidizes the sediment. The barrier lifetime is estimated to be hundreds to several thousands of years depending on the iron content of the sediment, barrier thickness, and transport rates of oxygen through the vadose zone.

The test results also indicate that it is possible to limit the amount of technetium (VII) that will move through the vadose zone using an in situ gaseous reduction vadose zone permeable reactive barrier. The change to technetium (IV) is reversible under natural conditions and, thus, technetium could be re-mobilized from the barrier once it is re-oxidized and returns to technetium (VII). This suggests that an in situ gaseous reduction permeable reactive barrier could be useful as a short-term measure to capture technetium (VII) that might be released during waste tank closure operations. The long-term viability of the barrier, however, is difficult to assess. It is possible that a mid- to long-term barrier useable lifetime could be achieved if the barrier is periodically recharged by treatment with additional hydrogen sulfide.

Uranium also was immobilized in both the untreated and treated laboratory tests. The mechanism responsible for the relatively low mobility of uranium (VI) is not clear. Uranium may have precipitated in the tests as a carbonate or hydroxide phase.

7.3.6.4 EVALUATION OF THE POTENTIAL FOR LONG-TERM CHROMIUM REOXIDATION IN HYDROGEN-SULFIDE-TREATED SEDIMENT

The length of time the immobilization treatment for contaminants will last is a critical issue. Chromium (VI) is readily changed to chromium (III) by reaction with hydrogen sulfide. It is generally regarded that the chromium (III) form is stable in the natural environment and relatively

insoluble. A long-term test was conducted during 2002 to determine whether or not re-oxidation of chromium could occur.

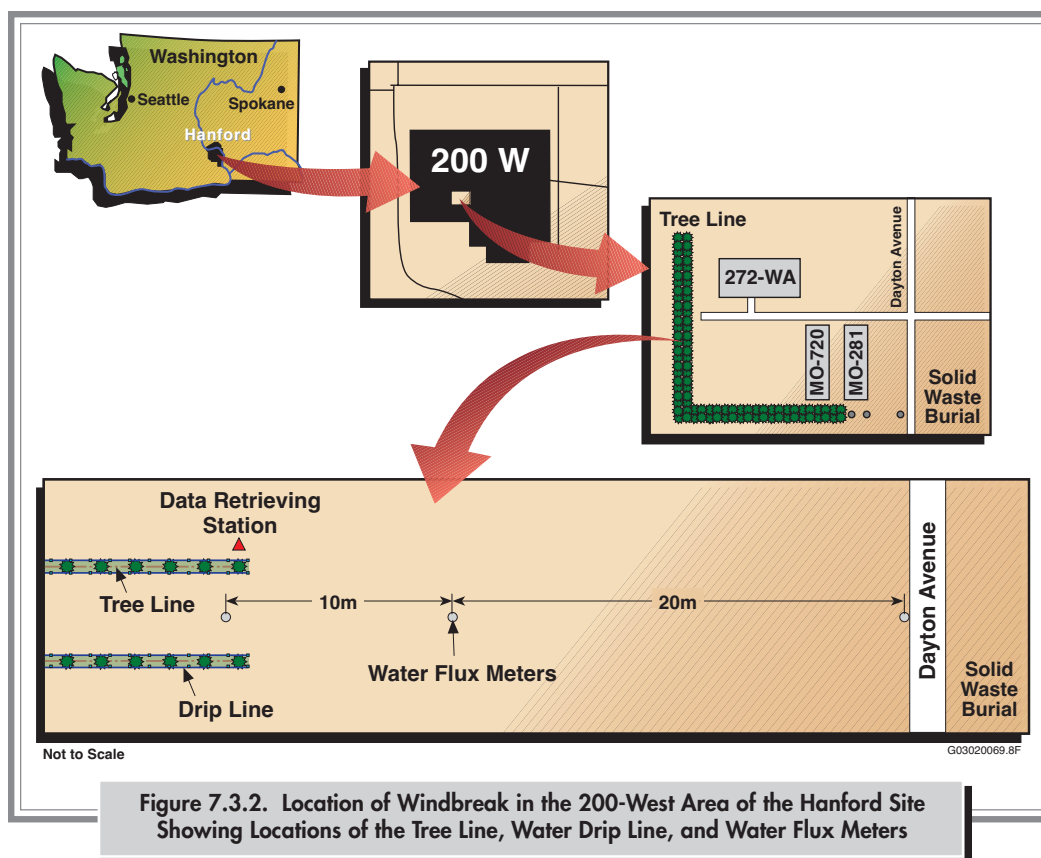
A chromate-contaminated sediment sample from the 100-K Area was treated with diluted hydrogen sulfide gas, then leached with water and the amount of chromium (VI) in the leachate was measured. Results from the test showed that levels of chromium (VI) in the sediment dropped and suggests that the chromium will not re-oxidize to the (VI) state.

7.3.7 WATER MONITORING OF THE TREE SHELTERBELT AT THE 200-WEST AREA

G. W. Gee, J. S. Carr, J. O. Goreham, and C. E. Strickland

Water entering the vadose zone from irrigating a tree shelterbelt (windbreak) in the 200-West Area of the Hanford Site (Figure 7.3.2) was monitored during the summer of 2002. Water rate and sediment-water contents were measured within the shelterbelt and at two locations just east of the shelterbelt to assess the effect of the irrigation on the vadose zone and to assist in optimizing the irrigation applications. During May 2002, sensors were placed in auger holes and connected to a computer system to gather data.

There was little rain (6 millimeters [0.24 inch]) between July and September 2002, so water applied to the soil was almost exclusively from irrigation. During the first 65 days of monitoring (June 26 through August 30, 2002), the application rate averaged 751 liters (198 gallons) per day per tree, over 13 times the design rate of 57 liters (15 gallons) per day per tree. Feedback from the monitoring data has resulted in subsequent reductions in both application and drainage rates within the tree line. Further adjustments have reduced the water application rate to 159 liters (42 gallons) per day per tree. Drainage within the tree line from irrigation has exceeded 3,100 millimeters (122 inches) of water for the 80-day monitoring period. The drainage rate was reduced by more than half, from 36 millimeters (1.4 inches) per day for the first 65 days, to 17 millimeters



(0.7 inch) per day for a 7-day period ending in September 24, 2002. In spite of these improvements, the irrigation and drainage rates were still not optimized as irrigation exceeded the design rate by almost a factor of three. Monitoring of two adjacent sites found no drainage during the 80-day monitoring period. Continued monitoring within and adjacent to the tree line will provide an evaluation of the overall efficiency of the irrigation system and help assess the effect of drainage on adjacent areas such as solid waste burial grounds.

7.3.8 SOIL-GAS INVESTIGATION AT THE 618-10 BURIAL GROUND

K. B. Olsen, P. E. Dresel, and R. E. Peterson

During 1999, groundwater samples taken from the 618-11 burial ground in the 300 Area contained 1.86 million pCi/L (68,889 Bq/L) of tritium. The 618-10 burial ground (originally named the 300 North Solid Waste Burial Ground) received similar waste, but the extent of groundwater

contamination was unknown there. Soil-gas investigations were undertaken at the 618-10 burial ground to determine if tritium levels in groundwater at this location were also elevated. These results became available during 2002.

The 618-10 burial ground was used between 1954 and 1963 and received a wide variety of solid, dry, radioactive waste. However, there is no evidence for significant quantities of liquid waste being placed in the burial ground, although small amounts of various liquid waste may have been included with the solid materials. In addition, several range fires occurred at the burial ground during which significant quantities of water may have been applied to the ground surface for fire suppression.

The use of helium-3/helium-4 ratios in soil gas to successfully detect and delineate tritium contamination at the 618-11 burial ground is described in PNNL-13675. The method is based on the decay of tritium to helium-3, which is a stable, inert isotope. When waste containing tritium comes in contact with sediment moisture, tritium can be incorporated with the sediment moisture, which then may migrate away from the tritium source. The tritiated

sediment-moisture mixes with infiltrating moisture from precipitation (e.g., rainfall, snowmelt), or moisture from human activities (e.g., dust control, irrigation, fire suppression), and migrates downward to subsequently enter groundwater. Concurrent with tritium's release to the vadose zone, its daughter isotope, helium-3, begins to build up in the vadose zone and/or the underlying groundwater at the rate of tritium decay. The helium-3 then diffuses away from its source and migrates toward the surface. Helium-3, thus, acts as a non-reactive tracer for tritium.

A soil-gas investigation for helium isotopes and volatile organic compounds was conducted around the perimeter of 618-10 burial ground during September 2002 to determine if a tritium plume originated from the burial ground and to assist in choosing locations for two new groundwater monitoring wells. Sampling points were installed and soil-gas samples were collected and analyzed for helium isotopes and volatile organic compounds.

Fourteen sampling locations were chosen for the survey near the burial ground and in adjacent areas downgradient of the burial ground. One location upgradient of the burial ground was included to provide background levels of the targeted parameters for the soil-gas samples. Six soil-gas locations were selected for the sampling of volatile organic compounds.

The result of the analyses identified numerous hydrocarbon compounds and several chlorinated hydrocarbon compounds in all six of the soil-gas samples, but they appeared to represent problems with sampling methods. Because soil-gas analyses showed only low levels of volatile chlorinated compounds, they are probably not of concern for routine monitoring in groundwater. The result of the soil-gas analysis for volatile chlorinated compounds failed to provide compelling evidence to recommend locations for two additional groundwater monitoring wells in the vicinity of the 618-10 burial ground.

Soil-gas samples were collected and analyzed for helium isotopes following procedures established during investigations at the 618-11 burial ground (PNNL-13675). The

helium-3/helium-4 ratios did not indicate high levels of tritium along the perimeter of the 618-10 burial ground. By comparison, helium-3/helium-4 ratios observed in soil gas near the 618-11 burial ground were much higher near the suspected buried sources and over the tritium groundwater plume that extends downgradient from that burial ground.

There appears to be little contribution of volatile organic compounds to the soil gas at the 618-10 burial ground based on the volatile chlorinated organic compounds results on the soil-gas samples. It was not possible to determine whether there were hydrocarbon compounds present in the soil gas because of the pervasiveness of contamination from the sample tubing.

7.3.9 STANDARDIZED STRATIGRAPHIC NOMENCLATURE

S. P. Reidel

One of the main goals of the Groundwater Protection Program is the integration of vadose zone and groundwater activities. Historically, the stratigraphy of the vadose zone sediment at the Hanford Site has been described by several nomenclature schemes such that there has been little consistency in naming and correlating the vadose zone sediment. The numerous site-specific nomenclatures developed over the years at Hanford resulted in confusion and made it difficult to compare the stratigraphy encountered across the Hanford Site. During 2002, the Groundwater Protection Program oversaw the publication of a standardized stratigraphic nomenclature for post-Ringold Formation deposits. The standardized nomenclature (Figure 7.3.3) was needed to support and integrate hydrogeologic characterization and performance assessment modeling at the Hanford Site. The new standardized nomenclature represents a consensus that was reached by Hanford Site geologists during 2002.

	Informal, Local, Hanford Site Nomenclature	DOE/RL-2002-39	
Hanford formation	Touchet Beds (previously formalized)	Interbedded sand-and silt-dominated facies association (ISSD)	
	H1a Upper sandy sequence	Stratigraphically highest sand-dominated facies association (SD)	
	H1 Upper gravel sequence	Stratigraphically highest gravel-dominated facies association (GD)	
	H2 Sandy sequence	Sand-dominated facies association (SD)	
	H3 Lower gravel sequence	Stratigraphically lowest gravel-dominated facies association (GD)	
	H4 Lowest sand sequence	Stratigraphically lowest sand-dominated facies association (SD)	
	Pre-Missoula gravels	Cold Creek unit	Mainstream alluvium facies
	Early "Palouse" soil/silt		Fluvial overbank and/or eolian facies
	Plio-Pleistocene unit		Side-stream facies
	Ringold Formation	Ringold Formation	
	Columbia River Basalt Group	Columbia River Basalt Group	

ecs03002

Figure 7.3.3. New Hanford Site Stratigraphic Nomenclature and Comparison to Previous Hanford Nomenclature. Four initialisms commonly used for units of the Hanford formation are shown next to descriptive names in bold.



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8.0 OTHER HANFORD SITE ENVIRONMENTAL PROGRAMS

R. W. Hanf

At the Hanford Site, a variety of environmental activities are performed to assure that operations and activities comply with laws and regulations, to help protect workers and the public, to enhance environmental quality, and to monitor the impact of environmental pollutants from site operations.

This section summarizes activities conducted during 2002 to monitor the site's climate and weather, to assess the

status of ecological monitoring and compliance, to monitor and manage cultural resources, to actively involve the public in environmental surveillance activities, to control invasive and unwanted plant species, and to re-evaluate cesium-137 levels in conifer forests in the Cascade Mountains of Washington State.



8.1 CLIMATE AND METEOROLOGY

D. J. Hoitink

Meteorological measurements are taken to support Hanford Site emergency preparedness and response, operations, and atmospheric dispersion calculations for dose assessments (Appendix E, Tables E.5 and E.7 through E.9). Support is provided through weather forecasting and maintaining and distributing 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 site operations. A summary of requests for meteorological data from facilities and organizations both on and off the Hanford Site during 2002 is provided in Table 8.1.1.

The Hanford Meteorology Station relies on data provided by the Hanford Meteorological Monitoring Network. This network consists of 30 remote monitoring stations that transmit data to the Hanford Meteorology Station via radio telemetry every 15 minutes. There are twenty-seven 9-meter (30-foot) towers and three 61-meter (200-foot) towers. Meteorological information collected at these stations includes wind speed, wind direction, temperature, precipitation, atmospheric pressure, and relative humidity; however, not all of these data are collected at all stations. Figure 8.1.1 shows the 2002 wind roses (i.e., diagrams showing direction and frequencies of wind) measured at a height of 9 meters (30 feet) for the 30 meteorological monitoring stations on and around the Hanford Site.

The Cascade Range, beyond Yakima to the west, greatly influences the climate of the Hanford Site because of its rain shadow effect. The regional temperatures, precipitation, and winds are affected also by the presence of mountain

barriers. The Rocky Mountains and ranges in southern British Columbia protect the inland basin from severe, cold polar air masses moving southward across Canada and winter storms associated with them.

The Hanford Meteorology Station is located on the Hanford Site's Central Plateau, where the prevailing wind direction is from the northwest during all months of the year. The secondary wind direction is from the southwest. Summaries of wind direction indicate that winds from the northwestern quadrant occur most often during winter and summer. During spring and fall, the frequency of southwesterly winds increases, with a corresponding decrease in the northwesterly flow. Monthly average wind speeds are lowest during winter months, averaging about 3 meters per second (6 to 7 miles per hour), and highest during summer, averaging about 4 meters per second (8 to 9 miles per hour). Wind speeds that are well above average are usually associated with southwesterly winds. However, summertime drainage winds are generally northwesterly and frequently exceed 13 meters per second (30 miles per hour). These winds are most prevalent over the northern portion of the site.

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

Real-time and historical data from the Hanford Meteorology Station can be obtained at <http://etd.pnl.gov:2080/HMS>. Data on this web site include hourly weather observations, 15-minute data from the Hanford Meteorological Monitoring Network, monthly climatological summaries, and historical data.

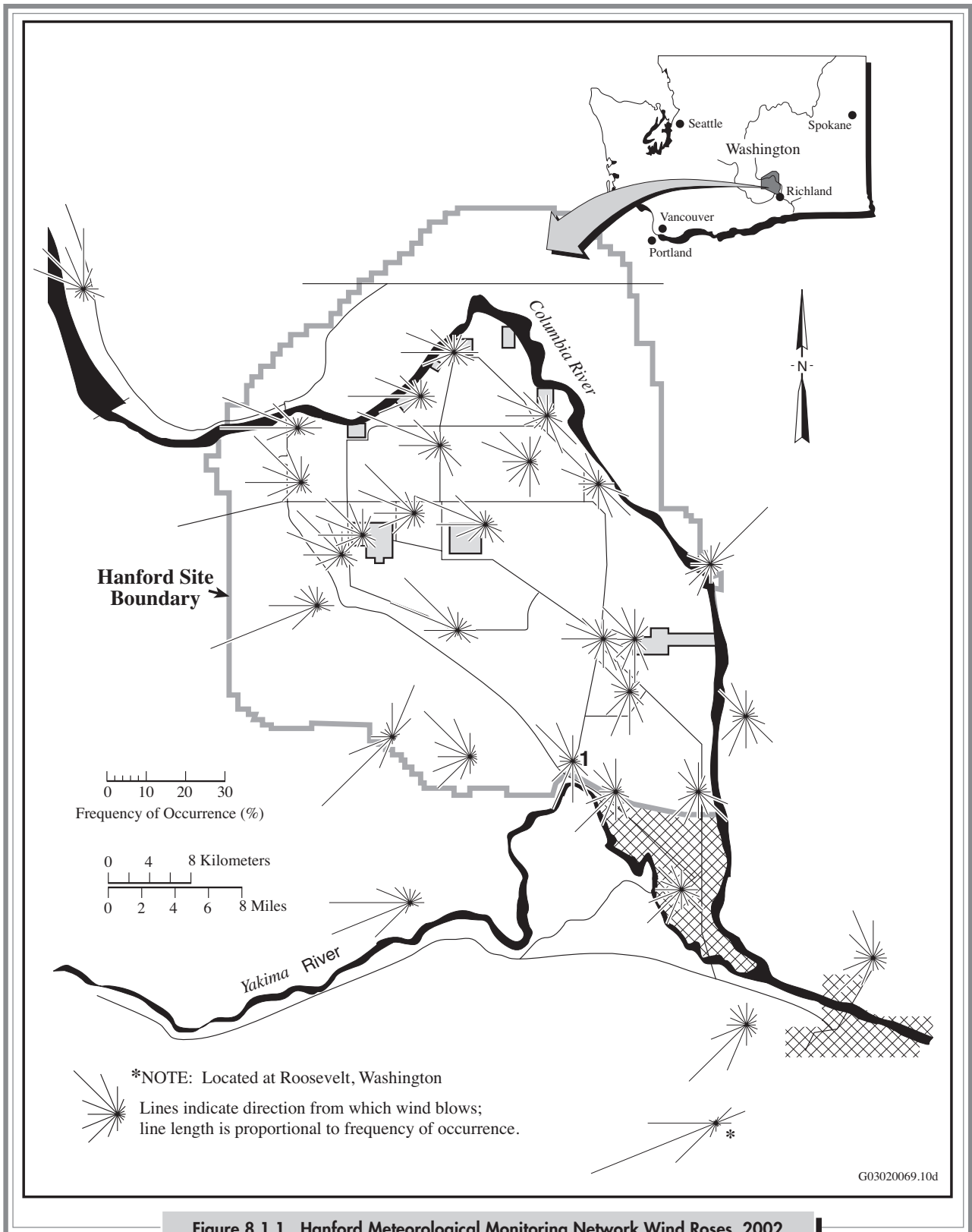
Table 8.1.1. Requests for Meteorological Data from Facilities and Organizations On and Off the Hanford Site, 2002

Requestor	Number of Requests												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Onsite													
100 Areas (other)	94	55	120	81	81	50	30	33	49	47	38	22	700
222S/WSCF Labs	3	3	2	1	1	2	1	0	2	2	2	1	20
300 Area (other)	19	11	15	8	7	11	2	3	32	11	12	9	140
BHI/subcontractors	2	0	4	1	3	1	2	6	2	1	2	7	31
Canister Storage	1	0	0	1	1	0	0	1	0	0	1	0	5
Construction	2	1	4	1	0	2	0	3	0	3	0	0	16
Crane and Rigging	1	0	1	0	0	0	1	0	1	2	1	2	9
DOE-RL	1	1	5	1	4	3	3	0	0	0	0	1	19
Electrical Dispatcher	25	21	22	22	27	16	25	19	26	16	22	24	265
Emerg. Preparedness	18	12	14	7	23	27	13	25	14	15	23	8	199
Energy Northwest	0	0	1	0	0	1	0	0	0	0	0	1	3
Evaporator Facility	0	0	0	1	0	0	0	0	0	0	0	0	1
FDH (other)	3	1	5	2	1	0	2	2	27	1	6	0	50
FFTF	1	3	0	2	1	0	3	1	3	0	1	0	15
Fire Dept.	31	30	34	35	40	57	28	31	27	30	28	27	398
HAMMER Facility	1	0	7	7	3	1	1	0	1	0	1	2	24
Hanford Patrol	3	1	3	0	1	3	3	0	0	2	0	4	20
Industrial Hygiene	24	21	22	10	12	7	2	14	14	13	10	9	158
Pest Control	6	5	13	14	9	8	6	15	11	10	6	1	104
PFP	59	40	32	16	7	3	1	3	5	18	30	26	240
Photography	5	1	0	0	0	0	0	0	0	2	1	0	9
PNNL	14	13	11	9	12	16	9	7	5	9	11	6	122
Salt Wells	0	1	6	2	4	2	4	22	29	8	5	3	86
Solid Waste	1	0	2	0	2	2	4	1	0	0	1	1	14
T Plant	0	3	0	2	1	0	0	0	0	1	0	1	8
Tank farms	336	300	513	338	390	303	382	291	348	272	234	284	3,991
Track/Road Maint.	8	5	7	1	1	0	0	0	0	1	1	13	37
Vitrification Plant	0	5	7	9	5	2	7	10	11	10	10	18	94
WBGT	0	0	0	0	0	89	202	62	8	0	0	0	361
WRAP/ERDF/other	0	0	3	0	2	0	1	0	1	1	2	0	10
Monthly Total	658	533	853	571	638	606	732	549	616	475	448	470	7,149

Table 8.1.1. (contd)

Requestor	Number of Requests												
Offsite	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
City of Richland	0	1	0	3	2	0	2	1	0	0	0	0	9
NWS	0	0	0	0	0	1	0	0	0	1	0	1	3
RLD Medical Off.	21	17	14	20	25	14	11	18	20	13	16	17	206
Tri-City Herald	1	2	0	0	0	0	4	0	0	2	0	2	11
TV/Radio Stns.	0	0	0	0	0	0	1	0	0	0	0	0	1
US Fish/Wildlife	0	0	1	0	0	0	0	0	0	1	0	0	2
Monthly Total	22	20	15	23	27	15	18	19	20	17	16	20	232

BHI = Bechtel Hanford, Inc.
 DOE-RL = DOE Richland Operations Office.
 ERDF = Environmental Restoration Disposal Facility.
 FDH = Fluor Hanford, Inc.
 FFTF = Fast Flux Test Facility.
 NWS = National Weather Service.
 PFP = Plutonium Finishing Plant.
 PNNL = Pacific Northwest National Laboratory.
 PUD = Public Utility District.
 RLD = Richland.
 WBGT = Wet bulb globe temperature (heat stress).
 WRAP = Waste Receiving and Packaging Facility.
 WSCF = Waste Sampling and Characterization Facility.



**Figure 8.1.1. Hanford Meteorological Monitoring Network Wind Roses, 2002
 (measured at a height of 9 meters [30 feet]).**

8.1.1 HISTORICAL CLIMATOLOGICAL INFORMATION

Daily and monthly averages and extremes of temperature, dew point temperature, and relative humidity for 1945 through 2002 are reported in PNNL-14242. From 1945 through 2002, the record maximum temperature was 45°C (113°F) recorded during August 1961 and July 2002, and the record minimum temperature was -30.6°C (-23°F) in February 1950. Normal monthly average temperatures ranged from a low of -0.2°C (31.7°F) in December to a high of 24.6°C (76.3°F) in July. During winter, the highest monthly average temperature at the Hanford Meteorology Station was 6.9°C (44.5°F) in February 1991, and the record lowest was -11.1°C (12.1°F) in January 1950. During summer, the record maximum monthly average temperature was 27.9°C (82.2°F) in July 1985, and the record minimum was 17.2°C (63.0°F) in June 1953. The normal annual relative humidity at the Hanford Meteorology Station is 54%. Humidity is highest during winter, averaging ~76%, and lowest during summer, averaging ~36%. Normal annual precipitation at the Hanford Meteorology Station is 17.7 centimeters (6.98 inches). The wettest year on record, 1995, received 31 centimeters (12.31 inches) of precipitation; the driest, 1976, received 8 centimeters (2.99 inches). Most precipitation occurs during late autumn and winter, with more than half of the annual amount occurring from November through February. The snowiest winter on record, 1992-1993, received 142.5 centimeters (56.1 inches) of snow.

8.1.2 RESULTS OF 2002 MONITORING

Calendar year 2002 was slightly warmer than normal and precipitation was below normal.

The average temperature for 2002 was 12.4°C (54.4°F), which was 0.4°C (0.8°F) above normal (12.0°C [53.6°F]). Seven months during 2002 were warmer than normal; four months were cooler than normal. January had the greatest positive departure, 3.2°C (5.8°F); and March, at 2.1°C (3.7°F) below normal, had the greatest negative departure.

Precipitation during 2002 totaled 13.7 centimeters (5.41 inches), 78% of normal (17.7 centimeters [6.98 inches]). Snowfall for 2002 totaled 7.1 centimeters (2.8 inches) (compared to an annual normal snowfall of 39.1 centimeters [15.4 inches]).

The average wind speed during 2002 was 3.5 meters per second (7.8 miles per hour), which was 0.1 meter per second (0.2 mile per hour) above normal. The peak gust for the year was 28.2 meters per second (63 miles per hour) on December 27.

There were eight dust storms recorded at the Hanford Meteorology Station during 2002. There has been an average of five dust storms per year at the Hanford Meteorology Station during the entire period of record (1945-2002).

Table 8.1.2 provides monthly and annual climatological data collected at the Hanford Meteorology Station during 2002.

Table 8.1.2. Monthly and Annual Climatological Data from the Hanford Meteorology Station, 2002

Hanford Meteorology Station, 40 kilometers (25 miles) northwest of Richland, Washington,
latitude 46° 34'N, longitude 119° 35'W, elevation 223 meters (733 feet)

Month	Temperatures, °C								Precipitation (cm)				Relative Humidity (%)		15-m Wind ^(a)				
	Averages				Extremes				Total	Departure ^(b)	Snowfall		Average	Departure ^(b)	Average Speed, m/s	Departure ^(b)	Peak Gusts		
	Daily Maximum	Daily Minimum	Monthly	Departure ^(b)	Highest	Date	Lowest	Date			Total	Departure ^(b)					Speed, m/s	Direction	Date
J	7.3	-1.2	3.1	+3.2	17.2	7	-10.6	29	1.1	-1.1	1.5	-9.1	73.1	-4.2	3.7	+0.8	25.5	W	12
F	9.8	-2.7	3.6	+0.3	20.0	21	-8.9	27 ^(c)	1.7	-T ^(d)	0.5	-6.1	67.7	-2.8	2.7	-0.4	19.7	SW	21
M	12.0	-0.4	5.8	-2.1	21.1	31	-7.8	3	0.5	-1.0	3.6	+2.5	57.0	+0.4	4.0	+0.3	26.8	SW	11
A	19.2	4.3	11.8	-0.2	26.7	30	-1.7	4	0.7	-0.4	0	-T ^(d)	46.0	-1.3	4.0	+0.1	22.4	WSW	14
M	23.1	8.2	15.6	-0.9	30.0	27	0.0	8	0.4	-1.0	0	0	42.5	-0.5	4.1	+0.1	23.2	W	5
J	29.9	14.0	22.0	+1.3	40.0	26	7.8	8 ^(c)	1.6	+0.6	0	0	40.4	+0.8	4.0	0	21.0	NW	7
J	35.4	17.6	26.4	+1.8	45.0	13	10.0	4	0.4	-0.3	0	0	32.1	-1.3	4.2	+0.3	23.7	NW	7
A	32.4	15.9	24.2	0	39.4	14	10.0	17	T ^(d)	-0.8	0	0	34.5	-1.1	3.7	+0.1	18.3	NW	10
S	27.6	10.4	19.1	+0.2	35.6	22	3.3	22	T ^(d)	-0.8	0	0	38.8	-3.5	3.4	0	17.4	WNW	15
O	18.6	1.9	10.2	-1.4	27.2	6	-13.9	31	0.3	-0.9	0	-0.3	50.1	-5.3	2.8	-0.2	19.2	NNE	29
N	10.3	-0.3	5.0	+0.5	19.4	19	-11.7	2 ^(c)	1.0	-1.5	T ^(d)	-5.8	72.7	-1.0	2.5	-0.3	16.1	SSW	16
D	5.3	0.4	2.9	+3.1	13.3	16	-5.0	22	6.0	+3.2	1.5	-13.2	88.7	+8.6	2.5	-0.1	28.2	SW	27
Y ^(e)	19.2	5.7	12.4	+0.4	45.0	Jul 13	-13.9	Oct 31	13.7	-4.0	7.1	-32.0	53.6	-1.0	3.5	+0.1	28.2	SW	Dec 27

NOTE: See Appendix A, Table A.2 in this report for unit conversion information.

(a) Measured on a tower 15 meters (50 feet) above the ground.

(b) Departure columns indicate positive or negative departure of meteorological parameters from 30-year (1971-2000) climatological normals.

(c) Latest of several occurrences.

(d) Trace.

(e) Yearly averages, extremes, and totals.



8.2 ECOSYSTEM MONITORING AND ECOLOGICAL COMPLIANCE

J. L. Downs, M. R. Sackschewsky, R. P. Mueller, B. L. Tiller, M. A. Simmons, and R. E. Durham

The Hanford Site is a relatively undisturbed area of shrub-steppe (a drought-resistant, grassland ecosystem) that contains a rich diversity of plant and animal species adapted to the region's semiarid environment. The Ecological Monitoring and Compliance Project provides data and information to fulfill U.S. Department of Energy (DOE) Richland Operations Office's needs to achieve compliance with natural resource-related legal and regulatory requirements for the biological resources found on Hanford. Under this project, surveys and monitoring of resources and key biota are conducted to assess the abundance, vigor or condition, and distribution of populations and species on the Hanford Site. Data collection and analysis are integrated with environmental monitoring of biotic and abiotic media under the Surface and Environmental Surveillance Project to characterize any potential risk or impacts to the biota. Ecological monitoring and ecological compliance support multiple objectives for completion of Hanford's waste management and environmental restoration mission by:

- Assuring Hanford Site operational compliance with laws and regulations including the *Endangered Species Act of 1973*, the *Bald and Golden Eagle Protection Act*, and the *Migratory Bird Treaty Act*.
- Providing data for environmental impact and ecological risk assessments.
- Providing maps and information useful for biological resource impact mitigation during facility expansion.
- Supporting Hanford Site land-use planning and stewardship.

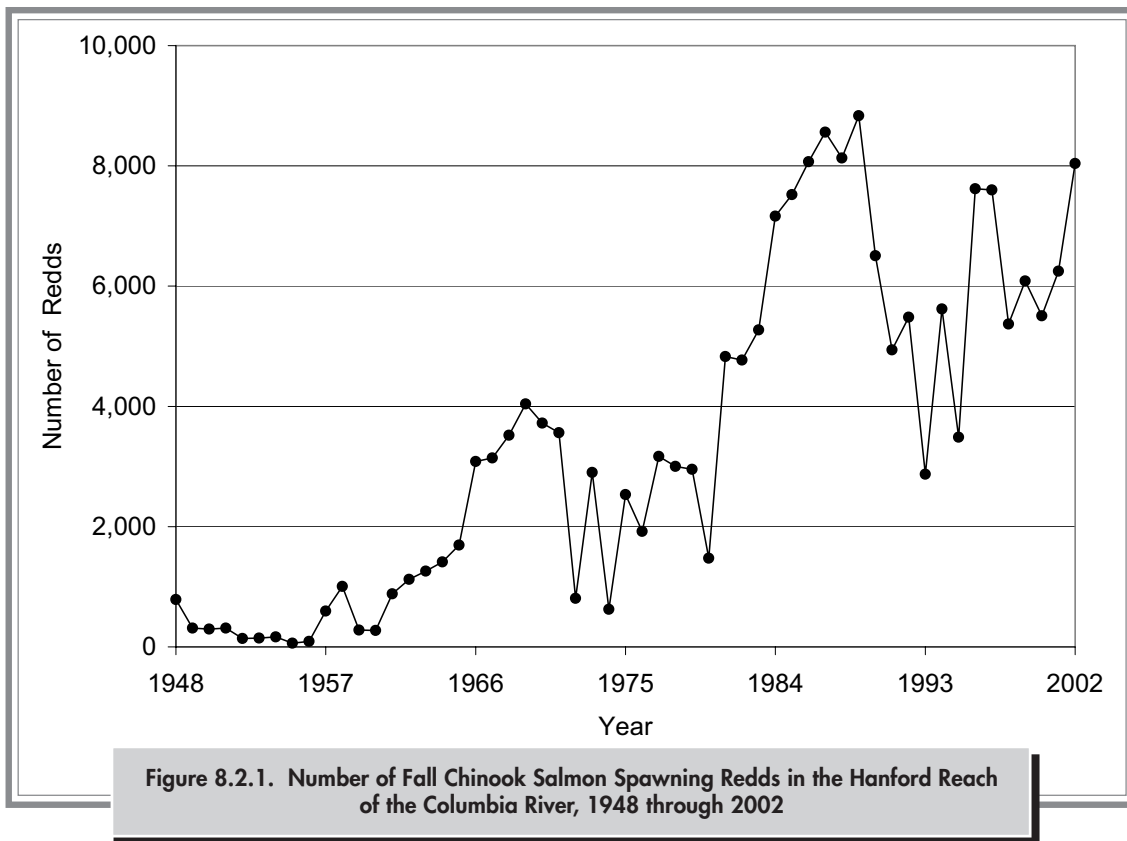
These activities are intended to assure protection of the natural resources within the DOE-operated portions of the Hanford Site including the DOE-managed portion of the Hanford Reach National Monument and provide information useful to the Hanford natural resource stakeholders and the public on the status of some of Hanford's most highly valued biological resources.

8.2.1 CHINOOK SALMON

Chinook salmon (*Oncorhynchus tshawytscha*) are an important resource in the Pacific Northwest; they are caught commercially and for recreation. Salmon are also of cultural importance to Native American tribes. Today, the most important natural spawning area in the mainstem Columbia River for the fall chinook salmon is found in the free-flowing Hanford Reach. In the early years of the Hanford Site, only a few spawning nests (redds) were found in the Hanford Reach. Between 1943 and 1973, a number of dams were constructed on the Columbia River and the formation of reservoirs behind these dams eliminated most mainstem spawning areas. These changes resulted in increased numbers of salmon spawning in the Hanford Reach. Fisheries management strategies aimed at maintaining spawning populations in the mainstem Columbia River also have contributed to the increased number of redds found in the Hanford Reach.

The number of fall chinook salmon redds estimated in the Hanford Reach by aerial surveys increased during the 1960s, 1970s, and 1980s until reaching a high in 1989 of nearly 9,000 (Figure 8.2.1). In the early 1990s, redd estimates declined to approximately one-third of the 1989 peak. The number of redds peaked again in 1996 and 1997 and then declined before rising again in 2001.

During 2002, ~8,040 redds were observed, an increase of nearly 1,800 from 2001 and similar to the numbers seen during the late 1980s. The main use areas for spawning were similar to previous years with the majority of redds occurring near Locke Island, the Columbia River islands between river miles 365-368 (Islands 8 [near the 100-D Area] through 10 [near the 100-F slough]), and Vernita Bar. Aerial surveys do not yield absolute redd counts because environmental conditions vary, depending on



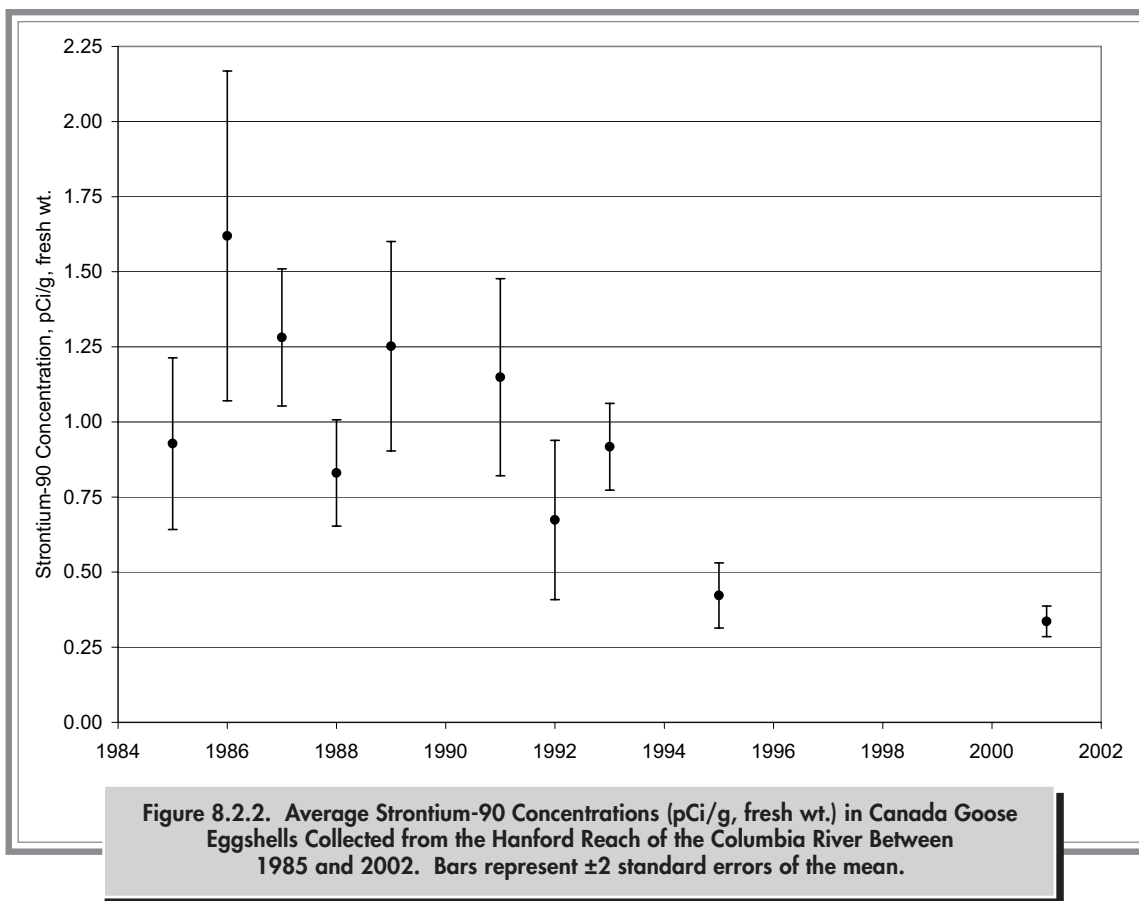
water depth and other factors, such as water turbidity and sun angle. In addition, the number of redds in high-density locations cannot be counted with absolute accuracy while flying. However, redd survey data are highly correlated with adult salmon escapement estimates obtained by state and federal agencies within the Columbia River Basin (Dauble and Watson 1997). The Hanford Reach remains the largest spawning area for fall chinook salmon in the mainstem Columbia River.

8.2.2 CANADA GOOSE NESTING ON THE HANFORD REACH

Canada goose (*Branta canadensis moffitti*) nesting surveys began during the 1950s to document the reproductive performance of the goose population and determine whether nesting performance would demonstrate a response to nuclear reactor operations. Continuous documentation of nesting performance has provided a way to evaluate the potential effects of legacy contamination from reactor operations, upstream industrial uses of Columbia River water, changes

introduced by hydroelectric dam operations, and increased recreational use of the region. During 2002, the nesting survey data and relevant contaminant information for this population were summarized.

Examination during 2002 of Canada goose nesting over the last 50 years reveals that the protection afforded the islands because of public exclusion from the Hanford Site has allowed geese to thrive. This trend is supported by the overall increases in numbers of nests and hatching rates. During 2001, strontium-90 and heavy metal concentrations were analyzed in egg shells collected from Canada goose nests where at least one egg hatched. Analytical results (Figure 8.2.2) show strontium-90 levels have continued to decrease since the late 1980s. Heavy metal concentrations were comparable to concentrations found at uncontaminated waterfowl and shorebird sites, except for nickel (Morera et al. 1997; Currie and Valkama 1998; Thomas 1999; Rodriguez et al. 2002). Nickel concentrations appeared elevated with respect to other bird species at contaminated sites (maximum concentrations of 12.4 µg/g in Hanford geese compared to 2.3 µg/g in curlew near a metal smelter; Currie and Valkama 1998). Nickel has no



known toxicological effects at these concentration levels (Outridge and Scheuhammer 1993). Birds appear to eliminate heavy metal by excretion and deposition in feathers and eggs (Burger 1994).

8.2.3 CHARACTERIZATION OF ASIATIC CLAMS

An assessment of contaminant concentrations in bivalves during 2001 demonstrated that this species could be used as a monitoring species in the Columbia River to identify patterns of contaminant uptake (PNNL-13692). Because bivalves are relatively sedentary filter-feeders, they represent organisms with high potential for exposure to contaminants of concern along the near-shore environment when or if contaminants reach the river. Therefore, in 2002, ecological monitoring and contaminant surveillance of bivalves was initiated. Asiatic clams (*Corbicula fluminea*) were collected during November 2002 to evaluate (1) demographics and distributions of the clam populations inhabiting Hanford shorelines, (2) bivalve tissue residue levels of

three radionuclides and 16 metals, and (3) histology of target organs. Results of tissue residue levels and histological inspections are expected to be available in 2003.

Densities (number per area) and sizes (lengths) of clams were measured along the Hanford Reach shoreline near existing reactor installations, the Hanford town site, the 300 Area, and at reference areas upstream from Hanford. The distribution of Asiatic clam shell lengths was used to separate the population into age groups; in this analysis, each identified mode is assumed to represent an age group (MacDonald and Pitcher 1979). From the analysis, there appear to be four distinct year classes: 0, 1, 2, and 3 years represented by peaks in the distribution (Figure 8.2.3). This information can be used to define duration of exposure.

Clam densities were measured with respect to substrate size and percent of the time the shoreline was inundated (i.e., covered with water). The percent inundation is related to daily and seasonal fluctuations of river flow in response to natural cycles, and operations of hydroelectric dams upstream and downstream of the Hanford Reach.

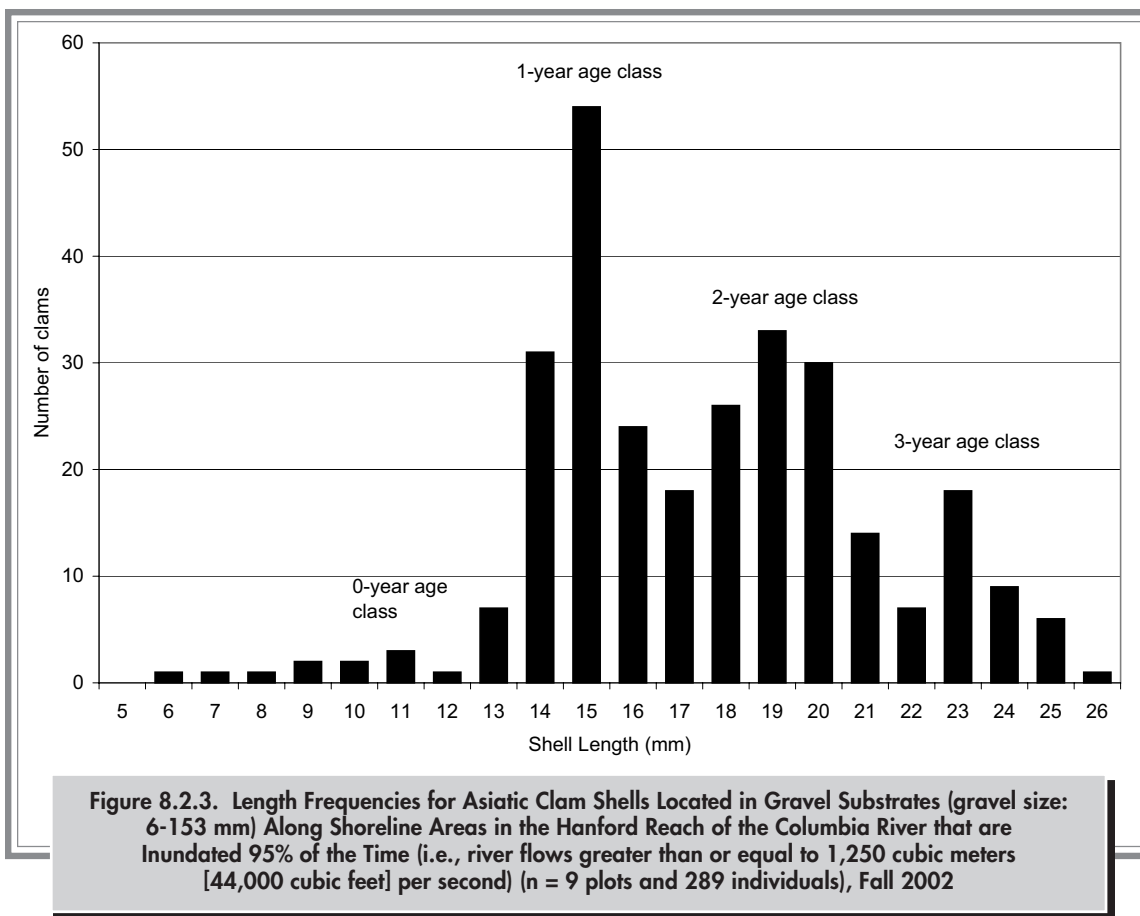
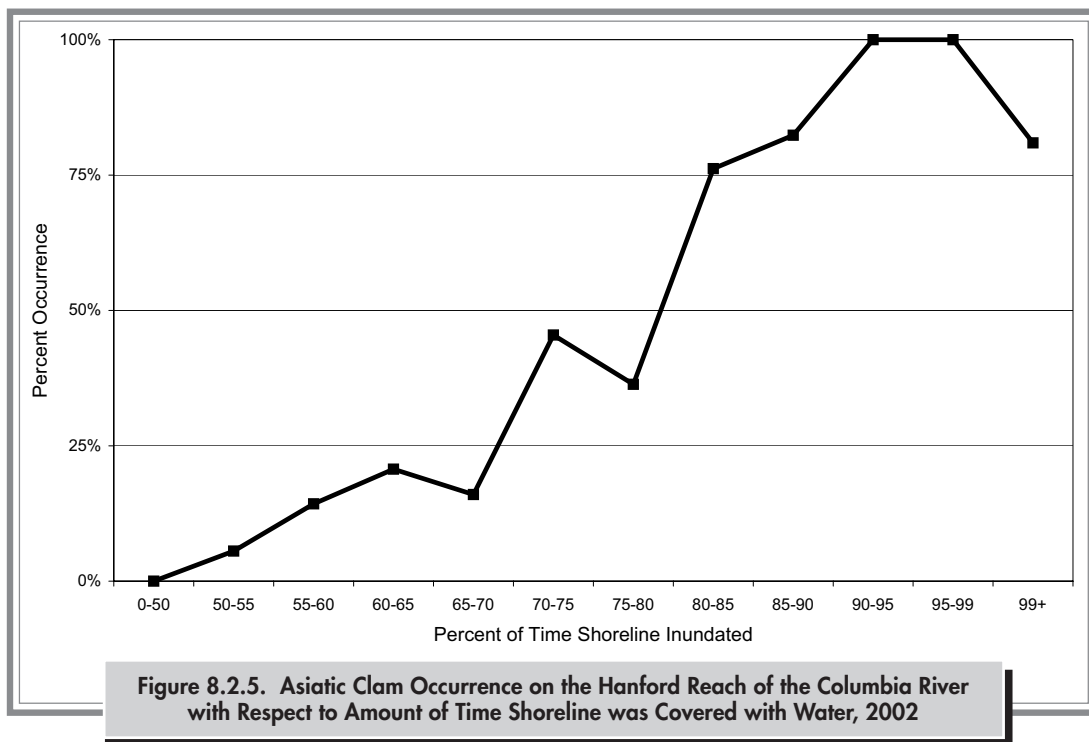
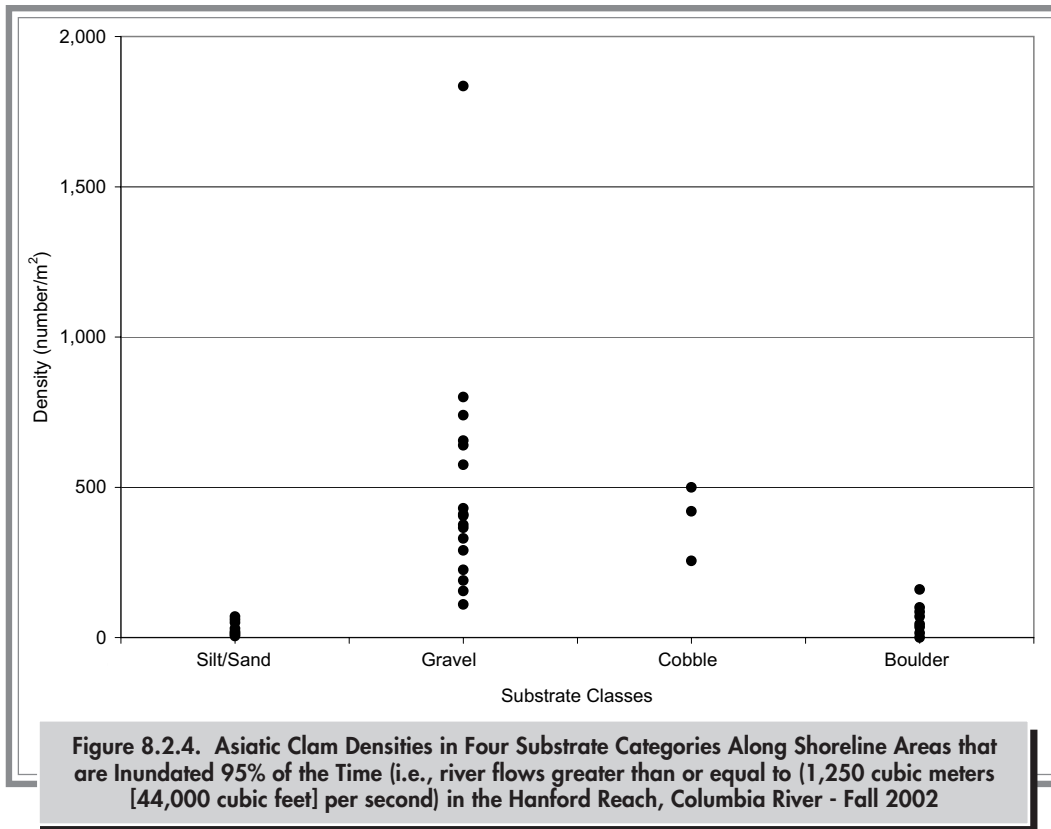


Figure 8.2.4 depicts clam densities (number of individuals per 1 square meter [10.8 square feet]) in four substrate classes found along the Columbia River. Clam densities were generally lowest where substrates were sand/silt or large boulders. Higher densities were found in gravels and cobbles, with the densities in gravel being highly variable.

Evaluating the clam densities (Figure 8.2.5) revealed that densities were highest in areas that were covered with water more than 80% of the time and that viable populations of clams did not persist in shoreline areas that are frequently exposed. High clam densities also appear to be correlated with the presence of periphyton and the absence of riparian vegetation. Knowledge of the distribution and abundance of clams in the near-shore environment will be used in further monitoring and surveys of contaminant uptake by biota.

8.2.4 VEGETATION SURVEYS AND MONITORING

The Hanford Site contains biologically diverse shrub-steppe plant communities that have been protected from disturbance, except for fire, over the past 55 years. This protection has allowed plant species and communities that have been displaced by agriculture and development in other parts of the Columbia Basin to thrive at Hanford. Surveys and mapping efforts have documented the occurrence and extent of rare plant populations and plant community types on the Hanford Site (Nature Conservancy 1999). Populations of rare plants include taxa listed by Washington State as endangered, threatened, or sensitive (Appendix G) and the locations of species that are listed as review group 1 (i.e., taxa in need of additional field work before status can be determined) (Washington Natural Heritage Program 1997). Data are collected for plant populations and plant communities to develop baseline



information and to monitor any changes resulting from Hanford operations. The data provide information that is used for site planning processes and land-use policy development.

More than 100 rare plant populations of 31 different taxa are found at the Hanford Site (Figure 8.2.6). The U.S. Fish and Wildlife Service has designated 5 of these 31 taxa (including the two species, Umtanum buckwheat [*Eriogonum codium*] and White Bluffs bladderpod [*Lesquerella tuplashensis*]) as species of concern in the Columbia River Basin ecoregion (<http://www.dnr.wa.gov/nhp/refdesk/lists/plantnrn.html>). These two species are proposed as candidates for federal listing. In addition to the rare plant populations, several areas on the Hanford Site are designated as special habitat types with regard to potential occurrence of plant species of concern listed by Washington State. These are areas that potentially support populations of rare annual forbs that have been documented in adjacent habitat.

Surveys during 2002 continued to document Piper's daisy (*Erigeron piperianus*) as a species of concern occurring in the 200 Areas. Surveys to the south of the 200 Areas documented previously known occurrences of grey cryptantha (*Cryptantha leucophaea*), but did not locate any additional populations. Populations of another species of concern in the Columbia River Basin ecoregion, persistent sepal yellowcress (*Rorippa columbiae*), declined as a result of the high river flow levels from 1995 through 2000. Persistent sepal yellowcress is a rhizomatous perennial found in moist soil along the Columbia River within the Hanford Site. This species is often inundated by river flows, but little is known concerning long-term survival under continuous inundation. While river flows were near normal during 2002, data collected by Washington State Natural Heritage Program documented decreases in yellowcress populations from previous survey years.

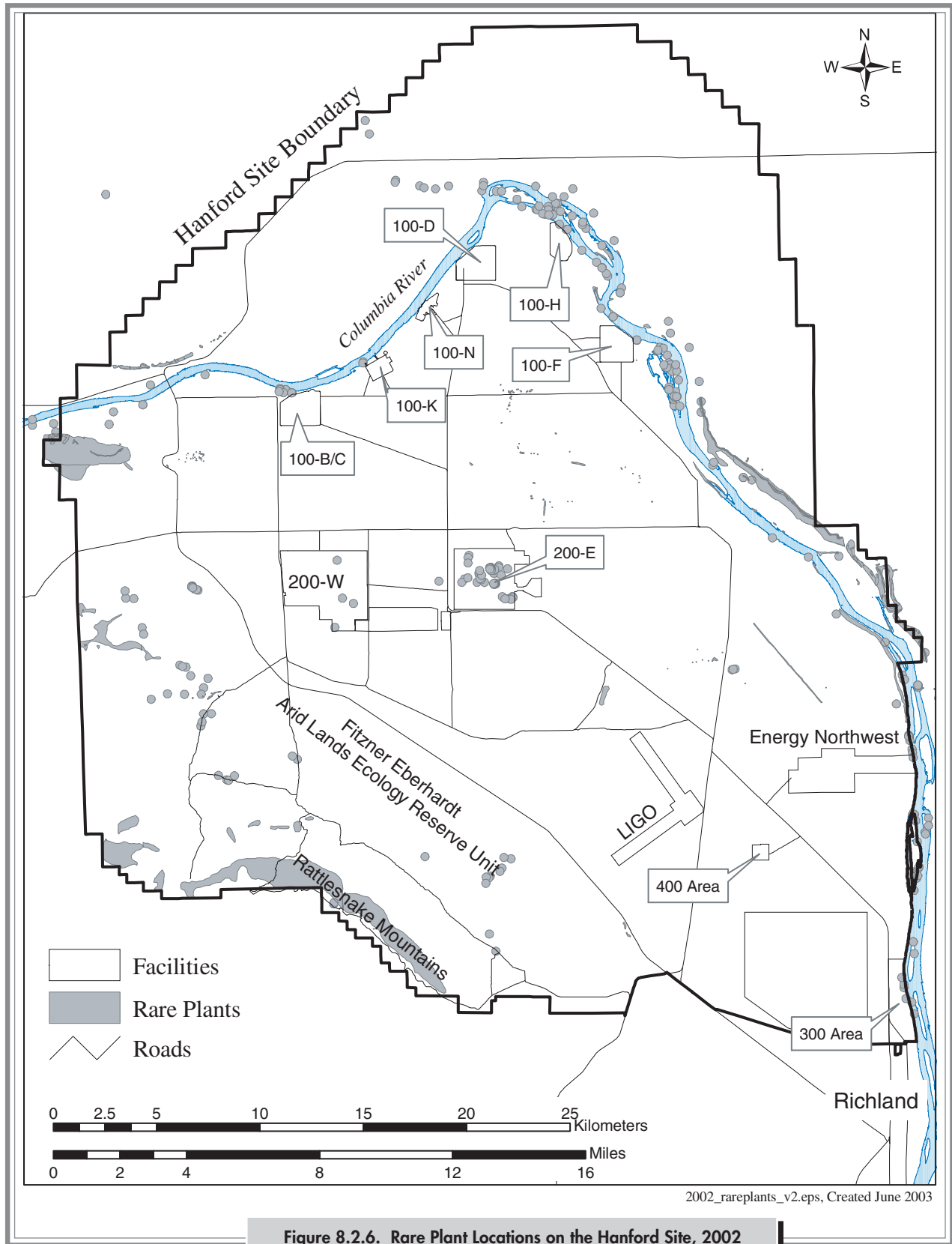
Vegetation on long-term monitoring plots within the footprint of the 24 Command Wildland Fire that occurred in 2000 was surveyed during 2001 and 2002 to evaluate vegetation status and habitat recovery. Figure 8.2.7 indicates that total vegetation cover has not recovered to pre-fire levels and that large amounts of bare soil still persist in communities where big sagebrush (*Artemisia tridentata*) was the dominant shrub. Decreases in total vegetative cover range from 12% to 79% for the nine vegetation cover types sampled.

Increased bare soil and lack of persistent native vegetation may offer increased opportunities for the establishment of invasive weeds. However, the overall frequency of occurrence of the common exotic annual grass, cheatgrass (*Bromus tectorum*), did not increase appreciably after the fire. In most communities, the frequency of cheatgrass decreased the year following the fire, but increased to near pre-fire levels during 2002 (Table 8.2.1). In three of the nine vegetation cover types sampled, cheatgrass frequencies increased significantly after the fire compared to pre-fire levels: cheatgrass frequency increased by 15% in the plots dominated by threetip sagebrush (*Artemisia tripartita*), by 40% in bluebunch wheatgrass-Sandberg's bluegrass monitoring plots, and by 40% in big sagebrush/bluebunch plots. However, the average cover of cheatgrass across all plots did not increase significantly and total cheatgrass cover did not increase significantly in vegetation where the frequency of this species increased. This indicates that there may be a greater number of individual cheatgrass plants scattered through the plot, but cheatgrass has not become a dominant species in the vegetation.

8.2.5 ECOLOGICAL COMPLIANCE

Policies of the DOE Richland Operations Office require that all projects having the potential to adversely affect biological resources have an ecological compliance review performed prior to initiation of the project. This review determines if the project will comply with the *Endangered Species Act of 1973* and the *Migratory Bird Treaty Act*. It also re-examines whether other significant resources such as Washington State listed species of concern, wetlands, and native shrub-steppe habitats are adequately considered during the project planning process. Where effects are identified, mitigation action is prescribed. Mitigation actions can include avoidance, minimization, rectification, or compensation.

Since many projects occur during periods of the year when the plants are not growing and plants are difficult to identify or evaluate, each of the operational areas (200-East and 200-West Areas, all of the 100 Areas, and the 300 Area) are surveyed each spring. All habitat areas within these areas are surveyed and each building is inspected for the nests of migratory birds. These baseline surveys provide information about the habitat types, and



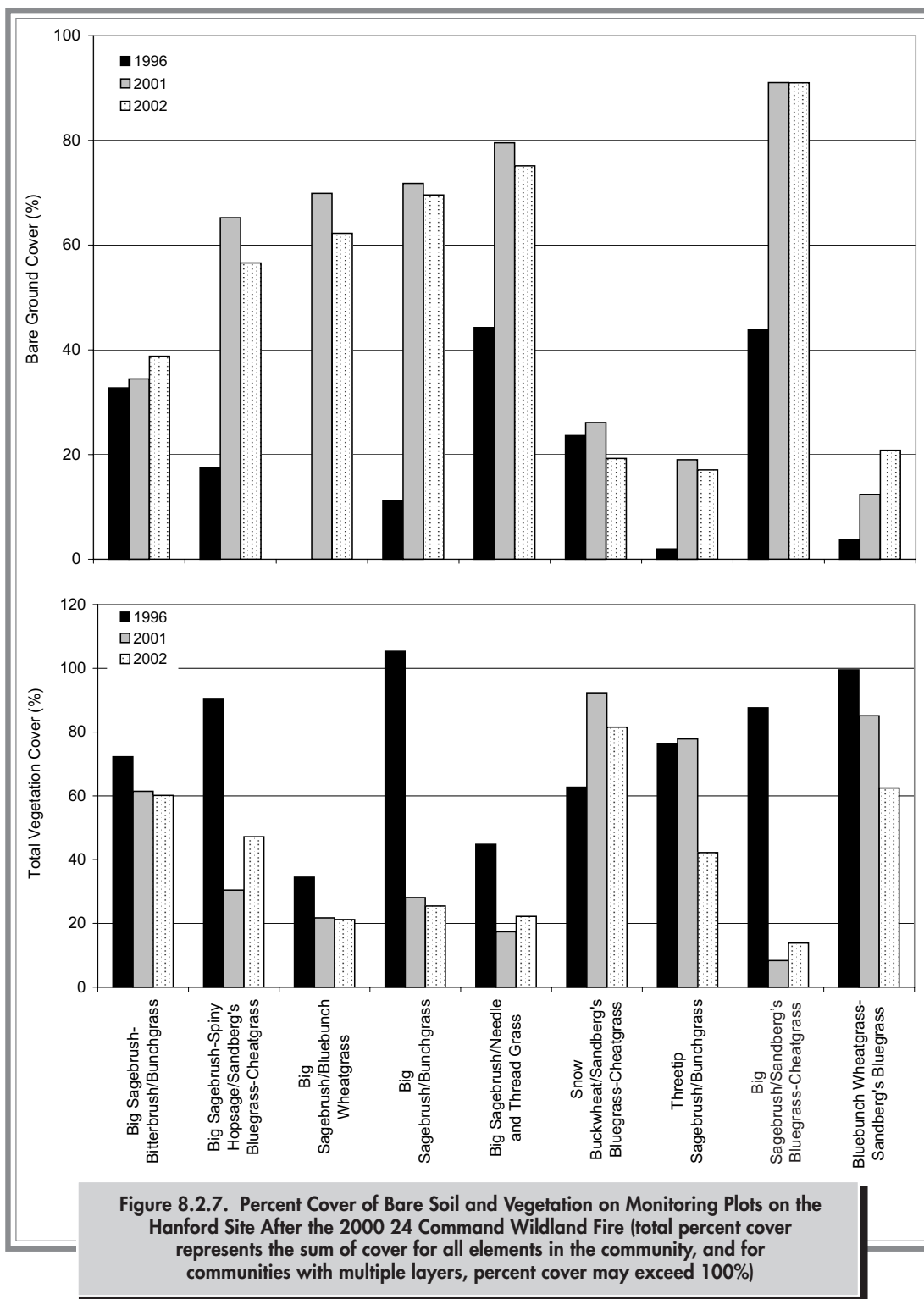


Table 8.2.1. Frequency of Occurrence and Average Canopy Cover of Cheatgrass (*Bromus tectorum*) on Hanford Site Monitoring Plots Before (1996) and After the 2000 24 Command Wildland Fire

<u>Survey Year</u>	<u>Frequency of Occurrence (%)</u>	<u>Frequency Standard Error</u>	<u>Canopy Cover (%)</u>	<u>Cover Standard Error</u>
1996	63.0	6.8	21.4	3.0
2001	54.7	7.2	7.5	1.7
2002	63.7	6.3	9.3	2.1

species inventories and abundance, which can be used throughout the rest of the year to assess potential impacts. Examples of the baseline survey maps are available at <http://www.pnl.gov/ecomon/compliance/comp.html>.

A total of 146 ecological compliance reviews were performed during 2002 in support of general Hanford Site activities. An additional 39 reviews were performed in support of environmental restoration activities. The total number of reviews prepared during 2002 (185) was slightly higher than the number of reviews performed during the previous 2 years (Table 8.2.2).

8.2.6 ECOLOGICAL COMPLIANCE FOR BALD EAGLES

The bald eagle is listed as a federally threatened species (50 CFR 17.11) and also a Washington State threatened species (Washington State Department of Wildlife 1994). Protection for bald eagles on the Hanford Site is guided by the management plan contained in DOE/RL-94-150 and coordinated with representatives of the U.S. Fish and

Wildlife Service. In accordance with the management plan, when the eagles are present, limited-access road closures within 800 meters (875 yards), or within 400 meters (437 yards) when out of sight of major perching, roost, and nesting sites have been mandated since 1994. While road closures for perch and roost sites are effective from November 15 to March 15, nest tending activities by the bald eagles have extended the closure until August. During the closures, only emergency activity is permitted in buffer zones; low-impact activities (well monitoring) are considered on a case-by-case basis and are generally permitted out of the line of sight, but not closer than 400 meters (437 yards) from the nest site.

Since monitoring started in 1961, no bald eagles have successfully nested on the Hanford Site. Nesting attempts have been documented since 1997. Some factors that may result in nest abandonment include (1) adverse weather, (2) food availability, (3) human activity near the nest, and (4) avian predator interactions. To evaluate the effect of human activities on nest abandonment and determine whether the present restrictions are adequate, data were collected on nesting behavior and on the eagles' flush responses.

Table 8.2.2. Ecological Reviews Performed on the Hanford Site, 1997 through 2002

<u>Calendar Year</u>	<u>100 Areas</u>	<u>200 Areas</u>	<u>300 Area</u>	<u>Other^(a)</u>	<u>Total</u>
1997	8	79	44	33	164
1998	42	91	28	47	208
1999	36	72	36	52	196
2000	36	52	27	47	161
2001	26	64	27	52	169
2002	36	68	26	55	185
Totals	184	426	188	286	1,083

(a) Includes the 400, 600, 700, Richland North, and former 1100 Areas.

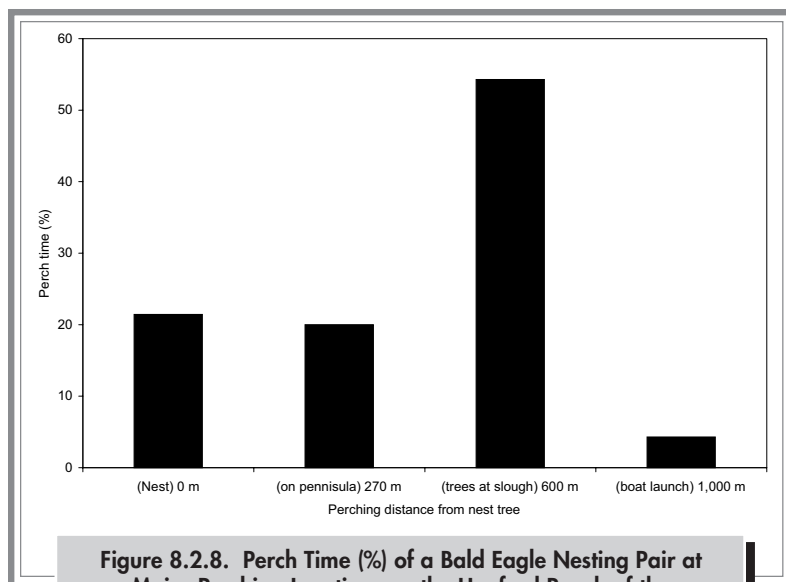


Figure 8.2.8. Perch Time (%) of a Bald Eagle Nesting Pair at Major Perching Locations on the Hanford Reach of the Columbia River Relative to Their Nest Location, 2002

During 2002, a single nesting eagle pair spent ~70% of their time (32.5 observation hours) perching. Much of that time was spent perching at the tree clumps within 600 meters (656 yards) of the nest. These trees also overlooked areas where food items (fish and waterfowl) were plentiful. Observations indicated that the nesting eagles primarily used an area within 600 meters (656 yards) of the nest (Figure 8.2.8).

The establishment of the 800-meter (875-yard) protection zone was originally developed from a number of published studies of flush-response patterns of eagles to various manmade disturbances. However, there has been no flush-response study for the bald eagles on the Hanford Site. Data on the flush response of bald eagles to the presence of vehicles or boats at various distances was collected from 1999 to 2001 and analyzed during 2002.

Factors having the greatest effect on eagle flush response included distance from disturbance, disturbance type (boat or vehicle), and age class. In general, juveniles were more susceptible to flushing than adults (Figure 8.2.9). Figure 8.2.10 illustrates the likelihood of flushing in response to distance from a boat or vehicle based on a multivariate logistic model. The model response

indicates that vehicles are more likely to flush eagles than boats, and that 800 meters (875 yards) is probably an adequate distance to protect the bald eagles at Hanford from human-related disturbances.

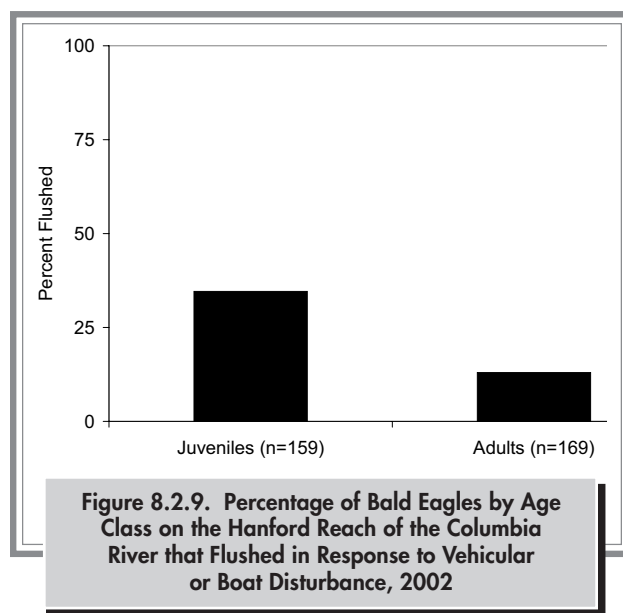
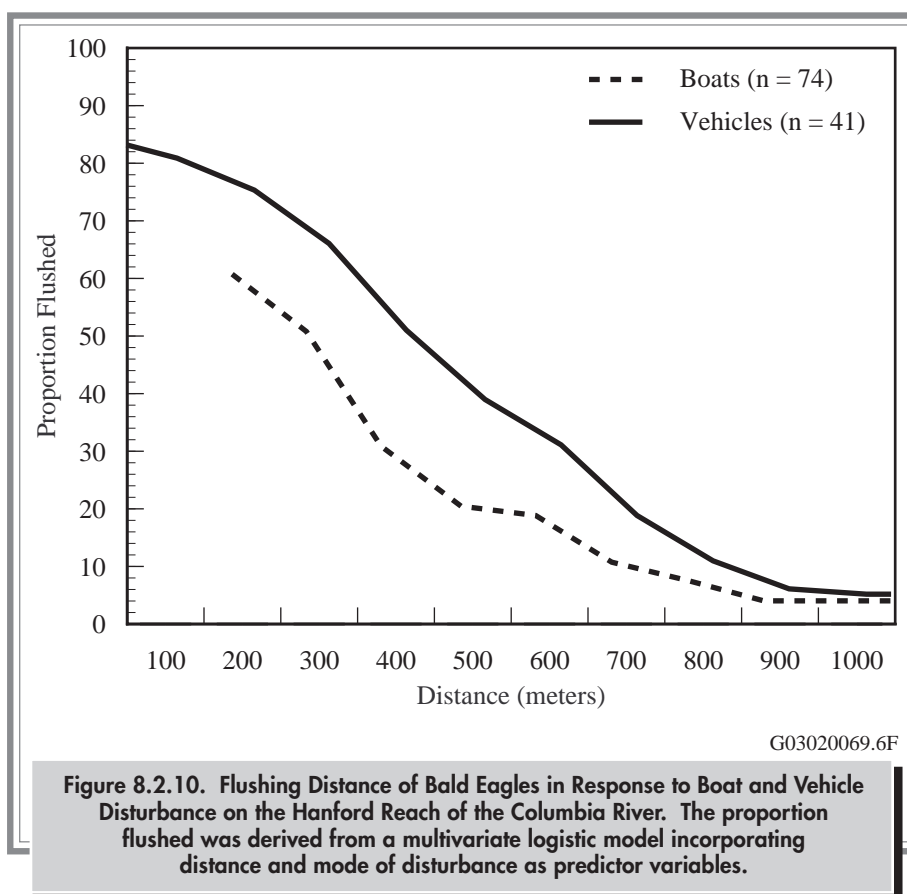


Figure 8.2.9. Percentage of Bald Eagles by Age Class on the Hanford Reach of the Columbia River that Flushed in Response to Vehicular or Boat Disturbance, 2002





8.3 CULTURAL RESOURCES

D. W. Harvey and L. L. Hale

The DOE Richland Operations Office established a cultural resources program in 1987 that is managed by the Hanford Cultural Resources Laboratory (PNL-6942) as part of the Pacific Northwest National Laboratory. Pacific Northwest National Laboratory, Bechtel Hanford, Inc., and CH2M HILL Hanford, Inc. provided support to DOE for the cultural resources program on the Hanford Site throughout 2002. The U.S. Fish and Wildlife Service also has managed cultural resources on Hanford Site national monument lands since October 1999.

8.3.1 MONITORING CULTURAL RESOURCES

The DOE Richland Operations Office has the responsibility for determining effective management and protection policies for the Hanford Site's cultural resources. The Hanford Cultural Resources Laboratory has maintained a monitoring program since 1987 to determine the impact of DOE Richland Operations Office policies and to safeguard cultural resources from adverse effects associated with natural processes or unauthorized excavation and collection that violate federal laws.

Monitoring conducted during 2002 focused on four sites or place categories: Locke Island's erosion archaeological sites with natural and visitor impacts, historic buildings and structures, and Native American sites.

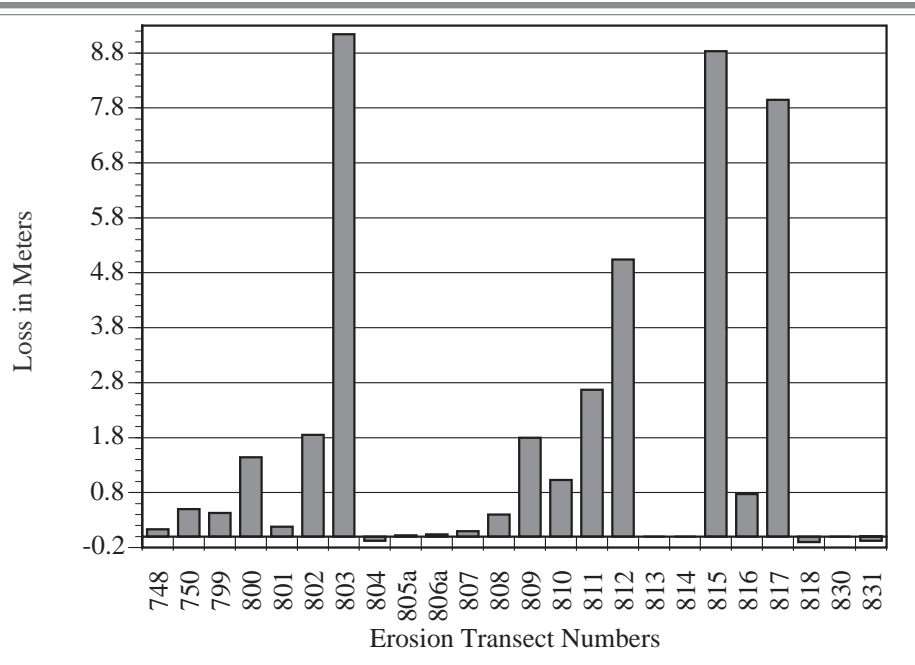
8.3.1.1 LOCKE ISLAND EROSION

Erosion monitoring at Locke Island has been ongoing since 1994. Locke Island, located on the Columbia River in the Hanford Reach National Monument, contains some of the best-preserved evidence of prehistoric village sites still existing in the Columbia Basin and is included within the Locke Island National Register Archaeological District. The island has sustained shoreline loss due to

erosion along its eastern shoreline that has affected archaeological materials. Recent studies have shown that this is due to a large landslide on the eastern side of the Columbia River.

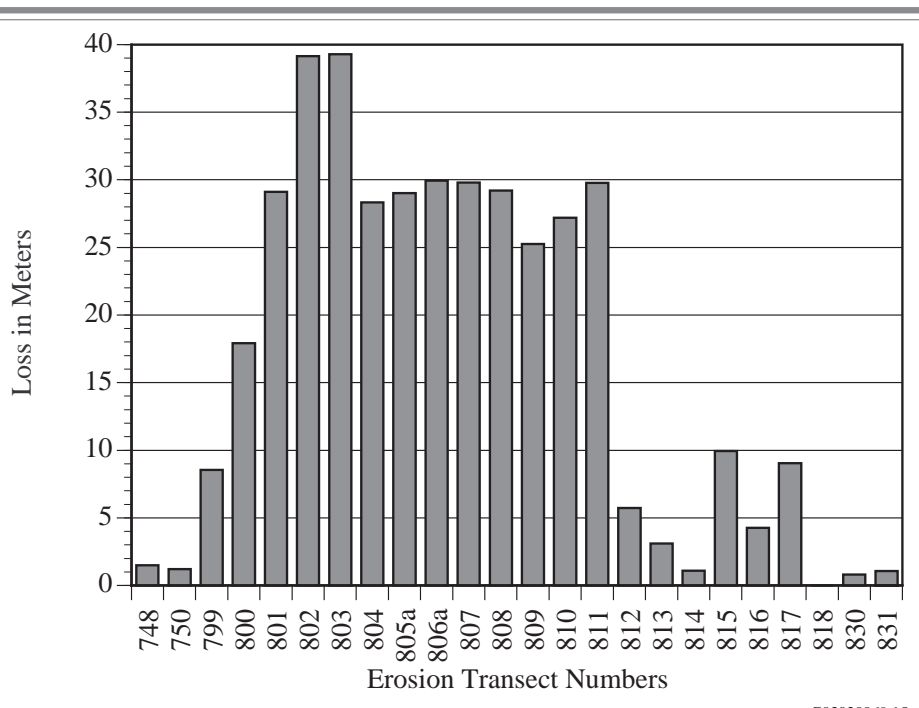
During the 1960s and 1970s, intensive irrigation development began to occur north and east of the White Bluffs, which form the eastern boundary of the Columbia River channel in this area. As a result, the White Bluffs began to show geological failures as irrigation water seeped out along the bluffs. One of the largest such slides, known as the "Locke Island Landslide," is located due east of Locke Island. By the early 1980s, this landslide extended into the river channel toward the island and directed the current toward the island's eastern perimeter. Erosion of the eastern bank of the island accelerated, threatening the cultural resources. By the early 1990s, the erosion had exposed cultural features and artifacts along the bank, leading to the beginning of intermittent monitoring of the erosion cutbank. During 1994, DOE initiated more scheduled, systematic monitoring of island erosion to better understand the physical processes involved as well as mitigate ongoing loss of the archaeological record (PNNL-11970).

Erosion monitoring continued at the Locke Island erosion transects during 2002. The greatest erosion recorded at any one monitoring transect was 9.14 meters (29.98 feet), as measured perpendicularly from the Columbia River (Figure 8.3.1). This amount of erosion was much less than the 19.6 meters (64.3 feet) of horizontal cutbank eroded to the river at a single transect in 1997 during a period of high water flow (PNNL-11970). Two transects showed gains of 0.08 meter (0.26 foot) and one transect showed a gain of 0.1 meter (0.32 foot) in 2002. These gains were caused by measuring discrepancies and bank separation prior to collapse. The overall reduction in erosion observed since the high water of 1997 was likely attributable to the fact that river flows have been lower since 1997, and the fact that the east channel was widened ~40 meters (~131 feet) as a result of erosion along the east bank of the island and along the toe of the landslide (PNNL-11970) (Figure 8.3.2).



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Figure 8.3.1. Measured Erosion at the Locke Island Erosion Transects Near the Hanford Site, 2002. Transects are spaced at eroding cutbanks along the full length of the island's eastern shoreline.



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Figure 8.3.2. Total Measured Erosion at the Locke Island Erosion Transects Near the Hanford Site Between November 1995 and September 2002. Transects are spaced at eroding cutbanks along the full length of the island's eastern shoreline.

8.3.1.2 ARCHAEOLOGICAL SITES

Monitoring archaeological sites with natural and visitor impacts began during 1998 and continued during 2002. Sixty-six archaeological sites were monitored to gather empirical data about the:

- Characteristics of each site (e.g., landform, stratigraphy).
- Processes adversely affecting the site (i.e., riverbank erosion, wind erosion, human visitation).
- Changes at the site (e.g., erosion, eventual stability).

Monitoring stations established at each archaeological site in this category facilitated the collection of standardized data unique to each site. During 2002, effects observed and measured at these sites were due to recreational use, collector digging, and/or weathering processes. The data collected at these archaeological sites are used to assess changes that may impact each site, predict outcomes, and manage other similar archaeological sites across the Hanford Site.

8.3.1.3 HISTORIC BUILDINGS

Monitoring of historic buildings during 2002 focused on Bruggemann's Warehouse, the only cobblestone structure remaining on the Hanford Site, the First Bank of White Bluffs building, Coyote Rapids Hydroelectric Pumping Plant, Hanford Electrical Substation, and the Hanford town site high school. The buildings were photographed and locations of structural deterioration were identified. Future monitoring inspections will continue to gather data about any crack widening and structural leaning.

8.3.1.4 CEMETERIES

Places with cemeteries or known human remains include locations that are sacred to the Wanapum, Yakama Nation, Confederated Tribes of the Umatilla Indian Reservation, and the Nez Perce Tribe. During 2002, all these places were monitored to document baseline conditions, determine whether wind or water erosion had exposed human remains, and assure that violations of federal laws were not occurring at these places. Overall, places with human remains were found to be stable during 2002. No violations were noted.

In summary, a total of 61 archaeological sites, 5 buildings, and a number of cemetery or burial locations were monitored during 2002. Of the findings recorded at these monitored places, 60 of 61 were related to natural causes such as animal trailing and digging, wind-caused erosion or aggradations, and water erosion. Twenty-seven percent of the findings were determined to be human-related. Most causes were related to vehicle traffic where sites are exposed in roads and sites near fishing or duck hunting areas. One percent of the findings were found to be associated with recent collector digging within archaeological site boundaries and/or surface collection of artifacts.

8.3.2 NATIVE AMERICAN INVOLVEMENT

Members of the Confederated Tribes of the Umatilla Indian Reservation, Yakama Nation, Nez Perce Tribe, and the Wanapum were actively involved in the cultural resources program during 2002. Each tribe was involved in deciding DOE's cultural resource program work scope, budget, and schedule.

Seven tribal meetings on cultural resources during 2002 provided a venue for the exchange of information between DOE, tribal staff members, and site contractors about projects and work on the Hanford Site. These meetings included discussions of site-wide projects dealing with a wide range of topics: impacts of Bonneville Power Administration road maintenance project on Gable Mountain and a memorandum of agreement to mitigate the impacts, archaeological excavation reports resulting from Section 106 projects (Section 8.3.4), development of alternative Section 106 procedures, 100-K Area remedial actions, stabilization characterizations of eroding sand dunes (that exposed human remains) in the 100-F Area, Fluor Hanford, Inc. pesticide programs, and updates on the *Archaeological Resources Protection Act of 1979* violations, the draft archaeological programmatic agreement and the *Hanford Cultural Resources Management Plan* (DOE/RL-98-10). Tribal staff and site contractors worked together during the completion of several field surveys to identify and record cultural features, sites, and landscapes in advance of new construction and archaeological test excavations and to monitor numerous projects requiring excavation during the year.

One member of the Wanapum assisted with cultural resource surveys, site form preparation, records management, and equipment use during 2002. Interviews were conducted with Wanapum elders concerning traditional cultural properties on the Hanford Site.

8.3.3 PUBLIC INVOLVEMENT

Public involvement is an important component of a cultural resources management program. To accomplish this, DOE developed mechanisms that allow the public access to cultural resources information and the ability to comment and make recommendations concerning the management of cultural resources on the Hanford Site. Major interest groups involved in assisting DOE with cultural resource initiatives included the B Reactor Museum Association, White Bluffs-Hanford Pioneer Association, the Washington State Railroad Historical Society, and local historical societies and museums.

Since 1987, workshops have been organized and conducted to seek public comment on a variety of cultural resource initiatives and projects undertaken by DOE. These workshop discussions indicated continual strong support for the use of B Reactor as a publicly accessible museum. Since 2000, comments have been sought on drafts of the *Hanford Cultural Resources Management Plan* (DOE/RL-98-10). The final draft management plan was submitted to DOE for approval in December 2002, and was approved and published in February 2003.

Additional public discussions over the past several years focused on the ongoing curation of Manhattan Project and Cold War era artifacts into the Hanford collection. Public input was also sought on the draft *History of the Plutonium Production Facilities at the Hanford Site Historic District, 1943-1990* (DOE/RL-97-1047). Staff of the Hanford Cultural Resources Laboratory, Bechtel Hanford, Inc., and DOE distributed the draft report for public review during 1999 through 2000. The final document was submitted to DOE Richland Operations Office for approval and clearance in 2001. DOE approved and published the book in June 2002.

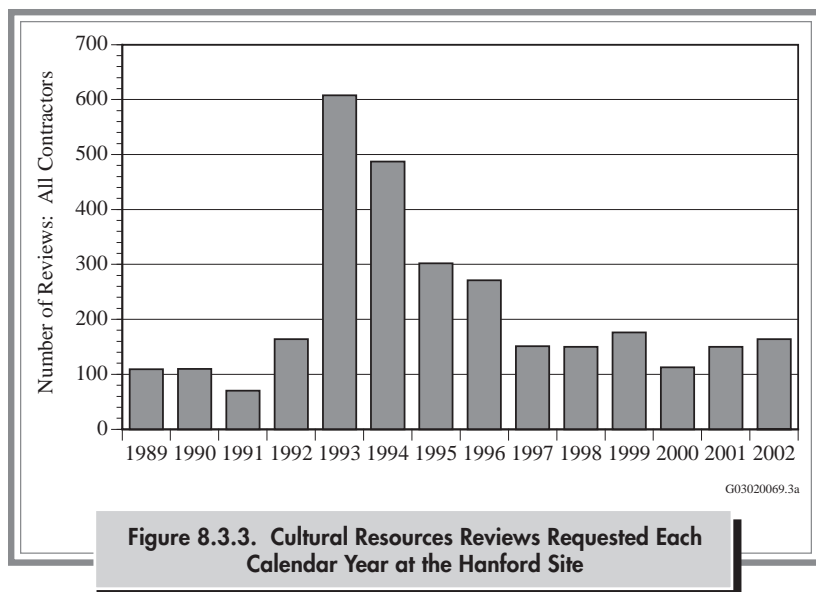
During 2002, DOE continued to document the oral histories of early residents of areas now part of the Hanford Site as well as Native Americans, former Hanford Site workers, and current site employees. A total of eight interviews were conducted during 2002.

8.3.4 CULTURAL RESOURCES REVIEWS

Pursuant to Section 106 of the *National Historic Preservation Act*, cultural resources reviews must be conducted before a federally funded, federally assisted, or federally licensed ground disturbance or building alteration/demolition project can take place. Because the Hanford Site is a federal facility, cultural resource reviews are required to identify properties within the proposed project area that may be eligible for, or listed in, the National Register of Historic Places and evaluate the project's potential to affect any such property. The recently modified cultural resource review process includes two review options. The first option allows DOE to consider the review process complete if the proposed projects have no potential to effect historic properties. The second option involves notification of the State Historic Preservation Officer, tribes, and interested parties if a project has potential to affect a historic property.

The Hanford Cultural Resources Laboratory worked closely with DOE during 2002 to educate Hanford Environmental Compliance officers on the Section 106 and the cultural resources review process.

During 2002, Hanford Site contractors requested 164 cultural resource reviews (Figure 8.3.3). A majority of the reviews involved areas that had been previously surveyed or were located on previously disturbed ground. Of the areas reviewed, 5 were monitored during the construction phase, 7 projects required an archaeological survey, and 33 involved proposed building modifications, demolitions, and Programmatic Agreement for the Built Environment (DOE/RL-96-77) exemptions. Exempt properties are those buildings and structures that are clearly not historic; therefore, they are not required to be evaluated for listing in the National Register of Historic Places due to their obvious lack of historic significance.



The following are major cultural resources reviews that were completed during 2002:

- Benton County Horn Rapids Park easement.
- Plutonium Finishing Plant decommissioning project.
- Demolition of 10 buildings that are eligible for listing in the National Register.
- Demolition and Deactivation of the Fast Flux Test Facility.
- Re-start of the Hanford railroad.
- Restore and maintain access roads under Bonneville Power Administration and transmission lines on Gable Mountain and on the Ostrander Line.

8.3.5 EVALUATIONS OF HISTORIC BUILDINGS OR STRUCTURES

Section 110 of the *National Historic Preservation Act* requires that federal agencies undertake a program to identify, evaluate, and nominate historic properties and consider the use and reuse of historic buildings or structures. Agencies are further required to maintain and manage historic properties in a way that considers preservation of their value and assures that preservation-related activities are completed in consultation with other agencies, the tribes, and the general public.

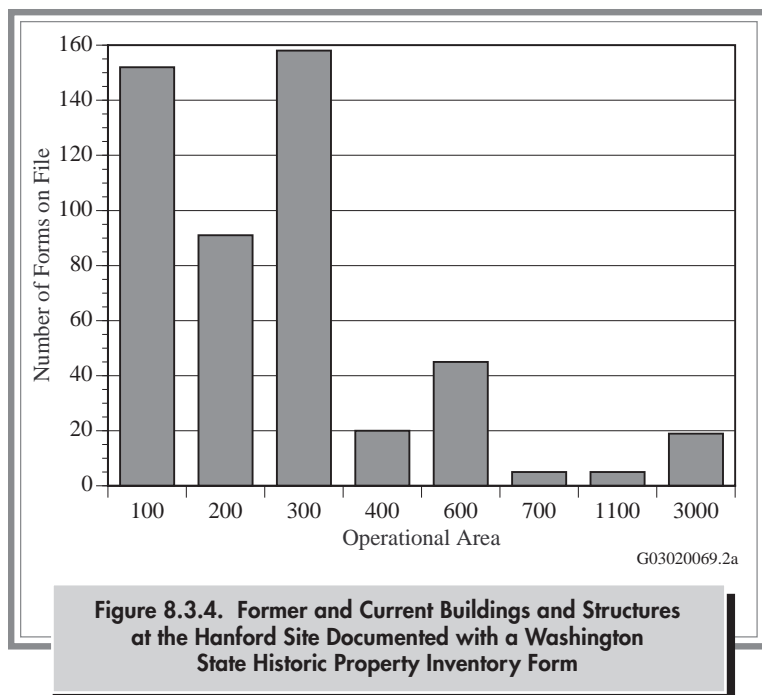
Since 1999, DOE has been evaluating the feasibility of retaining five buildings on the Hanford Site from the

pre-Manhattan Project era. An assessment of the structural condition of the First Bank of White Bluffs, Hanford town site high school, Coyote Rapids Hydroelectric Pumping Plant, and Bruggemann's Warehouse has been completed. The studies detailed existing conditions, interim actions, conservation needs, immediate stabilization requirements, and cost estimates for stabilization. A committee comprised of members of the interested public and staff of DOE, U.S. Fish and Wildlife Service, Bechtel Hanford, Inc., and Pacific Northwest National Laboratory continued to explore stabilization and restoration alternatives for the historic First Bank of White Bluffs building.

During 2002, management activities conducted to fulfill Section 110 requirements included continued implementation of the programmatic agreement for the built environment (DOE/RL-96-77) and application of the Hanford Site curation strategy to identify, evaluate, and preserve Manhattan Project and Cold War era artifacts (DOE/RL-97-71). Since Section 110 activities began on the Hanford Site, 506 buildings and structures within the current Hanford Site areas have been documented on historic property inventory forms and are on file at the Hanford Cultural Resources Laboratory (Figure 8.3.4).

Three surveys comprised the 2002 Section 110 efforts: the Groundwater Plume Survey-Phase I, the Fiscal Year 2002 Confederated Tribes of the Umatilla Indian Reservation Survey, and the Evaluate and Record Farm Sites Project. A total of ~4,923 hectares (~12,156 acres) were surveyed in 2002 for Section 110 compliance.

The Groundwater Plume Survey Phase I was designed as an initial investigation of lands overlying contaminated groundwater on the Hanford Site. The survey was intended as a proactive approach to identify cultural resources in areas that could be affected by ground-disturbing cleanup or monitoring activities related to groundwater contamination. The specific locale was also chosen for the pedestrian survey due to its close proximity to the Tsulim Bison Kill Site. It was hoped that direct archaeological materials, or other related data, could be revealed to gain more insight into the nature of activities that took place at this site.



The survey was conducted in June 2002. Staff from the Nez Perce Tribe, the Yakama Nation, and the Wanapum assisted in the survey.

A total of 11 newly identified archaeological sites and 12 newly identified isolated artifacts were found during the Groundwater Plume Survey. Of this total, only one isolate and one archaeological site were regarded as pre-contact cultural resources. The remaining sites and isolates were of historic vintage, most likely dating to the first half of the twentieth century. Several hypotheses were generated relating to the almost non-use of this area by pre-contact indigenous people, all of which remain to be tested by further survey investigations.

The Confederated Tribes of the Umatilla Indian Reservation Cultural Resource Protection Program surveyed ~4,030 hectares (~9,956 acres) of the Hanford Site during 2002 as part of their Hanford scope of work. The report on this and previous work will be submitted to DOE during 2003.

The final Section 110 survey during 2002 was the Evaluate and Record Farm Sites Project. This was a comprehensive effort designed to identify all of the farming-related sites eligible for listing in the National Register. Although field surveys were involved, the bulk of the effort involved analyzing historic records, interpreting historic and

contemporary aerial photographs, and collecting and analyzing oral histories. During 2002, efforts concentrated on refining the methods to be used in preparation for finalizing the effort in 2003.

8.3.5.1 HISTORIC DISTRICT

During 2002, the building mitigation project continued to implement the Programmatic Agreement for the Built Environment (DOE/RL-96-77) and the site-wide treatment plan (DOE/RL-97-56) at the Hanford Site. The treatment plan is stipulated in the programmatic agreement and directs that a mitigation document be produced that chronicles the history of the Hanford Site during the Manhattan Project and Cold War periods. The *History of the Plutonium Production Facilities at the Hanford Site Historic District, 1943-1990* was completed and distributed during 1999 for public review, regulatory review, and peer review. Review comments were received by DOE and included in the final document that was published during 2002 (DOE/RL-97-1047).

The Hanford Site Manhattan Project and Cold War Era Historic District was established in 1996, and 185 buildings, structures, and complexes were determined eligible for listing in the National Register of Historic Places as contributing properties within the historic district recommended for individual documentation. A contributing property is a building, structure, site, or object that adds to the historic significance of a historic district (Figure 8.3.5). Subsequent public meetings and staff evaluations identified additional properties in the 600, 700, and former 1100 Areas, including the Hanford Site railroad and the Hanford Atmospheric Dispersion Test Facility, as contributing properties within the historic district and recommended for individual documentation, bringing the total to 190 (Figure 8.3.6). All of the buildings, structures, and complexes recommended for individual documentation have been documented according to standards identified in the site-wide treatment plan (DOE/RL-97-56). Six historic properties, including B Reactor, have been documented at the Historic American Engineering Record level, 46 have been documented with Expanded Historic Property Inventory Forms, while standard Historic



Figure 8.3.5. Historic Sites are Commonly Discovered During Cultural Resource Surveys Conducted at the Hanford Site

Property Inventory Forms have been prepared for the remaining 138 buildings and structures.

Approximately 900 buildings and structures have been identified as either contributing properties with no individual documentation requirement or as non-contributing/exempt buildings and structures. These buildings will be documented in a database maintained by DOE. According

to the Programmatic Agreement for the Built Environment (DOE/RL-96-77), certain property types such as mobile trailers, modular buildings, storage tanks, towers, wells, and structures with minimal or no visible surface manifestations are exempt from the identification and evaluation requirement.

8.3.5.2 HANFORD CURATION STRATEGY

The application of the curation strategy for artifacts and records associated with the Hanford Site Manhattan Project and Cold War Era Historic District continued during 2002. The strategy is stipulated in the programmatic agreement for the built environment (DOE/RL-96-77), which directs DOE to assess the contents of Hanford's historic buildings and structures prior to the commencement of deactivation, decontamination, or decommissioning activities. The purpose of the assessments is to identify and preserve any artifacts (e.g., control panels, signs, scale models, machinery) that may have interpretive or educational value as exhibits within national, state, or local museums. The assessments are accomplished by conducting walkthroughs

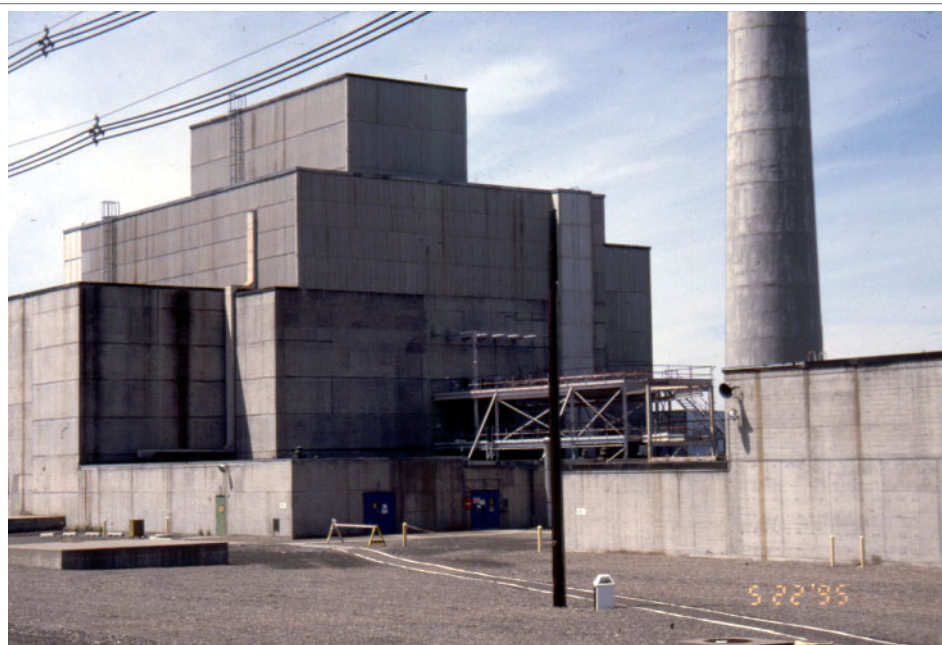


Figure 8.3.6. K-West Reactor, Eligible for Listing in the National Register of Historic Places as a Contributing Property Recommended for Mitigation within the Hanford Site Manhattan Project and Cold War Era Historic District

of the contributing properties within the historic district by teams of cultural resources specialists, historians, archivists/curators, and facility experts. Six walkthroughs were conducted during 2002, including two in facilities in the 200 Areas, three in the 300 Area, and one in the 400 Area. Industrial artifacts were tagged and recorded by the Hanford Cultural Resources Laboratory and transferred to the custody of the Columbia River Exhibition of History, Science and Technology museum in Richland for curation.

DOE's archaeological collections and associated records continued to be housed in Pacific Northwest National Laboratory's repositories during 2002. A draft management plan that deals specifically with archaeological collections, developed during 1998, was used during 2002 to guide access and use of the collections and to provide guidelines for acquisition and transfer of collections. A pest management and monitoring effort was conducted during 2002 of all archaeological collection repositories. The effort found some insects in Battelle's Sigma V Building repository.

8.3.6 EDUCATION AND RESEARCH

Educational activities associated with the cultural resources program during 2002 consisted of lectures on a variety of topics, to groups ranging from public school classrooms to civic groups, colleges, and professional societies. Several symposia were organized throughout the Pacific Northwest region to present DOE's cultural resources management techniques to professional groups and societies. Washington State's Archaeology Month provided educational opportunities in the form of lectures and for residents of the Tri-Cities' area. Staff and professionals from the Confederated Tribes of the Umatilla Indian Reservation, DOE, Fluor Hanford, Inc., and the Pacific Northwest National Laboratory conducted a one-day archaeology workshop at DOE's

Hazardous Materials Management and Emergency Response facility for the Girl Scouts from the Mid-Columbia Council.

The Hanford Cultural Resources Laboratory reprinted the booklet *History of the Hanford Site, 1943-1990* (Harvey 2000) during September 2002. The Hanford Cultural Resources Laboratory wrote the booklet during 2000 to educate the Hanford Site workforce on the historic significance of the Hanford Site, its important industrial buildings, and the significance of the Manhattan Project and Cold War era landscape and artifacts.

Several cultural resources newsletters were written by staff of the Pacific Northwest National Laboratory, DOE, and Bechtel Hanford, Inc. that focused on Hanford histories and cultural resources management issues on the Hanford Site, including the preservation of the Hanford Site's signature facilities, construction of the Hanford Site, identification and assessment of Hanford's Manhattan Project and Cold War artifacts, nomination of a Wanapum traditional fishing site to the National Register of Historic Places, declassification of historic Hanford photographs, identification and preservation of archaeological sites, early history of the railroads in the lower Columbia Basin, publication of the Hanford historic district book, and how properties are nominated to the National Register of Historic Places.

The Pacific Northwest National Laboratory participated in the Office of Fellowship Programs by hosting two student interns involved in field and laboratory work with Hanford Cultural Resources Laboratory staff.

Research activities continued during 2002 as part of compliance work. Research in the field of archaeology and history focused on archaeological site preservation and protection and documentation of the site's built environment from the Manhattan Project and Cold War periods.



8.4 COMMUNITY INVOLVEMENT IN ENVIRONMENTAL SURVEILLANCE

R. W. Hanf

During January 2002, the number of teacher-operated radiological air sampling stations near the Hanford Site was reduced from nine to four. All of the stations are still operating; however, sample collection responsibilities are being performed by staff from Pacific Northwest National Laboratory's Surface Environmental Surveillance Project rather than area teachers. The five stations that were affected are located in Benton City, Kennewick, Mattawa, Othello, and Pasco, Washington. The decrease in teacher-operated stations occurred in anticipation of budget reductions that were expected to take place later in 2002. The stations that continue to be operated by area teachers are located in Basin City, Richland, and Toppenish, Washington, and in north Franklin County at Edwin Markham Elementary School. These four stations have large, lighted displays that provide real-time weather and background radiation information to the public as well as general information on station equipment, sample types, and analyses (Figure 8.4.1).

Two teachers working near the stations were selected to manage each station. The equipment at each station includes air samplers to collect airborne dust and moisture for radiological analysis, a variety of weather monitors, and detectors to monitor ambient radiation levels. The teachers are responsible for collecting the air samples, preparing the samples and collection records for submission to the analytical laboratory, monitoring the performance of station equipment, performing minor station maintenance, and participating in scheduled training. They also serve as points of contact for local citizens. The station managers' names and telephone numbers are provided on the displays for anyone desiring additional information about the purpose of the station, station equipment, or analytical data. Pacific Northwest National Laboratory personnel work closely with the teachers to provide training, maintain station equipment and displays, and coordinate sampling and analytical efforts with other

Hanford Site environmental surveillance personnel. Computerized data collection systems have been installed at each station to collect and display weather and background radiation information. The data in the computers at Toppenish and Richland are accessible via telephone modem. The data from Basin City and Edwin Markham School are transmitted by radiotelemetry to the Hanford Meteorology Station computer where they are posted on the Internet every quarter hour (<http://etd.pnl.gov:2080/HMS/stamap.htm>). These stations are currently furnishing weather data to the Washington State Department of Transportation and the National Weather Service. Analytical results for the radiological air samples collected at these stations during 2002 are discussed in this report in Section 4.1. Results of gamma radiation measurements obtained at the stations during 2002 are discussed briefly in Section 4.7 of this report.

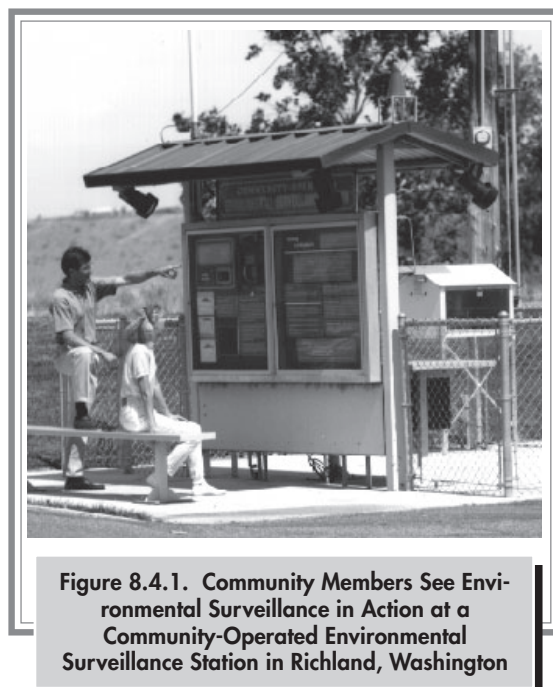


Figure 8.4.1. Community Members See Environmental Surveillance in Action at a Community-Operated Environmental Surveillance Station in Richland, Washington



8.5 BIOLOGICAL CONTROL PROGRAM

A. R. Johnson and R. C. Roos

The Biological Control Program at Hanford was established during 1998 in response to increasing incidents of radioactive contamination spread by biological vectors (DOE/RL-98-77). A biological vector is a plant or animal species that is involved in the transport of radioactive contamination. A common Hanford example is the Russian thistle or tumbleweed (*Salsola kali*), which has a tap-root that can transport radionuclides from below the ground surface into aboveground plant tissue, making it available for dispersal across the site by wind or other means.

Biological control (or often simply “control”) is any activity to prevent, limit, clean up, or remediate the impact to the environment, or human health and safety, from contaminated or undesirable plants or animals. The radiological component includes activities to control the spread of radioactive contamination. The non-radiological component includes activities to control pests (e.g., noxious weeds, arthropods, insects) that may affect the workplace and to assure compliance with federal, state, and local laws. The Biological Control Program is responsible for integration of (1) expanded radiological surveillance, (2) control of plants and animals, (3) cleanup of legacy and new contamination, and (4) restoration of sites affected by radioactive contamination spread by plants and animals.

Industrial weeds, noxious weeds, and pests are controlled by similar methods. Weeds on industrial sites at Hanford are not only a nuisance but can be fire hazards and can reduce the efficiency of men and machines working in the area. Occasionally, the objective of a weed control program at industrial sites is to totally eliminate vegetation in the affected area. On the Hanford Site, the control of weeds occurs at tank farms, radioactive waste pumping installations, industrial sites, power transmission lines and stations, buildings, storage and work areas, and along fence lines. Pest control prevents, limits, or removes undesirable animals through the application of chemical, cultural, or mechanical methods.

Biological control may include preventive measures or measures in response to existing contamination spread. Activities to prevent the spread of contamination include radiological surveys of the ground, vegetation, and flying insects; preventive controls, such as herbicide spraying; and the placement of engineered biological barriers. If contamination has already spread, typical response measures may include posting the area with radiation signs, stabilizing the contamination to keep it from spreading farther, and cleaning up and removing the contamination to an approved disposal location.

In some cases, remediation is necessary following cleanup and removal. Remediation is a common activity on the Hanford Site but has specific meanings and limitations when applied to biological control. Remediation may include soil removal and replacement, revegetation of the soil surface, or placement of engineered barriers to stop biological intrusion (biological barriers). Such remediation is typically performed where there is a potential for surface contamination or infestation problems to recur, with the objective of preventing recurrence.

8.5.1 BIOLOGICAL CONTROL

There were no incidents of offsite contamination by plants or animals during 2002, and all reported cases of new contamination on the site were cleaned up or scheduled for cleanup. In all areas of biological control, access to contaminated sites by professional control and cleanup crews improved during 2002. Facilities were able to request cleanup support without waiting to obtain contracts or set up work orders. Professionals were able to identify and treat problem areas without waiting for facility management to request or approve assistance.

During 2002, flying insects were routinely monitored on the Hanford Site and one contaminated housefly was

captured at an inactive liquid waste transfer facility in the 200-West Area. The source of the contamination was identified and sealed, and no recurrences have occurred; trapping continues at that location.

During 2002, 16 incidents of contaminated vegetation were identified. This is a decrease of ~81% compared to the peak year of 1999, and a decrease of ~52% compared to 2001. During 2002, ~4,613 hectares (~11,400 acres) were treated with chemical herbicides such as Krovar®, Tordon 22K®, or Sahara® to control undesirable vegetation. This is approximately the same amount treated during 2001, but nearly triple the 1,600 hectares (4,000 acres) treated during 1998, just before the program was initiated. Herbicide effectiveness during 2002 was ~90% compared to ~85% during 2001. Approximately 40 hectares (~100 acres), including ~3.2 kilometers (~2 miles) of posted roadways, were cleaned of windblown tumbleweeds and the roads opened. On the Hanford Site, ~809 hectares (~2,000 acres) that were burned by the 2000 range fire were re-seeded with vegetation to prevent the growth of tumbleweeds.

During 2002, there were 16,675 animal control responses. There were 10 contaminated animals detected, showing a decrease of ~78% compared to the peak year of 1998, but the same as in 2001. The control of rodents within and around the perimeters of the Hanford Site operations facilities used ~750 trap and bait stations. There were decreased areas for animals to hide and live because of increased effectiveness of vegetation control.

During 2002, recurring radioactive contamination events caused by deep-rooted vegetation or burrowing animals were treated with Biobarrier® to preclude invasion of waste sites by such biota. Biobarrier®, an engineered fabric impregnated with nodules of mitotic inhibitor to stop root penetration, was put down at 11 sites (~6,549 square meters [~70,500 square feet]). Demonstrations have shown this barrier to be an effective tool in preventing the spread of contamination.

8.5.2 NOXIOUS WEED CONTROL PROGRAM

Ten plant species are on a high priority list for control at the Hanford Site. These species are listed below with a summary of the 2002 control activities. These species are

targeted because of their ability to rapidly invade an area, ability to dominate a natural habitat, lack of natural predators, inability to be used by wildlife or domestic animals, or ability to cause chemical or physical harm to animals and habitat. Because they are designated as noxious weeds by the Washington State Department of Agriculture, they are specifically targeted for control by chemical, physical, or cultural (i.e., introducing natural insect predators) means.

Yellow Starthistle (*Centaurea solstitialis*). Yellow starthistle represents the most rapidly expanding weed infestation in the western United States. Hanford is at a critical point in the infestation cycle. Over 12,355 hectares (5,000 acres) have been infested, and a seed bank has been established in the soil. Many additional acres have scattered starthistle infestation. Applications of aerial herbicides during 1998 and 1999 have continued to be effective, dramatically reducing the acreage of yellow starthistle infestation requiring treatment during 2002. Seeds were found to have germinated in scattered locations where the populations were previously controlled. These plants were controlled by herbicide application, or hand-pulled and destroyed. Biological control organisms, primarily the parasitic insects *Eustenopus villosus* and *Bangasternus orientalis*, were common in starthistle located during 2002.

Rush Skeletonweed (*Chondrilla juncea*). Rush skeletonweed is widely scattered over large areas on the Hanford Site. Many areas of dense rush skeletonweed infestation have largely been eliminated. Nevertheless, considerable skeletonweed remains as scattered individuals. Populations of skeletonweed have increased on some areas burned in the 24 Command Wildland Fire in June 2000.

During 2002, control of rush skeletonweed concentrated on the area south of the Hanford town site. As in most years, some populations were highly affected by the biological control agents, skeletonweed gall midge (*Cystiphora schmidtii*), skeletonweed gall mite (*Eriophyes chondrillae*), and rush skeletonweed rust (*Puccinia chondrillina*), and flowering was eliminated. Other populations were less affected, and some were not significantly impacted by the biological control agents.

Medusahead (*Taeniatherum asperum*). Several individual plants of medusahead were discovered on the 200 Areas plateau during the winter of 2002. Seed heads with remaining seeds were collected and burned. Monitoring

and eradication efforts will continue during 2003 as the plants mature to the point they can be distinguished from neighboring grass species.

Babysbreath (*Gypsophila paniculata*). Efforts to control babysbreath during 2002 concentrated on the main infestation at the Hanford town site. Although babysbreath is resistant to control by herbicides, the invasion on the Hanford Site is relatively small. Control by physical removal while the population is limited is the practical alternative, although the herbicide Roundup® can help with control.

Dalmatian Toadflax (*Linaria genistifolia dalmatica*). Control of dalmatian toadflax focused on a small population at 100-B/C Area. The species at Hanford has yielded to past control efforts. Seedlings of the long-lived perennial plant will be eliminated as they are identified.

Spotted Knapweed (*C. maculosa*). Most populations of spotted knapweed on the Hanford Site have been reduced to scattered individuals, or seedlings germinating from the long-lived seeds. Cooperative work with neighboring landowners continues to eliminate spotted knapweed near the Hanford Site.

Diffuse Knapweed (*C. diffusa*). Aerial applications for control of diffuse knapweed have been effective in the past. Spot treatment of scattered individuals continues. The population of diffuse knapweed near the high water mark of the Columbia River has not actively been controlled

by herbicides due to the biological sensitivity of the area. Biological controls, such as banded gall fly (*Urophora affinis*), bronze knapweed root-borer (*Spenopterice jugoslavica*), and lesser knapweed flower weevil (*Larinus minutus*), have been established and are monitored to observe effectiveness in controlling the weed.

Russian Knapweed (*Acroptilon repens*). Biological controls for Russian knapweed are limited, and success in the arid climate of Hanford has been poor. Chemicals and techniques are being developed that promise to be effective with this difficult to control species.

Saltcedar (*Tamarix* spp.). Several individual plants of saltcedar are found on the Hanford Site. Most are remaining from ornamental plantings near homes in the early part of the previous century. A few populations are the result of natural seed dispersal. Most individuals south and west of the Columbia River have been eliminated. Those remaining alive continue to be treated with herbicide, and will be monitored until they no longer show signs of life.

Purple Loosestrife (*Lythrum salicaria*). Low density populations of purple loosestrife have become established along the south and west bank of the Columbia River. Portions of the riverbank and sloughs are monitored for purple loosestrife and identified individuals chemically treated with Rodeo® or physically removed.



8.6 RADIONUCLIDE SAMPLING IN CONIFER FORESTS IN THE CASCADE MOUNTAINS OF WASHINGTON STATE

W. H. Rickard and T. M. Poston

Radioactive debris was injected high into the air during aboveground nuclear detonations in the 1950s and early 1960s. This debris was deposited globally as fallout. Landscapes with higher precipitation generally received more fallout than landscapes with lesser amounts of precipitation. In Washington State, the Cascade Mountains received more precipitation and more fallout than the Hanford Site located in the semiarid interior Columbia River Basin, east of the Cascades.

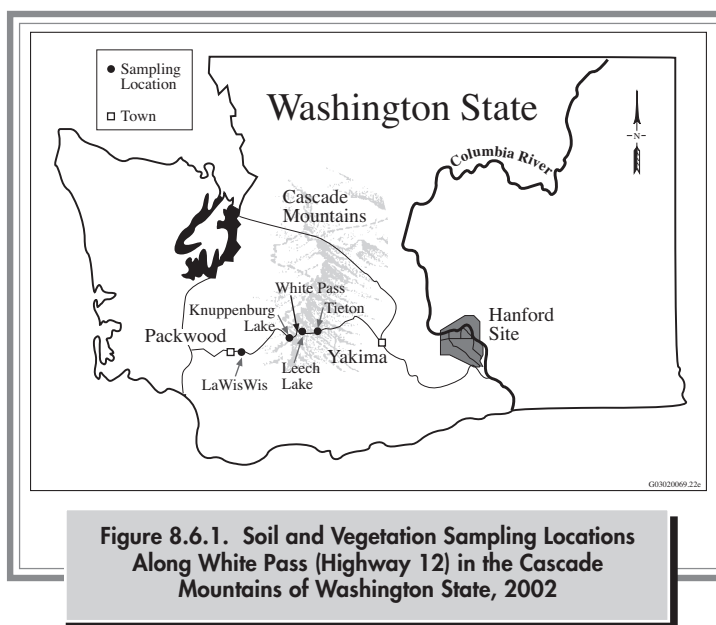
The natural vegetation of the Cascades is dominated by conifer trees. Fallout particles adhere to tree needles, twigs, and cones that fall to the forest floor. As this material decomposes, fallout particles are incorporated with decomposing organic matter and may migrate downward with percolating rainfall and snowmelt into the underlying mineral soil.

During September 2002, samples of living conifer needles, living moss, organic matter, and surface soil were collected from four locations in the Cascade Mountains, including two locations on the west side of the mountains and two locations on the east side (Figure 8.6.1), and analyzed for fallout radionuclides. The purpose of this work was to compare radionuclide concentration levels in the 2002 samples to concentrations measured in similar samples collected in or near the same forest stands in 1967 through 1969 (Rickard 1971). The 2002 data are useful for comparison to Hanford Site concentrations of fallout radionuclides. All samples collected during 2002 were analyzed for isotopic plutonium, isotopic uranium, strontium-90, and cesium-137. The samples collected during the late 1960s were analyzed for cesium-137. Cesium-137 data obtained from both

sampling efforts are compared here. Other radionuclide concentration data obtained during 2002 can be found in PNNL-14295, APP. 1.

It was expected that cesium-137 concentrations in the 2002 samples would be less than half of those measured in the samples collected during the late 1960s because of radioactive decay and reduced rates of deposits from fallout in the interim years. Concentrations of cesium-137 in soil were also expected to be lower because of dilution caused by volcanic ash deposits from the eruption of Mount Saint Helens in 1980. Estimated amounts of ash fall (uncompacted tephra) at the 2002 sampling sites range from 5 to 11 centimeters (2 to 4 inches) (USGS 2003).

The highest concentrations of cesium-137 measured in 2002 samples were measured in forest floor organic matter



at the two highest elevation study sites near the crest of the Cascade Mountains where deep snow cover persists throughout the late autumn, winter, and spring months (Table 8.6.1). These values were three to six times lower than the measurements made in the 1960s (Table 8.6.1). Since the 1960s, cesium-137 concentrations in moss at the lowest elevation on the western slope of the Cascades declined from 36 pCi/g (1.33 Bq/g) dry wt. to 0.56 pCi/g (0.02 Bq/g) dry wt. Cesium-137 concentrations in organic matter at all study sites showed strong declines, but concentrations in mineral soil were not greatly different between the 1960s and the 2002 samples.

The low concentrations of cesium-137 in live conifer needles collected during 2002 indicate that there is only a small amount of recycling of radioactive cesium from the soil to needles in these particular forest stands.

COMPARISONS TO HANFORD SITE

The Hanford Site, because of its arid climate, is not expected to have concentrations of cesium-137 that

exceed those levels observed in the Cascade Mountains. There are also significant differences in the vegetation and soil. Hanford soil generally is sandy and has little or no organic layers. Soil samples collected in 2001 from the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit of the Hanford Reach National Monument can be compared to mineral and organic soil samples from the Cascade Mountains. Cesium-137 concentrations in mineral soil collected from the upper 2.5-centimeter (1-inch) layer at sampling location found on the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit of the Hanford Reach National Monument were similar to concentrations in mineral soil found on White Pass, but generally less than levels present in the upper organic soil layer found in forests (Figure 8.6.2). Rainfall on the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit averages ~17 centimeters (6.7 inches) annually. In comparison, rainfall along White Pass ranges from 50 to 250 centimeters (20 to 100 inches) with the highest rainfall occurring at the summit of the pass (Oregon Climate Services 2003).

Table 8.6.1. Average Concentrations of Cesium-137 (pCi/g dry wt.)^(a) and Range of Values (in parentheses) in Conifer Forest Stands on the Western and Eastern Slopes of the Cascade Mountains in Washington State, 1967-1969 and September 2002

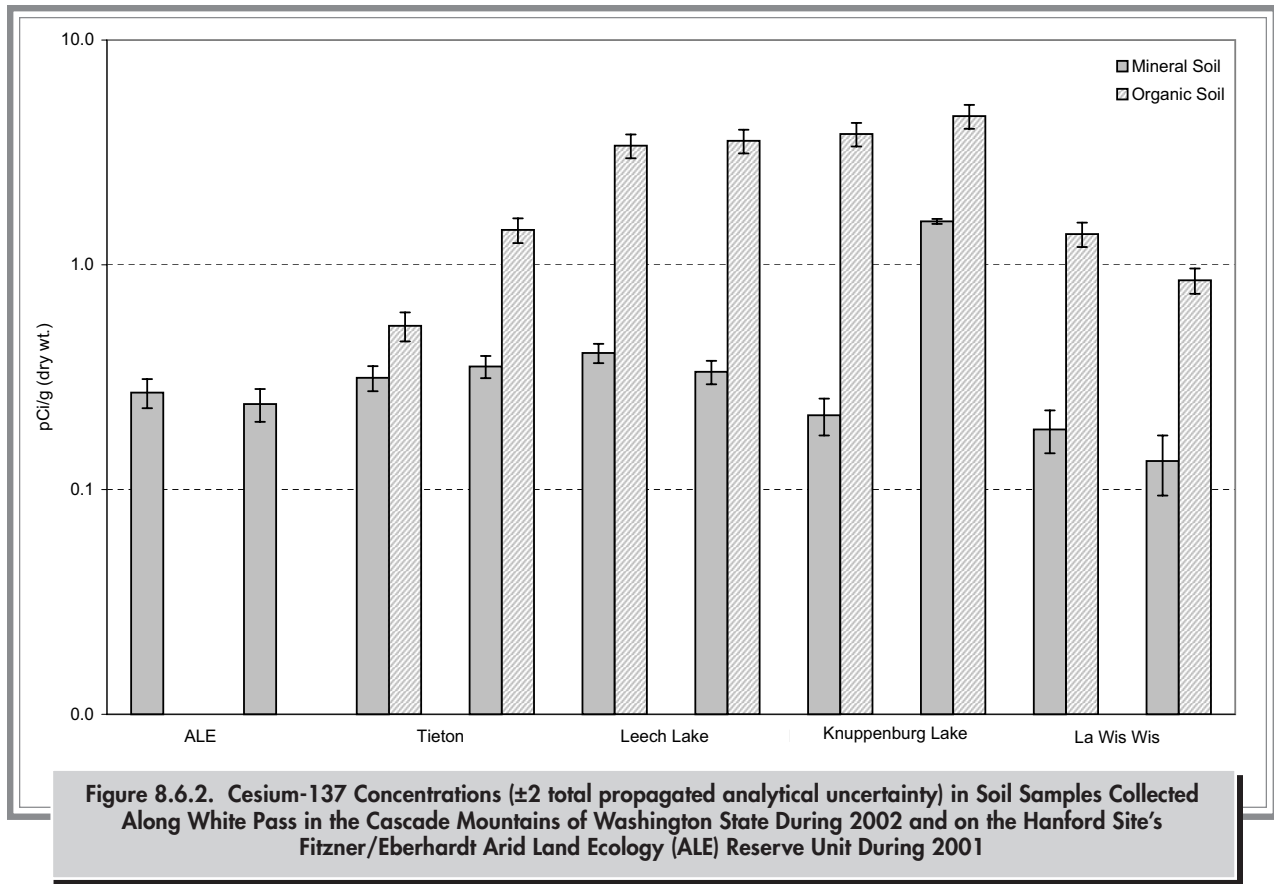
	Location (Slope)			
	La Wis Wis (Western)	Knuppenburg Lake (Western)	Leech Lake (Eastern)	Tieton (Eastern)
Elevation (m)	480	1,300	1,400	330
Rainfall (cm) ^(b)	150-200	150-200	150-200	50-100
1967-1969^(c)				
Moss	36 (23-31)	NA ^(d)	NA	NA
Organic matter	27 (23-31)	27 (15-35)	15 (11-18)	10 (8-14)
Soil	0.64 (0.54-0.72)	0.40 (0.38-0.40)	0.35 (0.30-0.40)	1.3 (1.1-1.4)
September 2002				
Moss (n=2)	0.56	NA	NA	NA
Organic matter (n=2)	1.1 (0.85-1.4)	4.2 (3.8-4.6)	3.5 (3.4-3.6)	0.98 (0.53-1.4)
Soil (n=2)	0.16 (0.13-0.18)	0.89 (0.21-1.6)	0.37 (0.33-0.40)	0.33 (0.31-0.33)
Live needles (n=1)	1.0	0.78	0.53	0.04

(a) To convert to becquerels per gram, multiply by 0.037.

(b) Oregon Climate Services (2003).

(c) Modified from Rickard (1971).

(d) NA = Not available.





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9.0 QUALITY ASSURANCE OF SURVEILLANCE AND MONITORING PROGRAMS

E. A. Lepel, L. P. Diediker, and D. L. Dyekman

Quality assurance and quality control practices encompassed all aspects of Hanford Site environmental monitoring and surveillance programs. This section provides descriptions of specific measures for maintaining quality in project management, sample collection, and analytical results.

Samples were collected and analyzed according to documented standard analytical procedures. Analytical data quality was verified by a continuing program of internal laboratory quality control, participation in interlaboratory crosschecks, replicate sampling and analysis, submittal of blind standard samples and blanks, and splitting samples with other laboratories.

Quality assurance/quality control for the Hanford Site environmental monitoring and surveillance programs also include procedures and protocols to:

- Document instrument calibrations.
- Conduct program-specific activities in the field.
- Maintain groundwater wells to collect representative samples.
- Avoid cross-contamination by using dedicated well sampling pumps.

9.0.1 ENVIRONMENTAL SURVEILLANCE AND GROUNDWATER MONITORING

During 2002, comprehensive quality assurance programs, including various quality control practices, were maintained to assure the quality of data collected through the Surface Environmental Surveillance Project and the

Hanford Groundwater Monitoring Project. Quality assurance plans were maintained for all program activities and defined the appropriate controls and documentation required by the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE) for the project-specific requirements.

9.0.1.1 PROJECT MANAGEMENT QUALITY ASSURANCE

Site environmental surveillance, groundwater monitoring, and related programs such as processing of thermoluminescent dosimeters and performing dose calculations were subject to an overall quality assurance program. This program implemented the requirements of DOE Order 414.1A. Quality assurance plans are maintained by the site surveillance and groundwater monitoring projects; these plans describe the specific quality assurance elements that apply to each project. These plans were approved by a quality assurance organization that conducted surveillances and audits to verify compliance with the plans. Work performed through contracts, such as sample analysis, must meet the same quality assurance requirements. Potential equipment and service suppliers are audited before service contracts or material purchases that could have had a significant impact on quality within the project are approved and awarded.

9.0.1.2 SAMPLE COLLECTION QUALITY ASSURANCE/QUALITY CONTROL

Surface Environmental Surveillance Project samples were collected by staff trained to conduct sampling according to

approved and documented procedures (PNL-MA-580). Continuity of all sampling location identities was maintained through careful documentation. Field replicates were collected for water and biota samples (Table 9.0.1). One hundred percent of the field replicate results with the result greater than the minimum detectable activity for 2002 were acceptable. The results were acceptable if the relative percent difference was $\leq \pm 30\%$ for the sample and duplicate, as specified in the analytical services contract.

Relative percent difference (RPD) – A measure of the precision of the measurement of a sample (S) and its duplicate (D). The formula is

$$RPD = 100 * |S-D| / ((STD)/2)$$

Samples for the Hanford Groundwater Monitoring Project were collected by trained staff according to approved and documented procedures (PNNL-14187, Appendix B). Chain-of-custody procedures were followed (EPA 1986). Samples representing full trip blanks and field duplicates were obtained during field operations. Summaries of the 2002 groundwater field quality control sample results are provided in Appendix B of PNNL-14187. The percentage of acceptable field blank and duplicate results during fiscal year 2002 was 96% for field blanks and 97% for field duplicates. For field blanks, a result was acceptable if it was less than two times the method detection limit for

non-radiological data, or less than two times the total propagated analytical uncertainty. This indicates that there was not a contamination problem found with the sample. For field duplicates, the result was acceptable if the measured precision was within 20%, as measured by the relative percent difference.

9.0.1.3 ANALYTICAL RESULTS QUALITY ASSURANCE/ QUALITY CONTROL

Routine chemical analyses of water samples were performed under contract primarily by Severn Trent Laboratories, Inc., St. Louis, Missouri, for environmental surveillance and groundwater monitoring. Some routine analyses of hazardous and non-hazardous chemicals for the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) groundwater program also were performed under contract by Lionville Laboratory, Inc., Lionville, Pennsylvania. Each laboratory participated in the EPA Water Pollution and Water Supply Performance Evaluation Studies. Each laboratory maintained an internal quality control program that met the requirements in *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, SW-846, Third Edition* (EPA 1986); each program was audited and reviewed internally and by Pacific Northwest National Laboratory. Pacific Northwest National Laboratory submitted additional quality control double-blind spiked samples for analysis.

Table 9.0.1. Summary of Field Replicate Results for the Surface Environmental Surveillance Project at Hanford, 2002

<u>Medium</u>	<u>Radionuclides</u>	<u>Number of Results Reported</u>	<u>Number Within Control Limits^(a)</u>
Water	Gross alpha	1	0
	Gross beta	1	1
	³ H	4	4
	⁷ Be, ⁴⁰ K, ⁶⁰ Co, ¹⁰⁶ Ru, ¹²⁵ Sb, ¹³⁴ Cs, ¹³⁷ Cs, ¹⁵⁴ Eu, ¹⁵⁵ Eu	9	0
	⁹⁰ Sr	3	3
	²³⁴ U, ²³⁵ U, ²³⁸ U	9	7
	²³⁸ Pu, ^{239/240} Pu	0	0
Biota	⁷ Be, ⁴⁰ K, ⁶⁰ Co, ¹⁰⁶ Ru, ¹²⁵ Sb, ¹³⁴ Cs, ¹³⁷ Cs, ¹⁵⁴ Eu, ¹⁵⁵ Eu	36	7
	⁹⁰ Sr	4	1

(a) The sample and duplicate results are acceptable if they have a relative percent difference of less than $\pm 30\%$ for the sample and duplicate and the result is above the detection limit or minimum detectable activity.

Double-blind spiked sample – A sample of known activity/concentration prepared to look like a typical sample submitted to the analytical service laboratory.

Routine radiochemical analyses of samples for the Surface Environmental Surveillance and Hanford Groundwater Monitoring Projects were performed primarily by Severn Trent Laboratories, Inc., Richland, Washington. Severn Trent Laboratories, Inc., Richland, participated in DOE's Quality Assessment Program at the Environmental Measurements Laboratory in New York, and the InterLab RadChem Proficiency Testing Program conducted by Environmental Resource Associates. Environmental Resource Associates prepared and distributed proficiency standard samples according to EPA requirements. A quality control blind spiked sample program also was conducted for each project by Pacific Northwest National Laboratory. The laboratory maintains an internal quality control program, which was audited and reviewed internally and by Pacific Northwest National Laboratory. Additional information on these quality control efforts is provided in the following sections.

9.0.1.4 DOE AND EPA COMPARISON STUDIES

Standard water samples were distributed blind (activities and concentrations unknown to the analytical laboratory) to participating laboratories as part of the EPA performance evaluation program. These blind samples contained specific organic and inorganic analytes that had concentrations unknown to the analyzing laboratories. After analysis, the results were submitted to Environmental Resource Associates, the EPA performance evaluation program sponsor, for comparison with known values and results from other participating laboratories. Summaries of the results for 2002 groundwater samples are provided in PNNL-14187, Appendix B, for the primary laboratory, Severn Trent Laboratories, Inc., St. Louis.

The DOE Quality Assessment Program and Environmental Resource Associates' Proficiency Testing Program provided standard samples of environmental media (e.g., water, air filters, soil, vegetation) that contained specific amounts of one or more radionuclides that were unknown

by the participating laboratory. After analysis, the results were forwarded to the DOE Quality Assessment Program or Environmental Resource Associates for comparison with known values and results from other laboratories. Both the DOE Quality Assessment Program and Environmental Resource Associates had established criteria for evaluating the accuracy of results (NERL-Ci-0045; EML-617; EML-618). Summaries of the 2002 results are provided in Tables 9.0.2 and 9.0.3. Ninety-three percent of the DOE quality assessment sample results fell within the acceptable control limits as defined by the DOE Quality Assessment Program. Ninety-eight percent of the Environmental Resource Associates samples fell within the acceptable control limit range as defined by the *National Standards for Water Proficiency Testing Studies Criteria* document (NERL-Ci-0045).

9.0.1.5 PACIFIC NORTHWEST NATIONAL LABORATORY EVALUATIONS

In addition to DOE and EPA interlaboratory quality control programs, Pacific Northwest National Laboratory maintained a quality control program to evaluate analytical contractor precision and accuracy and to conduct special intercomparisons. This program included the use of both radiological and non-radiological blind spiked samples. Blind spiked quality control samples and blanks were prepared and submitted to check the accuracy and precision of analyses at Severn Trent Laboratories, Inc., Richland. In 2002, 224 blind spiked samples were submitted for the Hanford Groundwater Monitoring Project (PNNL-14187, Appendix B) and 10 samples were submitted for the Surface Environmental Surveillance Project. The samples included air filters, soil, surface water, and vegetation (Table 9.0.4). The results of all water sample non-radiochemistry blind spiked determinations are discussed in Appendix B of PNNL-14187 and indicated an acceptable performance by the laboratory.

Blind spiked sample – A sample of known activity/concentration submitted to the analytical laboratory but not necessarily in the same physical geometry as the typical samples submitted.

Table 9.0.2. Summary of Laboratory Performance on DOE Quality Assessment Program Samples for the Surface Environmental Surveillance Project at Hanford, 2002

<u>Medium</u>	<u>Radionuclides</u>	<u>Number of Results Reported for Each Analyte</u>	<u>Number Within Acceptable Control Limits^(a)</u>
Severn Trent Laboratories, Richland, Washington			
Air filter particulate	Gross alpha, gross beta, ⁵⁴ Mn, ⁶⁰ Co, ⁹⁰ Sr, ¹³⁷ Cs, ²⁴¹ Am, total uranium	2	2
	²³⁸ Pu, ²³⁹ Pu	2	1
	²³⁴ U, ²³⁸ U	1	1
Soil	⁴⁰ K, ⁹⁰ Sr, ¹³⁷ Cs, ²¹² Pb, ²¹⁴ Bi, ²¹⁴ Pb, ²²⁸ Ac, ²³⁹ Pu, ²⁴¹ Am, total uranium	2	2
	²³⁴ Th	2	1
	²³⁴ U, ²³⁸ U	1	1
Vegetation	⁴⁰ K, ⁶⁰ Co, ¹³⁷ Cs, ²³⁹ Pu, ²⁴¹ Am, ²⁴⁴ Cm	2	2
	⁹⁰ Sr	1	1
Water	³ H, ⁶⁰ Co, ⁹⁰ Sr, ¹³⁷ Cs, ²³⁸ Pu, ²³⁹ Pu, ²⁴¹ Am, total uranium	2	2
	Gross alpha, gross beta, ¹³⁴ Cs	2	1
	²³⁴ U, ²³⁸ U	1	1

(a) Control limits are from EML-617 and EML-618.

Table 9.0.3. Summary of Laboratory Performance on Hanford Site Surface Environmental Surveillance Project Samples by the Environmental Resource Associates Proficiency Testing Program, 2002

<u>Medium</u>	<u>Radionuclides</u>	<u>Number of Results Reported for Each Analyte</u>	<u>Number Within Control Limits for Each Analyte^(a)</u>
Severn Trent Laboratories, Richland, Washington			
Water	Gross alpha, gross beta, ²²⁶ Ra, ²²⁸ Ra, total uranium	4	4
	⁶⁰ Co, ⁸⁹ Sr, ⁹⁰ Sr, ¹³⁷ Cs	3	3
	¹³⁴ Cs	3	2
	³ H, ¹³¹ I	2	2
	⁶⁵ Zn, ¹³¹ I	1	1

(a) Control limits are from NERL-Ci-0045.

Table 9.0.4. Summary of Hanford Site Surface Environmental Surveillance Project Blind Spiked Determinations, 2002

<u>Medium</u>	<u>Radionuclides</u>	<u>Number of Results Reported</u>	<u>Number Within Control Limits^(a)</u>
Severn Trent Laboratories, Richland, Washington			
Air Filters	⁶⁰ Co, ¹³⁴ Cs, ¹³⁷ Cs, ²³⁸ Pu	2	2
	⁹⁰ Sr, ¹²⁵ Sb	2	1
	^{239/240} Pu	1	1
Soil	⁴⁰ K, ⁹⁰ Sr, ¹³⁷ Cs, ^{239/240} Pu	2	2
	²³⁸ Pu	1	1
	⁶⁰ Co	1	0
Vegetation	⁴⁰ K, ⁶⁰ Co, ¹³⁷ Cs	2	2
	⁹⁰ Sr	2	1
	²³⁸ Pu	1	1
Surface Water	³ H, ⁶⁰ Co, ¹³⁷ Cs, ²³⁸ Pu, ^{239/240} Pu	2	2
	¹³⁴ Cs	1	1

(a) Control limit of $\pm 30\%$.

For all media, 91% of Severn Trent Laboratories, Inc., Richland, radiochemistry blind spiked determinations were within the control limits ($\pm 30\%$ of the known value), which indicated acceptable results. Two gamma determinations were not acceptable – an analysis for cobalt-60 in soil and an analysis for antimony-125 in an air filter. Also, a determination of strontium-90 in an air filter was lost in the laboratory.

9.0.1.6 QUALITY ASSURANCE TASK FORCE RESULTS

Pacific Northwest National Laboratory also participated in the Quality Assurance Task Force, a program coordinated by the Washington State Department of Health. Public and private organizations from Idaho, Oregon, and Washington participated in analyzing intercomparison samples in 1999, 2000, and 2001. For the 2002 intercomparison sample exchange, soil samples from the Hanford Site were collected and dried. Results for uranium-234, uranium-235, uranium-238, and total uranium were determined for three aliquots. The Pacific Northwest National Laboratory determinations and the average and 2 standard deviations of each analyte are presented in Table 9.0.5.

The results reported to the task force by other laboratories had not been released at the time of this report for comparison.

9.0.1.7 LABORATORY INTERNAL QUALITY ASSURANCE PROGRAMS

The analytical laboratories were required to maintain an internal quality assurance and control program. Periodically, the laboratories were audited for compliance to the quality assurance and control programs. At Severn Trent Laboratories, Inc., St. Louis, the quality control program met the quality assurance and control criteria in *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods*, SW-846, Third Edition (EPA 1986). The laboratories also were required to maintain a system to review and analyze the results of the quality control samples to detect problems that may have arisen from contamination, inadequate calibrations, calculation errors, or improper procedure performance. Method detection levels were determined at least annually for each analytical method.

The internal quality control program at Severn Trent Laboratories, Inc., Richland, involved routine calibrations

Table 9.0.5. Pacific Northwest National Laboratory Determinations of Quality Assurance Task Force Intercomparison Soil Sample at Hanford, 2002

Radionuclide	Determination Number	Intercomparison Sample Concentrations, pCi/g^(a)	Average $\pm 2SD$,^(b) pCi/g
Uranium-234	1	352 \pm 63	326 \pm 52
	2	300 \pm 48	
	3	328 \pm 59	
Uranium-235	1	14.7 \pm 2.8	13.4 \pm 1.8
	2	11.4 \pm 2.6	
	3	14.1 \pm 2.7	
Uranium-238	1	337 \pm 60	299 \pm 65
	2	267 \pm 43	
	3	314 \pm 56	
Total uranium	1	446 \pm 110	306 \pm 72
	2	451 \pm 110	
	3	363 \pm 86	

(a) To convert pCi/g to Bq/g, multiply by 0.037.

(b) SD = Standard deviation.

of counting instruments, yield determinations of radiochemical procedures, frequent radiation check sources and background counts, replicate and spiked sample analyses, matrix and reagent blanks, and maintenance of control charts to indicate analytical deficiencies. Available calibration standards traceable to the National Institute of Standards and Technology were used for radiochemical calibrations. Calculation of minimum detectable concentrations involved the use of factors such as the average counting efficiencies and background for detection instruments, length of time for background and sample counts, sample volumes, radiochemical yields, and a pre-designated uncertainty multiplier (EPA 520/1-80-012).

Periodically, inspections of services were performed that documented conformance with contractual requirements of the analytical facility and provided the framework to identify and resolve potential performance problems. Responses to assessment and inspection findings were documented by written communication, and corrective actions were verified by follow-up audits and inspections. In 2002, assessments of Severn Trent Laboratories, Inc., Richland, and Severn Trent Laboratories, Inc., St. Louis, were conducted January 22 to 25, 2002 and April 23 to 26, 2002, respectively. Representatives from Bechtel Hanford, Inc. and Pacific Northwest National Laboratory conducted both audits. The purpose of the assessments was to

evaluate the continued support of analytical services to Hanford Site contractors as specified in the statement of work between Fluor Hanford, Inc. and Severn Trent Laboratories, Inc. Additional information may be found in PNNL-14187, Appendix B.

Internal laboratory quality control program data were reported with the analytical results. Scientists at Pacific Northwest National Laboratory summarized the results quarterly. The Surface Environmental Surveillance Project and the Hanford Groundwater Monitoring Project indicated that each laboratory met the contract specified requirements for each quarter of calendar year 2002 (for the Surface Environmental Surveillance Project) and fiscal

year 2002 (for the Hanford Groundwater Monitoring Project).

9.0.1.8 MEDIA AUDITS AND COMPARISONS

Additional audits and comparisons were conducted on several specific types of samples. The Washington State Department of Health routinely co-sampled various environmental media and measured external radiation levels at multiple locations during 2002. Media that were co-sampled and analyzed for radionuclides included groundwater, irrigation water, water from 20 locations along and across the Columbia River, water from 7 river-bank springs, water from 2 onsite drinking water locations, sediment from 9 Columbia River sites, surface soil from 2 locations on the Hanford Site, and mineral and organic soil from White Pass. Also co-sampled and analyzed for radionuclides were upwind and downwind samples of bass, carp, cherries, leafy vegetables, mule deer, potato tubers, quail, and red and white wines. The Washington State Department of Health and Pacific Northwest National Laboratory co-sampled data may be found in PNNL-14295, APP. 1.

The U.S. Food and Drug Administration also received co-samples from upwind and downwind sampling locations and analyzed cherries, leafy vegetables, and potatoes for radionuclides (Table 9.0.6). One result determined by the U.S. Food and Drug Administration was a positive result. The one positive result was for strontium-90 in cherries and did not agree with its duplicate or the result determined by Pacific Northwest National Laboratory, making this a questionable value.

Quality control for environmental thermoluminescent dosimeters included the audit exposure of three environmental thermoluminescent dosimeters per quarter to known values of radiation (between 17 and 30 mR). For the 12 measurements, the lowest ratio of determined/known exposure was 0.94; the highest determined/known exposure ratio was 1.10, with an average of 1.02 ± 0.05 (Table 9.0.7).

9.0.2 EFFLUENT MONITORING AND NEAR-FACILITY ENVIRONMENTAL MONITORING

The Effluent Monitoring and Near-Facility Environmental Monitoring Programs were subject to the quality assurance requirements specified in the *Hanford Analytical Services Quality Assurance Requirements Document* (DOE/RL-96-68). This quality assurance program complied with DOE Order 414.1A, using standards from the American Society of Mechanical Engineers (ASME NQA-1-1997) as its basis. The program also adhered to the guidelines and objectives in EPA/005/80 and EPA QA/R-5.

The monitoring programs each have a quality assurance project plan describing applicable quality assurance elements. These plans were approved by contractor quality assurance groups, who conducted surveillances and audits to verify compliance with the project plans. Work such as sample analyses that were performed through contracts had to meet the requirements of these quality assurance project plans. Suppliers were audited before the contract selection was made for equipment and services that may have significantly affected the quality of a project.

9.0.2.1 SAMPLE COLLECTION QUALITY ASSURANCE

Samples for the Effluent Monitoring and Near-Facility Environmental Monitoring Programs were collected by staff trained for the task in accordance with approved procedures. Established sampling locations were accurately identified and documented to assure continuity of data for those sites and are described in DOE/RL-91-50.

9.0.2.2 ANALYTICAL RESULTS QUALITY ASSURANCE

Samples for the Effluent Monitoring and Near-Facility Environmental Monitoring Programs were analyzed by up to three different analytical laboratories. The use of these laboratories is dependent on the Hanford contractor collecting the samples and contract(s) established between the contractor and the analytical laboratory(s). Table 9.0.8 provides a summary of the analytical laboratories used by Hanford Site contractors for processing effluent monitoring and near-facility monitoring samples.

The quality of the analytical data was assured by several means. Counting room instruments, for instance, were kept within calibration limits through daily checks, the results of which were stored in computer databases. Radiochemical standards used in analyses were regularly measured and the results were reported and tracked. Formal, written laboratory procedures were used when analyzing samples. Analytical procedural control was assured through administrative procedures. Chemical technologists at the laboratory were qualified to perform analyses through formal classroom and on-the-job training.

The participation of the Hanford Site analytical laboratories in EPA and DOE laboratory performance evaluation programs also served to assure the quality of the data produced. The performance of the Waste Sampling and Characterization Facility was evaluated in four different laboratory performance studies for 2002. In the EPA Water Pollution Studies #84 and #90 for inorganic and organic analyses, 314 different analytes and compounds were submitted to the Waste Sampling and Characterization Facility for analysis. Of the 314 analyses performed, 277 results were acceptable while 37 were unacceptable for a total acceptable rate of 88%. The acceptance criteria

Table 9.0.6. Comparison of Co-Sampling Results for Samples Collected Near the Hanford Site, 2002^(a)

Medium	Sampling Area	Organization ^(b)	Strontium-90, pCi/g ^(c,d)	Cesium-137, pCi/g ^(c,d)	Ruthenium-106, pCi/g ^(c,d)	Iodine-131 pCi/g ^(c,d)	Tritium pCi/g ^(c,d)
Leafy vegetables (stem-leaf)	Sunnyside	FDA	<0.002	<0.045	<0.10	<0.045	<200
		FDA	<0.002	<0.045	<0.10	<0.045	<200
		PNNL	-0.00019 ± 0.0023	-0.0055 ± 0.011	0.059 ± 0.092	NA ^(e)	NA
	Riverview	FDA	<0.002	<0.045	<0.10	<0.045	<200
		FDA	<0.002	<0.045	<0.10	<0.045	<200
		PNNL	0.00139 ± 0.0022	-0.00389 ± 0.012	-0.0201 ± 0.11	NA	NA
Cherries/Fruit	Sagemoor	FDA	<0.002	<0.045	<0.10	<0.045	<200
		FDA	2.5 ± 0.7	<0.045	<0.10	<0.045	<200
		PNNL	-0.00102 ± 0.0018	0.00156 ± 0.0036	0.0063 ± 0.033	NA	NA
Potato tuber	Horn Rapids	FDA	<0.002	<0.045	<0.10	<0.045	<200
		FDA	<0.002	<0.045	<0.10	<0.045	<200
		PNNL	0.00915 ± 0.0083	0.00424 ± 0.0035	-0.02 ± 0.035	NA	NA
	Sunnyside	FDA	<0.002	<0.045	<0.10	<0.045	<200
		FDA	<0.002	<0.045	<0.10	<0.045	<200
		PNNL	0.0079 ± 0.0074	0.00022 ± 0.0051	0.0151 ± 0.043	NA	NA

(a) Sample results are wet weight.

(b) FDA = U.S. Food and Drug Administration; PNNL = Pacific Northwest National Laboratory.

(c) To convert pCi/g to Bq/g, multiply by 0.037.

(d) Errors reported are 2 standard deviations. Less than (<) values are minimum detectable activities at 3 standard deviations.

(e) NA = Not analyzed; not specifically requested by contract unless present.

Table 9.0.7. Comparison of Pacific Northwest National Laboratory Thermoluminescent Dosimeter Results with Known Exposure, 2002

Quarter	Exposure Date	Known Exposure ^(a,b) milliroentgen (mR)	Determined Exposure ^(c) milliroentgen (mR)	Ratio of Determined/ Known Exposure
1st	February 22, 2002	26 ± 0.97	27.83 ± 0.83	1.07
		22 ± 0.82	23.27 ± 0.12	1.06
		18 ± 0.67	19.88 ± 0.26	1.10
2nd	May 17, 2002	23 ± 0.86	24.47 ± 0.63	1.06
		29 ± 1.08	28.78 ± 0.62	0.99
		17 ± 0.63	17.67 ± 0.84	1.04
3rd	August 27, 2002	21 ± 0.78	20.62 ± 0.25	0.98
		28 ± 1.04	29.69 ± 0.55	0.95
		19 ± 0.71	20.66 ± 0.085	0.94
4th	November 15, 2002	27 ± 1	27.63 ± 0.69	1.02
		24 ± 0.89	25.00 ± 0.51	1.04
		20 ± 0.74	19.99 ± 0.54	1.00

(a) ±2 total propagated analytical uncertainty.

(b) Assumed 2 standard deviation error was 3.72%.

(c) ±2 times the standard deviation.

Table 9.0.8. Hanford Site Laboratories Used by Site Contractors and Types of Effluent Monitoring and Near-Facility Monitoring Samples Analyzed, 2002

Analytical Laboratory	Effluent Monitoring Samples						Near-Facility Environmental Monitoring Samples		
	Fluor Hanford, Inc.		Pacific Northwest National Laboratory	Bechtel Hanford, Inc.			Fluor Hanford, Inc.		
	Air	Water	Air	Air	Water		Air	Water	Other
Waste Sampling and Characterization Facility ^(a)	X	X		X	X		X	X	X
222-S Analytical Laboratory ^(a)									X
Severn Trent Laboratories, Inc., Richland	X	X	X	X	X				
Analytical Chemistry Laboratory ^(b)	X	X	X						

(a) Operated by Fluor Hanford, Inc.
(b) Operated by Pacific Northwest National Laboratory.

were defined by EPA. In the DOE Mixed Analyte Performance Evaluation Program studies (MAPEP-01-W9 and MAPEP-02-S9), 79 different radionuclides and analytes were submitted to the Waste Sampling and Characterization Facility for analysis. Of the 79 different analyses performed, 75 results were acceptable while 4 were unacceptable for a total acceptable rate of 95% as defined by the Mixed Analyte Performance Evaluation Program studies. In the National Institute of Standards and Technology Radiochemistry Program study, 8 different radionuclides were submitted to the Waste Sampling and Characterization Facility for 40 different analyses. All radionuclide

results were acceptable except for a strontium-90 result from an air filter. The acceptance criteria were defined by the National Institute of Standards. In the DOE Quality Assessment Program, 74 different radionuclides were submitted to the Waste Sampling and Characterization Facility for analysis. Of the 74 analyses performed, 70 results were acceptable while 4 were unacceptable for a total acceptable rate of 95%. The acceptance criteria were defined by the DOE Quality Assessment Program. Performance results for the DOE Quality Assessment Program and others are presented in Tables 9.0.9 through 9.0.11.

Table 9.0.9. The Hanford Site's Waste Sampling and Characterization Facility^(a) Performance on DOE Quality Assessment Program Samples, 2002

<u>Medium</u>	<u>Radionuclide</u>	<u>Number of Results Reported</u>	<u>Number Within Control Limits</u>
Air filters	⁵⁴ Mn, ⁶⁰ Co, ⁹⁰ Sr, ¹³⁴ Cs, ²³⁴ U, ²³⁸ Pu, ²³⁸ U, ²³⁹ Pu, ²⁴¹ Am, gross alpha, gross beta	22	21 (⁹⁰ Sr failed once)
Soil	⁴⁰ K, ⁹⁰ Sr, ¹³⁷ Cs, ²³⁴ U, ²³⁸ U, ²³⁹ Pu, ²⁴¹ Am	14	12 (²³⁴ U and ²³⁸ U failed once)
Vegetation	⁴⁰ K, ⁶⁰ Co, ⁹⁰ Sr, ¹³⁷ Cs, ²³⁹ Pu, ²⁴¹ Am, ²⁴⁴ Cm	14	14
Water	³ H, ⁶⁰ Co, ⁹⁰ Sr, ¹³⁴ Cs, ¹³⁷ Cs, ²³⁴ U, ²³⁸ Pu, ²³⁸ U, ²³⁹ Pu, ²⁴¹ Am, gross alpha, gross beta	24	23 (Gross alpha failed once)

(a) Onsite laboratory operated by Fluor Hanford, Inc.

Table 9.0.10. The Hanford Site's 222-S Analytical Laboratory^(a) Performance on DOE Quality Assessment Program Samples, 2002

<u>Medium</u>	<u>Radionuclide</u>	<u>Number of Results Reported</u>	<u>Number Within Acceptable Limits</u>
Air filters	⁵⁴ Mn, ⁶⁰ Co, ⁹⁰ Sr, ¹³⁴ Cs, ²³⁸ Pu, ²³⁹ Pu, ²⁴¹ Am, gross alpha, gross beta	18	17
Soil	⁹⁰ Sr, ¹³⁷ Cs, ²¹² Pb, ²¹⁴ Bi, ²¹⁴ Pb, ²²⁸ Ac, ²³⁹ Pu, total uranium	16	14
Vegetation	⁹⁰ Sr, ¹³⁷ Cs, ²³⁹ Pu, ²⁴¹ Am, ²⁴⁴ Cm	10	7
Water	³ H, ⁶⁰ Co, ⁹⁰ Sr, ¹³⁷ Cs, ²³⁸ Pu, ²³⁹ Pu, ²⁴¹ Am, gross alpha, gross beta, total uranium	21	15

(a) Onsite "high-level" radiological laboratory operated by Fluor Hanford, Inc. (Note: These samples are "low-level" environmental activity samples.)

Table 9.0.11. The Hanford Site's 222-S Analytical Laboratory^(a) Performance on EPA Laboratory Water Pollution Inorganic and Organic Studies, 2002

<u>Laboratory</u>	<u>Water Pollution Study (WP-87) June 2002 % Acceptable</u>	<u>Water Pollution Study (WP-93) December 2002 % Acceptable</u>
222-S Analytical Laboratory	96 ^(b)	98 ^(c)

(a) Onsite "high-level" radiological laboratory operated by Fluor Hanford, Inc.

(b) Ninety of 94 analytes defined by EPA as acceptable.

(c) One hundred and five of 107 analytes defined by EPA as acceptable.

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APPENDIX A

HELPFUL INFORMATION

R. W. Hanf

The following information is provided to assist the reader in understanding this report. Included here is information on scientific notation, units of measures, radioactivity units, radiological dose units, chemical and elemental nomenclature, understanding data tables and data uncertainty, understanding graphs, and greater than or less than symbols. Definitions of technical terms can be found in Appendix C.

SCIENTIFIC NOTATION

Scientific notation is used in this report to express very large or very small numbers. For example, the number 1 billion could be written as 1,000,000,000 or, by using scientific or "E" notation, written as 1×10^9 or 1.0E+09. Translating

from scientific notation to a more traditional number requires moving the decimal point either left or right from its current location. If the value given is 2.0×10^3 (or 2.0E+03), the decimal point should be moved three places to the **right** so that the number would then read 2,000. If the value given is 2.0×10^{-5} (or 2.0E-05), the decimal point should be moved five places to the **left** so that the result would be 0.00002.

UNITS OF MEASURE

The primary units of measure used in this report are metric. Table A.1 summarizes and defines the terms and corresponding symbols (metric and non-metric). A conversion table is also provided in Table A.2.

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

Symbol	Name	Symbol	Name
Temperature		Length	
°C	degree Celsius	cm	centimeter (1×10^{-2} m)
°F	degree Fahrenheit	ft	foot
Time		in.	inch
d	day	km	kilometer (1×10^3 m)
h	hour	m	meter
min	minute	mi	mile
s	second	mm	millimeter (1×10^{-3} m)
yr	year	µm	micrometer (1×10^{-6} m)
Rate		Area	
cfs (or ft ³ /s)	cubic foot per second	ha	hectare (1×10^4 m ²)
gpm	gallon per minute	km ²	square kilometer
mph	mile per hour	mi ²	square mile
mR/hr	milliroentgen per hour	ft ²	square foot
mrem/yr	millirem per year	Mass	
Volume		g	gram
cm ³	cubic centimeter	kg	kilogram (1×10^3 g)
ft ³	cubic foot	mg	milligram (1×10^{-3} g)
gal	gallon	µg	microgram (1×10^{-6} g)
L	liter	ng	nanogram (1×10^{-9} g)
m ³	cubic meter	lb	pound
mL	milliliter (1×10^{-3} L)	wt%	weight percent
yd ³	cubic yard		
Concentration			
ppb	parts per billion		
ppm	parts per million		
ppmv	parts per million by volume		

Table A.2. Conversion Table

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>	<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
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
gal	3.785	L	L	0.2642	gal
ft ²	0.093	m ²	m ²	10.76	ft ²
acre	0.405	ha	ha	2.47	acres
mi ²	2.59	km ²	km ²	0.386	mi ²
ft ³	0.0283	m ³	m ³	35.31	ft ³
yd ³	0.7646	m ³	m ³	1.308	yd ³
nCi	0.001	pCi	pCi	1,000	nCi
pCi/L	10 ⁻⁹	μCi/mL	μCi/mL	10 ⁹	pCi/L
pCi/m ³	10 ⁻¹²	Ci/m ³	Ci/m ³	10 ¹²	pCi/m ³
pCi/m ³	10 ⁻¹⁵	mCi/cm ³	mCi/cm ³	10 ¹⁵	pCi/m ³
mCi/km ²	1.0	nCi/m ²	nCi/m ²	1.0	mCi/km ²
Bq	2.7 x 10 ⁻¹¹	Ci	Ci	3.7 x 10 ¹⁰	Bq
Bq	27	pCi	pCi	0.037	Bq
Gy	100	rad	rad	0.01	Gy
Sv	100	rem	rem	0.01	Sv
ppb	0.001	ppm	ppm	1,000	ppb
°F	(°F - 32) ÷ 9/5	°C	°C	(°C x 9/5) + 32	°F
g	0.035	oz	oz	28.349	g
metric ton	1.1	ton	ton	0.9078	metric ton

RADIOACTIVITY UNITS

Much of this report deals with levels of radioactivity in various environmental media. Radioactivity in this report is usually discussed in units of **curies (Ci)**, with units of **becquerels (Bq)** in parenthesis (Table A.3). The curie is the basic unit used to describe the amount of radioactivity present, and activities are generally expressed in terms of curies per mass or volume (e.g., picocuries per liter). One curie is equivalent to 37 billion disintegrations per second or is a quantity of any radionuclide that decays at the rate of 37 billion disintegrations per second. Conversely, one becquerel is equivalent to one disintegration per second. Nuclear disintegrations produce spontaneous emissions of alpha or beta particles, gamma radiation, or combinations of these. Table A.4 includes selected conversions from curies to becquerels.

RADIOLOGICAL DOSE UNITS

The amount of ionizing radiation energy absorbed by a living organism is expressed in terms of radiological dose.

Radiological dose in this report is usually written in terms of effective dose equivalent and reported numerically in units of millirems (mrem), with the metric units millisieverts (mSv) following in parenthesis or footnoted (Table A.5). Millirem (millisievert) is a term that relates radiological dose and biological effect or risk (to humans). A dose of 0.01 millirem (1 millisievert) has a biological

Table A.3. Names and Symbols for Units of Radioactivity

<u>Symbol</u>	<u>Name</u>
Ci	curie
cpm	counts per minute
mCi	millicurie (1 x 10 ⁻³ Ci)
μCi	microcurie (1 x 10 ⁻⁶ Ci)
nCi	nanocurie (1 x 10 ⁻⁹ Ci)
pCi	picocurie (1 x 10 ⁻¹² Ci)
fCi	femtocurie (1 x 10 ⁻¹⁵ Ci)
aCi	attocurie (1 x 10 ⁻¹⁸ Ci)
Bq	becquerel (2.7 x 10 ⁻¹¹ Ci)
kBq	kilobecquerel (1 x 10 ³ Bq)
MBq	megabecquerel (1 x 10 ⁶ Bq)
mBq	millibecquerel (1 x 10 ⁻³ Bq)
GBq	gigabecquerel (1 x 10 ⁹ Bq)
TBq	terabecquerel (1 x 10 ¹² Bq)

Table A.4. Conversions for Radioactivity Units

aCi	fCi	fCi	pCi	pCi	nCi	nCi	μCi	μCi	mCi	mCi	Ci	Ci	kCi
27	1	27	1	27	1	27	1	27	1	27	1	27	1
1	37	1	37	1	37	1	37	1	37	1	37	1	37
μBq	μBq	mBq	mBq	Bq	Bq	kBq	kBq	MBq	MBq	GBq	GBq	TBq	TBq

New unit of quantity = Becquerel (Bq) (formerly curie [Ci]) ($1 \text{ Ci} = 3.7 \times 10^{10} \text{ dps}$).

1 Becquerel = 1 disintegration/sec (dps).

Table A.5. Names and Symbols for Units of Radiation Dose or Exposure

Symbol	Name
mrاد	millirad ($1 \times 10^{-3} \text{ rad}$)
mrem	millirem ($1 \times 10^{-3} \text{ rem}$)
Sv	sievert (100 rem)
mSv	millisievert ($1 \times 10^{-3} \text{ Sv}$)
μSv	microsievert ($1 \times 10^{-6} \text{ Sv}$)
R	roentgen
mR	milliroentgen ($1 \times 10^{-3} \text{ R}$)
μR	microroentgen ($1 \times 10^{-6} \text{ R}$)
Gy	gray (100 rad)
mGy	milligray ($1 \times 10^{-3} \text{ rad}$)

effect similar to the dose received from an approximate 1-day exposure to natural background radiation. An acute (short-term) dose of over 100 rems (1 sievert) can cause radiation sickness in humans. An acute dose of over 500 rems (5 sieverts), if left untreated, results in death ~50% of the time. Exposure to lower amounts of radiation (10 mrem [100 μSv] or less) produces no immediate observable effects, but long-term (delayed) effects are possible. The average person in the United States receives an annual dose from exposure to naturally produced radiation of ~3 mrem (~30 μSv). Medical and dental x-rays and air travel add to this total. (See Section 5.7 for a more in-depth discussion of risk comparisons.) Table A.6 includes selected conversions from rems to sieverts.

Also used in this report is the **rad**, with the corresponding unit **Gray (Gy)** in parenthesis or footnoted. The rad (Gray) is a measure of the energy absorbed by any material, whereas a rem relates to both the amount of radiation

energy absorbed by humans and its consequence. The Gray can be converted to rad by multiplying by 100. The conversions in Table A.6 can also be used to convert Grays to rads.

A **roentgen** is a measure of radiation exposure with no SI equivalent. In the metric system, it is expressed in terms of energy per unit mass over time (e.g., watts [W] per kilogram). For conversion purposes, 1 microroentgen per hour (μR/h) is equal to 2.109 picowatts per kilogram per second (pW/kg/s).

Additional information on radiation and dose terminology can be found in Appendix C. A list of the radionuclides discussed in this report, their symbols, and their half-lives are included in Table A.7.

CHEMICAL AND ELEMENTAL NOMENCLATURE

The chemical contaminants discussed in this report are listed in Table A.8 along with their chemical (or elemental) names and their corresponding symbols.

Table A.6. Conversions for Radiological Dose Units

μSv	μSv	μSv	μSv	μSv	mSv	mSv	mSv	Sv
0.01	0.1	1	10	100	1	10	100	1
1	10	100	1	10	100	1	10	100
μrem	μrem	μrem	mrem	mrem	mrem	rem	rem	rem

Unit of absorbed dose – Gray (Gy) (formerly rad).

Unit of dose equivalent – Sievert (Sv) (formerly rem).

Table also converts Gy to rad.

Table A.7. Radionuclides and Their Half-Lives^(a)

<u>Symbol</u>	<u>Radionuclide</u>	<u>Half-Life</u>	<u>Symbol</u>	<u>Radionuclide</u>	<u>Half-Life</u>
³ H	tritium	12.35 yr	^{137m} Ba	barium-137m	2.552 min
⁷ Be	beryllium-7	53.44 d	¹⁵² Eu	europium-152	13.3 yr
¹⁴ C	carbon-14	5,730 yr	¹⁵⁴ Eu	europium-154	8.8 yr
⁴⁰ K	potassium-40	1.3 x 10 ⁸ yr	¹⁵⁵ Eu	europium-155	5 yr
⁵¹ Cr	chromium-51	27.7 d	²¹² Pb	lead-212	10.6 h
⁵⁴ Mn	manganese-54	312.7 d	²²⁰ Rn	radon-220	56 s
⁵⁵ Fe	iron-55	2.7 yr	²²² Rn	radon-222	3.8 d
⁵⁹ Fe	iron-59	44.63 d	²³² Th	thorium-232	1.4 x 10 ¹⁰ yr
⁵⁹ Ni	nickel-59	75,000 yr	U or uranium	uranium total	~(b)
⁶⁰ Co	cobalt-60	5.3 yr	²³³ U	uranium-233	1.59 x 10 ⁵ yr
⁶³ Ni	nickel-63	100.1 yr	²³⁴ U	uranium-234	2.4 x 10 ⁵ yr
⁶⁵ Zn	zinc-65	243.9 d	²³⁵ U	uranium-235	7 x 10 ⁸ yr
⁸⁵ Kr	krypton-85	10.7 yr	²³⁷ Np	neptunium-237	2.14 x 10 ⁶ yr
⁹⁰ Sr	strontium-90	29.1 yr	²³⁸ U	uranium-238	4.5 x 10 ⁹ yr
⁹⁰ Y	yttrium-90	64.1 h	²³⁸ Pu	plutonium-238	87.7 yr
⁹⁵ Zr	zirconium-95	63.98 d	²³⁹ Pu	plutonium-239	2.4 x 10 ⁴ yr
⁹⁹ Tc	technetium-99	2.1 x 10 ⁵ yr	²⁴⁰ Pu	plutonium-240	6.5 x 10 ³ yr
¹⁰³ Ru	ruthenium-103	39.3 d	²⁴¹ Pu	plutonium-241	14.4 yr
¹⁰⁶ Ru	ruthenium-106	368.2 d	²⁴² Pu	plutonium-242	3.76 x 10 ⁵ yr
¹¹³ Sn	tin-113	115 d	²⁴¹ Am	americium-241	432.2 yr
¹²⁵ Sb	antimony-125	2.8 yr	²⁴³ Am	americium-243	7,380 yr
¹²⁹ I	iodine-129	1.6 x 10 ⁷ yr	²⁴³ Cm	curium-243	28.5 yr
¹³¹ I	iodine-131	8 d	²⁴⁴ Cm	curium-244	18.11 yr
¹³⁴ Cs	cesium-134	2.1 yr	²⁴⁵ Cm	curium-245	8,500 yr
¹³⁷ Cs	cesium-137	30 yr			

(a) From Shleien 1992.

(b) Natural uranium is a mixture dominated by ²³⁸U, thus the half-life is approximately 4.5 x 10⁹ years.

UNDERSTANDING THE DATA TABLES

Some degree of variability, or uncertainty, is associated with all analytical measurements. This uncertainty is the consequence of a series of minor, often unintentional or unavoidable, inaccuracies related to collecting and analyzing the samples. These inaccuracies could include errors associated with reading or recording the result, handling or processing the sample, calibrating the counting instrument, and numerical rounding. With radionuclides, inaccuracies can also result from the randomness of radioactive decay. In this report, the uncertainties used include standard deviation, total propagated analytical uncertainty, and standard error of the mean. If the reported concentration of a given constituent is smaller than its associated uncertainty (e.g., 40 ± 200), the sample may not contain

that constituent. Such low-concentration values are considered to be below detection, meaning the concentration of the constituent in the sample is so low that it is undetected by the method and/or instrument.

STANDARD DEVIATION

The standard deviation (SD) of sample data relates to the variation around the mean of a set of individual sample results. If differences in analytical results occur among samples, then two times the standard deviation (or ±2 SD) implies that 95% of the time, a re-count or re-analysis of the same sample would give a value somewhere between the mean result minus the standard deviation and the mean result plus the standard deviation. Analytical results that are close together will have a smaller deviation than the deviation for results that are spread farther apart.

Table A.8. Elemental and Chemical Constituent Nomenclature

<u>Symbol</u>	<u>Constituent</u>	<u>Symbol</u>	<u>Constituent</u>
Ag	silver	Hg	mercury
Al	aluminum	K	potassium
As	arsenic	LiF	lithium fluoride
B	boron	Mg	magnesium
Ba	barium	Mn	manganese
Be	beryllium	Mo	molybdenum
Br	bromine	NH ₃	ammonia
C	carbon	NH ₄ ⁺	ammonium
Ca	calcium	N	nitrogen
CaF ₂	calcium fluoride	Na	sodium
CCl ₄	carbon tetrachloride	Ni	nickel
Cd	cadmium	NO ₂ ⁻	nitrite
CHCl ₃	trichloromethane	NO ₃ ⁻	nitrate
Cl ⁻	chloride	Pb	lead
CN ⁻	cyanide	PO ₄ ³⁻	phosphate
Cr ⁺⁶	chromium (species)	P	phosphorus
Cr	chromium (total)	Sb	antimony
CO ₃ ²⁻	carbonate	Se	selenium
Co	cobalt	Si	silicon
Cu	copper	Sr	strontium
F ⁻	fluoride	SO ₄ ²⁻	sulfate
Fe	iron	Ti	titanium
HCO ₃ ⁻	bicarbonate	Tl	thallium
		V	vanadium

TOTAL PROPAGATED ANALYTICAL UNCERTAINTY

For samples that are prepared or manipulated in the laboratory prior to counting (counting the rate of radioactive emissions from a sample), the total propagated analytical uncertainty includes both the counting uncertainty and the uncertainty associated with sample preparation and chemical separations. For samples that are not manipulated in the laboratory before counting, the total propagated analytical uncertainty only accounts for the uncertainty associated with counting the sample. The uncertainty associated with samples that are analyzed but not counted includes only the analytical process uncertainty. In this situation, the total propagated analytical uncertainty is assumed to be the nominal detection limit.

STANDARD ERROR OF THE MEAN

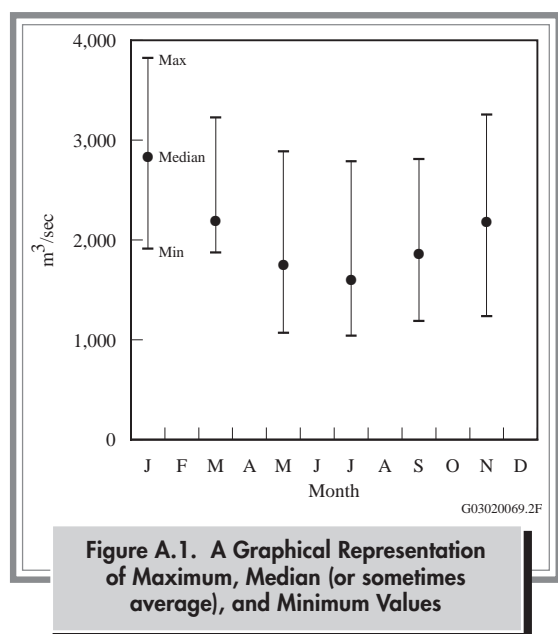
Just as individual values are accompanied by counting uncertainties, mean values (averages) are accompanied by

± 2 times the standard error of the calculated mean (or ± 2 SEM). If the data fluctuate randomly, then two times the standard error of the mean is a measure of the uncertainty in the estimated mean of the data from this randomness. If trends or periodic (e.g., seasonal) fluctuations are present, then two times the standard error of the mean is primarily a measure of the variability in the trends and fluctuations about the mean of the data. As with other uncertainties, two times the standard error of the mean implies that ~95% of the time the next calculated mean will fall somewhere between the reported value minus the standard error and the reported value plus the standard error.

MEDIAN, MAXIMUM, AND MINIMUM VALUES

Median (or sometimes mean), maximum, and minimum values are reported in some sections of this report. A median value is the middle value when all the values are arranged in order of increasing or decreasing magnitude. For example, the median value in the series of numbers - 1,

2, 3, 3, 4, 5, 5, 5, 6 is 4. The maximum value would be 6 and the minimum value would be 1. Median, maximum, and minimum values are reported when there are too few analytical results to accurately determine the mean with a \pm statistical uncertainty or when the data do not follow a bell-shape (i.e., normal) distribution. Figure A.1 provides a graphical representation of median, maximum, and minimum values. The upper line is the maximum value, the center dot is the median value, and the lower line is the minimum value.



NEGATIVE CONCENTRATIONS

There is always a small amount of natural radiation in the environment. The instruments used in the laboratory to measure radioactivity in Hanford Site environmental media are sensitive enough to measure the natural, or background, radiation along with any contaminant radiation in a sample. To obtain a true measure of the contaminant level in a sample, the natural, or background, radiation level must be subtracted from the total amount of radioactivity measured by an instrument. Because of the randomness of radioactive emissions and the very low activities of some contaminants, it is possible to obtain a background measurement that is larger than the actual contaminant measurement. When the larger background measurement is subtracted from the smaller contaminant measurement,

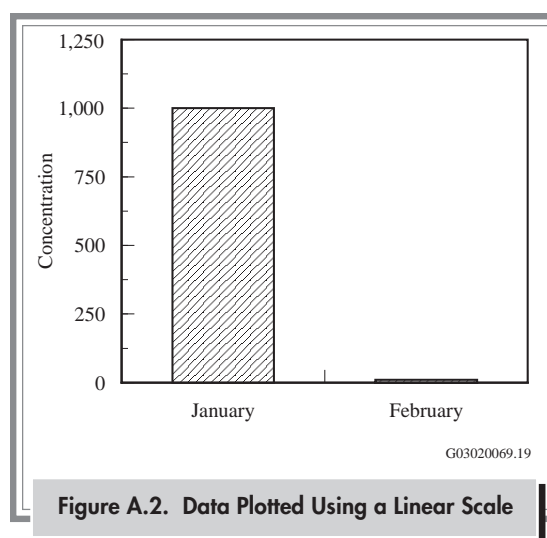
a negative result is generated. The negative results are reported because they are essential when conducting statistical evaluations of the data.

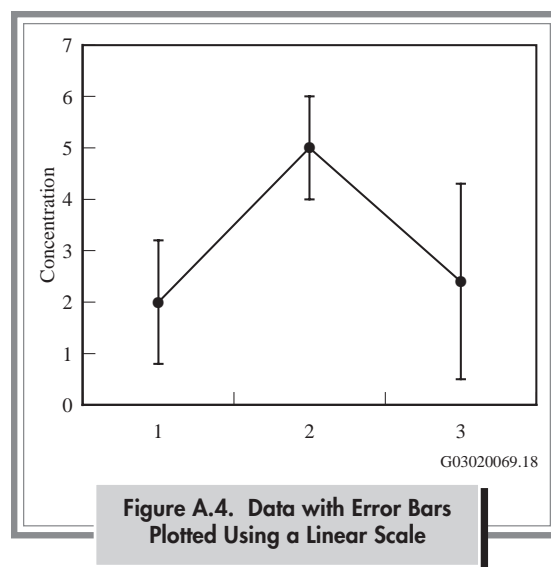
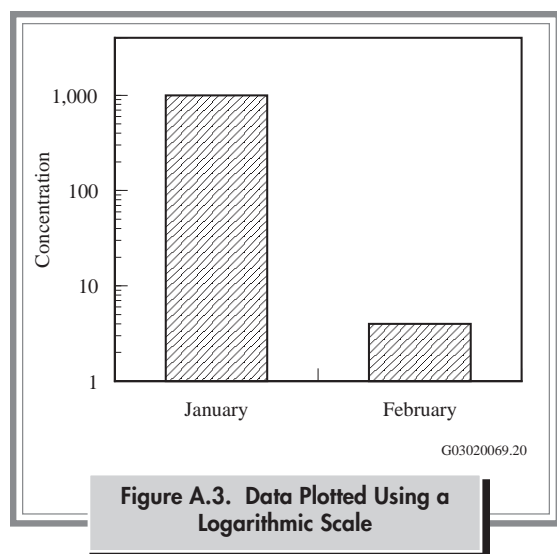
UNDERSTANDING GRAPHIC INFORMATION

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

Some of the data graphed in this report are plotted using logarithmic, or compressed, scales. Logarithmic scales are useful when plotting two or more numbers that differ greatly in size. For example, a sample with a concentration of 5 grams per liter would get lost at the bottom of the graph if plotted on a linear scale with a sample having a concentration of 1,000 grams per liter (Figure A.2). A logarithmic plot of these same two numbers allows the reader to see both data points clearly (Figure A.3).

The mean (average) and median (defined earlier) values graphed in this report have vertical lines extending above and below the data point. When used with a mean value, these lines (called error bars) indicate the amount of uncertainty (standard deviation, total propagated analytical





uncertainty, or two standard error of the mean) in the reported result. The error bars in this report represent a 95% chance that the mean is between the upper and lower ends of the error bar and a 5% chance that the true mean is either lower or higher than the error bar.^(a) For example, in Figure A.4, the first plotted mean is 2.0 ± 1.1 , so there is a 95% chance that the true mean is between 0.9 and 3.1, a 2.5% chance that it is less than 0.9, and a 2.5% chance that it is greater than 3.1. Error bars are computed statistically, employing all of the information used to generate the mean value. These bars provide a quick, visual indication that one mean may be statistically similar to or different from another mean. If the error bars of two or more means overlap, as is the case with means 1 and 3 and means 2 and 3, the means may be statistically similar. If the error bars do not overlap (means 1 and 2), the means may be statistically different. Means that appear to be very different visually (means 2 and 3) may actually be quite similar when compared statistically.

When vertical lines are used with median values, the lower end of each bar represents the minimum concentration measured; the upper end of each bar represents the maximum concentration measured.

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

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. An inequality symbol used with an underscore (\leq or \geq) indicates that the actual value is less than or equal to or greater than or equal to the number given, respectively.

REFERENCE

Shleien, B. 1992. *The Health Physics and Radiological Health Handbook, Revised Edition*. Scinta, Inc., Silver Spring,



APPENDIX B

ADDITIONAL MONITORING RESULTS

FOR 2002

G. W. Patton

This appendix contains additional information on 2002 monitoring results, supplementing the data summarized in

the main body of the report. More detailed information is available in PNNL-14295, APP. 1.

Table B.1. Radionuclide Concentrations in Columbia River Water Samples Collected at Priest Rapids Dam, Washington, 2002 Compared to Previous 5 Years

Radionuclide ^(a)	2002				1997-2001				Ambient Surface Water Quality Standard, pCi/L
	No. of Samples	Concentration, ^(b) pCi/L		No. of Samples	Concentration, ^(b) pCi/L				
		Maximum	Average		Maximum	Average			
Composite System									
Tritium	12	54 ± 8.0	35 ± 26	57	200 ± 22	38 ± 25	20,000 ^(c)		
Alpha (gross)	12	0.98 ± 0.88 ^(d)	0.29 ± 0.65 ^(d)	59	5.6 ± 3.1	0.56 ± 1.5	15 ^(e,f)		
Beta (gross)	12	3.2 ± 1.8	1.1 ± 1.8	59	7.7 ± 2.2	0.80 ± 3.4	50 ^(e,f)		
Strontium-90	12	0.10 ± 0.043	0.067 ± 0.031	59	0.13 ± 0.062	0.076 ± 0.036	8 ^(e,f)		
Technetium-99	12	0.53 ± 0.55 ^(d)	0.055 ± 0.52 ^(d)	59	1.6 ± 0.69	0.031 ± 0.50	900 ^(c)		
Iodine-129	4	0.000021 ± 0.0000028	0.000012 ± 0.000018	19	0.000022 ± 0.0000021	0.000082 ± 0.000012	1 ^(c)		
Uranium-234	12	0.24 ± 0.059	0.21 ± 0.037	59	0.42 ± 0.087	0.24 ± 0.097	-- ^(g)		
Uranium-235	12	0.014 ± 0.011	0.0045 ± 0.010	59	0.025 ± 0.016	0.0068 ± 0.013	--		
Uranium-238	12	0.24 ± 0.062	0.19 ± 0.060	59	0.38 ± 0.080	0.20 ± 0.094	--		
Uranium (total)	12	0.46 ± 0.083	0.40 ± 0.076	59	0.81 ± 0.12	0.45 ± 0.19	--		
Continuous System									
Cobalt-60	P	12	0.00092 ± 0.00071 ^(d)	0.00044 ± 0.0011 ^(d)	44	0.0013 ± 0.0016 ^(d)	0.00022 ± 0.00096 ^(d)	100 ^(c)	
	D	12	0.0033 ± 0.0021 ^(d)	0.0014 ± 0.0027 ^(d)	44	0.0051 ± 0.0053 ^(d)	0.00078 ± 0.0032 ^(d)		
Cesium-137	P	12	0.00096 ± 0.00071 ^(d)	0.00032 ± 0.00078 ^(d)	44	0.0032 ± 0.0013	0.00086 ± 0.0016	200 ^(c)	
	D	12	0.0025 ± 0.0025 ^(d)	0.0013 ± 0.0016 ^(d)	44	0.0034 ± 0.0021 ^(d)	0.00098 ± 0.0022 ^(d)		
Europium-155	P	12	0.0018 ± 0.0017 ^(d)	0.00024 ± 0.0017 ^(d)	44	0.0032 ± 0.0044 ^(d)	0.00023 ± 0.0022 ^(d)	600 ^(c)	
	D	12	0.0079 ± 0.0041 ^(d)	0.0024 ± 0.0046 ^(d)	44	0.012 ± 0.014 ^(d)	0.0013 ± 0.0061 ^(d)		
Plutonium-239/240	P	4	0.000040 ± 0.000022	0.000022 ± 0.000024	20	0.00028 ± 0.00010	0.000058 ± 0.00014	--	
	D	4	0.000039 ± 0.000058 ^(d)	0.000019 ± 0.000035 ^(d)	20	0.000056 ± 0.00010 ^(d)	0.000022 ± 0.000043		

(a) Radionuclides measured using the continuous system show the particulate (P) and dissolved (D) fractions separately. Other radionuclides are based on unfiltered samples collected by the composite system (see Section 4.2).

(b) Maximum values are ± total propagated analytical uncertainty (2 sigma). Averages are ±2 standard error of the calculated mean. To convert to international metric system units, multiply pCi/L by 0.037 to obtain Bq/L.

(c) WAC 173-201A-050 and EPA-570/9-76-003.

(d) Less than the detection limit.

(e) WAC 246-290.

(f) 40 CFR 141.

(g) Dashes indicate no concentration guides available.

Table B.2. Radionuclide Concentrations in Columbia River Water at the Richland Pump house in Richland, Washington, 2002 Compared to Previous 5 Years

Radionuclide ^(a)	2002				1997-2001				Ambient Surface Water Quality Standard, pCi/L
	No. of Samples	Concentration, ^(b) pCi/L		No. of Samples	Concentration, ^(b) pCi/L				
		Maximum	Average		Maximum	Average			
Composite System									
Tritium	12	110 ± 13	61 ± 49	57	150 ± 18	73 ± 48	20,000 ^(c)		
Alpha (gross)	12	1.0 ± 0.82 ^(d)	0.55 ± 0.69	59	2.2 ± 1.1	0.60 ± 0.85	15 ^(e,f)		
Beta (gross)	12	1.4 ± 1.5 ^(d)	0.54 ± 1.3 ^(d)	59	6.6 ± 2.5	0.78 ± 2.8	50 ^(e,f)		
Strontium-90	12	0.080 ± 0.033	0.058 ± 0.026	59	0.13 ± 0.048	0.072 ± 0.040	8 ^(e,f)		
Technetium-99	12	0.46 ± 0.55 ^(d)	0.0046 ± 0.51 ^(d)	59	0.53 ± 0.52	0.045 ± 0.28	900 ^(c)		
Iodine-129	4	0.000088 ± 0.000014	0.000066 ± 0.000057	19	0.00019 ± 0.000022	0.00010 ± 0.000082	1 ^(c)		
Uranium-234	12	0.32 ± 0.073	0.25 ± 0.064	59	0.40 ± 0.071	0.27 ± 0.096	-- ^(g)		
Uranium-235	12	0.012 ± 0.014 ^(d)	0.0051 ± 0.0074	59	0.024 ± 0.015	0.0091 ± 0.012	--		
Uranium-238	12	0.29 ± 0.067	0.22 ± 0.073	59	0.30 ± 0.066	0.22 ± 0.077	--		
Uranium (total)	12	0.62 ± 0.29	0.47 ± 0.14	59	0.70 ± 0.091	0.50 ± 0.16	--		
Continuous System									
Cobalt-60	P	12	0.00095 ± 0.00078 ^(d)	0.000082 ± 0.0010 ^(d)	44	0.0016 ± 0.0011 ^(d)	0.00026 ± 0.0011 ^(d)	100 ^(f)	
	D	12	0.0027 ± 0.0020 ^(d)	0.00081 ± 0.0016 ^(d)	44	0.0034 ± 0.0044 ^(d)	0.00063 ± 0.0027 ^(d)		
Cesium-137	P	12	0.0012 ± 0.00075 ^(d)	0.00043 ± 0.00091 ^(d)	44	0.0037 ± 0.0015	0.00094 ± 0.0015	200 ^(f)	
	D	12	0.0018 ± 0.0018 ^(d)	0.00052 ± 0.0019 ^(d)	44	0.0071 ± 0.0052 ^(d)	0.0012 ± 0.0028 ^(d)		
Europium-155	P	12	0.0023 ± 0.0020 ^(d)	0.00050 ± 0.0019 ^(d)	44	0.0022 ± 0.0017 ^(d)	0.0023 ± 0.0024 ^(d)	600 ^(f)	
	D	12	0.0042 ± 0.0045 ^(d)	-0.000016 ± 0.0058 ^(d)	44	0.0077 ± 0.013 ^(d)	0.00085 ± 0.0070 ^(d)		
Plutonium-239/240	P	4	0.000023 ± 0.000016	0.000011 ± 0.000015	20	0.00017 ± 0.000087	0.000044 ± 0.000089	--	
	D	4	0.000014 ± 0.000028 ^(d)	-0.00000029 ± 0.000034 ^(d)	20	0.00016 ± 0.000091	0.000042 ± 0.000092		

(a) Radionuclides measured using the continuous system show the particulate (P) and dissolved (D) fractions separately. Other radionuclides are based on unfiltered samples collected by the composite system (see Section 4.2).

(b) Maximum values are ± total propagated analytical uncertainty (2 sigma). Averages are ±2 standard error of the calculated mean. To convert to international metric system units, multiply pCi/L by 0.037 to obtain Bq/L.

(c) WAC 173-201A-050 and EPA-570/9-76-003.

(d) Less than the detection limit.

(e) WAC 246-290.

(f) 40 CFR 141.

(g) Dashes indicate no concentration guides available.

Table B.3. Radionuclide Concentrations Measured in Columbia River Water Samples Collected Along Transects of the Hanford Reach, 2002

Transect/Radionuclide	No. of Samples	Concentration, ^(a) pCi/L		
		Maximum	Minimum	Mean
Vernita Bridge (HRM 0.3) ^(b)				
Tritium	16	54 ± 8.0	20 ± 3.4	36 ± 20
Strontium-90	16	0.16 ± 0.051	0.043 ± 0.035 ^(c)	0.071 ± 0.056
Uranium (total)	16	0.54 ± 0.089	0.33 ± 0.061	0.41 ± 0.12
100-N Area (HRM 9.5)				
Tritium	7	38 ± 4.5	18 ± 3.3	25 ± 15
Strontium-90	7	0.095 ± 0.036	0.049 ± 0.035 ^(c)	0.067 ± 0.034
Uranium (total)	7	0.44 ± 0.075	0.35 ± 0.066	0.37 ± 0.061
100-F Area (HRM 19)				
Tritium	6	30 ± 4.3	21 ± 3.5	23 ± 6.8
Strontium-90	6	0.059 ± 0.026	0.040 ± 0.021	0.048 ± 0.013
Uranium (total)	6	0.45 ± 0.088	0.33 ± 0.063	0.37 ± 0.084
Hanford Town Site (HRM 28.7)				
Tritium	6	3,100 ± 160	20 ± 3.8	610 ± 2,500
Strontium-90	6	0.090 ± 0.041	0.057 ± 0.037	0.072 ± 0.028
Uranium (total)	6	0.49 ± 0.084	0.37 ± 0.067	0.41 ± 0.091
300 Area (HRM 43.1)				
Tritium	6	48 ± 5.2	32 ± 4.2	40 ± 11
Strontium-90	6	0.076 ± 0.035	0.042 ± 0.030 ^(c)	0.063 ± 0.022
Uranium (total)	6	0.75 ± 0.12	0.36 ± 0.065	0.46 ± 0.30
Richland Pumphouse (HRM 46.4)				
Tritium	26	190 ± 19	18 ± 3.3	52 ± 94
Strontium-90	26	0.097 ± 0.039	0.037 ± 0.027 ^(c)	0.067 ± 0.024
Uranium (total)	26	1.5 ± 0.21	0.32 ± 0.060	0.51 ± 0.48

(a) Maximum and minimum values are ± total propagated analytical uncertainty (2-sigma). Mean values are ±2 standard error of the mean. To convert to international metric system units, multiply pCi/L by 0.037 to obtain Bq/L.

(b) HRM = Hanford River Mile (e.g., Vernita Bridge crossing is Mile 0, the Richland Pumphouse is Mile 46.4).

(c) Below detection limit.

Table B.4. Radionuclide Concentrations Measured in Columbia River Water Samples Collected at Near-Shore Locations in the Hanford Reach, 2002

<u>Near-Shore/Radionuclide</u>	<u>No. of Samples</u>	<u>Concentration,^(a) pCi/L</u>		
		<u>Maximum</u>	<u>Minimum</u>	<u>Mean</u>
Vernita Bridge (HRM 0.3)^(b)				
Tritium	4	50 ± 7.7	33 ± 4.2	39 ± 15
Strontium-90	4	0.092 ± 0.076 ^(c)	0.050 ± 0.029	0.072 ± 0.039
Uranium (total)	4	0.49 ± 0.084	0.33 ± 0.061	0.41 ± 0.13
100-N Area (HRM 8.4 to 9.8)				
Tritium	6	38 ± 4.5	24 ± 3.8	29 ± 11
Strontium-90	6	0.22 ± 0.066	0.045 ± 0.028	0.11 ± 0.14
Uranium (total)	6	0.38 ± 0.067	0.34 ± 0.062	0.36 ± 0.026
100-F Area (HRM 18-23)				
Tritium	4	27 ± 3.8	21 ± 3.5	24 ± 4.5
Strontium-90	4	0.054 ± 0.025	0.020 ± 0.017 ^(c)	0.039 ± 0.029
Uranium (total)	4	0.38 ± 0.073	0.33 ± 0.063	0.35 ± 0.040
Hanford Town Site (HRM 26 to 30)				
Tritium	5	16,000 ± 490	22 ± 4.4	4,100 ± 13,000
Strontium-90	5	0.090 ± 0.041	0.056 ± 0.029	0.072 ± 0.028
Uranium (total)	5	1.1 ± 0.16	0.37 ± 0.067	0.55 ± 0.60
300 Area (HRM 41.5 to 43.1)				
Tritium	5	70 ± 6.9	34 ± 4.3	51 ± 31
Strontium-90	5	0.094 ± 0.040	0.066 ± 0.038	0.078 ± 0.020
Uranium (total)	5	0.42 ± 0.073	0.36 ± 0.065	0.38 ± 0.052
Richland Pumphouse (HRM 43.5 to 46.4)				
Tritium	22	190 ± 19	21 ± 3.4	78 ± 140
Strontium-90	22	0.096 ± 0.043	0.045 ± 0.029	0.070 ± 0.027
Uranium (total)	22	0.94 ± 0.14	0.34 ± 0.063	0.51 ± 0.42

(a) Maximum and minimum values are ± total propagated analytical uncertainty (2-sigma). Mean values are ±2 standard deviations. To convert to international metric system units, multiply pCi/L by 0.037 to obtain Bq/L.

(b) HRM = Hanford River Mile (e.g., Vernita Bridge crossing is Mile 0, the Richland Pumphouse is Mile 46.4).

(c) Below detection limit.

Table B.5. Selected U.S. Geological Survey Columbia River Water Quality Data for Vernita and Richland, Washington,^(a) 2002

<u>Analysis</u>	<u>Units</u>	<u>Vernita Bridge (upstream)</u>				<u>Richland Pumphouse (downstream)</u>				<u>Washington Ambient Surface Water Quality Standard^(b)</u>
		<u>No. of Samples</u>	<u>Median</u>	<u>Maximum</u>	<u>Minimum</u>	<u>No. of Samples</u>	<u>Median</u>	<u>Maximum</u>	<u>Minimum</u>	
Temperature	°C	4	12	19	4.0	4	12	18	4.0	20 (maximum)
Dissolved oxygen	mg/L	4	11	13	9.2	4	11	14	8.7	8 (minimum)
Turbidity	NTU ^(c)	4	1.6	3.0	<1.0	4	2.4	3.7	2.0	5 + background
pH	pH units	4	7.7	8.2	7.6	4	7.6	8.3	7.4	6.5 - 8.5
Sulfate, dissolved	mg/L	4	8.3	10	5.9	4	8.4	10	6.1	-- ^(d)
Dissolved solids, 180°C (356°F)	mg/L	4	78	90	58	4	76	83	60	--
Specific conductance	µS/cm	4	130	150	110	4	130	150	110	--
Total hardness, as CaCO ₃	mg/L	4	60	65	47	4	60	68	48	--
Alkalinity	mg/L	4	53	64	50	4	55	64	50	--
Phosphorus, total	mg/L	4	<0.6	<0.6	<0.4	4	<0.06	<0.06	<0.04	--
Chromium, dissolved	µg/L	4	<0.8	<0.8	<0.8	4	<0.8	<0.8	0.5 ^(e)	--
Dissolved organic carbon	mg/L	4	1.4	2.0	1.2	4	1.4	2.1	1.2	--
Iron, dissolved	µg/L	4	<10	10	<10	4	<10	31	7.0 ^(e)	--
Ammonia, dissolved, as N	mg/L	4	<0.04	<0.04	<0.04	4	<0.04	<0.04	<0.04	--
Nitrite + nitrate, dissolved, as N	mg/L	4	0.085	0.14	0.04 ^(e)	4	0.11	0.17	0.06	--

(a) Provisional data from U.S. Geological Survey National Stream Quality Accounting Network (NASQAN), subject to revision.

(b) From WAC 173-201A.

(c) NTU = Nephelometric turbidity units.

(d) Dashes indicate no standard available.

(e) Estimated value.

Table B.6. Concentrations ($\mu\text{g/L}$) of Dissolved Metals in Columbia River Transect and Near-Shore Water Samples Collected Near the Hanford Site, 2002

<u>Location</u>	<u>Metal</u>	<u>No. of Samples</u>	<u>Maximum</u>	<u>Minimum</u>	<u>Average</u>	<u>$\pm 2\text{SD}^{(a)}$</u>
Vernita Bridge	Antimony	12	0.26	0.12	0.19	0.093
	Arsenic	12	0.78	0.48	0.58	0.21
	Beryllium	12	0.055	0.008 ^(b)	0.024	0.032
	Cadmium	12	0.058	0.011 ^(b)	0.026	0.033
	Chromium	12	0.26	0.037	0.12	0.16
	Copper	12	1.0	0.40	0.57	0.37
	Lead	12	0.32	0.011 ^(b)	0.048	0.17
	Mercury	4	0.00036	0.00029	0.00033	0.000066
	Nickel	12	0.77	0.17	0.49	0.47
	Selenium	12	0.50 ^(b)	0.11 ^(b)	0.40	0.31
	Silver	12	0.013	0.0012 ^(b)	0.0046	0.0063
	Thallium	12	0.026	0.010	0.018	0.011
	Zinc	12	4.4	0.82	1.6	2.1
100-N Area	Antimony	10	0.22	0.17	0.18	0.028
	Arsenic	10	0.64	0.61	0.62	0.023
	Beryllium	10	0.024 ^(b)	0.024 ^(b)	0.024 ^(b)	0
	Cadmium	10	0.027	0.011	0.018	0.011
	Chromium	10	0.13	0.066	0.096	0.044
	Copper	10	0.69	0.56	0.62	0.074
	Lead	10	0.019	0.011 ^(b)	0.013	0.0053
	Mercury	0	--	--	--	--
	Nickel	10	0.25	0.15	0.21	0.066
	Selenium	10	0.50 ^(b)	0.50 ^(b)	0.50 ^(b)	0
	Silver	10	0.005 ^(b)	0.005 ^(b)	0.005 ^(b)	0
	Thallium	10	0.020	0.016	0.018	0.0023
	Zinc	10	3.7	0.80	1.3	1.7
100-F Area	Antimony	9	0.15	0.14	0.15	0.010
	Arsenic	9	0.60	0.50	0.53	0.066
	Beryllium	9	0.024 ^(b)	0.024 ^(b)	0.024 ^(b)	0
	Cadmium	9	0.014	0.011 ^(b)	0.012	0.0025
	Chromium	9	0.12	0.057	0.078	0.041
	Copper	9	0.43	0.39	0.42	0.026
	Lead	9	0.025	0.011	0.017	0.011
	Mercury	0	--	--	--	--
	Nickel	9	0.22	0.15	0.20	0.051
	Selenium	9	0.50 ^(b)	0.50 ^(b)	0.50 ^(b)	0
	Silver	9	0.005 ^(b)	0.005 ^(b)	0.005 ^(b)	0
	Thallium	9	0.017	0.013	0.015	0.0028
	Zinc	9	1.2	0.81	0.98	0.28
Hanford town site	Antimony	10	0.21	0.16	0.18	0.029
	Arsenic	10	1.6	0.57	0.76	0.63
	Beryllium	10	0.024 ^(b)	0.024 ^(b)	0.024 ^(b)	0
	Cadmium	10	0.029	0.013	0.019	0.0097
	Chromium	10	1.0	0.058	0.21	0.57
	Copper	10	0.88	0.54	0.64	0.18
	Lead	10	0.046	0.014	0.028	0.021
	Mercury	0	--	--	--	--
	Nickel	10	0.26	0.16	0.20	0.061
	Selenium	10	0.54	0.50 ^(b)	0.50	0.028
	Silver	10	0.005 ^(b)	0.005 ^(b)	0.005 ^(b)	0
	Thallium	10	0.021	0.016	0.019	0.0028
	Zinc	10	2.4	0.85	1.2	0.84

Table B.6. (contd)

Location	Metal	No. of Samples	Maximum	Minimum	Average	±2SD^(a)
300 Area	Antimony	10	0.17	0.13	0.15	0.020
	Arsenic	10	0.75	0.46	0.55	0.15
	Beryllium	10	0.024 ^(b)	0.024 ^(b)	0.024 ^(b)	0
	Cadmium	10	0.017	0.011 ^(b)	0.012	0.0037
	Chromium	10	0.17	0.098	0.14	0.047
	Copper	10	2.3	0.36	0.61	1.2
	Lead	10	0.049	0.011	0.022	0.023
	Mercury	0	--	--	--	--
	Nickel	10	0.27	0.14	0.20	0.096
	Selenium	10	0.50 ^(b)	0.50 ^(b)	0.50 ^(b)	0
	Silver	10	0.005 ^(b)	0.005 ^(b)	0.005 ^(b)	0
	Thallium	10	0.018	0.014	0.016	0.0023
	Zinc	10	1.5	0.74	1.0	0.49
Richland Pumphouse	Antimony	30	0.29	0.14	0.20	0.092
	Arsenic	30	0.75	0.40	0.59	0.17
	Beryllium	30	0.067	0.008 ^(b)	0.0024	0.033
	Cadmium	30	0.058	0.011	0.026	0.034
	Chromium	30	0.24	0.016	0.10	0.15
	Copper	30	0.91	0.39	0.56	0.33
	Lead	30	0.041	0.015	0.026	0.016
	Mercury	6	0.00047	0.00035	0.00040	0.000085
	Nickel	30	0.84	0.16	0.50	0.44
	Selenium	30	0.50	0.11 ^(b)	0.42	0.29
	Silver	30	0.0093	0.0012 ^(b)	0.0047	0.0056
	Thallium	30	0.026	0.0095	0.017	0.0077
	Zinc	30	2.7	0.78	1.5	1.3

(a) SD = Standard deviation.

(b) Below detection limit.

Table B.7. Radionuclide Concentrations in Sediment from the Columbia River Near the Hanford Site and from Columbia River Riverbank Springs Along the Hanford Site, 2002 Compared to Previous 5 Years

Location	Radionuclide	2002			1997-2001		
		No. of Samples	Concentration, pCi/g ^(a)		No. of Samples	Concentration, pCi/g ^(a)	
			Median ^(b)	Maximum ^(c)		Median ^(b)	Maximum ^(c)
River Sediment (2002 TOC Value) ^(d)							
100-F Slough (175 mg/kg)	Cobalt-60	1		0.0079 ± 0.019 ^(e)	5	0.016 ^(e)	0.024 ± 0.013 ^(e)
	Cesium-137	1		0.30 ± 0.041	5	0.28	0.36 ± 0.042
	Europium-155	1		0.046 ± 0.027 ^(e)	5	0.040 ^(e)	0.069 ± 0.062 ^(e)
	Plutonium-239/240	1		0.0014 ± 0.00039	5	0.0020	0.0023 ± 0.00054
	Strontium-90	1		0.0054 ± 0.013 ^(e)	5	0.0017	0.0052 ± 0.0037
	Uranium-234	1		0.17 ± 0.037	4	0.15	0.31 ± 0.062
	Uranium-235	1		0.011 ± 0.0058	5	0.0058	0.064 ± 0.068 ^(e)
	Uranium-238	1		0.17 ± 0.036	5	0.15	0.99 ± 0.33
Hanford Slough (3,310 mg/kg)	Cobalt-60	1		0.0099 ± 0.014 ^(e)	5	0.011	0.18 ± 0.028
	Cesium-137	1		0.0071 ± 0.013 ^(e)	5	0.13	0.25 ± 0.036
	Europium-155	1		0.011 ± 0.043 ^(e)	5	0.059 ^(e)	0.068 ± 0.029 ^(e)
	Plutonium-239/240	1		0.0045 ± 0.00093	5	0.0014	0.0037 ± 0.00083
	Strontium-90	1		0.0059 ± 0.019 ^(e)	5	0.0036	0.010 ± 0.0052
	Uranium-234	1		0.53 ± 0.10	4	0.24	0.37 ± 0.072
	Uranium-235	1		0.017 ± 0.0077	5	0.0090	0.040 ± 0.077 ^(e)
	Uranium-238	1		0.47 ± 0.092	5	0.27	1.4 ± 0.43
McNary Dam (6,270 - 8,630 mg/kg)	Cobalt-60	2	0.015 ^(e)	0.016 ± 0.018 ^(e)	24	0.030	0.12 ± 0.042 ^(e)
	Cesium-137	2	0.24	0.25 ± 0.039	24	0.36	1.1 ± 0.15
	Europium-155	2	0.067 ^(e)	0.079 ± 0.047 ^(e)	24	0.056 ^(e)	0.13 ± 0.066 ^(e)
	Plutonium-239/240	2	0.0081	0.0089 ± 0.0017	24	0.0078	0.032 ± 0.0048
	Strontium-90	2	0.025 ^(e)	0.027 ± 0.023 ^(e)	24	0.020	0.043 ± 0.028
	Uranium-234	2	0.82	0.85 ± 0.16	20	0.73	0.87 ± 0.17
	Uranium-235	2	0.024	0.030 ± 0.012	24	0.024	0.21 ± 0.10 ^(e)
	Uranium-238	2	0.70	0.70 ± 0.13	24	0.62	1.9 ± 0.49
Priest Rapids Dam (5,630 - 7,660 mg/kg)	Cobalt-60	2	0.000010 ^(e)	0.0068 ± 0.015 ^(e)	19	0.0080 ^(e)	0.042 ± 0.041 ^(e)
	Cesium-137	2	0.53	0.65 ± 0.086	19	0.34	0.60 ± 0.11
	Europium-155	2	0.040 ^(e)	0.066 ± 0.041 ^(e)	19	0.046 ^(e)	0.082 ± 0.088 ^(e)
	Plutonium-239/240	2	0.012	0.015 ± 0.0024	19	0.0087	0.017 ± 0.0030
	Strontium-90	2	-0.0049 ^(e)	-0.0023 ± 0.020 ^(e)	19	0.013	0.028 ± 0.028 ^(e)
	Uranium-234	2	0.62	0.72 ± 0.14	16	0.51	0.83 ± 0.14
	Uranium-235	2	0.023	0.024 ± 0.0094	19	0.018	0.14 ± 0.086 ^(e)
	Uranium-238	2	0.54	0.62 ± 0.12	19	0.56	1.4 ± 0.50

Table B.7. (contd)

Location	Radionuclide	2002		1997-2001		
		No. of Samples	Concentration, pCi/g ^(a)	No. of Samples	Concentration, pCi/g ^(a)	
			Median ^(b)		Maximum ^(c)	Median ^(b)
Richland (919 mg/kg)	Cobalt-60	1	-0.0035 ± 0.011 ^(e)	5	0.020 ^(e)	0.035 ± 0.012 ^(e)
	Cesium-137	1	0.12 ± 0.024	5	0.23	0.24 ± 0.049
	Europium-155	1	0.046 ± 0.030 ^(e)	5	0.035 ^(e)	0.062 ± 0.030 ^(e)
	Plutonium-239/240	1	0.0014 ± 0.00038	5	0.0016	0.0034 ± 0.00073
	Strontium-90	1	-0.025 ± 0.025 ^(e)	5	0.0041	0.0063 ± 0.0041
	Uranium-234	1	0.12 ± 0.030	4	0.21	0.25 ± 0.053
	Uranium-235	1	0.0047 ± 0.0046	5	0.011	0.053 ± 0.074 ^(e)
	Uranium-238	1	0.13 ± 0.032	5	0.24	0.83 ± 0.28 ^(e)
White Bluffs Slough (14,800 mg/kg)	Cobalt-60	1	0.060 ± 0.025 ^(e)	5	0.051	0.11 ± 0.024
	Cesium-137	1	0.64 ± 0.089	5	0.53	0.60 ± 0.067
	Europium-155	1	0.025 ± 0.058 ^(e)	5	0.052 ^(e)	0.10 ± 0.034 ^(e)
	Plutonium-239/240	1	0.0077 ± 0.0017	5	0.0044	0.0058 ± 0.0011
	Strontium-90	1	0.0028 ± 0.029 ^(e)	5	0.0023	0.0082 ± 0.0049
	Uranium-234	1	1.6 ± 0.30	4	0.39	0.69 ± 0.13
	Uranium-235	1	0.053 ± 0.016	5	0.0087	0.027 ± 0.010
	Uranium-238	1	1.3 ± 0.24	5	0.38	1.0 ± 0.36
Riverbank Spring Sediment						
100-B Spring	Cobalt-60	1	0.0031 ± 0.011 ^(e)	5	0.021 ^(e)	0.051 ± 0.024 ^(e)
	Cesium-137	1	0.059 ± 0.016	5	0.079	0.14 ± 0.026
	Europium-155	1	0.078 ± 0.030 ^(e)	5	0.077 ^(e)	0.11 ± 0.072 ^(e)
	Strontium-90	1	-0.0036 ± 0.021 ^(e)	5	0.0020 ^(e)	0.0041 ± 0.0083 ^(e)
	Uranium-234	1	0.19 ± 0.042	4	0.37	0.49 ± 0.087
	Uranium-235	1	0.0098 ± 0.0059	5	0.015	0.20 ± 0.10 ^(e)
	Uranium-238	1	0.20 ± 0.042	5	0.40	1.2 ± 0.40 ^(e)
100-F Spring	Cobalt-60	1	0.0057 ± 0.011 ^(e)	5	0.018 ^(e)	0.044 ± 0.024 ^(e)
	Cesium-137	1	0.071 ± 0.019	5	0.14	0.20 ± 0.035
	Europium-155	1	0.058 ± 0.034 ^(e)	5	0.030 ^(e)	0.070 ± 0.031 ^(e)
	Strontium-90	1	-0.0080 ± 0.027 ^(e)	5	0.0041	0.013 ± 0.032 ^(e)
	Uranium-234	1	0.52 ± 0.10	5	0.49	0.70 ± 0.14
	Uranium-235	1	0.024 ± 0.0097	6	0.036	0.083 ± 0.11 ^(e)
	Uranium-238	1	0.42 ± 0.083	6	0.54	0.97 ± 0.43 ^(e)

Table B.7. (contd)

Location	Radionuclide	2002			1997-2001		
		No. of Samples	Concentration, pCi/g ^(a)		No. of Samples	Concentration, pCi/g ^(a)	
			Median ^(b)	Maximum ^(c)		Median ^(b)	Maximum ^(c)
100-K Spring	Cobalt-60	1		0.0053 ± 0.013 ^(e)	1		0.015 ± 0.021 ^(e)
	Cesium-137	1		0.10 ± 0.023	1		0.19 ± 0.046
	Europium-155	1		0.057 ± 0.041 ^(e)	1		0.039 ± 0.047 ^(e)
	Strontium-90	1		0.015 ± 0.024 ^(e)	1		0.0085 ± 0.0048
	Uranium-234	1		0.30 ± 0.065	0		--
	Uranium-235	1		0.0085 ± 0.0066	1		0.14 ± 0.065 ^(e)
	Uranium-238	1		0.28 ± 0.060	1		0.82 ± 0.24 ^(e)
300 Area Spring	Cobalt-60	2	0.0092 ^(e)	0.013 ± 0.012 ^(e)	6	0.012 ^(e)	0.020 ± 0.010 ^(e)
	Cesium-137	2	0.15	0.25 ± 0.038	6	0.066	0.27 ± 0.035
	Europium-155	2	0.070	0.085 ± 0.037 ^(e)	6	0.038 ^(e)	0.086 ± 0.035 ^(e)
	Uranium-234	2	6.1	11 ± 2.0	11	1.5	3.9 ± 0.6
	Uranium-235	2	0.20	0.38 ± 0.075	12	0.072	0.19 ± 0.11 ^(e)
	Uranium-238	2	5.4	10 ± 1.8	12	1.8	3.7 ± 0.57
Hanford Spring	Cobalt-60	1		0.032 ± 0.012 ^(e)	5	0.049	0.067 ± 0.026
	Cesium-137	1		0.099 ± 0.024	5	0.22	0.25 ± 0.058
	Europium-155	1		0.10 ± 0.035 ^(e)	5	0.066 ^(e)	0.10 ± 0.053 ^(e)
	Uranium-234	1		0.57 ± 0.11	4	0.58	0.75 ± 0.13
	Uranium-235	1		0.015 ± 0.0073	5	0.017	0.024 ± 0.011
	Uranium-238	1		0.45 ± 0.089	5	0.47	1.6 ± 0.56

(a) To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.

(b) Median values are not provided when only one sample analyzed.

(c) Values are ± total propagated analytical uncertainty (2-sigma).

(d) TOC = Total organic content.

(e) Below detection limit.

Table B.8. Median Metal Concentrations (mg/kg dry wt.) in Sediment Samples Collected from the Columbia River Near the Hanford Site, 2002

<u>Metal</u>	(n=2) Priest Rapids Dam	(n=4) Hanford Reach^(a)	(n=2) McNary Dam	(n=6) Riverbank Springs^(b)
Antimony	0.84	0.0075	0.77	0.57
Arsenic	11	6.6	8.4	5.8
Beryllium	1.9	1.6	2.0	1.5
Cadmium	7.7	0.67	1.5	0.67
Chromium	84	64	61	68
Copper	47	20	32	18
Lead	62	28	25	24
Mercury	0.17	0.0074	0.081	0.014
Nickel	44	23	30	20
Selenium	0.42	0.18	0.34	0.37
Silver	0.16	0.023	0.094	0.082
Thallium	1.4	0.62	0.80	0.56
Zinc	640	210	260	160

(a) White Bluffs Slough, 100-F Slough, Hanford Slough, and Richland.

(b) 100-B Area, 100-K Area, 100-F Area, Hanford town site, and 300 Area.

Table B.9. Radionuclide Concentrations Measured in Columbia River Water Samples Collected from Riverbank Springs Along the Hanford Site, 2002 Compared to Previous 5 Years

Location/Radionuclide	2002			1997-2001			Washington State Ambient Surface Water Quality Standard, ^(b) pCi/L
	No. of Samples	Concentration, ^(a) pCi/L		No. of Samples	Concentration, ^(a) pCi/L		
		Maximum	Average		Maximum	Average	
100-B Area							
Alpha (gross)	3	2.4 ± 1.5	1.4 ± 1.9	16	9.4 ± 3.8	2.5 ± 4.2	15
Beta (gross)	3	7.3 ± 2.0	6.2 ± 1.9	16	24 ± 4.5	11 ± 13	50
Strontium-90	3	-0.0019 ± 0.24 ^(c)	-0.057 ± 0.12 ^(c)	16	7.4 ± 1.6	1.1 ± 4.8	8
Technetium-99	1	4.5 ± 0.77	--	7	10 ± 1.4	5.2 ± 6.6	900 ^(d)
Tritium	3	5,900 ± 360	4,800 ± 1,800	16	20,000 ± 870	9,200 ± 10,000	20,000
100-D Area							
Alpha (gross)	5	32 ± 9.8	13 ± 23	26	4.4 ± 2.3	1.1 ± 1.9	15
Beta (gross)	5	41 ± 8.1	23 ± 34	26	14 ± 3.6	4.1 ± 6.4	50
Strontium-90	0	--	--	12	5.3 ± 1.2	1.1 ± 2.8	8
Tritium	5	5,600 ± 380	2,600 ± 4,000	21	9,800 ± 730	3,400 ± 7,500	20,000
100-F Area							
Alpha (gross)	2	3.5 ± 1.8	3.4 ± 0.31	15	12 ± 3.1	4.7 ± 5.4	15
Beta (gross)	2	13 ± 3.5	12 ± 3.2	15	16 ± 2.8	8.8 ± 8.8	50
Strontium-90	2	0.13 ± 0.31 ^(c)	0.072 ± 0.17 ^(c)	15	1.5 ± 0.57	0.19 ± 0.90	8
Tritium	2	1,200 ± 190	1,200 ± 170	15	1,500 ± 320	1,000 ± 910	20,000
Uranium (total)	1	4.3 ± 0.57	--	6	5.2 ± 0.70	4.1 ± 2.1	-- ^(e)
100-H Area							
Alpha (gross)	7	1.2 ± 1.0 ^(c)	0.59 ± 0.93 ^(c)	32	10 ± 3.7	1.5 ± 3.5	15
Beta (gross)	7	13 ± 2.7	6.5 ± 10	32	72 ± 8.6	14 ± 32	50
Strontium-90	1	3.3 ± 0.71	--	10	17 ± 3.1	6.1 ± 14	8
Technetium-99	1	8.0 ± 0.97	--	10	77 ± 8.7	10 ± 48	900
Tritium	7	840 ± 170	380 ± 650	32	5,500 ± 470	990 ± 2,100	20,000
Uranium (total)	1	1.9 ± 0.26	--	10	9.3 ± 0.70	2.0 ± 5.2	--
100-K Area							
Alpha (gross)	4	3.4 ± 2.0	1.6 ± 2.8	19	4.1 ± 2.1	1.4 ± 2.4	15
Beta (gross)	4	13 ± 2.7	7.6 ± 7.0	19	46 ± 7.8	8.5 ± 21	50
Strontium-90	2	3.2 ± 0.72	1.6 ± 4.5	8	2.1 ± 0.52	0.60 ± 1.8	8
Technetium-99	2	1.1 ± 0.60	0.43 ± 2.0	4	2.3 ± 0.28	0.71 ± 2.1	900 ^(d)
Tritium	4	5,100 ± 350	1,600 ± 4,800	19	12,000 ± 970	3,100 ± 6,400	20,000

Table B.9. (contd)

Location/Radionuclide	No. of Samples	2002		No. of Samples	1997-2001		Washington State Ambient Surface Water Quality Standard, ^(b) pCi/L
		Concentration, ^(a) pCi/L			Concentration, ^(a) pCi/L		
		Maximum	Average		Maximum	Average	
100-N Area							
Alpha (gross)	1	2.2 ± 1.4	--	7	2.8 ± 1.2	1.6 ± 1.4	15
Beta (gross)	1	4.8 ± 1.7	--	7	16,000 ± 1,400	2,200 ± 12,000	50
Strontium-90	1	0.0042 ± 0.0034 ^(c)	--	7	9,900 ± 1,800	1,600 ± 8,100	8
Tritium	1	7,100 ± 320	--	7	24,000 ± 1,900	16,000 ± 11,000	20,000
300 Area							
Alpha (gross)	2	81 ± 19	57 ± 69	10	230 ± 49	89 ± 110	15
Beta (gross)	2	26 ± 4.7	23 ± 9.0	10	49 ± 7.9	26 ± 23	50
Iodine-129	2	0.0042 ± 0.00047	0.0040 ± 0.00058	10	0.0067 ± 0.00066	0.0045 ± 0.0036	1
Technetium-99	0	--	--	6	16 ± 2.0	12 ± 4.8	900 ^(d)
Tritium	2	8,100 ± 690	7,500 ± 1,700	12	12,000 ± 580	8,800 ± 3,700	20,000
Uranium (total)	2	99 ± 11	68 ± 89	14	210 ± 26	75 ± 99	--
Hanford Town Site							
Alpha (gross)	2	3.0 ± 1.7	2.4 ± 1.5	10	14 ± 5.9	4.0 ± 7.3	15
Beta (gross)	2	24 ± 4.4	23 ± 0.99	10	49 ± 7.9	29 ± 18	50
Iodine-129	2	0.19 ± 0.019	0.17 ± 0.05	10	0.41 ± 0.024	0.21 ± 0.19	1
Technetium-99	2	75 ± 4.7	71 ± 11	10	120 ± 8.0	81 ± 51	900 ^(d)
Tritium	2	58,000 ± 1,900	56,000 ± 6,400	10	120,000 ± 8,800	85,000 ± 47,000	20,000
Uranium (total)	2	2.4 ± 0.33	2.4 ± 0.039	10	8.6 ± 1.0	3.8 ± 3.9	--

(a) Maximum values are ± total propagated analytical uncertainty. Averages are ±2 standard deviations of the calculated mean. To convert to international metric system units, multiply pCi/L by 0.037 to obtain Bq/L.

(b) WAC 246-290, 40 CFR 141, and Appendix D, Table D.2.

(c) Value below the detection limit.

(d) WAC 173-201A-050 and EPA-570/9-76-003.

(e) Dashes indicate no concentration guides available.

Table B.10. Annual Average Dose Rates Measured On and Around the Hanford Site in Calendar Year 2002

<u>Location</u>	<u>Location Number</u>	<u>Annual Average (mrem/yr)^(a)</u>	<u>Location</u>	<u>Location Number</u>	<u>Annual Average (mrem/yr)^(a)</u>
Onsite^(b)			Community^(c)		
100 B Reactor Museum	1	87 ± 7	Mattawa	12	80 ± 8
100 K Area	2	76 ± 7	Othello	13	78 ± 9
100 D Area	3	87 ± 5	Basin City	14	78 ± 3
100 F Met Tower	4	83 ± 9	Edwin Markham School	15	77 ± 7
N of 200 E	5	90 ± 6	Pasco	16	87 ± 9
B Pond	6	83 ± 11	Kennewick - Ely Street	17	78 ± 7
E of 200 E	7	90 ± 8	Benton City	18	86 ± 8
200ESE	8	87 ± 9			
S of 200 E	9	95 ± 6	Distant^(c)		
200 Tel. Exchange	10	83 ± 5	Yakima	19	72 ± 5
SW of B/C Cribs	11	86 ± 15	Toppenish	20	72 ± 10
200 W SE	12	83 ± 7			
Army Loop Camp	13	89 ± 8	Columbia River Shoreline^(d)		
3705 Bldg. 300 Area	14	84 ± 10	Below 100N Outfall	1	100 ± 7
313 Bldg.	15	107 ± 6	Above Tip 100N Berm	2	83 ± 15
300 Water Intake	16	82 ± 6	100 N Trench Spring	3	93 ± 16
300 Southwest Gate	17	80 ± 12	S End Vernita Bridge ^(e)	4	74 ± 11
300 South Gate	18	83 ± 8	Above 100 B Area	5	82 ± 18
300 Trench	19	85 ± 4	Below 100B Ret Basin	6	95 ± 20
300 NE	20	86 ± 7	Above 1K Boat Ramp	7	87 ± 8
400 E	21	83 ± 9	Below 100 D Area	8	68 ± 20
400 W	22	88 ± 5	100-D Island	9	80 ± 17
400 S	23	83 ± 5	100 H Area	10	83 ± 12
400 N	24	82 ± 4	Lo End Locke Isl	11	90 ± 4
US Ecology NE Corner	25	86 ± 3	White Bluffs Fy Lnd.	12	87 ± 15
US Ecology SE Corner	26	91 ± 6	White Bluffs Slough ^(f)	13	93 ± 37
US Ecology NW Corner	27	89 ± 5	Below 100 F	14	82 ± 7
US Ecology SW Corner	28	99 ± 7	100 F Flood Plain	15	97 ± 19
Wye Barricade	29	86 ± 9	Hanford Slough	16	95 ± 25
WPPSS 1; S of WNP 2	30	83 ± 13	Hanf Powerline Xing	17	94 ± 2
Hanford Townsite	31	78 ± 8	Hanford RR Track	18	90 ± 11
West Lake	32	89 ± 7	Savage Isl Slough	19	79 ± 9
LIGO	33	76 ± 6	Ringold Island	20	88 ± 9
			Powerline Crossing	21	86 ± 12
Perimeter^(c)			S End Wooded Island	22	97 ± 18
Ringold Met Tower	1	91 ± 8	Islnd Above 300 Area	23	94 ± 8
W End of Fir Road	2	94 ± 5	Island Near 300 Area	24	86 ± 14
Dogwood Met Tower	3	94 ± 9	Port of Benton-River	25	84 ± 15
Byers Landing	4	98 ± 5	N. Richland ^(e)	26	76 ± 4
Battelle Complex	5	83 ± 8	Isl DS Bateman Isl ^(f)	27	98 ± 13
WPPSS 4; WPS Warehse	6	83 ± 11			
Horn Rapids Substa	7	86 ± 3			
Prosser Barricade	8	94 ± 3			
Yakima Barricade	9	98 ± 7			
Rattlesnake Springs	10	104 ± 32			
Wahlake Slope	11	94 ± 6			

(a) ±2 standard deviations of the dose rate.

(b) All locations are shown on Figure 4.6.1.

(c) All locations are shown on Figure 4.6.2.

(d) All locations are shown on Figure 4.6.3.

(e) Moved to Shoreline grouping due to vandalism.

(f) Only two quarters of data.

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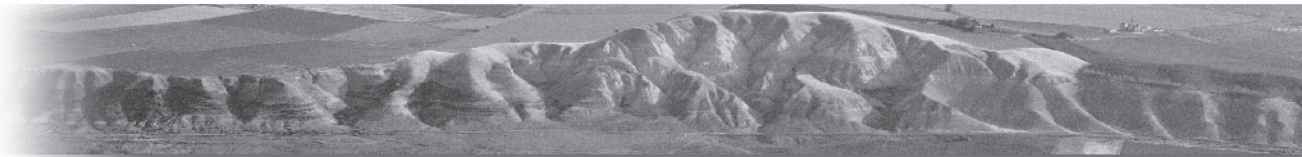
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WAC 173-201A. "Water Quality Standards for Surface Waters of the State of Washington." Washington Administrative Code, Olympia, Washington.

WAC 173-201A-50. "Radioactive Substances." Washington Administrative Code, Olympia, Washington.

WAC 246-290. "Group A Public Water Systems." Washington Administrative Code, Olympia, Washington.



APPENDIX C

GLOSSARY

Words appearing in *italic* are defined in this glossary.

absorbed dose - Energy absorbed per unit mass from any kind of ionizing *radiation* in any kind of matter. Unit: *rad*.

activation product - Material made radioactive by *exposure* to *radiation* from a source such as a nuclear reactor's neutrons.

adsorption - The accumulation of gases, liquids, or solutes on the surface of a solid or liquid.

alpha particle - A positively charged particle ejected spontaneously from the nuclei of some radioactive elements. It has low penetrating power and short range. The most energetic alpha will generally fail to penetrate the skin. Alphas are hazardous when an alpha-emitting *isotope* is introduced into the body.

anion - A negatively charged ion.

aquifer - Permeable geologic unit that can hold and/or 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 approximately 300 *millirems* of background *radiation* per year.

bank storage - Hydrologic term that describes river water that flows into and is retained in permeable stream banks during periods of high river stage. Flow is reversed during periods of low river stage.

becquerel (Bq) - Unit of *radioactivity* equal to one nuclear transformation per second ($1 \text{ Bq} = 1 \text{ disintegration/s}$). Another unit of *radioactivity*, the *curie*, is related to the becquerel: $1 \text{ Ci} = 3.7 \times 10^{10} \text{ Bq}$.

beta particle - A charged particle emitted from a nucleus during radioactive *decay*. Large amounts of beta particles may cause skin burns and are harmful if they enter the body. Beta particles are easily stopped by a thin sheet of metal or plastic.

boundary dose rate - *Dose rate* measured or calculated at publicly accessible locations on or near the Hanford Site boundary.

cation - A positively charged ion.

clean closed - A facility is classified as "clean closed" under RCRA regulations when all dangerous waste has been removed and *groundwater* monitoring is no longer required.

collective total effective dose equivalent - Sum of the *total effective dose equivalents* for individuals composing a defined population. The units for this are "person-rem" or "person-sieverts."

committed dose equivalent - The *dose equivalent* to organs or tissues that will be received from an intake of radioactive material by an individual during the 50-year period following intake.

committed effective dose equivalent - The sum of the *committed dose equivalent* from sources inside the body.

composite sample - Sample formed by mixing discrete samples taken at different times or from different locations.

confined aquifer - An *aquifer* bounded above and below by less-permeable layers. *Groundwater* 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*.

crib - An underground structure designed to receive liquid waste that percolates into the soil directly or percolates into the soil after having traveled through a connected tile field.

curie (Ci) - A unit of *radioactivity* equal to 37 billion (3.7×10^{10}) nuclear transformations per second. The curie is related to the *becquerel*: $1 \text{ Bq} = 0.00000000027 \text{ Ci}$.

decay - The decrease in the amount of any radioactive material with the passage of time. See *radioactivity*.

decay product - The atomic nucleus or nuclei that are left after radioactive transformation of a radioactive material. Decay products may be radioactive or non-radioactive (stable). Formerly called “daughter product.” See *radioactivity*.

deep-dose equivalent - The *dose equivalent* at a tissue depth of 1 centimeter from *radiations* originating outside of the body.

derived concentration guide (DCG) - Concentrations of *radionuclides* in air and water that an individual could continuously consume, inhale, or be immersed in at average annual rates, and not receive an *effective dose equivalent* of greater than 100 *millirems* per year.

detection level - Minimum amount of a substance that can be measured with a specified or implied confidence that the analytical result is greater than zero.

dispersion - Process whereby *effluent* is spread or mixed as they are transported by *groundwater* or air.

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*.

dose rate - A quantity indicating how fast or slow *radiation* dose is accumulated over time. “Dose rate” is generally used to denote *absorbed dose* rate, *dose equivalent* rate, etc. Units: *rads* or *millirads* per hour (rad/h or mrad/h) for *absorbed dose* rate; *rems* or *millirems* per hour (rem/h or mrem/h) for *dose equivalent* rate.

dosimeter - Portable device for measuring the total accumulated *exposure* or *absorbed dose* from ionizing *radiation* fields.

effective dose - See “*effective dose equivalent*.”

effective dose equivalent - The sum of products of *dose equivalent* to each tissue or organ and the tissue weighting factor for each tissue or organ. The tissue weighting factors put doses to various tissues and organs on an equal basis in terms of health *risk*.

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 - The interaction of an organism with a physical agent (e.g., *radiation*) or a chemical agent (e.g., arsenic) of interest. Also used as a term for quantifying *x* and *gamma radiation* fields. See *roentgen*.

external radiation - *Radiation* originating from a source outside the body.

facies - The aspect, appearance, and characteristics of a rock unit, usually reflecting the conditions of its origin (Bates and Jackson 1980).

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 - The splitting or breaking apart of a nucleus into at least two other nuclei, accompanied with a release of a relatively large amount 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*; see below).

fission products - Elements formed from fissioning. Many fission products are radioactive.

gamma radiation - High-energy electromagnetic *radiation* originating in radioactive *decay* or nuclear reactions. If needed, shielding can be lead, steel, concrete, earth, or water. The needed thickness of the shield is determined by the intensity and duration of *exposure*.

grab sample - A short duration sample (e.g., air, water, soil) that is “grabbed” from the collection site.

grand mean - A “means of means” or an “overall *mean*” where there is some subdivision of the data where means were already provided for each subdivision.

groundwater - 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.

high-level waste - Highly radioactive waste material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains *fission products* and other *radioisotopes* in sufficient concentrations to require permanent isolation.

internal radiation - *Radiation* from radioactive material inside the body.

ion exchange - The reversible exchange of one species of ion for a different species of ion within a medium.

irradiation - *Exposure* to *radiation*.

isotopes - *Nuclides* of the same chemical element with differing number of neutrons. *Isotopes* of the same element (e.g., ²³⁸Pu, ²³⁹Pu, ²⁴⁰Pu, ²⁴¹Pu) have almost identical chemical properties.

isotopic plutonium - Any of two or more atoms of the chemical element *plutonium* with the same atomic number and position in the periodic table and nearly identical chemical behavior but with differing atomic mass number and different physical properties. Plutonium-239 is produced by neutron *irradiation* of uranium-238.

isotopic uranium - Any of two or more atoms of the chemical element uranium with the same atomic number and position in the periodic table and nearly identical chemical behavior but with differing atomic mass number and different physical properties. Uranium exists naturally as a mixture of three *isotopes* of mass 234, 235, and 238 in the proportions of 0.006%, 0.71%, and 99.27%, respectively.

K_d value - Some dissolved elements move freely through sediment while others tend to bind to sediment grains. This tendency to bind to sediment is expressed as a K_d value. The higher the K_d value, the more the element binds to soil.

legacy waste - Waste that was generated prior to cleanup associated with deactivation and decommissioning.

low-level waste - Radioactive waste that is not high-level radioactive waste, spent nuclear fuel, *transuranic waste*, byproduct material, or naturally occurring radioactive material.

lysimeter - An instrument to measure the water percolating through soil and determine the materials dissolved by the water.

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 *radionuclides/radiation* originating 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 n is the number of measurements and X_i is the i th measurement.

median - Middle value in a set of results when the data are ranked in increasing or decreasing order.

millirem - A unit of *radiation dose equivalent* that is equal to one one-thousandth (1/1000) of a *rem*. According to U.S. Department of Energy standards, an individual member of the public may receive no more than 100 millirem per year from a site's operation. This limit does not include *radiation* received for medical treatment or the ~300 millirem that people receive annually from natural *background radiation*.

minimum detectable amount or concentration - Smallest amount or concentration of a chemical or radioactive material that can be reliably detected in a sample.

mitigation - Prevention or reduction of expected *risks* to workers, the public, or the environment.

mixed waste - A dangerous, extremely hazardous, or acutely hazardous waste that contains both a non-radioactive hazardous component and a radioactive component.

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 for radioactive noble gases are direct external dose from the surrounding air.

nuclide - A particular combination of neutrons and protons. A *radionuclide* is radioactive.

offsite locations - Sampling and measurement locations outside the Hanford Site boundary.

onsite locations - Sampling and measurement locations within the Hanford Site boundary.

operable unit - A discrete area for which an incremental step can be taken toward comprehensively addressing site problems. The cleanup of a site can be divided into a number of operable units, depending on the complexity of the problems associated with the site.

outfall - End of a drain or pipe that carries wastewater or other *effluent* into a ditch, pond, or river.

person-rem or person-sievert (person-Sv) - Unit of *collective total effective dose equivalent*. 1 person-Sv = 100 person-rem.

photon - A particle of high-energy electromagnetic *radiation*, characterized by energy, frequency, and wave length. *Gamma radiation* and *x radiation* (x-rays) are both comprised of photons.

plume - The cloud of a pollutant in air, surface water, or *groundwater* formed after the pollutant is released from a source.

plutonium - A heavy, radioactive, manmade metallic element consisting of several *isotopes*. One important *isotope* is ^{239}Pu , which is produced by the *irradiation* of

^{238}U . Routine analysis cannot distinguish between the ^{239}Pu and ^{240}Pu *isotopes*; hence, the term $^{239/240}\text{Pu}$ as used in this report is symbolic of the presence of one or both of these *isotopes* in the analytical results.

quality assurance - Actions that provide confidence that an item or process meets or exceeds that user's requirements and expectations.

quality control - Comprises all those actions necessary to control and verify the features and characteristics of a material, process, product, or service to specified requirements. Quality control is an element of *quality assurance*.

rad - The unit of *absorbed dose*. 1 rad = 0.01 gray (Gy).

radiation - The energy emitted in the form of *photons* or particles such as those thrown off by transforming (*decaying*) atoms. For this report, radiation refers to ionizing types of radiation; not radiowaves, microwaves, radiant light, or other types of non-ionizing radiation.

radiation limit - The permissible upper bounds of *radiation* doses.

radioactivity - Property possessed by some *radioisotopes* of emitting *radiation* (such as alpha, beta, or gamma *photons*) spontaneously in their *decay* process.

radioisotope - An unstable *isotope* of an element that *decays* or disintegrates spontaneously, emitting *radiation* (Shleien 1992).

radionuclide - A species of atoms having a particular number of protons (Z), a particular number of neutrons (A), and a particular atomic weight ($N = Z + A$) that happens to emit *radiation*. Carbon-14 is a radionuclide. Carbon-12 is not and is called just a "*nuclide*."

recruitment - Survival from one life form or stage to the next or from one age class to the next.

rem - A unit of *dose equivalent* and *effective dose equivalent*.

remediation - Reduction of known *risks* to the public and environment to an agreed upon level.

risk - The probability that a detrimental health effect will occur.

roentgen (R) - Unit of x-ray or gamma *photon exposure* measured in air, historically used to describe *external radiation* levels. An *exposure* of 1 roentgen typically causes an *effective dose* of 1 rem.

sievert (Sv) - Unit of *dose equivalent* and *effective dose equivalent* in the International System of Units (SI) equal to 100 rems.

special case waste - Waste for which there is an undetermined disposal path because of high levels of *radioactivity* and difficulties in characterization, classification, and packaging.

specific retention facilities - Historical structures consisting of cribs, ditches, trenches, or holes in the ground that received relatively small volumes of high concentration liquid radioactive waste. The small volume of liquid waste was designed to prevent flushing of the contaminants through the soil column to the *groundwater*.

spectrometer - A spectroscopy with a calibrated scale for measuring the positions of spectral lines.

spectroscopy - The branch of physics concerned with the production, measurement, and interpretation of electromagnetic spectra arising from either emission or absorption of radiant energy by various substances.

spent fuel - Uranium metal or oxide and its metal container that have been used to power a nuclear reactor. It is highly radioactive and typically contains *fission products*, *plutonium*, and residual uranium.

standard error of the mean - A measure of the precision of a *mean* of observed values; that is, an estimate of how close a *mean* of observed values is expected to be to the true *mean*. The standard error (SE) of the mean is computed as

$$SE = \sqrt{\frac{S^2}{n}}$$

where S^2 is the variance of the measurements, n , computed as

$$S^2 = \frac{1}{n-1} \sum_{i=1}^n (X_i - \bar{X})^2$$

\bar{X} is the *mean* of n measurements.

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.

thiourea - An organic chemical soluble in cold water used in photography, photocopying, and thyroid medication.

transient calibration - The trial-and-error adjustment of aquifer parameters under conditions of changing flow velocity.

transuranic - An element with an atomic number greater than 92 (92 is the atomic number of uranium).

transuranic waste - Waste containing more than 100 nanocuries (10^{-9} curies) of alpha-emitting *transuranic isotopes* (isotopes with atomic numbers greater than uranium) per gram of waste with *half-lives* greater than 20 years.

thermoluminescent dosimeter - A device containing 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 *absorbed dose* to the thermoluminescent dosimeter.

total effective dose equivalent - The sum of *committed effective dose equivalent* from intakes of radioactive material and *deep-dose equivalent* from *external radiation*. Unit: rem or sievert.

unconfined aquifer - An *aquifer* containing *groundwater* 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.

vadose zone - Underground area from the surface to the top of the *water table* or *aquifer*.

volatile organic compounds - Lightweight organic compounds that vaporize easily. Used in solvents and degreasing compounds as raw materials, volatile compounds are generally considered to be below the molecular weight of C_{10} hydrocarbons.

water table - Theoretical surface represented by the elevation of water surfaces in wells penetrating only a short distance into the *unconfined aquifer*.

wind rose - Star-shaped diagram that shows how often winds of various speeds blow from different directions, usually based on yearly averages.

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APPENDIX D

STANDARDS AND PERMITS

R. W. Hanf

Operations at the Hanford Site must conform to a variety of government standards and permits designed to assure the biological and physical quality of the environment for public health, ecological, or aesthetic considerations. The primary environmental quality standards and permits applicable to Hanford Site operations in 2002 are listed in the following tables. The state of Washington has water quality standards for the Columbia River, defined in Washington Administrative Code (WAC 173-201A). 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 D.1. Table D.2 summarizes drinking water standards from the U.S. Environmental Protection Agency (EPA) in the Code of Federal Regulations (40 CFR 141) and WAC 246-290. Select surface freshwater quality criteria for toxic pollutants are included in Table D.3.

Environmental radiation protection standards are published in U.S. Department of Energy (DOE) Order 5400.5. The order establishes limits for public radiation dose and gives guidance to keep radiation exposure to members of the public as low as reasonably achievable. 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. DOE initiated a policy to create and implement public radiation protection standards that are generally consistent with the standards used by the U.S. Nuclear Regulatory Commission to regulate and license non-DOE nuclear facilities, such as nuclear

power plants. Table D.4 shows the radiation standards from DOE Order 5400.5, 40 CFR 61, and 40 CFR 141. These standards govern allowable public exposure to ionizing radiation from DOE operations.

DOE Order 5400.5 established derived concentration guides that reflect the concentrations of radionuclides in water and air that an individual could continuously consume, inhale, or be immersed in at average annual levels without exceeding an effective dose equivalent of 100 mrem (1 mSv) per year. Derived concentration guides are not exposure limits but are simply reference values that are provided to allow for comparisons of radionuclide concentrations in environmental media. Table D.5 lists selected DOE derived concentration guides for radionuclides of particular interest at the Hanford Site. The guides are useful reference values but do not generally represent concentrations in the environment that assure compliance with either DOE, *Clean Air Act*, or drinking water dose standards.

Permits required for regulated releases to water and air have been issued by EPA under the National Pollutant Discharge Elimination System of the *Clean Water Act* and the "Prevention of Significant Deterioration" requirements of the *Clean Air Act*. Also, under authority granted by the *Clean Air Act*, the Washington State Department of Health issued a permit for Hanford Site radioactive air emissions. Permits to collect wildlife for environmental sampling are issued by the Washington Department of Fish and Wildlife and the U.S. Fish and Wildlife Service. Current permits are discussed in Table D.6.

Table D.1. Washington State Water Quality Standards for the Hanford Reach of the Columbia River^(a)

Parameter	Permissible Levels
Fecal coliform	<ol style="list-style-type: none"> 1) Geometric mean value less than or equal to 100 colonies/100 milliliters (0.026 gallons) 2) Less than or equal to 10% of samples may exceed 200 colonies/100 milliliters (0.026 gallons)
Dissolved oxygen	Greater than 8 mg/L (8 ppm)
Temperature	<ol style="list-style-type: none"> 1) Less than or equal to 18°C (64°F) as a result of human activities 2) When natural conditions exceed 18°C (64°F), no temperature increases will be allowed that will raise the temperature of the receiving water by more than 0.3°C (0.54°F) 3) Incremental temperature increases resulting from point sources shall not at any time exceed $t = 28/(T + 7)$, where t = maximum permissible temperature increase measured at a mixing zone boundary and T = background temperature. Incremental temperature increases resulting from non-point sources shall not exceed 2.8°C (5.04°F)
pH	<ol style="list-style-type: none"> 1) 6.5 to 8.5 range 2) Less than 0.5 unit induced variation
Turbidity	Turbidity shall be less than or equal to 5 nephelometric turbidity units over background turbidity when the background turbidity is 50 nephelometric units or less, and shall not increase more than 10% when the background turbidity is >50 nephelometric units
Toxic, radioactive, or deleterious materials	Concentrations shall be below those which have the potential either singularly or cumulatively to adversely affect characteristic water uses, cause acute or chronic conditions to the most sensitive biota dependent upon those waters, or adversely affect public health
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
Radioactive substances	Deleterious concentrations of radioactive materials for all classes shall be as determined by the lowest practicable level attainable and in no case shall exceed 1/12.5 of the values listed in WAC 246-221-290 or exceed EPA drinking water regulations for radionuclides, as published in the Federal Register of July 9, 1976 or subsequent revisions thereto (see Table D.2)
Toxic substances	Shall not be introduced above natural background levels in waters of the state that have the potential either singularly or cumulatively to adversely affect characteristic water uses, cause acute or chronic toxicity to the most sensitive biota dependent on those waters, or adversely affect public health, as determined by the department (see Table D.3)

(a) WAC 173-201A.

Table D.2. Selected Drinking Water Standards

<u>Radiological Constituent</u>	<u>Primary Maximum Contaminant Level</u>	<u>Interim Drinking Water Standard</u>	<u>Agency^(a)</u>	<u>Status</u>
Gross alpha ^(b)	15 pCi/L (0.56 Bq/L)		DOH, ^(c) EPA ^(d)	Final
Radium-226	20 pCi/L (0.74 Bq/L) ^(d)	3 pCi/L (0.111 Bq/L) ^(c)	DOH, EPA	Final
Beta particle and photon activity	4 mrem/yr (40 µSv/yr) ^(e)		DOH, ^(c) EPA ^(d)	Final
Tritium		20,000 ^(f) pCi/L (740 Bq/L)	DOH, ^(c) EPA ^(d)	Interim
Beryllium-7		6,000 ^(f) pCi/L (222 Bq/L)	EPA ^(g)	Interim
Cobalt-60		100 ^(f) pCi/L (3.7 Bq/L)	EPA ^(g)	Interim
Strontium-90		8 ^(f) pCi/L (0.296 Bq/L)	DOH, ^(c) EPA ^(d)	Interim
Technetium-99		900 ^(f) pCi/L (33.3 Bq/L)	EPA ^(g)	Interim
Ruthenium-106		30 ^(f) pCi/L (1.11 Bq/L)	EPA ^(g)	Interim
Antimony-125		300 ^(f) pCi/L (11.1 Bq/L)	EPA ^(g)	Interim
Iodine-129		1 ^(f) pCi/L (0.037 Bq/L)	EPA ^(g)	Interim
Iodine-131		3 ^(f) pCi/L (0.111 Bq/L)	EPA ^(g)	Interim
Cesium-134		20,000 ^(f) pCi/L (740 Bq/L)	EPA ^(g)	Interim
Cesium-137		200 ^(f) pCi/L (7.4 Bq/L)	EPA ^(g)	Interim
Europium-154		200 ^(f) pCi/L (7.4 Bq/L)	EPA ^(g)	Interim
Europium-155		600 ^(f) pCi/L (22.2 Bq/L)	EPA ^(g)	Interim
Uranium	30 µg/L (0.03 ppm) ^(h)		EPA ^(d)	Final ⁽ⁱ⁾
Fluoride	4 mg/L (4 ppm)		DOH, ^(c) EPA ^(d,j)	Final/under review
Nitrate, as NO ₃ ⁻	45 mg/L (45 ppm)		DOH, ^(c) EPA ^(d,j)	Final
Chromium	100 µg/L (0.1 ppm)		DOH, ^(c) EPA ^(d,j)	Final
Cyanide	200 µg/L (0.2 ppm)		EPA ^(c,d,j)	Final
Trichloroethene	5 µg/L (0.005 ppm)		DOH, ^(c) EPA ^(d,j)	Final
Tetrachloroethene	5 µg/L (0.005 ppm)		DOH, ^(c) EPA ^(d,j)	Final
Carbon tetrachloride	5 µg/L (0.005 ppm)		DOH, ^(c) EPA ^(d,j)	Final
Chloroform (THM) ^(k)	100 µg/L (0.1 ppm)		DOH, ^(c) EPA ⁽ⁱ⁾	Final
cis-1,2-Dichloroethene	0.07 mg/L (0.07 ppm)		EPA ⁽ⁱ⁾	Final

(a) DOH = Washington State Department of Health, EPA = U.S. Environmental Protection Agency.

(b) Excluding radium-226, radon, and uranium.

(c) WAC 246-290.

(d) 40 CFR 141.

(e) Beta and photon radioactivity from manmade radionuclides. Annual average activity shall not exceed an effective dose equivalent of 4 mrem per year.

(f) Activity assumed to yield an annual dose of 4 mrem per year.

(g) EPA-570/9-76-003.

(h) Equivalent to 27 pCi/L (assuming typical uranium natural abundance in rock).

(i) Final rule promulgated December 7, 2000 (65 FR 76708).

(j) EPA 822-R-96-001.

(k) Standard is for total trihalomethanes (THM).

Table D.3. Selected Surface Freshwater Quality Criteria for Toxic Pollutants

Compound	Level that Yields Acute Toxicity, µg/L (ppm)^(a)	Level that Yields Chronic Toxicity, µg/L (ppm)^(a)	Level to Protect Human Health for the Consumption of Water and Organisms, µg/L (ppm)^(b)
Dissolved Metals			
Antimony	--	--	14 (0.014)
Arsenic	360.0 (0.360)	190.0 (0.19)	0.018 (0.000018)
Cadmium	1.6 (0.0016) ^(c)	0.59 (0.00059) ^(d)	--
Chromium(VI)	16 (0.016)	10 (0.01)	--
Copper	8.4 (0.0084) ^(e)	6.0 (0.006) ^(f)	--
Lead	28 (0.028) ^(g)	1.1 (0.0011) ^(h)	--
Nickel	750 (0.75) ⁽ⁱ⁾	83 (0.083) ⁽ⁱ⁾	610 (0.61)
Silver	0.94 (0.00094) ^(k)	--	--
Thallium	--	--	1.7 (0.0017)
Zinc	60 (0.060) ^(l)	55 (0.055) ^(m)	--
Total Recoverable Metals			
Chromium(III) ⁽ⁿ⁾	300 (0.30) ^(o)	96 (0.096) ^(p)	--
Mercury	2.1 (0.0021)	0.012 (0.000012)	0.14 (0.00014)
Selenium	20 (0.02)	5.0 (0.005)	--
Anions			
Cyanide ^(q)	22.0 (0.022)	5.2 (0.0052)	700 (0.70)
Chloride ^(r)	860,000 (860)	230,000 (230)	--
Organic Compounds			
Benzene	--	--	1.2 (0.0012)
Carbon tetrachloride	--	--	0.25 (0.00025)
Chloroform	--	--	5.7 (0.0057)
1,2-Dichloroethane	--	--	0.38 (0.00038)
Methylene chloride	--	--	4.7 (0.0047)
Toluene	--	--	6,800 (6.80)
Tetrachloroethene	--	--	0.8 (0.0008)
1,1,2-Trichloroethane	--	--	0.60 (0.0006)
Trichloroethene	--	--	2.7 (0.0027)
Vinyl chloride	--	--	2 (0.002)
1,4-Dichlorobenzene	--	--	400 (0.40)

(a) WAC 173-201A-040. For hardness dependent criteria, the minimum value of 47 mg CaCO₃/L for 1992-2000 water samples collected near Vernita Bridge by the U.S. Geological Survey is used.

(b) 40 CFR 131.36.

(c) $(1.1017 - [\ln(\text{hardness})] 0.04184) \exp(1.128[\ln(\text{hardness})]-3.828)$. Hardness expressed as mg CaCO₃/L.

(d) $(1.1017 - [\ln(\text{hardness})] 0.04184) \exp(0.7852[\ln(\text{hardness})]-3.490)$.

(e) $(0.960) \exp(0.9422[\ln(\text{hardness})]-1.464)$.

(f) $(0.960) \exp(0.8545[\ln(\text{hardness})]-1.465)$.

(g) $(1.4620 - [\ln(\text{hardness})] 0.1457) \exp(1.273[\ln(\text{hardness})]-1.460)$.

(h) $(1.4620 - [\ln(\text{hardness})] 0.1457) \exp(1.273[\ln(\text{hardness})]-4.705)$.

(i) $(0.998) \exp(0.8460[\ln(\text{hardness})]+3.3612)$.

(j) $(0.997) \exp(0.8460[\ln(\text{hardness})]+1.1645)$.

(k) $(0.85) \exp(1.72[\ln(\text{hardness})]-6.52)$.

(l) $(0.978) \exp(0.8473[\ln(\text{hardness})]+0.8604)$.

(m) $(0.986) \exp(0.8473[\ln(\text{hardness})]+0.7614)$.

(n) Where methods to measure trivalent chromium are unavailable, these criteria are to be represented by total recoverable chromium.

(o) $(0.316) \exp(0.8190[\ln(\text{hardness})]+3.688)$.

(p) $(0.860) \exp(0.8190[\ln(\text{hardness})]+1.561)$.

(q) Criteria based on weak and dissociable method.

(r) Dissolved in association with sodium.

Table D.4. Radiation Standards (dose limits^(a)) for Protection of the Public from all Routine DOE Concentrations

All Pathways (limits from DOE Order 5400.5)

The effective dose equivalent for any member of the public from all routine DOE operations^(b) shall not exceed the values given below.

	<u>Effective Dose Equivalent^(c)</u>	
	<u>mrem/yr</u>	<u>mSv/yr</u>
Routine public dose	100	1
Potential authorized temporary public dose ^(d)	500	5

Dose to Native Aquatic Animal Organisms from Liquid Discharges (interim limits from DOE Order 5400.5)

Radioactive material in liquid waste discharged to natural waterways shall not cause an absorbed dose^(e) to native aquatic animal organisms that exceeds 1 rad (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) per year. DOE operations 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 (see Table D.2).

Air Pathways Only (limits from 40 CFR 61)

	<u>Effective Dose Equivalent^(c)</u>	
	<u>mrem/yr</u>	<u>mSv/yr</u>
Public dose limit at location of maximum annual air concentration as a consequence of routine DOE operations ^(b)	10	0.1

- (a) Radiation doses received from natural background, residual weapons testing and nuclear accident fallout, medical exposure, and consumer products are excluded from the implementation of these dose limits.
- (b) "Routine DOE operations" 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) and sievert (or millisievert).
- (d) Authorized temporary annual dose limits may be greater than 100 mrem (1 mSv) per year (but cannot exceed 500 mrem [5 mSv]) per year if unusual circumstances exist that make avoidance of doses greater than 100 mrem (1 mSv) per year to the public impracticable. DOE Richland Operations Office is required to request and receive specific authorization from DOE Headquarters 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 D.5. Selected DOE Derived Concentration Guides^(a,b,c)

Radionuclide	Ingested Water,		Inhaled Air,	
	pCi/L (Bq/L)		pCi/m ³ (Bq/m ³)	
Tritium	2,000,000	(74,000)	100,000	(3,700)
Carbon-14	70,000	(2,590)	500,000	(18,500)
Chromium-51	1,000,000	(37,000)	60,000	(2,220)
Manganese-54	50,000	(1,850)	2,000	(74)
Cobalt-60	5,000	(185)	80	(2.96)
Zinc-65	9,000	(333)	600	(22.2)
Krypton-85		NS ^(d)	3,000,000	(111,000) ^(e)
Strontium-90	1,000	(37)	9	(0.333)
Technetium-99	100,000	(3,700)	2,000	(74)
Ruthenium-103	50,000	(1,850)	2,000	(74)
Ruthenium-106	6,000	(222)	30	(1.11)
Antimony-125	60,000	(2,220)	1,000	(37)
Iodine-129	500	(18.5)	70	(2.59)
Iodine-131	3,000	(111)	400	(14.8)
Cesium-137	3,000	(111)	400	(14.8)
Cerium-144	7,000	(259)	30	(1.11)
Europium-154	20,000	(740)	50	(1.85)
Europium-155	100,000	(3,700)	300	(11.1)
Uranium-234	500	(18.5)	0.09	(0.00333)
Uranium-235	600	(22.2)	0.1	(0.0037)
Uranium-238	600	(22.2)	0.1	(0.0037)
Plutonium-238	40	(1.48)	0.03	(0.00111)
Plutonium-239	30	(1.11)	0.02	(0.00074)
Plutonium-240	30	(1.11)	0.02	(0.00074)
Americium-241	30	(1.11)	0.02	(0.00074)

- (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 (1 mSv) per year.
- (b) Values in this table represent the lowest, most-conservative, derived concentration guides considered potentially applicable to Hanford Site operations and may be adjusted upward (larger) if accurate solubility information is available.
- (c) From DOE Order 5400.5.
- (d) NS = No numerical standard, but the effective dose equivalent cannot exceed 100 mrem (1 mSv) per year.
- (e) Air immersion derived concentration guides.

Table D.6. Environmental Permits**Clean Air Act Permits**

Prevention of Significant Deterioration Permit No. PSD-X80-14, issued to DOE Richland Operations Office by EPA Region 10; covers emission of NO_x to the atmosphere from the Plutonium-Uranium Extraction Plant and the Uranium-TriOxide Plant. No expiration date.

Hanford Site Air Operating Permit 00-05-006 covers operations on the Hanford Site having a potential to emit airborne emissions. Effective July 2, 2001, expires July 1, 2006. The permit is intended to provide a compilation of applicable *Clean Air Act* requirements both for radioactive and non-radioactive emissions at the Hanford Site. It will be implemented through federal and state programs.

State License FF-01 was incorporated into the Hanford Site air operating permit.

Clean Water Act – National Pollutant Discharge Elimination System Permits

Permit WA-002591-7 (governing effluent discharges to the Columbia River) includes the outfall for the 300 Area Treated Effluent Disposal Facility and two outfalls in the 100-K Area.

Permit WAR05A57F, issued May 30, 2001, governs stormwater discharges.

Permit CR-IU005 allows wastewater from the Environmental and Molecular Sciences Laboratory to be discharged to the city of Richland's wastewater treatment facility.

Washington State Department of Ecology – State Wastewater Permits

Permit ST 4500 allows treated wastewater from the Effluent Treatment Facility to be discharged to the State-Approved Land Disposal Site. Expires August 1, 2005.

Permit ST 4501 allows for the discharge of cooling water and other primarily uncontaminated wastewater from 400 Area facilities to two ponds located north-northeast of the 400 Area perimeter fence. Expired July 31, 2001. A renewal application has been submitted. Re-issuance of a new permit is expected in 2003.

Permit ST 4502 allows treated effluent from the 200-East and 200-West Areas to be discharged to the 200 Area Treated Effluent Disposal Facility. Expires May 2005.

Permit ST 4507 allows domestic wastewater to be discharged to the 100-N Area sewage lagoon. Permit expired in May 2002. A renewal application has been submitted.

Permit ST 4508 allows for the discharge of wastewater associated with hydrotesting, maintenance, and construction activities under specific conditions. Expired May 30, 2002. A renewal application has been submitted.

Permit ST 4509 allows for cooling water, condensate discharges, and miscellaneous discharges from pump leaks, valve wastewater, and tank overflows under controlled conditions. Expires May 1, 2003. An application has been submitted to combine Permits 4508, 4509, and 4510 into a single permit.

Permit ST 4510 covers wastewater discharges associated with industrial stormwater under controlled conditions. Expires April 1, 2004.

Wildlife Sampling Permits

Scientific Collection Permit 02-129, issued by Washington Department of Fish and Wildlife to Pacific Northwest National Laboratory for 2002; covered the collection of food fish, shellfish, and wildlife, including game fish, for environmental monitoring purposes. Renewed annually.

Federal Fish and Wildlife Permit No. MB671877-0, issued by the U.S. Fish and Wildlife Service to Pacific Northwest National Laboratory; covers the collection of migratory wildlife. Expired December 31, 2002. A renewal application has been submitted.

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

State of Washington	U.S. Environmental Protection Agency	U.S. Department of Energy
Department of Ecology	Region 10	Richland Operations Office
P.O. Box 47600	1200 Sixth Avenue	825 Jadwin Avenue
Olympia, WA 92504-7600	Seattle, WA 98101	Richland, WA 99352

REFERENCES

40 CFR 61. U.S. Environmental Protection Agency. "National Emission Standards for Hazardous Air Pollutants." *Code of Federal Regulations*.

40 CFR 131.36. U.S. Environmental Protection Agency. "Toxics Criteria for Those States not Complying with the Clean Water Act Section 303(c)(2)(B)." *Code of Federal Regulations*.

40 CFR 141. U.S. Environmental Protection Agency. "National Primary Drinking Water Regulations." *Code of Federal Regulations*.

65 FR 76708. December 7, 2000. U.S. Environmental Protection Agency. "National Primary Drinking Water Regulations; Radionuclides; Final Rule." *Federal Register*.

Clean Air Act. 1986. Public Law 88-206, as amended, 42 USC 7401 et seq.

Clean Water Act. 1977. Public Law 95-217, as amended, 91 Stat. 1566 and Public Law 96-148, as amended.

DOE Order 5400.5. "Radiation Protection of the Public and the Environment."

EPA-570/9-76-003. 1976. *National Interim Primary Drinking Water Regulations*. Office of Water Supply, U.S. Environmental Protection Agency, Washington, D.C.

EPA 822-R-96-001. 1996. *Drinking Water Regulations and Health Advisories*. Office of Water, U.S. Environmental Protection Agency, Washington, D.C.

WAC 173-201A. "Water Quality Standards for Surface Waters of the State of Washington." Washington Administrative Code, Olympia, Washington.

WAC 173-201A-040. "Toxic Substances." Washington Administrative Code, Olympia, Washington.

WAC 246-221-290. "Appendix A - Annual Limits on Intake (ALI) and Derived Air Concentrations (DAC) of Radionuclides for Occupational Exposure; Effluent Concentrations; Concentrations for Release to Sanitary Sewerage." Washington Administrative Code, Olympia, Washington.

WAC 246-290. "Group A Public Water Systems." Washington Administrative Code, Olympia, Washington.



APPENDIX E

DOSE CALCULATIONS

E. J. Antonio

The radiological dose that the public could have received in 2002 from Hanford Site operations was calculated in terms of the “total effective dose equivalent.” The total effective dose equivalent is the sum of the effective dose equivalent from external sources and the committed effective dose equivalent for internal exposure. Effective dose equivalent is a weighted sum of doses to organs and tissues that accounts for the sensitivity of the tissue and the nature of the radiation causing the dose. It is calculated in units of millirem (millisievert)^(a) for individuals and in units of person-rem for the collective dose received by the total population within an 80-kilometer (50-mile) radius of the site operations areas. This appendix describes how the doses in this report were calculated.

Releases of radionuclides from Hanford Site operations are usually too low to be measured in offsite air, drinking water, and food crops. Therefore, the air dose calculations were based on measurements made at the point of release (stacks and vents). The water pathway dose calculations were based on measurements of releases to the Columbia River (from the 100 Areas) or the difference in detectable radionuclide concentrations measured upstream and downstream of the site. Environmental radionuclide concentrations were estimated from the effluent measurements by environmental transport models.

The transport of radionuclides in the environment to the point of exposure is predicted by empirically derived models of exposure pathways. These models calculate radionuclide levels in air, water, and foods. Radionuclides taken into the body by inhalation or ingestion may be distributed among different organs and retained for various

times. In addition, long-lived radionuclides deposited on the ground become possible sources for long-term external exposure and uptake by agricultural products. Dietary and exposure parameters were applied to calculate radionuclide intakes and radiological 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 (PNL-6584), which employs the dosimetry methodology described in International Commission on Radiological Protection reports (1979a, 1979b, 1980, 1981a, 1981b, 1982a, 1982b, 1988). The assumptions and data used in these calculations are described below.

The RAD-BCG calculator was used to screen the radionuclide concentrations in environmental media (water, sediment and soil) for exceeding conservatively set biota concentration guides. Both internal and external doses to aquatic, riparian, and terrestrial animals as well as to terrestrial plants are included in the screening process. The screening process is described in *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*.^(b)

The computer program, CAP88-PC, was used to calculate dose to a maximally exposed individual as required by the U.S. Environmental Protection Agency (EPA) through Title 40, Code of Federal Regulations, Part 61 (40 CFR 61), Subpart H from airborne radionuclide effluent (other than radon) released at U.S. Department of Energy (DOE) facilities. Technical details of the CAP88-PC calculations are provided in detail in the 2000 air emissions report (DOE/RL-2001-32).

(a) 1 rem (0.01 Sv) = 1,000 mrem (10 mSv).

(b) Memorandum from Dr. David Michaels (Assistant Secretary for Environmental, Safety, and Health) to Distribution, *Availability of DOE Technical Standard, “A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota (Project ENVR-0011),” for use in DOE Compliance and Risk Assessment Activities*, dated July 19, 2000.

TYPES OF DOSE CALCULATIONS PERFORMED

Calculations of radiological doses to the public from radionuclides released into the environment are performed to demonstrate compliance with applicable standards and regulations.

DOE Order 5400.5 requires the following:

- Effective dose equivalent to be used in estimating public doses.
- Biokinetic models and metabolic parameters given by the International Commission on Radiological Protection to be used when estimating doses.
- Doses to the public to be calculated using facility effluent data when environmental concentrations are too low to measure accurately.

The calculation of the effective dose equivalent takes into account the long-term (50 years) internal exposure from radionuclides taken into the body during the current year. The effective dose equivalent is the sum of individual committed (50 years) organ doses multiplied by weighting factors that represent the proportion of the total health effect risk that each organ would receive from uniform irradiation of the whole body. Internal organs may also be irradiated from external sources of radiation. The external exposure received during the current year is added to the committed internal dose to obtain the total effective dose equivalent. In this report, the effective dose equivalent is expressed in rem (or millirem) with the corresponding value in sievert (or millisievert) in parentheses. The numerous transfer factors used for pathway and dose calculations have been documented in PNL-6584 and in PNL-3777.

The following types of radiological doses were estimated.

Boundary Dose Rate (mrem/h and mrem/yr). The external radiological dose rates during the year in areas accessible by the general public were determined from measurements obtained near operating facilities.

Maximally Exposed Individual Dose (mrem). The maximally exposed individual is a hypothetical member of the public who lives at a location and has a lifestyle that makes it 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 N Reactor.
- Exposure to ground contaminated by both airborne deposition and irrigation water.
- Ingestion of fish taken from the Columbia River.
- Recreation along the Columbia River, including boating, swimming, and shoreline activities.

Determination of the Location of Maximally Exposed Individual. The location of the hypothetical maximally exposed individual can vary from year to year, depending on the relative contributions of the several sources of radioactive effluent released to the air and to the Columbia River from Hanford facilities. Since 1990, three separate locations (Figure 5.1) have been used to assess the dose to the maximally exposed individual: (1) the Ringold area, 26 kilometers (16 miles) east of separations facilities in the 200 Areas; (2) the Sagemoor area, across the Columbia River from the 300 Area; and (3) the Riverview area across the river from Richland. Scientists consider where a person would receive the maximum exposure to radionuclides from both air and water. Although the Ringold area is closer than Riverview to Hanford facilities that historically released airborne effluent, at Riverview the maximally exposed individual receives a higher dose rate from radionuclides in the Columbia River than a Ringold resident. The applicable exposure pathways for Ringold and Sagemoor are described in the following paragraphs. In 1990, the maximally exposed individual was located at Ringold. In 1991, 1992, 2000, and again in 2002, the maximally exposed individual resided in the Riverview area. However, from 1996 through 1999, and again in 2001, the hypothetical, maximally exposed individual was located across the Columbia River from the 300 Area at Sagemoor (Figure 5.2).

Ringold Maximally Exposed Individual. Because of its location, an individual in the Ringold area has the potential to receive the maximum exposure to airborne emissions from the 200 Areas, including direct exposure to a contaminated plume, inhalation, external exposure to

radionuclides that deposit on the ground, and ingestion of locally grown food products contaminated by air deposition. In addition, it is assumed that individuals in the Ringold area irrigate their crops with water taken from the Columbia River downstream of where groundwater enters the river from the 100 and 200-East Areas. This results in additional exposure from ingestion of irrigated food products and external irradiation from radionuclides deposited on the ground by irrigation. Recreational use of the Columbia River also is considered for this individual, resulting in direct exposure from water and radionuclides deposited on the shoreline and doses from ingestion of locally caught fish.

Riverview Maximally Exposed Individual. Because of its location, an individual in the Riverview area has the potential to receive the maximum exposure to waterborne emissions from effluent from Hanford facilities. For the calculation, it was assumed that the Riverview maximally exposed individual obtained domestic water from a local water treatment system that pumped from the Columbia River just downstream of the Hanford Site. In addition, it was assumed that individuals in the Riverview area irrigate their crops with water taken from the Columbia River. This results in additional exposure from ingestion of irrigated food products and external irradiation from radionuclides deposited on the ground by irrigation. Recreational use of the Columbia River was also considered, resulting in direct exposure from water and radionuclides deposited on the shoreline and doses from ingestion of locally caught fish. This individual also receives exposure via the air pathways, including direct exposure to a contaminated plume, inhalation, external exposure to radionuclides that deposit on the ground, and ingestion of locally grown food products contaminated by air deposition.

Sage Moor Maximally Exposed Individual. Because of the shift in site operations from nuclear weapons production to the current mission of managing waste products, cleaning up the site, and researching new ideas and technologies for waste disposal and cleanup, the significance of air emissions from production facilities in the 200 Areas has decreased compared to emissions from research facilities in the 300 Area.

An individual at Sage Moor, located ~1.5 kilometers (~1 mile) directly across the Columbia River from the 300 Area, receives the maximum exposure to airborne

emissions from the 300 Area. However, domestic water at this location comes from wells rather than from the river, and wells in this region are not directly contaminated by radionuclides of Hanford origin (EPS-87-367A). Because the farms located across from the 300 Area obtain irrigation water from the Columbia River upstream of the Hanford Site, the conservative assumption was made that the diet of an individual from the Sage Moor location consisted totally of foods purchased from the Riverview area, which could contain radionuclides present in both the liquid effluent and air emissions pathways. The added contribution of radionuclides in the Riverview irrigation water maximizes the calculated dose from the air and water pathways combined.

80-kilometer (50-mile) Collective 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-kilometer (50-mile) radius of Hanford Site operations is required by DOE Order 5400.5. The radiological dose to the collective population within 80 kilometers (50 miles) of the site operations areas was calculated to demonstrate compliance with environmental regulations, confirm adherence to DOE environmental protection policies, and provide information to the public. The 80-kilometer (50-mile) collective dose is the sum of doses to all individual members of the public within 80 kilometers (50 miles) of the site operations areas.

Pathways similar to those used for the maximally exposed individual were used to calculate doses to the offsite population. In calculating the effective dose, an estimate was made of the fraction of the offsite population expected to be 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 ~130,000 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. These crops are widely distributed.

- **River recreation** – These activities include swimming, boating, and shoreline recreation. Specific pathways include external exposure from radionuclides in the water or on the shoreline and ingestion of river water while swimming. An estimated 125,000 people who reside within 80 kilometers (50 miles) of the Hanford Site operations areas 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 kilograms (33,075 pounds) per year without reference to a specified human group of consumers.

DATA

The data that are needed to perform dose calculations are based on either measured upstream/downstream differences or measured effluent releases and include information on initial transport through the atmosphere or river, transfer or accumulation in terrestrial and aquatic pathways, and public exposure. By comparison, radiological dose calculations based on measured activities of radionuclides in food require data describing only dietary and recreational activities and exposure times. These data are discussed below.

POPULATION DISTRIBUTION AND ATMOSPHERIC DISPERSION

Geographic distributions of the population residing within an 80-kilometer (50-mile) radius of the Hanford Site operating areas are shown in PNNL-14295, APP. 1. These distributions are based on 2000 Bureau of the Census data (U.S. Census Bureau 2001a, 2001b). These data influence the population dose by providing estimates of the number of people exposed to radioactive effluent and their proximity to the points of release.

Atmospheric dispersion data are also shown in PNNL-14295, APP. 1. These data describe the transport and dilution of airborne radioactive material, which influence the amounts of radionuclides being transported through the air to specific locations.

TERRESTRIAL AND AQUATIC PATHWAYS

Important parameters affecting the movement of radionuclides within exposure pathways such as irrigation rates, growing periods, and holdup periods are listed in Table E.1. Certain parameters are specific to the lifestyles of either maximally exposed or average individuals.

PUBLIC EXPOSURE

The offsite radiological dose is related to the extent of external exposure to or intake of radionuclides released from Hanford Site operations. Tables E.2 through E.4 give the parameters describing the diet, residency, and river recreation parameters assumed for maximally exposed and average individuals.

DOSE CALCULATION DOCUMENTATION

DOE established the Hanford Dose Overview Panel to promote consistency and defensibility of environmental dose calculations at Hanford. The panel is responsible for defining standard, documented computer codes and input parameters used for radiological dose calculations for the public in the vicinity of the Hanford Site. Only those procedures, models, and parameters previously defined by the panel were used to calculate the radiological doses (PNL-3777). The calculations were then reviewed by the panel. Summaries of dose calculation technical details for this report are shown in Tables E.5 through E.9 and in PNNL-14295, APP. 1.

400 AREA DRINKING WATER

Drinking water at the Fast Flux Test Facility contained slightly elevated levels of tritium. The potential doses to 400 Area workers consuming this water in 2002 are given in Table E.10.

Table E.1. Food Pathway Parameters Used in Hanford Site Dose Calculations, 2002

<u>Medium</u>	<u>Holdup, d^(a)</u>		<u>Growing Period, d</u>	<u>Yield,</u>		<u>Irrigation Rate,</u>	
	<u>Maximally Exposed Individual</u>	<u>Average Individual</u>		<u>kg/m² (lb/m²)</u>		<u>L/m²/mo (gal/m²/mo)</u>	
Leafy vegetables	1	14	90	1.5	(3.3)	150	(40)
Other vegetables	5	14	90	4	(8.2)	170	(45)
Fruit	5	14	90	2	(4.41)	150	(40)
Cereal	180	180	90	0.8	(1.76)	0	
Eggs	1	18	90	0.8	(1.76)	0	
Milk	1	4	--	--		--	
Hay	(100) ^(b)	(100)	45	2	(4.41)	200	(53)
Pasture	(0)	(0)	30	1.5	(3.3)	200	(53)
Red meat	15	34	--	--		--	
Hay	(100)	(100)	45	2	(4.41)	200	(53)
Grain	(180)	(180)	90	0.8	(1.76)	0	
Poultry	1	34	90	0.8	(1.76)	0	
Fish	1	1	--	--		--	
Drinking water	1	1	--	--		--	

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

(b) Values in () are the holdup in days between harvest and consumption by farm animals.

Table E.2. Dietary Parameters Used in Hanford Site Dose Calculations, 2002

<u>Medium</u>	<u>Consumption</u>			
	<u>Maximally Exposed Individual</u>		<u>Average Individual</u>	
Leafy vegetables	30 kg/yr	(66 lb/yr)	15 kg/yr	(33 lb/yr)
Other vegetables	220 kg/yr	(485 lb/yr)	140 kg/yr	(309 lb/yr)
Fruit	330 kg/yr	(728 lb/yr)	64 kg/yr	(141 lb/yr)
Grain	80 kg/yr	(176 lb/yr)	72 kg/yr	(159 lb/yr)
Eggs	30 kg/yr	(66 lb/yr)	20 kg/yr	(44 lb/yr)
Milk	270 L/yr	(71 gal/yr)	230 L/yr	(61 gal/yr)
Red meat	80 kg/yr	(176 lb/yr)	70 kg/yr	(154 lb/yr)
Poultry	18 kg/yr	(40 lb/yr)	8.5 kg/yr	(19 lb/yr)
Fish	40 kg/yr	(88 lb/yr)	-- ^(a)	
Drinking water	730 L/yr	(193 gal/yr)	440 L/yr	(116 gal/yr)

(a) Average individual consumption not identified; radiation doses were calculated based on estimated total annual catch of 15,000 kg (33,075 lb).

AIR SURVEILLANCE INHALATION DOSES

Radionuclide concentrations measured in ambient air at locations on or near the Hanford Site were used to calculate

radiological doses from breathing. Inhalation rates were taken from International Commission on Radiological Protection (1994). Occupancy times ranged from 100% at offsite locations to 33% for onsite locations.

Table E.3. Residency Parameters Used in Hanford Site Dose Calculations, 2002

Parameter	Exposure, h/yr	
	Maximally Exposed	Average
	Individual	Individual
Ground contamination	4,383	2,920
Air submersion	8,766	8,766
Inhalation ^(a)	8,766	8,766

(a) Inhalation rates: adult 270 cm³/s (16.5 in.³/s).

Table E.4. Recreational Parameters Used in Hanford Site Dose Calculations, 2002

Parameter	Exposure, h/yr ^(a)	
	Maximally Exposed	Average
	Individual	Individual
Shoreline	500	17
Boating	100	5
Swimming	100	10

(a) Assumed river-water travel times from 100-N Area to the point of aquatic recreation were 8 hours for the maximally exposed individual and 13 hours for the average individual. Correspondingly lesser times were used for other locations.

Table E.5. Technical Details of Airborne Release Dose Calculations for the 100 Areas of the Hanford Site, 2002

Facility name	100-K Area
Releases (Ci [Bq])	⁹⁰ Sr (1.2 x 10 ⁻⁵ [444 x 10 ³]), ¹³⁷ Cs (2.2 x 10 ⁻⁵ [814 x 10 ³]), ²³⁸ Pu (2.9 x 10 ⁻⁷ [10.7 x 10 ³]), ^{239/240} Pu (2.1 x 10 ⁻⁶ [77.7 x 10 ³]), ^(a) ²⁴¹ Pu (2.5 x 10 ⁻⁵ [925 x 10 ³]), ²⁴¹ Am (1.5 x 10 ⁻⁶ [55.5 x 10 ³])
Meteorological conditions	2002 annual average, calculated from data collected at the 100-K Area and the Hanford Meteorology Station from January through December 2002, using the computer code HANCHI
\bar{X}/Q'	Maximally exposed individual, 2.1 x 10 ⁻⁹ s/m ³ at 53 km (33 mi) SSE; 80-km (50-mi) population, 1.1 x 10 ⁻³ s/m ³ person-s/m ³
Release height	10-m (33-ft) effective stack height
Population distribution	~482,000 (PNNL-14295, APP. 1, Table D-1)
Computer code	GENII, Version 1.485, December 3, 1990 (PNL-6584)
Doses calculated	Chronic, 1-yr exposure, 50-yr committed internal dose equivalent, and annual effective dose equivalent to individual and population
Pathways considered	External exposure to plume and ground deposits Inhalation Ingestion of foods produced locally at Riverview
Files addressed	Radionuclide Library, Rev. 7-1-92 Food Transfer Library, Rev. 8-29-88 External Dose Factor Library, Rev. 5-9-88 Internal Dose Factor Library, Rev. 12-3-90

(a) This value includes gross alpha release data. Gross alpha and unspecified alpha results assumed to be ^{239/240}Pu for dose calculations.

Table E.6. Technical Details of Liquid Release Dose Calculations for the 100-N Area of the Hanford Site, 2002

Facility name	100-N Area
Releases (Ci [Bq])	^3H (1.3×10^{-2} [481×10^6]), ^{90}Sr (9.8×10^{-2} [$3,629 \times 10^6$]), ^{239}Pu (1.1×10^{-5} [0.41×10^6]), ^{241}Am (2.3×10^{-5} [0.85×10^6])
Mean river flow	3,340 m ³ /s (118,000 ft ³ /s)
Shore-width factor	0.2
Population distribution	70,000 for drinking water pathway 125,000 for aquatic recreation 2,000 for consumption of irrigated foodstuffs 15,000 kg/yr (33,075 lb/yr) total harvest of Columbia River fish
Computer code	GENII, Version 1.485, December 3, 1990 (PNL-6584)
Doses calculated	Chronic, 1-yr exposure, 50-yr committed internal dose equivalent, and annual effective dose equivalent to individual and population
Pathways considered	External exposure to irrigated soil, to river water, and to shoreline sediments Ingestion of aquatic foods and irrigated farm products
Files addressed	Radionuclide Library, Rev. 7-1-92 Food Transfer Library, Rev. 8-29-88 External Dose Factor Library, Rev. 5-9-88 Internal Dose Factor Library, Rev. 12-3-90

Table E.7. Technical Details of Airborne Release Dose Calculations for the 200 Areas of the Hanford Site, 2002

Facility name	200 Areas
Releases (Ci [Bq])	<p>200-East Area</p> <p>^{90}Sr (1.6×10^{-4} [5.92×10^6]), ^{125}Sb (9.1×10^{-10} [0.34×10^3]), ^{129}I (1.2×10^{-3} [44.4×10^6]), ^{137}Cs (6.2×10^{-5} [$2,294 \times 10^3$]), ^{155}Eu (1.7×10^{-7} [6.29×10^3]), $^{239/240}\text{Pu}$ (1.4×10^{-6} [51.8×10^3]), ^{241}Pu (8.8×10^{-7} [32.6×10^3]), ^{241}Am (1.3×10^{-6} [48.1×10^3])</p> <p>200-West Area</p> <p>^{60}Co (9.3×10^{-10} [0.034×10^3]), ^{90}Sr (2.8×10^{-5} [$1,036 \times 10^3$]), ^{106}Ru (2.8×10^{-6} [103.6×10^3]), ^{137}Cs (1.1×10^{-5} [407×10^3]), ^{152}Eu (4.7×10^{-8} [1.74×10^3]), ^{238}Pu (1.5×10^{-6} [55.5×10^3]), $^{239/240}\text{Pu}$ (8.6×10^{-5} [$3,182 \times 10^3$]), ^{241}Pu (8.4×10^{-5} [$3,108 \times 10^3$]), ^{241}Am (1.5×10^{-5} [555×10^3])</p>
Meteorological conditions	2002 annual average, calculated from data collected at the Hanford Meteorology Station from January through December 2002, using the computer code HANCHI
\bar{X}/Q'	Maximally exposed individual, 5.0×10^{-9} s/m ³ at 43 km (27 mi) SE; 80-km (50-mi) population, 1.1×10^{-3} person-s/m ³
Release height	89-m (292-ft) effective stack height
Population distribution	~486,000 (PNNL-14295, APP. 1, Table D-2)
Computer code	GENII, Version 1.485, December 3, 1990 (PNL-6584)
Doses calculated	Chronic, 1-yr exposure, 50-yr committed internal dose equivalent, and annual effective dose equivalent to individual and population
Pathways considered	<p>External exposure to plume and ground deposits</p> <p>Inhalation</p> <p>Ingestion of foods produced locally at Riverview</p>
Files addressed	<p>Radionuclide Library, Rev. 7-1-92</p> <p>Food Transfer Library, Rev. 8-29-88</p> <p>External Dose Factor Library, Rev. 5-9-88</p> <p>Internal Dose Factor Library, Rev. 12-3-90</p>

Table E.8. Technical Details of Airborne Release Dose Calculations for the 300 Area of the Hanford Site, 2002

Facility name	300 Area
Releases (Ci)	^3H (as HT) ^(a) (2.8×10^1 [$1,036 \times 10^9$]), ^3H (as HTO) ^(a) (8.8×10^1 [3.256×10^9]), ^{85}Kr (2.0×10^{-3} [74×10^6]), ^{90}Sr (9.5×10^{-6} [351.5×10^3]), ^{137}Cs (5.4×10^{-7} [19.98×10^3]), ^{220}Rn (5.0×10^{-1} [18.5×10^9]), ^{234}U (1.9×10^{-10} [0.007×10^3]), ^{235}U (5.3×10^{-11} [0.002×10^3]), ^{237}Np (2.5×10^{-8} [0.92×10^3]), ^{238}Pu (9.9×10^{-10} [0.037×10^3]), ^{238}U (7.1×10^{-11} [0.0026×10^3]), $^{239/240}\text{Pu}$ (7.1×10^{-7} [26.3×10^3]), ^{241}Am (2.8×10^{-8} [1.04×10^3])
Meteorological conditions	2002 annual average, calculated from data collected at the 300 Area and the Hanford Meteorology Station from January through December 2002, using the computer code HANCHI
\bar{X}/Q'	Maximally exposed individual at residence, 7.8×10^{-8} s/m ³ at 13 km (8 mi) SSE; 80-km (50-mi) population, 9.6×10^{-3} person-s/m ³
Release height	10 m (33 ft)
Population distribution	~349,000 (PNNL-14295, APP. 1, Table D-3)
Computer code	GENII, Version 1.485, December 3, 1990 (PNL-6584)
Doses calculated	Chronic, 1-yr exposure, 50-yr committed internal dose equivalent, and annual effective dose equivalent to individual and population
Pathways considered	External exposure to plume and ground deposits Inhalation Ingestion of foods produced locally at Riverview
Files addressed	Radionuclide Library, Rev 7-1-92 Food Transfer Library, Rev. 8-29-88 External Dose Factor Library, Rev. 5-9-88 Internal Dose Factor Library, Rev. 12-3-90

(a) HT = Elemental tritium; HTO = Tritiated water vapor.

Table E.9. Technical Details of Airborne Release Dose Calculations for the 400 Area of the Hanford Site, 2002

Facility name	400 Area
Releases (Ci [Bq])	³ H (as HTO) ^(a) (1.9 x 10 ⁻² [0.70 x 10 ⁹]), ¹³⁷ Cs (4.9 x 10 ⁻⁶ [181.3 x 10 ³]), ^{239/240} Pu (2.7 x 10 ⁻⁷ [9.99 x 10 ³])
Meteorological conditions	2002 annual average, calculated from data collected at the 400 Area and the Hanford Meteorology Station from January through December 2002, using the computer code HANCHI
\bar{X}/Q'	Maximally exposed individual at residence, 2.6 x 10 ⁻⁸ s/m ³ at 22 km (14 mi) SSE; 80-km (50-mi) population, 5.6 x 10 ⁻³ person-s/m ³
Release height	10 m (33 ft)
Population distribution	~354,000 (PNNL-14295, APP. 1, Table D-4)
Computer code	GENII, Version 1.485, December 3, 1990 (PNL-6584)
Doses calculated	Chronic, 1-yr exposure, 50-yr committed internal dose equivalent, and annual effective dose equivalent to individual and population
Pathways considered	External exposure to plume and ground deposits Inhalation Ingestion of foods produced locally at Riverview
Files addressed	Radionuclide Library, Rev 7-1-92 Food Transfer Library, Rev. 8-29-88 External Dose Factor Library, Rev. 5-9-88 Internal Dose Factor Library, Rev. 12-3-90

(a) HTO = Tritiated water vapor.

Table E.10. Annual Dose to Workers in the 400 Area of the Hanford Site from Ingestion of Drinking Water Obtained from Groundwater Wells, 2002

Radionuclide	Drinking Water Activity, pCi/L (mBq/L)^(a)	Intake, pCi/yr (Bq)^(b)	Ingestion Dose Factor, rem/pCi^(c)	Ingestion Dose, rem/yr (Sv/yr)
Gross beta ^(d)	7.2 ± 1.9 (266.4 ± 70.3)	1,730 (64)	5.00 x 10 ⁻⁸ (500 pSv/pCi)	8.8 x 10 ⁻⁵ (8.8 x 10 ⁻⁷)
Tritium	3,160 ± 269 (116,920 ± 9,953)	7.6 x 10 ⁵ (28, 120)	6.40 x 10 ⁻¹¹ (0.6 pSv/pCi)	4.9 x 10 ⁻⁵ (4.9 x 10 ⁻⁷)
²²⁶ Ra	0.032 ± 0.024 (1.18 ± 0.89)	7.68 (0.28)	1.3 x 10 ⁻⁶ (0.013 μSv/pCi)	1.0 x 10 ⁻⁵ 1.0 x 10 ⁻⁷
Total				1.5 x 10 ⁻⁴ (1.5 x 10 ⁻⁶)

(a) Drinking water concentrations are annual averages obtained from quarterly samples taken during 2002.

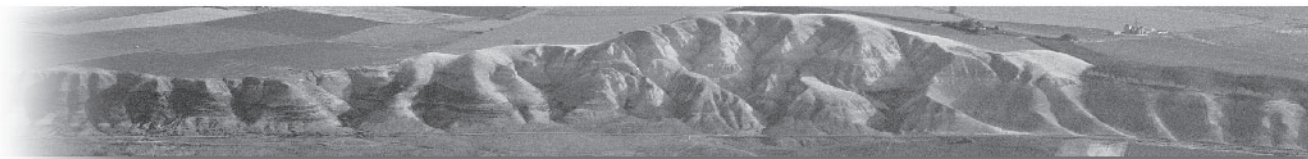
(b) Intake is based on the assumption that a worker ingests 1 L/d (0.264 gal/d) of groundwater during the entire working year (taken to be 240 days for the analysis).

(c) Ingestion intake-to-dose conversion factors are taken from EPA/520/1-88-020 and converted from International System of Units (SI). Where the document lists dose factors for more than one chemical form of a radionuclide, the most soluble chemical form was assumed.

(d) Gross beta concentrations were assumed to be ¹³⁷Cs for the purposes of this analysis.

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APPENDIX F

RADIONUCLIDES DETECTED BY GAMMA SPECTROSCOPY (GAMMA SCAN)

E. J. Antonio

One of the several forms of radiation is gamma radiation. Gamma radiation is emitted by many radionuclides. Gamma spectroscopy, sometimes called a gamma scan, is used to detect the presence of the radionuclides shown in Table F.1. These radionuclides may be natural or result from Hanford Site operations. They include activation

products formed by the absorption of a neutron by a stable element and fission products that occur following fission (splitting) of nuclear fuel radionuclides such as uranium-235 or plutonium-239. Some of these radionuclides may not be discussed in the main body of this report if they are below detection levels.

Table F.1. Radionuclides Analyzed by Gamma Spectroscopy

<u>Radionuclide</u>	<u>Symbol</u>	<u>Source</u>
Beryllium-7 ^(a)	⁷ Be	Natural
Sodium-22	²² Na	Activation product
Sodium-24	²⁴ Na	Activation product
Potassium-40 ^(a)	⁴⁰ K	Natural
Manganese-54	⁵⁴ Mn	Activation product
Cobalt-58	⁵⁸ Co	Activation product
Cobalt-60 ^(a)	⁶⁰ Co	Activation product
Iron-59	⁵⁹ Fe	Activation product
Zinc-65	⁶⁵ Zn	Activation product
Zirconium/niobium-95	⁹⁵ Zr/Nb	Activation product and fission product
Molybdenum-99	⁹⁹ Mo	Activation product and fission product
Ruthenium-103	¹⁰³ Ru	Activation product and fission product
Ruthenium-106 ^(a)	¹⁰⁶ Ru	Fission product
Antimony-125 ^(a)	¹²⁵ Sb	Activation product
Iodine-131	¹³¹ I	Fission product
Cesium-134 ^(a)	¹³⁴ Cs	Activation product
Cesium-137 ^(a)	¹³⁷ Cs	Fission product
Barium/lanthanum-140	¹⁴⁰ Ba/La	Fission product
Cerium-141	¹⁴¹ Ce	Activation product and fission product
Cerium/praseodymium-144	¹⁴⁴ Ce/Pr	Fission product
Europium-152	¹⁵² Eu	Activation product
Europium-154 ^(a)	¹⁵⁴ Eu	Activation product
Europium-155 ^(a)	¹⁵⁵ Eu	Activation product

(a) Routinely reported by contracting laboratory for Pacific Northwest National Laboratory environmental surveillance samples.



APPENDIX G

THREATENED AND ENDANGERED SPECIES

M. R. Sackschewsky

This appendix discusses the federal and state threatened and endangered species, candidate or sensitive animal species, and plant species of concern potentially found on the Hanford Site. Threatened and endangered species are listed at Title 50, Code of Federal Regulations, Part 17 (50 CFR 17); Washington Natural Heritage Program (2003); and Washington Department of Fish and Wildlife (2003).

ENDANGERED SPECIES ACT OF 1973

The purposes of the *Endangered Species Act of 1973*, as amended, are to (1) provide a means to conserve critical ecosystems, (2) provide a program for the conservation of threatened and endangered species, and (3) assure that appropriate steps are taken to achieve the purposes of the treaties and conventions established in the act. There are several species of plants and animals listed as threatened or endangered by either the federal or state governments that occur or potentially occur on the Hanford Site (Table G.1).

Identification of candidate species (Table G.2) and species at lower listing levels (Table G.3) can assist environmental planning efforts by providing advance notice of potential listing as a threatened or endangered species, allowing resource managers to alleviate threats and thereby possibly remove the need to list species as endangered or threatened. Even if a candidate species is subsequently listed, the early notice could result in fewer restrictions on human activities in the environment by prompting candidate conservation measures to alleviate threats to the species.

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There are, however, one bird species and two fish species on the federal list of threatened and endangered species (Table G.1). No plants or mammals known to occur on the Hanford Site are currently on the federal list of endangered and threatened species (50 CFR 17), but two species of plants, one species of mammal, and one species of bird are currently candidates for listing under the *Endangered Species Act of 1973* (Tables G.1 and G.2). In addition, eleven species of plants and six species of birds have been listed as either threatened or endangered by Washington State. The National Oceanic and Atmospheric Administration Fisheries has the responsibility for the federal listing of anadromous fish (i.e., fish which require both saltwater and freshwater to complete a life cycle). Upper-Columbia River steelhead (*Oncorhynchus mykiss*) and upper-Columbia River spring-run chinook salmon (*Oncorhynchus tshawytscha*) were listed as endangered evolutionary significant units by National Marine Fisheries Service in August 1997 and March 1999, respectively (National Marine Fisheries Service 2003). In March 2003, Pacific Northwest National Laboratory staff found spawning areas of upper-Columbia River steelhead near the 300 Area. Consultation with the National Oceanic and Atmospheric Administration Fisheries regarding this spawning area is currently underway.

Several species of plants and animals are listed at the candidate species or other levels by Washington State. There are 25 state-level candidate species of animals (Table G.2) and 40 plant species of concern (Table G.3).

Table G.1. Federal or Washington State Threatened and Endangered Species on the Hanford Site

<u>Common Name</u>	<u>Scientific Name</u>	<u>Federal</u>	<u>State</u>
Plants			
awned halfchaff sedge	<i>Lipocarpha</i> (= <i>Hemicarpha</i>) <i>aristulata</i>		Threatened ^(a)
desert dodder	<i>Cuscuta denticulata</i>		Threatened ^(a)
Geyer's milkvetch	<i>Astragalus geyeri</i>		Threatened ^(a)
grand redstem	<i>Ammannia robusta</i>		Threatened ^(a)
loeflingia	<i>Loeflingia squarrosa</i> var. <i>squarrosa</i>		Threatened ^(a)
lowland toothcup	<i>Rotala ramosior</i>		Threatened ^(a)
persistent sepal yellowcress	<i>Rorippa columbiae</i>	Species of concern ^(b)	Threatened ^(a)
rosy pussypaws	<i>Calyptridium roseum</i>		Threatened ^(a)
Umtanum desert buckwheat	<i>Eriogonum codium</i>	Candidate ^(c)	Endangered ^(d)
White Bluffs bladderpod	<i>Lesquerella tuplashensis</i>	Candidate ^(c)	Threatened ^(a)
white eatonella	<i>Eatonella nivea</i>		Threatened ^(a)
Fish			
spring-run chinook salmon	<i>Oncorhynchus tshawytscha</i>	Endangered ^(d)	Candidate ^(c)
steelhead	<i>Oncorhynchus mykiss</i>	Endangered ^(d)	Candidate ^(c)
Birds			
American white pelican	<i>Pelecanus erythrorhynchos</i>		Endangered ^(d)
bald eagle ^(e)	<i>Haliaeetus leucocephalus</i>	Threatened ^(a)	Threatened ^(a)
ferruginous hawk	<i>Buteo regalis</i>	Species of concern ^(b)	Threatened ^(a)
peregrine falcon	<i>Falco peregrinus</i>	Species of concern ^(b)	Endangered ^(d)
sandhill crane	<i>Grus canadensis</i>		Endangered ^(d)
western sage grouse	<i>Centrocercus urophasianus phaios</i>	Candidate ^(c)	Threatened ^(a)

(a) Species likely to become endangered in the foreseeable future.

(b) Species that are not currently listed or candidates under the *Endangered Species Act of 1973*, but are of conservation concern within specific U.S. Fish and Wildlife Service regions (personal communication, Gregg Kurz, U.S. Fish and Wildlife Service, June 9, 2003).

(c) Species that are believed to qualify for threatened or endangered species status, but for which listing proposals have not been prepared.

(d) Species in danger of extinction within all or a significant portion of its range.

(e) Currently under review for change in status.

Table G.2. Washington State Candidate Animal Species on the Hanford Site

<u>Common Name</u>	<u>Scientific Name</u>
Molluscs	
giant Columbia River spire snail ^(a)	<i>Fluminicola (= Lithoglyphus) columbiana</i>
giant Columbia River limpet	<i>Fisherola (= Lanx) nuttalli</i>
Fish	
mountain sucker	<i>Catostomus platyrhynchus</i>
leopard dace	<i>Rhinichthys flacatus</i>
river lamprey ^(a)	<i>Lampetra ayresi</i>
spring-run chinook salmon ^(b)	<i>Oncorhynchus tshawytscha</i>
steelhead ^(b)	<i>Oncorhynchus mykiss</i>
Insects	
Columbia River tiger beetle ^(c)	<i>Cicindela columbica</i>
Birds	
burrowing owl ^(a)	<i>Athene cunicularia</i>
common loon ^(d)	<i>Gavia immer</i>
flamulated owl ^(e)	<i>Otus flammeolus</i>
golden eagle	<i>Aquila chrysaetos</i>
Lewis woodpecker ^(e)	<i>Melanerpes lewisii</i>
loggerhead shrike ^(a)	<i>Lanius ludovicianus</i>
merlin	<i>Falco columbarius</i>
northern goshawk ^(a,e)	<i>Accipiter gentilis</i>
Oregon vesper sparrow	<i>Poocetes gramineus affinis</i>
sage sparrow	<i>Amphispiza belli</i>
sage thrasher	<i>Oreoscoptes montanus</i>
western grebe	<i>Aechmorus occidentalis</i>
Reptiles	
sagebrush lizard	<i>Sceloporus graciosus</i>
striped whipsnake	<i>Masticophis taeniatus</i>
Mammals	
black-tailed jackrabbit	<i>Lepus californicus</i>
Merriam's shrew	<i>Sorex merriami</i>
Washington ground squirrel ^(e,f)	<i>Spermophilus washingtoni</i>
white-tailed jackrabbit	<i>Lepus townsendii</i>

(a) Federal species of concern.

(b) Federal endangered.

(c) Probable, but not observed, on the Hanford Site.

(d) State sensitive (i.e., taxa vulnerable or declining) and could become endangered or threatened.

(e) Reported, but seldom observed, on the Hanford Site.

(f) Federal candidate.

Table G.3. Washington State Plant Species of Concern on the Hanford Site

<u>Common Name</u>	<u>Scientific Name</u>	<u>State Listing^(a)</u>
annual paintbrush	<i>Castilleja exilis</i>	W
annual sandwort	<i>Minuartia pusilla</i> var. <i>pusilla</i>	R1
basalt milk-vetch	<i>Astragalus conjunctus</i> var. <i>rickardii</i>	W
beaked spike-rush	<i>Eleocharis rostellata</i>	S
bristly combseed	<i>Pectocarya setosa</i>	W
brittle prickly pear	<i>Opuntia fragilis</i>	R1
Canadian St. John's wort	<i>Hypericum majus</i>	S
chaffweed	<i>Centunculus minimus</i>	R1
Columbia milkvetch	<i>Astragalus columbianus</i>	S ^(b)
Columbia River mugwort	<i>Artemisia lindleyana</i>	W
coyote tobacco	<i>Nicotiana attenuata</i>	S
crouching milkvetch	<i>Astragalus succumbens</i>	W
desert evening-primrose	<i>Oenothera caespitosa</i>	S
dwarf evening primrose	<i>Camissonia</i> (= <i>Oenothera</i>) <i>pygmaea</i>	S
false pimpernel	<i>Lindernia dubia anagallidea</i>	W
fuzzytongue penstemon	<i>Penstemon eriantherus whitedii</i>	S
giant helleborine	<i>Epipactis gigantea</i>	S
gray cryptantha	<i>Cryptantha leucophaea</i>	S ^(b)
Great Basin gilia	<i>Gilia leptomeria</i>	S
hedge hog cactus	<i>Pediocactus simpsonii</i> var. <i>robustior</i>	R1
Hoover's desert parsley	<i>Lomatium tuberosum</i>	S ^(b)
Kittitas larkspur	<i>Delphinium multiplex</i>	W
medic milkvetch	<i>Astragalus speirocarpus</i>	W
miner's candle	<i>Cryptantha scoparia</i>	S
mousetail	<i>Myosurus clavicaulis</i>	S
Piper's daisy	<i>Erigeron piperianus</i>	S
porcupine sedge	<i>Carex hystericina</i>	S
Robinson's onion	<i>Allium robinsonii</i>	W
rosy balsamroot	<i>Balsamorhiza rosea</i>	W
scilla onion	<i>Allium scilloides</i>	W
shining flatsedge	<i>Cyperus bipartitus (rivularis)</i>	S
small-flowered evening-primrose	<i>Camissonia</i> (= <i>Oenothera</i>) <i>minor</i>	S
small-flowered nama	<i>Nama densum</i> var. <i>parviflorum</i>	W
smooth cliffbrake	<i>Pellaea glabella simplex</i>	W
Snake River cryptantha	<i>Cryptantha spiculifera</i> (= <i>C. interrupta</i>)	S
southern mudwort	<i>Limosella acaulis</i>	W
stalked pod milkvetch	<i>Astragalus sclerocarpus</i>	W
Suksdorf's monkey flower	<i>Mimulus suksdorfii</i>	S
Thompson's sandwort	<i>Arenaria franklinii thompsonii</i>	R2
winged combseed	<i>Pectocarya penicillata</i>	W

(a) S = Sensitive (i.e., taxa vulnerable or declining) and could become endangered or threatened without active management or removal of threats.

R1 = Review List 1 - Taxa for which there are insufficient data available to support listing as threatened, endangered, or sensitive.

R2 = Review List 2 - Taxa with unresolved taxonomic questions.

W = Watch List - Taxa that are more abundant and/or less threatened than previously assumed.

(b) U.S. Fish and Wildlife Service Columbia Basin federal species of concern

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APPENDIX H

ERRATA IN THE HANFORD SITE ENVIRONMENTAL REPORT FOR CALENDAR YEAR 2001

The following errors were identified in the *Hanford Site Environmental Report for Calendar Year 2001* (PNNL-13910):

- Footnote (a) in Table 4.7.5, on page 4.80, should read “ \pm counting error” rather than “ ± 2 standard deviations.”
- Footnote (a) in Table 7.3.2, on page 7.33, should read “Percent fines = Percent of soil particles < 0.05 mm in spherical diameter” rather than “... < 2 mm in spherical diameter.”
- Statistical uncertainty values in Table 3.2.8 (page 3.20) and Table 3.2.13 (page 3.24) were mistakenly reported as ± 2 standard deviations. These were actually ± 2 standard error of the mean.
- Tables A.4 and A.6 in Appendix A, Helpful Information, are incorrectly labeled. Table A.4 should be labeled “Conversions for Radioactivity Units” and Table A.6 should be labeled “Conversions for Radiological Dose Units.”



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When the information on a page is located in the figure, the page number is followed by a F. When it is located in a table, T. If the information on a page is in the text as well as a figure or table, just the page number is used.

The following acronyms are used in the index: LLW = low-level waste, RCRA = *Resource Conservation and Recovery Act*, TPA = Hanford Federal Facility Agreement and Consent Order.

Facilities, waste sites, areas, and other locations that begin with a number, such as the 100 Areas, are filed at the end of the index.

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