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U.S. Department of Energy

Hanford Site Environmental Report for Calendar Year 2003

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THE HANFORD SITE ENVIRONMENTAL REPORT FOR CALENDAR YEAR (CY) 2003 (PNNL-687), RICHLAND, WASHINGTON, SEPTEMBER 2004

The Hanford Site Environmental Report is prepared and published annually by the U. S. Department of Energy (DOE) for distribution to local, state, and federal government agencies, Congress, the public, news media, and Hanford Site employees. The purpose of the report is to provide the reader with the most recent information available on Hanford Site environmental management activities and environmental compliance issues.

This report includes information for CY 2003 (including some early 2004 information) and contains sections summarizing the results of environmental monitoring efforts on and around the site; information on the Hanford Site's conformance to environmental permits; the status of the sites's compliance with federal, state, and local regulations; and discussions on important issues and actions.

The report was prepared for DOE by the Pacific Northwest National Laboratory (PNNL) with the support of other site contractors and describes programs conducted by PNNL, the research and development contractor; Fluor Hanford, Inc., the prime contractor for the nuclear legacy cleanup; Bechtel Hanford, Inc. (BHI), the environmental restoration contractor; CH2M HILL Hanford Group, Inc., the contractor responsible for nuclear and chemical waste stored in Hanford's 177 underground storage tanks; Bechtel National, Inc. (BNI), the contractor responsible for designing, building, and commissioning a waste treatment plant for vitrifying Hanford's tank waste; and S. M. Stoller Corporation, a prime contractor to DOE's office in Grand Junction, Colorado, which is performing vadose zone work at the Hanford Site; and numerous subcontractors at the Hanford Site.

If you have any questions or comments about this report, please contact us, or you may contact Dana C. Ward, Site Closure Team, on (509) 372-1261 or by e-mail at Dana_C_Ward @ rl.gov.

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PNNL-14687

HANFORD SITE ENVIRONMENTAL REPORT FOR CALENDAR YEAR 2003

(INCLUDING SOME EARLY 2004 INFORMATION)

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SEPTEMBER 2004

Prepared for the U.S. Department of Energy by staff
from the Pacific Northwest National Laboratory
under contract DE-AC06-76RL01830, with
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its subcontractors; Bechtel National, Inc.;
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and S.M. Stoller Corporation

PACIFIC NORTHWEST NATIONAL LABORATORY
RICHLAND, WASHINGTON 99352

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) and DOE Order 231.1A, "Environment, Safety, and Health Reporting." The report provides an overview of activities at the site; demonstrates the status of the site's compliance with applicable federal, state, and local environmental laws and regulations, executive orders, and DOE policies and directives; and summarizes environmental data that characterize Hanford Site environmental management performance. The report also highlights significant environmental programs and efforts. Some historical and early 2004 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 scientific notation, units of measure, unit conversion information, and nomenclature that may help readers understand the report. Appendix B is a glossary of terms.

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

Inquiries regarding this report should be directed to D. C. (Dana) Ward, DOE Richland Operations Office, Closure Division, P.O. Box 550, MS A2-17, Richland, Washington 99352 <dana_c_ward@rl.gov> or to T. M. (Ted) Poston, Pacific Northwest National Laboratory, P.O. Box 999, MS K6-75, Richland, Washington 99352 <ted.poston@pnl.gov>.

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-14687-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 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. Individual sections of the report are designed to:

- Describe the Hanford Site and its mission.
- Summarize the status of compliance with environmental regulations.
- Discuss the status and results of Hanford Site cleanup and remediation activities.
- Describe the environmental and groundwater surveillance and protection programs at the Hanford Site.
- Summarize and discuss effluent monitoring, environmental monitoring and surveillance, and groundwater protection and monitoring information.
- Discuss the estimated radiation exposure to the public from 2003 Hanford Site activities.
- Discuss activities conducted to assure data quality.

The current mission of DOE at the Hanford Site includes cleaning up and shrinking the size of the site. It is the policy of the 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 2003

The site's compliance with federal acts in 2003 is summarized in Table S.1 and discussed in detail in 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 the 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 2003, there were 36 specific Tri-Party Agreement cleanup milestones scheduled for completion: 35 were completed on or before their required due dates, and 1 was completed beyond its established due date.

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. A summary of waste generated on the site or received from off the site in 2003 is provided in Table S.2. Major contributors to the solid waste generated on the Hanford Site (by weight) included the 300 Area projects (18%), Tank Farms (18%), and the N Springs remediation project (10%). Similarly, Pacific EcoSolutions (formerly Allied Technology Group Corporation) (35%), DOE Fermi National Accelerator Laboratory (31%), and DOE Argonne National Laboratory (12%) were the primary contributors of solid waste received from offsite sources (by weight).

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 places awaiting cleanup and ultimate safe storage or disposal. 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).

Table S.1. Compliance with Federal Acts at the Hanford Site in 2003 (details in Section 2.2)

Regulation	What it Covers	2003 Status
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 materials 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)	Tracking hazardous waste from generator to treatment, storage, or disposal.	The Washington State Department of Ecology identified four non-compliance issues during 2003: (1) Concerns regarding inspection and repair of leak detection systems used at AY, AZ, and SY Tank Farms; (2) Concern about storing chemicals; (3) and (4) Concerns about DOE complying with Washington Administrative Code and Revised Code of Washington regulations. All corrective actions were completed and accepted.
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. There were no non-compliance issues.
Clean Water Act	Discharges to U.S. waters.	The Hanford Site had one National Pollutant Discharge Elimination System Permit, one storm water permit, and ten State Wastewater Discharge Permits in 2003.
Safe Drinking Water Act	Drinking water systems operated by DOE at Hanford.	There were nine public water systems on the Hanford Site in 2003. The systems were monitored and all analytical results for 2003 met the requirements of the Washington State Department of Health.
Toxic Substances Control Act	Primarily regulation of chemicals called polychlorinated biphenyls.	Non-radioactive and certain categories of radioactive polychlorinated biphenyl waste were disposed in accordance with 40 CFR 761 or remained in storage onsite pending the development of adequate treatment and disposal technologies.
Federal Insecticide, Fungicide, and Rodenticide Act	Storage and use of pesticides.	At the Hanford Site, pesticides are applied by commercial pesticide operators licensed by the state.
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 five 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 forty-two 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 2003, there were 20 site-wide categorical exclusions – actions that have already been analyzed by DOE and have been determined not to result in a significant environmental impact.
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.

Table S.2. Hanford Waste Summary, 2003

Activity	Waste Type	Amount
Waste generated during onsite cleanup activities	Solid mixed waste Radioactive waste	929,000 pounds 1.6 million pounds
Waste received at Hanford from off the site	Solid mixed waste Radioactive waste	1.4 million pounds 898,200 pounds
Waste shipped off of Hanford Site	Hazardous waste	494,200 pounds
Waste generated at Hanford and added to double-shell tanks	Liquid waste	2.5 million gallons
Waste volume in double-shell tanks at the end of 2003	Liquid waste	24.5 million gallons

Environmental Occurrences

Environmental releases of radioactive and regulated materials from the Hanford Site are reported to the 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 2003, there were no environmentally significant emergency occurrence reports or environmentally significant unusual occurrence reports filed at the Occurrence Notification Center. Two off-normal occurrences with environmental impacts are discussed in Section 2.4.3. One was contaminated wasp nests found outside of a contaminated area in the 100-H Area. The second event was a contaminated wasp nest discovered on a generator in the 100-N Area; investigation determined that the generator had been used in the 100-H Area before it was brought to 100-N Area and probably had contaminated mud on it. Throughout the summer of 2003, contaminated wasp nests were found around the H Reactor building. Investigation determined the mud from the floor of 100-H Basin had been used by the wasps to make their nests. Mitigation activities included using Borax as a deterrent, applying pesticides to eliminate the wasps, creating clean mud sources, and reducing the amount of exposed mud in the basin.

Environmental Monitoring

Environmental monitoring at the Hanford Site includes near-facility environmental monitoring (Section 3.2), surface environmental surveillance (Chapter 4), groundwater monitoring (Chapter 6), and vadose zone monitoring (Chapter 6). 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 protecting the Columbia River, human health and the environment; treating groundwater contamination; and limiting the movement of groundwater contamination. Vadose monitoring was conducted to better understand the properties of the vadose zone and its contaminants and the extent of subsurface contamination. 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, public health, and worker protection policies; and support environmental and waste management decisions.

Environmental monitoring and surveillance results for 2003 are summarized in Table S.3. For detailed discussions of results, refer to the appropriate sections of this report.

Effluent Monitoring

Liquid effluent and airborne emissions that may contain radioactive or hazardous constituents are continually

Table S.3. Hanford Site Monitoring Results for 2003

	What was Monitored?	The Bottom Line
Air	Air particles and gases were analyzed for radioactive materials. Air was sampled at 23 locations on Hanford, 11 perimeter locations, 8 community locations, 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 Hanford Reach 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 2003, 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 springs. 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 those observed in near-shore river but similar to. local groundwater. However, concentrations in river water downtream of the shoreline springs remained far below federal and state limits.
Groundwater	Groundwater samples were collected from 652 wells and 48 shoreline aquifer tubes to monitor contaminant concentrations. Water levels were measured in several hundred wells on the site to map groundwater movement.	Samples showed that groundwater contaminant plumes are continuing to move 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 were conducted to better understand the properties of contaminants and the extent of the contamination.	Vadose zone monitoring was conducted at the single-shell tank farms to detect changes or trends in contaminants. Characterization of vadose zone contaminants occurred at past-practice disposal sites.
Drinking Water	The quality of the drinking water supplied by nine DOE-owned systems on the Hanford Site was monitored.	All DOE-owned drinking water systems on the Hanford Site met Washington State and EPA standards.
Food and Farm Products	Samples of alfalfa, apples, asparagus, honey, leafy vegetables, milk, potatoes, tomatoes, and wine were collected from 20 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 13 locations. Carcass, bone, and muscle samples were analyzed to evaluate radionuclide levels.	Samples of fish, geese, rabbits, crayfish, and clams 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.	Compliance with all applicable effluent monitoring requirements was achieved in 2003.

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. 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 2003, 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). Non-radioactive hazardous materials in liquid effluent were discharged to both the State-Approved Land Disposal Site and to the Columbia River at designated (permitted) discharge points. Monitoring indicated that no known releases of hazardous substances exceeding reportable quantities occurred at these discharge points in 2003 (Section 3.1.5).

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 2003. Non-radioactive air pollutants from such things as diesel-powered electrical generating plants were also monitored. Table 3.1.2 summarizes the non-radioactive discharges to the air on the Hanford Site during 2003.

Waste Site Remediation

Full-scale remediation of waste sites began in the 100 Areas in 1996 and continued in 2003 at the 100-B/C, 100-K, 100-N, 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 backfill activities were completed in the 100-F Area and began in the 100-B/C Area. A total of 506,275 tonnes (558,073 tons) of contaminated soil from 100 Areas remediation activities were disposed at the Environmental Restoration Disposal Facility (near the 200-West Area) during 2003.

Since cleanup activities began in 1996, the primary focus has been on liquid effluent waste sites. After nearly 7 years of work the number of liquid effluent waste sites requiring remediation has been reduced and cleanup activities now are turning to remediation of waste burial grounds. The volume of contamination in waste burial grounds is less than in liquid effluent waste sites; however, the burial grounds may contain unknown materials and additional time may be required to characterize the waste and dispose of it properly.

Remediation work at the 300-FF-1 Operable Units began in 1997 and was completed in 2003. Remediation continued at the 300-FF-2 Operable Unit. In 2003, more than 52,590 tonnes (57,970 tons) of contaminated soil from 300 Area remediation were removed and disposed of at the Environmental Restoration Disposal Facility.

Pollution Prevention Program. This program (Section 2.3.1) is an organized and continuing effort to reduce the quantity and toxicity of hazardous, radioactive, mixed, and sanitary waste produced at Hanford. The program fosters the conservation of resources and energy, reduction in the use of hazardous substances, and prevention or minimization of pollutant releases to all environmental media from all operations and site cleanup activities.

The DOE met the 2003 goals for reducing low-level waste and mixed low-level waste generation and increasing sanitary waste (including paper, plastic, cardboard, glass, etc.) recycling. The goal of purchasing more environmentally preferable products containing recycled material was also achieved.

However, the generation goal for routine hazardous waste was not met at the Hanford Site in 2003. Hanford generated 17.78 cubic meters (23.2 cubic yards) of hazardous waste, which exceeded goal of 16.39 cubic meters (21.4 cubic yards) by 1.39 cubic meters (1.82 cubic yards). This was largely due a diesel oil spill at the Waste Treatment Project, which resulted in 6.1 cubic meters (8 cubic yards) of contaminated soil.

The Hanford Site generated 20,454 cubic meters (26,754 cubic yards) of low-level waste, mixed low-level waste, and hazardous waste during 2003. This was well below the goal of 28,604 cubic meters (37,414 cubic yards).

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 2003, the project continued to make accelerated progress on removing spent fuel from underwater storage in the K Basins

and placing it in dry interim storage in the 200-East Area. Major accomplishments of the Spent Nuclear Fuel Project during 2003 included the following:

- Two hundred shipments of spent fuel were transferred from the K-East Basin to the K-West Basin, completing 215 of 380 planned shipments (56% complete).
- One hundred thirteen multi-canister overpacks of spent fuel were removed from the K-West Basin and dried, for a total of 293 multi-canister overpacks out of approximately 385 (75% complete). The 2003 progress brought the total amount of fuel removed and dried to approximately 1,600 tonnes (1,800 tons).
- One hundred twenty multi-canister overpacks were permanently closed (at the Canister Storage Building) with "N-Stamped" welds (those meeting the highest nuclear quality standards of the American Society of Mechanical Engineers). The welding subproject remained consistently ahead of schedule.
- Scrap-processing equipment was installed in the K-West Basin and the loading of fuel scraps into multi-canister overpacks was begun.
- The washing and loading of aged fuel canisters for disposal as low-level nuclear waste continued. By end of 2003, 3,700 canisters (55% of the total) had been washed and disposed.

Sludge Retrieval and Disposition Project. In late 2003, to bring more focus and dedicated resources to sludge issues, Fluor Hanford, Inc. separated the sludge work from the Spent Nuclear Fuel Project and created the new Sludge Retrieval and Disposition Project (Section 2.3.3). T Plant had always been an interim storage site, and Fluor Hanford, Inc. and the DOE desired to establish a path leading more directly toward sludge disposal.

Throughout much of 2003, Fluor Hanford, Inc. managed the effort to retrieve sludge from the K Basins as part of the larger Spent Nuclear Fuel Project. The plan called for collection of the sludge in large steel containers, which would then be transported to T Plant in Hanford's 200-West Area for interim storage as remote-handled transuranic waste. This waste would be included in a treatment and disposition path with other remote-handled transuranic waste at Hanford.

K-East Basin contains a mixture of sludge from fuel canisters and from the basin floor and pits. The K-West Basin sludge exists in four discrete types. These types include sludge in pits, sludge dispersed on the basin floor, and canister and fuel wash sludge that collects in the Integrated Water Treatment System equipment used for spent nuclear fuel processing. The K-West Basin sludge also includes metallic uranium fuel fragments and fuel corrosion products from spent fuel of slightly higher enrichment levels than the K-East Basin spent fuel. Because composition of the sludge is complex, Fluor Hanford, Inc. obtained assistance from Pacific Northwest National Laboratory and others to determine suitable methods to handle and treat the sludge.

At the end of 2003, the new Sludge Retrieval and Disposition Project had been in existence only 3 months. The project staff had begun to study potential sludge treatment methods and had initiated treatment of the approximately 6 cubic meters (7.85 cubic yards) of KE North Loadout Pit sludge from the K-East Basin in a pilot grouting program. In the pilot grouting program, North Loadout Pit sludge will be mixed in concrete to prepare it for disposal at the DOE's Waste Isolation Pilot Plant in New Mexico as contact-handled transuranic waste.

Central Plateau Remediation Project. This project's mission (Section 2.3.4) is to deactivate and close facilities on the Central Plateau 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, 224-B, 224-T, and 233-S Plutonium Concentration Facility Decommissioning Project, Central Plateau Surveillance and Maintenance Project, and Canyon Disposition Initiative.

Fast Flux Test Facility. Deactivation activities continued at the Fast Flux Test Facility (Section 2.3.5) in 2003. Repairs and upgrades to reactor-fuel handling equipment were completed and successfully tested. Following removal of a hold order imposed by a U.S. District Court, the liquid sodium coolant was drained from secondary heat transport system loops to the Sodium Storage Facility tanks, where it is stored pending future conversion to sodium hydroxide for use by the Waste Treatment Plant. Eighty-one reactor fuel components were washed, packaged, and placed in approved interim storage. This included 32 un-irradiated mixed-oxide fuel assemblies, which were placed in storage

at the Plutonium Finishing Plant. Fluor Hanford, Inc. awarded a contract to TransNuclear Inc. to fabricate the remaining interim reactor-fuel storage casks and to design a pump that will be used to drain the reactor vessel.

Advanced Reactors Transition Project. The mission of this project (Section 2.3.6) is to transition or convert the Plutonium Recycle Test Reactor facility, and other facilities used for nuclear research, into structures that are safe, stable, and suitable for reuse or low cost surveillance and maintenance. During 2003, facility surveillance activities continued.

Plutonium Finishing Plant. During 1996, the DOE issued a shutdown order for this plant, authorizing deactivation and transition of the plutonium processing portions of the facility to prepare for decommissioning. Workers at the Plutonium Finishing Plant complex embarked on a large and multifaceted effort to stabilize, immobilize, re-package, and/or properly dispose of nearly 18 tonnes (19.8 tons) of plutonium-bearing materials in the plant, and had nearly completed this mission by the end of 2003 (completion occurred in February 2004). The workers also began to deactivate and dismantle the processing facilities, while still providing for the safe and secure storage of nuclear materials in the facilities. Significant accomplishments achieved at the Plutonium Finishing Plant during 2003 included the following:

- Nearly 1,000 plutonium-bearing polycubes were stabilized using a unique thermal stabilization method devised specifically for this project.
- The original 4 tonnes (4.4 tons) of plutonium-bearing residues identified for action by the Defense Nuclear Facilities Safety Board in 2000 were re-packaged, and additional materials categorized as residues were packaged.
- Re-packaged plutonium-bearing residues were shipped off of the Hanford Site to the Waste Isolation Pilot Plant in Carlsbad, New Mexico, for disposal.
- Stabilized plutonium forms were welded into sturdy, triple-layered cans meeting strict specifications of the DOE's "3013" safety standard.
- Plutonium-bearing oxides containing large amounts of chloride salts were stabilized using a unique process developed for this project.
- Approximately 90% of the total plutonium inventory in the plant was stabilized by the end of 2003.
- Plutonium held in a glove box known as HC-7C in the main Plutonium Finishing Plant Facility was cleaned up and cleanup in a second large glove box known as HC-9B was initiated.
- Equipment removal in the 232-Z incinerator facility in the Plutonium Finishing Plant complex was started and key environmental documentation in preparation for additional deactivation work was completed.
- One million safe work hours were obtained and the Plutonium Finishing Plant became the first high-hazard nuclear facility in the DOE complex to achieve Star Status in DOE's Voluntary Protection Program.

Waste Encapsulation and Storage Facility Project. The mission of the Waste Encapsulation and Storage Facility Project (Section 2.3.8) 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 strontium fluoride and cesium chloride capsules stored at the facility. The capsules will be stored at the Waste Encapsulation and Storage Facility until 2018 when they will either be treated at the Waste Treatment Plant or transported to the national repository.

Tri-Party Agreement milestone M-92-05 was revised in 2003 to require an assessment of the viability of directly disposing the capsules at the national high-level waste repository as an alternative to onsite vitrification. The completed assessment is due June 30, 2007, to Washington State Department of Ecology.

Solid Waste Management. Solid waste management at the Hanford Site in 2003 included the treatment, storage, and disposal of solid waste at many Hanford locations (Section 2.3.10). Onsite solid waste facilities include the Central Waste Complex, Waste Receiving and Processing Facility, Radioactive Mixed Waste Disposal Facility, and T Plant Complex. During 2003, 3,138 cubic meters (110,820 cubic feet) of mixed low-level solid waste were treated and/or directly disposed onsite. Two defueled reactor compartments from the U.S. Navy were received and disposed of at the 200-East Area in 2003; this brings the total number of reactor compartments received to 112.

Liquid Effluent Treatment. Liquid effluent is managed in facilities that comply with RCRA and state regulations (Section 2.3.11). The 242-A evaporator in the 200-East

Area concentrates dilute liquid tank waste by evaporation. This reduces the volume of liquid waste sent to the double-shell tanks for storage and reduces the potential need for double-shell tanks. The 242-A evaporator completed four campaigns during 2003. The volume of waste treated was 14.53 million liters (3.84 million gallons) and the waste volume reduction was 4.28 million liters (1.13 million gallons) or 29%. The volume of process condensate transferred from the 242-A evaporator to the Liquid Effluent Retention Facility for subsequent treatment was 5.68 million liters (1.50 million gallons).

Approximately 46.56 million liters (12.3 million gallons) of liquid waste were stored at the Liquid Effluent Retention Facility at the end of 2003. The 200 Area Treated Effluent Disposal Facility received 1,269 million liters (335.4 million gallons) of unregulated effluent for disposal in 2003. 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 2.3.11.5). The volume of industrial wastewater treated and disposed of during 2003 was 145.5 million liters (38.4 million gallons).

Environmental Restoration Project. The Environmental Restoration Project (Section 2.3.12) includes activities to characterize and remediate contaminated soil, decontaminate and decommission facilities, maintain inactive waste sites, and to transition facilities into the surveillance and maintenance program. In 2003, work began on two new cells at the Environmental Restoration Disposal Facility with completion expected in 2004.

During 2003, interim safe storage of the F Reactor was completed. Demolition of the 117-DR Exhaust Filter Building and associated tunnels was also completed. The D Reactor Safe Storage Enclosure design was completed, and the subcontractor initiated construction activities. The demolition and closure of the 1720-HA Arsenal in 100-H Area was completed, and demolition of the H Reactor basin was initiated and is nearing completion. Demolition and closure of the 118-C-4 Horizontal Control Rod Storage Cave in the 100-B/C Area was also completed in 2003. Decontamination and decommissioning activities were also initiated in 100-N Area with demolition of the 1304-N Emergency Dump Tank, which was in progress.

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 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 seed, shrub seedlings, and native grass-plugs. The final Environmental Restoration Disposal Facility mitigation planting was completed in November 2003.

Groundwater Remediation Project. The Groundwater Remediation Project (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.4 is a summary of groundwater and vadose zone protection activities conducted in 2003. Figure S.1 shows the location of groundwater remediation systems.

Office of River Protection. The Office of River Protection manages the DOE's River Protection Project, which is responsible for storage, retrieval, treatment, and disposal of high-level tank waste and closure of tank farms on the Hanford Site (Section 2.3.9). The status of 177 waste tanks on the Hanford Site was reported in *Waste Tank Summary Report for Month Ending December 31, 2003*.

During the year, more than 1 million liters (300,000 gallons) of waste was pumped from single-shell tanks into the double-shell tank system. At the end of 2003, tank 241-U-108 was the only remaining single-shell tank that still needs to be stabilized.

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

Table S.4. Summary of Groundwater Pump-and-Treat Systems and a Vadose Zone Soil-Vapor Extraction System

Location	Startup Date	Contaminant	Mass Removed 2003	Mass Removed – Since Startup
Groundwater Pump-and-Treat Systems				
100-D and 100-H Areas	1997	Hexavalent chromium	43 kilograms (94.7 pounds)	204 kilograms (450.4 pounds)
100-K Area	1997	Hexavalent chromium	36.7 kilograms (80.9 pounds)	221.9 kilograms (489.2 pounds)
100-N Area	1995	Strontium-90	0.20 curies	1.45 curies removed; ~12 curies decayed naturally
200-West Area (200-ZP-1) Operable Unit	1994	Carbon tetrachloride	799 kilograms (1,761 pounds)	7,848 kilograms (17,302 pounds)
200-West Area (200-UP-1) Operable Unit	1994	Carbon tetrachloride	2.7 kilograms (6 pounds)	26.04 kilograms (57.4 pounds)
	1994	Nitrate	3.191 kilograms (7,035 pounds)	27,343 kilograms (60,290 pounds)
	1994	Technetium-99	10.1 grams (0.0222 pound)	103.3 grams (0.2316 pound)
	1994	Uranium	18.2 kilograms (40.1 pounds)	181 kilograms (399 pounds)
Soil-Vapor Extraction				
200-West Area	1992	Carbon tetrachloride	294 kilograms (658 pounds)	78,092 kilograms (172,163 pounds)

During 2003, CH2M HILL Hanford Group, Inc. retrieved waste from tank 241-C-106, dissolving and mobilizing the waste with an acid solution. Retrieval also began at tank 241-S-112, where water was used to dissolve and mobilize the waste. Evaluation of a third waste retrieval technology, the mobile retrieval system, continued. This third technology is intended for use on solid waste. It consists of a remote controlled in-tank vehicle (used to push tank waste to a central location) and an articulated mast (used to guide the vacuum pump intake to the waste positioned for retrieval by the in-tank vehicle). Workers plan to deploy the articulated mast in 2004 for waste retrieval in the C-200 series tanks. The entire mobile waste retrieval system, both the mast and the in-tank vehicle, is planned for deployment in 2005 to retrieve waste from the C-100 series tanks.

The DOE revised the closure plan for the single-shell tank system during 2003 based on comments received from the Washington State Department of Ecology. The process and integration necessary to achieve accelerated closure of single-shell tanks and waste management areas and the first closure activities will be performed on tank 241-C-106.

CH2M HILL Hanford Group, Inc. selected a single supplemental treatment technology, bulk vitrification, for further evaluation of treatment of retrieved low-activity tank waste and is pursuing a field assessment of that technology. The evaluation will address the feasibility of using vitrification (i.e., heating and melting inert materials to form a solid glass matrix) to immobilize low-activity waste in a form suitable for disposal. Planning and design have begun for a 2005 demonstration, and the required environmental permit applications have been submitted.

In addition, CH2M HILL Hanford Group, Inc. continues its evaluation of a separate disposal path for select mixed transuranic tank waste. The approach will include onsite treatment and packaging for shipment and final disposal at the DOE Waste Isolation Pilot Plant in New Mexico. The National Environmental Policy Act documentation and environmental permit applications have been prepared, and a contract was awarded for design and fabrication of the waste treatment and packaging system.

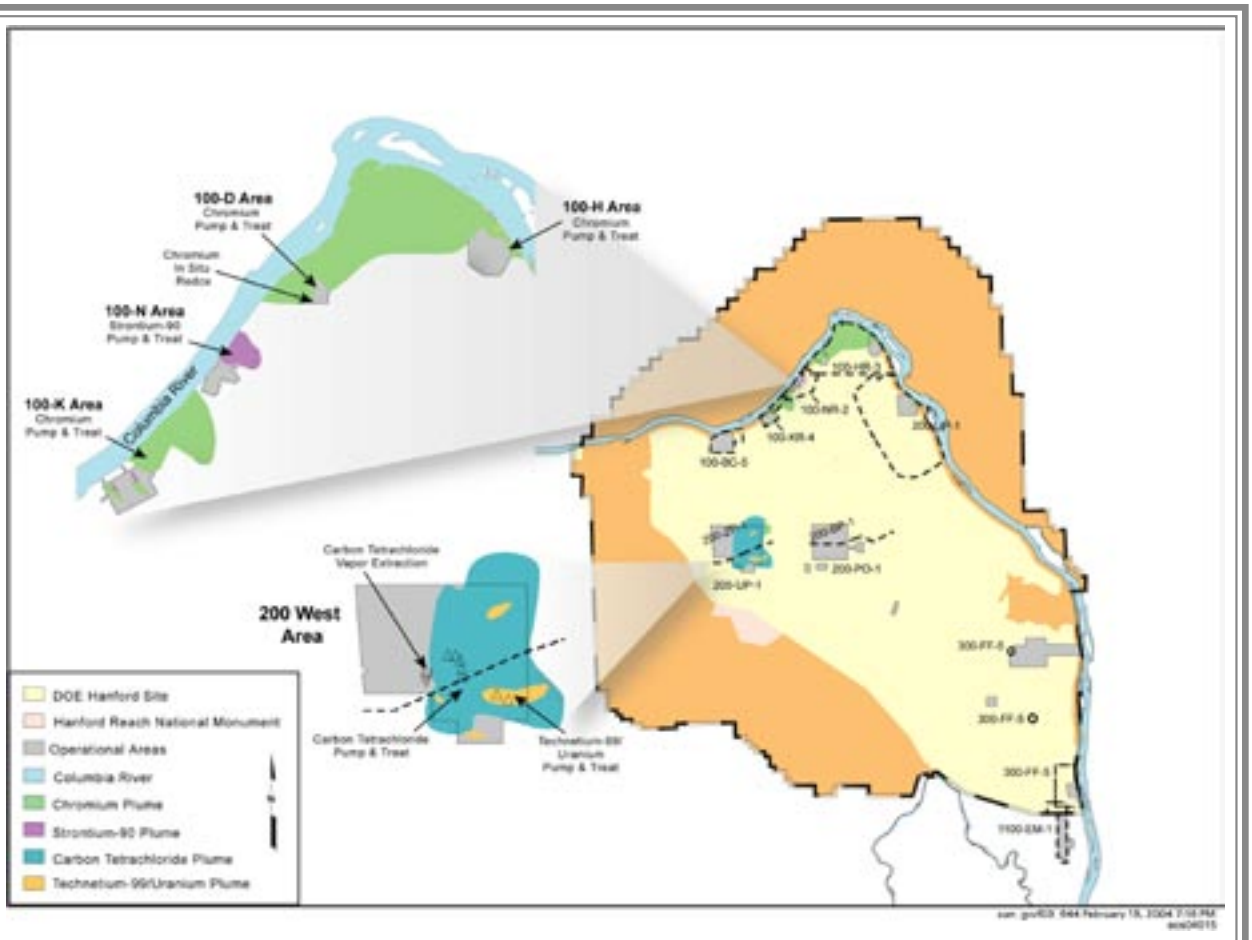

Figure S.1. Hanford Site Groundwater Pump-and-Treat and Soil-Vapor Extraction Systems

Geophysical Logging. S.M. Stoller Corporation is responsible for all geophysical logging at the Hanford Site (Section 2.3.9.3). Log data are collected in new and existing boreholes to support ongoing remedial investigation activities conducted by other Hanford contractors. S.M. Stoller Corporation is also responsible for a baseline characterization program, where the objective is to log all existing boreholes associated with waste disposal sites on the Hanford Central Plateau and establish a baseline of vadose zone contamination conditions against which future measurements can be compared to assess contaminant mobility.

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 monitoring in 2003 was to identify changes in contaminant levels.

Waste Immobilization. The Waste Treatment Plant is being built on 26 hectares (65 acres) located on the Central Plateau outside of 200-East Area to treat radioactive and hazardous waste currently stored in 177 underground tanks (Section 2.3.9.5). 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 2003, construction continued on the Pretreatment Plant building (approximately 27% complete), High-Level Waste Vitrification Plant building (approximately

10% complete), and Low-Activity Waste Vitrification Plant building (approximately 13% complete). The balance of facilities, which includes support facilities and utilities not associated with the Pretreatment Plant, High-Level Waste Vitrification Plant, or Low-Level Waste Vitrification Plant, is approximately 25% complete.

Potential Radiological Doses from 2003 Hanford Operations

During 2003, potential radiological doses to the public and biota from Hanford operations were evaluated to determine compliance with pertinent regulations and limits (Chapter 5). The methods used to calculate the potential doses are presented in Appendix E. The potential dose to the offsite maximally exposed individual in 2003 was 0.06 mrem (0.6 μSv) per year. 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 approximately 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 (Section 7.1). Weather forecasting and maintenance and distribution of climatological data are provided. A complete listing of climatological data for calendar year 2003 is contained in *Hanford Site Climatological Data Summary 2003 with Historical Data*.

Calendar year 2003 was slightly warmer than normal and precipitation was above normal.

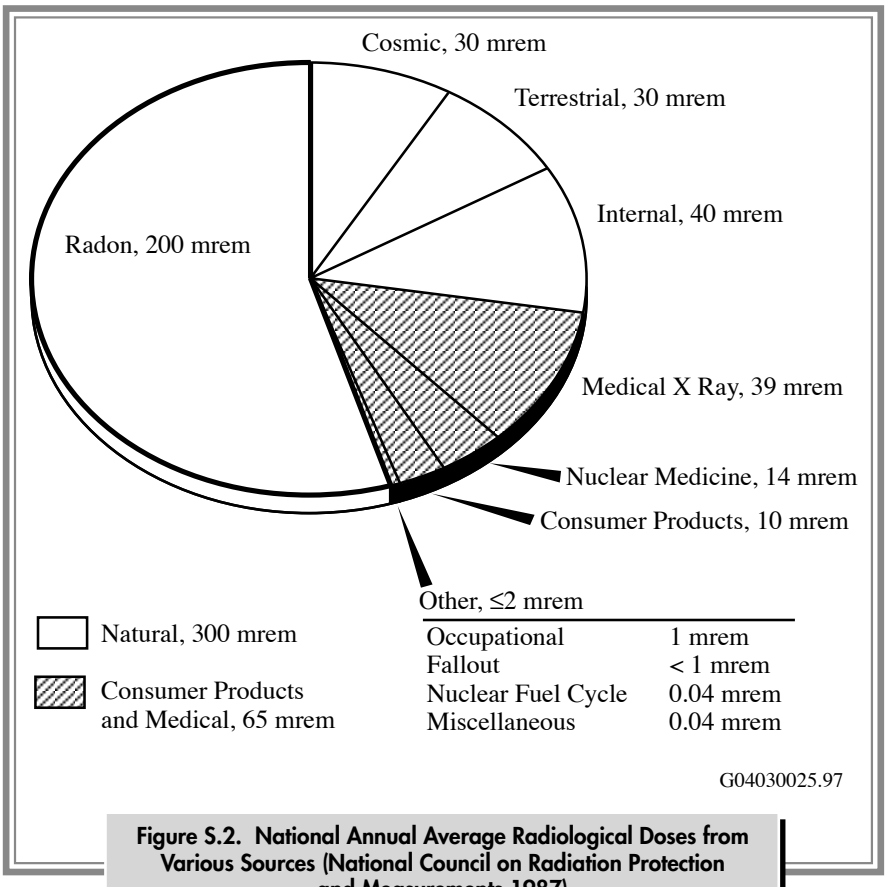

Figure S.2. National Annual Average Radiological Doses from Various Sources (National Council on Radiation Protection and Measurements 1987)

The average temperature for 2003 was 13.1°C (55.6°F), which was 1.1°C (2.0°F) above normal (12.0°C [53.6°F]). Nine months during 2003 were warmer than normal; three months were cooler than normal. January had the greatest positive departure, 3.4°C (6.2°F); and November, at 1.3°C (2.3°F) below normal, had the greatest negative departure.

Precipitation during 2003 totaled 20.7 centimeters (8.14 inches), 117% of normal (17.7 centimeters [6.98 inches]). Snowfall for 2003 totaled 22.1 centimeters (8.7 inches) (compared to an annual normal snowfall of 39.1 centimeters [15.4 inches]).

The average wind speed during 2003 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 26.8 meters per second (60 miles per hour) on October 28. There were two dust storms recorded at the Hanford Meteorology Station on the Central Plateau during 2003 (March 5 and October 28). There has been an average of five dust storms per year at the Hanford Meteorology Station during the entire period of record (1945-2003).

Cultural Resources

The DOE is responsible for managing and protecting the Hanford Site's cultural and historic resources. The Hanford Cultural and Historic Resources Program, which is maintained by DOE, assures that cultural and historic resources entrusted to DOE are managed responsibly and in accordance with applicable regulatory requirements.

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. As such, cultural resource reviews are required at Hanford 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. During 2003, 142 cultural resource reviews were requested and conducted. Of the areas reviewed, 2 were monitored during the construction phase; 6 projects required an archaeological survey; and 21 involved proposed building modifications, demolitions, and exemptions from the Programmatic Agreement for the Built Environment. The remaining reviews (113) involved areas that had been previously surveyed or were located on previously disturbed ground.

Routine monitoring of known cultural sites is performed to evaluate the potential impacts of DOE operations on cultural resources and safeguard them from adverse effects associated with natural processes or unauthorized excavations and collections that violate federal laws. Monitoring conducted during 2003 focused on erosion on Locke Island (located in the Hanford Reach), archaeological sites with natural and visitor impacts, historic buildings and structures, and Native American sites.

During 2003, 53 archaeological sites, 5 buildings, and 15 cemetery or burial locations were monitored to gather data about the characteristics of each site, processes adversely affecting the site, and changes at the site. Of the findings recorded at these monitored places, most were related to natural causes.

Locke Island contains some of the best preserved evidence of prehistoric village sites existing in the Columbia Basin. It is included within the Locke Island National Register Archaeological District. It has sustained loss due to erosion along its eastern shoreline that has affected archaeological materials. Surveys in 2003 recorded erosional losses of up to 3.3 feet, as measured perpendicularly from the Columbia River.

Monitoring of historic buildings during 2003 focused on Bruggemann's Warehouse, the only pre-1943 cobblestone structure remaining on the Hanford Site; the First Bank of White Bluffs building; Coyote Rapids Pumping Plant; Hanford town site electrical substation; and the Hanford town site high school. The buildings were photographed and locations of structural deterioration were identified.

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. Overall, places with human remains were found to be stable during 2003. No violations were noted.

Native American and public involvement are important components of cultural resource management. During 2003, four tribal meetings on cultural resources provided

a venue for exchange of information between DOE, tribal staff members, and site contractors about projects and work on the Hanford Site. Similarly, a public issues exchange meeting was held during 2003 to hear comments and recommendations of the interested public concerning the management of cultural and historic resources at Hanford.

Since 2000, the public and Tribes provided comments on drafts of the *Hanford Cultural Resources Management Plan*. The management plan was submitted to DOE for approval in December 2002, and was approved and published in February 2003.

In addition, interviews are occasionally conducted with early residents of areas now part of the Hanford Site as well as Native Americans, former Hanford Site workers, and current site employees to document the historical perspective of those present during past Hanford operations. In 2003, past interviews were inventoried and summarized in the *Hanford Cultural Resources Laboratory Oral History and Ethnography Task Annual Report*.

Biological Control Program

The Biological Control Program was established in 1998 to prevent, limit, clean up, or remediate the impact of contaminated or undesirable plants or animals to the environment or to human health and safety. The program integrates (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 2003, 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. Onsite, 32 incidents of contaminated vegetation occurred. This is a decrease of 52% compared to the peak year of 1999 (84), but a two-fold increase over 2002 (16).

There were approximately 17,000 animal control responses in 2003, and approximately 750 trap/bait stations were used to control populations of rodents in and near facilities and offices. Increased vegetation control continued to provide fewer locations for animals to hide and live in critical areas. There were 26 contaminated animals discovered during 2003. This is approximately 57% less than the peak number of 46 in 1999, but is a 2.6-fold increase over the total for 2002 (10).

Flying insects on the Hanford Site were routinely monitored for radiological contaminants. Nineteen of the contaminated animal samples collected in 2003 were related to flying insects (wasps) in the area of the H Reactor decommissioning effort.

Ten plant species categorized as noxious by the U.S. and Washington State Departments of Agriculture, and found to be replacing native species on the Hanford Site, are on a high priority list for control at the Hanford Site. These species are yellow star thistle (*Centaurea solstitialis*), rush skeletonweed (*Chondrilla juncea*), medusahead (*Taeniatherum asperum*), babysbreath (*Gypsophila paniculata*), dalmatian toadflax (*Linaria genistifolia ssp. Dalmatica*), spotted knapweed (*Centaurea maculosa*), diffuse knapweed (*Centaurea diffusa*), Russian knapweed (*Acroptilon repens*), saltcedar (*Tamarix spp.*), and purple loosestrife (*Lythrum salicaria*). Because these species can adversely affect the natural habitat, they are specifically targeted for control by chemical, physical, or cultural (i.e., introducing natural insect predators) means.

Community-Operated Environmental Surveillance Program

This program was initiated in 1990 to increase the public's involvement in and awareness of Hanford's environmental surveillance program. During 2003, four radiological air sampling stations were operated at schools near the Hanford Site. Area teachers at Basin City, Richland, and Toppenish, Washington, and at Edwin Markham Elementary School in Franklin County manage the stations.

Quality Assurance

Comprehensive quality assurance programs, which include various quality control practices and methods to verify data, are maintained by monitoring and surveillance projects to assure 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 used in 2003 included replicate sampling and analysis, analysis of field blanks and blind reference standards, participation in interlaboratory crosscheck studies, and splitting samples with other laboratories.

In 2003, sample collection and laboratory analyses were conducted using documented and approved procedures. When sample results were received, they were 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

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The report was prepared by Pacific Northwest National Laboratory staff: LF Morasch, text editor, and KR Neiderhiser, text processor. Graphics were prepared by DL Liddell (Lockheed Martin Services, Inc.), CA Newbill, JT Rieger, and RK Zufelt (Pacific Northwest National Laboratory). SB Villarreal (Pacific Northwest National Laboratory) designed the report cover and layout. Duplicating and printing arrangements were managed by SJ Kophs, who was supported by OP Valadez and MI Barrera. This report was produced using Adobe® InDesign and formatted for the Internet by DA Schulz and others in Pacific Northwest National Laboratory's Scientific and Technical Information Department.

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: CA Wagner, Manager, and DR Johns, Alternate Manager

Basin City Elementary School, Basin City: CL Stevenson, Manager, and K McEachen, Alternate Manager

Edwin Markham Elementary School, North Franklin County: MP Madison, Manager, and KA Thomas, Alternate Manager

Heritage College, Toppenish: RA Landvoy, Manager, and H Ferguson, Alternate Manager.

Contents

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1.0 Introduction

R. W. Hanf

This report, published annually since 1958, includes information and summary analytical data that (1) provide an overview of activities at the Hanford Site during calendar year 2003; (2) demonstrate the site's compliance with applicable federal, state, and local environmental laws and regulations, executive orders, and U.S. Department of Energy (DOE) policies and directives; (3) 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 conducted for the following programs and projects:

- Effluent and Near-Facility Environmental Monitoring Programs.
- Surface Environmental Surveillance Project.
- Groundwater Performance Assessment Project.
- Vadose Zone Monitoring Programs.
- Meteorological and Climatological Services Project.
- Ecosystem Monitoring and Ecological Compliance Project.
- Hanford Cultural Resources Laboratory.
- 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 is presented to assist the reader in understanding this report and provide additional details about environmental monitoring. Appendix A contains helpful information about units of measure, scientific notation, unit conversions, and interpreting graphs. Appendix B is a glossary of terms used in this report. Appendix C contains specific monitoring results for calendar year 2003 to supplement the summary information provided in this report. Appendix D contains information about a variety of government standards and permits that are pertinent to Hanford Site operations. Appendix E contains information about radiological dose calculations. Appendix F contains a list of radionuclides detected and measured by gamma spectroscopy. Appendix G contains information about threatened and endangered species, candidate or sensitive animal species, and plant species of concern occurring or potentially occurring on the Hanford Site.

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 focused on the development of new waste treatment and disposal technologies and characterizing and remediating materials and contamination left from historical operations.

Currently, the Hanford Site's primary mission is accelerating the completion of waste cleanup. The report *Performance Management Plan for the Accelerated Cleanup of the Hanford Site* (DOE/RL-2002-47) states that the cleanup mission includes six strategies:

1. Restoring the Columbia River corridor by accelerating cleanup of 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. Ending the tank waste program by 2033 by accelerating waste retrieval, increasing the capacity of the Waste Treatment Plant, and starting the process of closing waste tanks.
3. Accelerating the cleanup of Hanford's other urgent risks.
4. Accelerating treatment and disposal of mixed low-level waste, and the retrieval of transuranic waste and its shipment off the site.
5. Accelerating cleanup of excess facilities on the Central Plateau.
6. Accelerating cleanup and protection of groundwater beneath the Hanford Site.

The goal of these strategies is to accelerate the completion of site cleanup, excluding tanks, from 2070 to 2035, and possibly as soon as 2025, and to do so in a cost-effective manner that protects public health and safety and the environment.

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 approximately 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 the following locations:

- **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 approximately 11 square kilometers (4 square miles).
- **200-West and 200-East Areas** – centrally located on a plateau. These areas are approximately 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-East and 200-West Areas cover a total of approximately 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 activities 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 approximately 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 and decommissioning during 2004/2005. This nuclear reactor was designed to test various types of nuclear fuel. The 400 Area covers approximately 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 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 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 the 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.

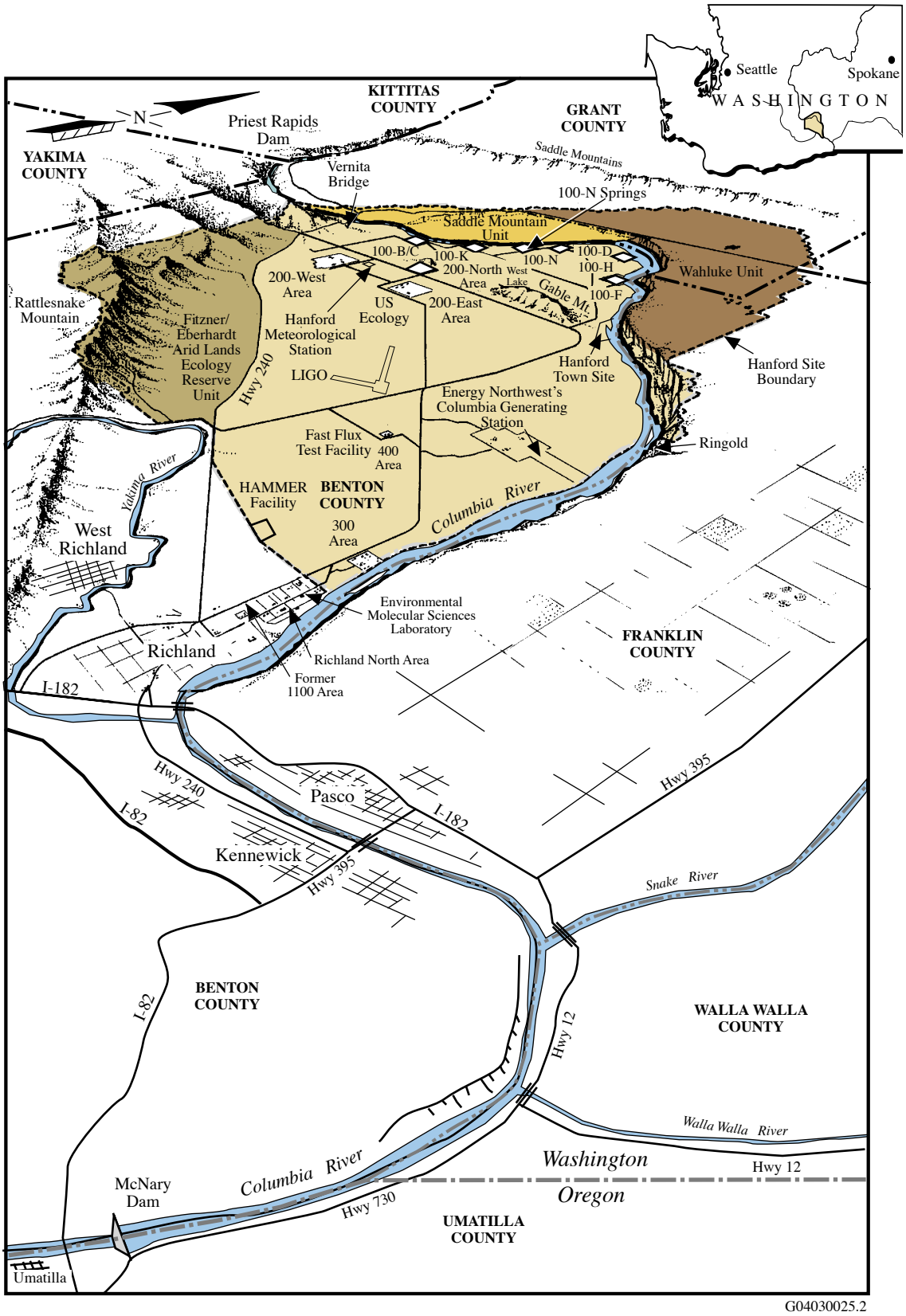

Figure 1.0.1. The Hanford Site and Surrounding Area

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 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 [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 and sponsored by the National Science Foundation. R. H. Smith Distributing operates vehicle-fueling stations in the 200 Areas. 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.

Near the city of Richland, immediately adjacent to the southern boundary of the Hanford Site, AREVA (formerly Framatome ANP) operates a commercial nuclear fuel fabrication facility and Pacific EcoSolutions (formerly 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 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 Pacific Northwest Site Office of the DOE Office of Science oversees Pacific Northwest National Laboratory in support of the DOE's Science and Technology programs, goals, and objectives. Pacific Northwest National Laboratory is a DOE facility operated by Battelle Memorial Institute for the 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. The U.S. Fish and Wildlife Service manages portions of the Hanford Reach National Monument.

The DOE Richland Operations Office. The DOE Richland Operations Office serves as landlord of the Hanford Site and manages legacy cleanup, research, and other programs.

During 2003, 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 in 2003 were CH2M HILL Hanford, Inc. and Eberline Services Hanford, Inc. Washington Closure Company, LLC, was awarded the River Corridor Closure Contract in April 2003. This team of companies consisting of Washington Group International, Inc., Fluor Federal Services, and Earth Tech, LLC, would replace Bechtel Hanford, Inc. and the personnel from Fluor Hanford, Inc. doing 300 Area decontamination and decommissioning work. A protest over the contract award was filed by Bechtel National, Inc. in May 2003 and this halted the transition of work from Bechtel Hanford, Inc. and Fluor Hanford, Inc. to the Washington Closure Company. As of early calendar year 2004, the outcome of the protest remained uncertain and Bechtel Hanford, Inc. and Fluor Hanford Inc. were continuing with the actual cleanup work.
- Fluor Hanford, Inc. is the primary management contractor for Project Hanford. It manages and integrates work to support cleanup of former DOE nuclear production facilities at the site. In 2003, 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 Government Group.

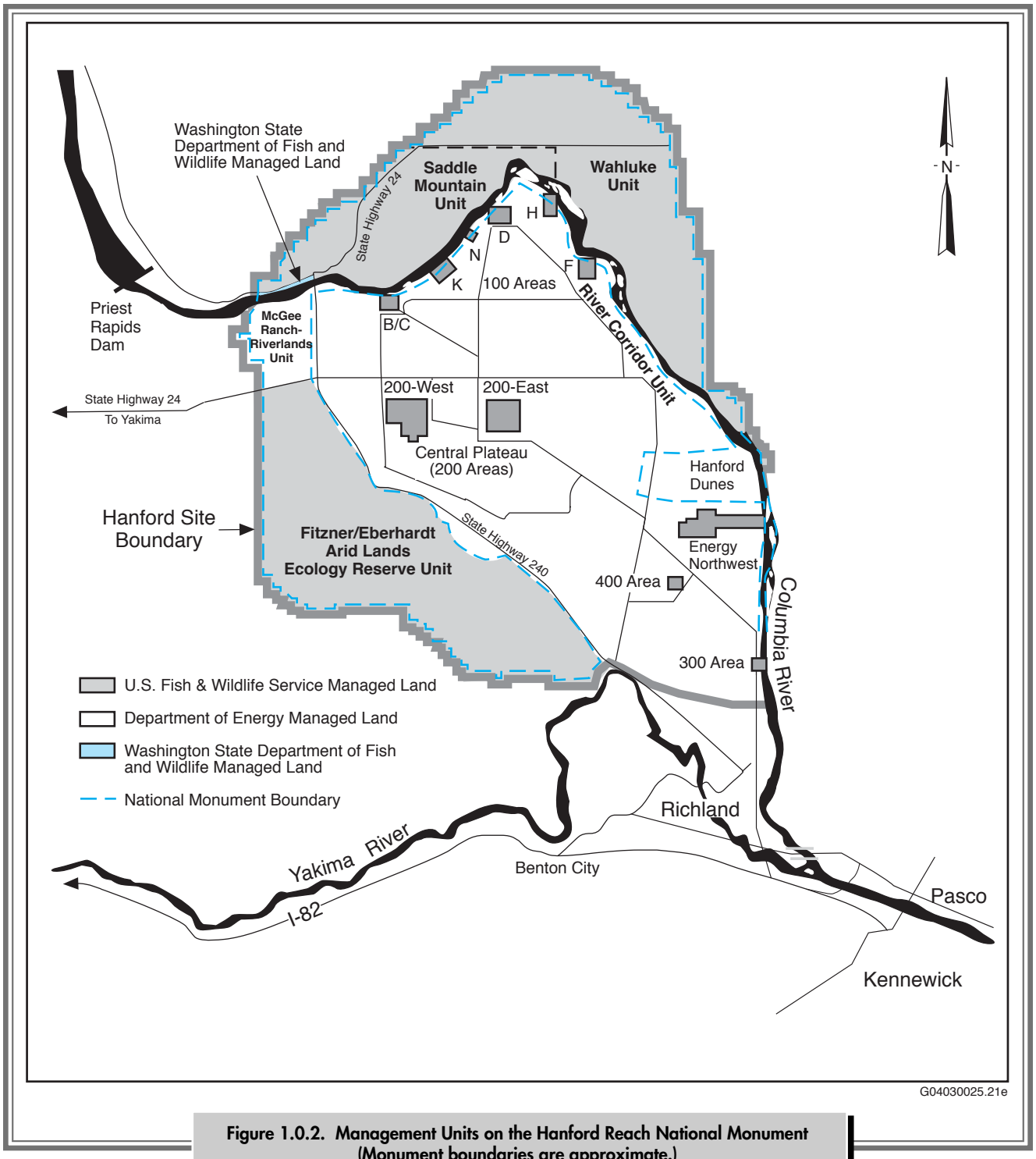

Figure 1.0.2. Management Units on the Hanford Reach National Monument (Monument boundaries are approximate.)

- The Hanford Environmental Health Foundation was the occupational health contractor on the site in 2003. The foundation 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. In June 2004, AdvanceMed of Reston, Virginia, took over occupational medical services at the Hanford Site, replacing the Hanford Environmental Health Foundation, which had provided these services at the site for 38 years.
- S.M. Stoller Corporation monitors and characterizes radioactive contamination in the vadose zone for both the DOE Richland Operations Office and DOE Office of River Protection. The primary goal of activities performed for the DOE Richland Operations Office is characterization of liquid waste disposal sites and solid waste burial grounds on the Central Plateau. For the DOE Office of River Protection, the effort involves vadose zone monitoring around the single-shell tanks to detect continuing migration of contamination resulting from tank leaks or other contamination sources.

The DOE Office of River Protection. The DOE Office of River Protection was established by Congress in 1998 as a field office to manage Hanford tank waste retrieval, treatment, and disposal.

The principal contractors for the DOE Office of River Protection in 2003 and their respective responsibilities included the following:

- **Bechtel National, Inc**. – Bechtel National, Inc.'s contract mission is to design and build 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 subcontractor to Bechtel National, Inc., Washington Group International is a participant in the mission to design and construct the Waste Treatment (vitrification) Plant.
- **CH2M HILL Hanford Group, Inc**. – This contractor has the responsibility to retrieve and store for treatment about 201 million liters (53 million gallons) of radioactive and chemically 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.

Hanford Reach National Monument. During 2003, the DOE, U.S. Fish and Wildlife Service, and Washington Department of Fish and Wildlife managed the Hanford Reach National Monument. The U.S. Fish and Wildlife Service administered three major management units of the monument totaling about 668 square kilometers (258 square miles). These included (1) the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit, a 312-square-kilometer (120-square-mile) tract of land with no public access in the southwestern portion of the Hanford Site; (2) the Saddle Mountain Unit, a 130-square-kilometer (50-square-mile) tract of land with no public access 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 1.0.2).

The portion of the monument administered by the DOE included the McGee Ranch/Riverlands Unit (north and west of State Highway 24 and south of the Columbia River), the Columbia River Islands Unit in Benton County, the Columbia River corridor (one-quarter mile [0.4 kilometer] inland from the Hanford Reach shoreline) on the Hanford (Benton County) side of the river, and the Hanford 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 were managed by Washington 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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DOE/RL-2002-47, Rev. D. 2002. *Performance Management Plan for the Accelerated Cleanup of the Hanford Site*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available URL: http:///www.hanford.gov/docs/hpmp

2.0 Environmental Regulatory Compliance

J. P. Duncan

This chapter describes how the U.S. Department of Energy (DOE) and its contractors achieve and maintain environmental and regulatory compliance. Sections 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 operations 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 the 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. 1989) 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 Agency and Public Involvement

J. P. Duncan

A number of federal, state, and local governmental agencies; tribal governments; advisory boards; activist groups; and individuals exercise various roles with respect to the DOE's mission of waste management, environmental restoration, and protection of public health and safety at the Hanford Site. For example, federal and state agencies exercise a mandated regulatory role over contaminant releases and concentrations of contaminants in various media; several tribes assure, through a government-to-government relationship with the DOE, that treaty rights and other values important to Native Americans are taken into account. The roles of some of the regulatory agencies, organizations, and the public are addressed in the following sections.

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.

The 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, the 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 the EPA's requirements. For instance, the EPA has delegated the authority for enforcement of certain air pollution control and hazardous waste management regulations to Washington State Department of Ecology. In other activities, the state program is assigned direct environmental oversight of the DOE, as provided by federal law. For example, Washington State Department of Health has direct authority under the Washington State *Clean Air Act* to enforce its 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 DOE is required to submit an annual report on radionuclide emissions at the Hanford Site. Where federal regulatory authority is not delegated or only partially authorized to the state, the EPA Region 10 is responsible for reviewing and enforcing compliance with EPA regulations as they pertain to the Hanford Site. The EPA periodically reviews state environmental programs and may directly enforce federal environmental regulations.

Although Oregon does not have regulatory authority at the Hanford Site, the DOE recognizes its interest in Hanford Site cleanup because of the site's location along the Columbia River, upriver from where the river serves as a border between Washington and Oregon. 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, and participates in the Hanford Natural Resource Trustee Council.

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. 1989) 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 to meet the changing conditions and needs of site 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 DOE's Public Reading Room located in the Consolidated Information Center in 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 the 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

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 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 special and unique legal and political relationship with the government of the United States defined by history, treaties, statutes, court decisions, and the U.S. Constitution. In recognition of this relationship, the 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 Cultural Resources Program, and provide review and comments on draft documents. Both the Wanapum and the Confederated Tribes of the Colville Reservation also are provided an opportunity to comment on documents and participate in cultural resource management activities.

The DOE American Indian and Alaska Native Tribal Government Policy (revised in November 2000) guides the 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 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. The DOE provides financial assistance 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 of 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 the 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. In that regard, 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 Department of Fish and Wildlife, and Oregon Department of Energy.

The DOE cooperates and coordinates with trustees and has coordinated assessments, investigations, and planning; and devised and implemented 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 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 2003 to discuss cleanup issues concerning the Central Plateau and Columbia River Corridor. In addition to cooperation and information sharing, the council is preparing a project management plan to guide coordination of response work between the DOE and other natural resource trustees. Information about the council, including its history and projects, can be found at http://www.hanford.gov/boards/nrtc.

2.1.5 Public Participation

Y. T. Sherman

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 (the 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. The Washington State Department of Ecology, DOE, and EPA developed and revised the plan with input from the public. The plan was approved in 1990 and 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 news media.

To inform the public of upcoming opportunities for public participation, The Hanford Update, a synopsis of all ongoing and upcoming Tri-Party Agreement public involvement activities, is published approximately 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 from the Washington State Department of Ecology Hanford Cleanup Line at 1-800-321-2008. 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

Y. T. Sherman

The Hanford Advisory Board was chartered during January 1994 under the *Federal Advisory Committee Act* to advise the 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 the 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 committees: two technical committees (River and Plateau Committee and Tank Waste Committee) and three cross-site committees (Budgets and Contracts, Health Safety and Environmental Protection, and Public Involvement and Communications).

The board held six 2-day meetings during 2003. Members are engaged in discussions with representatives from the Tri-Party Agreement agencies on major cleanup issues; plans to treat tank waste and the role of supplemental technologies; storage, treatment and/or disposal of waste; and budget priorities. The board issued 12 pieces of consensus advice, 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. 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.

2.2 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 also 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. 1989) commits the 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 2003, a total of 809 milestones have been completed and 282 target dates have been met. During 2003, there were 36 specific cleanup milestones scheduled for completion: 35 were completed on or before their required due dates and 1 was completed beyond its established due date.

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 2003 milestones completed under the terms of the Tri-Party Agreement:

- **M-015-38A** – Submit 200-CW-1 Gable Mountain Pond/B Pond and Ditch Cooling Water Group Feasibility Study and Proposed Plan/Proposed RCRA Permit Modification.
- **M-015-39A** – Complete chemical sewer group field work through sample collection and analysis.
- **M-015-40B** – Submit Draft A 200-CW-5 U Pond/Z-Ditches Cooling Water Group Remedial Investigation Report including the past-practice waste site in the 200-CS-2 S-Ponds/Ditches Cooling Water Group, 200-CW-4 T-Ponds/Ditches Cooling Water Group, and 200-SC-1 Steam Condensate Group.
- **M-015-47** – Submit a proposed plan to the EPA and/or Washington State Department of Ecology to conduct remedial action(s) for source control at a high-risk waste site(s) which includes an engineering evaluation of an engineered surface barrier.
- **M-016-27C** – Complete 100-HR-3 Phase III, in situ redox manipulation barrier emplacement, planning, well installation, and barrier emplacement.
- **M-016-28A** – Connect well 199-K-126 to the 100-KR-4 pump-and-treat extraction system.
- **M-020-29B** – Submit sodium storage facility and sodium reaction facility closure plan or request for procedural closure to the Washington State Department of Ecology as defined in Agreement Section 6.3.3.
- **M-020-56** – Submit Canister Storage Facility Part B dangerous waste permit application to the Washington State Department of Ecology.

- **M-020-57** – Submit immobilized low-activity tank waste disposal facility certified Part B permit application to the Washington State Department of Ecology.

- **M-023-25C** – Complete the installation of liquid observation wells and begin weekly liquid observation monitoring for four single-shell tanks.

- **M-023-25D** – Complete the installation of liquid observation wells and begin weekly liquid observation monitoring for four additional single-shell tanks.

- **M-023-26** – Submit to the Washington State Department of Ecology, as a primary document, a schedule to perform liquid-level assessments for single-shell tanks 241-AX-151-CT, 241-BY-ITS2 tank 2, 241-AX-IX, 241-BY-ITSH1.

- **M-024-57** – The DOE shall install a minimum of 15 groundwater monitoring wells by December 31, 2003.

- **M-026-01M** – Submit an annual Hanford land disposal restrictions report in accordance with Agreement requirements to cover the period from January 1, 2002 through December 31, 2002.

- **M-043-16** – Start construction for upgrades in the fifth tank farm.

- **M-045-02L** – Submit annual updates to single-shell tanks retrieval sequence document.

- **M-045-03D** – Complete S-112 saltcake waste retrieval technology demonstration design (to include all physical systems including design and operating strategies necessary for leak detection monitoring and mitigation). The design will be considered complete when 90% of the design has been approved for fabrication and/or construction.

- **M-045-05B** – Complete S-102 initial retrieval project design (to include all physical systems including design and operating strategies necessary for leak detection monitoring and mitigation). The design will be considered complete when 90% of the design has been approved for fabrication and/or construction.

- **M-045-05D** – Establish completion date for the second (single-shell) tank initial waste retrieval.

- **M-045-11** – Complete 244-AR vault interim stabilization.

- **M-046-00J** – Complete the double-shell tank space evaluation. A tank volume projection report shall be submitted on an annual basis to the Washington State Department of Ecology and EPA.

- **M-046-01I** – Concurrence of additional tank acquisition and establish new milestones, if required.

- **M-048-02F** – Submit to Washington State Department of Ecology a report assessing technology to 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-048-02G** – Submit to Washington State Department of Ecology a report assessing technology to 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-048-11** – Submit a written report to Washington State Department of Ecology documenting results of ultrasonic testing of the primary tank walls in four double-shell tanks not previously examined.

- **M-062-01F** – Submit an Office of River Protection Project Compliance Report.

- **M-062-01G** – Submit an Office of River Protection Project Compliance Report.

- **M-062-07A** – Initial erection of Low-Activity Waste Vitrification Facility elevation -21 feet structural steel columns, beams and Q Deck at elevation +3.

- **M-081-12** – Initiate Fast Flux Test Facility sodium drain. This milestone will be complete when the drain of the first secondary loop is begun. Completion will be achieved when all the preparatory actions (i.e., procedures written and approved, plant configuration line-up, operator training, facility startup review) have been completed and sodium is being transferred to tank T-44.

- **M-083-20** – Submit facility transition end-point criteria document as a primary document to Washington State Department of Ecology pursuant to Agreement Action Plan Section 8.5.3.
- **M-083-30** – Submit to Washington State Department of Ecology a closure plan as a primary document for the 241-Z waste treatment facility and glovebox HA-20MB.
- **M-091-03A** – Submit revision of the Hanford Site transuranic mixed waste and mixed low-level waste project management plan to Washington State Department of Ecology.
- **M-091-40 (Partial)** – The DOE shall first initiate retrieval at its burial ground 218-W-4C no later that November 15, 2003.
- **M-091-40 (Partial)** – In regard to the carbon tetrachloride vapor plume in the vadose zone in the vicinity of trench 4 in burial ground 218-W-4C, the DOE shall start vapor extraction by November 15, 2003 to reduce carbon tetrachloride vapors.
- **M-093-16** – Complete the DR Reactor interim safe storage.

Milestone completed after its established due date in 2003 under the terms of the Tri-Party Agreement:

- **M-034-28** – Complete removal of spent nuclear fuel equivalent to 1,619 metric tons (1,785 tons) heavy metal from the KW Basin (completed on January 13, 2004, 13 days after its due date of December 31, 2003).

2.2.1.2 Approved Modifications to the Tri-Party Agreement

During 2003, 25 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 Order 450.1, are intended to protect the worker, public, and environment by integrating environment, safety, and health into the way work is planned and performed. 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.

The DOE has verified the following Hanford Site 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 Pacific Northwest National Laboratory (1998). Efforts continued in 2003 to implement and improve these environmental, safety, and health programs. 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://wwwi.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. Since 2002, Bechtel Hanford, Inc. has maintained performance measures and indicators to monitor the health function of their Integrated Safety Management System (BHI-01550).

2.2.3 Chemical Management Systems

M. T. Jansky

The DOE, through its contractors, uses a variety of approaches for chemical management in processes and

Table 2.2.1. Hanford Site Tri-Party Agreement Change Requests Approved During 2003

Change Request	Date Approved	Title
L-03-01	04-07-03	Update EPA Executive Manager/Interagency Management Integration Team member title
M-013-03-01	10-23-03	Modify completion date for Tri-Party Agreement major milestone M-013-00N
M-16-03-01	03-27-03	Complete remediation of the waste sites in the 300-FF-1 Operable Unit to include excavation, verification, and re-grading, including the 618-4 burial ground in accordance with an approved remedial design report/remedial action work plan
M-16-03-02	09-05-03	Modification of Tri-Party Agreement interim milestone M-016-63
M-23-02-02	06-30-03	Modification of Tri-Party Agreement and milestone M-23 to reflect the agreements reached in dispute resolution to proposed Washington State Department of Ecology Change Request Package M-23-02-02
M-26-02-01	04-02-03	Modification of the reporting frequency for the tritium treatment technology report prepared under Tri-Party Agreement interim milestone M-026-05
M-45-02-03	04-22-03	Modification of Tri-Party Agreement requirements regarding retrieval and closure of Hanford Site single-shell tanks. Establishment of single-shell tanks retrieval and closure demonstration projects, associated regulatory (hazardous waste facility closure and post-closure plan and the Hanford Facility RCRA Permit (Permit No. WA7890008967) [site-wide permit]) process documentation requirements, and related double-shell tank space optimization activities.
M-45-02-06	01-30-03	Modification of Tri-Party Agreement milestones M-045-05D and M-45-05F in order to allow necessary time to finalize the M-45-02-03 change request which when finalized completes the requirements of milestones M-045-05D and M-045-05F
M-45-03-01	09-18-03	Modification of Tri-Party Agreement interim milestone M-45-00 series and target due dates pertaining to retrieval and closure activities of Hanford Site single-shell tanks S-112 and S-102
M-45-03-02	03-27-03	Modification of Tri-Party Agreement milestones M-045-05D and M-45-05F in order to allow necessary time to finalize the M-45-02-03 change request which when finalized completes the requirements of milestones M-045-05D and M-045-05F
M-45-03-04	06-30-03	Modification of Tri-Party Agreement requirements regarding leak detection monitoring and mitigation demonstrations, specifically deleting leak detection monitoring and mitigation demonstrations in single-shell tanks S-112 and S-102 and replacing the leak detection monitoring and mitigation demonstration requirements to at least one of the S-105, S-106, and S-103 single-shell tank retrieval and closures
M-45-03-05	10-27-03	Re-align completion dates for Tri-Party Agreement milestones M-45-55, M-45-58, and M-45-60
M-46-03-01	02-26-03	Modification of Tri-Party Agreement milestone M-46-01I in order to allow coordinated review of the need for additional tank storage space, including review of the DOE's single-shell tank retrieval sequence and double-shell tank space evaluation (RPP-8554, Rev. 1)
M-46-03-02	11-18-03	Modification of Tri-Party Agreement milestone M-46-01J to allow the completion of the M-45-00C milestone negotiations and continued review of the DOE's single-shell tank retrieval sequence and double-shell tank space evaluation (RPP-8554, Rev. 2)
M-47-03-01	12-24-03	Modification of Tri-Party Agreement requirements M-47-00, M-47-01, M-47-02, M-47-03, M-47-03A, M-47-04, and M-47-06 to accelerate joint agency decisions and establish the schedule regarding completion of tank waste treatment options
M-62-03-02	12-24-03	Modification of Tri-Party Agreement requirements M-62-00A, M-62-03, M-62-07B, M-62-08, M-62-09, M-62-10, M-62-11, and M-62-12 to accelerate joint agency decisions and schedule the establishment of requirements regarding the completion of tank waste treatment
M-81-02-01	05-21-03	Re-establish milestones and target dates for the shutdown (transition, pursuant to Tri-Party Agreement Section 8) of the Fast Flux Test Facility (milestones M-81-00 series and M-20-29A)
M-90-03-02	12-23-03	Modification of Tri-Party Agreement requirements M-90-10 and M-90-11 to accelerate joint agency decisions and establish the schedule regarding the completion of tank waste treatment options
M-91-02-02	01-02-03	Extend due date of milestone M-091-12A
M-91-03-02	08-11-03	Deletion of milestones M-91-06-T01 and M-91-14-T01
M-91-03-04	08-27-03	Milestone M-91-03 Project Management Plan initial revision due date modification
M-92-02-01	07-21-03	Re-establish Tri-Party Agreement interim milestones M-92-09 and M-92-10 associated with the management and disposition of DOE Hanford Site radioactive sodium as product.

Table 2.2.1. (contd)

Change Request	Date Approved	Title
M-92-03-02	04-01-03	Modify the Tri-Party Agreement interim milestone M-92-05, Inclusion of Hanford Site Cesium and Strontium Treatment and/or Repackaging Parameters in DOE Tank Waste Remediation System Phase II Request for Proposals (Treatment and/or Repackaging of all remaining Cesium and Strontium)
M-94-03-01	09-05-03	Modification of Tri-Party Agreement interim milestone M-094-01
P-10-02-01	03-25-03	Updates to Tri-Party Agreement Action Plan Sections 4.0, 10.0, 14.0, and Appendix E

EPA = U.S. Environmental Protection Agency.
RCRA = *Resource Conservation and Recovery Act*.
Tri-Party Agreement = Hanford Federal Facility Agreement and Consent Order (Ecology et al. 1989).

facilities at the Hanford Site. 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

B. L. Vedder

During 1980, 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. The EPA is the lead regulatory agency responsible for oversight of the DOE's implementation of CERCLA. There is significant overlap between the state RCRA corrective action program (Section 2.2.6) and the CERCLA program. 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 the Hanford Site and is generally consistent with the national contingency plan process. There are several remediation activities under way at the Hanford Site 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 2.3.4 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 local emergency planning committee and periodically provide

information to support the emergency planning process. Facilities must also notify the state emergency response commission and 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 *2003 Hanford Site Tier Two Emergency and Hazardous Chemical Inventory* (DOE/RL-2004-19) contains information about hazardous chemicals stored at the facility in amounts exceeding minimum threshold levels. The *2003 Hanford Site Toxic Chemical Release Inventory* (DOE/RL-2004-20) contains information about total annual releases of certain toxic chemicals and associated waste management activities.

For 2003, the Hanford Site issued the reports and notifications required by the *Emergency Planning and Community Right-To-Know Act*. The *2003 Hanford Site Tier Two Emergency and Hazardous Chemical Inventory* (DOE/RL-2004-19) was provided to 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 *2003 Hanford Site Toxic Chemical Release Inventory* report (DOE/RL-2004-20), which included releases and waste management activities involving lead and ethylene glycol, was provided to the EPA and Washington State Department of Ecology. Table 2.2.2 provides an overview of 2003 reporting under the *Emergency Planning and Community Right-To-Know Act*.

Types, quantities, and locations of hazardous chemicals are tracked through prime contractor-specific chemical management system requirements (Section 2.2.3). Table 2.2.3 summarizes the information reported, listing the 10 hazardous chemicals stored in greatest quantity on the Hanford Site in 2003.

2.2.6 Resource Conservation and Recovery Act

M. J. Hartman

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. Washington State Department of Ecology has the authority to enforce RCRA requirements in the state under WAC 173-303. At Hanford, RCRA applies to approximately 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 2003

Sections of the Act	Yes[a]	No[a]	Not Required[a]
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 2003.

Table 2.2.3. Average Quantity of Ten Hazardous Chemicals[a] Stored on the Hanford Site, 2003

Hazardous Chemical	Average Quantity, kg (lb)
Mineral oil	1,700,000 (3,800,000)
Sodium	1,000,000 (2,300,000)
Portland cement	360,000 (794,000)
Diesel fuel (Grades 1 and 2)	360,000 (794,000)
Ethylene glycol	210,000 (460,000)
Fly ash (class F)	180,000 (400,000)
Propane	130,000 (280,000)
Argon (compressed)	97,000 (210,000)
Nitrogen (compressed)	75,000 (170,000)
Sulfuric acid	34,000 (76,000)

(a) Includes chemicals defined as hazardous under the Occupational Safety and Health Act Hazard Communication Standard [29 CFR 1910.1200(c)].

2.2.6.1 Hanford Facility RCRA Permit

S. A. Thompson

The Hanford Facility RCRA Permit (Permit No. WA7890008967) was issued by the Washington State Department of Ecology during September 1994 (Ecology 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. 1989). The Hanford Facility RCRA Permit is issued to seven permittees: the DOE Richland Operations Office and DOE Office of River Protection as the owners/operators and to five of their contractors as co-operators. The permit expires September 27, 2004, requiring the permittees to re-apply by March 31, 2004, 180 days before the permit expires, as required by WAC 173-303. This application was submitted.

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 approximately 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 to Washington State Department of Ecology.

During 2003, seventeen Part A, Form 3, revisions were certified and submitted to Washington State Department of Ecology. These include: single-shell tank system, 242-A evaporator, 222-S Laboratory Complex, Waste Receiving and Processing Facility, Central Waste Complex, Immobilized High-Level Waste Interim Storage Unit, Integrated Disposal Facility, 1324-N Surface Impoundment, 1301-N Liquid Waste Disposal Facility, 1325-N Liquid Waste Disposal Facility, 1324-NA Percolation Pond, 200 Area Effluent Treatment Facility (Rev 3A and B), Plutonium-Uranium Extraction (PUREX) Plant Storage Tunnels, and Liquid Effluent Retention Facility (Rev 6A and B) (DOE/RL-88-21). Three Part B permit applications were submitted to Washington State Department of Ecology for the Hanford Facility Dangerous Waste Permit Application, Double-Shell Tank System (DOE/RL-90-39), Hanford Facility Dangerous Waste Permit Application, Immobilized High-Level Waste Interim Storage Unit (DOE/RL-2002-26), and *Hanford Facility Dangerous Waste Permit Application, Integrated Disposal Facility* (DOE/RL-2003-12).

2.2.6.3 RCRA Groundwater Monitoring

M. J. Hartman

RCRA groundwater monitoring is part of the Hanford Site Groundwater Performance Assessment Project (Chapter 6). Table 2.2.4 lists the 24 units (or waste management areas) on the Hanford Site that require groundwater monitoring and notes their monitoring status. An additional planned facility, the Integrated Disposal Facility, will require groundwater monitoring in the future. Groundwater samples were analyzed for a variety of dangerous waste constituents and site-specific constituents as required under RCRA. A summary of groundwater monitoring activities for these sites during 2003 is provided in Chapter 6 and is available in the annual groundwater monitoring report (PNNL-14548).

Table 2.2.4. Regulated Facilities and Waste Management Areas on the Hanford Site Requiring Groundwater Monitoring in 2003

Facility or Waste Management Area	Type of Groundwater Monitoring
RCRA Sites	
1301-N Liquid Waste Disposal Facility	Detection[a]
1324-N/NA facilities	Detection[a]
1325-N Liquid Waste Disposal Facility	Detection[a]
183-H solar evaporation basins	Corrective action[b]
216-A-29 ditch	Detection[a]
216-B-3 pond	Detection;[a] alternative statistical method trial period
216-B-63 trench	Detection[a]
216-S-10 pond and ditch	Detection[a]
216-U-12 crib	Assessment[c]
316-5 process trenches	Compliance[c] and corrective action;[b] alternative statistical method trial period
Integrated Disposal Facility	Planned detection[a] (proposed facility)
Liquid Effluent Retention Facility	Detection[a]
Low-Level Waste Management Area 1	Detection[a]
Low-Level Waste Management Area 2	Detection[a]
Low-Level Waste Management Area 3	Detection[a]
Low-Level Waste Management Area 4	Detection[a]
Nonradioactive Dangerous Waste Landfill	Detection[a]
PUREX Plant cribs[d]	Assessment[c]
Single-shell tanks WMA A-AX	Detection[a]
Single-shell tanks WMA B-BX-BY	Assessment[c]
Single-shell tanks WMA C	Detection[a]
Single-shell tanks WMA S-SX	Assessment[c]
Single-shell tanks WMA T	Assessment[c]
Single-shell tanks WMA TX-TY	Assessment[c]
Single-shell tanks WMA U	Assessment[c]
Other Regulated Units	
200 Area Treated Effluent Retention Facility	Washington State dangerous waste discharge permit
400 Area process ponds	Washington State dangerous waste discharge permit
Solid Waste Landfill	Washington State solid waste handling regulations
State-Approved Land Disposal Site	Washington State dangerous waste discharge permit

(a) Monitored to determine if site has contaminated groundwater.
(b) Monitored during groundwater remediation.
(c) Monitored to evaluate the extent of groundwater contamination from the site.
(d) Plutonium-Uranium Extraction Plant cribs (216-A-10, 216-A-36B, and 216-A-37-1) comprise one waste management area.
RCRA = *Resource Conservation and Recovery Act*.
WMA = Waste management area.

In 2003, the DOE, Washington State Department of Ecology, and EPA agreed to revise Tri-Party Agreement milestone M-24 to allow prioritization of groundwater drilling for CERCLA and *Atomic Energy Act of 1954* wells along with RCRA wells. During 2003, drillers completed seven new RCRA monitoring wells, nine CERCLA monitoring wells, and two wells for research on chromate bioremediation.

At the end of 2003, 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 extent of known contaminants, and two were monitored to determine the progress of corrective action for groundwater contamination. The facilities monitored under RCRA are scheduled for closure under the Hanford Site Part B RCRA Permit except for the liquid effluent retention facility, low-level burial grounds (Low-Level Waste Management Areas 1 to 4), and planned Integrated Disposal Facility, which will receive permits as operating facilities.

Non-RCRA Groundwater Monitoring (Washington Administrative Code Monitoring)

Groundwater monitoring was required for four regulated, non-RCRA waste facilities in 2003 (Table 2.2.4). The 200 Area Treated Effluent Disposal Facility, State-Approved Land Disposal Site, and 400 Area process ponds are monitored under state discharge permits (WAC 173-216). The Solid Waste Landfill is monitored for the requirements of WAC 173-304. These facilities are monitored for waste constituents specified in their permits. The permit for the 400 Area process ponds was recently modified, and groundwater monitoring was no longer required as of October 1, 2003.

2.2.6.4 RCRA Inspections

R. C. Bowman

Hanford Site contractors and the DOE worked to resolve notices of violation and warning letters of non-compliance that were received from Washington State Department of Ecology during 2003. These documents identified conditions that were alleged to be non-compliant with RCRA requirements. The following items are the RCRA non-compliance documents that were received in 2003:

- **Notice of Non-Compliance for Double-Shell Tank Leak Detection Equipment** – Washington State Department of Ecology issued a Notice of Non-Compliance letter to the DOE Office of River Protection and CH2M HILL Hanford Group, Inc. on February 6, 2003. The notice documented state concerns regarding the inspection and repair of leak detection equipment associated with AY, AZ, and SY double-shell tank farms. Washington State Department of Ecology alleged that leak detection equipment associated with the AY, AZ, and SY Tank Farms had not been inspected or maintained in accordance with applicable Washington Administrative Code or Code of Federal Regulation requirements. This Notice of Non-Compliance identified three alleged violations and one concern. All corrective actions were completed as required.

- **Administrative Order No. 03NWPKW-5494** – Washington State Department of Ecology issued Administrative Order No. 03NWPKW-5494 on April 30, 2003. The Administrative Order required the DOE to comply with Chapter 70.105 of the Revised Code of Washington Hazardous Waste Management Act, Chapter 173-303 of the Washington Administrative Code, and by reference Chapter 40 of the Code of Federal Regulations, as they applied to: (1) the management of "retrievably stored waste" in unlined trenches; (2) transuranic, transuranic mixed waste, and mixed low-level waste currently stored above ground; and (3) similar waste projected to be generated. This Administrative Order was resolved through issuance of a Settlement Agreement (USA and Ecology 2003) that was approved on October 23, 2003.

- **Notice of Non-Compliance Associated with Pacific Northwest National Laboratory Chemical Management Practices** – Washington State Department of Ecology issued a Notice of Non-Compliance letter to the DOE Richland Operations Office and Pacific Northwest National Laboratory on June 17, 2003. This letter documented concerns identified during a hazardous waste inspection conducted on June 3, 2003, in laboratories at the 318, 320, 329,

and 338 Buildings. Washington State Department of Ecology alleged that five 1-gallon plastic jugs containing chemical materials located in room 122 of the 329 Building were not being managed properly. The Notice of Non-Compliance identified one alleged violation and one concern. All corrective actions were completed and accepted by the Washington State Department of Ecology.

- **Notice of Non-Compliance for Inspections at Project W-211 Upgrades** – Washington State Department of Ecology issued a Notice of Non-Compliance letter to the DOE Office of River Protection and CH2M HILL Hanford Group, Inc. on December 8, 2003. This letter documented concerns regarding compliance with Washington Administrative Code and Code of Federal Regulation requirements for owners/operators to ensure that new hazardous waste tank system components were independently inspected prior to covering. During an inspection conducted by Washington State Department of Ecology on October 1, 2003, installation records that were reviewed did not indicate that independent inspections per WAC 173-303-640(3)(c) and 40 CFR 265.192(b) were performed for Project W-211 transfer piping installations. Washington State Department of Ecology required submittal of an inspection plan (within 60 days of the notice date) that addressed independent inspection of newly installed tank system components. This plan was submitted to Washington State Department of Ecology as required in 2004.

2.2.7 Clean Air Act

K. A. Peterson

Federal, state, and local agencies, as appropriate, are mandated to enforce the standards and requirements of the *Clean Air Act* to regulate air emissions at facilities such as the Hanford Site. The 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 for Radionuclides NESHAP* (EPA 1994) were met during 2003, and Hanford Site air emissions remained well below the levels that approach the EPA offsite emission standard of 10 mrem (100 μSv) per year (40 CFR 61.92). 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 the EPA and monitored by Washington State Department of Health. Data for the sources are documented annually in the *Radioactive Air Emissions Report for the Hanford Site* (e.g., DOE/RL-2003-21).

Washington State Department of Health's Division of Radiation Protection regulates radioactive air emissions statewide through Washington State legislative authority. Washington State Department of Health implements the federal and state requirements mainly 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 Washington State Department of Health and the EPA for review and approval. Typical requirements for radioactive air emission sources include adequate emission controls, emission monitoring/sampling, and 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 is 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., DOE/RL-2002-38) and an annual compliance certification to Washington State Department of Ecology.

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.

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

Clean Air Act Enforcement Inspections

R. C. Bowman

Hanford Site contractors and the DOE received no notices of violation or warning letters of non-compliance associated with *Clean Air Act* requirements from Washington State Department of Health or Washington State Department of Ecology during 2003.

2.2.8 Clean Water Act

R. Ranade

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, issued by the EPA 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 storm water permit during 2003. The EPA's National Pollutant Discharge Elimination System Storm Water Multi-Sector General Permit WAR05A57F establishes the terms and conditions under which storm water discharges associated with industrial activity are authorized. This permit was issued on May 30, 2001, and supersedes all other National Pollutant Discharge Elimination System storm water permits previously in effect at the site. Fluor Hanford, Inc. is the holder of this permit.

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 by the city of Richland to Battelle on October 1, 2001.

There are numerous sanitary waste discharges to the ground throughout the site. Sanitary wastewater from the 400 Area is discharged to a treatment facility of Energy Northwest's Columbia Generating Station (Figure 1.0.1). Sanitary wastewater from the 300 Area, the former 1100 Area, and other facilities north of and in Richland is discharged to the city of Richland treatment facility. Sanitary wastewater in the 200 Areas of the Hanford Site is primarily treated in a series of onsite sewage systems. The placement of these systems is based on population centers and facility locations. In recent years, extensive efforts have been made to regionalize the onsite sewage systems. Many of the small onsite sewage systems have been replaced with larger systems. These larger systems (with design capacities of 13,248 to 54,883 liters [3,500 to 14,500 gallons] per day) operate under permits issued by 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 has a State Wastewater Discharge Permit Program that regulates the discharge or disposal of wastewater to groundwater.

The DOE is complying with this program at the Hanford Site and is currently holding several state wastewater discharge permits. During 2003, the Hanford Site had 10 state waste discharge permits issued by 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 2003. All public water systems must comply with requirements of the *Safe Drinking Water Act*, *Safe Drinking Water Act Amendments of 1986*, and *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 Hanford Site drinking water program has been updated to comply with the changing regulatory requirements. A complete revision of WAC 246-290 was issued on April 27, 2003, and all site water programs have had the necessary changes incorporated.

Eight of the nine public drinking water systems onsite are supplied from the Columbia River. The water treatment plants supplied from the Columbia River must demonstrate compliance with 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 the 200-East and 200-West Areas as the primary water supply. The 200-East Area water treatment plant remains on standby to be put into service if needed. The DOE's 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 well 499-S1-8J, one of three local groundwater wells. 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 byproduct precursors, disinfectant byproducts, and microorganisms including total and fecal coliform bacteria. In 2003, all chemical contaminant concentrations met the requirements of Washington State Department of Health and were well below the maximum contaminant levels set by the EPA. There were four total coliform (a broad class of bacteria common in the environment) detections during the 2003 monitoring cycle for the 400, 300, and 200-East and 200-West Area water systems. To investigate the possibility of contamination, each positive sample was tested further and found to be negative for E. coli organisms. Follow-up samples were taken at the sites of the original unsatisfactory samples and at locations throughout associated distribution systems. All additional samples provided "satisfactory" results as reported by the state-accredited laboratory. All analytical results for 2003 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 polychlorinated biphenyls are found in 40 CFR 761. (Washington State also regulates certain classes of non-*Toxic Substances Control Act*-regulated polychlorinated biphenyls 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 onsite pending the development of adequate treatment and disposal technologies and capacities. Electrical equipment that might contain polychlorinated biphenyls or polychlorinated biphenyl items is maintained and serviced in accordance with 40 CFR 761.

To encourage consistent interpretation and implementation of the *Toxic Substances Control Act* polychlorinated biphenyl regulations throughout the Hanford Site, a *Toxic Substances Control Act* Polychlorinated Biphenyl Hanford Site Users Guide was drafted in 2001. In 2003, the polychlorinated biphenyl guide was revised to add additional sections on management of polychlorinated biphenyls and polychlorinated biphenyl waste. During 2003, Hanford submitted both a 2002 polychlorinated biphenyl annual document log (DOE/RL-2003-35) and a 2002 polychlorinated biphenyl annual report (DOE/RL-2003-40) to the EPA as required by 40 CFR 761.180. The reports describe the management and disposal activities taking place for polychlorinated biphenyl waste at the Hanford Site. The "Framework Agreement for Management of Polychlorinated Biphenyls in Hanford Tank Waste," signed on August 31, 2000 <http://yosemite.epa.gov/R10/OWCM.NSF/permits/hanfordframework>, resulted in the EPA, 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 the tank farms. The flexibility of the 1998 polychlorinated biphenyl disposal amendments in 40 CFR 761 is used at the Hanford Site to allow necessary storage and to expedite disposal of *Toxic Substances Control Act* regulated polychlorinated biphenyl waste.

In October 2003, the EPA approved a risked-based disposal approval for management of certain aqueous polychlorinated biphenyl remediation waste generated from cleanup of Hanford 100-K Area basins at the 200 Areas liquid waste processing facilities. In November 2003, the EPA approved an extension of a risked-based disposal approval to operate the Hanford Site 242-A evaporator. The original risked-based disposal approval was issued in March 2001. The extension allowed continued campaigns through early 2004. The 242-A evaporator is located in the 200-East Area, and its operation results in reduction of tank waste volume. Two risked-based disposal approvals were submitted to the EPA in 2002 – one for the double-shell tank system and another for operation of the Hanford Site 200 Areas liquid waste processing facilities. The approvals are still under review by the EPA and no responses or comments were received in 2003.

2.2.11 Federal Insecticide, Fungicide, and Rodenticide Act

J. M. Rodriguez

The *Federal Insecticide, Fungicide, and Rodenticide Act* is administered by the EPA. The standards administered by Washington State Department of Agriculture to regulate implementation of the act in Washington State include the *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 along the Hanford Reach of the Columbia River. The bald eagle (*Haliaeetus leucocephalus*) occurs on the site and steelhead trout (*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 Washington Department of Fish and Wildlife as endangered, threatened, or sensitive (Appendix G).

Bald eagles are seasonal visitors to the Hanford Site. 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 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 adverse impacts 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

During 2003, 142 cultural resource reviews were conducted on the Hanford Site to comply with Section 106 of the *National Historic Preservation Act*. 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, *Protection and Enhancement of the Cultural Environment* (36 FR 8921), 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.

Cultural resources on the Hanford Site are mainly subject to the provisions of the following seven acts, two executive orders, 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*, Proclamation 7319 of June 9, 2000 (65 FR 37253), and Executive Order 13287 of March 3, 2003, *Preserve America* (68 FR 10635). Compliance with these regulations is accomplished through an active management and monitoring program. Included in the program are reviews 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 *American Indian Religious Freedom Act* requires federal agencies to help protect and preserve the rights of Native Americans to practice their traditional religions. The DOE cooperates with Native Americans by providing site access for organized religious activities. The regulations of the *Native American Graves Protection and Repatriation Act* provide 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 the DOE Richland Operations Office and 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 Bill Clinton issued a memorandum to the Secretary of Energy the same day the proclamation was signed directing the 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.

President George W. Bush signed Executive Order 13287 of March 3, 2003, *Preserve America*, which reinforces the federal government's responsibilities under the *National Historic Preservation Act* to preserve the nation's heritage through the protection and enhancement of historic properties. "The federal government shall recognize and manage the historic properties in its ownership as assets that can support department and agency missions while contributing to the vitality and economic well-being of the Nation's communities" (68 FR 10635). Additionally, the federal government shall pursue preservation partnerships for the purpose of promoting historic preservation through assistance to "... States, Indian tribes, and local communities in promoting the use of historic properties for heritage tourism and related economic development in a manner that contributes to the long-term preservation and productive use of those properties" (68 FR 10635).

See Section 7.3 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 significantly affect 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 affect the environment and, therefore, would require the preparation of an environmental impact statement. A supplement 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 the DOE and have been determined to not normally 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 less than 10 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 2003, there were 20 site-wide categorical exclusions.

National Environmental Policy Act documents for the Hanford Site are prepared and approved in accordance with the Council on Environmental Quality National Environmental Policy "Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act" (40 CFR 1500-1508), the DOE *National Environmental Policy Act* implementation procedures (10 CFR 1021), and DOE Order 451.1B Change 1. 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 supplement analyses as appropriate are conducted during the course of the actions, as described in the records of decision.

The final environmental impact statement addressing the Hanford Site Solid (Radioactive and Hazardous) Waste program was issued in January 2004 (DOE/EIS-0286F). The final statement analyzed alternatives to (1) dispose of immobilized low-activity waste from the Hanford tanks, low-level waste, and mixed low-level waste; (2) treat mixed low-level waste; and (3) process and certify transuranic waste prior to its shipment to the Waste Isolation Pilot Plant in New Mexico for disposal. Records of decision are expected to be issued in 2004.

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 record of decision was issued in July 1996 (61 FR 36352). A supplement analysis (DOE/EIS-0244-FS/SA10) was issued on April 7, 2003, and provided the basis for determining if a supplemental environmental impact statement was required before washing select plutonium-bearing oxides to remove chloride salts. It was determined that a supplemental environmental impact statement was not required.

A final environmental impact statement for the management and disposal of tank waste and cesium and strontium capsules was issued in January 1997 (DOE/EIS-0189). The capsules are currently stored at the Waste Encapsulation and Storage Facility. In the record of decision issued in February 1997, the DOE decided to implement the preferred alternative identified in the final environmental impact statement for retrieval, treatment, and disposal of tank waste, the "Phased Implementation Alternative," and to defer the decision on disposition of the cesium and strontium capsules. In 2003, a supplement analysis (DOE/EIS-0189-SA3) was prepared to determine if a supplemental environmental impact statement would be required. Two previously prepared supplement analyses (DOE/EIS-0189-SA1 and DOE/EIS-0189-SA2) resulted in determinations that the *National Environmental Policy Act* required no additional analyses. However, based on DOE/EIS-0189-SA3, issued on March 20, 2003, the DOE determined that two supplemental environmental impact statements would be required. The first supplemental environmental impact statement addressed immobilized low-activity waste, and was incorporated into the scope of the *Final Hanford Site Solid (Radioactive and Hazardous) Waste Program Environmental Impact Statement* (DOE/EIS-0286F). The second environmental impact statement (68 FR 1052-1057) is currently being prepared and addresses the impact of proposed retrieval, treatment, and disposal of tank waste being managed in high-level waste tank farms, and closure of the 149 single-shell tanks and associated facilities in the tank farms. Washington State Department of Ecology is a cooperating agency in the preparation of this environmental impact statement. In 2003, the draft environmental impact statement schedule was under review.

A supplement analysis (DOE/EIS-0189-SA4) was issued on December 15, 2003, and provided the basis for determining if a supplemental environmental impact statement was required before the retrieval, packaging, characterization, certification, and temporary storage of contact-handled transuranic mixed waste from single-shell tanks at the Hanford Site. It was determined that a supplemental environmental impact statement was not needed; however, an amended record of decision would be required.

The *Final Programmatic Environmental Impact Statement for Accomplishing Expanded Civilian Nuclear Energy Research and Development and Isotope Production Missions in the United States, Including the Role of the Fast Flux Test Facility* (DOE/EIS-0310) was issued in December 2000. A record of decision was issued in January 2001 (66 FR 7877) indicating the Fast Flux Test Facility would be permanently deactivated. The ruling was later postponed pending review. The decision was upheld in February 2003 and deactivation of the Fast Flux Test Facility has resumed under an earlier *Environmental Assessment: Shutdown of the Fast Flux Test Facility, Hanford Site, Richland, Washington* (DOE/EA-0993).

A draft environmental impact statement is being prepared to consider alternatives for final disposition of the Fast Flux Test Facility. Public participation will be sought to develop the environmental impact statement, and the draft will be issued for public comment. During 2003, the draft environmental impact statement schedule was under review.

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. 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. The final environmental impact statement is still in preparation.

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, the DOE Richland Operations Office is a cooperating agency. The draft environmental impact statement is scheduled to be issued for public comment in October 2004.

2.2.15.2 Recent Environmental Assessments

An environmental assessment (DOE/EA-1469) was prepared to determine whether an environmental impact statement would be required for the deactivation of the Plutonium Finishing Plant. 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 October 20, 2003, determining that no further review was required under the *National Environmental Policy Act*.

An environmental assessment (DOE/EA-1454) was prepared to determine whether an environmental impact statement would be required to re-open the former borrow sites and to construct haul roads in the 100 Areas of the Hanford Site to provide backfill materials for remedial actions in the 100-F, 100-H, 100-K, and 100-N Areas. 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 7, 2003, determining that no further review was required under the *National Environmental Policy Act*.

An environmental assessment (DOE/EA-1462) was prepared to determine whether an environmental impact statement would be required for tank closure activities on single-shell tank 241-C-106 in the Hanford 200-East Area. 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 June 16, 2003, determining that no further review was required under the *National Environmental Policy Act*.

2.2.16 Hanford Site Institutional Controls Plan

A. E. Teimouri

Section 4.2 of the *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions*, DOE/RL-2001-41, dated July 30, 2001, requires the DOE Richland Operations Office to conduct an annual assessment regarding the performance of the institutional controls described in the plan. The plan calls for a focused and periodic self-assessment and reporting of institutional controls to (1) assess the performance of institutional controls to ensure their effectiveness and (2) identify the need to make any adjustments to the institutional controls based on performance findings. Initially, the plan required an assessment be conducted on an annual basis within 12 months of its issuance and a report be submitted to the EPA and Washington State Department of Ecology as a "primary" Tri-Party Agreement document as described in Section 9.2.1 of the Tri-Party Agreement. This institutional controls assessment addresses objectives outlined in the assessment plan by conducting a performance-based review of selected areas of institutional controls located within the four National Priorities List sites at the Hanford Site. An assessment team primarily comprised of DOE staff is usually designated and the assessment team reviews any prior institutional controls self-assessments/performance reviews and the contractor's oversight program as it pertains to this activity. The first annual assessment report was submitted to regulators in July 2003. Subsequently, the regulators provided comments to the DOE Richland Operations Office. On January 14, 2004, the DOE Richland Operations Office met with regulators to resolve comments made in 2003. A March 12, 2004, letter to the regulators documents an assessment strategy that has been negotiated between the DOE, EPA, and Washington State Department of Ecology, which focuses and streamlines the efforts of the institutional controls

assessments. This was intended as a response to the regulators concerns about the 2003 reviews. The annual directions provided to the Hanford Site contractors were received in March 2004. The final assessment report is due to regulators on September 30, 2004.

2.2.17 Defense Nuclear Facilities Safety Board

The Defense Nuclear Facilities Safety Board is an independent federal agency established by Congress in 1988. The board's mandate under the *Atomic Energy Act of 1954* is to provide safety oversight of the nuclear weapons complex operated by the DOE. The nuclear weapons program remains a complex and hazardous operation. The DOE must maintain readiness of the nuclear arsenal, dismantle surplus weapons, dispose of excess radioactive materials, clean up surplus facilities, and construct new facilities for many purposes. It is the board's responsibility to help assure that all of these activities are carried out by the DOE in a manner that provides adequate protection for the public, workers, and the environment.

2.2.17.1 Defense Nuclear Facilities Safety Board, DOE Richland Operations Office

S. M. Hahn

The DOE Richland Operations Office has accelerated site cleanup and continues to improve the effectiveness of their Integrated Safety Management Systems to reduce risk and perform work safely.

Risk Reduction

- The DOE Richland Operations Office met or exceeded fiscal year 2003 goals for reducing risk in all areas, except spent nuclear fuel removal (K Basins).

DOE Richland Operations Defense Nuclear Facilities Safety Board Recommendations and Safety Issues

- Defense Nuclear Facilities Safety Board Recommendation 2000-2 is fully institutionalized at the DOE Richland Operations Office in both contractor and engineering operations. Institutionalization was completed on schedule and all recommendation commitments were closed by the end of 2002.
- The Plutonium Finishing Plant is on track to complete stabilization and packaging of plutonium oxides by February 2004, which will complete Commitment 111 for Recommendation 2000-1. Commitments 115 (the complete stabilization and packaging of polycubes) and 116 (the complete stabilization and packaging of residues at Hanford) were completed in 2003.
- The DOE Richland Operations Office completed Commitment 4.1.3 to Defense Nuclear Facilities Safety Board Recommendation 2002-1 to identify the federal positions whose duties and responsibilities require them to provide assistance, guidance, direction, oversight, or evaluation of software used in the safety analysis and design of defense nuclear facilities quality assurance activities.

The Defense Nuclear Facilities Safety Board recommendations are available online at http://www.deprep.org.

2.2.17.2 Defense Nuclear Facilities Safety Board, DOE Office of River Protection

C. M. Fetto

The DOE Office of River Protection has worked closely with the Defense Nuclear Facilities Safety Board over the past year addressing safety questions related to the design and construction of the Waste Treatment Plant. Primary areas of interest included the following:

- Control of hydrogen generation.
- Seismic analysis.
- Unique design features.
- Construction/supplier quality assurance.
- Fire protection.

The Defense Nuclear Facilities Safety Board did not identify any inadequacies that affected the DOE Office of River Protection's environmental cleanup programs in 2003.

2.2.18 Key Provisions of DOE Order 435.1 Ruled Invalid

DOE Order 5820.2A, "Radioactive Waste Management," was issued in 1988. During September 1994, the Defense Nuclear Facilities Safety Board issued recommendation 94-2, addressing problems with the DOE's radioactive waste management. In July 1999, the DOE issued a revised directive on managing radioactive waste, DOE Order 435.1, "Radioactive Waste Management," with its associated manual and guidance documents, reflecting advances in radioactive waste management practices. DOE Order 435.1 included a compliance date of July 12, 2000.

The U.S. District Court for the District of Idaho ruled on July 3, 2003, that a key provision of DOE Order 435.1 is invalid. The ruling applies to that portion of the order that allows waste that is incidental to reprocessing to be managed as low-level radioactive waste. Such classification is viewed by the DOE as important to speeding the treatment and reducing associated disposal costs of liquid wastes generated by the DOE's prior reprocessing of spent nuclear fuel. Waste incidental to reprocessing that remains in Hanford tanks could be disposed of in place, as low-level waste, for example, rather than being disposed of in a repository as high-level waste.

The Natural Resources Defense Council, along with other groups, challenged the provision as inconsistent with the *Nuclear Waste Policy Act of 1982*. The court agreed that part of DOE Order 435.1 was inconsistent with the *Nuclear Waste Policy Act of 1982*.

The court declined plaintiff's request that it enjoin the DOE from implementing specific plans including closing waste tanks by filling them with grout. The court found "no indication" that the DOE would "continue with any plan inconsistent with the *Nuclear Waste Policy Act*." Plaintiffs may bring the issue back before the court should the need arise.

In a letter to Congress on August 1, 2003, the Secretary of Energy submitted draft legislation to Congress to clarify that high-level waste does not include radioactive materials from reprocessing that the DOE, in consultation with the Nuclear Regulatory Commission, determines do not require disposal in a geologic repository designed for spent nuclear fuel and high-level waste in order to protect public health and safety. The Secretary also filed a Notice of Appeal on August 27, 2003. The government's brief was filed on January 29, 2004; plaintiffs' brief was due March 18, 2004, and was filed. The decision and other documents filed in this case are available online at http://www.id.uscourts.gov under Case Files, District, non-restricted cases, case number 01-413.

If upheld on appeal, this decision could adversely impact accelerated cleanup of the Hanford tank waste, as well as increase the cost of cleanup.

2.3 Hanford Cleanup Operations

J. P. Duncan

This section describes continuing Hanford Site environmental protection, enhancement, and regulatory activities with respect to cleanup of the Hanford Site. Included are discussions on solid waste management, liquid effluent treatment, environmental restoration, groundwater protection, waste tank research, and project regulatory compliance activities.

2.3.1 Pollution Prevention Program

J. G. Coenenberg

Pollution prevention is the 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, reduction of hazardous substance use, and 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.

The 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. The Hanford Site met the fiscal year 2003 Secretarial Goals (as defined in a DOE memorandum)[(a)] for low-level waste and mixed low-level routine waste generation and sanitary waste (including paper, plastic, cardboard, glass, etc.) recycling. In 2003, the program reported recycling of 2,339.79 tonnes (2,579.17 tons) of sanitary and hazardous waste. This recycled waste included 398.42 tonnes (439.18 tons) of office and mixed paper, 251.81 tonnes (277.58 tons) of iron/steel, 73.37 tonnes (80.87 tons) of non-ferrous metal, and 33.60 tonnes (37.04 tons) of computers and hardware.

However, the routine hazardous waste generation goal for the Hanford Site was not met. Routine hazardous waste generation was 17.78 cubic meters (23.2 cubic yards), which exceeded the fiscal year 2003 goal ceiling of 16.39 cubic meters (21.4 cubic yards) by 1.39 cubic meters (1.82 cubic yards). This was largely due to cleanup of a diesel oil spill at the Waste Treatment Project, which accounted for approximately 6.1 cubic meters (8 cubic yards).

Affirmative procurement (the purchase of environmentally preferable products containing recycled material) at the Hanford Site achieved 100% of the 2003 goal. The Hanford Site generated 20,454 cubic meters (26,754 cubic yards) of cleanup/stabilization waste (i.e., low-level waste, mixed low-level waste, and hazardous waste), which was 8,150 cubic meters (10,660 cubic yards) below the 2003 cleanup/stabilization goal ceiling of 28,604 cubic meters (37,414 cubic yards).

(a) Memorandum from B. Richardson (The Secretary of Energy) to Heads of Departmental Elements, *Pollution Prevention and Energy Efficiency Leadership Goals for Fiscal Year 2000 and Beyond*, dated November 12, 1999.

2.3.2 Spent Nuclear Fuel Project

M. S. Gerber

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 leading to final disposal. Most of Hanford's spent nuclear fuel was stored in the K Basins attached to the now-defunct K-East and K-West defense production reactors. The K Basins contained 2,100 tonnes (2,300 tons) of N Reactor spent fuel and a small quantity of slightly irradiated single-pass reactor fuel when the Spent Nuclear Fuel Project began.

The Spent Nuclear Fuel Project's strategy is to remove spent fuel from underwater storage in the K Basins, dry it, and place it in dry interim storage in the 200-East Area. Fuel in the K-East Basin is transferred into the K-West Basin for processing. In the K-West Basin, the fuel is cleaned (washed) and packaged into containers called multi-canister overpacks. The multi-canister overpacks are then vacuum processed to remove any water and mechanically sealed at the Cold Vacuum Drying Facility located in the 100-K Area. The dried overpacks are then transported to the Canister Storage Building in the 200-East Area where they are placed in storage in below-ground steel tubes. After an observation period to detect any internal issues that might develop, each multi-canister overpack is brought back to the ground-level operating deck of the Canister Storage Building, and a permanent steel cap is welded over the mechanical seal. The multi-canister overpacks will be maintained in dry storage pending a federal decision 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. 1989) date of July 2004.

During 2003, the Spent Nuclear Fuel Project made progress as follows:

- Transferred 200 shipments of fuel from the K-East Basin to the K-West Basin, completing 215 of 380 planned shipments (56% complete).
- Removed and dried 113 multi-canister overpacks of fuel from the K-West Basin, for a total of 293 multi-canister overpacks out of approximately 385 (75% complete). The 2003 progress brought the total amount of fuel removed and dried to approximately 1,600 tonnes (1,800 tons).
- Started welding operations in the Canister Storage Building (February 2003) and 120 multi-canister overpacks were permanently closed with "N-Stamped" welds (those meeting the highest nuclear quality standards of the American Society of Mechanical Engineers). The welding subproject remained consistently ahead of schedule.
- Installed scrap-processing equipment in the K-West Basin and began loading fuel scraps into multi-canister overpacks in autumn 2003.
- Continued the washing and loading of aged fuel canisters for disposal as low-level nuclear waste. By end of 2003, 3,700 cans (55% of the total) had been washed and disposed.

During 2003, the Spent Nuclear Fuel Project achieved 5 million safe work hours (a project record) in the summer and another 1 million safe hours by December 2003. The project also opened a Career Resource Information Center to help guide employees to new job opportunities when the project ends.

2.3.3 Sludge Retrieval and Disposition Project

M. S. Gerber

The corrosion of spent nuclear fuel stored underwater in Hanford's K Basins for many years, as well as fuel handling operations related to the Spent Nuclear Fuel Project, contributed to the accumulation of sludge in the basins. The sludge, defined as particulate debris that will pass through a strainer with 0.64-centimeter- (0.25-inch-) diameter holes, is a non-homogeneous collection of bits of degrading irradiated fuel and other components, natural accumulation of insects, and windblown sand and soil. The sludge contains fuel corrosion products (i.e., uranium oxides, hydrates, and hydride), pieces of corroded fuel cladding, racks and canisters, ion exchange resin beads, and polychlorinated biphenyls. Sludge can be found on the

floor of the basins, in canisters stored underwater, and in basin pits (smaller areas connected to the basins at either end used during the defense production area to handle special materials or special use equipment). Approximately 60 cubic meters (80 cubic yards) of sludge exist in the K Basins, with about 80% found in the K-East Basin.

In its current condition, the sludge is commingled with spent fuel and not considered as waste. However, when the sludge is separated from the fuel and removed from the basins, it becomes waste and will be dispositioned as transuranic waste, as prescribed in a September 1999 record of decision (EPA/ROD/R10-99/059) developed under the CERCLA.

Throughout much of 2003, Fluor Hanford, Inc. managed the effort to retrieve sludge from K Basins as part of the larger Spent Nuclear Fuel Project. The plan called for collection of the sludge in large steel containers, and transport to T Plant in Hanford's 200-West Area for interim storage as remote-handled transuranic waste. This waste would then be included in a treatment and disposition path for other remote-handled transuranic waste at Hanford.

In late 2003, to bring more focus and dedicated resources to sludge issues, Fluor Hanford, Inc. separated the sludge work scope from the Spent Nuclear Fuel Project and created the new Sludge Retrieval and Disposition Project. T Plant had always been an interim storage site, and Fluor Hanford, Inc. and the DOE desired to establish a path leading more directly toward sludge disposal. Fluor Hanford, Inc. organized and staffed its new Sludge Retrieval and Disposition Project with experts who focused on the various types of sludge and sludge locations within the K Basins. K-East Basin contains a mixture of fuel canister sludge and sludge from the basin floor and pits, while K-West Basin sludge exists in four discrete streams. These streams include sludge in pits, sludge dispersed on the basin floor, and canister and fuel wash sludge that collects in the Integrated Water Treatment System equipment used for spent nuclear fuel processing. The Integrated Water Treatment System equipment captures sludge greater than 500 micrometers in knock out pots and/or strainers, and the balance in an arrangement of settling tanks. K-West Basin sludge also includes metallic uranium fuel fragments and fuel corrosion products from fuel of slightly higher enrichment levels than the K-East Basin fuel. Because composition of the sludge is complex, Fluor Hanford, Inc. obtained assistance from Pacific Northwest National Laboratory and others, to determine suitable methods to handle and treat the sludge.

At the end of 2003, the new Sludge Retrieval and Disposition Project had been in existence only 3 months. The project staff had begun to study potential sludge treatment methods and had initiated treatment of the approximately 6 cubic meters (7.85 cubic yards) of KE North Loadout Pit sludge in a pilot grouting program. The project obtained a sample of sludge from the KE North Loadout Pit for analysis and treatability testing, and initiated treatment studies and equipment design to disposition the balance of the K Basins sludge. In the pilot grouting program, North Loadout Pit sludge will be mixed in concrete to prepare it for disposal at the DOE's Waste Isolation Pilot Plant in New Mexico as contact-handled transuranic waste.

2.3.4 Central Plateau Remediation Project

The Hanford Site's Central Plateau Remediation Project's mission is to transition the Central Plateau (200-East and 200-West Areas) from its current post-operational state to a state where excess facilities and waste sites are cleaned up in an environmentally sound, safe, secure, and efficient manner. The activities discussed in the following sections were performed during 2003.

2.3.4.1 224-B Plutonium Concentration Facility Decommissioning Project

C. R. Haas and D. L. Klages

The 224-B Plutonium Concentration Facility (224-B Facility) is located in the 200-East Area, to the south and parallel to the 221-B Separations Facility. The 224-B Facility was used to purify and concentrate product plutonium nitrate solution from the 221-B Separations Facility bismuth-phosphate process. From the 224-B Facility, the concentrated solution was shipped to the 231-Z Isolation Building in the 200-West Area. Plutonium concentration

operations were performed in conjunction with 221-B separations activities from 1944 to 1953. The 224-B Facility's process components were deactivated shortly thereafter.

Operational reports from 1953 indicate the process was shut down normally, and documentation specifically states that process equipment and lines were flushed and drained. However, radionuclide contamination and residual amounts of process chemicals may remain in the facility. The remaining inventory of radionuclides and process chemicals has not been quantified.

Following deactivation of the 224-B Facility, the load out area was converted to a regulated workshop, which is an area used to perform work on radiologically contaminated equipment. Office space was constructed on the gallery (non-contaminated) side of the facility during this time. Decontamination and decommissioning work was initiated in the early 1980s, and a number of tanks and other equipment were removed from the galleries.

The 224-B Facility is currently an inactive surplus facility and is administered under a surveillance and maintenance program while awaiting final disposition. The DOE has identified no further use for the 224-B Facility, making the facility a candidate for decontamination and decommissioning.

This decontamination and decommissioning project is a CERCLA non-time critical removal action defined in the 224-B Engineering Evaluation/Cost Analysis (DOE/RL-2000-06). The decontamination and decommissioning work will be performed per a Removal Action Work Plan subsequent to publication of an Action Memorandum. The purpose of the decontamination and decommissioning activities is to safely dismantle the facility and dispose of the demolition waste in a manner that is protective of human health and the environment, and is cost-effective. Development of documentation to support the CERCLA process is ongoing. No other work is anticipated to be performed in fiscal year 2004.

2.3.4.2 224-T Plutonium Concentration Facility Decommissioning Project

C. R. Haas and D. L. Klages

The 224-T Plutonium Concentration Facility (224-T Facility) is located in the 200-West Area, to the south and parallel to the T Plant Complex Canyon Building (221-T). Completed in 1944 and originally designated the 224-T Bulk Reduction Building, the purpose of the 224-T Facility was to concentrate the plutonium nitrate solution produced in the first major step in the plutonium recovery process conducted at the T Plant complex. It operated in this capacity from January 16, 1945 until early 1956, when the T Plant complex was retired from active service as a chemical processing facility.

The 224-T Facility was idle before being modified in 1975 to meet the requirements for storing plutonium-bearing waste. In 1985, the building became the 224-T Waste Storage and Assay Facility and operated in that capacity until the late 1990s.

These past operations resulted in contamination throughout the structure. The 224-T Facility is currently an inactive surplus facility and is administered under a surveillance and maintenance program while awaiting final disposition. The DOE has identified no further use for the 224-T Facility, making the facility a candidate for decontamination and decommissioning.

This decontamination and decommissioning project is a CERCLA non-time critical removal action defined in the 224-T Engineering Evaluation/Cost Analysis (DOE/RL-2003-62). The work will be performed per a Removal Action Work Plan subsequent to publication of an Action Memorandum. The purpose of the decontamination and decommissioning activities is to safely dismantle the facility and dispose of the demolition waste in a manner that is protective of human health and the environment, and is cost-effective. Development of documentation to support the CERCLA process is ongoing. Some work is anticipated to be performed during fiscal year 2004 including setting up structures and equipment necessary to support the Decontamination and Decommissioning Project and

limited facility characterization of radiological and chemical conditions within the facility.

2.3.4.3 Accelerated Deactivation Project

D. E. Rasmussen

The mission of the Accelerated Deactivation Project is to complete deactivation and closure activities at facilities 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 buildings and structures that date back to 1943. It includes fuel fabrication facilities that were used to support the manufacturing of nuclear fuel for Hanford Site reactors. Significant accomplishments during 2003 included the following activities:

- Completed demolition of the 303-K Building in support of the RCRA closure plan.
- Performed surveillance and maintenance of 300 Area Accelerated Deactivation Project facilities.

2.3.4.4 327 and 324 Facilities Deactivation Project

D. E. Rasmussen

Construction of the 327 and 324 facilities was completed and operations began in 1953 and 1966, respectively. These facilities contain hot cells that were used for radiological research and development work. Deactivation of both facilities was assigned to Fluor Hanford, Inc. during 1996. Facility disposition is to be completed by the new River Corridor Closure contractor (contract award pending).

Significant accomplishments achieved at the 327 Building during 2003 included the following:

- Continuation of waste shipment activities for completion of the 327 Building portion of Tri-Party Agreement milestone M-92-16.
- Completion of initial hot cell deactivation activities enabling the facility to enter into a minimum safe mode (i.e., the minimum required preventive and corrective maintenance activities necessary to maintain compliance with regulatory requirements and facility safety basis requirements).

Significant accomplishments achieved at the 324 Building during 2003 include the following:

- Completion of packaging and shipment of special-case waste (i.e., radioactive waste for which there was no previously identified economic disposal or storage pathway) from the building. These activities resulted in completion of the 324 Building portion of Tri-Party Agreement milestone M-92-16.
- Continuation of facility deactivation activities in support of the *324 Building Radiochemical Engineering Cells, High-Level Vault, Low-Level Vault, and Associated Areas Closure Plan* (DOE/RL-96-73).
- Initiation of decommissioning and decontamination activities in the basement and Shielded Material Facility within the 324 Building.

2.3.4.5 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 to 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.

No funding was available to support the continuation of the Equipment Disposition Project during 2003. Therefore, only minimal surveillance and maintenance activities were conducted.

2.3.4.6 233-S Plutonium Concentration Facility Decommissioning Project

D. L. Klages

Decontamination and decommissioning activities continued in 2003 at the 233-S Plutonium Concentration Facility (233-S Facility) located in the 200-West Area adjacent to the Reduction-Oxidation (REDOX) Plant. This work is being performed as a CERCLA non-time-critical removal action. The 233-S Facility and associated process equipment were used to concentrate plutonium produced at the Reduction-Oxidation (REDOX) Plant from 1955 to 1967.

Equipment cleaning and waste disposal activities took place throughout 2003, 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. Demolition of the 233-S Facility began in 2003 and is scheduled for completion in 2004.

2.3.4.7 Central Plateau Surveillance and Maintenance Project

G. J. LeBaron

Disposition of 200 Areas facilities includes the surveillance, maintenance, and deactivation of buildings and waste sites in the 200-East, 200-West, and 200-North Areas, and on the Fitzner/Eberhardt Arid Lands Ecology Reserve.

Included in the facilities managed by the Central Plateau Surveillance and Maintenance 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 [PUREX] Plant, B Plant, Reduction-Oxidation [REDOX] Plant, and U Plant), was transferred from Bechtel Hanford, Inc. to the Central Plateau Surveillance and Maintenance Project managed by Fluor Hanford, Inc. Three operating major air emission units and three operating minor emission stacks as defined by 40 CFR 61 are now maintained by the project.

During 2003, facility work conducted under this project included closing one major emission unit (the B Plant filters vent), inspecting and cleaning the sample probe and line, and collecting data at the B Plant stack to show that it is a minor emission unit. This work was done in addition to the normal surveillances and maintenance that were conducted to ensure that the facilities are secure and maintained and do not pose a threat to human health or the environment.

The Radiation Area Remedial Action Program is part of the Central Plateau Surveillance and Maintenance Project. The project 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.

2.3.4.8 Canyon Disposition Initiative

J. R. Robertson

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. ("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 of 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 and 2003, work was done to finalize the draft feasibility study (DOE/RL-2001-11) and to prepare the associated draft proposed plan for public review.

Following regulator and public review of the Phase I feasibility study for the Canyon Disposition Initiative (DOE/RL-97-11), five options were selected for final evaluation and screening: (1) no action (2) full removal and disposal, (3) entombment with internal waste disposal, (4) entombment with internal/external waste disposal, and (5) close in place – collapsed structure. The feasibility study (DOE/RL-2001-11) determined that options 2, 3, 4, and 5 meet the requirements to protect human health and the environment, and that options 3 and 4 are consistent with the *Performance Management Plan for the Accelerated Cleanup of the Hanford Site* (DOE/RL-2002-47). The final option for U Plant will be selected during the record of decision process. Selecting the final option for the five canyon buildings figures prominently in the 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.

2.3.5 Fast Flux Test Facility

D. A. Gantt

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 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 systems were deactivated during the previous deactivation period from 1993 to 1997.

The Fast Flux Test Facility continued with deactivation in April 2003. The repairs and upgrades to the fuel handling equipment were completed and successfully tested. Following the removal of a hold order imposed by U.S. District Court, the sodium was drained from the secondary heat transport system loops to the Sodium Storage Facility tanks, where it is stored pending future conversion to sodium hydroxide for use by the Waste Treatment Plant. Eighty-one fuel components were washed, packaged, and placed in approved interim storage. This included 32 un-irradiated mixed-oxide fuel assemblies, which are now in storage at the Plutonium Finishing Plant.

Fluor Hanford Inc. awarded a contract to TransNuclear, Inc. for fabrication of the remainder of the interim storage casks, and work to design a pump to drain the reactor vessel continued.

2.3.6 Advanced Reactors Transition Project

J. M. Bishop

The mission of the Advanced Reactors Transition Project is to convert the Plutonium Recycle Test Reactor facility, located inside the 309 Facility, into a structure that is suitable for low-cost surveillance and maintenance. During 2003, facility surveillance activities were conducted.

2.3.7 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, the DOE issued a shutdown order for the plant, authorizing deactivation and transition of the plutonium processing portions of the facility in preparation for decommissioning.

Workers at the Plutonium Finishing Plant complex embarked on a large and multifaceted effort to stabilize, immobilize, re-package, and/or properly dispose of nearly 18 tonnes (19.8 tons) of plutonium-bearing materials in the plant, and had nearly completed this mission by the end of 2003 (completion occurred in February 2004). The workers also began to deactivate and dismantle the processing facilities, while still providing for the safe and secure storage of nuclear materials until final disposition.

Significant accomplishments achieved at the Plutonium Finishing Plant during 2003 included the following:

- Completed stabilizing nearly 1,000 plutonium-bearing polycubes using a unique thermal stabilization method devised specifically for this project.
- Completed re-packaging the original 4 tonnes (4.4 tons) of plutonium-bearing residues identified for action by the Defense Nuclear Facilities Safety Board in 2000, and went on to package additional materials categorized as residues since 2000.
- Began shipment and disposal of re-packaged plutonium-bearing residues off of the Hanford Site to the Waste Isolation Pilot Plant in Carlsbad, New Mexico.
- Continued welding stabilized plutonium forms into sturdy, triple-layered cans meeting strict specifications of the DOE's "3013" safety standard.
- Began stabilizing a collection of plutonium-bearing oxides containing large amounts of chloride salts, using a unique process developed for this project.
- Stabilized approximately 90% of the total plutonium inventory by the end of 2003.
- Completed cleanout of plutonium held in an initial glove box known as HC-7C in the main Plutonium Finishing Plant Facility and began cleanout in a second large glove box known as HC-9B.
- Began equipment removal in the 232-Z Incinerator facility in the Plutonium Finishing Plant complex and completed key environmental documentation in preparation for additional deactivation work.
- Attained over 1 million safe work hours and became the first high-hazard nuclear facility in the DOE complex to achieve Star Status in DOE's Voluntary Protection Program.

2.3.8 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 strontium fluoride and cesium chloride capsules stored at the facility. The capsules will be stored at the Waste Encapsulation and Storage Facility until 2018 when they will either be treated at the Waste Treatment Plant or transported to the national repository.

Tri-Party Agreement milestone M-92-05 was revised in 2003 to assess the viability of directly disposing of the capsules at the national high-level waste repository as an alternative to vitrification. The completed assessment is due June 30, 2007, to Washington State Department of Ecology.

2.3.9 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 the 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.

2.3.9.1 Waste Tank Status

J. D. Doughty

The Hanford Federal Facility Agreement and Consent Order, or Tri-Party Agreement (Ecology et al. 1989), formally establishes a schedule for stabilization, retrieval, and closure of the Hanford 200 Areas waste tanks. Stabilization is achieved by removing all pumpable liquids from a tank; pumpable liquids are those that will, under the force

of gravity, flow from the waste matrix to the pump intake. Retrieval is achieved by removing all waste that can be accessed, mobilized, and retrieved from a tank, to the limits of the selected retrieval technology. All waste removed from a single-shell tank during stabilization and retrieval activities is transferred to a double-shell tank.

A monthly waste tank summary report documents the status of waste tanks. The December 2003 report, HNF-EP-0182, *Waste Tank Summary Report for Month Ending December 31, 2003*, provided 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 single-shell tanks are assumed to have leaked at some time in the past.
- The volume of liquid waste that may have leaked from these tanks has been conservatively estimated to be between 3 and 4 million liters (750,000 and 1 million gallons).

During 2003, ten single-shell tanks were declared stabilized: 241-U-107, 241-AX-101, 241-A-101, 241-S-107, 241-SX-102, 241-SX-101, 241-C-103, 241-U-111, 241-SX-103, and 241-BY-105. Two additional tanks, 241-BY-106 and 241-S-101, are believed to be stabilized, but are being further evaluated. As of December 31, 2003, only tank 241-U-108 remains to be stabilized. Calendar year 2003 stabilization activities transferred more than 1 million liters (300,000 gallons) of waste from single-shell tanks to double-shell tanks.

At the close of 2003, waste in 13 tanks was in some stage of retrieval. Four tanks were in retrieval status but were not yet being prepared for waste retrieval: 241-C-103, 241-C-105, 241-S-103 and 241-S-105. Seven tanks were in preparation for retrieval: 241-C-104, 241-S-102, 241-S-106, and four 241-C-200 series tanks. Waste retrieval from tank 241-S-112 was begun, with completion scheduled for 2004. Waste retrieval was declared complete for tank 241-C-106 in December 2003, and the tank is now in an evaluation mode to verify retrieved status. Retrieval activities removed approximately 4.9 million liters (1.3 million gallons) of waste from single-shell tanks.

To support safe waste storage and retrieval, the contents of 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 2003, CH2M HILL Hanford Group, Inc. retrieved waste from tank 241-C-106, dissolving and mobilizing the waste with an acid solution. Retrieval also began at tank 241-S-112, where water was used to dissolve and mobilize the waste. Evaluation of a third technology, the mobile retrieval system, continued. This third technology is intended for use on solid waste. It consists of a remote controlled in-tank waste vehicle (used to push tank waste to a central location) and an articulated mast (used to guide the vacuum pump intake to the waste positioned for retrieval by the in-tank vehicle). Workers plan to deploy the articulated mast in 2004 for waste retrieval in the C-200 series tanks. The entire mobile waste retrieval system, both the mast and the in-tank vehicle, is planned for deployment in 2005 to retrieve waste from the C-100 series tanks.

2.3.9.2 Waste Tank Closure Acceleration

J. D. Doughty

During 2003, the DOE revised the closure plan for the single-shell tank system based on comments received from Washington State Department of Ecology. The process and integration necessary to achieve accelerated closure of single-shell tanks and waste management areas and the first closure activities will be performed on tank 241-C-106 (RPP-13774).

CH2M HILL Hanford Group, Inc. selected a single supplemental treatment technology, bulk vitrification, for further evaluation of treatment of retrieved low-activity tank waste and is pursuing a field assessment of that technology. The project will address the feasibility of using vitrification (i.e., heating and melting inert materials to form a solid glass matrix) to immobilize low-activity waste in a form suitable for disposal. Vitrification will be achieved by mixing S-109 tank waste and matrix materials (glass formers) in a container and then applying electrical resistance heating through electrodes buried in the waste/glass forming mixture. The heat produced will melt the glass mixtures and encapsulate the low-activity waste. If

selected for full-scale implementation, this technology will provide treatment capacity to supplement the treatment provided by the Waste Treatment Plant, facilitating accelerated tank waste retrieval and tank closure. Planning and design have begun for a 2005 demonstration, and the required environmental permit applications have been submitted.

In addition, CH2M HILL Hanford Group, Inc. continues its evaluation of a separate disposal path for select mixed transuranic tank waste. The approach will include onsite treatment and packaging for shipment and final disposal at the DOE Waste Isolation Pilot Plant in New Mexico. The *National Environmental Policy Act* documentation and environmental permit applications have been prepared, and a contract was awarded for design and fabrication of the waste treatment and packaging system.

2.3.9.3 Geophysical Data Logging for Vadose Zone Characterization and Monitoring

R. G. McCain and B. W. Mathis

Geophysical data logging at the Hanford Site is performed by S.M. Stoller Corporation under their contract with the DOE Grand Junction Office. This work draws upon capabilities and experience established for the National Uranium Resource Evaluation Program. The primary logging capability is high-resolution spectral gamma logging. The spectral gamma logging system uses cryogenically cooled high purity germanium detectors to collect in situ gamma energy spectra. Specific gamma-emitting radionuclides are identified and quantified from their characteristic energy levels, and the results are plotted as a function of depth. Other logging capabilities include neutron moisture and passive neutron. The neutron moisture log irradiates the formation with neutrons from an americium-beryllium source and measures neutron backscatter, which is primarily due to the presence of moisture in the vadose zone. For the neutron moisture log, the count rate is an indication of volumetric moisture content. The passive neutron log measures ambient neutron activity in the subsurface. The primary reaction contributing to neutron activity is the interaction between alpha particles and oxygen in the formation. Thus, the passive neutron log is a qualitative indicator of alpha-emitting radionuclides.

Log data are collected in new and existing boreholes to support ongoing remedial investigation activities conducted by other Hanford contractors. S.M. Stoller Corporation is also responsible for a baseline characterization program, where the objective is to log all existing boreholes associated with waste disposal sites on the Hanford Central Plateau and establish a baseline of vadose zone contamination conditions against which future measurements can be compared to assess contaminant mobility.

2.3.9.4 Monitoring Activities in the Single-Shell Tank Farms

R. G. McCain and B. W. Mathis

The tank farms geophysical logging baseline characterization effort was completed in 2000. This work delineated subsurface contaminant plumes in the vicinity of 12 single-shell tank farms. Cobalt-60, cesium-137, europium-152, europium-154, uranium-235, and uranium-238 were the dominant manmade gamma-emitting contaminants. Minor amounts of tin-126 and antimony-125 were also detected. Shorter-lived contaminants, such as ruthenium-106 (half life = 1.02 years) were found to have decayed below detectable levels.

Since specific contaminants have been identified and quantified by the baseline characterization program, it is only necessary to identify changes in contaminant levels over time. For this purpose, the radionuclide assessment system was deployed in 2000. This logging system uses scintillation detectors, which are more sensitive, in terms of photon interactions, but their energy resolution is relatively poor, and they may not be able to resolve specific energy lines associated with manmade radionuclides. Since specific radionuclides have been identified in the baseline characterization program, this is not critical for monitoring purposes. The overall result is a faster and simpler logging system capable of detecting changes in gamma activity levels over time.

Specific boreholes and depth intervals for routine monitoring are selected and prioritized on the basis of intersection with known contaminant plumes, proximity to tanks known or suspected of leaking, or proximity to tanks containing relatively large volumes of drainable liquid. Monitoring frequency is determined on the basis of overall

priority. The goal is to log high-priority boreholes on at least a yearly basis and all boreholes at least once in a 5-year period.

Initiation of waste retrieval operations in selected tanks has created a demand for additional monitoring in boreholes associated with tanks undergoing retrieval. Dry well monitoring is an important component of the overall leak detection and mitigation activity for waste retrieval operations. Currently, boreholes around a tank are logged at least once immediately prior to waste retrieval operations, and at monthly intervals during waste retrieval. After retrieval operations are completed, monthly monitoring is specified for an additional 6 months. In addition to gamma activity, the neutron moisture log is also used for monitoring purposes. Monthly logging measurements are supplemented by more frequent measurement over limited depth intervals with hand-held moisture gauges operated by tank farms personnel.

See Section 6.0.6 for additional information on vadose zone monitoring in 2003.

2.3.9.5 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 chemically 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 2003, the contractor continued construction for the Pretreatment Plant, High-Level Waste Vitrification Plant, and Low-Activity Waste Vitrification Plant. Walls and floors are being placed. Several tanks are being constructed, such as the Pretreatment Plant 4-pack tanks. In the Low-Activity Waste Vitrification Plant, the contamination zone number 3/5 drain sump collection vessel was placed in the north side of the facility. The Pretreatment Plant building is approximately 27% complete, the High-Level Waste Vitrification Plant building is approximately 10% complete, and the Low-Activity Waste Vitrification Plant building is approximately 13% complete. The balance of facilities, which includes support facilities and utilities not associated with the Pretreatment Plant, High-Level Waste Vitrification Plant, or Low-Level Waste Vitrification Plant, is approximately 25% complete.

2.3.10 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 obtained from offsite sources that are authorized by the DOE to ship waste to the site. The following sections contain information regarding specific site locations.

2.3.10.1 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 the 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 20,800 cubic meters (735,000 cubic feet) of mixed low-level waste and transuranic waste. This capacity is adequate to store the projected volumes of transuranic, mixed waste, and radioactively contaminated polychlorinated biphenyls to be generated, assuming on-schedule receipts and transfer for treatment or disposal of the stored waste. The dangerous waste designation of each waste container is established at the point of origin based on process knowledge or sample analysis.

2.3.10.2 Waste Receiving and Processing Facility

H. C. Boynton

Waste destined for the Waste Receiving and Processing Facility includes stored 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 operating 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 processed and shipped 1,881 drums and 112 boxes of waste during 2003.

2.3.10.3 Radioactive Mixed Waste Disposal Facility

R. R. Connolly

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. Disposal to trench 34 began during September 1999. Currently, there are approximately 2,000 cubic meters (70,600 cubic feet) of waste disposed in about 1,150 waste packages in trench 34, and there are approximately 60 cubic meters (2,100 cubic feet) of waste stored in about 180 waste packages in trench 31. 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.

2.3.10.4 T Plant Complex

B. M. Barnes

The T Plant Complex in the 200-West Area provides waste treatment, storage, and decontamination services for the Hanford Site as well as for offsite facilities. The T Plant Complex currently operates under RCRA interim status. In 2003, the following activities occurred at the T Plant Complex:

- Head-space gas was sampled in hundreds of containers of transuranic waste to support 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.
- Approximately 40 Shippingport reactor fuel elements were shipped to the Canister Storage Building. Twenty-eight fuel elements remain in storage. The fuel elements are from the Shippingport Atomic Power Station, a nuclear generating station in western Pennsylvania that is being decommissioned.
- Approximately 25 containers of material were shipped to the 400 Area Consolidation Center.
- 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 Facility RCRA Permit (Ecology 1994). Washington State Department of Ecology has requested an update to this permit for their review. This review is in support of the Washington State Department of Ecology eventually incorporating this permit into the Hanford Facility RCRA Permit (Ecology 1994).

The T Plant Complex has completed all necessary activities to receive K Basin sludge for storage.

The T Plant Complex continued with upgrades to the 291-T-1 stack. Upgrades included removal of fans #1 and #2 from service, installation of a new fan (fan #4), removal of ducting, and installation of new ducting. Upgrades also included installation of a new stack cabinet monitoring system containing continuous air monitors for alpha and beta gamma.

2.3.10.5 Mixed Low-Level Waste Treatment Contracts

R. R. Connolly

During 2003, Fluor Hanford, Inc. continued to ship mixed low-level waste offsite to commercial treatment units. Fluor Hanford, Inc. had contracts with Pacific EcoSolutions to non-thermally treat mixed low-level waste debris and radioactive lead solids. Under these contracts, 873 cubic meters (30,826 cubic feet) of mixed low-level waste were treated and disposed of at Hanford.

Additionally during 2003, Fluor Hanford, Inc. contracted with PermaFix to thermally treat mixed low-level waste labpacks and solids contaminated with RCRA organic constituents. Under this contract, 15.4 cubic meters (544 cubic feet) of mixed low-level waste were treated and disposed of at Hanford.

2.3.10.6 Mixed Low-Level Waste Treatment and Disposal

R. R. Connolly

During 2003, 2,250 cubic meters (79,450 cubic feet) of mixed low-level waste were treated and/or direct disposed:

- 873 cubic meters (1,142 cubic yards) of waste, or approximately 4,195 drum equivalents (based on a standard 208-liter [55-gallon] drum), were non-thermally treated to RCRA land disposal restriction standards at the Pacific EcoSolutions facility located in Richland, Washington. The treated waste was returned to Hanford and disposed of in trench 34 of the Radioactive Mixed Waste Disposal Facility.
- 50 cubic meters (65 cubic yards), or approximately 240 drum equivalents of waste, were removed from inventory at the Central Waste Complex after it was determined that they met disposal standards. This waste was direct disposed in the Hanford Site low-level burial grounds.
- 104 cubic meters (136 cubic yards), or approximately 500 drum equivalents of waste, were directly disposed into the Radioactive Mixed Waste Disposal Facility. This waste came from various Hanford Site operations and either met land disposal restriction standards in the "as generated" state, or was treated according to treatment-by-generator provisions in WAC 173-303-170(3)(b) to meet RCRA and state land disposal restrictions.
- 1,512 cubic meters (1,978 cubic yards), or approximately 7,270 drum equivalents of waste, were removed from inventory at the Central Waste Complex and directly disposed into the Environmental Restoration Disposal Facility. The waste disposed was all originally from the 183-H basins and had been stored in the Central Waste Complex since the late 1980s. Approval to dispose of this waste in the Environmental Restoration Disposal Facility was obtained through an engineering evaluation/cost analysis determination, which was approved in July 2003. There remains in the Central Waste Complex approximately 2,200 cubic meters (2,877 cubic yards) of this waste, which is scheduled to be shipped to the Environmental Restoration Disposal Facility during calendar years 2004 and 2005.
- 15.4 cubic meters (20 cubic yards), or approximately 73 drum equivalents of waste, were thermally treated to RCRA land disposal restriction standards at PermaFix, in Oak Ridge, Tennessee. The treated waste was returned to Hanford and disposed of in trench 34 of the Radioactive Mixed Waste Disposal Facility.

2.3.10.7 Navy Reactor Compartments

S. G. Arnold

Two disposal packages containing defueled U.S. Navy reactor compartments were received and placed in trench 94 in the 200-East Area during 2003. This brings the total number of reactor compartments received to

112. 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 approximately 10 meters (33 feet) in diameter and 14.3 meters (47 feet) long. They weigh between 908 and 1,362 tonnes (1,000 and 1,500 tons). Decommissioned cruiser reactor compartments are approximately 10 meters (33 feet) in diameter and 12.8 meters (42 feet) high. They weigh approximately 1,362 tonnes (1,500 tons).

2.3.11 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.

2.3.11.1 242-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 liquid waste sent to double-shell tanks for storage and reduces the potential need for additional double-shell tanks. The 242-A evaporator completed four campaigns during 2003. The volume of waste treated was 14.53 million liters (3.84 million gallons). The waste volume reduction was 4.28 million liters (1.13 million gallons), or approximately 29%, and the volume of process condensate transferred to the Liquid Effluent Retention Facility for subsequent treatment in the Effluent Treatment Facility was 5.68 million liters (1.50 million gallons).

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 2.3.11.3) 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.

2.3.11.2 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 windblown soil and weeds and to minimize evaporation of small amounts of organic compounds and tritium that may be present in 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 2003 was approximately 98 million liters (26 million gallons). The wastewater received for interim storage during 2003 included approximately 7 million liters (2 million gallons) of RCRA-regulated wastewater (primarily 242-A evaporator process condensate), and approximately 91 million liters (24 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 majority of the wastewater was received via pipeline direct from the generators. Approximately 2.26 million liters (598,000 gallons) of wastewater was received from various generators by tanker trucks.

The volume of wastewater transferred to the Effluent Treatment Facility for treatment and disposal during 2003 was 98 million liters (26 million gallons).

The volume of wastewater being stored in the Liquid Effluent Retention Facility at the end of 2003 was 46.56 million liters (12.3 million gallons). This included 2.89 million liters (763,000 gallons) of RCRA-regulated wastewater and 43.67 million liters (11.54 million gallons) of CERCLA-regulated wastewater.

2.3.11.3 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 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 2003 was approximately 98 million liters (26 million gallons), which included approximately 11 million liters (3 million gallons) of RCRA-regulated wastewater (primarily 242-A evaporator process condensate), and 87 million liters (23 million gallons) of CERCLA-regulated wastewater (primarily groundwater from the 200-UP-1 Operable Unit in the 200-West Area).

2.3.11.4 200 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 approximately 18 kilometers (11 miles) of buried pipeline connecting three pumping stations, one disposal sample station (the 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 2003 was 1,269 million liters (335.4 million gallons). The major source of this effluent was uncontaminated cooling water and steam condensate from the 242-A evaporator, with a variety of other uncontaminated waste streams received from other Hanford facilities.

2.3.11.5 300 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 the 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 to continuously receive 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 2003

was 145.5 million liters (38.43 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 2003 was 6.21 million liters (1.64 million gallons).

2.3.12 Environmental Restoration Project

The 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 CERCLA cleanup operations on the Hanford Site. To provide a barrier to contaminant migration from the disposal facility, the facility was constructed to RCRA Subtitle C Minimum Technology Requirements, which included a double liner on the bottom of the disposal cell and a leachate collection system to remove fluids that accumulate in the cell. Remediation waste disposed in the facility includes 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 the lower levels of cells 3 and 4 was completed during 2002 and is proceeding in the upper levels of those two cells. The construction of two new cells (cells 5 and 6) was initiated in 2003 with completion expected in 2004. As of the end of 2003, the facility had received over 4.2 million tonnes (4.6 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, J. D. Fancher, and M. A. Buckmaster

Full-scale remediation of waste sites began in the 100 Areas in 1996. Remediation activities in 2003 were performed in the 100-B/C, 100-K, 100-N, and 100-F Areas. Additionally, backfill activities were completed in the 100-F Area and began in the 100-B/C Area. Various records of decision issued by the DOE, EPA, and Washington State Department of Ecology authorize the remediation activities. At the 100-N Area, remediation of the treatment, storage, and disposal units is also performed in accordance with the Hanford Facility RCRA Permit. Figure 1.0.1 shows the former reactor areas (100 Areas) along the Columbia River.

A total of 506,275 tonnes (558,073 tons) of contaminated soil was removed and disposed of at the Environmental Restoration Disposal Facility from the 100 Areas remediation activities in 2003. The breakdown of volumes for each area is stated below:

- 108,808 tonnes (119,940 tons) from the 100-B/C Area
- 2,954 tonnes (3,257 tons) from the 100-K Area
- 323,535 tonnes (356,636 tons) from the 100-N Area
- 70,978 tonnes (78,240 tons) from the 100-F Area.

Since cleanup activities began in 1996, the primary focus has been on liquid effluent waste sites. After nearly 7 years of work, the number of liquid effluent waste sites requiring remediation is significantly reduced. Cleanup activities are now phasing into remediation of burial ground waste sites, while still maintaining progress on completing the liquid effluent waste sites. The volume of contaminated soil in burial grounds is less than in liquid effluent waste sites. However, the burial grounds may contain unknown materials, and additional time may be necessary to characterize and properly dispose of the waste.

Remedial actions were completed at the 618-4 and 618-5 burial grounds in 2003. Between 1998 and 2003, more than 46,200 tonnes (51,000 tons) of contaminated soil and debris were transported from the 618-4 burial ground to the Environmental Restoration Disposal Facility. More than 45,800 tonnes (50,500 tons) of contaminated soil and debris were transported to the Environmental Restoration Disposal Facility from excavation and loadout operations at the 618-5 burial ground, which began in 2002.

Remediation work at the 300-FF-1 Operable Unit began in the 300 Area in 1997 (Figure 1.0.1), and was completed in 2003. Backfill and re-grading operations at the remediated 300 Area waste sites began in November 2003 and were completed in February 2004. Remediation activities in the 300-FF-1 Operable Unit are authorized by the 300-FF-1 record of decision (ROD 1996), which was approved by the DOE and the EPA. No additional remediation is necessary in the 300-FF-1 Operable Unit. The 300-FF-2 record of decision (ROD 2001) authorizes remediation activities for the 300-FF-2 Operable Unit. Remediation for the 300-FF-2 Operable Unit is scheduled to continue in 2004.

In 2003, more than 52,590 tonnes (57,970 tons) of contaminated soil were removed and disposed of at the Environmental Restoration Disposal Facility from the 300 Area remediation activities. The breakdown of quantities for each operable unit is stated below:

- More than 15,040 tonnes (16,579 tons) for the 300-FF-1 Operable Unit
- More than 37,550 tonnes (41,391 tons) for the 300-FF-2 Operable Unit.

2.3.12.3 Facility Decommissioning Project

J. W. Golden

Decontamination and decommissioning activities continued during 2003 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 public and reduces surveillance and maintenance costs. These activities are conducted as non-time-critical removal actions under CERCLA.

During 2003, interim safe storage of the F Reactor was completed. Demolition of the 117-DR Exhaust Filter Building and associated tunnels was also completed. This facility was part of the Large Sodium Fire Facility, a permitted treatment, storage, and disposal facility undergoing RCRA closure. The D Reactor Safe Storage Enclosure design was completed, and the subcontractor initiated construction activities. The demolition and closure of the 1720-HA Arsenal in the 100-H Area was completed, and demolition of the H Reactor basin was initiated and is nearing completion. Demolition and closure of the 118-C-4 Horizontal Control Rod Storage Cave in the 100-B/C Area was also completed in 2003.

Decontamination and decommissioning activities were also initiated in the 100-N Area with the demolition of the 1304-N Emergency Dump Tank, which is in progress.

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 basins) and the 308 Building in the 300 Area.

2.3.12.5 Revegetation and Mitigation Planning

A. L. Johnson and H. Newsome

To compensate for damage to the environment by the original construction of cells 1 and 2 at the Environmental Restoration Disposal Facility, a compensation plan was approved by the DOE Richland Operations Office and U.S. Fish and Wildlife Service to revegetate portions of the Fitzner/Eberhardt Arid Lands Ecology Reserve.

The Environmental Restoration Disposal Facility mitigation project included three separate planting elements: a native grass seeding, shrub seedling planting, and native grass plug planting. The native grass seeding and a majority of the shrub seedling planting was completed in December

2002 and monitored for initial survival in the spring of 2003 with results documented in the annual environmental restoration contractor monitoring report (e.g., BHI-01694). The final Environmental Restoration Disposal Facility mitigation planting element, planting native grass plugs and remaining shrub seedlings, was completed in November 2003. Approximately 21,000 65.6-cubic-centimeter (4-cubic-inch) grass plugs were planted on the Fitzner/Eberhardt Arid Lands Ecology Reserve. The grass plugs included 10,000 thickspike wheatgrass (*Agropyron dasystachyum*), 3,500 Indian ricegrass (*Oryzopsis hymenoides*), and 7,500 needle-and-thread grass (*Stipa comata*). Approximately 20,000 164-cubic-centimeter (10-cubic-inch) shrub seedlings were planted, which included 14,000 bitterbrush (*Purshia tridentata*), 1,920 sagebrush (*Artemesia tridentata*), and 4,000 rabbitbrush (*Chrysothamnus sp.*).

All Environmental Restoration Disposal Facility mitigation planting efforts will be monitored for survival. The 120-N-1 and 120-N-2 sites were remediated by Bechtel Hanford, Inc., the environmental restoration contractor, in accordance with the Hanford RCRA documentation (closure plan) (DOE/RL-96-39). Once remediation was completed, the sites were backfilled to grade using material from a nearby borrow pit. In preparation for revegetation, the top 15.24 centimeters (6 inches) of the area to be seeded was ripped with a spring tooth drawn implement. In mid-January, the 1.6-hectare (3.95-acre) area was broadcast seeded with 11.2 kilograms per hectare (10 pounds per acre) Sandberg's bluegrass (*Poa Sandbergii*), 2.8 kilograms per hectare (2.5 pounds per acre) Indian ricegrass, 2.8 kilograms per hectare (2.5 pounds per acre) thickspike wheatgrass, 2.8 kilograms per hectare (2.5 pounds per acre) bluebunch wheatgrass, 1.12 kilograms per hectare (1 pound per acre) needle-and-thread grass, 0.56 kilograms per hectare (0.5 pound per acre) sagebrush, 0.14 kilograms per hectare (0.125 pound per acre) yarrow, and small amounts of cushion fleabane, false yarrow, phlox, wall flower, and rabbitbrush. One half of the 1.6-hectare (3.95-acre) area received 112 kilograms per hectare (100 pounds per acre) of fertilizer co-applied during seeding, while the remaining area was treated with Biosol, an organic, slow release fertilizer, at a rate of approximately 1,120 kilograms per hectare (1,000 pounds per acre).

Upon completion of seeding and fertilizer application, the entire seeded area was irrigated with 0.62 centimeter (0.24 inch) of water. One-half of the fertilized area and one-half of the Biosol-treated area were each hydromulched with the industry standard mulch fiber. The remaining fertilizer- and Biosol-treated areas were mulched with grass straw at approximately 4.5 tonnes (4.96 tons) per hectare and crimped into the soil surface. Initial vegetation surveys were conducted on May 13, 2003; 21 species were recorded on the entire site including all 12 of the seeded species. Total cover was greatest on the fertilizer/straw mulch area with 18 species and 68% cover, followed by the Biosol/straw mulch area with 13 species and 44.1% cover. The fertilizer/hydromulch area yielded 13 species and 29.1% cover followed by the Biosol/hydromulch area with 12 species and 18.5% cover. This revegetation project will be incorporated into the environmental restoration contractor annual revegetation monitoring project report (e.g., BHI-01694).

In anticipation of future environmental restoration projects, a possible need for additional borrow material, and the need to protect ecological resources, an environmental assessment (*Environmental Assessment for Reactivation and Use of Three Former Borrow Sites in the 100-F, 100-H, and 100-N Areas* [DOE/EA-1454]) was completed in March 2003. These sites were not included in the 2001 *Draft Industrial Mineral Resources Management Plan* (DOE-RL-2000-61). As described in the environmental assessment, the borrow pit at the 100-F Area was developed in the summer of 2003 to supply material for the restoration of a 100-F Area liquid waste site. Prior to the excavation of fill materials, the top 30.5 centimeters (12 inches) of topsoil was salvaged and stockpiled for redistribution across the borrow pit upon completion of project activities. Following borrow pit re-contouring and topsoil redistribution, the entire 61.75-hectare (152.59-acre) pit area was broadcast seeded with 11.2 kilograms per hectare (10 pounds per acre) Sandberg's bluegrass; 2.8 kilograms per hectare (2.5 pounds per acre) Indian ricegrass, 2.8 kilograms per hectare (2.5 pounds per acre) thickspike wheatgrass, and 2.8 kilograms per hectare (2.5 pounds per acre) bluebunch wheatgrass and fertilized with 112 kilograms per hectare (100 pounds per acre) of fertilizer co-applied during seeding. The entire seeded area was irrigated with 0.62 centimeter (0.244 inch) of water per hectare and mulched with approximately 4.5 tonnes (4.96 tons) per hectare that

was crimped into the soil surface. Revegetation efforts at the borrow pit will be monitored for success with results documented in the environmental restoration contractor revegetation monitoring report (BHI-01694).

2.3.13 Groundwater Remediation Project

B. H. Ford

The DOE established the Groundwater/Vadose Zone Integration Project (Integration Project) in 1997. On July 1, 2002, the project was transferred from the environmental restoration contractor (Bechtel Hanford, Inc.) to Fluor Hanford, Inc. and designated the Groundwater Remediation Project. The purpose of the Groundwater Remediation Project is to coordinate all projects at the Hanford Site involved in characterization, monitoring, and remediation of groundwater and vadose zone contamination, with the overall objective of protecting the Columbia River.

The Groundwater Remediation Project 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 Performance Assessment Project is under the umbrella of the Groundwater Remediation Project.

During 2003, the Groundwater Remediation Project team compiled an array of accomplishments that span its key focus areas – groundwater remediation, soil zone remediation, waste site investigations, assessment of Hanford Site impacts, science and technology, and integration management. The efforts within these focus areas directly support the DOE's plan for the Hanford Site.

2.3.13.1 Groundwater Remediation

G. G. Kelty and D. B. Erb

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 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 part per million) of chromium (WAC 173-201A). Chromium concentrations exceeding 600 µg/L (0.6 part per million) have been measured in the porewater of riverbed sediment adjacent to the 100-D Area (BHI-00778). Background chromium concentrations are usually less than 1 µg/L (1 part per billion) in the river.

During 1994, a pilot-scale groundwater extraction system was installed in the 100-D Area to test chromium removal from groundwater using ion exchange technology. Following the issuance of a record of decision in 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 2003, the total amount of groundwater treated by pump-and-treat systems in the 100-D and 100-H Areas was 416.6 million liters (110 million gallons), with the removal of approximately 43 kilograms (94.7 pounds) of hexavalent chromium. Since 1997, more than 1.95 billion liters (514.8 million gallons) of groundwater have been treated, with 204.3 kilograms (450.4 pounds) of chromium removed. 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 2003, the 100-KR-4 pump-and-treat system treated 517.6 million liters (136.7 million gallons) of groundwater and removed 36.7 kilograms (80.9 pounds) of chromium. Total chromium removed since operations began in 1997 is 221.9 kilograms (489.2 pounds) through treatment of

2.20 billion liters (581.1 million gallons) of water. Treated groundwater is re-injected into the aquifer upgradient from the 100-KR-4 extraction wells.

In addition to pump-and-treat remediation, use of in situ redox manipulation technology continued in the southwest portion of the 100-D Area to treat 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-ferric 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 2003, the treatment zone was expanded by injecting the chemical reducing agent into five wells.

Chromium concentrations in wells along the barrier axis are generally less than 20 µg/L (0.02 part per million), except in 14 barrier wells where concentrations are as high as 980 µg/L (0.98 part per million). Compliance wells to the west of the barrier still have high concentrations ranging from 11 to 1,200 µg/L (0.011 to 1.2 parts per million).

Barrier construction continued during 2003. By the end of 2003, five additional wells had been treated, increasing the barrier length to 680 meters (2,230 feet). The barrier is approximately 15 meters (48 feet) wide.

Strontium-90. The 100-NR-2 (N Springs) pump-and-treat system began operating in September 1995 north of N Reactor and was designed to reduce the flux of strontium-90 to the Columbia River. 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 2003. Approximately 114.1 million liters (30.1 million gallons) of water were processed during 2003. During that period, 0.20 curies (7.4 gigabecquerels) of strontium-90 were removed from the groundwater. More than 900.8 million liters (237.9 million gallons) of groundwater have been processed since the system began operation, removing 1.5 curies (55.5 gigabecquerels) of strontium-90.

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-scale operation beginning in 1996. During 2003, 255 million liters (67.3 million gallons) of groundwater were treated, removing 799 kilograms (1,761 pounds) of carbon tetrachloride. A total of 2.21 billion liters (584 million gallons) of groundwater have been processed since startup, removing 7,848 kilograms (17,302 pounds) of carbon tetrachloride.

Uranium, Technetium-99, Carbon Tetrachloride, and Nitrate. Treatment of the groundwater plume underlying the 200-UP-1 Operable Unit in the 200-West Area continued throughout 2003. 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 was used 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 2003. Three extraction wells were used during the year. The primary extraction well, 299-W19-39, ran continuously and was supplemented with smaller amounts of water from two upgradient wells, 299-W19-36 and 299-W19-43, in the high concentration part of the plume. Combined, the three extraction wells pumped 93.9 million liters (24.8 million gallons) of groundwater. The Effluent Treatment Facility treated 86.4 million liters (22.8 million gallons) of groundwater. Treatment of groundwater removed 10.1 grams (0.0222 pound) of technetium-99, 18.2 kilograms (40.1 pounds) of uranium,

2.7 kilograms (6.0 pounds) of carbon tetrachloride, and 3,191 kilograms (7,035 pounds) of nitrate. To date, the system has treated 714 million liters (189 million gallons) of water, removing 103.3 grams (0.2316 pound) of technetium and 181 kilograms (399 pounds) of uranium. The pump-and-treat operation made progress toward reducing technetium-99 to below required cleanup concentration levels as concentrations in all monitoring and extraction wells were below the remedial action objective of 9,000 pCi/L. Similar progress was made with uranium (DOE/RL-2003-58) as concentrations at all but one well, 299-W19-43, were below the remedial action objective of 480 μg/L. For well 299-W19-43, the reported concentration of uranium was exactly at the remedial action objective level.

During 2003, technetium-99 concentrations peaked at 188,000 pCi/L (6,956 Bq/L) at S-SX Tank Farm in well 299-W23-19. Concentrations declined to an average of 43,000 pCi/L (1,591 Bq/L) by the end of 2003. After completing a field evaluation and facility modification, it was decided that this well should be extensively purged prior to sampling. Purging (greater than 3,785 liters [1,000 gallons]) during quarterly sampling events was implemented starting in March 2003 (RPP-10757). The purgewater 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 2003. 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 2003; the other two systems are no longer operational. 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 2003. In 2003, 294 kilograms (658 pounds) of carbon tetrachloride were removed. Since operations began, soil-vapor extraction has removed 78,092 kilograms (172,163 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 2003 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. The following summary provides descriptions of activities that were performed during 2003.

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 in 2003. 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 remedial alternative evaluations 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. Under Tri-Party Agreement milestone M-015-38A, the feasibility study and proposed plan were submitted to the state and federal regulators on March 31, 2003. Comments from the regulators are being incorporated. In addition, ecological sampling was conducted on two of the 200-CW-1 waste sites in the fall of 2003. Additional ecological sampling is planned for the spring of 2004. The feasibility study will be revised to incorporate the data from these sampling events and to support the public review of the proposed plan, anticipated for early 2005.

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 final remedial investigation activities were performed in 2003 and included test pit characterization work at the 216-B-63 trench, 216-S-10 pond, and 216-S-10 ditch. In addition, three boreholes (one at each waste site) were installed at the 216-A-29 ditch, 216-B-63 trench and 216-S-10 ditch. The borehole at the 216-S-10 ditch was completed as a RCRA groundwater monitoring well. Previous test pit characterization work was completed in 2002 at the 216-A-29 ditch and partially completed at the 216-B-63 trench. The borehole at the 216-S-10 pond was installed during 1999 and completed as a RCRA groundwater monitoring well.

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, the 242-S evaporator, 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. Data from the field work were compiled into a remedial investigation report (DOE/RL-2003-11), which was provided to the regulators for review during May 2003 in fulfillment of Tri-Party Agreement milestone M-015-40B. Comments are being incorporated into this document and an update to the work plan was also initiated. In the fall of 2003, a feasibility study was initiated to evaluate the remedial alternatives that could be applied to the waste sites in these operable units.

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 at T Plant. A work plan (DOE/RL-2001-66) was approved in 2002 that 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. During late 2003, two 30.4-meter-(100-foot-) deep boreholes were drilled in the 216-B-58 trench in anticipation of the transfer of four 200-LW-1 waste sites in the BC cribs and trenches area into the 200-TW-1 Operable Unit. Remaining field activities will be conducted in 2004.

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 investigative work includes installing vadose zone boreholes and test pits to collect soil samples and geophysical logging. These activities are scheduled to be conducted in 2004.

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, the Reduction-Oxidation Plant, and the Plutonium-Uranium Extraction Plant, as well as the 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, which received regulator approval in February 2003 to proceed with field work, proposed 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). Field work was completed in October 2003 and included installing vadose zone boreholes to collect soil samples and conduct geophysical logging. In addition, five drive casings were installed and geophysically logged at the 216-A-10 crib to determine the optimum location for the characterization borehole that was installed. Evaluation of the data was initiated in conjunction with preparation of the remedial investigation report for these operable units. This report is scheduled to be provided to the regulators in June 2004.

200-TW-1, 200-TW-2, and 200-PW-5 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 200-PW-5 Operable Unit consists of cribs, French drains, and unplanned releases that received similar types of wastes and quantities of effluents as the 200-TW-2 Operable Unit. The work plan (DOE/RL-2000-38) prescribed 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 operable units were completed in 2001 and consisted of installing three vadose zone boreholes (one each at the 216-T-26 crib, the 216-B-38 trench, and the 216-B-7A crib), collecting soil samples, and geophysical logging. Data from the laboratory analyses were compiled into a remedial investigation report (DOE/RL-2002-42), which was submitted to state and federal regulators in 2003 under Tri-Party Agreement milestone M-015-41B. The remedial investigation report includes a human health risk assessment and a screening of ecological impacts. In late 2003, following preparation and approval of a sampling and analysis plan, a borehole was drilled in the 216-B-26 trench. Data will be incorporated into a feasibility study and proposed plan that were initiated in 2003 to evaluate remedial alternatives to address the contamination at the waste sites in the combined 200-TW-1, 200-TW-2, and 200-PW-5 Operable Units.

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 work plan for this operable unit was submitted for review during 2001 (DOE/RL-2001-01). The work plan includes a strategy to reach final decisions for remediation of carbon tetrachloride in the 200-West Area. The work plan 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 S Plant (reduction-oxidation or redox process), A Plant (plutonium-uranium extraction or PUREX process), U Plant (uranium recovery process), and the C Plant (201-C Building or hot semi-works process). The 200-PW-6 Operable Unit waste sites received plutonium-rich process waste from the Plutonium Finishing Plant. The revised work plan is expected to be approved during 2004.

The remedial investigation at the 200-PW-1 Operable Unit is expected to focus on one representative waste site, 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 and was completed in 2003 (CP-13514). 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, pipelines that conveyed liquid waste to those discharge sites, and solid waste burial ground trenches. The second step in the carbon tetrachloride vadose zone investigation will extend deeper in the vadose zone and to locations beyond the study area investigated during the first step. The representative waste site investigation includes soil sampling, soil vapor sampling, and geophysical logging during drilling of a slant borehole beneath the 216-Z-9 trench. The representative waste site investigation and initiation of the second step in the carbon tetrachloride vadose zone investigation are scheduled for 2004.

The remedial investigation at the 200-PW-3 Operable Unit is expected to focus on one representative waste site, the 216-A-8 crib. The representative waste site investigation, which includes soil sampling and geophysical logging, is scheduled for 2004.

200-UR-1 Waste Group Operable Unit. The 200-UR-1 Waste Group Operable Unit includes unplanned releases that generally consisted of small volume spills to the ground surface or subsurface; or windblown radioactive particulates, plant materials, and/or animal feces. Many of the unplanned release sites in the 200 Areas resulted from loss of control of radioactive materials during waste transfer or containment in areas with process facilities, roads, railroad lines, or tank farms. A small number of unplanned release sites were associated with burial grounds, trenches, and cribs. Causes for the releases were attributed to administrative failures, equipment failures, and operator error as well as to vegetation and animal intrusion. In the fall of 2003, a work plan and data quality objectives process were initiated. The data quality objectives process grouped the 147 unplanned release sites to allow consistent and streamlined remedial decision making.

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 2003. Activities included water balance monitoring, stability surveys, and biotic surveys. A draft report to document the monitoring results was prepared during 2003.

U Plant Closure Area. The U Plant Closure Area project is a prototype for area closures that will focus on addressing high risk sites and associated contiguous areas in a cost-effective and integrated manner. Key components of this strategy include cleanup of waste sites, facilities, and pipelines within a defined geographic area. For this area closure, it is anticipated that a separate record of decision will be needed for the high risk sites and 221-U facility, separate engineering evaluation/cost analyses and action memoranda will be needed for ancillary facilities and pipelines, and a separate record of decision will be needed for the 200-UP-1 Groundwater Operable Unit. These components are being executed separately because they require distinct alternatives and specific responses. A *Focused Feasibility Study for the U Plant Closure Area Waste Sites* (DOE/RL-2003-23) and the *Proposed Plan for the U Plant Closure Area Waste Sites* (DOE/RL-2003-24) was submitted to the EPA and Washington State Department of Ecology on June 27, 2003, which satisfied Tri-Party Agreement milestone M-015-47. The focused feasibility study and proposed plan continue to undergo regulator review and comment resolution. The most recent version of the proposed plan recommends that four high-risk cribs (216-U-1, 216-U-2, 216-U-8, and 216-U-12) be modified with barriers or caps; a remove and dispose alternative be implemented at 14 waste sites (e.g., trenches, unplanned release sites, French drains, one pipeline); institutional controls, monitoring of natural attenuation, and maintenance of existing soil cover be implemented at 8 sites (e.g., cribs, reverse wells, septic systems); and no action be taken at 4 sites (e.g., dump sites and septic tank). The record of decision is expected to be issued in 2004 and remedial action initiated in 2005. A remedial design report/remedial action work plan for these waste sites is expected to be completed in 2004. To support confirmation of the proposed actions and collect needed remedial design data, a *Data Quality Objectives Summary Report for the U Plant Closure Area Waste Sites* (CP-16244) was completed in 2003.

Regulators are currently reviewing a sampling and analysis plan (DOE/RL-2003-51) based on the data quality objectives. The document is expected to be issued in 2004. Characterization activities planned for 2004 include surface geophysical surveys, surface radiation surveys of selected

waste sites, and installation of drive casings to facilitate spectral gamma logging at the 216-U-1, 216-U-2, 216-U-8, and 216-U-12 cribs.

BC Cribs and Trenches Area. The BC cribs and trenches area was identified for accelerated closure during 2003. Two trenches were identified for further characterization to facilitate an eventual decision regarding remedial action(s). The 216-B-58 trench, previously selected as a representative site for the 200-LW-1 Operable Unit, was the focus of two boreholes in 2003. The first borehole was located at the point of apparent highest concentration. The second borehole was drilled following the discovery of cobalt-60 at the west end of the trench during geophysical logging of drive casings that were placed to determine the point in the trench having highest contamination. The 216-B-26 trench, in the 200-TW-1 Operable Unit, was also sampled following approval of a sampling and analysis plan (DOE/RL-2003-44).

Specific data from waste sites within the BC cribs and trenches area were deemed essential to adequately characterize waste sites in this area. Efforts were also initiated to transfer four 200-LW-1 Operable Unit waste sites in the BC cribs and trenches area to the 200-TW-1 Operable Unit. This assembly of waste sites will be included in a feasibility study and proposed plan that will be submitted for regulator review at the end of March 2004. At this point, it is uncertain whether a partial record of decision for the BC cribs and trenches area will be sought.

618-10 and 618-11 Burial Grounds. In July 2002, the DOE assigned responsibility for the remedial design, planning, and execution of remedial actions for the 618-10 and 618-11 burial grounds in the 300-FF-2 Operable Unit to the Groundwater Protection Program (now the Groundwater Remediation Project). In June 2003, a remedial design technical workshop was held to gather technical experts from several DOE sites, academia, and industry who have experience in dealing with buried waste containing transuranic elements. The workshop was designed to share lessons learned and identify issues and potential solutions for a wide range of topics that affect the remedial design for these burial grounds. Results of the workshop are documented in WMP-17684.

In parallel with the workshop, a safety analysis was conducted of these burial grounds to systematically identify and analyze the hazards associated with surveillance, characterization, and groundwater monitoring activities. The basis for interim operations (CP-14592) was issued in August 2003. In parallel with this document, an unreviewed safety question program was developed and implemented, preliminary remedial design activities were initiated, and an update to a portion of the *Remedial Design Report/Remedial Action Work Plan for the 300 Area* (DOE/RL-2001-47) was generated. With funding support from DOE Headquarters, a program was also initiated to demonstrate technologies for the in situ delineation and excavation of transuranic waste using innovative technologies. This program is scheduled to continue through fiscal year 2006.

2.3.13.4 Assessment of Hanford Impact

R. W. Bryce and C. T. Kincaid

During 1999, the DOE initiated development of an assessment tool that will enable 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 local cultures and economy. This tool was named the System Assessment Capability. An assessment was completed during 2002 with the System Assessment Capability that demonstrated it is a functional assessment capability. The results of that assessment were presented in *An Initial Assessment of Hanford Impact Performed with the System Assessment Capability* (PNNL-14027).

During 2003, preparations were initiated to support an update to the Hanford Site's composite analysis. A composite analysis was first performed for Hanford in 1998 (PNNL-11800). This analysis assessed the future impact on human health from all radioactive waste sources that will remain at Hanford and was based on model simulations of the movement of contaminants from these sources through the environment. The analysis was required by DOE Order 435.1 as a condition of the disposal authorization for low-level radioactive waste at the Hanford Site. Modifications were made to the capability and to the database supporting the simulations.

The major changes to the capability included the addition of a model to simulate contaminant transport through the air pathway. This was required because the composite analysis is an all pathways analysis, while the System Assessment Capability was initially assembled to examine the vadose zone/groundwater/river pathway. A soil model was also added so that the accumulation of contamination in the soil as a result of air transport of contaminants and irrigation with contaminated groundwater could be simulated. The results from this model will be used to assess uptake by plants and exposure to humans and ecological species.

Improvements to the database supporting the assessment include primarily improvements to the inventory database. Inventory has been estimated for additional waste sites through the use of the Soil Inventory Model developed by the Science and Technology Project (BHI-01496). This model uses information from historic facility operation records along with chemical reaction models to estimate the amount and form of various contaminants in waste streams discharged or disposed to the waste sites at Hanford. Results of field characterization efforts at waste sites are also used to validate the results of the Soil Inventory Model and have led to an improvement in the estimates.

Not only have the estimates of inventory at these waste sites been improved, but the inventory, transport, and impact of additional radionuclides will be considered in the update to the composite analysis. Table 2.3.1 lists the contaminants to be examined in this assessment of the impact of radioactive wastes. Data are being assembled to simulate chromium, carbon tetrachloride, and nitrate contaminant sources in future assessments.

Table 2.3.1. Radioactive Contaminants Evaluated in the Composite Analysis and Hazardous Chemical Contaminants Planned for Future Analyses

Radioactive Contaminants	
Tritium	Europium-152
Carbon-14	Radium-226
Chlorine-36	Protactinium-231
Selenium-79	Uranium-233
Strontium-90	Uranium-234
Technetium-99	Uranium-235
Iodine-129	Neptunium-237
Cesium-137	Uranium-238
Hazardous Chemical Contaminants	
Chromium	Nitrate
Carbon Tetrachloride	

Prior use of aggregated waste sites has been dropped during preparation for the composite analysis. Where groups of similar waste sites were aggregated in past analyses, the current effort is incorporating waste site specific data enabling the simulation of each waste site as an individual source to the vadose zone and groundwater.

Site-wide assessment results were used in several planning efforts at Hanford during 2003. The results were used by Fluor Hanford, Inc. to prioritize work in Hanford's strategy for groundwater protection, remediation, and monitoring (DOE/RL-2002-68). Assessments performed with the System Assessment Capability identified the BC cribs and trenches as one waste site where groundwater protection could be enhanced through acceleration of remedial actions. Characterization in support of the record of decision for the BC cribs and trenches area was initiated in 2004 rather than waiting until 2020 with the expectation that through earlier action the potential release of technetium-99 from the BC cribs and trenches area can be delayed and the concentration in groundwater will be reduced when the release occurs. The capability was also used to support a draft optimization strategy for Central Plateau closure. A site-wide cumulative assessment was also included in the Hanford Solid Waste Environmental Impact Statement (DOE/EIS-0286F).

2.3.13.5 Remediation and Closure Science Project

M. D. Freshley

The Groundwater Remediation Project includes a science and technology effort to provide data, tools, and scientific understanding to fill information gaps to make remediation and site closure decisions. These activities are accomplished under the Remediation and Closure Science Project. The following is a description of 2003 accomplishments.

Soil Inventories. During 2003, the Soil Inventory Model was applied to estimate inventories for more than 300 past-practice soil waste disposal sites. This data will be used for the 2004 Composite Analysis, which will be performed with using the System Assessment Capability computer

model. Work is continuing to estimate radionuclide inventories for the remaining waste sites to complete development of the Soil Inventory Model in 2004.

Tank Farm Investigations. The results of laboratory and modeling studies for the B-BX-BY Tank Farm were summarized in Appendix D of the Field Investigation Report (RPP-10098). The laboratory and modeling efforts included contributions from the Remediation and Closure Science Project and the Environmental Management Science Program. Activities were initiated to evaluate transport of uranium and technetium-99 in the T-TX-TY Tank Farm.

Vadose Zone Transport Field Study. Science and Technology Project staff completed the final field experiment, which evaluated reactive transport of non-radioactive strontium in the vadose zone at a clastic dike (a common sedimentary structure in the vadose zone at Hanford) located along Army Loop Road. The results of field experiments are being used to update conceptual and numerical models of water and contaminant transport in the vadose zone incorporating lateral spreading. This information is important for designing and implementing surface barriers over waste sites.

Biological Fate and Transport. During 2003, the Science and Technology team completed laboratory experiments to determine the uptake of strontium-90 by aquatic species. The goal of these experiments was to determine the rate at which radionuclide uptake occurred and the total uptake amount for determining exposures. The results are being incorporated into ecological risk assessment modules of the System Assessment Capability.

2.3.13.6 Integration Management: Strategic Planning, Public Involvement, and Databases

T. W. Fogwell and K. L. Nickola

During 2003, the Groundwater Protection Program's name was changed to the Groundwater Remediation Project to more closely align project work scope with similar site-wide DOE project work scopes and align the project with "end state" goals and remedial actions. Throughout the year, Groundwater Remediation Project personnel continued to work closely with the DOE and Hanford regulators to characterize, protect, remediate, and monitor Hanford Site groundwater. Project staff continued to 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 Remediation Project team worked throughout 2003 to complete work found in the project's master plan of action, *Hanford's Groundwater Plan: Accelerated Cleanup and Protection* (DOE/RL-2002-68). Developed in 2002, the plan describes how and when accelerated cleanup work will be accomplished. Project personnel also worked to revise the *Optimization Strategy for Central Plateau Closure* (WMP-18061).

Public Involvement. During 2003, 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. Project 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 Internet website with information about the project's missions, a calendar of upcoming events, and links to a variety of valuable resources was launched in 2003 at http://www.hanford.gov/cp/gpp/. The Groundwater Remediation Project team also produced a 24-page, full-color 2002 progress report and a 4-page, full-color brochure, available in hard copy form or electronically on the Internet website under the Program Library link.

Databases. The Groundwater Remediation Project manages several Hanford Site environmental databases, available on its Internet and/or Intranet websites. These databases, collectively referred to as the Virtual Library, provide a web-based resource of Hanford environmental data to Hanford Site staff. Through the use of stand-alone modules, users can retrieve, graph, and generate reports with data contained in the electronic library. During 2003, several additions were made to the Virtual Library, including user-requested enhancements to the Environmental Monitoring module. The Environmental Monitoring module contains data for groundwater, soil, soil gas, air, surface water, and miscellaneous material samples captured in the Hanford Environmental Information System

(HEIS 1994) database. Over 50 new features were added, at user request. Data from the Hydrodat database maintained by Pacific Northwest National Laboratory were also added to the Environmental Monitoring module, giving scientists access to Hanford Site water-level data from groundwater monitoring wells. "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. The "orphaned" database added during 2003 contained particle size and distribution data for Hanford Site soil.

In addition to the Virtual Library, the Groundwater Remediation Project manages the Hanford Environmental Information System, Hanford Well Information System, Hanford Geographic Information System, and Waste Information Data System databases. During 2003, the Hanford Geographic Information System was expanded to include data associated with more than 131 land survey jobs, and Waste Information Data System software was updated to include use of a map portal. The Groundwater Remediation Project also documented closure of 14 waste sites between July 2002 and June 2003 through the Waste Information Data System. Other databases supporting specific activities within the Groundwater Remediation Project were maintained during 2003, including pump-and-treat project-specific databases and the in situ redox manipulation project-specific database.

2.3.14 Hanford Tank Waste Science and Technology

J. P. Duncan

In 1994, the DOE's Office of Environmental Management created the Tanks Focus Area designed to integrate radioactive tank waste remediation efforts across the DOE complex. During September 2002, responsibility for the Tank Focus Area was transferred to the DOE Office of the Associate Manager for Science and Technology. Following this transition, CH2M HILL Hanford Group, Inc. and Pacific Northwest National Laboratory signed a memorandum of agreement (Memorandum of Understanding 2002) on science and technology integration in support of Hanford tank cleanup and closure. This partnership's 2003 contributions are discussed in the following sections.

2.3.14.1 Safe Tank Waste Storage

Remotely Operated Non-Destructive Evaluation 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 Evaluation System was developed in 2002. This system uses sound waves that are processed by a technique known as Synthetic Aperture Focusing, which is transformed with software developed by Pacific Northwest National Laboratory to produce high resolution images of the entire knuckle region. These images are used to detect and locate stress and corrosion cracks.

During 2003, Pacific Northwest National Laboratory developed a two-transducer Remotely Operated Non-Destructive Evaluation technique (Tandem Synthetic Aperture Focusing) that enables accurate measurements of the length and depth of a crack. In late August 2003, prototype testing of the technique was completed following successful performance demonstration testing. The system was successfully deployed in tank 241-AW-102.

2.3.14.2 Double-Shell Tank Thermal and Seismic Analysis

Under Tri-Party Agreement milestone M-48-14, an integrity assessment of the double-shell tank system is required. As a result, Pacific Northwest National Laboratory has initiated a 3-year effort under CH2M HILL Hanford Group, Inc.'s Double-Shell Tank Integrity Program to assess thermal and operation loads, seismic analyses, liquid level increases, minimum tank wall thicknesses, and tank bucklings.

During 2003, Pacific Northwest National Laboratory completed a finite element model of a representative double-shell tank and analysis of initial thermal and operating load cases. Analysis of soil elements beyond the tank boundaries and temperature distribution within the concrete forming the tanks and in the surrounding soil was completed, as was

a 60-year thermal cycling and concrete creep test (deformation of the concrete over time due to constant stress). Other studies were initiated in 2003 to determine the adequacy of tank footings, evaluate the soil modulus under the tank (resistance to loads), and to develop calculations to demonstrate structural integrity.

2.3.14.3 Tank Waste Retrieval

During 2003, Pacific Northwest National Laboratory and CH2M HILL Hanford Group, Inc. conducted testing and provided technical support for the resolution of vapor and gas issues associated with the retrieval and transfer of tank waste. Non-radioactive simulants were used in conjunction with the C-200 vacuum retrieval system to estimate the amount of suspended materials in the C-200 series tanks (PNNL-14408).

Pacific Northwest National Laboratory and CH2M HILL Hanford Group, Inc. assessed the costs associated with waste mixing and mobilization. The assessment determined that one mixer pump, not two as was previously planned, would be sufficient for double-shell tank AN-101. This change resulted in savings of approximately $1 million.

2.3.14.4 Tank Waste Treatment Technologies

DOE continues to investigate systems to treat large quantities of mixed low-level waste. A treatment system is needed that can reduce the volume of waste for final disposal, isolate the radionuclides in a final waste form, and destroy the hazardous component in the waste. During 2003, three technologies were evaluated to supplement the processing of low-level tank waste: steam reforming, bulk vitrification, and containerized grout. These technologies are being evaluated as methods to accelerate waste cleanup and reduce costs.

One method that was tested is steam reforming. Steam is superheated and reacts with the organics in mixed low-level waste, generating a hydrogen-rich gas, and isolates radioactive and non-radioactive inorganics in a form that can then be encapsulated and/or vitrified. The small-scale tests performed during 2003 indicate that the mass and volume of waste is reduced using this method. Steam reforming would allow acceleration of the cleanup of tank waste by reducing the amount of waste requiring vitrification in the Waste Vitrification Plant

Bulk vitrification is the conversion of radioactive and mixed waste into radioactive glass within a container suitable for land disposal. Pacific Northwest National Laboratory conducted laboratory tests using crucible melts to develop a successful baseline aluminosilicate glass formula. This formulation was found to be less sensitive to sulfate concentrations compared to borosilicate glass formula, suggesting higher waste loading capability. Bulk vitrification would allow accelerated tank waste cleanup by reducing the mass of sodium requiring vitrification in the Waste Treatment Plant.

Containerized grout consists of solidifying waste with grout-forming additives to form immobilized waste suitable for land disposal. Containerized grout would allow acceleration of the tank waste cleanup by reducing the amount of sodium that the Waste Treatment Plant would need to process.

During 2003, Pacific Northwest National Laboratory completed waste form contaminant release calculations for steam reforming, bulk vitrification, and containerized grout technologies, as well as the baseline Waste Treatment Plant glass (PNNL-14414).

2.3.14.5 Accelerating Tank Closure

During 2003, Pacific Northwest National Laboratory characterized the sludge and drainable liquid from double-shell tank AY-102 to develop models for long-term risk assessments required to close underground radioactive waste tanks. Tests included physical characterization of the waste, quantitative analysis of waste composition, and water leachability and acid digestion. Results indicated technetium-99 was not completely water leachable as was previously assumed.

Sludge and drainable liquid samples from tank AY-102 were found to contain approximately 80% non-water leachable technetium-99, while technetium-99 from tank BX-101 was 100% water leachable, indicating that sludge and liquid samples are tank specific.

Characterization of solid phases within tank waste solutions was also initiated during 2003. Solubility of the solid and liquid components is necessary to prevent unwanted precipitation or gel formations that can affect remediation pretreatment.

2.3.14.6 Radiological Clearance for Release of Selected Hanford Reach National Monument Lands

Significant progress was made in 2003 toward the radiological release of selected Hanford Reach National Monument lands. The document, *Historical Site Assessment: Select Hanford Reach National Monument Lands – Fitzner/Eberhardt Arid Lands Ecology Reserve (ALE), McGee Ranch/Riverlands, and North Slope Units* (PNNL-13989), was completed and issued in July 2003. The objectives of this assessment were to determine locations where radioactive contamination may exist on these units, what activities could have resulted in radioactive contamination of these units, which radionuclides are most likely to exist at locations within these units based on existing environmental monitoring data, and an estimate of the current concentrations of radionuclides within these units.

Authorized limits, or radiological release criteria, that are required to release real property per DOE Order 5400.5 were developed and submitted to DOE Headquarters for approval in December 2003. The Authorized Limit Request was approved by DOE Headquarters in early March 2004, and issued as a Pacific Northwest National Laboratory document in April (PNNL-14622). This is the first such approved authorized limit for such a significant transfer of real property in the nation. The technical basis, which provides the radiation dose modeling analysis supporting the technical derivation of the authorized limit, was published as a Pacific Northwest National Laboratory document in March (PNNL-14531).

In addition, a soil sampling and analysis plan was prepared for the Fitzner/Eberhardt Arid Lands Ecology Reserve, *Fitzner-Eberhardt Arid Lands Ecology (ALE) Reserve Soil Sampling and Analysis Plan*, PNNL-14633, that is currently being carried out to confirm soil concentrations on the reserve are below the approved authorized limit. Fifty sample locations were identified; 31 randomly selected sites across the reserve based on a systematic grid pattern and a random starting location, 10 sites on two research lysimeter plots that are known to have used radionuclides in past years, and 9 sites located in alluvial fans at the base of Rattlesnake Mountain, in drainage washes, or from areas that appear to have collected windblown sand.

2.4 Environmental Occurrences

B. G. Fritz

Releases of radioactive and regulated materials to the environment are reported to the 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 the DOE Public Reading Room located in Richland, Washington. The following sections summarize the environmental occurrences that took place during 2003. 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 2003.

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 was one unusual occurrence with environmental impacts:

- Diesel spill from portable tank at 242-S Facility (RP-CHG-TANKFARM-2003-0004).

On January 22, 2003, two operators arrived at a hot water fill station near the 242-S Facility in the 200-West Area to fill a hot water truck. Upon entering the area, the operators noticed a strong fuel odor. They identified the smell as being diesel fuel and pinpointed standing puddles near two portable diesel powered air compressors as the source of the odor. Shortly after the spill, Health Physics Technicians cordoned off the area and isolated the spill with adsorbent material. It was later discovered that approximately 757 liters (200 gallons) of diesel had leaked as a result of a fuel line hose being incorrectly attached during maintenance activities. The effected soil was excavated and moved to a remediation area. To avoid a repeat of this incident, more robust hoses and fittings were installed on the compressors and a protector was installed over the fuel lines on the compressors. This will reduce maintenance activities, which will reduce the possibility of error.

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 occurred during 2003:

- Contaminated wasp nest discovered at 100-N Area (Roll-Up) (RL-BHI-GENAREAS-2003-0003).

On August 12, 2003, radiological control support was requested at the 1143 Maintenance Building in the 100-N Area to perform a radiological survey of a generator that contained three wasp nests. The following day, three additional wasp nests were found at the 100-N Area maintenance facility. All of the nests were located within a Radiologically Controlled Area but outside of a posted

Contamination Area. The nests discovered on August 12 had beta-gamma levels of 260,000 dpm direct and 17,000 dpm removable. The nests discovered on August 13 were lower in activity, with the highest level of 18,000 dpm direct. No alpha radioactivity was discovered. The generator was used in the 100-H Area before it was moved to the 100-N Area; therefore, the mud used by the wasps to build nests most likely originated from water used to control dust in the 105-H Basin.

- Contaminated wasp nests discovered outside of contamination area (Roll-Up) (RL-BHI-DND-2003-0004).

Throughout the summer of 2003, contaminated wasp nests were found around the 105-H Reactor Building in the 100-H Area. Surveys for contaminated wasp nests were prompted by initial discoveries of nests with beta-gamma levels as high as 120 millirad per hour (beta) and 1 millirem per hour (gamma). Numerous contaminated nests were identified over the course of the summer. Contaminated wasp nests were removed and disposed of in accordance with 10 CFR 835. The contamination originated in the 105-H Basin where a 5.1-centimeter (2-inch) layer of water was maintained on the floor. The water on the basin floor resulted in the creation of an abundant mud source. The 5.1-centimeter (2-inch) water level on the floor of the 105-H Basin was implemented to control dust in response to a 2002 occurrence (RL-BHI-DND-2002-0013). Mitigation activities for the wasp problem included using Borax as a deterrent/poison, applying pesticides to eliminate the wasps, creating clean mud areas to attract wasps away from the 105-H Basin, and reducing the amount of exposed mud in the basin.

2.5 Waste Management

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Waste produced from Hanford Site cleanup operations is classified as either radioactive, non-radioactive, mixed, or dangerous. Radioactive waste is categorized as transuranic, high-level, and low-level. Mixed waste has both radioactive and dangerous non-radioactive substances. Dangerous waste contains hazardous substances. Hanford's dangerous waste is managed in accordance with the state of Washington dangerous waste regulations (WAC 173-303).

Radioactive and mixed waste is 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 the 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 generators (as defined in 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-2004-23). Dangerous waste is treated, stored, and prepared for disposal at several Hanford Site facilities or is shipped offsite for disposal or destruction. Some types of dangerous waste, such as used lead acid batteries and used aerosol products, are shipped offsite for recycling.

Non-dangerous waste is waste that does not contain hazardous or radioactive substances. 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.

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-dangerous 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 solid waste generated onsite, received, shipped offsite, and disposed of at the Hanford Site (HNF-EP-0125-16). 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 quantities generated onsite or received from offsite and disposed of at the Hanford Site from 1998 through 2003 are shown in Tables 2.5.1 and 2.5.2. Quantities of dangerous waste shipped offsite from 1998 through 2003 are shown in Table 2.5.3. Table 2.5.4 provides a detailed summary of the radioactive solid waste stored or disposed of in 2003.

The quantities of liquid waste generated in 2003 and stored in underground storage tanks are included in the annual dangerous waste report (DOE/RL-2004-23). Table 2.5.5 is a summary of the liquid waste generated from 1998 through 2003, which are stored in underground storage tanks.

Table 2.5.1. Quantities of Solid Waste[a] Generated on the Hanford Site, 1998 through 2003, kg (lb)

Waste Category	1998	1999	2000	2001	2002	2003
Mixed	509,000 (1,123,000)	421,000 (928,300)	441,000 (973,500)	328,500 (724,300)	1,025,200 (2,260,600)	421,000 (929,000)
Radioactive	1,470,000 (3,230,000)	957,000 (2,109,700)	700,000 (1,544,300)	1,675,200 (3,693,800)	1,588,000 (3,500,900)	758,000 (1,671,000)

(a) Solid waste includes containerized liquid waste.

Table 2.5.2. Quantities of Solid Waste[a] Received on the Hanford Site from Offsite Sources, 1998 through 2003, kg (lb)

Waste Category	1998	1999	2000	2001	2002	2003
Mixed	267 (589)	1,306 (2,880)	1,381 (3,045)	127,000 (280,000)	112,000 (246,200)	667,000[b] (1,470,500)
Radioactive	2,870,000 (6,328,400)	2,325,700 (5,128,100)	6,958,000 (15,343,500)	4,736,500 (10,444,100)	1,517,000 (3,345,800)	407,000 (898,200)

(a) Solid waste contains containerized liquid waste. Solid waste quantities do not include United States Navy reactor compartments.
(b) Total includes Hanford generated waste treated by offsite contractor and returned as newly generated waste.

Table 2.5.3. Quantities of Dangerous Waste[a] Shipped Off the Hanford Site, 1998 through 2003, kg (lb)

Waste Category	1998	1999	2000	2001	2002	2003
Containerized	65,700 (144,900)	1,732,700[b] (3,820,700)	33,200[b] (73,200)	56,000[b] (124,200)	78,400[b] (172,900)	83,500[b] (184,100)
		70,000[c] (154,300)	315,500[c] (695,700)	2,600[c] (5,800)	3,500[c] (7,800)	91,800[c] (202,400)
Bulk Solids	47,500 (104,700)	402,300[d] (887,000)	0	0	0	0
Bulk Liquids	41,800 (92,200)	0	0	0	50,700 (111,700)	48,400 (106,900)
Total	155,000 (341,800)	2,205,000 (4,862,000)	348,700 (768,900)	58,600 (130,000)	132,600 (292,400)	223,700 (493,400)

(a) Does not include *Toxic Substances Control Act* waste.
(b) Dangerous waste only.
(c) Mixed waste (radioactive and dangerous).
(d) Includes 399,875 kg (881,724 lb) from extraction of carbon tetrachloride from soil.

Table 2.5.4. Radioactive Solid Waste Stored or Disposed of on the Hanford Site, 2003

Constituent[b,c]	Quantity, Ci[a] Low-Level Waste	Mixed Low-Level Waste	Transuranic Waste
Tritium	4,780	1.4	(d)
Carbon-14	12.5	(d)	(d)
Manganese-54	3.04	0.0219	(d)
Iron-55	6,290	2,210	(e)
Nickel-59	141	(d)	(d)
Cobalt-60	6,490	(d)	21.5
Nickel-63	16,900	26,700	(d)
Strontium-90	18,300	66.6	63.0
Yttrium-90	18,300	66.6	63.0
Technetium-99	0.0402	0.174	0.0581
Iodine-129	0.0000133	0.00953	0.00000129
Cesium-137	26.7	59.7	105.0
Barium-137m	25.2	56.5	99.8
Uranium-234	0.0622	0.0123	0.00561
Uranium-235	0.0031	0.000241	0.0136
Uranium-236	0.0007	0.00000703	0.0000724
Neptunium-237	(d)	(d)	0.00488
Uranium-238	0.185	0.0108	0.399
Plutonium-238	(d)	(d)	1,440
Plutonium-239	(d)	(d)	10,400
Plutonium-240	(d)	(d)	3,980
Plutonium-241	(d)	(d)	82,800
Plutonium-242	(d)	(d)	2.5
Americium-241	(d)	(d)	6,480
Americium-243	(d)	(d)	0.0252
Curium-243	(d)	(d)	0.0261
Curium-244	0.126	0.00405	3.63
Curium-245	(d)	(d)	0.000212
Total	71,300	29,200	106,000

(a) 1 Ci = 37 GBq.
(b) Constituents for which values are given are those that are in abundance, or are otherwise thought to be of interest.
(c) See Appendix A, Table A.7 for radionuclide half-lives.
(d) Value is insignificant relative to other waste types.
(e) No inventory was reported for this waste type.

Table 2.5.5. Quantities of Liquid Waste[a] Generated and Stored Within the Tank Farm System on the Hanford Site During 2003 and During Each of the Previous 5 Years, L (gal)

Type of Waste	1998[b,c]	1999[b,c]	2000[b]	2001[b]	2002	2003
Volume of waste added to double-shell tanks	1,715,000 (453,100)	5,420,000 (1,432,000)	8,920,000 (2,357,000)	2,980,000 (788,000)	9,280,000 (2,452,000)	9,710,000 (2,565,000)
Total volume in double-shell tanks (year end)	70,969,000 (18,750,000)	73,290,000 (19,363,200)	79,630,000 (21,038,000)	79,980,000 (21,131,000)	87,683,000 (23,166,000)	92,693,000 (24,487,000)
Volume evaporated at 242-A evaporator	0	-3,097,000 (-818,200)	-2,580,000 (-682,000)	-2,580,000 (-682,000)	-1,578,000 (-417,000)	-4,720,000 (-1,247,000)
Volume pumped from single-shell tanks[d]	859,000 (227,000)	2,930,000 (774,100)	2,250,000 (595,000)	590,000 (155,000)	5,288,000 (1,397,000)	6,185,000 (1,634,000)

(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 corrected figure for these years.
(d) Volume does not include dilution or flush water. 2003 volume includes quantities from both stabilization and retrieval activities.

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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 2003* (PNNL-14687, APP. 2) and in *Environmental Releases for Calendar Year 2002* (HNF-EP-0527-13).

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 and Emissions Monitoring

L. P. Diediker and D. J. Rokkan

Liquid effluent and airborne emissions that may contain radioactive or hazardous constituents are continually monitored when released to the environment at the Hanford Site. Facility operators perform the monitoring mainly through analyzing samples collected near points of release to the environment. Effluent and emissions 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 and emissions treatment and control systems and pollution-management practices. Major facilities have their own individual effluent monitoring plans, which are part of the comprehensive Hanford Site Environmental Monitoring Plan (DOE/RL-91-50).

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

Tritium, strontium-90, iodine-129, cesium-137, plutonium-238, plutonium-239/240, plutonium-241, americium-241, and several other radionuclides 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 cessation of nuclear processing operations and the evolution of the site mission to environmental cleanup are largely responsible for the downward trend in radioactive effluent and the resulting lower radiological doses to the public. Figures 3.1.1 and 3.1.2 depict quantities of several longer-lived radionuclides released from the site over the past 12 years.

Effluent and emissions release data are documented in several reports besides this one, and all are available to

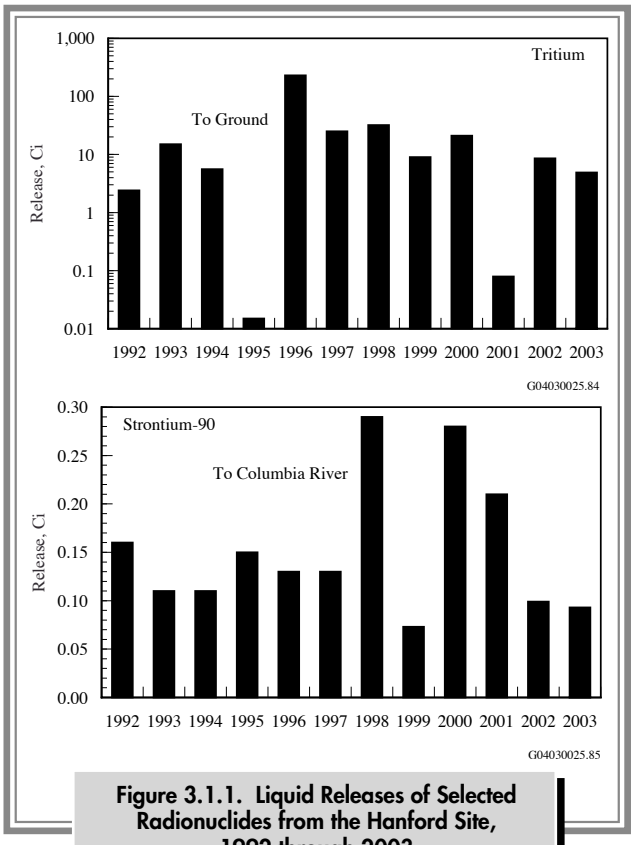


Figure 3.1.1. Liquid Releases of Selected Radionuclides from the Hanford Site, 1992 through 2003

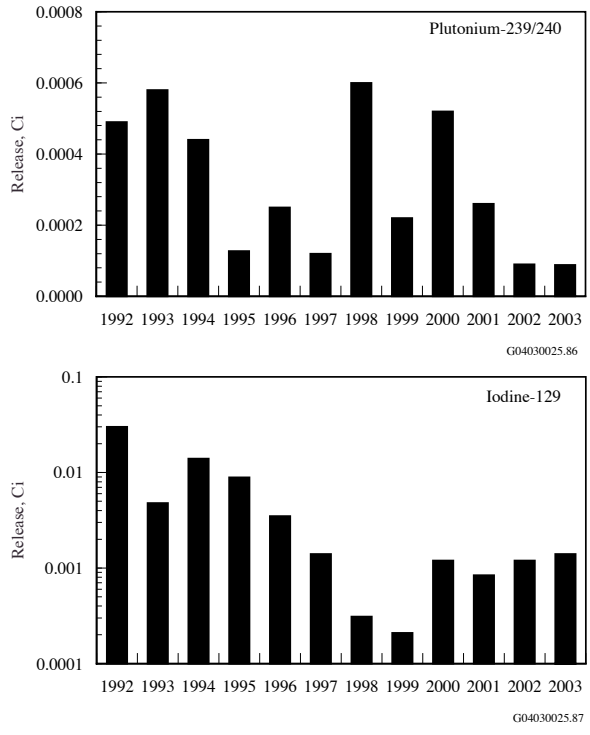


Figure 3.1.2. Airborne Releases of Selected Radionuclides from the Hanford Site, 1992 through 2003

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-2004-09), in compliance with Title 40, Code of Federal Regulations, Part 61 (40 CFR 61) and Washington Administrative Code (WAC) 246-247. Data quantifying radioactive liquid effluent and airborne emissions are reported to the DOE annually in an environmental releases report (HNF-EP-0527-13). That report includes summaries of monitoring results on liquid effluent discharged to the Columbia River, regulated by the National Pollutant Discharge Elimination System permit and reported quarterly to the EPA; liquid effluent discharges to the soil regulated by WAC 173-216 and reported quarterly to the Washington State Department of Ecology; and non-radioactive air emissions, which are 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. The selection of the specific radionuclides sampled, analyzed, and reported is based on (1) an evaluation of potential unabated emissions from known radionuclide inventories in a facility or an 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 emissions points when the potential exists for radioactive emissions to exceed normal operating ranges at levels requiring immediate personnel alert.

Radioactive emissions discharge points, which usually are active ventilation stacks, are located in the 100, 200, 300, 400, and 600 Areas. The number of emissions points by operating area is summarized as follows:

- In the 100 Areas, emissions originated from evaporation at two water-filled storage basins (100-K East and 100-K West Basins [i.e., 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 2003, there were five active radioactive emissions points in the 100 Areas.
- In the 200 Areas, the primary sources of radioactive 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 2003, there were 63 radioactive emissions points in the 200 Areas, the majority of which were active.
- The 300 Area primarily has laboratories and research facilities. Principle sources of airborne radioactive

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 2003, there were 22 radioactive emissions points in the 300 Area, the majority of which were active.

- 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 2003, there were five active radioactive emissions points in the 400 Area.
- The 600 Area has the Waste Sampling and Characterization Facility, where 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 active radioactive emissions points during 2003. 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 Hanford Site radioactive airborne emissions in 2003 is provided in Table 3.1.1.

3.1.2 Non-Radioactive Airborne Emissions

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

In past years, gaseous ammonia has been emitted from the Plutonium-Uranium Extraction Plant, 242-A evaporator,

Table 3.1.1. Radionuclides Discharged to the Atmosphere at the Hanford Site, 2003

		Release, Ci[a]				
Radionuclide	**Half-Life**	**100 Areas**	**200-East Area**	**200-West Area**	**300 Area**	**400 Area**
Tritium (as HT)[b]	12.3 yr	NM[c]	NM	NM	7.8	NM
Tritium (as HTO)[b]	12.3 yr	NM	NM	NM	3.5×10^{1}	6.6×10^{-1}
Cobalt-60	5.3 yr	ND[d]	3.9×10^{-8}	ND	ND	NM
Strontium-90	29.1 yr	9.0×10^{-6}[e]	1.2×10^{-4}[e]	3.0×10^{-5}[e]	1.3×10^{-6}[e]	NM
Ruthenium-106	373 d	1.1×10^{-6}	ND	ND	ND	NM
Iodine-129	16,000,000 yr	NM	1.4×10^{-3}	NM	NM	NM
Cesium-137	30 yr	7.5×10^{-6}	6.3×10^{-5}	1.5×10^{-5}	1.1×10^{-5}[f]	4.9×10^{-6}[f]
Radon-220	55.6 s	NM	NM	NM	2.3×10^{2}	NM
Uranium-234	240,000 yr	NM	NM	NM	6.3×10^{-11}	NM
Uranium-235	704,000,000 yr	NM	NM	NM	4.6×10^{-11}	NM
Neptunium-237	2,140,000 yr	NM	NM	NM	ND	NM
Uranium-238	4,500,000,000 yr	NM	NM	NM	3.5×10^{-11}	NM
Plutonium-238	87.7 yr	3.4×10^{-7}	3.8×10^{-8}	1.3×10^{-6}	4.9×10^{-9}	NM
Plutonium-239/240	24,000 yr	2.5×10^{-6}[g]	1.7×10^{-6}[g]	8.3×10^{-5}[g]	1.1×10^{-7}[g]	1.4×10^{-7}[g]
Plutonium-241	14.4 yr	2.3×10^{-5}	ND	7.2×10^{-5}	ND	NM
Americium-241	432 yr	1.7×10^{-6}	2.0×10^{-6}	1.4×10^{-5}	8.7×10^{-8}[h]	NM

(a) 1 Ci = 3.7×10^{10} becquerels.
(b) HT = Elemental tritium; HTO = tritiated water vapor.
(c) NM = Not measured.
(d) 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).
(e) This value includes unspecified gross beta release data, treated as strontium-90 in dose calculations.
(f) This value includes unspecified gross beta release data, treated as cesium-137 in dose calculations.
(g) This value includes gross alpha release data, treated as plutonium-239/240 in dose calculations.
(h) This value includes unspecified gross alpha release data, treated as americium-241 in dose calculations.

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 2003, 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 the EPA. If the emissions remain stable at predicted levels, they may be reported annually with the EPA's permission. Table 3.1.2 summarizes the emissions of non-radioactive pollutants discharged to the atmosphere at Hanford during 2003 (Note: the 100, 400, and 600 Areas have no non-radioactive emissions sources of regulatory concern). Table 3.1.2 also includes emissions 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.

Table 3.1.2. Non-Radioactive Emissions Discharged to the Atmosphere at the Hanford Site, 2003

Constituent	Release, kg (lb)	
Particulate matter	1,800	(3,900)
Nitrogen oxides	16,000	(34,000)
Sulfur oxides	3,800	(8,300)
Carbon monoxide	17,000	(38,000)
Lead	0.64	(1.4)
Volatile organic compounds[a,b]	11,000	(25,000)
Ammonia[c]	16,000	(36,000)
Other toxic air pollutants[d]	8,100	(18,000)

(a) The estimate of volatile organic compounds does not include emissions from certain 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 200 Area Effluent Treatment Facility.
(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 200 Area Effluent Treatment Facility.
(d) 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 200 Area Effluent Treatment Facility.

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 2003, only facilities in the 200 Areas discharged radioactive 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 effluent is provided in Table 3.1.3. Table 3.1.4 summarizes

Table 3.1.3. Radionuclides in 200 Area Liquid Effluent Discharged to the State-Approved Land Disposal Site at the Hanford Site, 2003

Radionuclide	Half-Life	Release, Ci[a]
Tritium	12.3 yr	4.9

(a) 1 Ci = 3.7×10^{10} becquerels.

Table 3.1.4. Radionuclides in Liquid Effluent from the Hanford Site's 100 Areas Discharged to the Columbia River, 2003

Radionuclide	Half-Life	Release, Ci[a]
Tritium	12.3 yr	0.015
Strontium-90	29.1 yr	0.094
Plutonium-238	87.7 yr	0.00000038
Plutonium-239/240	24,000 yr	0.0000071

(a) 1 Ci = 3.7×10^{10} becquerels.

data on radionuclides in 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.

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 effluent exceed reportable CERCLA quantities, the release totals are immediately reported to the EPA. If the effluent remains stable at predicted levels, it may, with the 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 Reportable Releases to the Environment

Releases that are reportable to the state and/or EPA include spills or discharges of hazardous substances or 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 CERCLA Section 103(f)(2).

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 are 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 releases occurred during 2003.

3.2 Near-Facility Environmental Monitoring

C. J. Perkins, R. T. Coffman, 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 Basins; inactive nuclear facilities such as N Reactor and the Plutonium-Uranium Extraction (PUREX) 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 DOE Order 5400.1 in January 2003), and 5400.5; DOE Manual 231.1-1A; 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 2003 are summarized in the following sections. Strontium-90 results for this report period show overall lower values compared to historical trends. This was primarily due to changes in laboratory background correction calculations that were implemented in 2003. Both historical and current values are within accepted statistical ranges as evidenced by laboratory quality assurance and performance evaluation programs. Additional data may be found in *Hanford Site Near-Facility Environmental Monitoring Data Report for Calendar Year 2003* (PNNL-14687, APP. 2). The type and general locations of samples collected for near-facility monitoring during 2003 are summarized in Table 3.2.1.

3.2.1 Air Monitoring

During 2003, routine monitoring for radioactive materials 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-14687, APP. 2). Air samplers were located primarily at or within approximately 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 the Pacific Northwest National Laboratory.

Table 3.2.1. Hanford Site Near-Facility Routine Environmental Monitoring Samples and Locations, 2003

Sample Type	Number of Sampling Locations	Sampling Locations in Each Operational Area								
		100-B/C	100-D/DR	100-K	100-F	100-H	100-N	ERDF[a]	200/600	300/400
Air	82	6	3	11	6	2	5	3	41[b]	5
Water	10	0	0	0	0	0	10	0	0	0
Soil	82	5	0	2	2	0	1	1	57	14
Vegetation	65	0	0	0	0	0	4	0	48	13
External radiation	134	4	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.

Samples were collected according to a schedule established before the 2003 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 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 annual average concentrations of selected radionuclides in the 100 and 200/600 Areas compared to the DOE derived concentration guides and, when available, air concentrations measured in distant communities. The DOE derived concentration guides (DOE Order 5400.5) are dose-based 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 radionuclide concentrations than did those samples collected farther away. In general, analytical results for most radionuclides were at or near Hanford Site background levels, which are 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 2003. A complete listing of the 2003 near-facility ambient air monitoring results can be found in PNNL-14687, APP. 2. Results for selected Pacific Northwest National Laboratory air samples are also reported in PNNL-14687, APP. 2, as well as in Section 4.1.

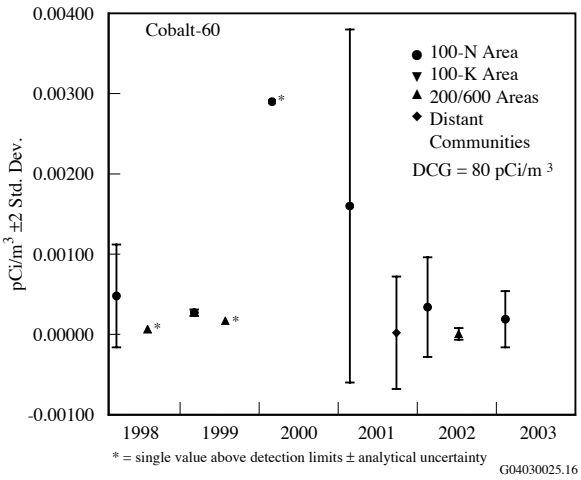
At the remedial action project site in the 100-B/C Area, ambient air monitoring was conducted at five locations in 2003. The radionuclides uranium-234 and uranium-238 were consistently detected. Beginning in late February 2003 and continuing through early July 2003, one additional air sampling station was added in the 100-B/C Area during the decommissioning of the retired 118-C-4 rod cave. Isotopic analyses of the composited filter from this location detected only uranium-234 and uranium-238.

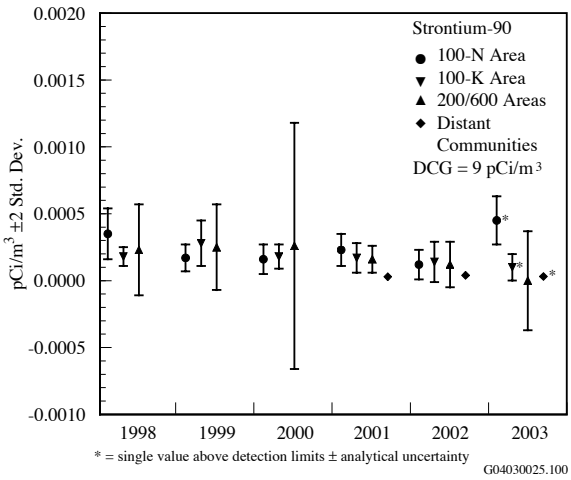
During 2003, air monitoring continued at seven locations associated with the interim safe storage of the reactor buildings in the 100-D/DR, 100-F, and 100-H Areas. Specifically, there was one sampling location at the 105-D site and two each at the 105-DR, 105-F, and 105-H sites. The quarterly analytical results from these air samples showed radionuclide concentrations and frequency of detection consistent with results observed over the past 4 years. Uranium-234 was consistently detected (in 72% of the samples) in all of the interim safe storage project's

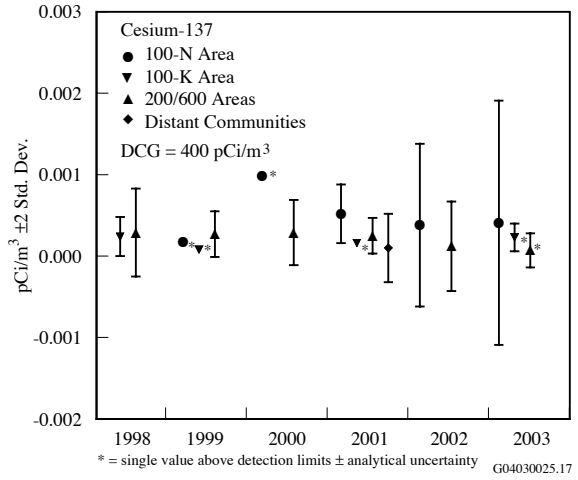
Table 3.2.2. Hanford Site Near-Facility Air Sampling Locations and Analyses, 2003

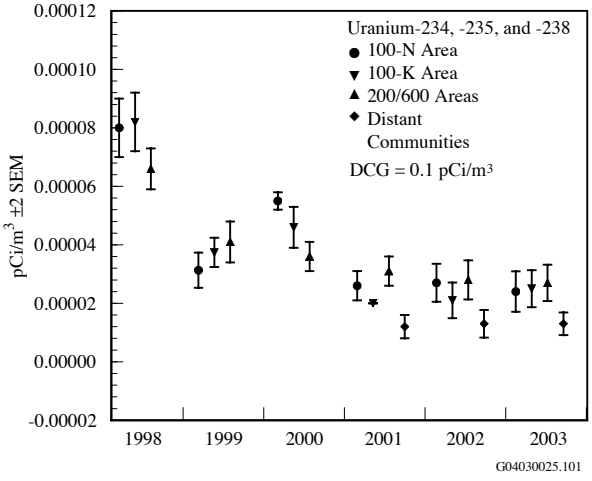
Site	Number of Samplers	EDP Code[a]	Analyses	
			Biweekly	Composite[b]
100-B/C remedial action project	5	N464, N465, N466, N496, N497	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
118-C-4 decommissioning project	1	N536	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
105-D interim safe storage project	1	N523	Gross alpha, gross beta	GEA, Sr-90, Pu-iso, U-iso
105-DR interim safe storage project	2	N492, 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	N538, N539, N540	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-14687, 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.









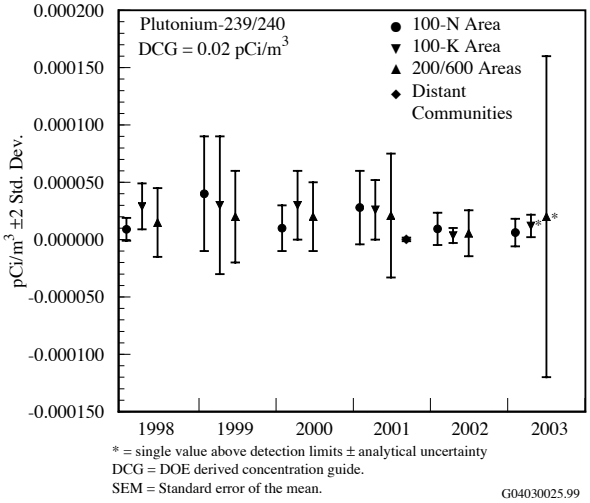


Figure 3.2.1. Average Concentrations of Selected Radionuclides in Near-Facility Air Samples Collected on the Hanford Site Compared to Those Collected in Distant Communities (PNNL-14295), 1998 through 2003. Radionuclide concentrations below analytical detection limits are not shown. As a result of figure 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, 2003

Cobalt-60

Site	Average[b]	Maximum[c]	EDP Code[d]
100-B/C RA[e]	21 ± 59	81 ± 78	N464
100 Area ISS[f]	-12 ± 580	360 ± 1,200	N523
100-F RA	-13 ± 92	7.8 ± 120	N521
100-K SNF[g]	4.1 ± 120	81 ± 93	N403
100-K RA	-5.7 ± 140	110 ± 84	N529
100-N	190 ± 370	540 ± 230	N105
200-East	11 ± 95	93 ± 91	N970
200-West	1.5 ± 96	160 ± 90	N165
300-FF-1 (300 Area)	30 ± 220	300 ± 130	N485
ERDF[h]	14 ± 120	88 ± 89	N963
Distant community[i]	25 ± 550	730 ± 1,000	
DCG[j]		80,000,000	

Strontium-90

Site	Average[b]	Maximum[c]	EDP Code[d]
100-B/C RA[e]	-39 ± 110	69 ± 78	N465
100 Area ISS[f]	-100 ± 820	670 ± 260	N524
100-F RA	-74 ± 210	-23 ± 140	N522
100-K SNF[g]	-36 ± 120	100 ± 99	N403
100-K RA	-61 ± 160	-0.36 ± 3.6	N528
100-N	-36 ± 390	450 ± 180	N103
200-East	62 ± 500	1,000 ± 330	N984
200-West	-51 ± 150	140 ± 110	N441
300-FF-1 (300 Area)	-130 ± 360	-7.0 ± 65	N130
ERDF[h]	-34 ± 190	100 ± 110	N482
Distant community[i]	31 ± 100	100 ± 74	
DCG[j]		9,000,000	

Cesium-137

Site	Average[b]	Maximum[c]	EDP Code[d]
100-B/C RA[e]	4.6 ± 81	74 ± 78	N464
100 Area ISS[f]	93 ± 710	1,300 ± 1,800	N523
100-F RA	52 ± 130	35 ± 140	N520
100-K SNF[g]	4.0 ± 110	100 ± 92	N402
100-K RA	52 ± 180	230 ± 170	N529
100-N	410 ± 1,600	2,500 ± 790	N526
200-East	55 ± 180	300 ± 150	N973
200-West	79 ± 230	510 ± 210	N155
300-FF-1 (300 Area)	13 ± 88	84 ± 87	N485
ERDF[h]	48 ± 54	84 ± 77	N482
Distant community[i]	-100 ± 450	350 ± 380	
DCG[j]		400,000,000	

Uranium-234

Site	Average[b]	Maximum[c]	EDP Code[d]
100-B/C RA[e]	11 ± 11	20 ± 78	N465
100 Area ISS[f]	24 ± 26	57 ± 63	N523
100-F RA	13 ± 17	12 ± 14	N521
100-K SNF[g]	13 ± 6.9	18 ± 9.8	N404
100-K RA	14 ± 13	22 ± 12	N528
100-N	13 ± 10	24 ± 14	N105
200-East	13 ± 11	29 ± 14	N976
200-West	13 ± 10	27 ± 18	N304
300-FF-1 (300 Area)	40 ± 38	69 ± 28	N487
ERDF[h]	18 ± 13	27 ± 14	N518
Distant community[i]	19 ± 17	34 ± 14	
DCG[j]		90,000	

Uranium-235

Site	Average[b]	Maximum[c]	EDP Code[d]
100-B/C RA[e]	2.6 ± 3.2	4.8 ± 78	N496
100 Area ISS[f]	5.6 ± 13	22 ± 22	N523
100-F RA	5.8 ± 3.6	6.8 ± 6.8	N521
100-K SNF[g]	2.4 ± 3.4	5.5 ± 4.7	N401
100-K RA	2.2 ± 1.8	3.3 ± 3.4	N528
100-N	1.5 ± 4.0	5.7 ± 4.8	N526
200-East	3.0 ± 4.8	8.4 ± 6.9	N481
200-West	2.8 ± 5.1	13 ± 15	N304
300-FF-1 (300 Area)	4.0 ± 4.5	7.1 ± 6.7	N487
ERDF[h]	3.1 ± 3.1	5.8 ± 5.2	N518
Distant community[i]	0.52 ± 3.7	2.7 ± 4.4	
DCG[j]		100,000	

Uranium-238

Site	Average[b]	Maximum[c]	EDP Code[d]
100-B/C RA[e]	8.2 ± 8.6	19 ± 78	N496
100 Area ISS[f]	16 ± 27	64 ± 96	N523
100-F RA	6.1 ± 2.2	6.1 ± 6.4	N522
100-K SNF[g]	9.8 ± 7.3	18 ± 10	N402
100-K RA	10 ± 4.9	15 ± 8.5	N529
100-N	9.9 ± 8.8	16 ± 9.1	N526
200-East	11 ± 13	40 ± 19	N976
200-West	11 ± 11	27 ± 14	N433
300-FF-1 (300 Area)	29 ± 34	58 ± 25	N527
ERDF[h]	14 ± 16	27 ± 14	N482
Distant community[i]	19 ± 10	28 ± 11	
DCG[j]		100,000	

Plutonium-238

Site	Average[b]	Maximum[c]	EDP Code[d]
100-B/C RA[e]	1.7 ± 21	22 ± 78	N465
100 Area ISS[f]	-3.4 ± 110	52 ± 140	N523
100-F RA	-3.6 ± 7.5	-3.4 ± 15	N521
100-K SNF[g]	2.5 ± 22	24 ± 29	N404
100-K RA	-0.54 ± 19	14 ± 15	N529
100-N	-4.3 ± 15	7.3 ± 14	N106
200-East	1.7 ± 18	37 ± 28	N480
200-West	1.1 ± 15	21 ± 20	N449
300-FF-1 (300 Area)	5.8 ± 12	9.9 ± 24	N130
ERDF[h]	-0.43 ± 13	11 ± 13	N482
Distant community[i]	-0.83 ± 1.4	0.063 ± 1.5	
DCG[j]		30,000	

Plutonium-239/240

Site	Average[b]	Maximum[c]	EDP Code[d]
100-B/C RA[e]	1.7 ± 4.5	7.0 ± 78	N496
100 Area ISS[f]	23 ± 120	300 ± 240	N523
100-F RA	14 ± 54	1.8 ± 27	N521
100-K SNF[g]	4.3 ± 10	12 ± 9.8	N401
100-K RA	4.7 ± 6.7	9.9 ± 8.6	N529
100-N	6.2 ± 12	20 ± 12	N526
200-East	4.8 ± 14	26 ± 14	N967
200-West	34 ± 180	500 ± 190	N165
300-FF-1 (300 Area)	2.9 ± 3.5	4.1 ± 8.3	N130
ERDF[h]	12 ± 43	64 ± 28	N963
Distant community[i]	0.32 ± 1.3	1.5 ± 2.4	
DCG[j]		20,000	

Table 3.2.3. (contd)

Plutonium-241			
Site	**Average[b]**	**Maximum[c]**	**EDP Code[d]**
100-K SNF[g]	100 ± 800	890 ± 1,100	N403
200-East	-150 ± 1,000	360 ± 670	N481
Distant community[i]		Not reported	
DCG[j]		1,000,000	

Americium-241			
Site	**Average[b]**	**Maximum[c]**	**EDP Code[d]**
100-K SNF[g]	6.3 ± 13	19 ± 15	N478
200-East	3.2 ± 8.4	6.7 ± 10	N481
Distant community[i]		Not reported	
DCG[j]		20,000	

(a) To convert to international metric system units, multiply aCi/m^3 by 0.000000037 to obtain Bq/m^3.
(b) ±2 times the standard deviation.
(c) ± total analytical uncertainty.
(d) See PNNL-14687, APP. 2.
(e) RA = Remedial action project.
(f) ISS = Interim safe storage projects at 105-DR/F/D/H and 117-DR.
(g) SNF = Spent nuclear fuel.
(h) ERDF = Environmental Restoration Disposal Facility.
(i) See Section 4.1.
(j) DOE derived concentration guide.

air samples. Strontium-90, uranium-238, and plutonium-239/240 were detected in approximately 15%, 50%, and 25% of the quarterly samples, respectively.

In late April 2003, remedial action activities were completed and air sampling subsequently concluded at the four locations at the 100-F Area remedial action site. Uranium-234 and uranium-238 were detected consistently; strontium-90 and plutonium-239/240 were detected occasionally.

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 were reduced substantially in 1996 and subsequent radionuclide concentrations in the ambient air samples have been near detection limits. Uranium-234 and uranium-238 were detected consistently in 2003. Occasionally, strontium-90, uranium-235, and plutonium-239/240 were detected also. Though routinely analyzed for, americium-241 and plutonium-241 were not detected in 2003.

Air sampling continued in 2003 at three locations at the 100-KR-1 remedial action site. Uranium-234 and uranium-238 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 2003 were similar to those measured in previous years. Uranium-234 and uranium-238 were detected consistently. Occasionally detected were cobalt-60, cesium-137, and plutonium-239/240.

During 2003, radionuclide levels measured in the 200-East Area were generally similar to those measured over the previous years. Uranium-234 and uranium-238 were detected in more than 80% of the samples. Occasionally, strontium-90, 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. Uranium-234 and uranium-238 were detected in more than 90% of the samples, and plutonium-239/240 was detected in approximately 50% of the samples. Strontium-90, cesium-137, and uranium-235 were detected only 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 2003 analytical results were comparable to 2002 levels. Consistently detected were uranium-234 and uranium-238. Uranium-235 and plutonium-239/240 were detected occasionally.

During June 2003, remediation work at the 300-FF-1 Operable Unit (located just north of the 300 Area) was completed and air sampling was concluded. 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 the DOE derived concentration guides and were slightly lower than those measured during previous remediation activities conducted at the 300-FF-1 Operable Unit during 1997 through 2000. Uranium-234 and uranium-238 were detected in 100% of the samples and uranium-235 in approximately 50% of the samples.

The remedial action, interim safe storage, and surveillance and maintenance/transition activities discussed above are described in more detail in Section 2.3.13.

3.2.2 Spring Water Monitoring

In the past, radioactive effluent streams from operations in the 100-N Area were sent to the now retired 116-N-1 (1301-N) and 116-N-3 (1325-N) liquid waste disposal facilities (i.e., engineered soil columns). After moving through the soil column to the water table, this wastewater 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 release estimates 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-0527-13. 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 2003. Additional discussion about this system and its effects may be found in Section 2.3.13.1.

During October 2003, samples were collected from ten 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 eight 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 2003 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

Table 3.2.4. Radionuclide Concentrations (pCi/L[a]) in Samples Collected from Wells Along the Columbia River Shoreline in the 100-N Area of the Hanford Site, 2003

	Shoreline Springs Monitoring Well 199-N-46		Shoreline Wells		
Radionuclide	Maximum[b]	Average[c]	Maximum[b]	Average[c]	DCG[d]
Tritium	970 ± 243	635 ± 948	Not detected		2,000,000
Strontium-90	5,100 ± 765	4,100 ± 2,828	23 ± 3.4	7.7 ± 15	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 times the standard deviation.
(d) DCG = DOE derived concentration guide (DOE Order 5400.5).

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 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-14687, APP. 2). In addition, all paved roadways are surveyed annually and the intersections along the Environmental Restoration Disposal Facility haul route are surveyed quarterly.

No new surface or underground radioactively contaminated areas of significant size were discovered during 2003. The Hanford Site had approximately 3,651 hectares (9,022 acres) of outdoor contaminated areas (all types) and approximately 666 hectares (1,646 acres) that contained underground radioactive materials not including active facilities. It was estimated that the external dose rate at 80% of the outdoor contaminated areas was less than 1 mrem (0.01 mSv) per 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 global positioning systems were again used during 2003 to 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.

The number and size of contaminated areas vary from year to year for several reasons. Reductions are generally attributable to the stabilization of areas of known contamination. Increases are typically due to the discovery of new areas of contamination that result from either contaminant migration or increased efforts to investigate existing radiologically contaminated areas. Ongoing improvements of the geographical measurements of contaminated areas using global positioning system technology to better define area boundaries can result in a either a reduction or an increase in the size and number of contaminated areas and underground radioactive materials areas. Similarly, document reviews and/or administrative reclassification of contaminated areas may lead to changes. Table 3.2.6 summarizes the causes and effects of these efforts during 2003.

Table 3.2.5. Status of Outdoor Contamination at the Hanford Site, 2003

Area	Contamination Areas,[a] ha (acres)		Underground Radioactive Materials Areas,[b] ha (acres)	
100-B/C	10	(25)	49	(121)
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[c]	72	(178)	141	(348)
200-West[c]	29	(72)	223	(551)
300	23	(57)	45	(111)
400	0	(0)	0	(0)
600[d]	3,478	(8,594)	48	(119)
Totals	**3,651**	**(9,022)**	**666**	**(1,646)**

(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.
(c) Includes tank farms.
(d) Includes BC controlled area, Environmental Restoration Disposal Facility, and waste disposal facilities outside the 200-East and 200-West Area boundaries.

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 radioactive material and to detect potential migration and deposition of facility emissions. Special samples also were collected where potential physical or biological pathway

Table 3.2.6. Status Change of Posted Contaminated Areas on the Hanford Site, 2003

Areas	Changes[a]	Area, ha (acres)	
100	RCA to CA[b]	2	(5)
100	RCA to URM[b]	10	(25)
200-East	CA to URM[c]	1	(2)
200-West	CA to URM[c]	1	(2)
200-West	URM to CA[b]	2	(5)
300	RCA to URM[d]	4	(10)
400	None to report	0	(0)
600	URM to None[d]	7	(17)

(a) RCA = Radiologically controlled area.
CA = Contamination/soil contamination area.
URM = Underground radioactive material area.
(b) Changes due to contamination migration.
(c) Changes due to stabilization activities.
(d) Administrative correction/re-classification.

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 inactive surface-water disposal units, or animal intrusion at a waste site. The soil and vegetation sampling methods and locations used for near-facility monitoring are discussed in detail in DTS-OEM-001. All soil and vegetation samples were analyzed for strontium-90, uranium isotopes, plutonium isotopes, and gamma-emitting radionuclides.

The number and location of soil and vegetation samples collected during 2003 are summarized in Table 3.2.1. A comprehensive presentation of the analytical data from these samples can be found in PNNL-14687, 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 (approximately 500 grams [16.1 ounces]) consisted of new-growth leaf cuttings taken from the available brushy, deep-rooted species of interest at a sample location (e.g., sagebrush and/or rabbitbrush). 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 analytical results are compared to concentrations in samples collected offsite at various 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-14687, APP. 2 for complete listing of concentrations). 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 sample concentrations from year to year are expected. In general, radionuclide concentrations in soil and vegetation samples collected from, or adjacent to, waste disposal facilities in 2003 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 in 2003 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 200/600 Areas, and uranium in the 300/400 Areas.

3.2.4.1 Radiological Results for Soil Samples

In near-facility soil samples collected in 2003, 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 2003 and the preceding 5 years. Some individual levels demonstrate a high degree of variability, though overall trends are stable.

Historical results for surface soil samples collected near the 116-N-1 liquid waste disposal facility were somewhat higher than radiological results from historical samples collected at the other soil sampling locations in the 100-N Area. During 2003, however, all but one of the routine sampling locations in the 100-N Area were not accessible or had been destroyed during decommissioning activities and comparative values were, therefore, not available.

Average radionuclide concentrations detected in the surface soil samples collected in the 100-N Area from 1998 through 2003 are presented in Table 3.2.7. The 2002 and 2003 values reported for 100-N Area surface soil represent a single routine sampling location. The 2003 result and the average for distant communities and accessible soil concentrations are compared in Table 3.2.8.

Soil samples were collected from 57 sampling locations in the 200/600 Areas during 2003. Analytical results from these soil samples demonstrated comparable average radionuclide concentration levels from 2002 compared to 2003 (Table 3.2.9). The 2003 maximums, averages, distant community 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-14687, APP. 2.

Soil samples were collected from 14 sampling locations in the 300/400 Areas in 2003: 13 from the 300 Area and 1 from the 400 Area. Analytical results for 2003 and the preceding 5 years are summarized in Table 3.2.11. The 2003 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-14687, APP. 2. For the samples collected during 2003, average values reported for uranium isotopes were somewhat less than the concentrations reported in 2002. 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 2003, five 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 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 near-facility sampling locations at Hanford. Table 3.2.13 provides a summary of the selected analytical results for samples from these remedial action locations. All of the 2003 data are provided in PNNL-14687, APP. 2.

3.2.4.2 Radiological Results for Vegetation Samples

In 2003 near-facility 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 onsite during 2003 and the preceding 5 years and results through 2001 for distant communities. The results demonstrate a high degree of variability.

Four vegetation samples were collected at locations in the 100-N Area. Average radionuclide concentrations detected in all of the near-facility vegetation samples collected in the 100-N Area from 1998 through 2003 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 2003 maximum and average concentrations for vegetation samples collected at the 100-N Area are compared to historic distant community

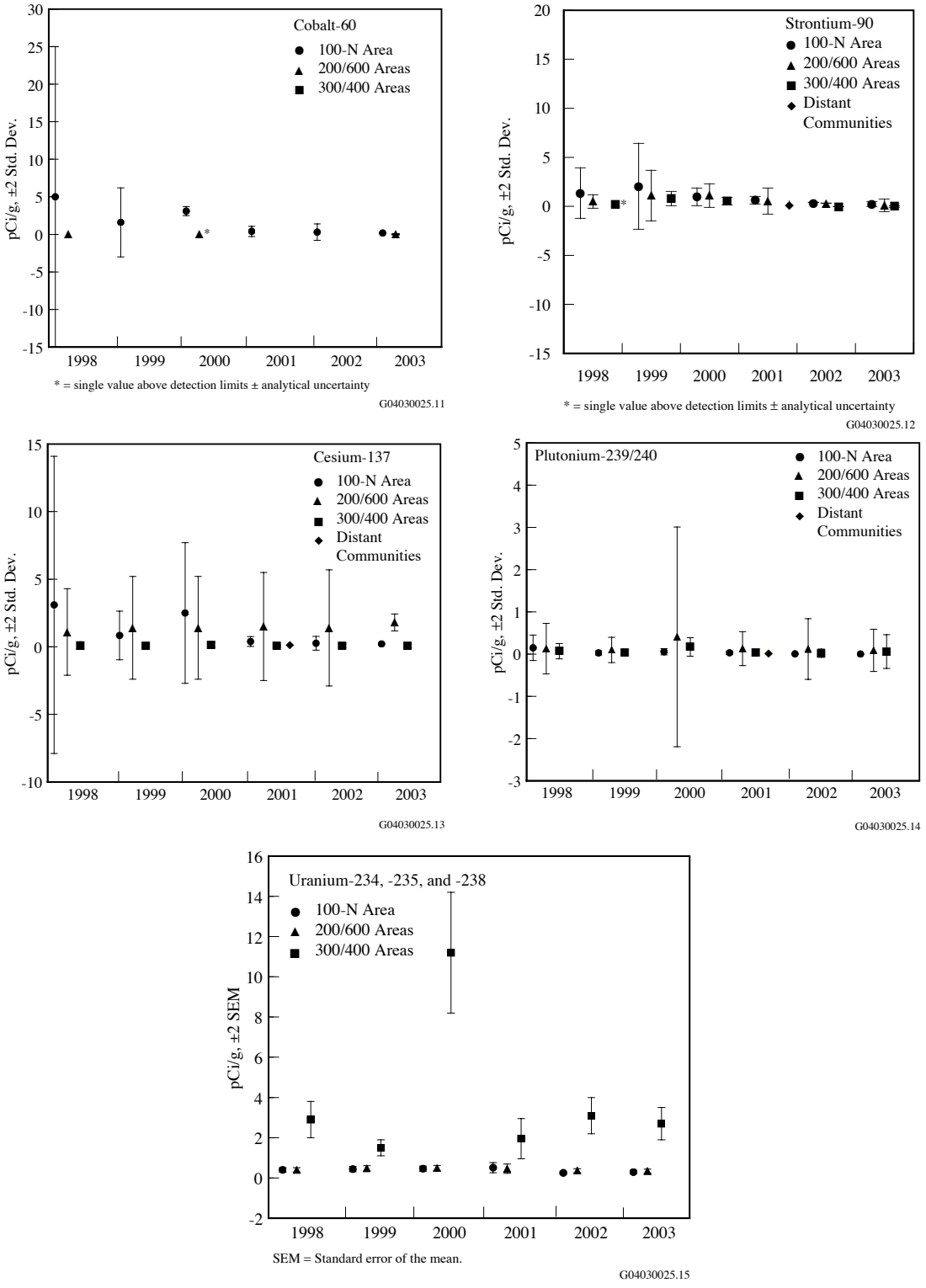


Figure 3.2.2. Average Concentrations of Selected Radionuclides in Near-Facility Soil Samples Collected on the Hanford Site Compared to Those Collected in Distant Communities (PNNL-13910), 1998 through 2003. Radionuclide concentrations below analytical detection limits are not shown. As a result of figure 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, 1998 through 2003

Year	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{238}U	$^{239/240}$Pu
1998	4.9 ± 20	1.0 ± 2.6	3.1 ± 11	0.214 ± 0.063	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	0.20 ± 0.03	0.026 ± 0.05
2000	3.1 ± 0.6	0.84 ± 0.9	2.1 ± 5.2	0.22 ± 0.09	0.22 ± 0.03	0.050 ± 0.074
2001	0.27 ± 0.68	0.20 ± 0.42	0.32 ± 0.44	0.24 ± 0.09	0.25 ± 0.07	0.022 ± 0.04
2002[c]	0.3 ± 1.1	0.15 ± 0.47	0.26 ± 0.51	0.13 ± 0.05	0.11 ± 0.04	0.006 ± 0.006
2003[c]	0.18 ± 0.02	-0.08 ± 0.24	0.21 ± 0.04	0.14 ± 0.05	0.15 ± 0.05	0.002 ± 0.006

(a) To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.
(b) ±2 times the standard deviation.
(c) Represents one sample site only; ± total analytical uncertainty.

Table 3.2.8. Concentrations of Selected Radionuclides (pCi/g[a] dry wt.) in a Surface Soil Sample Collected from the 100-N Area on the Hanford Site, 2003

	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{238}U	$^{239/240}$Pu
Result[b]	0.18 ± 0.02	-0.08 ± 0.24	0.21 ± 0.04	0.14 ± 0.05	0.15 ± 0.05	0.002 ± 0.006
Distant community[c,d]	NR[e]	0.052 ± 0.11	0.15 ± 0.32	NR	0.13 ± 0.11	0.0055 ± 0.012
Accessible soil concentration (WHC-SD-EN-TI-070)[f]	7.1	2,800	30	630	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) ±2 times the standard deviation.
(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, 1998 through 2003

Year	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{238}U	$^{239/240}$Pu
1998	0.014 ± 0.09	0.21 ± 0.67	1.0 ± 3.1	0.19 ± 0.07	0.19 ± 0.07	0.08 ± 0.49
1999	ND[c]	0.51 ± 1.9	1.3 ± 3.8	0.23 ± 0.13	0.22 ± 0.13	0.08 ± 0.27
2000	0.006 ± 0.006	0.99 ± 1.3	1.4 ± 3.8	0.23 ± 0.22	0.23 ± 0.22	0.29 ± 2.3
2001	ND	0.31 ± 1.1	1.5 ± 4.0	0.22 ± 0.11	0.22 ± 0.11	0.10 ± 0.37
2002	ND	0.27 ± 0.66	1.4 ± 4.3	0.17 ± 0.10	0.17 ± 0.11	0.12 ± 0.72
2003	0.002 ± 0.013[d]	0.084 ± 0.63	1.8 ± 0.63	0.16 ± 0.10	0.17 ± 0.10	0.09 ± 0.50

(a) To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.
(b) ±2 times the standard deviation.
(c) ND = Not detected.
(d) Single value above detection limit.

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, 2003

	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{238}U	$^{239/240}$Pu
Maximum[b]	0.002 ± 0.013[c]	1.5 ± 0.30	14 ± 2.3	0.35 ± 0.10	0.41 ± 0.12	1.8 ± 0.47
Average[d]	0.002 ± 0.013[c]	0.08 ± 0.63	1.8 ± 0.63	0.16 ± 0.10	0.17 ± 0.10	0.09 ± 0.50
Distant community[d,e]	NR[f]	0.052 ± 0.11	0.15 ± 0.32	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	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) Single value above detection limit; ± total analytical uncertainty.
(d) ±2 times the standard deviation.
(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, 1998 through 2003

Year	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{238}U	$^{239/240}$Pu
1998	ND[c]	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	5.4 ± 24	5.4 ± 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	1.5 ± 6.4	1.5 ± 6.4	0.02 ± 0.10
2003	ND	0.06 ± 0.07	0.08 ± 0.14	1.3 ± 5.1	1.3 ± 5.2	0.08 ± 0.40

(a) To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.
(b) ±2 times the standard deviation.
(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, 2003

	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{238}U	$^{239/240}$Pu
Maximum[b]	ND[c]	0.06 ± 0.07[d]	0.21 ± 0.034	8.5 ± 1.6	8.6 ± 1.6	0.73 ± 0.15
Average[e]	ND	0.06 ± 0.07[d]	0.08 ± 0.14	1.3 ± 5.1	1.3 ± 5.2	0.08 ± 0.40
Distant community[e,f]	NR[g]	0.052 ± 0.11	0.15 ± 0.32	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	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; ± total analytical uncertainty.
(e) ±2 times the standard deviation.
(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 for the Environmental Restoration Contractor on the Hanford Site, 2003

Site	Sample Location[c]	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{238}U	$^{239/240}$Pu
ERDF[d]	D146	0.011 ± 0.008	ND[e]	0.023 ± 0.008	0.18 ± 0.06	0.20 ± 0.064	ND
100-B/C	D150	ND	ND	0.38 ± 0.061	0.13 ± 0.047	0.16 ± 0.054	ND
100-B/C	D153	ND	ND	0.26 ± 0.044	0.16 ± 0.054	0.16 ± 0.054	0.18 ± 0.061
100-F	D154	ND	ND	0.089 ± 0.022	0.12 ± 0.038	0.11 ± 0.036	ND
100-F	D155	ND	ND	0.25 ± 0.036	0.067 ± 0.028	0.092 ± 0.031	ND
100-B/C	D160	ND	0.34 ± 0.32	0.13 ± 0.027	0.17 ± 0.056	0.16 ± 0.054	ND
100-B/C	D161	ND	ND	0.17 ± 0.032	0.15 ± 0.053	0.14 ± 0.049	ND
100-KR-1	D162	ND	0.23 ± 0.26	0.13 ± 0.028	0.13 ± 0.047	0.14 ± 0.049	ND
100-KR-1	D163	ND	ND	0.21 ± 0.030	0.21 ± 0.069	0.20 ± 0.066	ND
100-B/C	D165	ND	0.34 ± 0.27	0.18 ± 0.030	0.13 ± 0.047	0.096 ± 0.037	ND
Distant communities[f,g]		NR[h]	0.066 ± 0.059	0.0022 ± 0.034	NR	ND	0.0008 ± 0.002
Accessible soil concentration[i]		7.1	2,800	30	630	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-14687, APP. 2.
(d) ERDF = Environmental Restoration Disposal Facility.
(e) ND = Not detected.
(f) ±2 times the standard error of the mean.
(g) See PNNL-13910.
(h) NR = Not reported.
(i) Hanford soil that is not behind security fences.

averages in Table 3.2.15. A complete list of radionuclide concentrations and sampling location maps are provided in PNNL-14687, APP. 2. In 2003, analytical results from vegetation samples collected from the 100-N Area were comparable to those observed in 2002. The radionuclide levels measured in 100-N Area vegetation in 2003 were greater than those measured at distant communities in 2001.

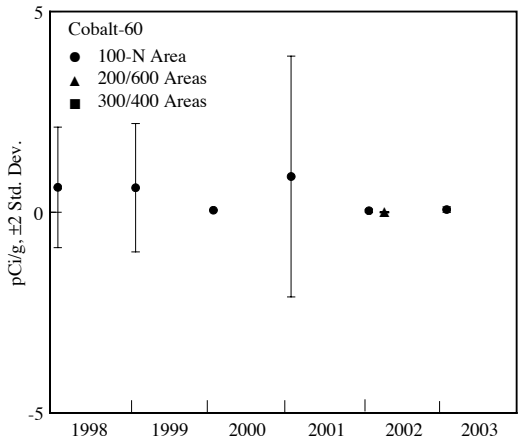
Vegetation samples from 48 sampling locations were collected in the 200/600 Areas during 2003. Concentrations of selected radionuclides reported for 1998 through 2003 are summarized in Table 3.2.16. Analytical results from vegetation samples taken in 2003 from the 200/600 Areas were comparable to those 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 2003 maximum and average concentrations for selected radionuclides are compared to distant communities in Table 3.2.17. A complete list of radionuclide concentrations and sampling location maps are provided in PNNL-14687, APP. 2.

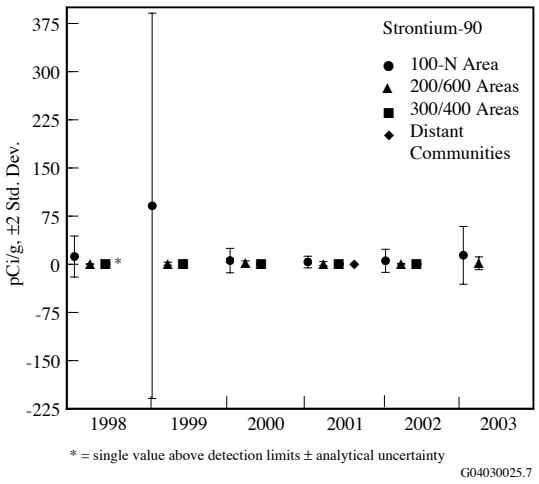
Thirteen vegetation samples were collected from the 300/400 Areas in 2003. Table 3.2.18 provides a summary of the 300/400 Areas results from vegetation samples collected from 1998 through 2003. The levels of most radionuclides measured in the 300 Area were greater than those measured off the Hanford Site, and uranium levels were higher than levels measured in 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.

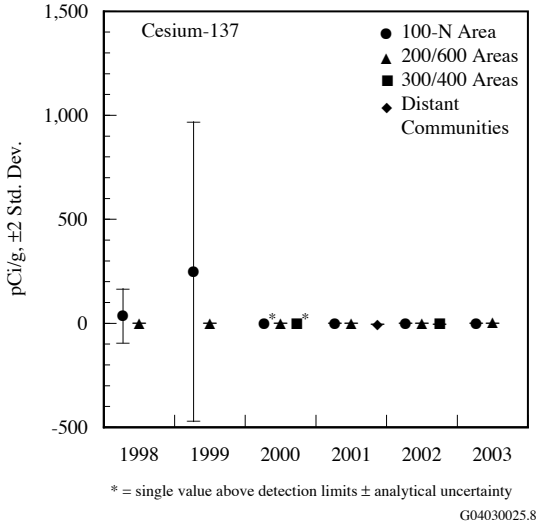
The 2003 maximum, average, and distant community average concentrations for 300/400 Areas samples are listed in Table 3.2.19. Complete listings of radionuclide concentrations and sampling location maps are provided in PNNL-14687, APP. 2.

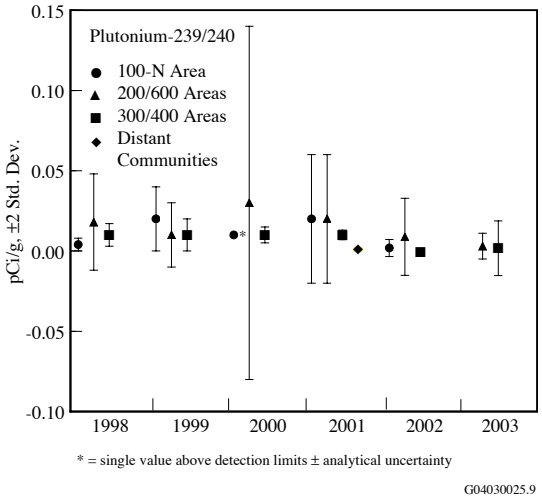
3.2.5 External Radiation

External radiation fields were monitored near facilities and waste handling, storage, and disposal sites to measure









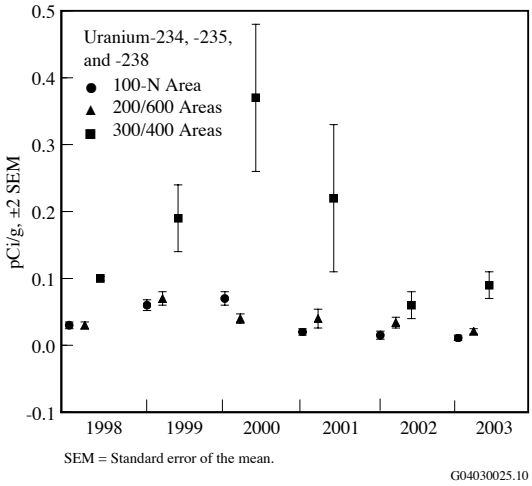


Figure 3.2.3. Average Concentrations of Selected Radionuclides in Near-Facility Vegetation Samples Collected on the Hanford Site Compared to Those Collected in Distant Communities (PNNL-13910), 1998 through 2003. Radionuclide concentrations below analytical detection limits are not shown. As a result 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, 1998 through 2003

Year	^{60}Co	^{90}Sr	^{137}Cs	$^{239/240}$Pu
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
2003	0.066 ± 0.068	14 ± 45	0.15 ± 0.15	ND[c]

(a) To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.
(b) ±2 times the 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, 2003

	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{238}U	$^{239/240}$Pu
Maximum[b]	0.066 ± 0.068	53 ± 7.9	0.15 ± 0.15	0.0083 ± 0.0056	0.0059 ± 0.0047	ND[c]
Average[d]	0.066 ± 0.068[b,e]	14 ± 45	0.15 ± 0.15	0.0068 ± 0.0021	0.0046 ± 0.029	ND
Distant communities[d,f]	NR[g]	0.066 ± 0.059	0.0022 ± 0.034	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) ±2 times the standard deviation.
(e) Single value above detection limit.
(f) PNNL-13910.
(g) NR = Not reported.

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, 1998 through 2003

Year	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{238}U	$^{239/240}$Pu
1998	ND[c]	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
2003	ND	1.5 ± 10	0.27 ± 2.0	0.01 ± 0.01	0.008 ± 0.009	0.003 ± 0.008

(a) To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.
(b) ±2 times the standard deviation.
(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, 2003

	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{238}U	$^{239/240}$Pu
Maximum[b]	ND[c]	25 ± 3.8	6.0 ± 4.3	0.022 ± 0.010	0.022 ± 0.010	0.023 ± 0.011
Average[d]	ND	1.5 ± 10	0.27 ± 2.0	0.01 ± 0.01	0.008 ± 0.009	0.003 ± 0.008
Distant communities[d,e]	NR[f]	0.066 ± 0.059	0.0022 ± 0.034	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) ±2 times the standard deviation.
(e) PNNL-13910.
(f) NR = Not reported.

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, 1998 through 2003

Year	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{238}U	$^{239/240}$Pu
1998	ND[c]	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]
2003	ND	ND	ND	0.043 ± 0.11	0.036 ± 0.19	0.0017 ± 0.017[e]

(a) To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.
(b) ±2 times the standard deviation.
(c) ND = Not detected.
(d) Negative value indicates a result at or below background levels of radioactivity.
(e) Single value above detection limit; ± total analytical uncertainty.

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, 2003

	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{238}U	$^{239/240}$Pu
Maximum[b]	ND[c]	ND	ND	0.22 ± 0.05	0.19 ± 0.04	0.0017 ± 0.017[d]
Average[e]	ND	ND	ND	0.043 ± 0.011	0.036 ± 0.19	0.0017 ± 0.017[d]
Distant communities[e,f]	NR[g]	0.066 ± 0.059	0.0022 ± 0.034	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; ± total analytical uncertainty.
(e) ±2 times the standard deviation.
(f) PNNL-13910.
(g) NR = Not reported.

and assess the impact of operations. Thermoluminescent dosimeters were used at numerous fixed locations to gather dose rate information over long 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 2002 and 2003 thermoluminescent dosimeter results for waste handling facilities on the Hanford Site, as well as historical comparative results from offsite locations can be found in Table 3.2.20. Individual thermoluminescent dosimeter results and locations are provided in PNNL-14687, APP. 2. Specific information regarding external radiation sampling methods and locations can be found in DTS-OEM-001. Additional dose rate information for Hanford Site 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.

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 waste 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) calibrated the response of the dosimeters; results were reported in terms of external dose.

During 2003, there were 134 near-facility thermoluminescent dosimeter locations collecting external radiation

Table 3.2.20. Near-Facility Thermoluminescent Dosimeter Results (mrem/yr)[a] at the Hanford Site for 2002 and 2003 and Comparative Offsite Location Results for 1998 through 2003

Hanford Site Locations	No. of Locations, 2003	2002 Maximum[b]	2002 Mean[b]	2003 Maximum[b]	2003 Mean[b]	% Change[c]
100-B/C	4	93 ± 10	87 ± 9	88 ± 6	85 ± 5	-2
100-F	5	93 ± 7	86 ± 9	80 ± 22	76 ± 4	-12
100-K	11	439 ± 120	129 ± 210	523 ± 1,060	162 ± 304	26
100-KR-1	5	106 ± 2	96 ± 20	103 ± 11	95 ± 15	-1
100-N	14	1,042 ± 178	274 ± 543	993 ± 71	261 ± 485	-5
200-East	42	289 ± 82	113 ± 97	482 ± 225	118 ± 138	4
200-West	24	215 ± 36	108 ± 64	189 ± 21	106 ± 52	-2
200-North	1	3,400 ± 89	3,200 ± 400	3,400 ± 131	3,000 ± 570	-6
300	8	129 ± 49	99 ± 39	112 ± 2	92 ± 24	-7
300 TEDF[d]	6	88 ± 3	85 ± 4	90 ± 12	85 ± 5	0
400	7	86 ± 3	82 ± 5	85 ± 7	81 ± 5	-1
CVDF[e]	4	83 ± 7	79 ± 5	82 ± 4	80 ± 6	1
ERDF[f]	3	95 ± 5	90 ± 10	99 ± 11	94 ± 11	4

Offsite Locations[g]	No. of Locations, 2003	2003 Maximum[b]	2003 Mean[h]	1998-2002 Maximum[b]	1998-2002 Mean[h]
Perimeter	11	96 ± 3	90 ± 3	106 ± 8	90 ± 2
Community	7	88 ± 5	79 ± 3	90 ± 9	79 ± 2
Distant	2	72 ± 6	72 ± 1	75 ± 8	71 ± 1

(a) To convert to international metric system units, multiply mrem/yr by 0.01 to obtain mSv/yr.
(b) ±2 times the standard deviation.
(c) Numbers indicate a decrease (-) or increase from the 2002 mean.
(d) TEDF = 300 Area Treated Effluent Disposal Facility.
(e) CVDF = Cold Vacuum Drying Facility.
(f) ERDF = Environmental Restoration Disposal Facility.
(g) Section 4.6.
(h) ±2 times the standard error of the mean.

information. At three of the operational areas, the dosimeter results showed a decrease of 6% or more in external radiation from 2002 levels. In the 100-K Area, there was a 26% increase in the annual average dose rate in 2003, which was attributable to the transfer and storage of radioactive materials associated with cleanup activities in the K Basins. At the remaining operational areas, changes in the external radiation levels from 2002 to 2003 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), four thermoluminescent dosimeter sites monitored dose rates in 2003. Dose rates measured at these locations were comparable to those measured in 2002.

In the 100-F Area, five thermoluminescent dosimeter monitoring sites were used from January through April 2003, coinciding with the conclusion of remedial action activities in that area. Dose rates measured during the 4-month period were approximately 4% lower than 2002 levels.

Cleanup activities at the 100-K Area Basins and adjacent retired reactor buildings continued in 2003 and dose rates were monitored at 11 locations. Overall average dose rates measured in 2003 increased by approximately 26% relative to 2002 values. This increase was primarily due to temporary, elevated dose rates at two monitoring locations situated near radioactive materials transfer and storage areas; one location was near the 105-K East load-out station and the other was near the 105-K West basin. Dose rates at both locations decreased by year's end to typical site background levels.

Four thermoluminescent dosimeter monitoring sites around the 100-K Area's Cold Vacuum Drying Facility also showed a slight annual dose rate increase of 1% in 2003.

Five thermoluminescent dosimeters, installed during the fourth quarter of 2002 to monitor activities at the 100-KR-1 (100-K Area) remedial action site, showed dose rate levels in 2003 to be at typical site background levels.

The 2003 results for the 100-N Area again indicated direct radiation levels to be highest near facilities that contained or received liquid effluent from N Reactor. These facilities primarily included the retired 116-N-1 (1301-N) and 116-N-3 (1325-N) liquid waste disposal facilities. The levels at these two facilities were noticeably higher than those for other 100-N Area thermoluminescent dosimeter locations. Three of the five monitoring locations near the 116-N-1 trench showed an increase of approximately 17% in annual average dose rate levels compared to those measured at the same locations in 2002. This increase may be ascribed to the removal of low-level, radioactively contaminated material from selected portions of the 116-N-1 trench soil column. Removal of this layer of natural shielding from atop the residual, slightly higher level radioactively contaminated subsurface materials may have led to the moderate increases observed in dose rates in the immediate vicinity of the excavation work. Remedial action activities will resume in mid-2004 to remove additional contamination with a scheduled completion date of fiscal year 2005. The 2003 annual average dose rate levels at the three monitoring locations at the 116-N-3 facility showed a decrease of approximately 12% from 2002 levels. This reduction in dose rates 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 2003 was approximately 5% lower than that measured in 2002. Annual average thermoluminescent dosimeter results for the entire 100-N Area from 1987 through 2003 are presented in Figure 3.2.4.

Dose rates were measured at the 100-N Area shoreline springs to determine potential external radiation doses to the public as well as to onsite workers. Cleanup activities at these former liquid waste disposal facilities located near the Columbia River have reduced the "skyshine" effect (i.e., radiation reflected by the atmosphere back to the earth's surface) at the springs and the dose rates there have decreased notably over the past few years. The 2003 levels were unchanged from the 2002 levels (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 in 2003 was in the 200-East Area at the A Tank Farm. The average annual dose rate measured in 2003 in the 200 Areas was slightly higher than the 2002 average level. The annual average thermoluminescent dosimeter results in the 200 Areas from 1987 through 2003 are presented in Figure 3.2.6.

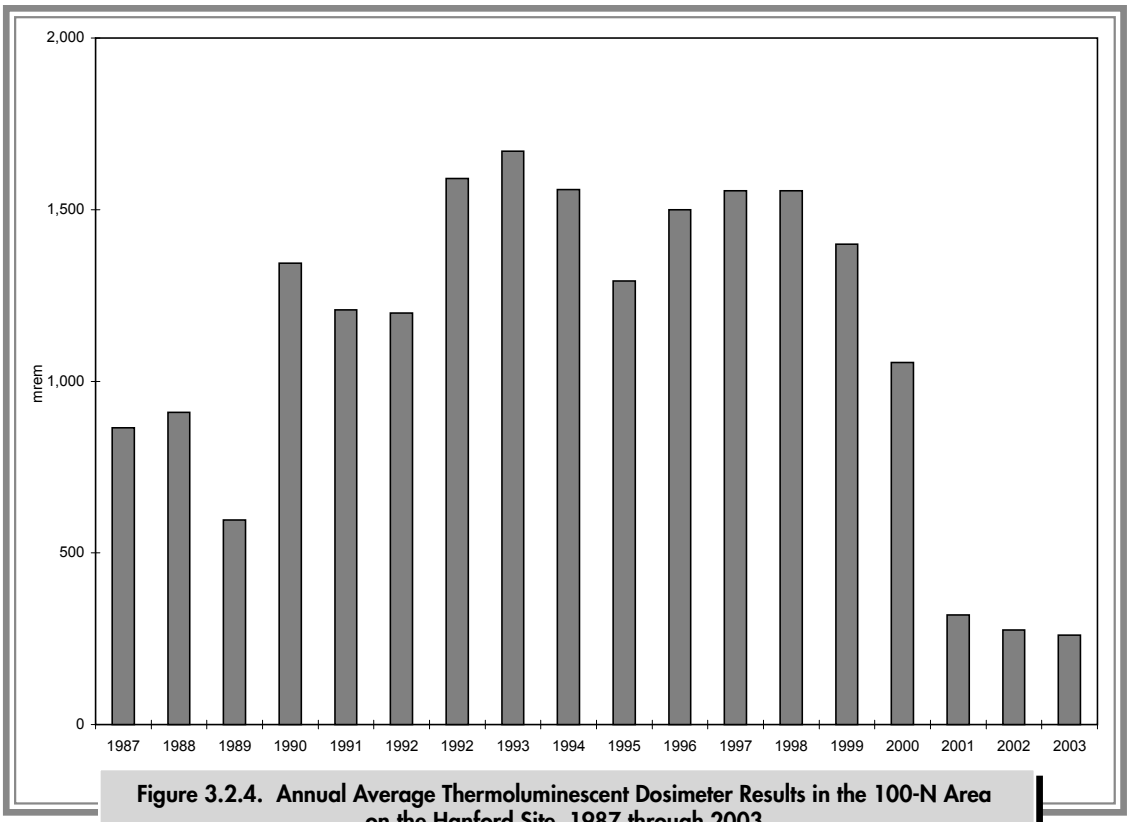


Figure 3.2.4. Annual Average Thermoluminescent Dosimeter Results in the 100-N Area on the Hanford Site, 1987 through 2003

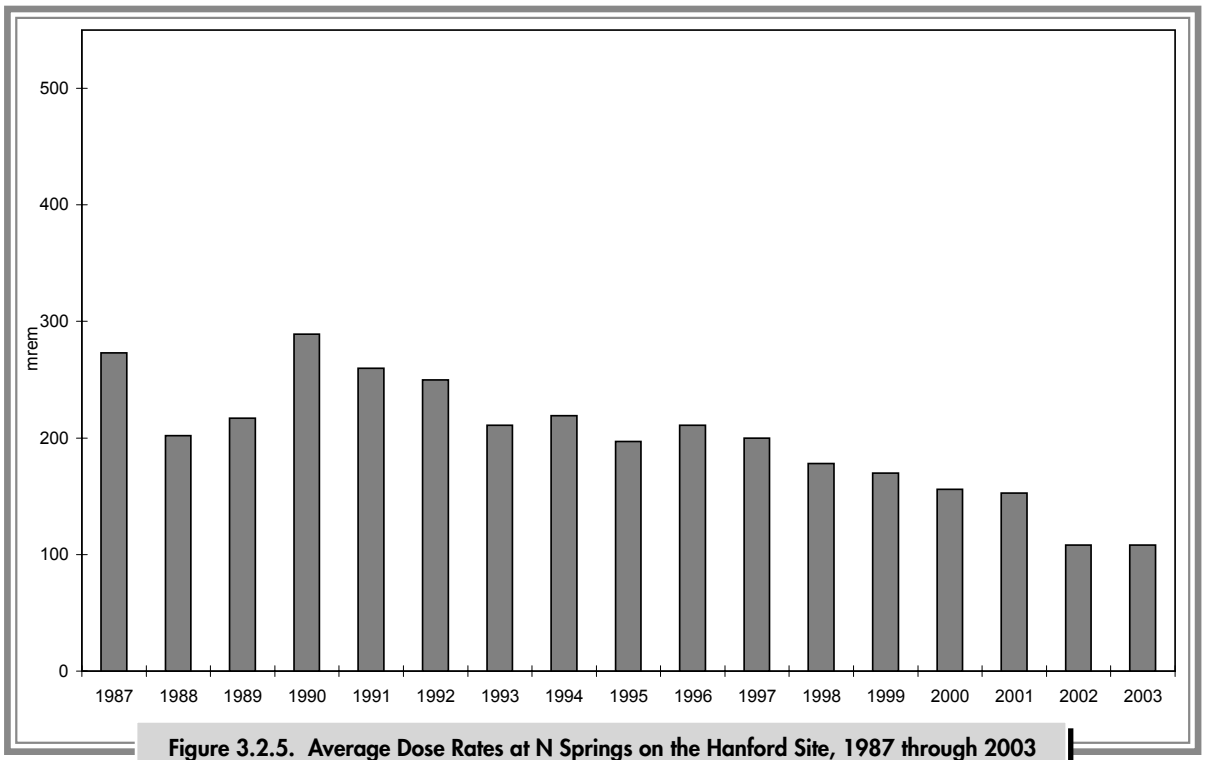


Figure 3.2.5. Average Dose Rates at N Springs on the Hanford Site, 1987 through 2003

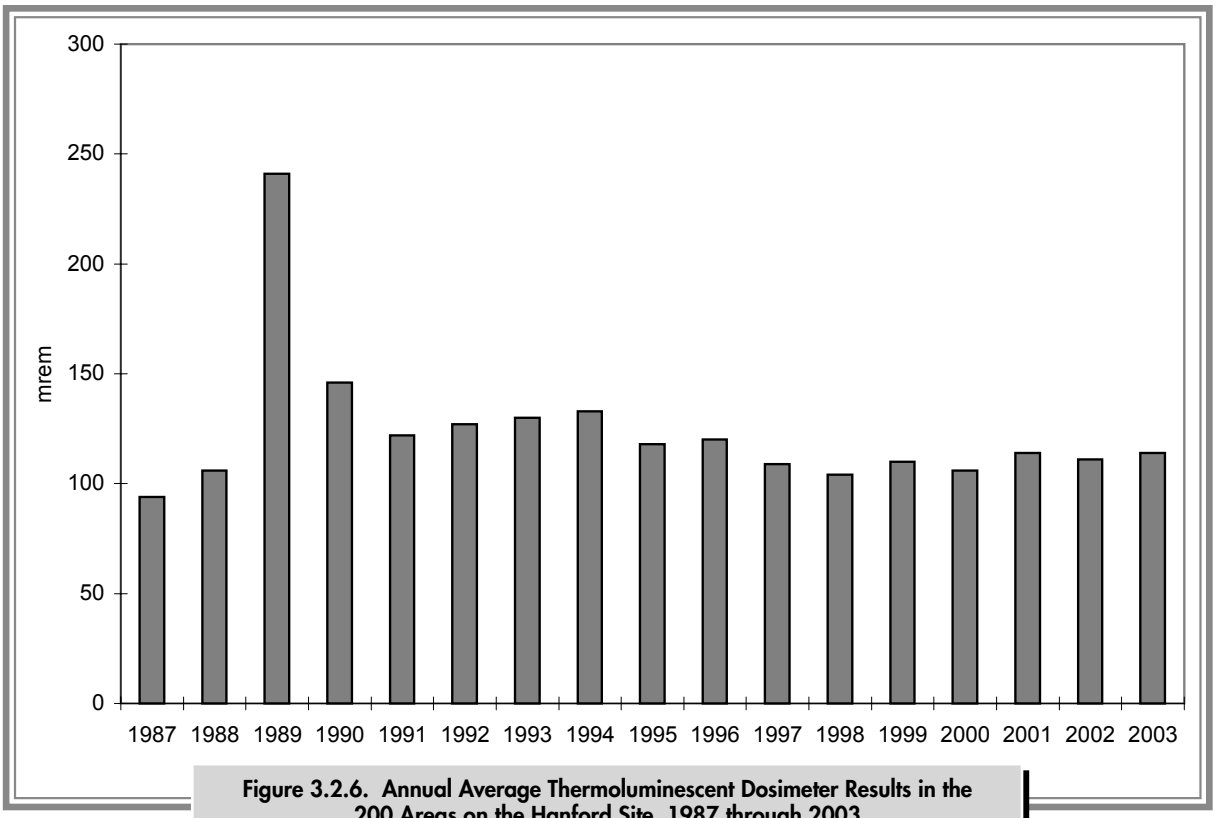


Figure 3.2.6. Annual Average Thermoluminescent Dosimeter Results in the 200 Areas on the Hanford Site, 1987 through 2003

Average dose rates measured in 2003 at the Environmental Restoration Disposal Facility were similar to 2002 levels, with only a slight increase of approximately 4%.

The average dose rates in the 300 Area in 2003 were approximately 7% lower than the 2002 levels, while those observed at the 300 Area Treated Effluent Disposal Facility and in the 400 Area were virtually unchanged from the dose rates measured in 2002. The annual average thermoluminescent dosimeter results for the 300 and 400 Areas from 1991 through 2003 are presented in Figure 3.2.7.

One thermoluminescent dosimeter monitoring site is located in the unoccupied 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 the 212-R Railroad Car Disposition Area in 2003 (approximately 3,000 mrem/yr) showed a decrease of 6% compared to 2002.

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 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.

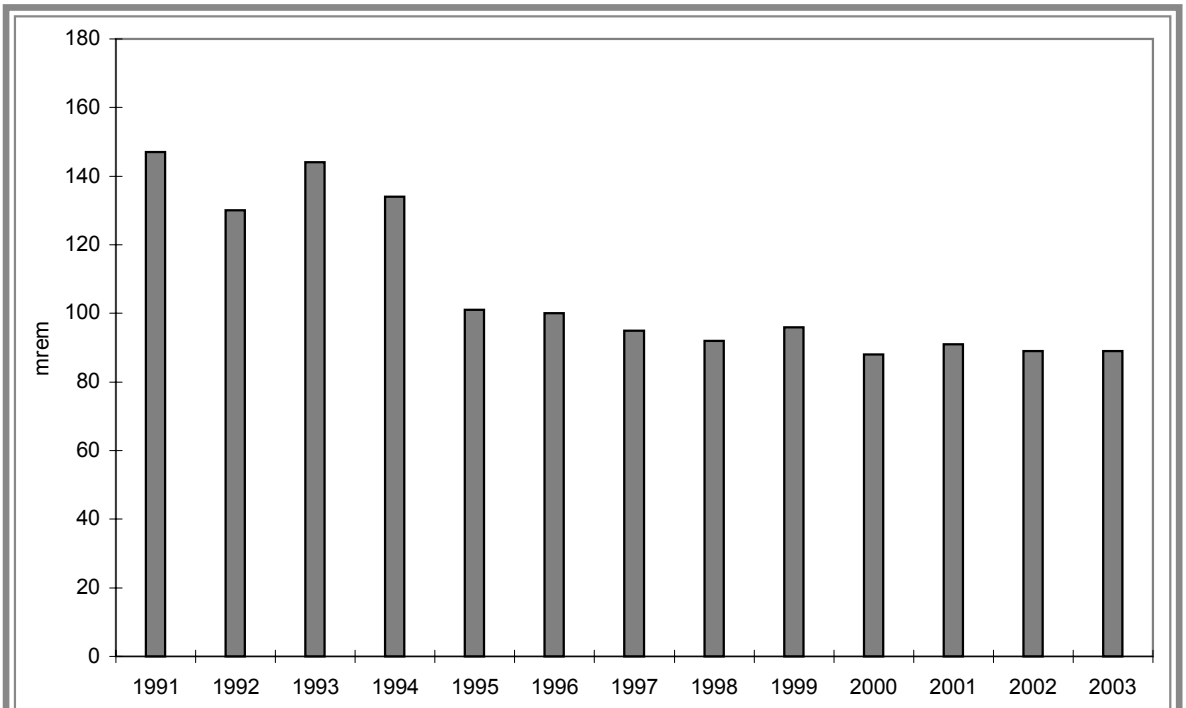


Figure 3.2.7. Annual Average Thermoluminescent Dosimeter Results in the 300/400 Areas of the Hanford Site and at the 300 Area Treated Effluent Disposal Facility, 1991 through 2003

Generally, the predominant radionuclides detected 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 2003 included soil, vegetation, and animals. Methods for collecting investigative samples are described in DTS-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-Mueller detector, while alpha radiation field surveys were performed with a portable alpha meter.

In 2003, investigative samples were analyzed for radionuclides at the 222-S laboratory in the 200-West Area. Refer to 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 2003, there were 89 of these. Laboratory analyses results and field readings are provided in PNNL-14687, APP. 2, Chapter 7.

Table 3.2.21. Investigative Samples Collected on the Hanford Site, 1994 through 2003[a]

	Sample Type		
Year	Soil	Vegetation	Wildlife[b]
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
2003	30	32	26

(a) Annual number of samples collected.
(b) May include wildlife-related materials (e.g., feces, nests)

During 2003, there were 30 instances of radiological contamination in investigative soil samples. Of the 30, 19 were identified as speck or soil speck contamination. One of the investigative soil samples was submitted for radioisotopic analysis. Twenty-two of the 30 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 2003 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.

In February 2003, contaminated soil was found to the west of the TX-TY Tank Farm (200-West Area) in an old construction debris site. Contaminants included strontium-89/90 and cesium-137.

During 2003, there were 32 instances of radiological contamination in investigative vegetation samples. Identified were tumbleweeds (Russian thistle [*Salsola kali* var. *tenuifolia*]), tumbleweed fragments, and gray rabbitbrush (*Chrysothamnus nauseosus*). None were analyzed for radionuclide activity. One sample, collected outside the BX-BY Tank Farm 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 are deep-rooted species and become radiologically contaminated by the uptake of belowground contaminants through their root systems. Herbicide application is intended to halt vegetation growth before this uptake occurs. In 2003, application techniques were enhanced, and administrative procedures were implemented to improve vegetation management. The overall reduction in the number of contamination incidents since 1999 reflects these improvements. Nevertheless, contaminated vegetation continued to be identified by radiological surveys.

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 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 2003, and their levels and ranges of radioactivity were within historical levels (WHC-MR-0418).

In 2003, 26 contaminated wildlife and wildlife-related incidents were investigated and from these, 6 wildlife specimens were surgically transitioned into 9 samples that were submitted for laboratory analysis. The analytical results and field readings obtained from each sample can be found in PNNL-14687, APP. 2, Tables 7-1 and 7-2, respectively. 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 result locations, and the costs involved, rather than prescheduled sampling at established sampling points.

In November 2002, two contaminated mice were found along the perimeter of the BX-BY Tank Farm in the 200-East Area. Contaminants included strontium-89/90 and cesium-137. The results are being reported in 2003 because analyses were not completed in time to be included in the 2002 report.

In June 2003, a contaminated mouse was found in the 105-KE radiological monitoring office in the 100-KE Area. Contaminants included strontium-89/90 and cesium-137.

In June 2003, a contaminated starling carcass was found in the 317 Building stairwell. Contaminants included cobalt-60, strontium-89/90, and cesium-134/137.

In August 2003, a contaminated house mouse was found at the 105-KE reactor building. Contaminants included strontium-89/90 and cesium-137.

In August 2003, a contaminated cottontail rabbit was found outside the 272-S paint shop (200-West Area) east of the S-SX-SY Tank Farm complex. Samples of skin, bone, gastrointestinal tract, and muscle were analyzed.

Contaminants included strontium-89/90 and cesium-137 with the highest result of cesium-137 found in the muscle tissue.

Listed below are special characterization projects conducted or completed during 2003 to ascertain the radiological status, and in some cases, physical condition of specific sites or operations:

- A preoperational monitoring plan (RPP-6877) was developed in support of the Waste Vitrification initiative. As part of this plan, an ongoing environmental survey is being conducted on the proposed location for the Integrated Disposal Facility, formerly the Immobilized Low-Activity Waste Disposal Facility, in the 200-East Area. Tasks completed in 2003 included bulk soil sampling for geophysical properties. Following the completion of all the tasks outlined in the monitoring plan, the data collected will be published in a final report. The report is currently scheduled for publication in 2005.
- Soil, vegetation, and ground-dwelling invertebrate samples were collected at the location of the former Gable Mountain Pond and B Pond in October 2003 to identify potential exposure pathways to biota and to support remedial action decisions (Lane et al. 2003).

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4.0 Environmental Surveillance Information

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Results of the Hanford Site Surface Environmental Surveillance and Drinking Water Surveillance Projects for 2003 are described in the following sections 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. Quality assurance and quality control programs developed to assure the value of surveillance data are described in Chapter 8.

Many samples are collected and analyzed for the Hanford Site environmental surveillance and drinking water surveillance projects, 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 may be important to the environment or human health and safety. Supplemental data for some sections can be found in Appendix C. More detailed results for specific surface environmental surveillance sampling locations are contained in *Hanford Site Environmental Surveillance Data Report for Calendar Year 2003* (PNNL-14687, APP. 1). The intent of these sections (4.1 through 4.6) is to provide current surveillance data, to compare 2003 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 (Chapter 5) 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 at selected locations.

The environmental surveillance 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 the 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 contaminant releases to the environment from DOE facilities and operations, to assess doses to members of the

public, and to monitor potential impacts of contaminants on other biota, and to alert the DOE to the possible need for corrective action (DOE Orders 450.1 and 5400.5; DOE/EH-0173T).

The surveillance objectives include

- Determine 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.
- Determine background levels and site contributions of contaminants in the environment.
- Determine long-term accumulations of site-related contaminants in the environment and predict trends.
- Characterize and define trends in the physical, chemical, and biological conditions of environmental media.
- Determine the effectiveness of treatments and controls in reducing effluents and emissions.
- Determine the validity and effectiveness of models to predict concentrations of pollutants in the environment.
- Detect and quantify unplanned releases.
- Identify and quantify new environmental quality problems.
- Maintain the capability to assess the consequence of accidents.
- Provide public assurance; address issues of concern to the public, stakeholders, regulators, and business community.
- Enhance public understanding of site environmental issues, primarily through public involvement and by providing environmental information to the public.
- Provide environmental data and assessments to assist the DOE and its contractors 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 nearly 60 years of environmental surveillance and studies at the Hanford Site provides valuable technical background information for planning surveillance activities and managing the site.

The Hanford Site environmental surveillance project historically has focused on radionuclides in various media and non-radiological water quality parameters. However, surveillance for non-radiological constituents, including metals and 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 2003 pathway analysis was based on 2003 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 the DOE, was used to screen doses to biota (DOE-STD-1153-2002). The results of the pathway analysis and exposure assessment (discussed in Chapter 5) serve as a basis for future years' surveillance program design.

Exposure can be defined as the interaction of an organism with a physical or chemical agent of interest, the absorption of radiation, or the ingestion of a radionuclide (Shleien and Terpilak 1984). Thus, exposure can be quantified

as the amount of chemical or physical agent available in the proper form for absorption, intake, or uptake at the organism's exchange boundaries (i.e., skin, mouth, lungs, gastrointestinal tract). An exposure pathway is identified based on (1) examination of the types, location, and sources (e.g., contaminated air, water, vegetation, food, soil) of contaminants; (2) principal release mechanisms; (3) probable environmental fate and transport (including persistence, partitioning, and intermediate transfer) of contaminants of interest; and, most importantly, (4) location and activities of the potentially exposed populations of people or animals. Several mechanisms influence the fate and transport of radionuclides and chemicals through the environment. Thus, once a radionuclide or chemical enters 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 radioactive decay).
- Biologically transformed (e.g., biodegradation).
- Accumulated in the receiving media (e.g., sorbed strongly in the soil column, stored in organism tissues [bio-accumulation]).

The principal pathways for movement of radioactive materials and chemicals from the Hanford Site to the public are the atmosphere and surface water (Figure 4.0.1).

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 contractual detection limits established for the analytical laboratory (DOE/RL-91-50). 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 where people reside. Concentrations of radionuclides and chemicals were measured in the following three general surveillance zones that extended from onsite facilities and operations to the offsite environs:

- **Onsite Zone** – Sampling locations were situated between the Near-Facility Environmental Monitoring Program samplers (located near active and inactive facilities) and the Hanford Site perimeter. Samples were collected at these locations to monitor potential fugitive emissions such as windblown contaminated soil and unplanned contaminant releases from facilities, and to verify the effectiveness of effluent and emissions controls.
- **Perimeter Zone** – Sampling locations were located along or near the Hanford Site boundary, along State Highway 240, and along the Hanford Reach of the Columbia River.
- **Nearby Community Zone** – Sampling locations were located 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 2003. A summary of the number and types of samples collected during 2003, 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 and are scheduled for collection again in 2004. A number of samples are collected and analyzed by or for other agencies and organizations each year either for their own use or to evaluate the precision and accuracy of the analytical laboratories that are analyzing samples for the DOE. Other samples are collected and archived in a storage facility in the event that additional material is needed for further or repeat analyses (Table 4.0.2).

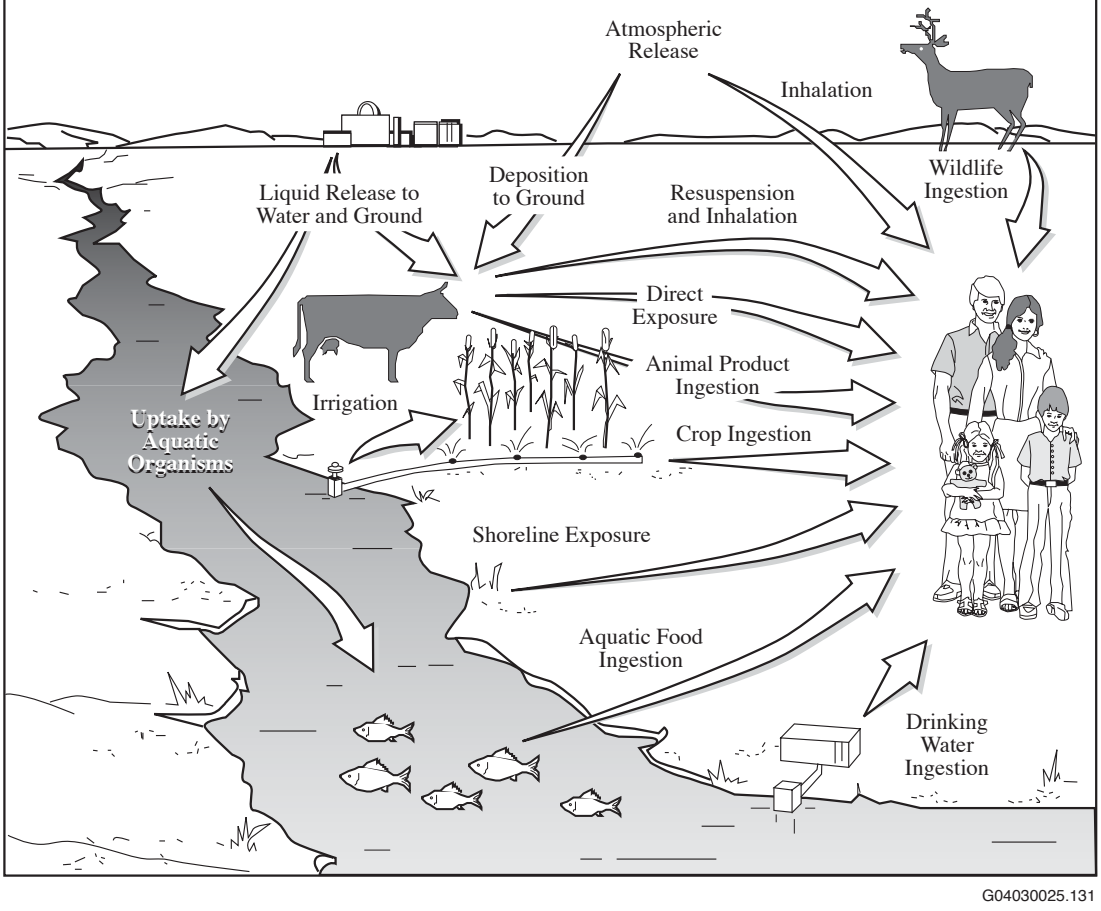


Figure 4.0.1. Potential Pathways for Human and Biota Exposure to Effluent and Emissions from the DOE's Hanford Site

Background concentrations of contaminants were measured at distant locations and compared with concentrations measured on the site and at perimeter and community locations. Background locations are assumed to be 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 contaminant concentrations measured on or near the site indicated the impact, if any, of Hanford Site operations.

The environmental surveillance design is reviewed annually and documented in the environmental surveillance master sampling schedule (e.g., PNNL-14184).

Table 4.0.1. Routine Environmental Surveillance Sample Types and Measurement Locations On and Around the Hanford Site in Washington State, 2003

		Sample Locations						
						Columbia River		
Type	Total Number	Onsite[a]	Site Perimeter[b]	Nearby[c]	Distant[c]	Upstream[c]	Hanford Reach[b]	Downstream[c]
Air	44	23	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	8			6	2			
Alfalfa	4			3	1			
Wildlife	6	4			2			
Aquatic biota	2					1	1	
External dose[e]	80	33	12	6	2	1	23	3
External shoreline radiation[f]	14					1	13	
Exposure rate (PIC)[g]	4			3	1			

(a) Surveillance Zone 1 (between the Near-Facility Environmental Monitoring Program sampling locations and 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.
(e) Thermoluminescent dosimeters.
(f) Handheld survey instruments.
(g) Pressurized ionization chambers.

Table 4.0.2. Samples Collected by the Hanford Site Surface Environmental Surveillance Project, 2003

Media	Number of Samples Collected and Submitted for Analyses	Number of Analytical Results Obtained	Number of Samples Collected and Archived or Submitted to Other Agencies and Organizations[a]
Air	1,556	4,101	
Biota	384	3,827	141
Soil and sediment	141	1,286	82
Surface water	709	7,192	95
Groundwater	12	156	4
Drinking water	38	101	
External radiation	310	310	
Miscellaneous materials	3	58	2
Totals	3,153	17,031	324

(a) Selected samples were collected and archived, not submitted for analyses. Some samples were relinquished to Bechtel Hanford, Inc., Washington State Department of Health, Washington State Department of Ecology, U.S. Food and Drug Administration, or Oregon Department of Energy.

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's Environmental Monitoring Plan for the Hanford Site (DOE/RL-91-50). Comparing measured radionuclide concentrations from locations on and around the Hanford Site to concentrations measured at 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-14687, APP. 1). In addition to the radiological monitoring network, a small non-radiological monitoring network is operated onsite. This network measures particulate matter (dust) concentrations at a few locations across the Hanford Site. Results are mainly used for scientific studies in an attempt to better understand windblown dust on and around the Hanford Site.

4.1.1 Collection of Air Samples and Analytes Tested

During 2003, airborne radionuclide samples were collected at 44 continuously operating samplers. The sampling stations are grouped into four location groups: onsite (23 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 7.4) that were managed and operated by local schoolteachers 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 7.1). 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-14184) and analyzed for up to 8 analytes (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 of radionuclides of concern. 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 gamma-emitting radionuclides (Appendix F). Most composite samples were also analyzed for strontium-90, plutonium-238, plutonium-239/240, uranium-234, uranium-235, and uranium-238.

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.

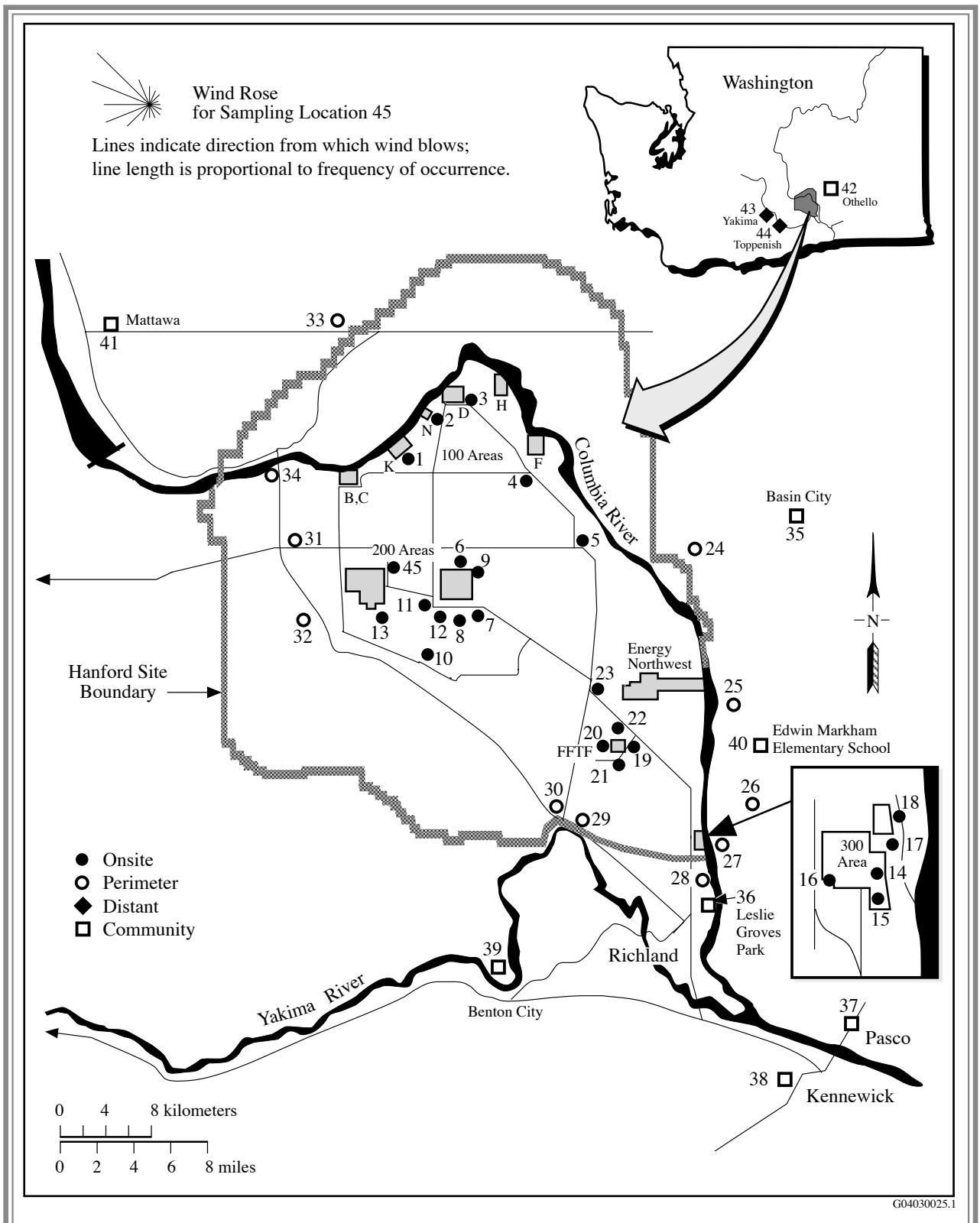


Figure 4.1.1. Pacific Northwest National Laboratory Air Sampling Locations On and Around the Hanford Site During 2003 (see Table 4.1.1 for location names)

Table 4.1.1. Pacific Northwest National Laboratory Air Sampling Locations On and Around the Hanford Site, Sample Composite Groups, and Analytes, 2003

Map Location[a]	Sampling Location	Analytes[b]	Composite Group	Analytes[c]
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	200 ESE	Alpha, Beta, ^{3}H, ^{129}I	200 E Area	Gamma, Sr, Pu, U
8	S of 200 E	Alpha, Beta		
9	B Pond	Alpha, Beta	B Pond	Gamma, Sr, Pu, U
10	Army Loop Camp	Alpha, Beta	200 W South East	Gamma, Sr, Pu, U
11	200 Tel. Exchange	Alpha, Beta, ^{3}H		
12	SW of B/C Crib	Alpha, Beta		
13	200 W SE	Alpha, Beta	200 West	Gamma, Sr, Pu, U
14	300 Water Intake	Alpha, Beta, ^{3}H	300 Area	Gamma, Sr, Pu, U
15	300 South Gate	Alpha, Beta, ^{3}H		
16	300 South West	Alpha, Beta, ^{3}H		
17	300 Trench	Alpha, Beta, ^{3}H U, Gamma	300 NE	Sr, Pu
18	300 NE	Alpha, Beta, ^{3}H U, Gamma		
19	400 E	Alpha, Beta, ^{3}H	400 Area	Gamma, Sr, Pu
20	400 W	Alpha, Beta		
21	400 S	Alpha, Beta		
22	400 N	Alpha, Beta		
23	Wye Barricade	Alpha, Beta	Wye Barricade	Gamma, Sr, Pu, U
Perimeter				
24	Ringold Met Tower	Alpha, Beta, ^{3}H, ^{129}I	Ringold Met Tower	Gamma, Sr, Pu
25	W End of Fir Road	Alpha, Beta	W End of Fir Road	Gamma, Sr, Pu, U
26	Dogwood Met Tower	Alpha, Beta, ^{3}H	Dogwood Met Tower	Gamma, Sr, Pu, U
27	Byers Landing	Alpha, Beta, ^{3}H, ^{129}I	Byers Landing	Gamma, Sr, Pu, U
28	Battelle Complex	Alpha, Beta, ^{3}H	Battelle Complex	Gamma
29	Horn Rapids Substation	Alpha, Beta	Prosser Barricade	Gamma, Sr, Pu, U
30	Prosser Barricade	Alpha, Beta, ^{3}H		
31	Yakima Barricade	Alpha, Beta	Yakima Barricade	Gamma, Sr, Pu
32	Rattlesnake Springs	Alpha, Beta		
33	Wahluke Slope	Alpha, Beta, ^{3}H	Wahluke Slope	Gamma, Sr, Pu
34	S End Vernita Bridge	Alpha, Beta		

Table 4.1.1. (contd)

Map Location[a]	Sampling Location	Analytes[b]	Composite Group	Analytes[c]
Nearby Communities				
35	Basin City School[d]	Alpha, Beta, ^{3}H	Basin City School	Gamma, Sr, Pu, U
36	Leslie Groves-Rchlnd[d]	Alpha, Beta, ^{3}H	Leslie Groves-Rchlnd	Gamma, Sr, Pu, U
37	Pasco	Beta	Tri-Cities	Gamma, Sr, Pu
38	Kennewick	Alpha, Beta		
39	Benton City	Beta	Benton City	Gamma
40	Edwin Markham School[d]	Alpha, Beta, ^{3}H	Edwin Markham School	Gamma, Sr, Pu, U
41	Mattawa	Beta	Mattawa	Gamma
42	Othello	Beta	Othello	Gamma
Distant Communities				
43	Yakima	Alpha, Beta, ^{3}H, ^{129}I	Yakima	Gamma, Sr, Pu, U
44	Toppenish[d]	Alpha, Beta, ^{3}H	Toppenish	Gamma, Sr, Pu, U
Non-Radiological Monitoring				
45	Hanford Meteorology Station	PM_{10}, $PM_{2.5}$[e]		

(a) See Figure 4.1.1.
(b) Alpha (gross) and beta (gross) samples are collected and analyzed every 2 weeks, ^{3}H samples are collected and analyzed every 4 weeks, and ^{129}I samples are collected every 4 weeks, combined into a quarterly composite sample and analyzed for each location.
(c) Gamma spectroscopy, strontium-90, isotopic plutonium (^{238}Pu, $^{239/240}Pu$), and isotopic uranium (^{234}U, ^{235}U, ^{238}U) analyses are performed on quarterly composite samples.
(d) A community-operated environmental surveillance station.
(e) See Section 4.1.3.

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 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.

4.1.2 Radiological Results for Air Samples

All sample results showed low to very low radiological concentrations in air during 2003. All samples were below the DOE derived concentration guides for each radionuclide analyzed (Appendix D, Table D.5). The DOE derived concentration guide values are based on a 100 mrem/year dose. A more conservative dose standard is the U.S. Environmental Protection Agency (EPA) *Clean Air Act* standard of 10 mrem/year from airborne radiological material. All air samples collected in 2003 were below one-tenth of the DOE derived concentration guide values, which would be equivalent to concentrations that would result in a 10 mrem/year dose.

During 2003, the annual average onsite gross alpha concentration was higher than the average concentration measured at the distant location by a small but statistically significant amount (two-sample means t-test, 95% confidence level) (Figure 4.1.2). The highest average gross alpha concentration for 2003 was observed at onsite locations (650 aCi/m^3 [24 Bq/m^3]). The average gross alpha concentrations observed at each location group during

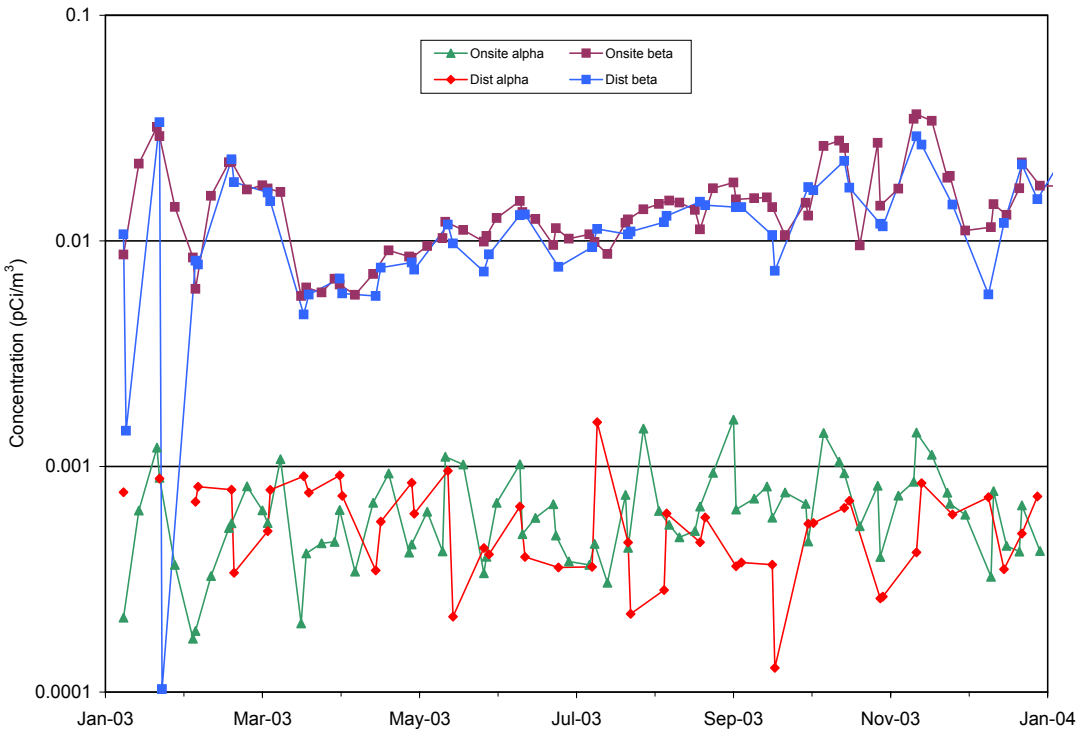


Figure 4.1.2. Gross Alpha and Gross Beta Concentrations in Airborne Particulate Samples Collected at Onsite and Distant Locations from the Hanford Site During 2003 (1 pCi = 0.037 Bq)

2003 were similar to the 5-year average concentrations observed from 1998 through 2002 (Table 4.1.2).

Gross beta concentrations in air peaked during the winter months of 2003 (Figure 4.1.2), repeating a pattern of natural radioactivity fluctuations (Eisenbud 1987). The annual average gross beta concentration at onsite locations during 2003 was slightly higher than at the distant locations. The difference was small but statistically significant (two-sample means t-test, 95% confidence level). The average gross beta concentrations reported for 2003 were similar to concentrations reported from 1998 through 2002 (Table 4.1.2).

Average tritium concentrations measured during 2003 were slightly higher than average values reported for 1998 through 2002 (Table 4.1.2 and Figure 4.1.3). The 2003 annual average tritium concentrations at each location group were also elevated relative to the 2002 annual average concentrations (PNNL-14295). Approximately 98% of atmospheric moisture samples collected in 2003 contained detectable amounts of tritium (Table 4.1.2). In the 5-year period from 1998 through 2002, about 75% of the samples collected had detectable levels of tritium. In 2003, the tritium sampling systems were modified to provide a more accurate measurement of sample volume. These modifications resulted in more consistent sampling rates over the sampling period. These improvements may have been partially responsible for the elevated tritium concentrations observed in 2003 and the more frequent detection of tritium. The annual average 300 Area, perimeter, and community concentrations were higher by a statistically significant amount relative to the distant location (two-sample means t-test, 95% confidence level). The sample with the highest tritium concentration measured during 2003 (74 pCi/m^3 [2.7 Bq/m^3]) was collected at the Battelle Complex in Richland (location 28 in Figure 4.1.1) during the month of July. This concentration was 0.074% 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 (PUREX), at two downwind perimeter locations, and at a distant location (Yakima) in 2003

Table 4.1.2. Airborne Radionuclide Concentrations in the Environs of the Hanford Site, 2003 Compared to Previous Years

Radionuclide (approximate detection limit)	Location Group[a]	2003 No. of Samples	2003 No. of Detections[b]	2003 Maximum[c]	2003 Average[d]	1998-2002 No. of Samples	1998-2002 No. of Detections[b]	1998-2002 Maximum[c]	1998-2002 Average[d]	Derived Concentration Guide[e]
				pCi/m^3[f]	pCi/m^3[f]			pCi/m^3[f]	pCi/m^3[f]	pCi/m^3[f]
Tritium (1.5 pCi/m^3)	300 Area	76	76	23 ± 3.5	8.2 ± 7.7	351	336	25 ± 3.0	4.6 ± 7.1	100,000
	Onsite	67	67	16 ± 2.4	5.4 ± 6.4	321	226	15 ± 1.3	2.3 ± 3.7	
	Perimeter	82	82	74 ± 10	8.6 ± 19	350	231	36 ± 3.6	2.9 ± 7.3	
	Nearby communities	42	42	47 ± 6.8	9.1 ± 18	187	137	33 ± 2.9	2.9 ± 7.0	
	Distant communities	25	21	11 ± 2.2	4.0 ± 6.4	126	60	7.9 ± 1.1	1.6 ± 2.9	
Gross beta (0.001 pCi/m^3)	Onsite	586	584	0.041 ± 0.0071	0.015 ± 0.015	3,014	3,007	0.084 ± 0.014	0.015 ± 0.018	No standard
	Perimeter	286	286	0.038 ± 0.0064	0.014 ± 0.013	1,307	1,306	0.074 ± 0.012	0.015 ± 0.017	
	Nearby communities	206	206	0.037 ± 0.0066	0.015 ± 0.013	1,062	1,061	0.056 ± 0.0094	0.015 ± 0.017	
	Distant communities	53	52	0.034 ± 0.0058	0.013 ± 0.013	286	285	0.059 ± 0.010	0.014 ± 0.017	
				aCi/m^3[g]	aCi/m^3[g]			aCi/m^3[g]	aCi/m^3[g]	aCi/m^3[g]
Gross alpha (350 aCi/m^3)	Onsite	586	472	2,600 ± 880	650 ± 820	2,875	1,916	3,600 ± 1,500	610 ± 880	No standard
	Perimeter	286	241	2,900 ± 920	640 ± 730	1,251	870	5,100 ± 1,300	610 ± 910	
	Nearby communities	113	102	1,900 ± 700	620 ± 550	557	390	6,300 ± 1,700	680 ± 1,100	
	Distant communities	53	41	1,600 ± 600	560 ± 570	283	168	5,500 ± 1,900	580 ± 1,100	
Strontium-90 (70 aCi/m^3)	Onsite	40	16	180 ± 86	40 ± 90	174	42	1,300 ± 280	32 ± 230	9,000,000
	Perimeter	28	6	110 ± 64	34 ± 94	119	15	390 ± 79	13 ± 96	
	Nearby communities	16	4	160 ± 62	50 ± 100	68	7	220 ± 190	19 ± 96	
	Distant communities	8	1	100 ± 74	38 ± 110	34	3	300 ± 100	10 ± 130	
Iodine-129 (0.01 aCi/m^3)	Onsite	4	4	26 ± 2.6	21 ± 8.9	20	20	27 ± 1.3	19 ± 8.7	70,000,000
	Perimeter	8	8	0.78 ± 0.062	0.49 ± 0.40	40	40	1.5 ± 0.12	0.60 ± 0.74	
	Distant communities	4	4	0.029 ± 0.0037	0.025 ± 0.0062	20	20	0.22 ± 0.015	0.059 ± 0.087	
Plutonium-238 (2 aCi/m^3)	Onsite	40	3	2.5 ± 1.6	0.06 ± 1.3	174	8	5.3 ± 1.7	0.020 ± 1.7	30,000
	Perimeter	28	0	1.5 ± 3.0	-0.22 ± 1.5	119	1	1.9 ± 1.4	-0.15 ± 0.96	
	Nearby communities	16	1	3.7 ± 3.6	0.46 ± 2.2	68	0	2.2 ± 3.2	-0.13 ± 1.3	
	Distant communities	8	0	0.063 ± 1.5	-0.92 ± 1.6	34	0	0.37 ± 1.8	-0.36 ± 0.70	
Plutonium-239/240 (2 aCi/m^3)	Onsite	40	6	14 ± 4.3	1.2 ± 5.2	174	49	36 ± 6.4	1.4 ± 7.3	20,000
	Perimeter	28	1	1.7 ± 2.7	0.28 ± 1.7	119	7	5.2 ± 2.5	0.38 ± 1.8	
	Nearby communities	16	0	1.9 ± 2.5	0.48 ± 1.2	68	4	2.1 ± 1.2	0.36 ± 1.2	
	Distant communities	8	0	1.5 ± 2.4	0.47 ± 1.2	34	1	3.2 ± 2.9	0.37 ± 1.9	

Table 4.1.2. (contd)

Radionuclide (approximate detection limit)	Location Group[a]	2003				1998-2002				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]	aCi/m^3[g]
Uranium-234 (10 aCi/m^3)	Onsite	32	30	120 ± 31	32 ± 50	141	135	150 ± 52	23 ± 40	90,000
	Perimeter	16	16	76 ± 20	33 ± 35	68	68	140 ± 32	30 ± 42	
	Nearby communities	12	12	53 ± 15	35 ± 24	51	50	58 ± 21	26 ± 27	
	Distant communities	8	7	34 ± 14	20 ± 16	34	33	41 ± 15	18 ± 17	
Uranium-235 (10 aCi/m^3)	Onsite	32	0	6.5 ± 8.5	0.57 ± 4.1	141	5	4.0 ± 4.7	0.40 ± 2.6	100,000
	Perimeter	16	0	3.9 ± 5.8	0.99 ± 2.6	68	2	6.0 ± 6.0	0.69 ± 2.8	
	Nearby communities	12	0	2.1 ± 3.0	-0.57 ± 4.4	51	0	6.2 ± 5.6	0.60 ± 3.9	
	Distant communities	8	0	2.7 ± 4.4	0.46 ± 4.2	34	0	7.0 ± 9.3	0.20 ± 3.9	
Uranium-238 (10 aCi/m^3)	Onsite	32	29	160 ± 37	33 ± 63	141	130	120 ± 47	21 ± 36	100,000
	Perimeter	16	16	61 ± 18	32 ± 32	68	66	140 ± 32	28 ± 42	
	Nearby communities	12	12	40 ± 14	28 ± 19	51	49	56 ± 18	24 ± 25	
	Distant communities	8	8	28 ± 11	19 ± 12	34	34	33 ± 15	17 ± 15	
Cobalt-60 (1,200 aCi/m^3)	Onsite	48	0	730 ± 950	69 ± 560	217	1	3,800 ± 2,500	100 ± 470	80,000,000
	Perimeter	32	0	720 ± 570	62 ± 610	145	0	910 ± 740	10 ± 400	
	Nearby communities	28	0	860 ± 810	56 ± 800	127	0	1,800 ± 3,600	90 ± 450	
	Distant communities	8	0	730 ± 1,000	58 ± 600	37	0	700 ± 600	50 ± 270	
Cesium-137 (950 aCi/m^3)	Onsite	48	0	920 ± 690	46 ± 460	217	1	540 ± 870	-5.1 ± 580	400,000,000
	Perimeter	32	0	850 ± 770	2 ± 610	145	0	1,200 ± 2,000	39 ± 590	
	Nearby communities	28	0	690 ± 900	-12 ± 660	127	0	2,100 ± 3,100	22 ± 680	
	Distant communities	8	0	99 ± 480	-130 ± 340	37	0	530 ± 520	42 ± 580	

(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).

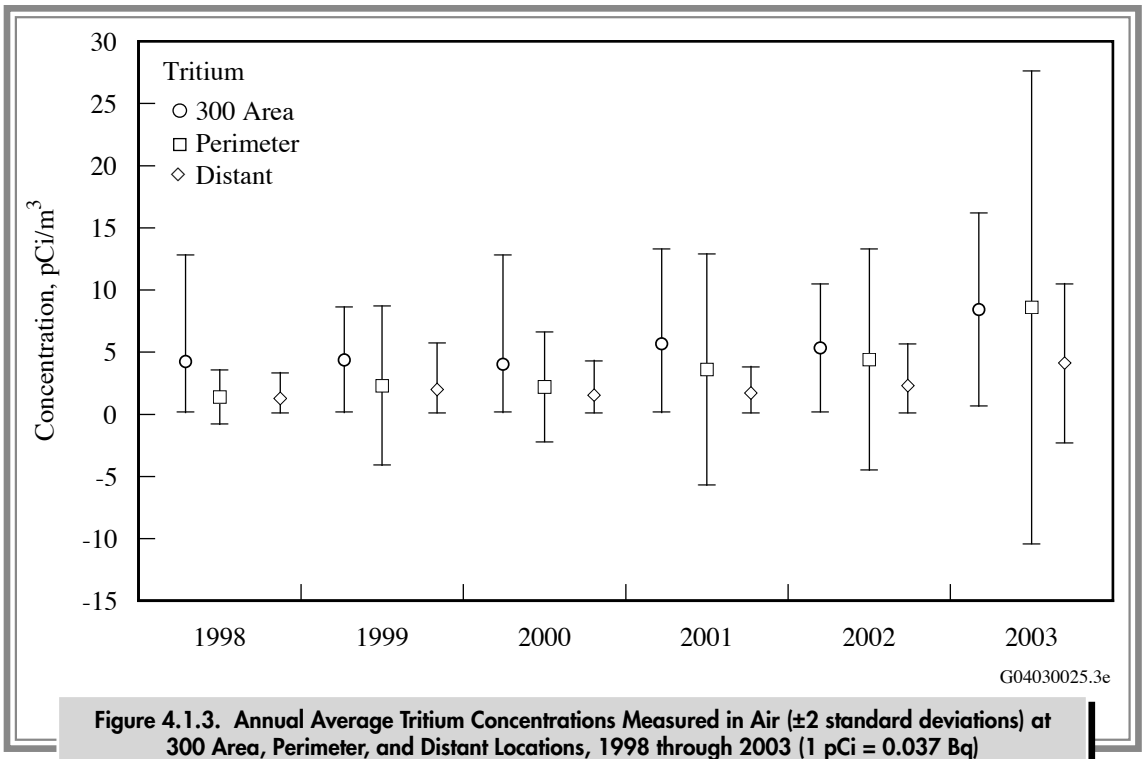


Figure 4.1.3. Annual Average Tritium Concentrations Measured in Air (±2 standard deviations) at 300 Area, Perimeter, and Distant Locations, 1998 through 2003 (1 pCi = 0.037 Bq)

(Table 4.1.1). Concentrations measured onsite during 2003 were elevated compared to those measured at the site perimeter, and perimeter levels were higher than those measured at the distant location in 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 observed in 2003 were consistent with the levels observed from 1998 through 2002 (Figure 4.1.4). Onsite air concentrations of iodine-129 were influenced by minor emissions (Table 3.1.1) from the Plutonium-Uranium Extraction Plant (PUREX) and possible releases from waste storage tanks and cribs. The annual average iodine-129 concentration (0.49 ± 0.40 aCi/m^3 [0.018 ± 0.015 µBq/m^3]) observed at the downwind perimeter in 2003 was 0.0000007% of the DOE derived concentration guide (70 million aCi/m^3 [2.6 Bq/m^3]).

Plutonium-238 was detected in three onsite composite samples during 2003 (Table 4.1.2). The maximum reported plutonium-238 concentration in 2003 was 3.7 ± 3.6 aCi/m^3 (0.14 ± 0.13 µBq/m^3), or 8,000 times below the DOE derived concentration guide for plutonium-238 (30,000 aCi/m^3 [1.1 mBq/m^3]).

The annual average plutonium-239/240 concentration (Figure 4.1.5 measured in air samples in 2003 at onsite locations was 1.2 ± 5.2 aCi/m^3 (0.044 ± 0.19 µBq/m^3). Of the 40 onsite samples analyzed for plutonium-239/240, 6 had detectable amounts in the sample (Table 4.1.2). Four of

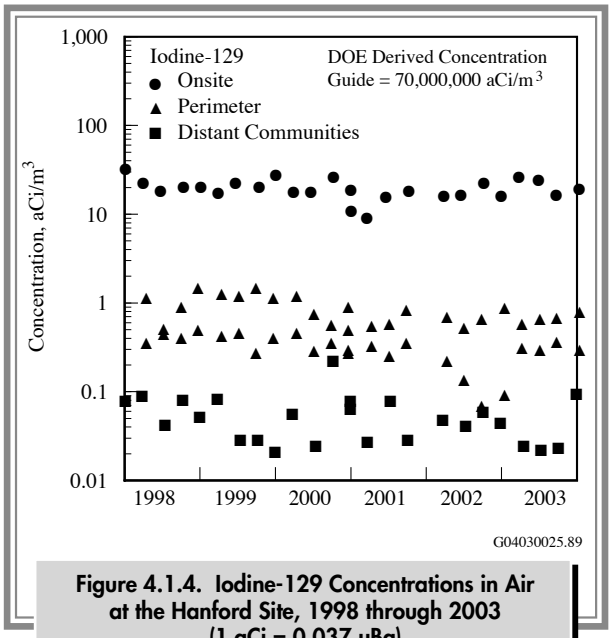


Figure 4.1.4. Iodine-129 Concentrations in Air at the Hanford Site, 1998 through 2003 (1 aCi = 0.037 µBq)

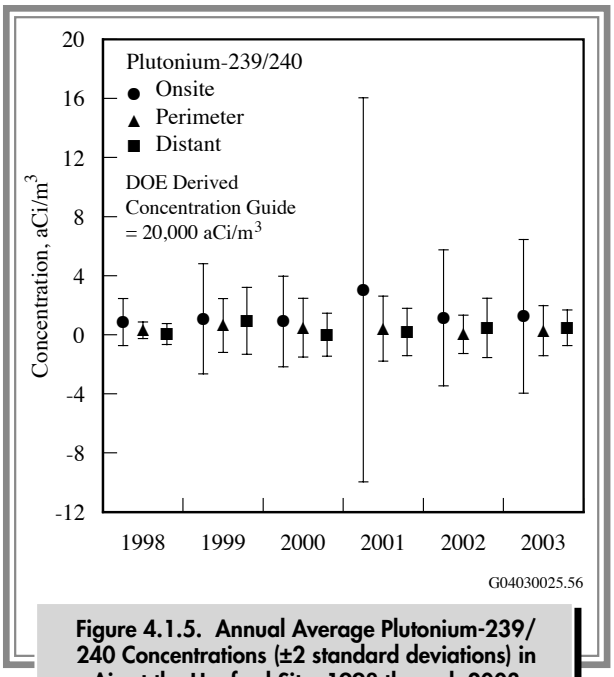


Figure 4.1.5. Annual Average Plutonium-239/240 Concentrations (±2 standard deviations) in Air at the Hanford Site, 1998 through 2003 (1 aCi = 0.037 µBq)

the samples were from the 100 Areas composite group (Table 4.1.1), and may have been impacted by cleanup activities ongoing at various locations in the 100 Areas. Only 1 of the 52 perimeter, community, and distant samples collected in 2003 had a detectable amount of plutonium-239/240. The maximum Hanford Site plutonium-239/240 air concentration (14 ± 4.3 aCi/m^3 [0.52 ± 0.16 µBq/m^3]) was observed for the 100 Areas fourth quarter composite group sample (locations 1, 2, and 3 on Figure 4.1.1). This maximum reported concentration was 0.07% of the DOE derived concentration guide (20,000 aCi/m^3 [0.73 mBq/m^3]) for plutonium-239/240.

Average isotopic uranium concentrations (uranium-234, uranium-235, and uranium-238) in airborne particulate matter in 2003 were similar to average concentrations between 1998 and 2002 for all location groups (Table 4.1.2). The 2003 annual average uranium-238 concentration for the site perimeter was 32 ± 32 aCi/m^3 (1.2 ± 1.2 µBq/m^3), which is 0.03% of the DOE derived concentration guide (100,000 aCi/m^3 [3.7 mBq/m^3]). The onsite and perimeter uranium-234 and uranium-238 average concentrations were higher than the average distant community concentrations by a statistically significant amount (two-sample means t-test, 95% confidence level).

A total of 92 airborne particulate samples were analyzed for strontium-90 in 2003 (Table 4.1.2). While 40% of the onsite samples had detectable concentrations of strontium-90, only one of the distant community samples had a detectable concentration. Comparison of the average concentrations from different location groups was considered meaningless due to the low number of detected sample results and the large variability in concentrations. The highest measured strontium-90 concentration (180 ± 86 aCi/m^3 [6.7 ± 3.2 µBq/m^3]) was only 0.002% of the DOE derived concentration guide (9 million aCi/m^3 [0.33 Bq/m^3]).

All 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. None of the 116 samples analyzed by gamma spectroscopy had concentrations of cobalt-60 or cesium-137 above their respective minimum detectable concentrations (Table 4.1.2). This is consistent with the 5-year average data from 1998 though 2002 (Table 4.1.2).

4.1.3 Monitoring of Particulate Matter

Airborne particulate matter (dust) is one of the EPA's criteria pollutants. The EPA classifies particulate matter by particle size. PM_{10} is an air pollutant consisting of small particles with aerodynamic diameters less than or equal to 10 micrometers. Similarly, $PM_{2.5}$ is an air pollutant consisting of small particles with aerodynamic diameters less than or equal to 2.5 micrometers (PM_{10} particles can include $PM_{2.5}$, since particles smaller than 2.5 micrometers are also smaller than 10 micrometers). 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 less than 150 µg/m^3, and an annual average concentration less than 50 µg/m^3. There is currently no enforced EPA standard for $PM_{2.5}$, although proposed standards are 65 µg/m^3 for a 24-hour average concentration and a 15 µg/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 μg/m^3 increase in PM_{10} concentrations results in a 17% increase in 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 Wildfire in 2000 (PNNL-13487), as well as information requests from the public. It was expected that the decrease in vegetative cover would result in increased wind erosion, and subsequently, increased particulate matter concentrations in air. In 2003, particulate monitoring was done at the Hanford Meteorological Station (location 45, Figure 4.1.1 and Table 4.1.1) using a tapered element oscillating microbalance. The unique design of this instrument measures the difference in mass collected on a filter by measuring the change in frequency of oscillation of the filter. The instrument records an hourly average concentration, but daily average concentration data were calculated for this report. PM_{10} concentration data have been collected at the Hanford Meteorology Station since February 2001, while $PM_{2.5}$ concentration data collection began at the Hanford Meteorology Station in October 2001.

Figure 4.1.6 illustrates the daily average PM_{10} concentrations recorded at the Hanford Meteorology Station during 2003 for all time periods where the instrument was operating. Daily average concentrations on the Hanford Site were higher than the EPA 24-hour average standard twice during 2003 (March 5 and October 28). The observed annual average PM_{10} concentration at the Hanford Meteorology Station during 2003 (14 μg/m^3) was well below the EPA annual average standard (50 μg/m^3). Hanford Site measurements are not used to determine compliance with air quality standards (Section 2.2.7). EPA

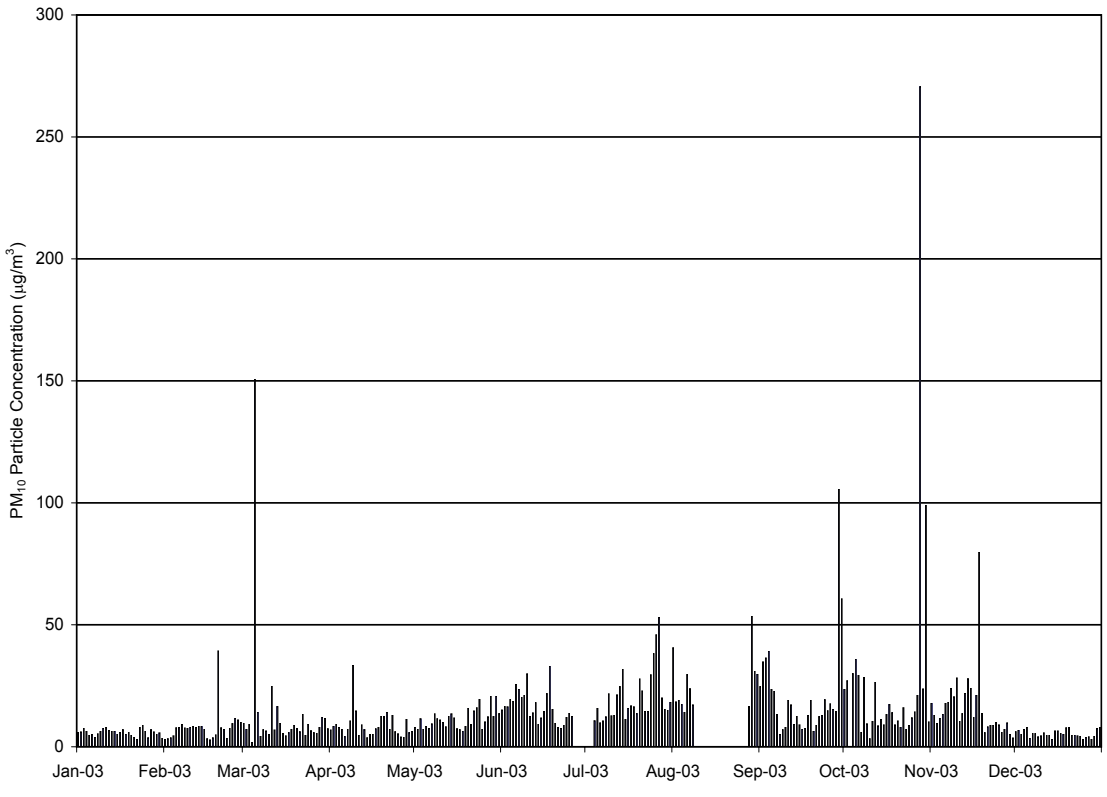


Figure 4.1.6. Daily Average PM_{10} Particle Concentrations at the Hanford Meteorology Station, 2003 (EPA 24-hour National Ambient Air Quality Standard's concentration is 150 μg/m^3)

policy also allows exemptions for natural events that result in high particulate matter concentrations, such as windstorms. The 2 days with elevated PM_{10} concentrations observed on the Hanford Site in 2003 appeared to be a result of high winds (Table 4.1.3).

There is currently no enforced EPA concentration standard for $PM_{2.5}$. However, the $PM_{2.5}$ concentrations measured at the Hanford Meteorology Station during 2003 (Figure 4.1.7) were well below the proposed EPA standards for $PM_{2.5}$ (15 μg/m³ annual average, 65 μg/m³ 24-hour average). The measured annual average $PM_{2.5}$ concentration at the Hanford Meteorology Station during 2003 was 6 μg/m³, while the highest 24-hour average concentration observed was 29 μg/m³.

Table 4.1.3. Daily Average PM_{10} Concentrations and Corresponding Wind Speed Data for Several Days Before and After an Exceedance of the 150 μg/m³ PM_{10} Threshold

Date	Daily Average PM_{10} Concentration (μg/m³)	Daily Average Wind Speed (m/s)	Peak Gust Wind Speed (m/s)
March 4, 2003	2	2.8	12
March 5, 2003	150	7.3	24
March 6, 2003	14	8.3	20
March 7, 2003	4	3.4	12
October 27, 2003	21	1.8	12
October 28, 2003	270	7.8	27
October 29, 2003	24	4.7	16
October 30, 2003	99	9.1	18
October 31, 2003	10	4.9	13

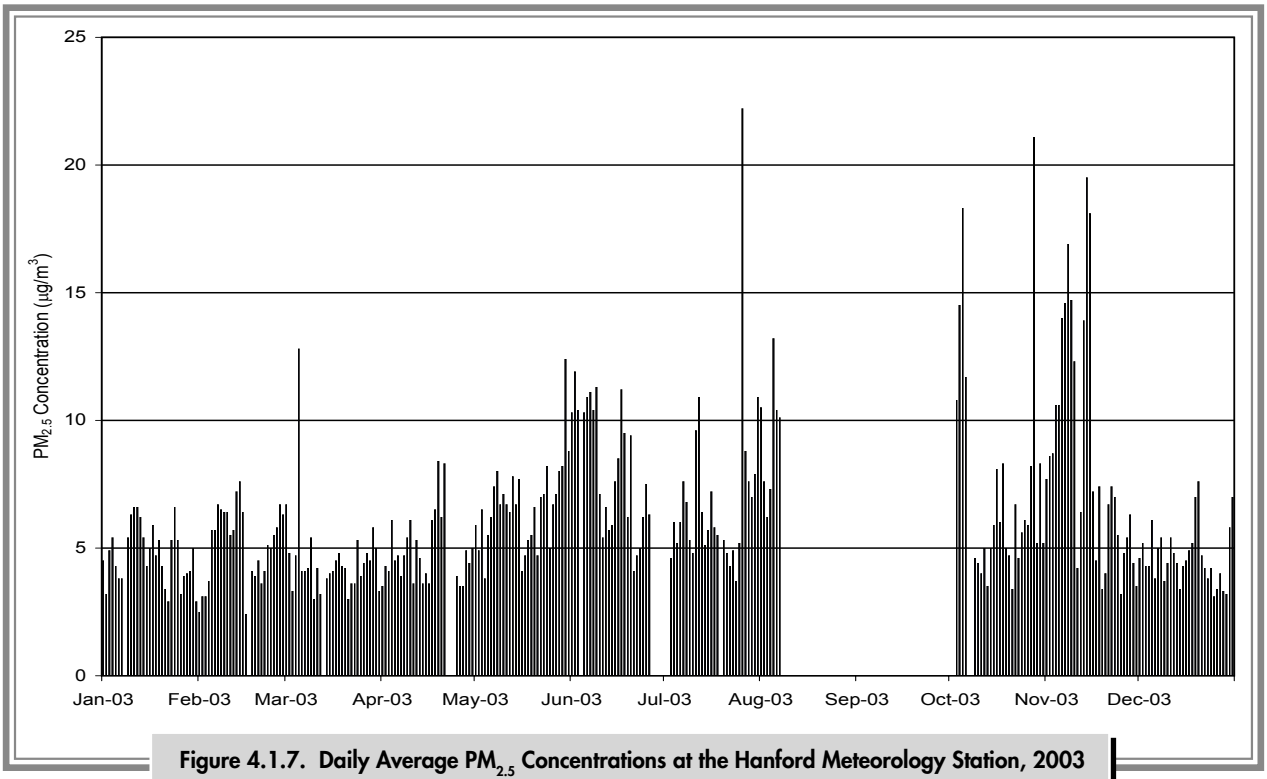


Figure 4.1.7. Daily Average $PM_{2.5}$ Concentrations at the Hanford Meteorology Station, 2003

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 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 offsite 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 2003. This section describes the surveillance efforts and summarizes the results for these aquatic environments. Detailed analytical results are reported in PNNL-14687, 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 immediately downstream of the site also is used for crop irrigation in Benton and Franklin Counties. 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 Rocky Mountains of eastern British Columbia, the Columbia River and its tributaries drain an area of approximately 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; four of the dams are 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 downstream 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 (first dam upstream from the ocean) that remains unimpounded.

River flow through the Hanford Reach fluctuates significantly and is controlled primarily by operations at Priest Rapids Dam. Changing river flows result in changes in concentrations of contaminants in river water for users downstream of Hanford (PNL-8531). Annual average flow of the Columbia River downstream of Priest Rapids Dam is approximately 3,400 cubic meters (120,000 cubic feet) per second (WA-94-1). In 2003, the Columbia River had below normal flows; the average daily flow rate downstream of Priest Rapids Dam was 2,860 cubic meters (101,000 cubic feet) per second. The peak monthly average flow rate occurred during June (4,160 cubic meters [147,000 cubic feet] per second) (Figure 4.2.2). The lowest monthly average flow rate occurred during September (1,910 cubic meters [67,500 cubic feet] per second). Daily flow rates varied from 1,210 to 5,130 cubic meters (42,600 to 181,000 cubic feet) per second during 2003. 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

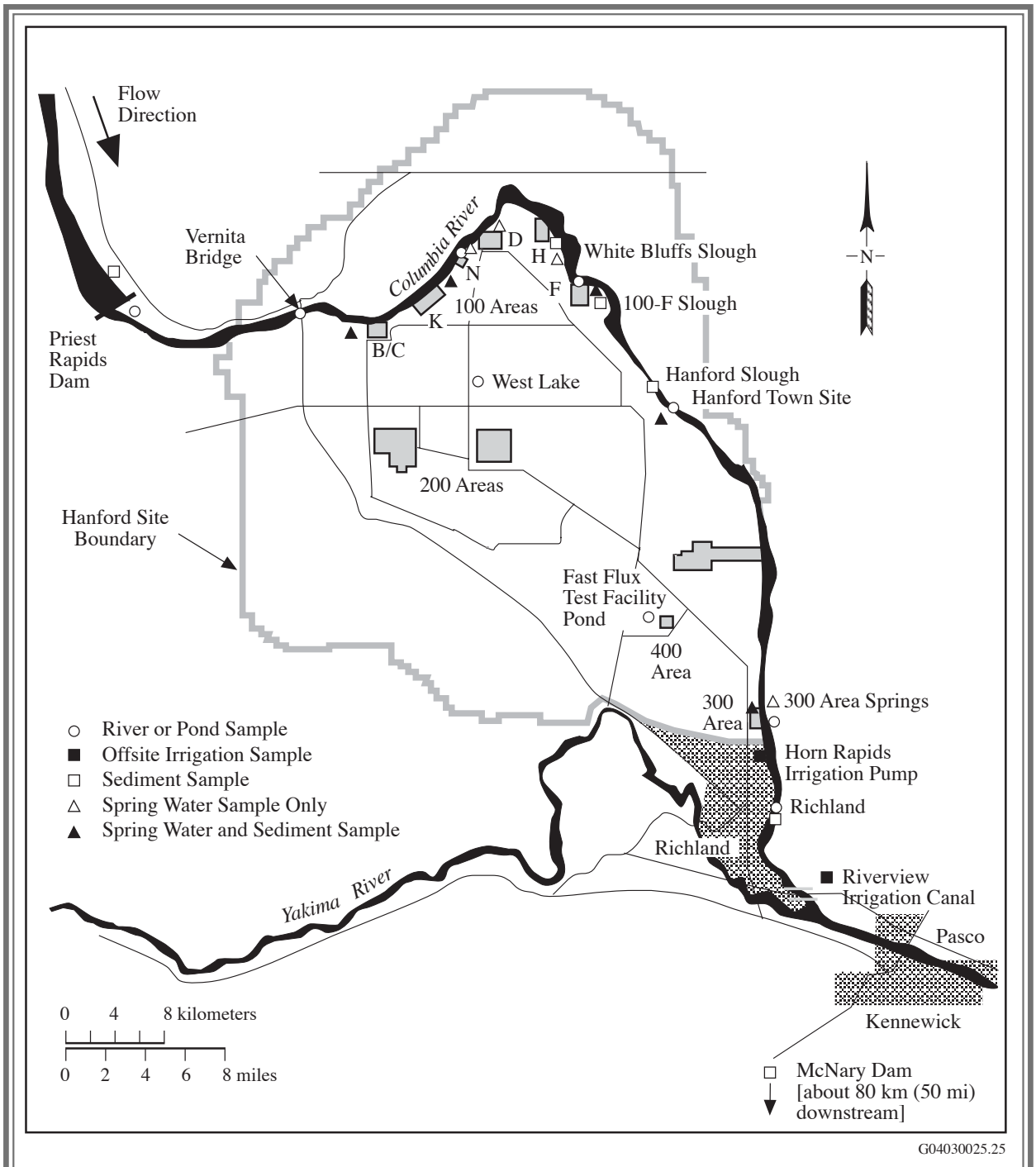


Figure 4.2.1. Hanford Site Environmental Surveillance Project Sampling Locations for Water and Sediment, 2003

Table 4.2.1. Surface Water Surveillance On and Near the Hanford Site, 2003

Location	Sample Type	Frequency[a]	Analyses
Columbia River - Radiological			
Priest Rapids Dam and Richland	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	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[i]	Grab	3/year	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, metals
	Grab (transects)	Quarterly	(filtered and unfiltered), anions
	Grab (transects)	Annually	VOA[j]
100-F, 100-N, 300, and Hanford town site	Grab (transects)	Annually	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, metals (filtered and unfiltered), anions
100-F Area	Grab	Annually	Alpha, beta, ^{3}H, ^{90}Sr, U, gamma energy analysis, metals (filtered and unfiltered), anions, VOA
100-B Area	Grab	Annually	Alpha, beta, ^{3}H, ^{90}Sr, ^{99}Tc, gamma energy analysis, 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, 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, metals (filtered and unfiltered), anions
300 Area	Grab	Annually	Alpha, beta, ^{3}H, ^{129}I, ^{90}Sr, U, gamma energy analysis, 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 ^{3}H = 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 hourly and composited for quarterly analysis.
(f) M Cont = River water was sampled for 2 weeks 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 weeks 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) VOA = Volatile organic compounds.

Table 4.2.2. Columbia River Sediment Surveillance from Priest Rapids Dam to McNary Dam, 2003

Location[a]	Frequency	Analyses
River		All river sediment analyses included gamma energy analysis, ^{90}Sr, U[b], Pu[c], metals, SEM/AVS[d]
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		All springs sediment analyses included gamma energy analysis, ^{90}Sr, U, 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 = Isotopic uranium-234, uranium-235, and uranium-238 analyzed by low-energy photon analysis.
(c) Pu = Isotopic plutonium-238 and plutonium-239/240.
(d) SEM/AVS = Simultaneously extracted metals and acid volatile sulfide.

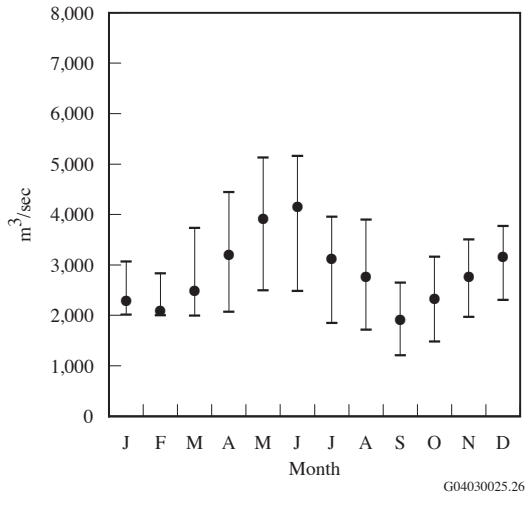


Figure 4.2.2. Mean, Maximum, and Minimum Columbia River Flow Rates at Priest Rapids Dam, Washington, 2003

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 approximately 300 to 1,000 meters (980 to 3,300 feet) through the Hanford Site.

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 general water use and water quality criteria for 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 2003, samples were collected from fixed-location monitoring stations at Priest Rapids Dam and Richland, Washington, 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 (Figure 4.2.1). Samples were collected upstream from Hanford Site facilities at Priest Rapids Dam and the 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 Site operations, including a municipal drinking water supply and points of withdrawal for irrigation water downstream of the Hanford Site. Sampling of irrigation water systems is discussed in Section 4.2.5.

The fixed-location monitoring stations at Priest Rapids Dam and Richland, Washington, 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 to collect a composite sample for a period of 7 days. These weekly samples were combined into monthly and quarterly 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 the following criteria:

- 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 river water samples collected at Priest Rapids Dam and Richland, Washington, included gross alpha, gross beta, selected gamma-emitting radionuclides, 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). Analytical detection levels (defined as the laboratory reported minimum detectable concentration) for all radionuclides were less than or equal to 10% 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, alpha at 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 Richland, Washington. 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 (typically less than 5 meters [16 feet] from shore). This sampling pattern was used during 2003 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 Richland, Washington, transects and near-shore locations were sampled quarterly during 2003. 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 to provide the highest probability of detecting Hanford contaminants (PNL-8531).

Columbia River transect water samples collected during 2003 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 monitoring conducted by Pacific Northwest National Laboratory, water quality monitoring was performed by the U.S. Geological Survey for the Pacific Northwest National Laboratory. Samples were collected three times per year along Columbia River transects at Vernita Bridge and Richland (Appendix C, Table C.6). 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 Richland, Washington, during 2003 are reported in PNNL-14687, APP. 1 and summarized in Appendix C (Tables C.1 and C.2). These tables also list the maximum and average concentrations of selected radionuclides detected in Columbia River water in 2003 and for the previous 5 years. All individual radiological contaminant concentrations measured in Columbia River water during 2003 were less than DOE derived concentration guides (DOE Order 5400.5), less than 1/25 of the DOE derived concentration guides (i.e., DOE derived concentration guides are based on a 100 mrem (1 mSv) standard; dividing by 25 allows for more direct comparison of the 4 mrem (0.04 mSv) standard used for drinking water), 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 2003, the radionuclides tritium, strontium-90, iodine-129, uranium-234, uranium-238, plutonium-239/240, and naturally occurring beryllium-7 and potassium-40 were consistently measured in river water at levels greater than their reported minimum detectable concentrations. The concentrations of all other radionuclides were typically below the minimum detectable concentrations. 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 2003 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 Richland were not performed because the majority of the concentrations were below the 1 and 3 pCi/L (0.037 and 0.11 Bq/L) minimum detectable concentrations, respectively (Figures 4.2.3 and 4.2.4). The average gross alpha and gross beta concentrations in Columbia River water at Richland during 2003 were less than the Washington State ambient surface-water quality criteria levels of 15 and 50 pCi/L (0.56 and 1.9 Bq/L).

The 2003 annual average tritium concentrations measured upstream and downstream of the Hanford Site were similar to concentrations measured in recent years. Statistical analyses indicated that monthly tritium concentrations in river water samples at Richland were higher than concentrations in samples from Priest Rapids Dam (Figure 4.2.5). However, 2003 average tritium concentrations in Columbia River water collected at Richland were only 0.4% of the Washington State ambient surface-water quality criteria level of 20,000 pCi/L (740 Bq/L). Onsite sources of tritium entering the river include

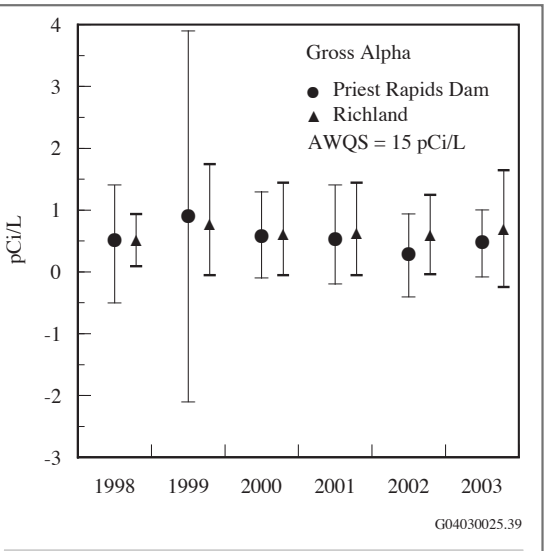


Figure 4.2.3. Annual Average Gross Alpha Concentrations (±2 standard deviations) in Columbia River Water Upstream and Downstream of the Hanford Site, 1998 through 2003 (AWQS = ambient water quality standard)

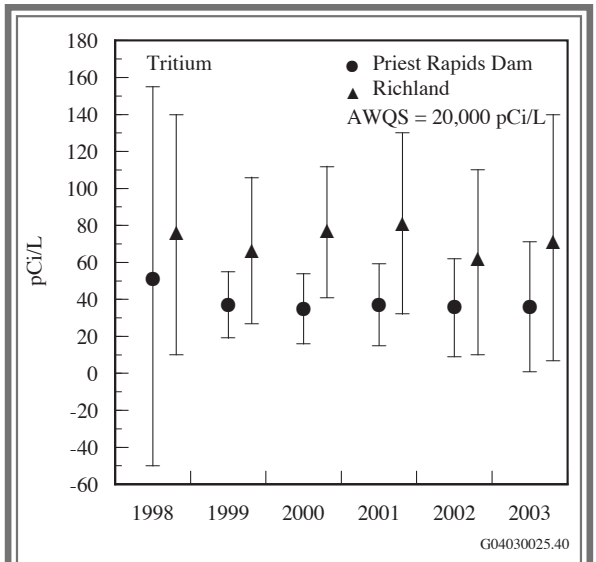


Figure 4.2.5. Annual Average Tritium Concentrations (±2 standard deviations) in Columbia River Water Upstream and Downstream of the Hanford Site, 1998 through 2003 (AWQS = ambient water quality standard)

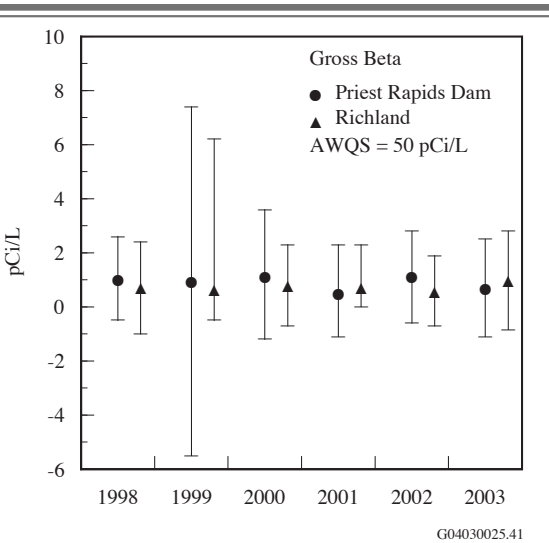


Figure 4.2.4. Annual Average Gross Beta Concentrations (±2 standard deviations) in Columbia River Water Upstream and Downstream of the Hanford Site, 1998 through 2003 (AWQS = ambient water quality standard)

groundwater seepage and direct discharge from the 100-K Area permitted outfall (Section 3.1.3). Tritium concentrations measured at Richland, 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 sample intake. This plume is not completely mixed within the river at Richland. Sampling along cross-river transects at Richland during 2003 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 at Richland 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 2003 were similar to those reported previously (Figure 4.2.6). Groundwater plumes containing strontium-90 enter the Columbia River throughout the 100 Areas. 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 Richland

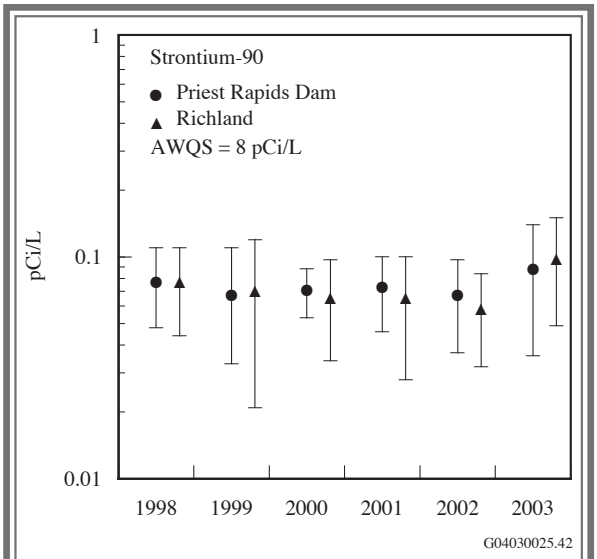


Figure 4.2.6. Annual Average Strontium-90 Concentrations (±2 standard deviations) in Columbia River Water Upstream and Downstream of the Hanford Site, 1998 through 2003 (AWQS = ambient water quality standard)

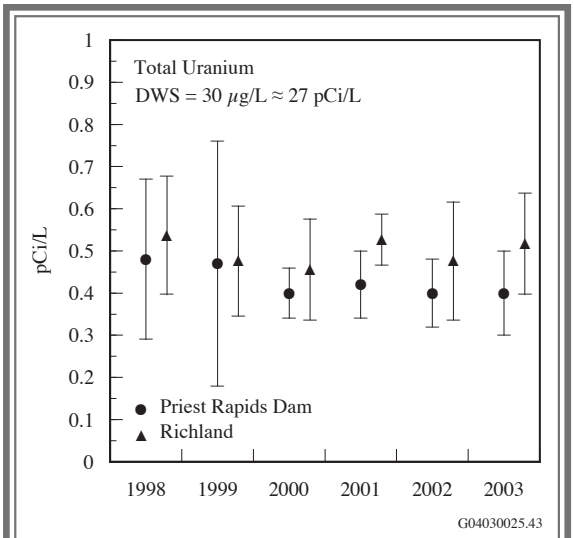


Figure 4.2.7. Annual Average Total Uranium Concentrations (±2 standard deviations) in Columbia River Water Upstream and Downstream of the Hanford Site, 1998 through 2003 (DWS = drinking water standard)

during 2003. Average strontium-90 concentrations in Columbia River water at Richland were less than 1.2% of the Washington 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 2003 were similar to those observed during recent years (Figure 4.2.7). Monthly total uranium concentrations measured at Richland during 2003 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. Groundwater contaminants have been detected at elevated levels in riverbank springs at the 300 Area in the past (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 Washington State ambient surface-water quality criteria levels directly applicable to uranium. However, total uranium levels in the river during 2003 were well below the EPA drinking water standard of 30 μg/L (approximately 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 Richland was extremely low during 2003 (0.008% of the Washington 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. The iodine-129 plume originated in the 200 Areas from past waste disposal practices. Quarterly iodine-129 concentrations in Columbia River water at Richland were statistically higher than those at Priest Rapids Dam indicating a Hanford source of iodine-129. In general, the iodine-129 values at Priest Rapids Dam are largely unaffected by river stage; however, the concentrations measured for river water at Richland are inversely proportional to river stage (i.e., during lower flow, the concentrations of iodine-129 are higher and vise versa). The influence of river stage on concentrations of iodine-129 at Richland is reflected in the larger standard deviation, compared to the samples from Priest Rapids Dam, for the annual averages shown in Figure 4.2.8.

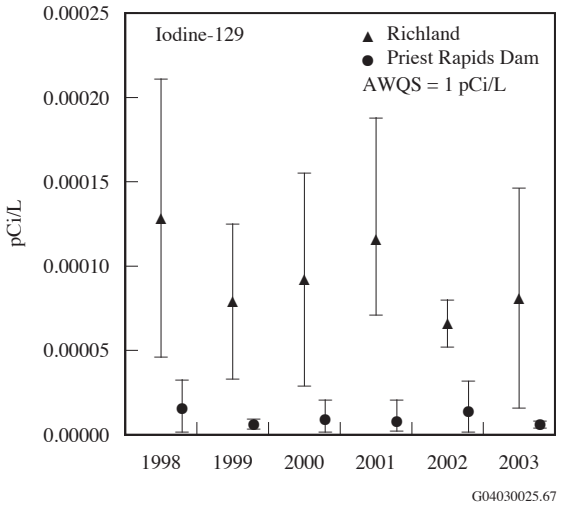


Figure 4.2.8. Annual Average Iodine-129 Concentrations (±2 standard deviations) in Columbia River Water Upstream and Downstream of the Hanford Site, 1998 through 2003 (AWQS = ambient water quality standard)

Average plutonium-239/240 concentrations for filtered river water samples at Richland were extremely low during 2003. Plutonium was only above the average minimum detectable concentration of 0.00004 pCi/L (0.0000015 Bq/L) for the particulate fraction of the continuous water sample (i.e., detected on the filters but not detected on the resin column [dissolved fraction]). All concentrations were below the DOE derived concentration guide of 30 pCi/L (1.1 Bq/L) (Appendix D, Table D.5). No Washington State ambient surface-water quality criteria level exists for plutonium-239/240. Results for filter samples for plutonium-239/240 were not statistically higher at Richland compared to Priest Rapids Dam; thus, there was no observed Hanford Site contribution. Statistical comparisons for dissolved plutonium concentrations at Priest Rapids Dam and Richland were not performed because all of the concentrations were below the reported minimum detectable concentrations.

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 during 2003 are presented in Appendix C (Tables C.3 and C.4) and PNNL-14687, APP. 1. Sampling locations were documented using a global positioning system. Radionuclides consistently measured at concentrations greater than the minimum detectable activity included tritium, strontium-90, uranium-234, and uranium-238. All measured concentrations of these radionuclides were less than applicable Washington State ambient surface-water quality criteria levels.

Tritium concentrations measured along Columbia River transects during September 2003 are depicted in Figure 4.2.9. The results are displayed such that the observer's view is upstream from Richland. The Vernita Bridge is the most upstream transect. Stations 1 and 10 are located along the Benton County and Franklin/Grant Counties shorelines, respectively. The 100-N Area, Hanford town site, 300 Area, and Richland transects have higher tritium concentrations near the Hanford (Benton County) shore relative to the opposite shore. The presence of a tritium concentration gradient in the Columbia River at Richland supports previous studies showing that contaminants in the 200 Areas' groundwater plume entering the river at, and upstream of, the 300 Area are not completely mixed at Richland (HW-73672; PNL-8531). 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 transect has been less than that measured in monthly composited samples from the transect, illustrating the conservative bias (i.e., overestimate) of the fixed-location monitoring station. For samples collected in 2003, the highest tritium concentration detected in cross-river transect water was 3,400 ± 560 pCi/L (130 ± 21 Bq/L) (Appendix C, Table C.3), which was detected along the shoreline of the Hanford town site. This is a location where groundwater containing tritium at concentrations greater than the Washington State ambient surface-water quality criterion (20,000 pCi/L [740 Bq/L]) is known to discharge to the river (Chapter 6, Figure 6.0.14).

Tritium concentrations for near-shore water samples collected at the Hanford (Benton County) shoreline (typically less than 5 meters [16 feet] from shore) during September 2003 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 (approximately 1.6 kilometers [1 mile] apart) that originate at the Vernita Bridge (Hanford river marker #0) and end at Ferry Street in Richland (Hanford river marker #46).

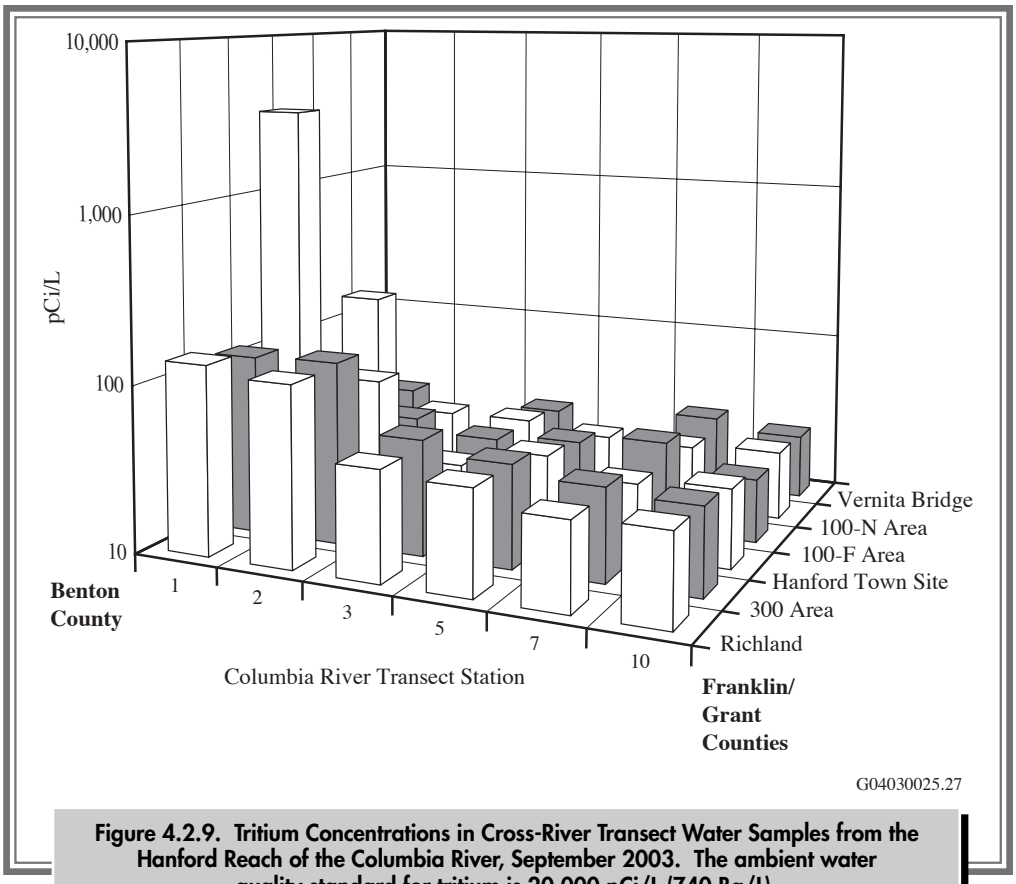


Figure 4.2.9. Tritium Concentrations in Cross-River Transect Water Samples from the Hanford Reach of the Columbia River, September 2003. The ambient water quality standard for tritium is 20,000 pCi/L (740 Bq/L).

The concentrations of tritium in near-shore water samples collected at the 100-N Area, Hanford town site, 300 Area, and Richland 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, Figure 6.0.14). During 2003, the highest tritium concentration observed in near-shore water samples was 19,000 ± 1,400 pCi/L (700 ± 52 Bq/L) (Appendix C, Table C.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 3,400 ± 560 pCi/L (130 ± 21 Bq/L).

During 2003, 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 Richland was similar to those measured in monthly composite samples from Richland, 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 2003 were elevated along the Benton and Franklin County shorelines for the 300 Area transect. Total uranium concentrations were also elevated along the Franklin County shoreline for the Richland transect. The highest total uranium concentration was measured in March near the Franklin County shoreline of the Richland transect (1.2 ± 0.16 pCi/L [0.044 ± 0.0059 Bq/L]) (Appendix C, Table C.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).

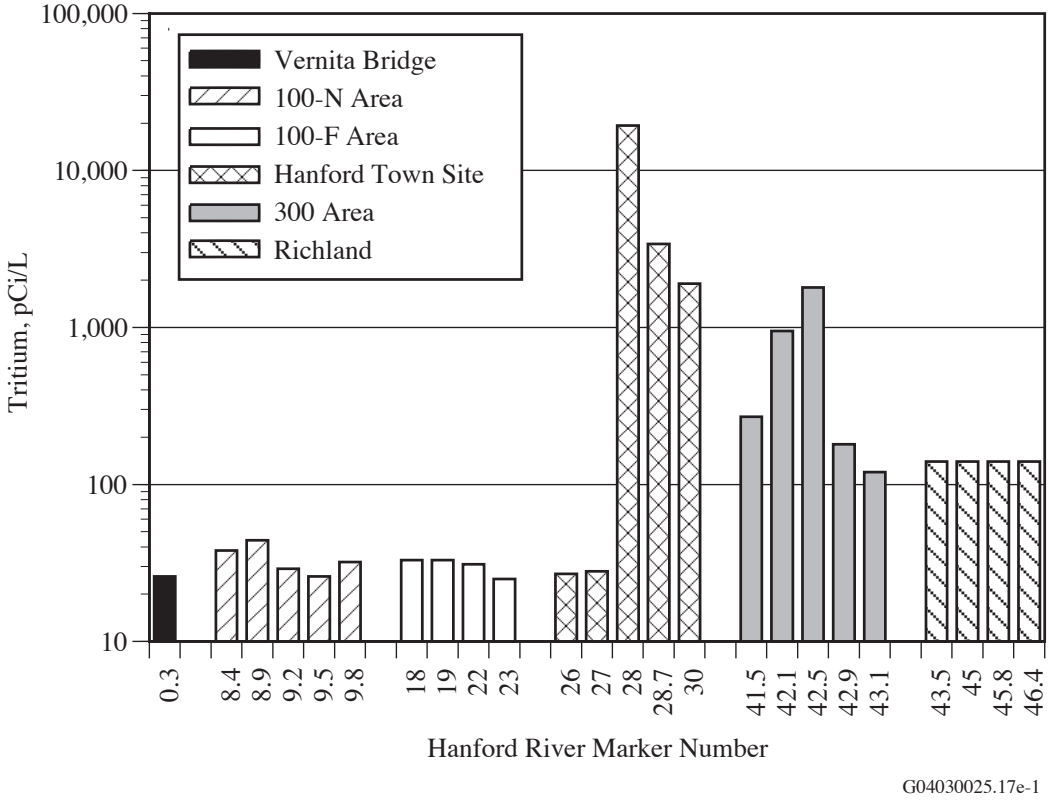


Figure 4.2.10. Tritium Concentrations in Columbia River Water Collected at the Hanford Site Shoreline, 2003. The Hanford river markers (HRMs) are a set of signposts on the Hanford shore that are roughly a mile apart. Vernita Bridge is HRM #0 and Ferry Street in Richland is HRM #46. Samples collected between markers are assigned a decimal (e.g., halfway between HRM #12 and HRM #13 is HRM #12.5). The ambient water quality standard for tritium is 20,000 pCi/L (740 Bq/L).

4.2.1.3 Chemical and Physical Results for River-Water Samples

Pacific Northwest National Laboratory and the U.S. Geological Survey (under contract to Pacific Northwest National Laboratory) compiled chemical and physical water quality data for the Columbia River during 2003. 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) and industrial, agricultural, and mining effluent located upstream from the Hanford Site.

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 at the Vernita Bridge, 100-F Area, 100-N Area, Hanford town site, 300 Area, and Richland are provided in PNNL-14687, APP. 1. The concentrations of metals and anions observed in river water during 2003 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, lead, nickel, and zinc were detected in the majority of samples, with similar levels at most locations. Beryllium, cadmium, chromium, lead, selenium, silver, and thallium were detected occasionally. For samples collected on the cross-river transects, concentrations of chloride, nitrate, and sulfate measured near the Hanford shoreline transect samples were elevated at the 300 Area and the Hanford town site. Nitrate concentrations for water samples from the Benton County

shoreline near Richland were slightly higher compared to mid-river samples. Chloride, nitrate, and sulfate concentrations were elevated, compared to mid-river samples, along the Franklin County shoreline at Richland and 300 Area transects and likely resulted from groundwater seepage associated with extensive irrigation (the water for which is drawn from the Columbia River upstream of the Hanford Site) 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 transect compared to the Vernita Bridge transect.

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 the Vernita Bridge and Richland over the past years. The total hardness reported by the U.S. Geological Survey at those locations from 1992 through 2003 ranged from 47 to 77 mg/L as calcium carbonate. All metal and anion concentrations in river water were less than the Washington State ambient surface-water quality criteria levels for the protection of aquatic life (Appendix C, Table C.5 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 approximately 10,500 times lower than the Washington State chronic toxicity value and similar concentrations were found at the Vernita Bridge and Richland (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.

U.S. Geological Survey. Figure 4.2.11 shows U.S. Geological Survey results for the Vernita Bridge and at Richland for 1998 through 2003 (2003 results are preliminary) for water quality parameters with respect to their applicable standards. The list of preliminary results is documented in PNNL-14687, APP. 1 and is summarized in Appendix C (Table C.6). Final results are published annually by the U.S. Geological Survey (e.g., WA-99-1). The 2003 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 2003, 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).

4.2.2 Riverbank Spring Water

The Columbia River is the primary discharge area for the unconfined aquifer underlying the Hanford Site. 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. In addition, contaminants in groundwater near the Columbia River are monitored using aquifer sampling tubes (Section 6.0.1.1) (PNNL-14444). The contaminant concentrations in water from riverbank springs are typically lower than those found in near-shore groundwater wells because of bank storage effects.

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 a 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

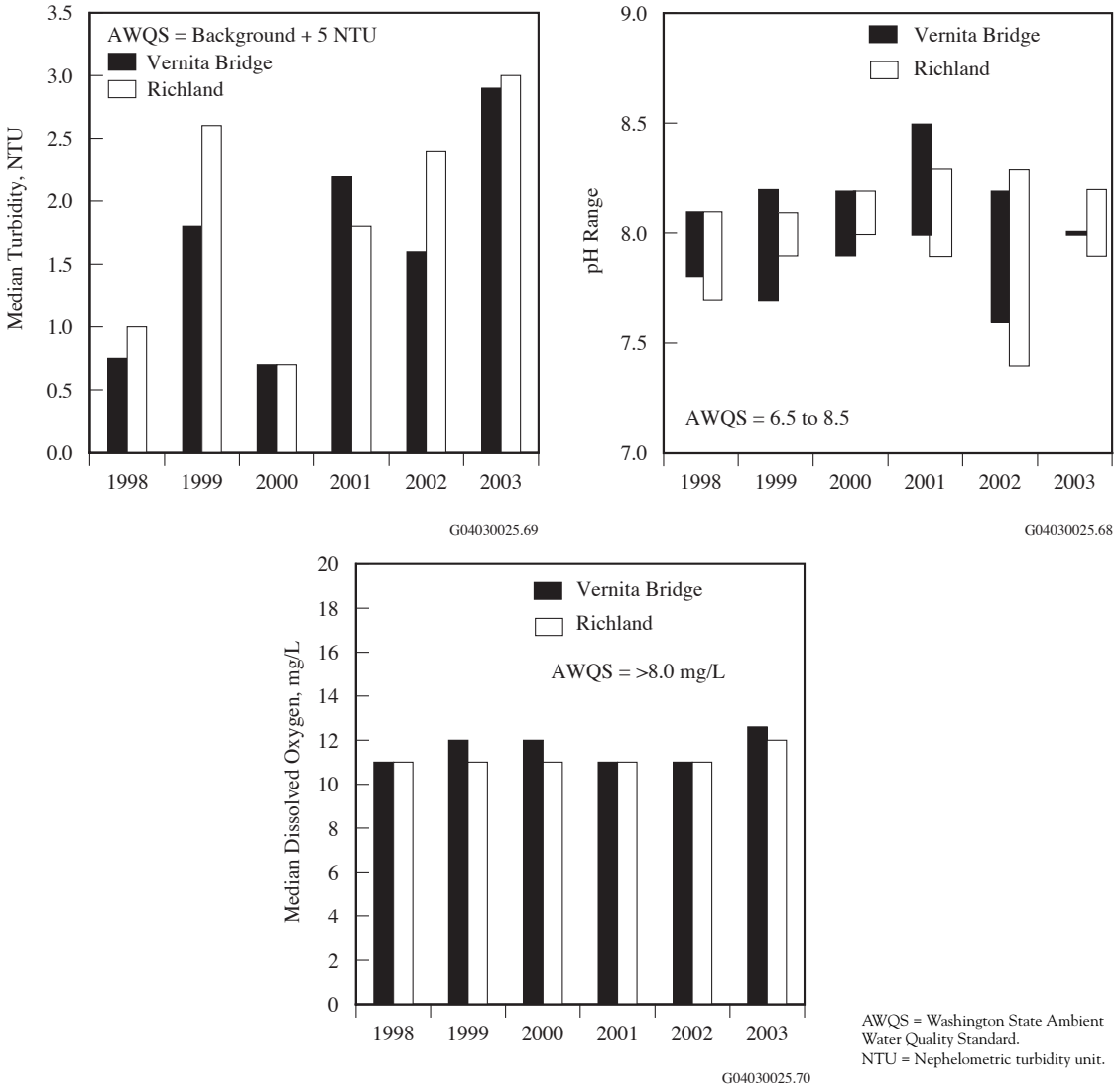


Figure 4.2.11. U.S. Geological Survey Water Quality Measurements for the Columbia River Upstream and Downstream of the Hanford Site, 1998 through 2003 (2003 results are preliminary)

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 systems that are being used 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 Hanford Reach are heavily influenced by river stage fluctuations. Water levels in the Hanford Reach of the Columbia River are controlled by upriver conditions and operations at Priest Rapids Dam. As water levels fluctuate, groundwater levels and, thus, the presence of riverbank springs in the Hanford Reach vary. In addition, for the 300 Area, the water levels are influenced by the height of the McNary Dam pool. Water flows into the aquifer (as bank storage) as the river stage rises and then discharges from the aquifer in the form of a riverbank spring 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 discharged 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 increases 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, as well as variations in aquifer thickness, porosity, and plume concentrations, it is difficult to accurately estimate the volume of contaminated groundwater discharged to the Columbia River within the Hanford Reach. Studies of riverbank springs conducted during 1983 (PNL-5289) and 1988 (PNL-7500), and results of near-shore studies (PNNL-11933; PNNL-13692) 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 flow 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 early fall.

All samples collected during 2003 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 C, Table C.9; PNNL-14687, APP. 1).

4.2.2.2 Radiological Results for Water Samples from Riverbank Springs

Contaminants of Hanford-origin continued to be detected in water from riverbank springs entering the Columbia River along the Hanford Site during 2003. 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 were detected in spring water (Appendix C, Table C.9). All radiological contaminant concentrations measured in riverbank springs during 2003 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 7 years; thus, an alternative spring was sampled in the 100-N Area in 2003.

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 measured in riverbank springs was at the Hanford town site (14,000 ± 1,100 pCi/L [520 ± 41 Bq/L]), which was below the Washington 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 (10,000 ± 820 pCi/L [370 ± 30 Bq/L]), and the 100-N Area (10,000 ± 800 pCi/L [370 ± 30 Bq/L]). Tritium concentrations in all riverbank spring samples were elevated compared to the 2003 average Columbia River concentration at Priest Rapids Dam (36 ± 35 pCi/L [1.3 ± 1.3 Bq/L]). Figure 4.2.12 depicts concentrations of selected radionuclides in the 300 Area riverbank spring water (spring 42-2 and spring DR 42-2) from 1998 through 2003. 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). Tritium was the only specific radionuclide detected in 100-N Area riverbank spring water during 2003 (Table 4.2.3).

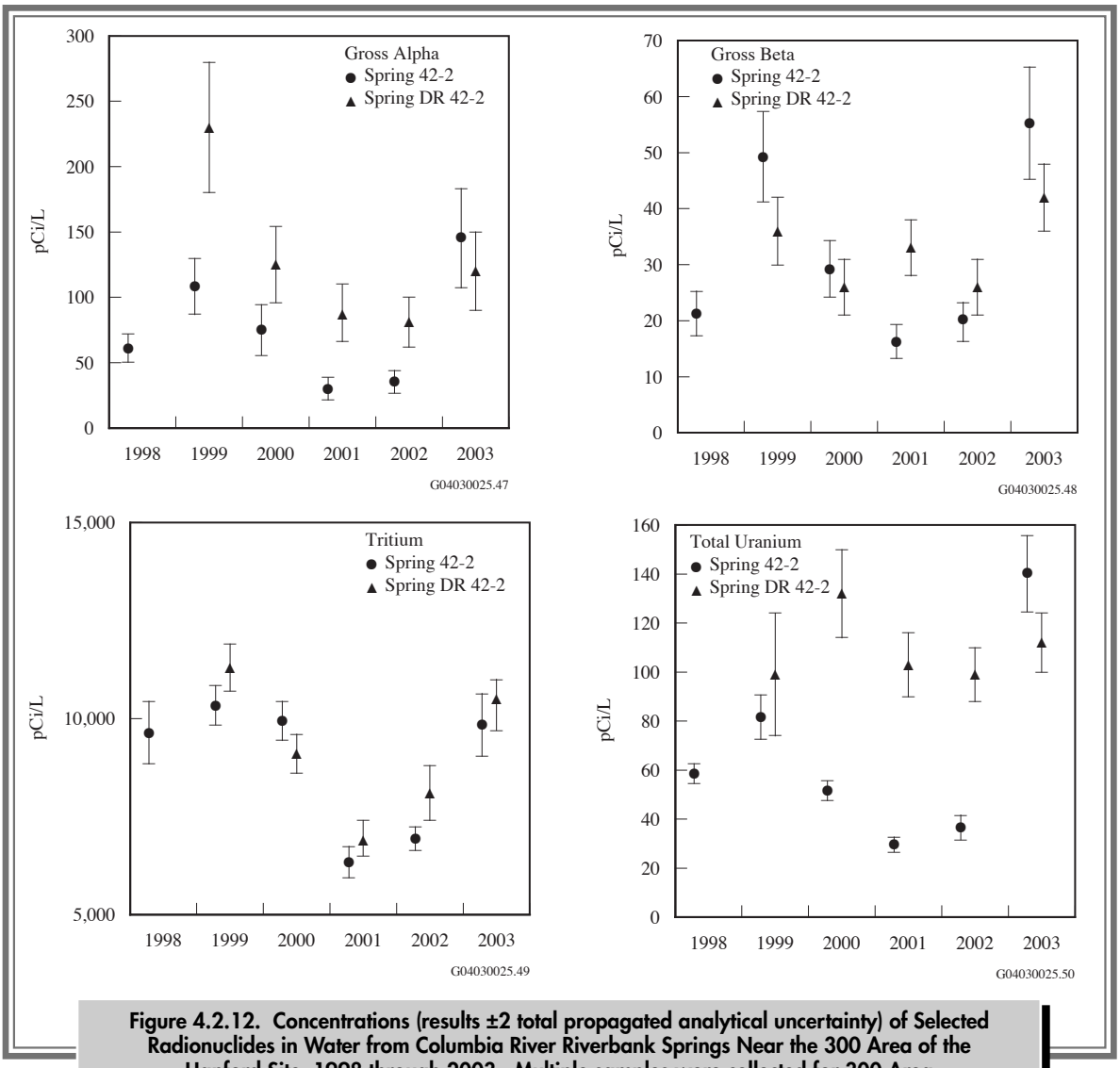


Figure 4.2.12. Concentrations (results ±2 total propagated analytical uncertainty) of Selected Radionuclides in Water from Columbia River Riverbank Springs Near the 300 Area of the Hanford Site, 1998 through 2003. Multiple samples were collected for 300 Area riverbank springs in 2001, the results are for the May 10, 2001 sampling event.

Samples from riverbank springs were analyzed for strontium-90 in the 100-B, 100-K, 100-N, 100-D, 100-H, 100-F, and 300 Areas. The highest strontium-90 concentration detected in riverbank spring water was at the 100-H Area (14 ± 2.0 pCi/L [0.52 ± 0.0.074 Bq/L]). This value exceeded the ambient surface-water quality criterion of 8 pCi/L (0.30 Bq/L). Groundwater at the 100-N Area has the highest strontium-90 concentrations; however, from 1993 to 2003, there were no visible riverbank springs directly adjacent to wells 199-N-8T or 199-N-46, which are near the plume maximum. At the 100-N Area, the Surface Environmental Surveillance Project has not found a flowing riverbank spring at the intersection of the groundwater plume and the Columbia River since 1997. Since 1997, riverbank spring samples at the 100-N Area have been collected from a downstream 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.

Samples from riverbank springs in the 100-B, 100-K, 100-H Areas, and at 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

Table 4.2.3. Selected Radionuclide Concentrations in 100-N Area Riverbank Spring Water at the Hanford Site, 1998 through 2003

	Concentration, pCi/L[a]		
Year	Tritium	Gross Beta	Strontium-90
1998[b]	24,000 ± 1,900	2.3 ± 2.1	[c]
1999[b]	14,000 ± 670	2.9 ± 1.7	0.026 ± 0.034[d]
2000[b]	18,000 ± 800	5.9 ± 2.1	-0.0026 ± 0.037[d]
2001[b]	17,000 ± 800	3.7 ± 1.8	0.013 ± 0.043[d]
2001[b]	6,500 ± 430	5.5 ± 2.0	0.039 ± 0.044[d]
2002[b]	7,100 ± 320	4.8 ± 1.7	0.0042 ± 0.0034[d]
2003[b]	10,000 ± 800	9.3 ± 2.4	0.041 ± 0.063[d]

(a) Concentrations are ±2 total propagated analytical uncertainty. To convert to international metric system units, 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) Sample was lost during processing at the analytical laboratory.
(d) Value below the detection limit.

(33 Bq/L) (Appendix D, Table D.2). The highest technetium-99 concentration was found in riverbank spring water from the Hanford town site (14 ± 1.1 pCi/L [0.52 ± 0.041 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 (0.14 ± 0.012 pCi/L [0.0052 ± 0.00044 Bq/L]). This Hanford town site value was roughly 30,000 times higher than the 2003 average measured at Priest Rapids Dam (0.0000046 ± 0.0000020 pCi/L [0.00000017 ± 0.000000074 Bq/L]) but was below the surface-water quality criteria level of 1 pCi/L (0.037 Bq/L) (Appendix D, Table D.2). Concentrations of selected radionuclides in riverbank spring water near the Hanford town site (spring 28-2) from 1998 through 2003 are provided in Figure 4.2.13. Annual fluctuations in these values may reflect the influence of bank storage during the sampling period.

Uranium was sampled in riverbank spring water in the 100-H Area, 100-F Area, Hanford town site, and 300 Area in 2003 (Figure 4.2.12). The highest total uranium level was found in 300 Area spring water (140 ± 15 pCi/L [5.2 ± 0.56 Bq/L] or approximately 160 ± 17 µg/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 µg/L (approximately 27 pCi/L [1.0 Bq/L]). The 300 Area spring had an elevated gross alpha concentration (140 ± 36 pCi/L [15 ± 1.3 Bq/L]. The gross alpha level in 300 Area spring water also exceeded the Washington State ambient surface-water quality criterion of 15 pCi/L (0.56 Bq/L) (Appendix D, Table D.2). 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 increase in uranium concentrations in the most recent samples from riverbank spring 42-2 is not unexpected. A pulse of increased uranium concentrations in groundwater was created by waste site excavation activities during fall 2002 at a location just inland of this riverbank spring (PNNL-14548). The pulse has passed well 399-1-10A, located adjacent to the spring, and has now probably discharged to the river. The gross alpha and gross beta concentrations in 300 Area riverbank springs water from 1998 through 2003 parallel uranium and are likely associated with its presence.

4.2.2.3 Chemical Results for Water Samples from Riverbank Springs

Hanford-origin contaminants continued to be detected in water from riverbank springs entering the Columbia River along the Hanford Site during 2003. 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; trichloroethene was the only analyte with detectable values (2.2 µg/L at both 100-K Area spring 6-3 and 300 Area spring DR 42-2). Concentration ranges of selected chemicals measured in riverbank springs water during 1999 through 2003 are presented in Table 4.2.4. For most locations, the 2003 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-D, 100-K, and 100-H Areas' riverbank springs. Hanford groundwater monitoring results for 2003 indicated similar contaminant concentrations in shoreline areas (Chapter 6, Figure 6.0.6).

The ambient surface-water quality criteria for cadmium, copper, lead, nickel, silver, and zinc are total-hardness

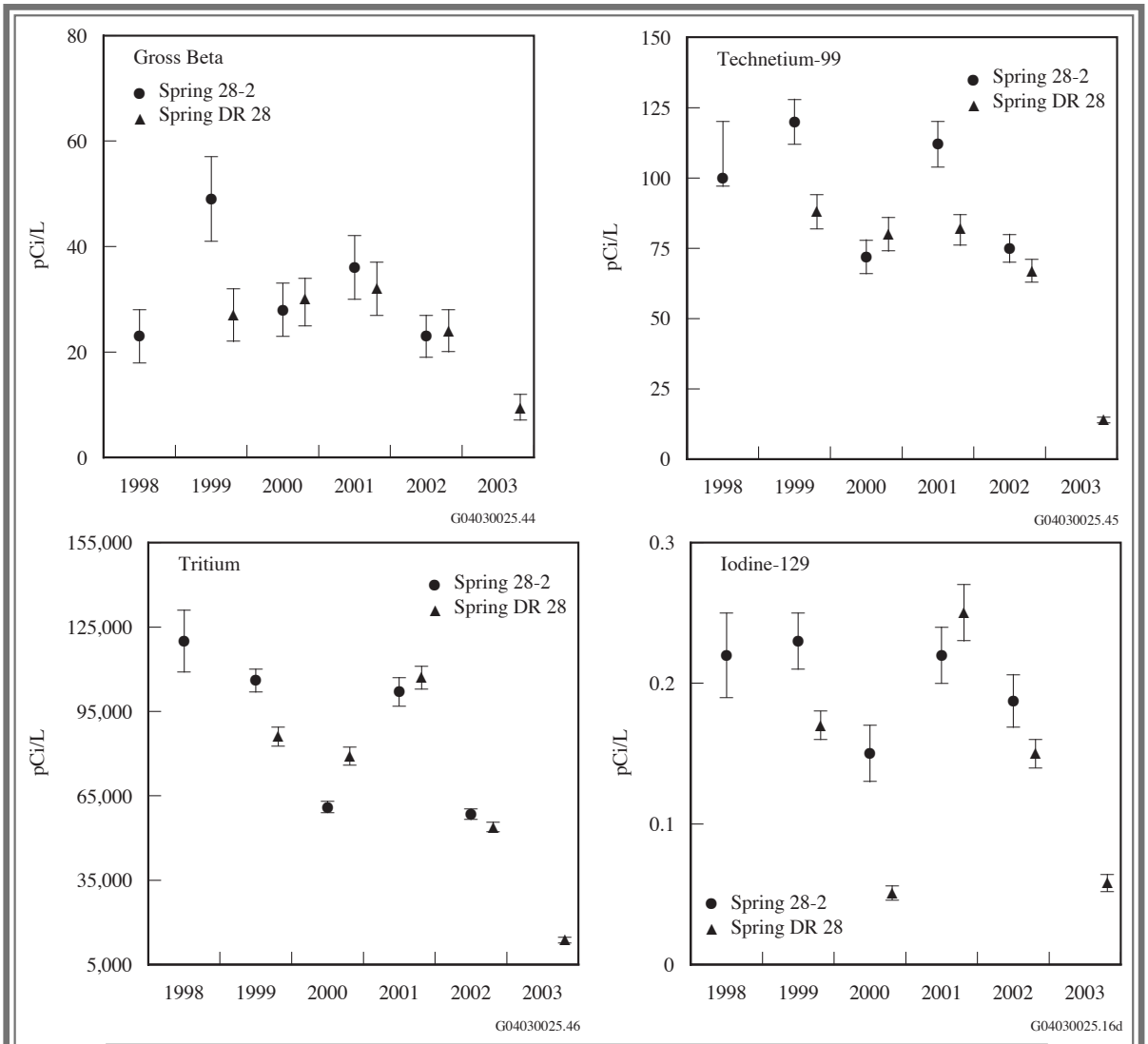


Figure 4.2.13. Concentrations (results ±2 total propagated analytical uncertainty) of Selected Radionuclides in Columbia River Riverbank Spring Water at the Hanford Town Site (Spring 28-2 and Spring 28-2 DR), 1998 through 2003. As a result of figure scale, some uncertainties (error bars) are concealed by the point symbol.

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 2003 were below Washington State 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 Areas riverbank spring water were above Washington State ambient surface-water acute toxicity levels (Appendix D, Table D.3). Arsenic concentrations in riverbank spring water were well below Washington 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 Washington 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).

Table 4.2.4. Concentration Ranges for Selected Chemicals in Water from Columbia River Springs at the Hanford Site, 1999 through 2003

	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		12	10	6	8	14	6	8	7
Dissolved Metals (µg/L)									
Antimony	NA	0.081 - 0.31	0.13 - 0.24	0.16 - 0.24	0.17 - 0.22	0.18 - 0.42	0.096 - 0.23	0.13 - 0.39	0.18 - 0.36
Arsenic	190	0.93 - 1.6	0.32 - 2.1	1.4 - 3.4	0.60 - 1.3	0.30 - 3.0	1.5 - 2.6	2.5 - 4.8	0.95 - 2.9
Cadmium	0.59	0.0096 - 0.024	0.0044 - 0.051	0.011 - 0.031	0.017 - 0.093	0.0044 - 0.040	0.0091 - 0.023	0.010 - 0.089	0.012 - 0.078
Chromium	10[b]	7.5 - 20	0.97 - 82	5.6 - 12	12 - 150	4.0 - 88	3.3 - 22	0.55 - 4.6	2.2 - 5.0
Copper	6	0.20 - 2.1	0.37 - 1.1	0.25 - 0.43	0.38 - 1.4	0.29 - 5.6	0.32 - 1.1	0.20 - 0.88	0.32 - 0.60
Lead	1.1	0.004 - 0.22	0.004 - 0.016	0.0050 - 0.016	0.0073 - 0.033	0.0050 - 0.57	0.0078 - 0.033	0.004 - 0.075	0.0050 - 0.062
Nickel	83	0.028 - 1.6	0.12 - 1.7	0.027 - 1.0	0.22 - 3.0	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	0.004 - 0.053	0.0049 - 0.021
Thallium	NA	0.0035 - 0.020	0.0035 - 0.023	0.0071 - 0.016	0.009 - 0.098	0.0059 - 0.026	0.0035 - 0.011	0.01 - 0.028	0.013 - 0.038
Zinc	55	0.14 - 5.0	0.43 - 3.7	1.2 - 3.7	1.2 - 12	0.35 - 5.0	0.66 - 2.5	0.54 - 3.1	0.93 - 3.0
No. of Samples		9	10	6	8	13	6	12	9
Total Recoverable Metals (µg/L)									
Chromium	96[d]	7.2 - 20	1.2 - 93	7.6 - 14	11 - 190	4.0 - 99	10 - 33	0.88 - 5.4	1.9 - 24
Mercury	0.012	0.00042 - 0.0013[e]	0.00098 - 0.014[f]	0.00044 - 0.0062[g]	0.00077 - 0.020[e]	0.00056 - 0.041[h]	0.0017 - 0.0076[g]	0.00079 - 0.0028[i]	0.00074 - 0.0047[e]
Selenium	5	0.50 - 2.2	0.11 - 2.2	0.41 - 0.96	0.50 - 2.7	0.39 - 2.9	0.68 - 2.3	0.45 - 2.3	1.7 - 4.1
No. of Samples		14	11	5	14[j]	17	7	10	7
Anions (mg/L)									
Nitrate	45[k]	0.1 - 3.4	0.028 - 4.9	2.0 - 4.9	0.41 - 6.3	0.10 - 20	0.58 - 33	1.1 - 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) Number of samples = 7.
(f) Number of samples = 6.
(g) Number of samples = 4.
(h) Number of samples = 9.
(i) Number of samples = 10.
(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.

4.2.3 Columbia River and Riverbank Springs Sediment

Upon release to the Columbia River, some radioactive and non-radioactive materials were deposited on the riverbed as sediment (particularly in upstream areas near dams). The concentrations of the radioactive material decreased as they underwent radioactive decay. Fluctuations in the river flow, as a result of the operation of hydroelectric dams, annual spring high river flows, and occasional floods, have resulted in the resuspension, relocation, and subsequent redeposition of the sediment (DOE/RL-91-50). Upper layer 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 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 4.2.2).

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 2003, 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 as well as atmospheric fallout from weapons testing 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 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 2003 included potassium-40, strontium-90, cesium-137, uranium-238, plutonium-238, and plutonium-239/240. The concentrations of all other radionuclides were below the reported minimum detectable concentrations for most samples (PNNL-14687, 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 sediment criteria are available to assess the sediment quality of the Columbia River (EPA 822-R-96-001). Radionuclide concentrations reported in river sediment during 2003 were, with the exception of strontium-90, similar to those reported for previous years (Appendix C, Table C.7) and there were no obvious differences between locations. Strontium-90 concentrations were below the reported minimum detectable concentrations for most samples for years 2000 to 2003. There were no obvious differences in concentrations for strontium-90 between upriver and downriver locations. Median, maximum, and minimum concentrations of selected radionuclides measured in Columbia River sediment (1998 through 2003) 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 predominantly of large cobble and are unsuitable for sample collection.

During 2003, 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 Area location because the scheduled spring was not flowing and an alternate spring was sampled (i.e., only water samples were collected; no sediment was found). Results for 2003 samples (Figure 4.2.14) were similar to those observed for previous years (PNNL-14687; APP. 1; Appendix C, Table C.7). Potassium 40, cesium-137, and uranium isotopes were the only radionuclides reported above the minimum detectable concentrations. During 2003, radionuclide concentrations in riverbank spring sediment were similar to those observed in Columbia River sediment, with the exception of the 300 Area where uranium concentrations were roughly twice the background concentrations measured for sediment from Priest Rapids Dam. Elevated uranium concentrations for 300 Area spring sediment compared to Priest Rapids Dam sediment have been previously reported (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 C, Table C.8; PNNL-14687, 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

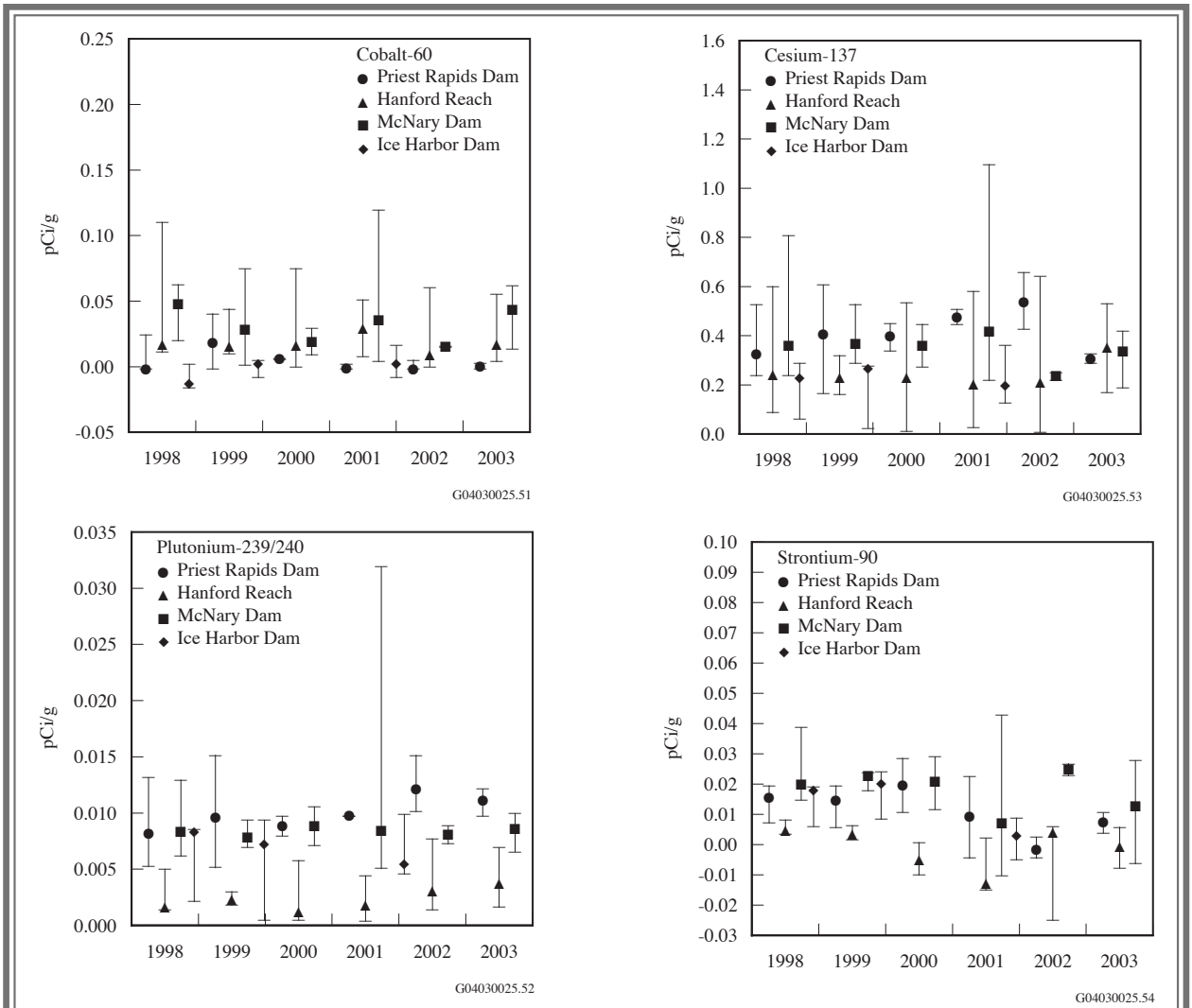


Figure 4.2.14. Median, Maximum, and Minimum Concentrations of Selected Radionuclides Measured in Columbia River (Washington and Oregon) and Snake River (Washington) Sediment, 1998 through 2003. All 2001, 2002, and 2003 results for cobalt-60 (except for Hanford Slough, 2003) and 2002 and 2003 results for strontium-90 were below detection limits.

differences between locations. Metal concentrations in riverbank spring sediment samples during 2003 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.

Since 1997 (no samples were collected in 2001), annual Columbia River sediment samples have been 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 valance 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

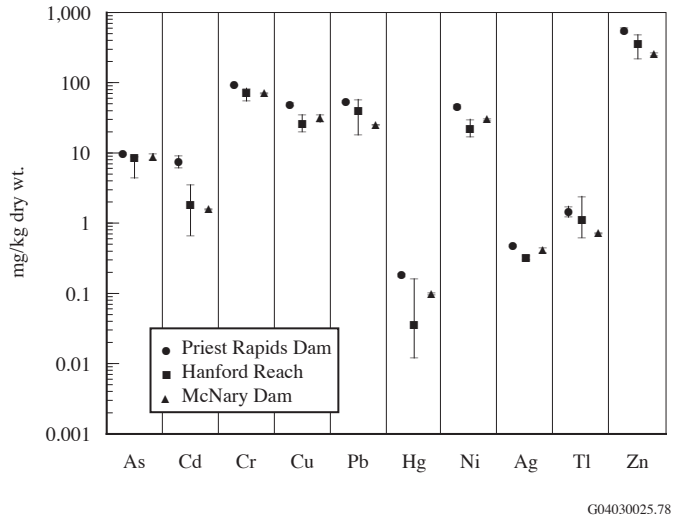


Figure 4.2.15. Median, Maximum, and Minimum Concentrations of Selected Metals Measured in Columbia River Sediment (Washington and Oregon), 2003

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 2003 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 2003 were similar to previous years with concentrations varying from 0.41 to 14 µmol/g (White Bluffs Slough had the highest measured acid volatile sulfide level). 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. During 2003, the acid volatile sulfide values in sediment from the Priest Rapid Dam reservoir had concentrations ranging from 3.8 to 7.5 µmol/g. Sediment from the McNary Dam reservoir had lower concentrations of acid volatile sulfide, with values ranging from 0.12 to 1.6 µmol/g. SEM/AVS molar ratios for sediment from the Priest Rapids Dam and McNary Dam reservoirs were above 1.0, indicating a potential for some dissolved metals to be present in the sediment porewater. Hanford Reach sediment samples had SEM/AVS molar ratios below one (i.e., low potential for dissolved metals in sediment porewater). For all locations, zinc was the primary SEM metal present.

Overall results from 1997 to 2003 reveal an apparent difference in the acid volatile sulfide concentrations in sediment from Priest Rapids Dam reservoir, which generally has 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 and Hanford Reach sediment, average zinc values were of similar magnitude as the average acid volatile sulfide concentrations. In McNary Dam sediment, the average zinc concentrations were

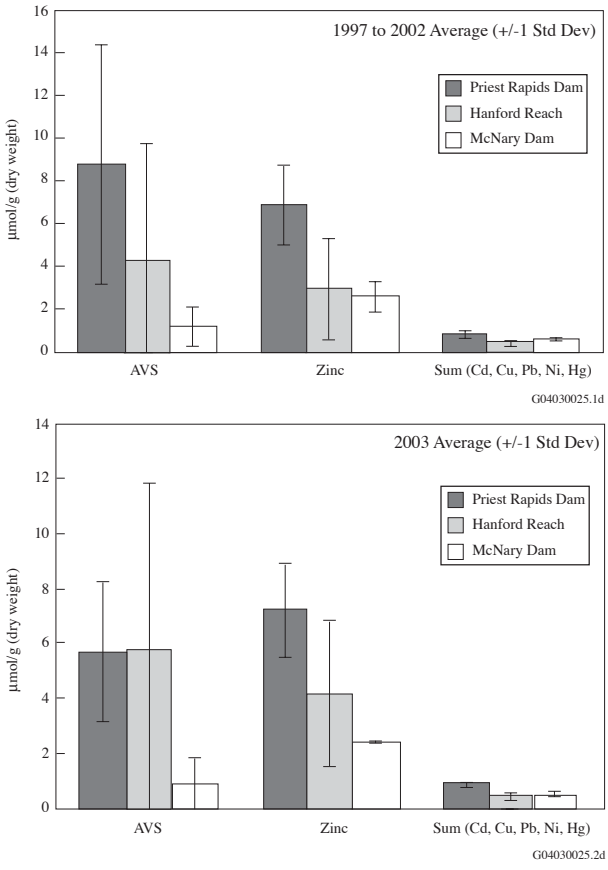


Figure 4.2.16. Average Acid Volatile Sulfide/ Simultaneously Extracted Zinc and Sum of Simultaneously Extracted Metals in Columbia River Sediment, 1997 through 2000 Compared to 2003 Data

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 facilities in various stages of remediation, were sampled periodically during 2003. The ponds are inaccessible to the public and, therefore, did not constitute a direct offsite environmental impact during 2003. 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 2003, 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 (Chapter 6) and this has decreased the size of West Lake and caused the suspended sediment loading to increase. Starting in 2002, it has not been 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 samples were less than applicable DOE derived concentration guides (DOE Order 5400.5; Appendix D, Table D.5) and Washington State ambient surface-water quality criteria levels (WAC 173-201A; 40 CFR 141; PNNL-14687, APP. 1; Appendix D, Tables D.1 and D.2).

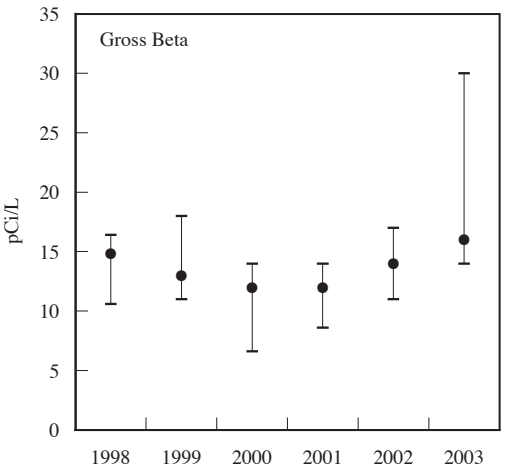
Figure 4.2.17 shows the annual gross beta and tritium concentrations in Fast Flux Test Facility pond water from 1998 through 2003. Median levels of both constituents have remained stable in recent years. The median tritium concentration in Fast Flux Test Facility pond water during 2003 was 15% of the Washington State ambient surface-water quality criterion of 20,000 pCi/L (740 Bq/L).

Median tritium concentrations in West Lake water during 2003 were similar to those observed in the past (Figure 4.2.18). The median concentration of tritium in West Lake water in 2003 was 0.8% of the Washington 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 2003 had the following detectable values:

- Gross alpha – 5.5 to 17 pCi/g (0.20 to 0.63 Bq/g)
- Gross beta – 19 to 29 pCi/g (0.70 to 1.1 Bq/g)
- Potassium-40 – 14 to 17 pCi/g (0.52 to 0.63 Bq/g)
- Strontium-90 – 0.30 to 0.65 pCi/g (0.011 to 0.024 Bq/g)
- Cesium-137 – 0.80 to 1.8 pCi/g (0.030 to 0.067 Bq/g)
- Uranium-234 – 0.55 to 9.1 pCi/g (0.020 to 0.34 Bq/g)
- Uranium-235 – 0.022 to 0.34 pCi/g (0.00081 to 0.013 Bq/g)
- Uranium-238 – 0.50 to 8.5 pCi/g (0.018 to 0.32 Bq/g).

These levels of radionuclides are similar to previous measurements (PNL-7662). Uranium concentrations are believed to result from high levels of naturally occurring uranium in the surrounding soil (BNWL-1979).



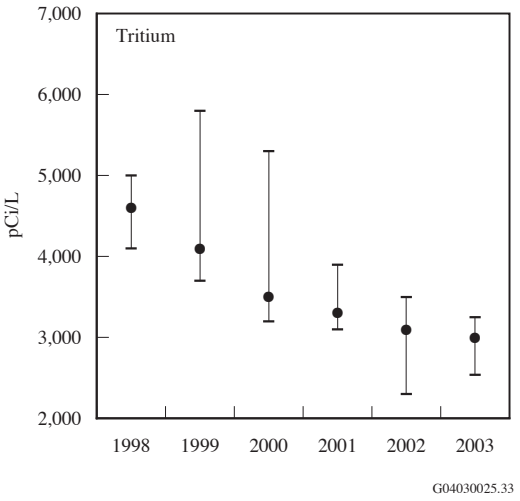


Figure 4.2.17. Median, Maximum, and Minimum Gross Beta and Tritium Concentrations in Water Samples from the Fast Flux Test Facility Pond on the Hanford Site, 1998 through 2003

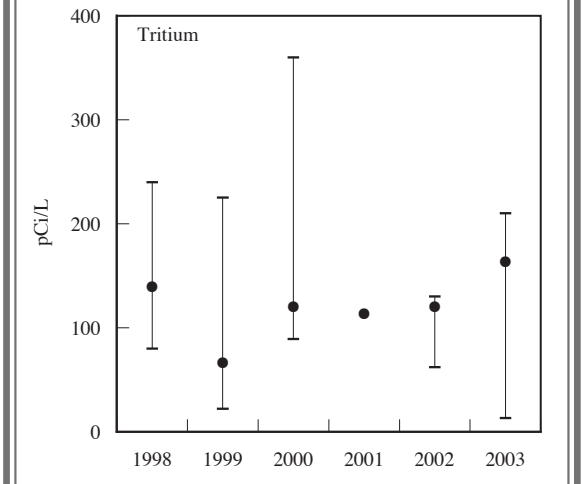


Figure 4.2.18. Median, Maximum, and Minimum Concentrations of Tritium in Water Samples from West Lake on the Hanford Site, 1998 through 2003

4.2.5 Irrigation Water

During 2003, 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) (Figure 4.2.1). 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 the 2003 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 2003, radionuclide concentrations measured in irrigation water were at the same levels detected in the Columbia River (PNNL-14687, APP. 1). All radionuclide concentrations were below their respective DOE derived concentration guides and Washington 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 2003 ranged from 0.082 ± 0.038 to 0.10 ± 0.036 pCi/L (0.0030 ± 0.0014 to 0.0037 ± 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 2003, 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 onsite drinking water.

Hanford water systems are classified as non-transient non-community public water systems. However, radionuclides in Hanford Site drinking water are monitored to community system requirements to comply with the requirements of DOE Order 5400.5. In Washington State, adherence to these requirements 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 (e.g., PNNL-14687, APP. 1). Non-radiological data are reported to the state directly by the state-accredited laboratory performing the analyses and Fluor Hanford, Inc. but are not otherwise published.

All DOE-owned drinking water systems on the Hanford Site were in compliance with community drinking water standards for radiological contaminant levels during 2003. Contaminant concentrations measured during the year were similar to those observed in recent years (see Section 4.3 in PNNL-13910 for 2001; PNNL-14295 for 2002).

4.3.1 Hanford Site Drinking Water Systems

During 2003, drinking water was supplied to DOE facilities on the site by nine DOE-owned, contractor-operated, water treatment and distribution systems, 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 near the Fast Flux Test Facility. 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 2003, radionuclide concentrations in onsite drinking water were monitored at four DOE-owned water supply facilities (Figure 4.3.1). Most site facilities were provided with drinking water pumped from the Columbia River. The 400 Area continued to use well 499-S1-8J as the primary drinking water supply well, with wells 499-S0-8 and 499-S0-7 serving as backup sources. 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 2003. Well 499-S0-8 supplied 3.38 million liters (893,000 gallons) to the distribution system during a 2-week period in March. At that time, the primary supply well (499-S1-8J) was off-line due to an electrical outage.

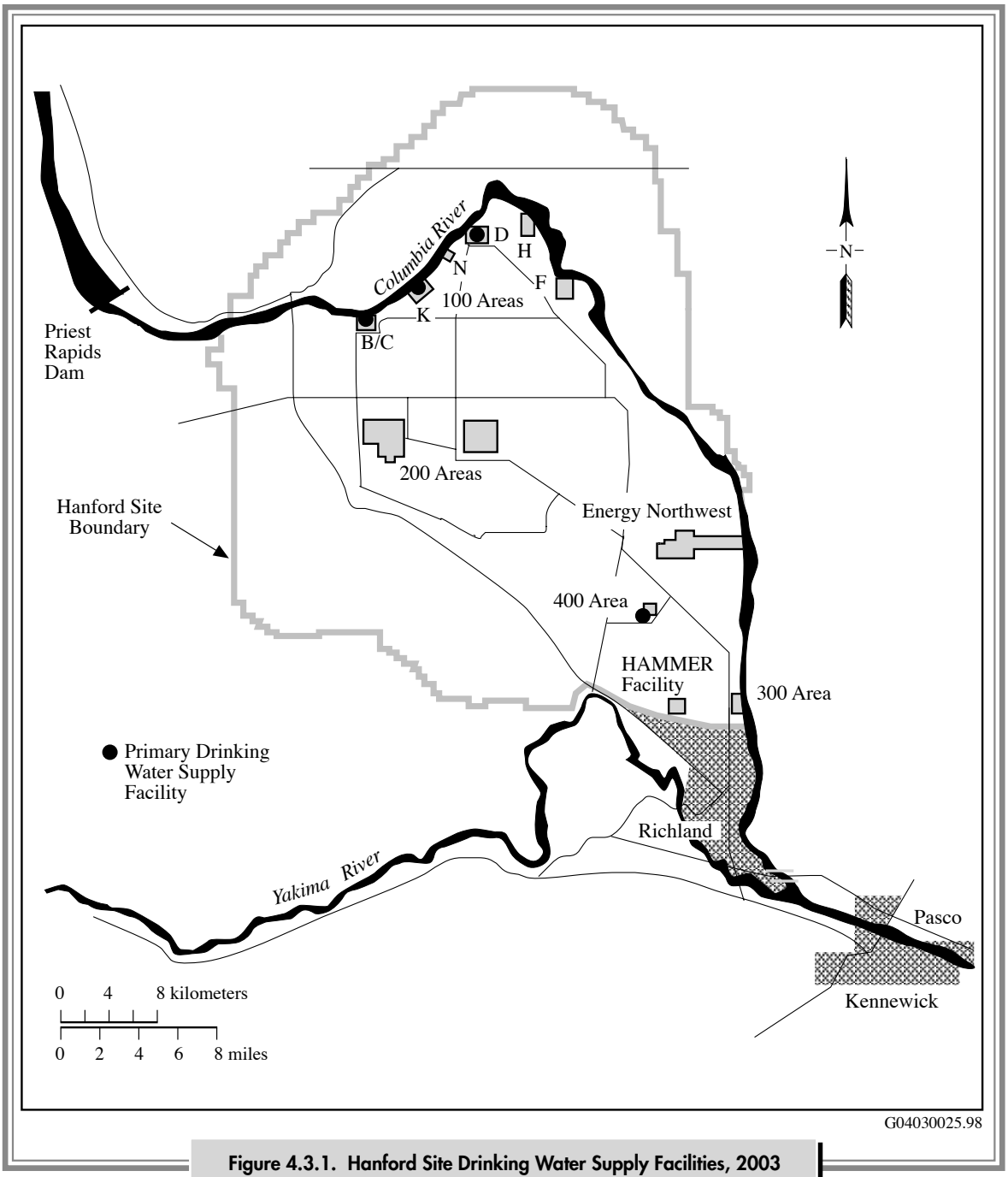


Figure 4.3.1. Hanford Site Drinking Water Supply Facilities, 2003

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-14184). Samples at all of the locations were collected and analyzed quarterly. All were samples of treated water collected before the water was distributed for general use. The Hanford Groundwater Performance Assessment Project also collected and analyzed samples of raw well water from each of the 400 Area drinking water wells during the calendar year.

Drinking water in the 300 and Richland North Areas and at the HAMMER facility is supplied by the city of Richland and was not routinely monitored for radiological contaminants by DOE contractor personnel. However, personnel from Pacific Northwest National Laboratory's Surface Environmental Surveillance Project routinely collected water samples from the Columbia River at Richland. The Columbia River is the primary source of the city of Richland's drinking water. The analytical results (radiological) for these raw river water samples can be found in Appendix C (Table C.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/RICHLAND/Utilities/index.cfm?PageNum=15>.

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 2003 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 2003 are summarized in Table 4.3.1. Individual analytical results are reported in PNNL-14687, 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 greater than 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

Table 4.3.1. Concentrations (pCi/L)[a] of Selected Radiological Constituents in Hanford Site Drinking Water, 2003

Constituent	No. of Samples Analyzed	Systems				Standards
		100-K Area	100-N Area	200-West Area	400 Area	
Gross alpha[b]	4[c]	0.38 ± 0.22[d]	0.40 ± 0.70[d]	0.34 ± 1.25	0.41 ± 1.81[d]	15[e,f]
Gross beta[b]	4[g]	1.41 ± 1.81[d]	1.19 ± 2.24[d]	1.24 ± 2.96	7.00 ± 0.81	50[f]
Tritium[h]	1[i]	-0.94 ± 84	148 ± 94	164 ± 100	3,350 ± 311	20,000[f]
Strontium-90[h]	1[i]	0.07 ± 0.03	0.10 ± 0.03	0.09 ± 0.04	-0.00 ± 0.04	8[e,f]
Iodine-131[b]	4[c]	0.05 ± 0.48[d]	0.00 ± 0.31[d]	0.11 ± 0.44[d]	0.01 ± 0.19[d]	3[j]
Radium-226[b]	4[c]	0.04 ± 0.03	0.04 ± 0.03	0.06 ± 0.03	0.04 ± 0.07	combined
Radium-228[b]	4[c]	0.50 ± 0.72	0.36 ± 0.50	0.37 ± 0.71	0.35 ± 0.26[d]	5[f]

(a) Multiply pCi/L by 0.037 to convert to Bq/L.
(b) Annual average ±2 times the standard deviation.
(c) Samples are collected and analyzed quarterly.
(d) Analytical results for all samples were below the detection limit.
(e) WAC 246-290.
(f) 40 CFR 141.
(g) Samples are collected monthly, composited, and analyzed quarterly.
(h) Single result ±2 times the total propagated analytical error.
(i) Samples are collected quarterly, composited, and analyzed annually.
(j) EPA-570/9-76/003.

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 2003, 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 15 of 16 gross alpha results were below their respective minimum detectable concentrations. Eleven of 12 gross beta results for river water samples were also below the minimum detectable concentration, as was 1 of 3 river water tritium results and 4 of 12 river water radium-228 results. Radium-226 was detected in every sample analyzed and gross beta and tritium were measured in all 400 Area well water samples. Strontium-90 was measured in all river water samples but was not detected in 400 Area well water (Table 4.3.1).

The Groundwater Performance Assessment Project collected and analyzed raw water samples from all three 400 Area drinking water wells. 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. During 2003, 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 (Table 4.3.2; Figure 4.3.2).

A sample of drinking water was collected from the well at the Laser Interferometer Gravitational Wave Observatory (LIGO) (see Figure 1.0.1) in July 2003 as part of a special study. The sample was analyzed for carbon-14, iodine-129, technetium-99, tritium, uranium 234, uranium-235, and uranium-239. None of these radionuclides were detected in the sample.

Table 4.3.2. Tritium Concentrations (pCi/L)[a] in Hanford Site 400 Area Drinking Water Wells, 2003[b]

Sampling Date	Primary Drinking Water Well 499-S1-8J (P-16)	Backup Drinking Water Well 499-S0-8 (P-14)	Backup Drinking Water Well 499-S0-7 (P-15)
February 4, 2003	3,010 ± 250	2,970 ± 250	11,000 ± 520
April 8, 2003	2,990 ± 250	3,220 ± 260	13,600 ± 650
July 16, 2003	3,770 ± 280	3,350 ± 280	14,200 ± 750
October 9, 2003	2,970 ± 260	3,050 ± 260	10,400 ± 580

(a) Multiply pCi/L by 0.037 to convert to Bq/L.
(b) Reported concentration ±2 total propagated analytical error.

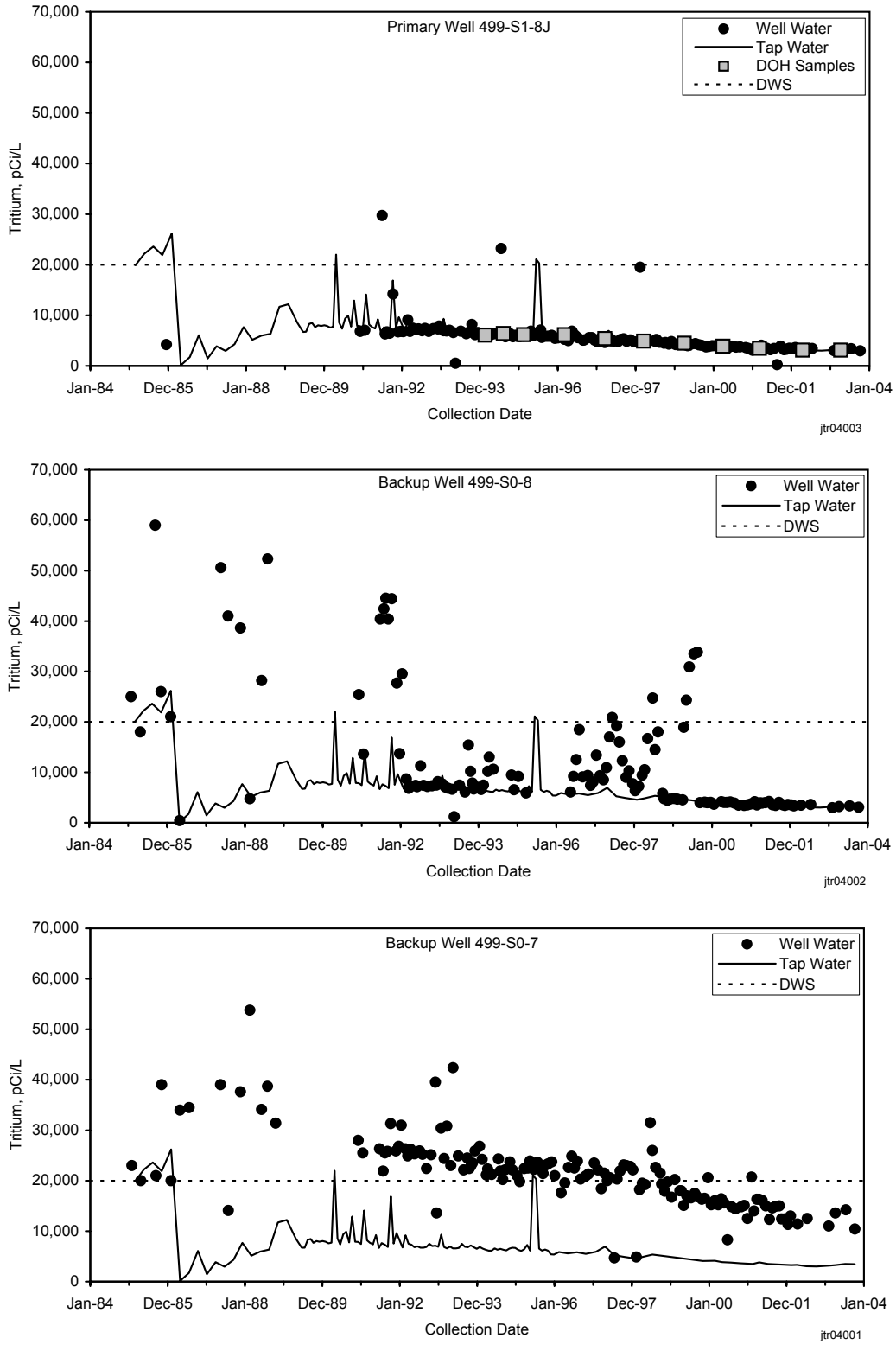


Figure 4.3.2. Tritium Concentrations in Drinking Water from Three Wells in the Hanford Site's 400 Area, 1985 through 2003. (DOH = Washington State Department of Health, DWS = drinking water standard). Multiply pCi/L by 0.037 to convert to Bq/L.

4.4 Food and Farm Product Surveillance

B. L. Tiller

Food products, including fruits, leafy vegetables, milk, potatoes, honey, and wine were collected routinely during 2003 at several locations surrounding the Hanford Site (Figure 4.4.1). Routine samples were collected primarily from locations in the prevailing downwind directions (east and southeast of the site) where airborne emissions or contaminated 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 (background) radiation levels in food.

Routine food and farm product sampling assesses the potential influence of Hanford Site releases in three ways:

- Through the comparison of analytical results obtained from samples collected from the same regions over long periods of time.
- Through the comparison of analytical results from samples collected at downwind locations to results from samples obtained from generally upwind or distant locations.
- Through the comparison of analytical results from samples collected in areas irrigated with Columbia River water withdrawn downstream from the Hanford Site to analytical results from samples obtained from locations irrigated with water from other sources.

Food and farm product samples are collected annually but some products may only be sampled every 2 or 3 years (DOE/RL-91-50; PNNL-14184). Table 4.4.1 shows the types of food or farm products collected, sampling locations, sampling frequencies, and number and types of analyses during 2003.

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 and apples were analyzed for tritium. Most results for fruits and vegetables are reported in picocuries per gram (pCi/g) wet weight. Results for milk and for tritium in water extracted from fruits and vegetables 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 and other gamma emitters are present in atmospheric fallout from nuclear weapons testing and are found in Hanford Site radiological waste sites. Uranium occurs naturally in most soil, in fertilizers used in agriculture, and in Hanford's fuel fabrication and reprocessing areas and 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 to indicate the upper bound of concentration for that radionuclide. For this purpose, two times the total propagated analytical uncertainty is reported. 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. 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-14687, APP. 1. Radiological dose considerations were calculated and are reported in Chapter 5.

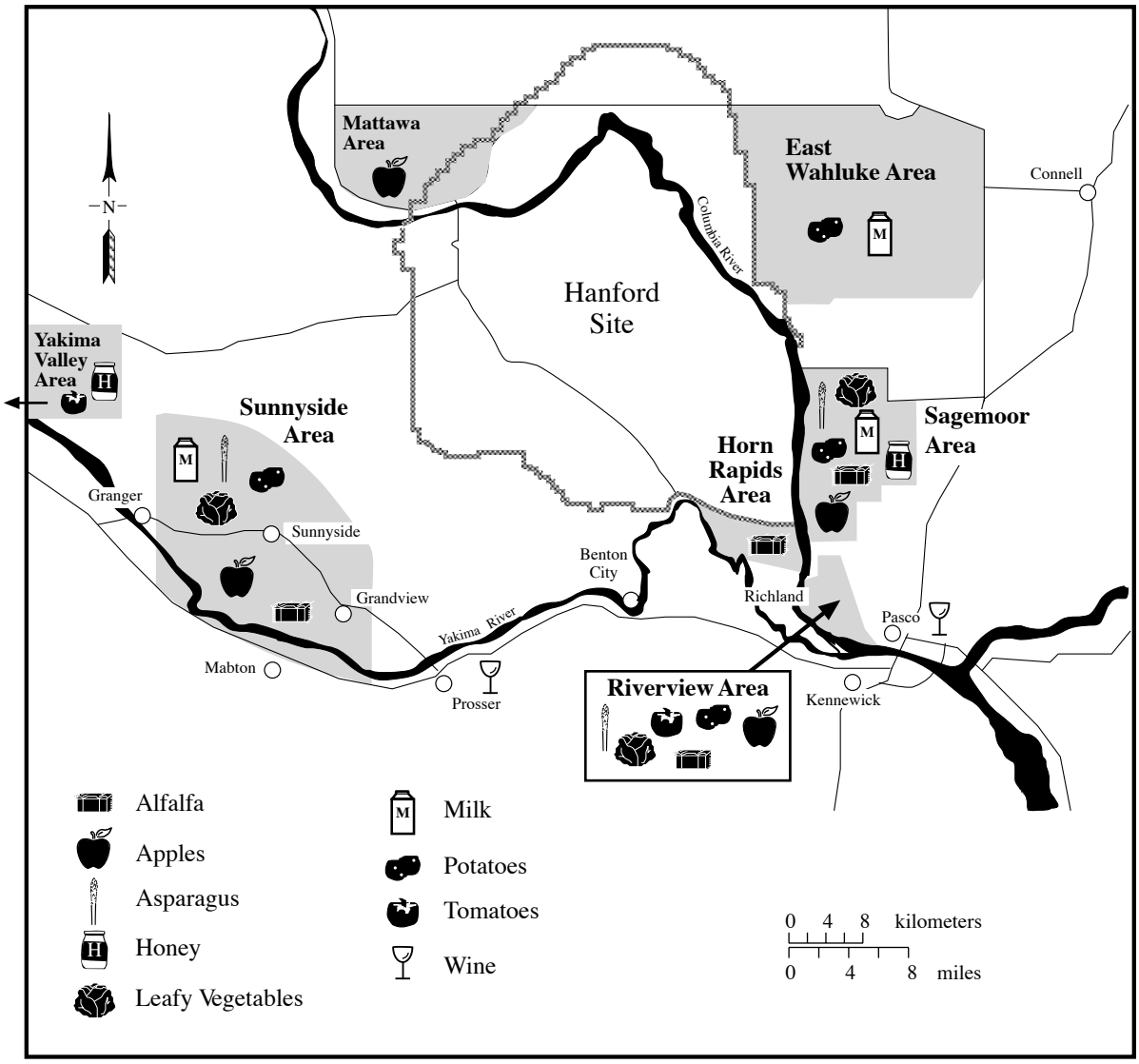


Figure 4.4.1. Food and Farm Product Sampling Locations, 2003

Table 4.4.1. Sampling Locations, Frequencies, and Analyses Performed for Food and Farm Products Routinely Sampled Around the Hanford Site, 2003[a]

	Number of Locations			Number of Samples Analyzed			
Product	Upwind	Downwind	Sampling Frequency[b]	^{3}H	Gamma	^{90}Sr	^{129}I
Milk	1	2	Q or SA	12	12	12	6
Vegetables	1	3	A	2	6	6	0
Fruit	3	2	A	2	6	6	0
Wine	2	2	A	4	4	0	0
Alfalfa	2	2	BE	0	4	4	0

(a) Products may include multiple varieties for each category.
(b) Q = quarterly, SA = semiannually, A = annually, BE = biennially.

4.4.1 Milk Sample Results and Analytes of Interest

Composite samples of unpasteurized, whole milk were collected during 2003 from three dairies in the East Wahluke area and from three dairies in the Sagemoor area. These sampling areas were located near the site perimeter in the prevailing downwind direction from likely Hanford sources of airborne contaminants (Figure 4.4.1). Milk samples also were collected from one dairy in the Sunnyside area to represent reference radionuclide concentrations at a location generally upwind of Hanford.

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. In the past, these radionuclides in milk were attributable principally to Hanford Site production operations and worldwide fallout from nuclear weapons testing. In recent times, in the absence of production and testing, the influence of Hanford operations on contaminant levels has diminished and levels of radionuclides in milk from dairies generally downwind of the Hanford Site have been similar to levels measured in milk from dairies located generally upwind of Hanford. During 2003, gamma scans, tritium, and strontium-90 analyses of milk samples were conducted quarterly; iodine-129 analyses were conducted on two semiannual composite samples. Although there is no protection guidelines for tritium in milk per se, for perspective, the maximum contaminant level for tritium in water is 20,000 pCi/L (740 Bq/L) (Appendix D, Table D.2).

Six of 48 (13%) milk samples had strontium-90 concentrations above the analytical detection limit during 1999, 2000, 2001, and 2002. During 2003, strontium-90 was detected in three of eight (38%) milk samples from downwind regions, and two of four (50%) samples collected upwind near Sunnyside, Washington (Figure 4.4.2). The samples from all three sampling areas analyzed during 2003 contained the highest maximum concentrations of strontium-90 reported in milk samples from these areas since the mid-1990s. The maximum concentration measured at Sunnyside, Washington, was 2.1 pCi/L (0.08 Bq/L), compared to 1.8 pCi/L (0.06 Bq/L) in the Sagemoor area and 1.2 pCi/L (0.04 Bq/L) in the East Wahluke area. All

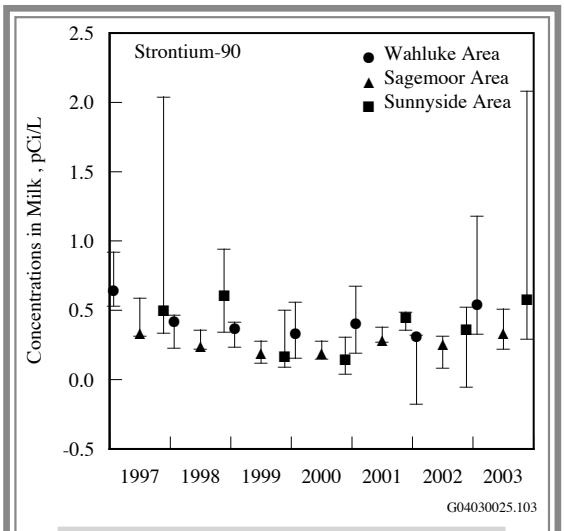


Figure 4.4.2. Median, Maximum, and Minimum Strontium-90 Concentrations in Milk Samples Collected Near the Hanford Site, 1997 through 2003

maximum values were seen during the third quarter (July-August) sampling period. The reason for these higher concentrations is currently being investigated. While there is no strontium-90 standard for milk, for perspective, the standard for drinking water (based on a 2-liter [0.5-gallon] per day consumption rate) is 8 pCi/L (0.3 Bq/L) (Appendix D, Table D.2). The maximum milk consumption rate used in this report for estimating dose to the maximally exposed individual (Chapter 5) is approximately 270 liters (71 gallons) per year (Appendix E, Table E.2).

Iodine-129 concentrations in six milk samples from three locations were determined by high-resolution mass spectrometry in 2003. The levels of iodine-129 in milk collected from downwind dairies in the Sagemoor and East Wahluke areas were greater than levels measured upwind in Sunnyside (Figure 4.4.3). Iodine-129 concentrations declined with the end of nuclear materials production at the Hanford Site but have been consistent and low (less than 0.001 pCi/L) in the past 5 years. While there is no concentration standard for iodine-129 in milk, for perspective, the standard for drinking water is 1.0 pCi/L (0.037 Bq/L) (EPA-570/9-76-003).

No manmade gamma emitters (including cesium-137) were detectable in 2003 milk samples (PNNL-14687, APP. 1).

Tritium levels in milk samples collected from the East Wahluke, Sagemoor, and Sunnyside areas (Figure 4.4.1)

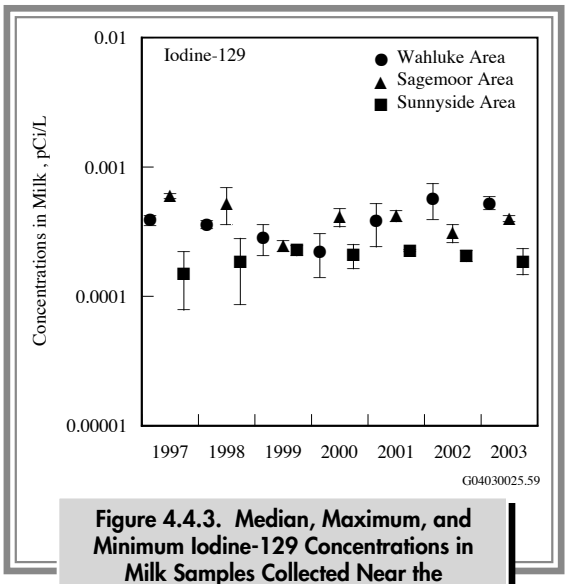


Figure 4.4.3. Median, Maximum, and Minimum Iodine-129 Concentrations in Milk Samples Collected Near the Hanford Site, 1997 through 2003. The bars represent the maximum and minimum concentrations.

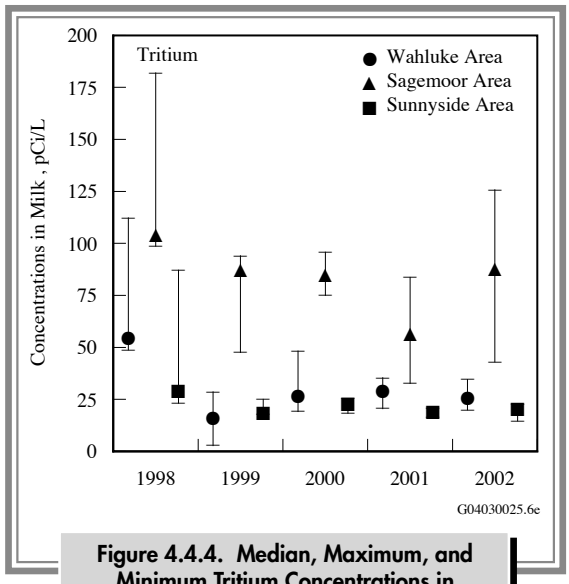


Figure 4.4.4. Median, Maximum, and Minimum Tritium Concentrations in Milk Samples Collected Near the Hanford Site, 1998 through 2002. The bars represent the maximum and minimum concentrations.

during 2003 were not available at the time this report was prepared. The tritium results obtained from samples from these areas during previous years indicated that 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 4.4.4). The reason for the higher tritium levels may be due to the use of shallow groundwater at the dairies (PNNL-13230). 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 milk over the past 4 years (Figure 4.4.4).

4.4.2 Vegetable Sample Results and Analytes of Interest

Samples of spinach, asparagus, and potatoes were obtained during the summer of 2003 from gardens and farms to monitor for airborne contaminants (Table 4.4.1; Figure 4.4.1). The Riverview area was specifically sampled because of its exposure to potentially contaminated irrigation water withdrawn from the Columbia River downstream of the Hanford Site.

Concentrations of manmade gamma-emitting radionuclides (cesium-137 and cobalt-60) in vegetable samples collected in 2003 were all less than their detection limit (approximately 0.02 pCi/g [0.0007 Bq/g] wet weight) and were consistent with results seen in recent years (PNNL-13910; PNNL-14295). Strontium-90 was detected in three of six vegetable and leafy vegetable samples collected during 2003, and the highest concentration reported from upwind regions (0.01 ± 0.003 pCi/g [0.0004 ± 0.0001 Bq/g] wet weight) was similar to the highest concentration reported from the downwind regions. Both concentrations of strontium-90 and gamma-emitting radionuclides were measured in potato samples. In recent years, few vegetable samples have had measurable concentrations of strontium-90 or cesium-137.

4.4.3 Fruit Sample Results and Analytes of Interest

Tomatoes and apples from selected locations around the Hanford Site (Figure 4.4.1) were collected and analyzed for gamma-emitting radionuclides (cesium-137 and cobalt-60) and strontium-90 during 2003. No measurable levels of gamma-emitting radionuclides were reported. Strontium-90 was found above the analytical detection limit in one tomato sample collected from the Riverview area. Tritium was monitored in all tomato samples collected during 2003, but was not found at detectable levels.

These results were consistent with concentrations in grapes, cherries, apples, tomatoes, 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 approximately 0.02 pCi/g (0.0008 Bq/g) wet weight and strontium-90 was 0.002 to 0.05 pCi/g (0.000074 to 0.0019 Bq/g) wet weight.

4.4.4 Wine Sample Results and Analytes of Interest

Locally produced red and white wines (2003 vintage grapes) were analyzed for gamma-emitting radionuclides and tritium (Table 4.4.1). The wines were made from grapes grown at specific 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.

Tritium levels in 2003 wine samples were not available at the time this report was prepared. While there is no tritium standard for wine, the drinking water standard is 20,000 pCi/L (740 Bq/L), approximately 430 times greater than maximum concentrations reported in wines from these two areas during 2002 (PNNL-14295; EPA-570/9-76-003). Gamma spectroscopy did not indicate the presence of cesium-137 or any other manmade gamma-emitting radionuclide in any of the 2003 wine samples.

4.4.5 Other Farm Product Sample Results and Analytes of Interest (Alfalfa and Honey)

Alfalfa samples from one area upwind of Hanford and from a few areas downwind of the Hanford Site (Figure 4.4.1) were analyzed for gamma-emitting radionuclides and strontium-90 in 2003. Naturally occurring beryllium-7 and potassium-40 were detected in three of the four alfalfa samples collected and analyzed. No other gamma-emitting radionuclides were detected. Strontium-90 was detected in three of four alfalfa samples collected during 2003 and concentrations ranged from (0.03 ± 0.01 pCi/g [0.001 ± 0.0004 Bq/g]) in the Sagemoor area to 0.1 ± 0.02 pCi/g [0.004 ± 0.0008 Bq/g]) in the Riverview area. The Riverview area has consistently shown slightly elevated levels of strontium-90 in alfalfa since the early 1990s.

Two samples of honey were obtained from local honey producers in 2003 and analyzed for gamma-emitting radionuclides, strontium-90, and plutonium 238/239. The honey was produced by bees in commercial hives that were installed around pollen sources (fields) located both upwind and downwind of the Hanford Site (Figure 4.4.1). This food product has not been traditionally assessed as part of the Hanford Site environmental monitoring programs; however, bees are known to collect components of the honey from local plants, and honey has been shown to be an indicator of environmental contamination (LA-14085-ENV). No detectable levels of manmade gamma-emitting radionuclides or plutonium were detected in honey analyzed during 2003. Strontium-90 was detected in both honey samples analyzed during 2003, and the results from both the upwind (Yakima Valley) and downwind (Sagemoor) areas were the same (0.07 ± 0.03 pCi/g [0.003 ± 0.001 Bq/g]).

4.5 Fish and Wildlife Surveillance

B. L. Tiller

Contaminants in wildlife that inhabit the Columbia River and Hanford Site are monitored because terrestrial wildlife has access to areas of the site that contain radioactive or chemical contamination, and aquatic organisms can be exposed to contamination entering the river along the shoreline. Some fish and wildlife species exposed to Hanford contaminants might be harvested for food and may potentially contribute to offsite public exposure. In addition, the level of contaminants in tissues of key organisms (ecological sentinels) may help identify changes in environmental conditions over time and may help describe the extent and degree to which Hanford Site materials are found in the environment.

A primary consideration when selecting wildlife species for routine human-exposure sampling was the likelihood that these species could be consumed by members of the public. The primary considerations when selecting ecological sentinels included (1) the likelihood that the organism would frequent contaminated areas on and near the site and accumulate contaminants in body tissues, (2) the type of organisms ecological guild (e.g., herbivore, predator, primary producer), and (3) the possibility of relating ambient contaminant levels in abiotic media (e.g., water, soil, air) to the contaminant concentrations measured in tissues of the organism. In 2003, several types of organisms were collected at locations on and around the Hanford Site (Figure 4.5.1) and analyzed for selected metals, radionuclides, and organics that are suspected or known to be present on the Hanford Site (Table 4.5.1). Samples were also collected at locations that were distant from the site to obtain reference (background) contaminant measurements.

Fish and wildlife samples for routine human-exposure pathway assessments are collected annually on or near the Hanford Site, but specific species are sampled every 2 or 3 years. Routine samples are collected approximately every 5 years at locations believed to be unaffected by Hanford Site effluents and emissions.

In 2003, all fish and wildlife samples collected were monitored for strontium-90 contamination and were analyzed by gamma spectrometry to detect a number of gamma emitters (Appendix F) including cesium-137. Cesium-137 is present in Hanford effluents and in historical atmospheric fallout. Since the 1990s, strontium-90 and cesium-137 have been the most frequently measured radionuclides in fish and wildlife samples. Strontium-90 is chemically similar to calcium and accumulates in hard tissues rich in calcium such as bones, antlers, and shells. Hard-tissue concentrations may profile an organism's exposure to strontium-90. However, strontium-90 generally does not contribute much to human dose because it does not accumulate in edible tissues. Contaminated groundwater that enters the Columbia River via shoreline springs near the 100-N and 100-H Areas is the primary Hanford source of strontium-90 to the river; however, the current contribution of this contaminant to the river, compared to historical fallout from atmospheric nuclear weapons testing, is less than 2% (PNL-8817). Cesium-137 is a gamma-emitter of special importance because it is chemically similar to potassium, which is found in edible muscle tissues.

A number of trace metals that have the potential to accumulate in certain fish and wildlife tissues have been identified in the Hanford Site environment as potential contaminants of concern (e.g., chromium, copper, lead, and mercury), particularly in areas of the site where contaminated groundwater enters the Columbia River along the shoreline (PNNL-14295). Trace metal concentrations were monitored in Canada geese (*Branta canadensis*), cottontail rabbits (*Sylvilagus nuttallii*), whitefish

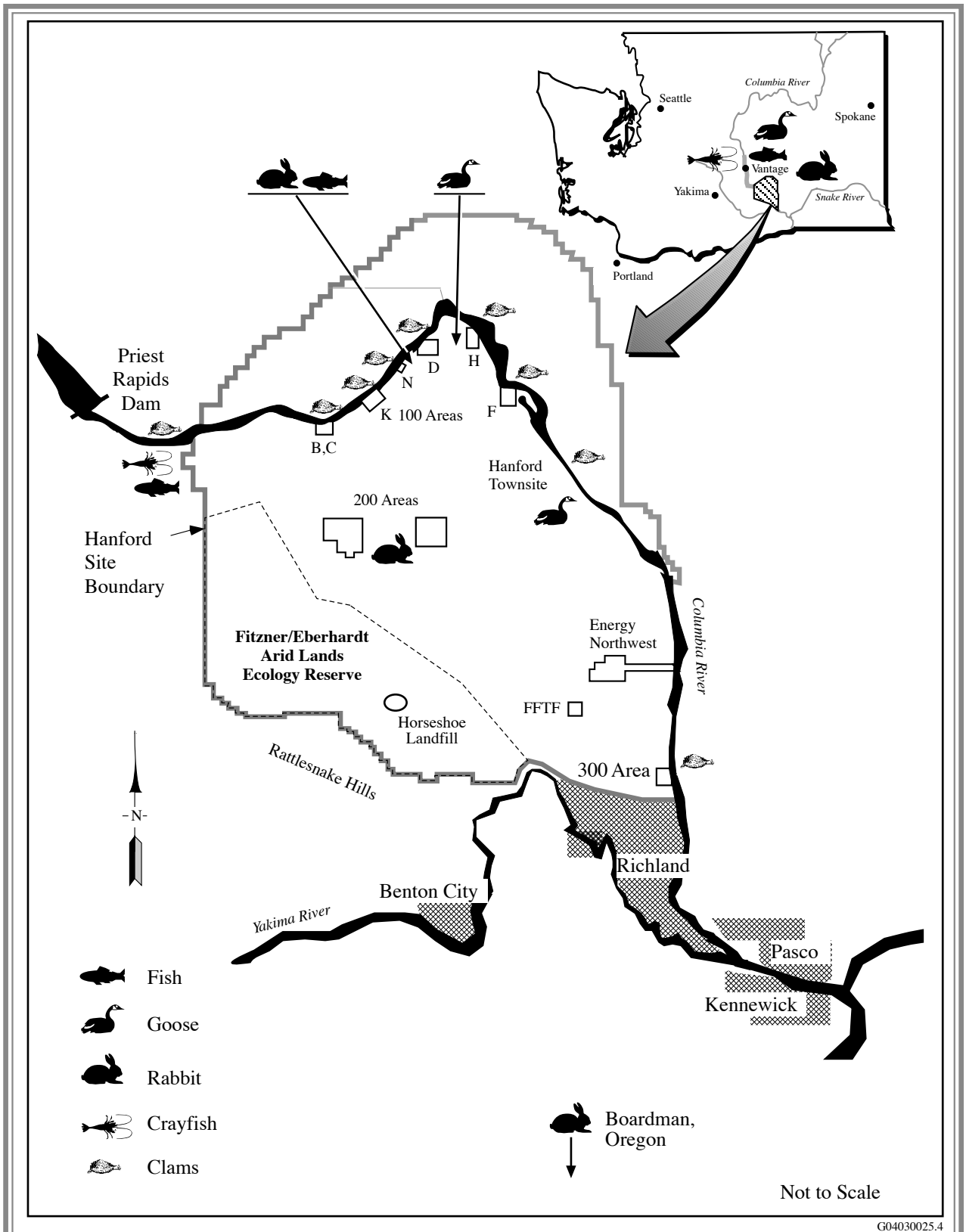


Figure 4.5.1. Fish and Wildlife Sampling Locations On and Around the Hanford Site, 2003

Table 4.5.1. Locations, Species, and Contaminants Sampled for Fish and Wildlife, 2003

Biota	No. of Offsite Locations	No. of Onsite Locations	No. of Analyses		
			Gamma	Strontium-90	Trace Metals
Fish (whitefish)	1[a]	1	6	6	6
Fish (sculpin)	2[b]	0	0	5	10
Canada goose	1[a]	2	11	11	11
Rabbits	0	1	4	4	4
Crayfish	2[b]	0	0	5	10
Asiatic clams	5[b]	18	0	18	18

(a) Samples collected at Vantage, Washington.
(b) Samples collected near Vernita Bridge.

(*Prosopium williamsonii*), crayfish (*Pacificastus leniusculus*), prickly sculpin (*Cottus asper*), and Asiatic clams (*Corbicula fluminea*) in 2003, but only the data from the Asiatic clams are discussed in this report. Trace metal data for the other organisms are not discussed because of the limited number of samples collected during 2003 and the lack of elevated levels of Hanford Site contaminants in the samples analyzed. The data are summarized in PNNL-14687, APP. 1.

For many radionuclides and metals, concentrations are below levels that can be detected by the analytical laboratory. When this occurs, the minimum detectable activity is used as an estimate of the minimum detectable amount of the contaminant. Results and minimum detectable activities for all 2003 analytical results are tabulated in PNNL-14687, APP. 1.

4.5.1 Fish and Wildlife Sampling

Routinely monitoring various fish and wildlife for uptake of, and exposure to, radionuclides both near and distant from Hanford Site operations helps to verify that the consumption of fish and wildlife obtained near the Hanford Site does not pose a threat to humans. Monitoring also provides data to map long-term contamination trends in selected ecosystem components. Terrestrial and riverine wildlife sampled and analyzed during 2003 included mountain whitefish, Canada geese, and cottontail rabbits.

4.5.1.1 Fish Sample Results and Analytes of Interest

During 2003, five mountain whitefish were collected between the 100-N and the 100-D Areas, and one whitefish was collected from an upstream reference site near Vantage, Washington (Figure 4.5.1). Fillet (muscle) samples were analyzed by gamma spectrometry for cesium-137 and other gamma-emitting radionuclides (PNNL-14687, APP. 1) and the eviscerated remains (head, skeleton, and tail) were analyzed for strontium-90 (Table 4.5.1). Cesium-137 concentrations in the fillet samples from both locations were below the analytical detection limit (0.04 pCi/g [0.0015 Bq/g] wet weight). These results were consistent with results reported throughout the 1990s.

Strontium-90 was not found above the analytical detection limit (0.02 pCi/g [0.0007 Bq/g] wet weight) in any of the six whitefish carcass samples collected and analyzed during 2003. These results were similar to levels reported for the 100 Areas in preceding years (Figure 4.5.2). The highest concentration of strontium-90 reported over the preceding 7 years was in a reference whitefish collected from the Clearwater River near Orofino, Idaho, during 1999.

4.5.1.2 Goose Sample Results and Analytes of Interest

Ten geese were collected from the Hanford Reach of the Columbia River and two were collected from a reference

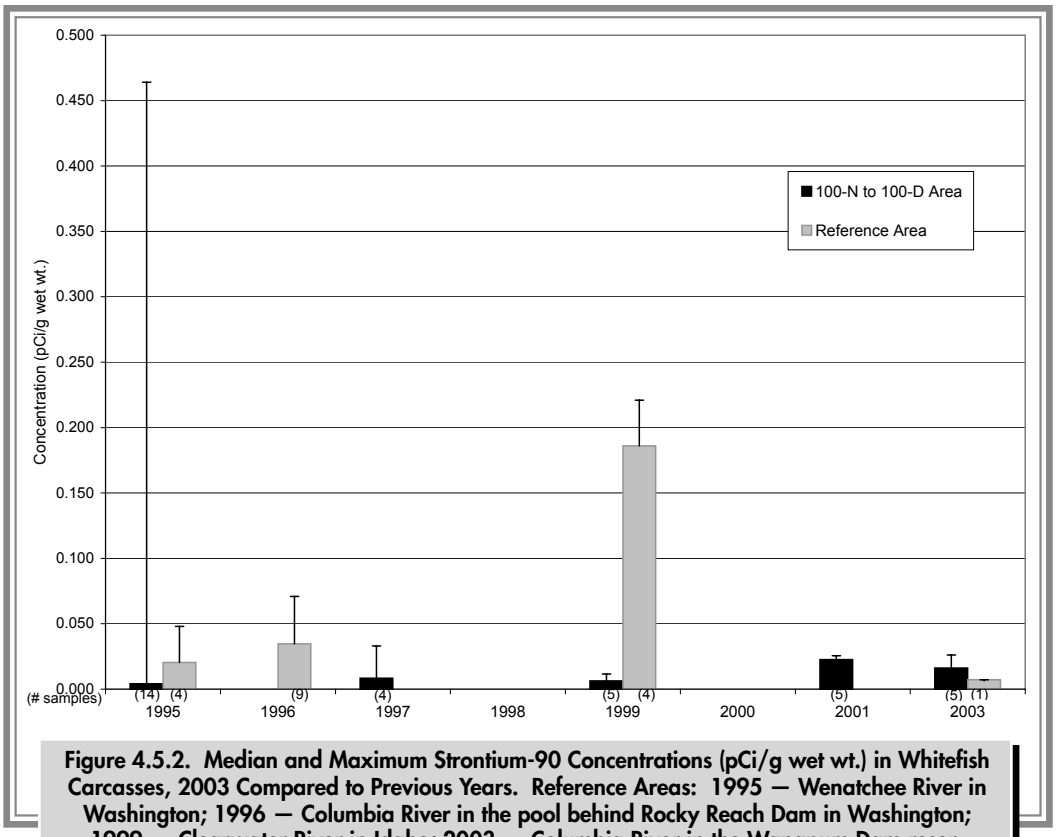


Figure 4.5.2. Median and Maximum Strontium-90 Concentrations (pCi/g wet wt.) in Whitefish Carcasses, 2003 Compared to Previous Years. Reference Areas: 1995 — Wenatchee River in Washington; 1996 — Columbia River in the pool behind Rocky Reach Dam in Washington; 1999 — Clearwater River in Idaho; 2003 — Columbia River in the Wanapum Dam reservoir in Washington. Maximum concentrations are represented by the upper bar.

location near Vantage, Washington, in the early fall of 2003 (Figure 4.5.1). All organisms were analyzed for gamma-emitting radionuclides (including cesium-137) in muscle tissue and strontium-90 in bones.

Manmade gamma-emitting radionuclides, including cesium-137, were not found in any of the muscle samples analyzed in 2003 (minimum detectable activities were 0.01 to 0.3 pCi/g [0.00037 to 0.001 Bq/g] wet weight). These results were similar to results reported for 38 goose samples collected from the Hanford Reach from 1995 through 2001. All of these analytical results suggest that Canada geese are not accumulating measurable amounts of cesium-137 along the Hanford Reach of the Columbia River.

Strontium-90 concentrations found in goose bones were all above the analytical detection limit and levels found during 2003 in all Hanford Reach and reference area samples were similar (Figure 4.5.3). Median and maximum concentrations in Hanford Reach goose samples in 2003 were similar to results reported during 2001 (median approximately 0.1 pCi/g [0.004 Bq/g] wet weight), which were higher than any reported from 1995 through 2000 (n=28), but were similar to results from reference area (background) samples obtained in 1995 (n=10), 1999 (n=3), and 2003 (n=3). While the apparent increases in strontium-90 concentrations in Hanford Site goose samples obtained in 2001 and 2003 are noteworthy, the measured concentrations in bone would need to exceed approximately 60 pCi/g (2.2 Bq/g) wet weight to be near the current DOE dose limit of 0.1 rad (0.0008 Gy) per day for terrestrial organisms (Chapter 5).

4.5.1.3 Rabbit Sample Results and Analytes of Interest

Rabbits are useful onsite for detecting localized radioactive contamination because they have relatively small home ranges, occupy burrows in potentially contaminated soil, and can enter fenced-restricted areas that contain radioactive waste materials. They may also be useful as sentinel organisms both on and off the site. In the fall of 2003,

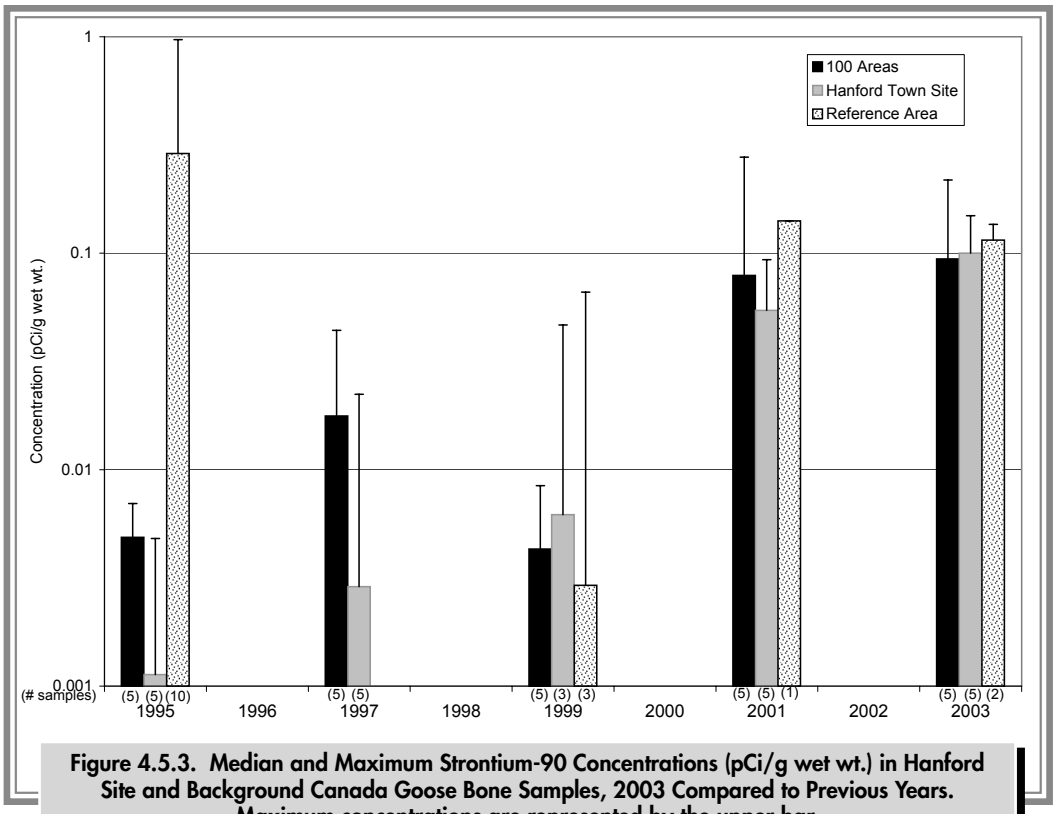


Figure 4.5.3. Median and Maximum Strontium-90 Concentrations (pCi/g wet wt.) in Hanford Site and Background Canada Goose Bone Samples, 2003 Compared to Previous Years. Maximum concentrations are represented by the upper bar.

cottontail rabbits were collected from a reference area, the 200 Areas, and 100-N Area. Four cottontail rabbits were collected near the 100-N Area, two were collected near the 200-West Area, four were collected near the 200-East Area, and one was collected from the reference area near Vantage, Washington (Figure 4.5.1). Ten reference cottontail rabbit samples were collected near Boardman, Oregon, in 1990 and the data from these organisms are used here for comparison. All rabbits were monitored for cesium-137 in muscle tissue and strontium-90 in bones.

Cesium-137 concentrations in muscle samples from seven of ten rabbits collected on the Hanford Site during 2003 were below the analytical detection limit (0.02 pCi/g [0.00074 Bq/g] wet weight). The results from the six rabbits collected near the 200 Areas were similar to those reported from the reference locations sampled in 1990 and 2003 and do not indicate elevated exposures from Hanford-derived sources. Three of the four rabbit samples collected near 100-N Area during 2003 contained detectable levels of cesium-137 ranging between 0.05 ± 0.02 pCi/g (0.002 ± 0.0007 Bq/g) wet weight and 0.9 ± 0.03 pCi/g (0.03 ± 0.0008 Bq/g) wet weight. These levels were above the detection limit but were too low to contribute substantially to any public dose if a similar rabbit with a similar contaminant burden were collected offsite and consumed (Chapter 5).

Strontium-90 concentrations in bone tissues from the ten rabbits collected onsite during 2003 were all above the analytical detection limit with median concentrations ranging from 0.4 pCi/g (0.0148 Bq/g) to 2.68 ± 0.8 pCi/g (0.10 ± 0.03 Bq/g) wet weight (Figure 4.5.4). Three of the four highest concentrations reported during 2003 were collected near the 100-N Area. Results from rabbits collected near the 100-N Area have historically been higher and more variable than results obtained from reference areas. This indicates a portion of the rabbit population near the 100-N Area has been exposed to 100-N Area sources of strontium-90. Although low sample sizes limit the ability to interpret the long-term trends, major changes in strontium-90 levels within rabbit bone tissues have not been apparent over the past decade (Figure 4.5.4). Strontium-90 concentrations in bone tissues would need to exceed approximately 60 pCi/g (2.2 Bq/g) wet weight to

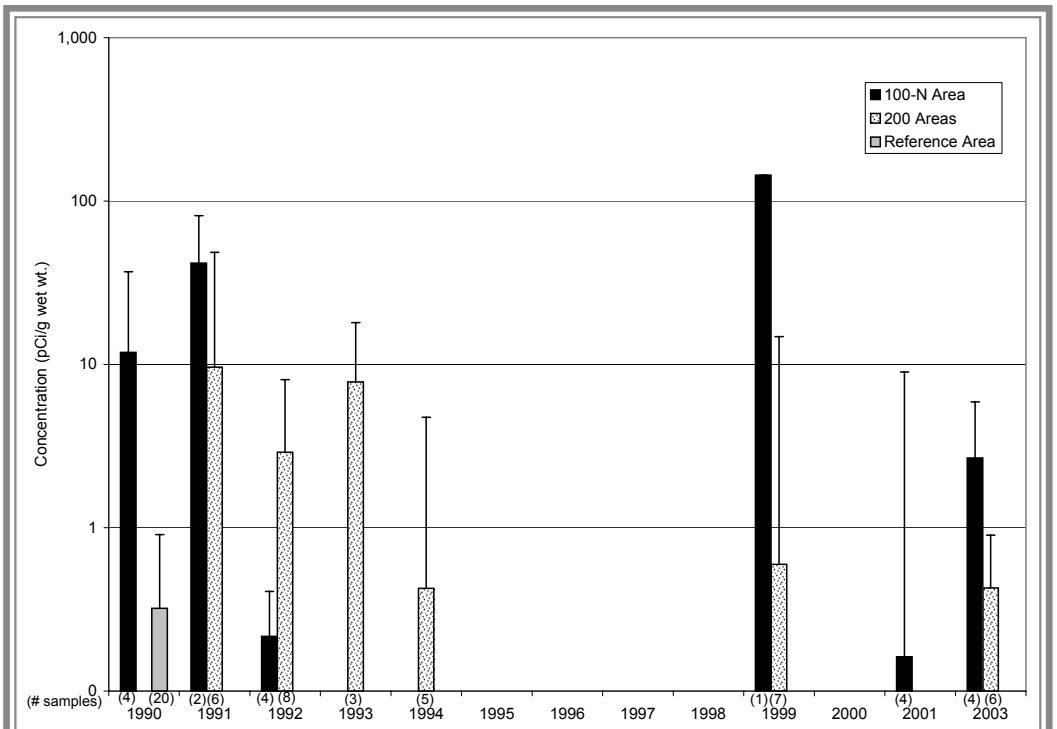


Figure 4.5.4. Median and Maximum Strontium-90 Concentrations (pCi/g wet wt.) in Hanford Site and Background Rabbit Samples, 2003 Compared to Previous Years. Maximum concentrations are represented by the upper bar.

be near the current DOE dose limit of 0.1 rad (0.0008 Gy) per day for ecological receptors such as rabbits (Chapter 5).

4.5.2 Sentinel Organisms

For environmental monitoring purposes, biological organisms can be used to (1) detect and quantify contaminants in a given ecosystem (sentinel organisms) and (2) indicate damage or injury to an ecosystem (indicator organisms). Organisms that are best suited for accumulating contaminants and serving as biological monitors of environmental contaminants are termed "sentinel species," whereas organisms (or defined assemblages of organisms) that are sensitive to damage or injury from elevated levels of environmental contaminants are referred to as "indicator species." In practice, the desirable features of both the sentinel and indicator species are often found only in a limited number of organisms present in the ecosystem. The organisms chosen for monitoring environmental health often have both sentinel and indicator species attributes.

Asiatic clams may be one of the best sentinel organisms along the Hanford Reach of the Columbia River for DOE cleanup and monitoring objectives on the Hanford Site. This organism is relatively immobile its entire life (0 to 3 years), lives in shallow shoreline areas, is a filter-feeder that feeds on phytoplankton, and is common along the Hanford Reach shoreline. These habitat and food source preferences make this organism an ideal candidate for monitoring contaminants in groundwater seeping into the Columbia River via shoreline springs. Samples of Asiatic clams were collected along the Hanford Reach during November 2002 through March 2003 to evaluate the usefulness of this species as a sentinel organism for monitoring the spatial patterns of Hanford radiological and non-radiological contaminants entering the Columbia River environments.

Sampling points were selected near the river's low-water mark, which was visually identified by the presence of persistent periphyton colonies growing on bottom substrates (during portions of the year, periphyton dries out above the low-water mark). Clam samples were collected from this point along a transect extending into the river perpendicular to the shoreline at standard water depths of 0.25 meter (0.8 foot), 0.5 meter (1.6 feet), 1 meter (3.3 feet), and 1.5 meters (4.9 feet).

Clam samples were flash-steamed for approximately 15 to 30 seconds using deionized water and shell tissues were separated from soft tissues. Shells taken from a number of individual clams from each sampling site were composited for strontium-90 and technetium-99 analyses. Soft tissues (from 2 to 50 organisms per sample) were composited and analyzed for a number of trace metals, including chromium, mercury, and uranium.

Crayfish and sculpin samples were also collected during 2003 from a reference region upstream of the Hanford Site and were analyzed for gamma-emitting radionuclides, strontium-90, technetium-99, and trace metals. A number of individuals were composited (5 to 25 individuals) for the radionuclide analyses. Liver samples from sculpins and hepatopancreas samples from crayfish were analyzed for trace metals.

4.5.2.1 Asiatic Clam Sample Results and Analytes of Interest

Concentrations of most metals and radionuclides in Hanford Reach clam samples were at or below levels found in samples collected upstream of the Hanford Site near the Vernita Bridge. Chromium concentrations were consistently elevated compared to concentrations at the Vernita Bridge (Table 4.5.2). The tissue burdens of chromium reported in clams indicate the highest exposures generally occurred in the shallowest areas and decreased as water depth increased. The few exceptions appeared to occur in areas where shorelines were relatively steep.

Strontium-90 levels in shells were highest near the 100-N and 100-H Areas, respectively (Figure 4.5.5). Technetium-99 was found in shell samples near the 100-B/C and 300 Areas at levels that were elevated compared to levels in samples collected from the upstream reference area.

4.5.2.2 Crayfish Sample Results and Analytes of Interest

Five samples of crayfish tissue were collected during 2003 and analyzed for gamma-emitting radionuclides, strontium-90, and technetium-99. Gamma-emitting radionuclides were not found above the minimum detectable activity (0.05 pCi/g [0.002 Bq/g] wet weight) in any sample. All five samples contained measurable quantities of strontium-90 with concentrations between 0.09 and 0.13 pCi/g [0.003 and 0.005 Bq/g] wet weight. Technetium-99 was not detected in any of the crayfish samples. These results indicate that crayfish may be a useful sentinel organism because they contained measurable

Table 4.5.2. Trace Metals (ppm dry wt.) and Radionuclides (pCi/g wet wt.) in Columbia River Asiatic Clams,[a] Hanford Reach Samples Compared to Reference Area Samples Collected Upstream of the Vernita Bridge, 2001-2003

Sampling Locations	Trace Metals										Radionuclides	
	Silver	Aluminum	Arsenic	Barium	Beryllium	Cadmium	Chromium	Copper	Mercury		Strontium-90	Technetium-99
100-B/C Area												
100-K Area												
100-N Area												
100-D Area												
100-H Area												
100-F Area												
Hanford town site												
300 Area												
	Nickel	Manganese	Lead	Antimony	Selenium	Thorium	Thallium	Uranium	Zinc			
100-B/C Area												
100-K Area												
100-N Area												
100-D Area												
100-H Area												
100-F Area												
Hanford town site												
300 Area												

(a) Metals analyses on soft tissues and radiological analyses on shells.

	Maximum concentrations in Hanford Reach samples below maximum concentrations reported from reference area.
	Maximum concentrations in Hanford Reach samples between 1 and 2 times the maximum concentrations reported in reference area samples.
	Maximum concentrations in Hanford Reach samples between 2 and 5 times the maximum concentrations reported in reference area samples.
	Maximum concentrations in Hanford Reach samples between 5 and 10 times the maximum concentrations reported in reference area samples.
	Maximum concentrations in Hanford Reach samples greater than 10 times the maximum concentrations reported in reference area samples.

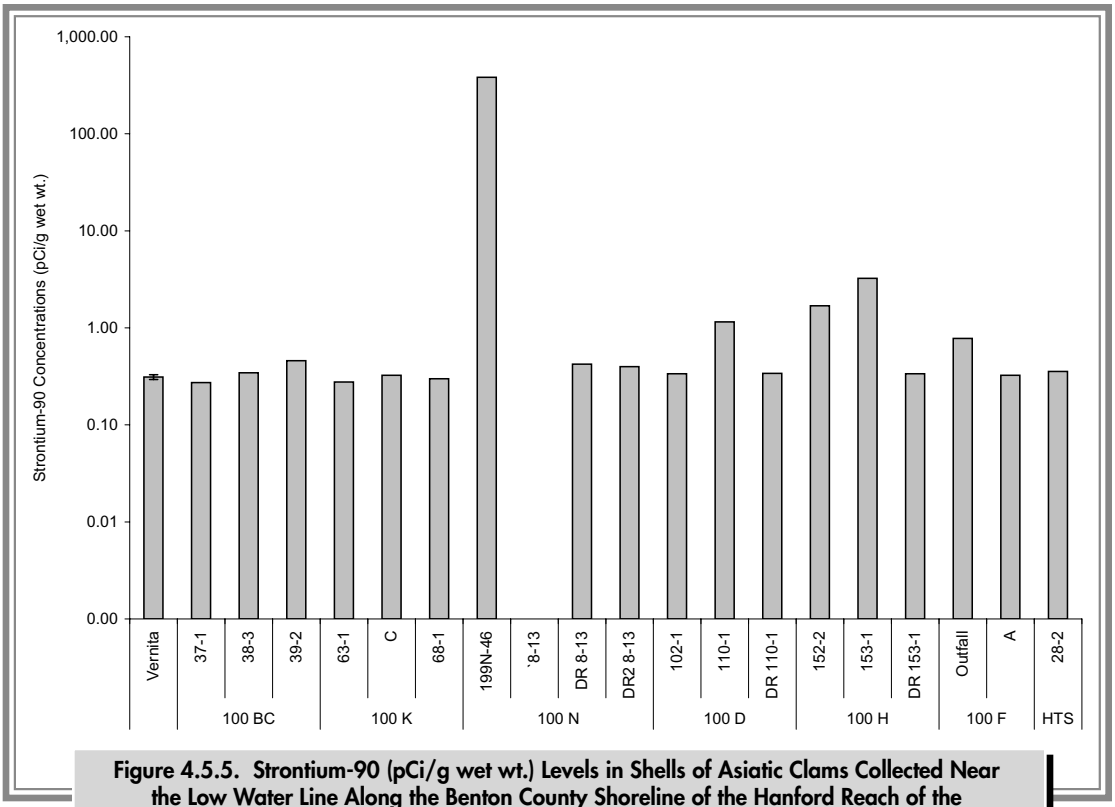


Figure 4.5.5. Strontium-90 (pCi/g wet wt.) Levels in Shells of Asiatic Clams Collected Near the Low Water Line Along the Benton County Shoreline of the Hanford Reach of the Columbia River, 2002-2003

amounts of strontium-90 and the range of results reported was relatively small. Trace metal concentrations in hepatopancreas samples are not discussed in this report because too few samples were analyzed for a valid interpretation.

4.5.2.3 Sculpin Sample Results and Analytes of Interest

Sculpins probably best represent the ideal sentinel fish along the Hanford Reach of the Columbia River because they have relatively small home ranges, eat aquatic insects, dwell on the river bottom, and are abundant. Five sculpin samples were collected and analyzed for gamma-emitting radionuclides, strontium-90, and technetium-99 in 2003. Each sample consisted of a number of individual organisms because the mass required for these analyses was larger than the weight of any individual organism. No gamma-emitting radionuclides were detected in the five samples and neither were strontium-90 and technetium-99. These results provide a baseline for future Hanford-specific assessments. Trace metal results from liver samples are not discussed in this report due to low sample sizes and the variability of the results.

4.5.3 Monitoring DDT, DDD, and DDE in the Vicinity of the Horseshoe Landfill

4.5.3.1 Background

The Horseshoe Landfill is a former CERCLA waste site that is located near the southeast boundary of the Hanford Site and within the boundaries of the Fitzner/Eberhardt Arid Lands Ecology Unit on the Hanford Reach National Monument (Figure 4.5.1). This landfill is about the size of a football field (91 by 49 meters [100 by 53 yards]) and was a solid waste disposal site used by the military in the 1950s and 1960s. The site received commercial-grade pesticides dominated by dichlorodiphenyl trichloroethane

(DDT) and its breakdown products dichlorodiphenyl dichloroethane (DDD) and dichlorodiphenyl dichloroethylene (DDE).

During the 1990s, contaminated soil was removed from the landfill by the U.S. Army Corps of Engineers. Follow-up assessments of ecological risk were conducted at the site by comparing the concentrations of DDT, DDD, and DDE in soil and biota collected near the landfill to Washington State ecological protection guidelines. The assessments (DOE/RL-2002-35) suggested that environmental conditions following soil removal were acceptable.

At the request of tribal governments, the DOE initiated a modest monitoring program at the landfill in 2003. A limited number of soil and biota samples were collected and analyzed to reconfirm concentrations of DDT and its breakdown products DDD and DDE. The results from this landfill sampling effort are compared to results from samples collected from reference locations in 2003 and to results obtained in the original follow-up assessment.

4.5.3.2 Sample Collections

Concentrations of DDT/DDD/DDE were measured in samples of soil, plants, and invertebrates and in the brain tissues of small mammals and birds collected at and near Horseshoe Landfill and from reference areas in 2003 (Figure 4.5.6). Most sampling occurred between June 19 and June 25, 2003. One soil sample was collected on July 30, 2003.

Soil samples were taken with a 7-centimeter (3-inch) diameter, 2.5 centimeters (1 inch) deep, round polyethylene container. A total of seven soil samples were collected at locations at or near the landfill (Figure 4.5.6). Four samples were obtained from the southern portion of the landfill and three samples were from the northern portion. A reference soil sample was also collected near the landfill.

Plant samples (hoary aster [*Machaeranthera canesens*]) were collected using pre-cleaned stainless steel scissors and all sample material was thoroughly rinsed with deionized water before it was placed into the sample containers. Three plant samples were obtained from the south region of the landfill, one sample was collected from the landfill's north region, and two were collected south of the landfill (Figure 4.5.6). A reference sample was also collected near the landfill.

Invertebrate samples (spiders, ants, beetles, and grasshoppers) were collected within a 5-meter (15-foot) radius of an established sampling point using pre-cleaned stainless steel tweezers. Two samples were collected from the south region of the landfill and one was collected from the north region (Figure 4.5.6). An invertebrate sample was also collected at a nearby reference location.

Small mammal samples (Great Basin pocket mouse [*Perognathus parvus*]) were collected using Sherman live traps. Three samples were obtained from Horseshoe Landfill and one was collected from a reference location near the landfill (Figure 4.5.6).

Birds (Western meadowlark [*Sturnella neglecta*] and horned lark [*Eremophila alpestris*]) were collected from the nest or by using a firearm. A Western meadowlark sample was collected from a site located west of the landfill. Reference samples of a horned lark and a Western meadowlark were also collected. No birds were collected on the landfill.

4.5.3.3 Sample Analysis Results

Each soil sample from the southern portion of the landfill contained combined concentrations of DDT and its derivatives of 6.3, 7.3, 9.2, and 19.1 ppm, respectively. These concentrations were 6,000 to 20,000 times greater than the combined concentrations in the sample from the reference site. The combined concentration of DDT and its derivatives in the reference soil sample was less than the nominal analytical detection limit of 0.002 ppm. The three soil samples collected from the northern region of the landfill contained relatively low levels of DDT/DDD/DDE that ranged between 0.01 and 0.09 ppm.

Plant samples obtained on the landfill site contained elevated levels of DDT and its derivatives compared to the concentrations in reference samples and in two samples collected south of the landfill site. The DDT/DDD/DDE concentration in the single vegetation sample collected from the reference area was less than 0.001 ppm (nominal analytical detection limit reported for result). Concentrations of DDT and its derivatives reported in three of the four vegetation samples taken on the landfill ranged between 1.0 and 9.0 ppm, approximately 1,000 to 9,000 times greater than the values seen in vegetation samples collected south of the landfill.

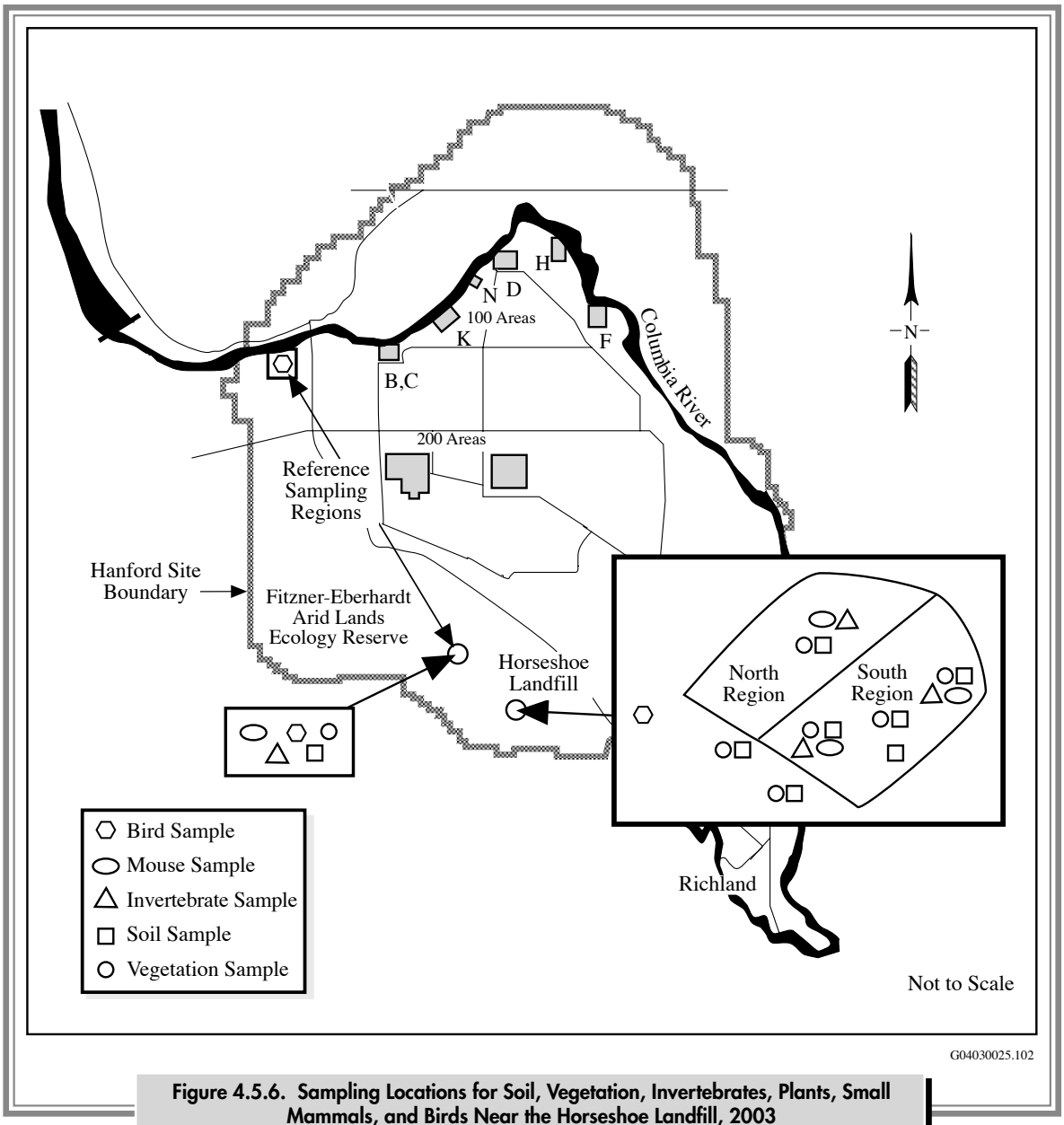


Figure 4.5.6. Sampling Locations for Soil, Vegetation, Invertebrates, Plants, Small Mammals, and Birds Near the Horseshoe Landfill, 2003

Mouse samples from the landfill contained detectable concentrations of DDT and its derivatives; results ranged between 0.01 and 0.95 ppm. These concentrations were from 2 to 188 times greater than the concentrations found in the single mouse sampled at the reference location near the landfill (Figure 4.5.7).

Results from all three invertebrate samples collected from the landfill site contained detectable concentrations of DDT and its derivatives; results ranged between 0.02 and 6.2 ppm. These concentrations were approximately 20 to 6,781 times higher than the concentration in the single invertebrate sample collected at the reference location.

The single Western meadowlark sample collected near the landfill contained 0.85 ppm of DDT and its derivatives compared to 0.03 ppm reported in horned lark and Western meadowlark samples collected from the reference regions.

The greatest concentrations of DDT/DDD/DDE measured in this study were found in invertebrate samples from the south region of the landfill site where the highest concentrations in soil, vegetation, and small mammal samples

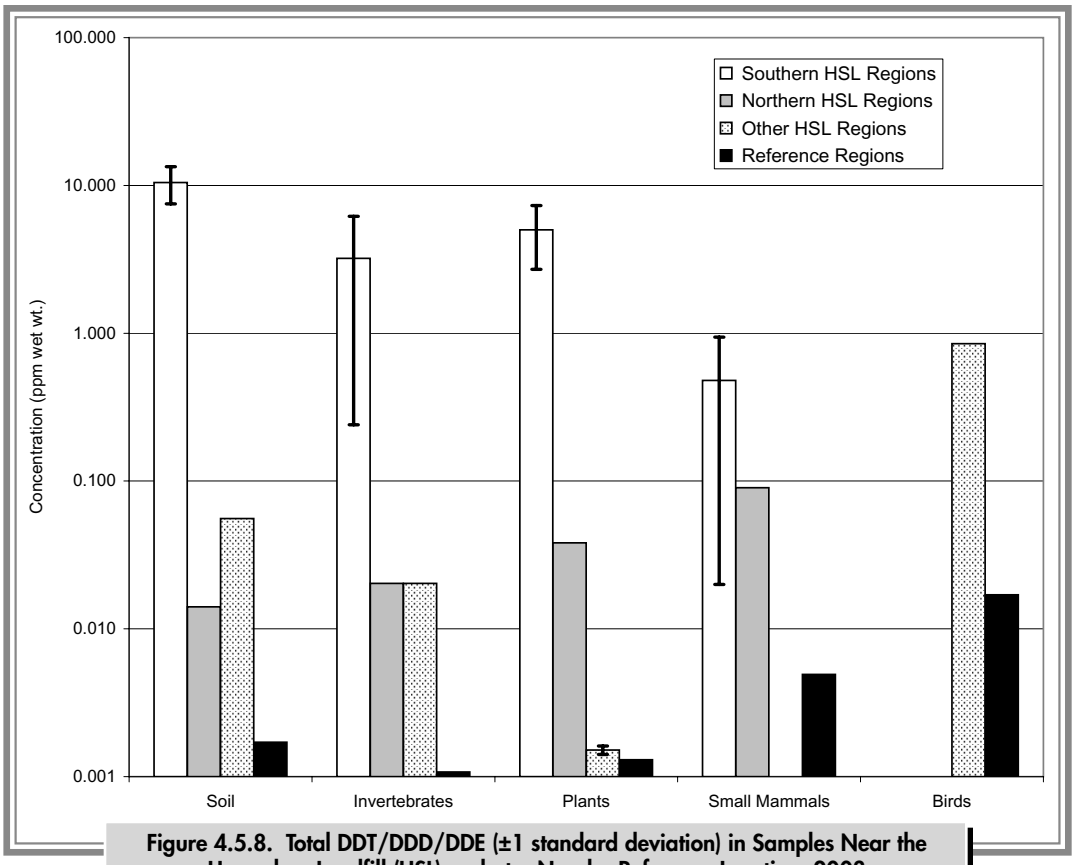


Figure 4.5.8. Total DDT/DDD/DDE (±1 standard deviation) in Samples Near the Horseshoe Landfill (HSL) and at a Nearby Reference Location, 2003

were also measured. Figure 4.5.7 illustrates the propensity of organochloride pesticides such as DDT and its derivatives to accumulate in organisms at the top of the food chain like insect-eating birds such as the Western meadowlark.

Concentrations in soil samples obtained during 2003 were consistent with concentrations measured in the previous assessment in the 1990s. All samples collected from the south region of the landfill had the highest concentrations of DDT/DDD/DDE.

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 to a lesser extent (3) radiation from an airborne component, primarily radon and its progeny. The manmade component consists of radionuclides generated for or from nuclear medicine, electric power, research, waste management, and consumer products containing nuclear materials, e.g., smoke detectors. Environmental radiation fields also may be influenced by the presence of radionuclides deposited as worldwide fallout from historical atmospheric testing of nuclear weapons or those produced and released to the environment at the Hanford Site during the production of defense materials. 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 1975).

During 2003, environmental external radiation exposure was measured at 33 locations on the Hanford Site (Figure 4.6.1), 11 locations around the perimeter of the site, 9 locations in surrounding communities including 2 at distant locations (Figure 4.6.2), and 27 locations along the Columbia River shoreline (Figure 4.6.3) using thermoluminescent dosimeters and pressurized ionization chambers. A pressurized ionization chamber is a stainless steel spherical 8-liter (2.1-gallon) chamber, about the size of a basketball, that is filled to a pressure of 25 atmospheres with ultra-high purity argon gas. Radiation penetrating the chamber wall is captured and converted by instruments to an electric current that can be related directly to an exposure rate. The dosimeter exposure was converted to dose rates by the process described in Appendix E, then the dose rates were divided by the length of time the dosimeter was in the field. Annual results for 2003 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 (CaF_2:Dy) chips and provides both shallow and deep dose measurement capabilities by use of filters within the dosimeter. The two TLD-700 chips were used to determine the average total environmental dose at each location. The average daily dose rate was determined by dividing the average total environmental dose by the number of days the dosimeter was exposed. Daily dose equivalent rates (millirem per day) at each location were converted to annual dose equivalent rates (millirem per year) by averaging the daily 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 used during 2003. Thermoluminescent dosimeters were positioned approximately 1 meter (3.3 feet) above the ground and were collected and read quarterly.

To determine the maximum dose rate for each distance classification, the annual average dose rates, calculated for each location as described above, 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 converted to annual rates.

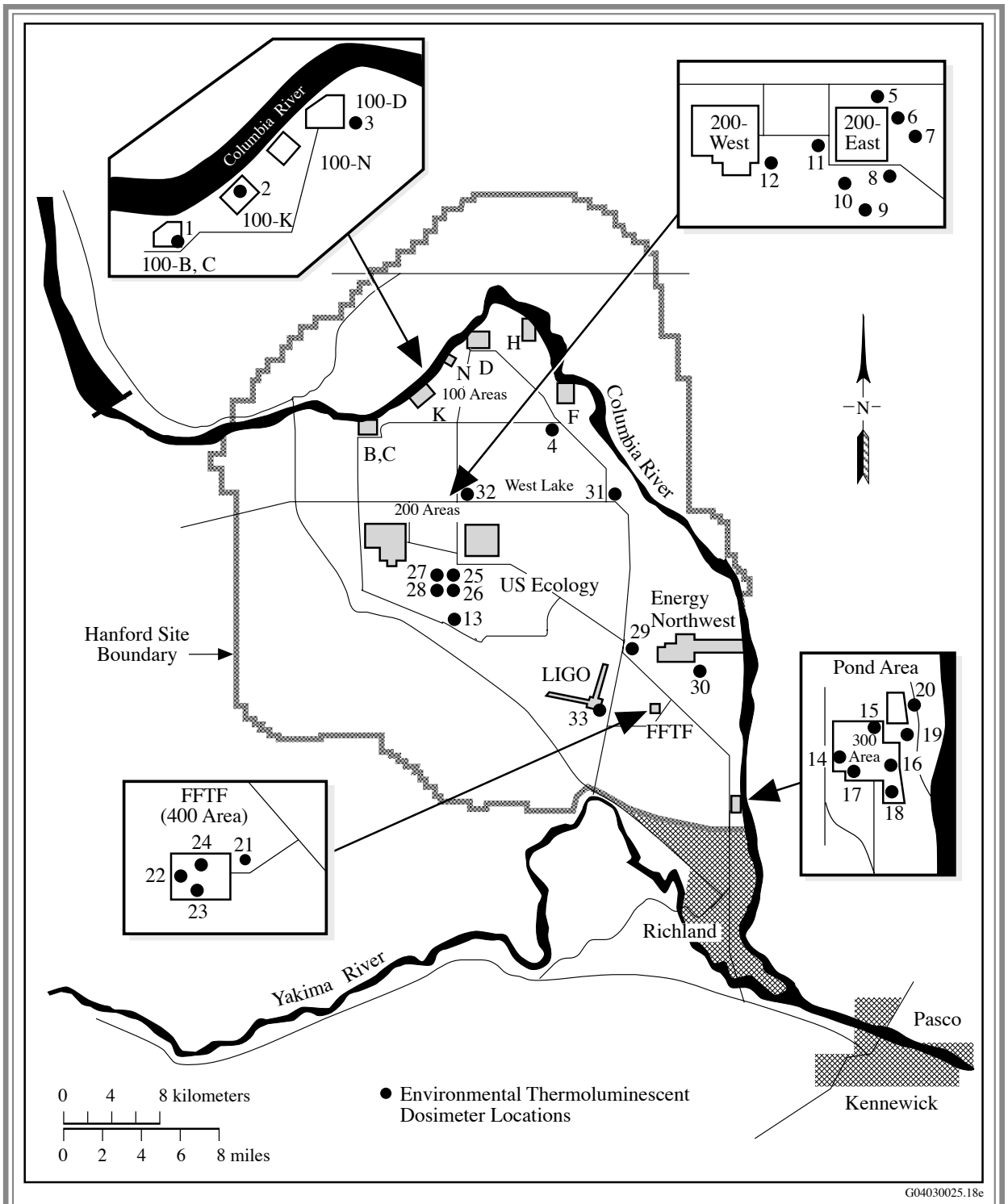


Figure 4.6.1. Surface Environmental Surveillance Project Thermoluminescent Dosimeter Locations (and Station Numbers) on the Hanford Site, 2003 (see Appendix C, Table C.10 for station names)

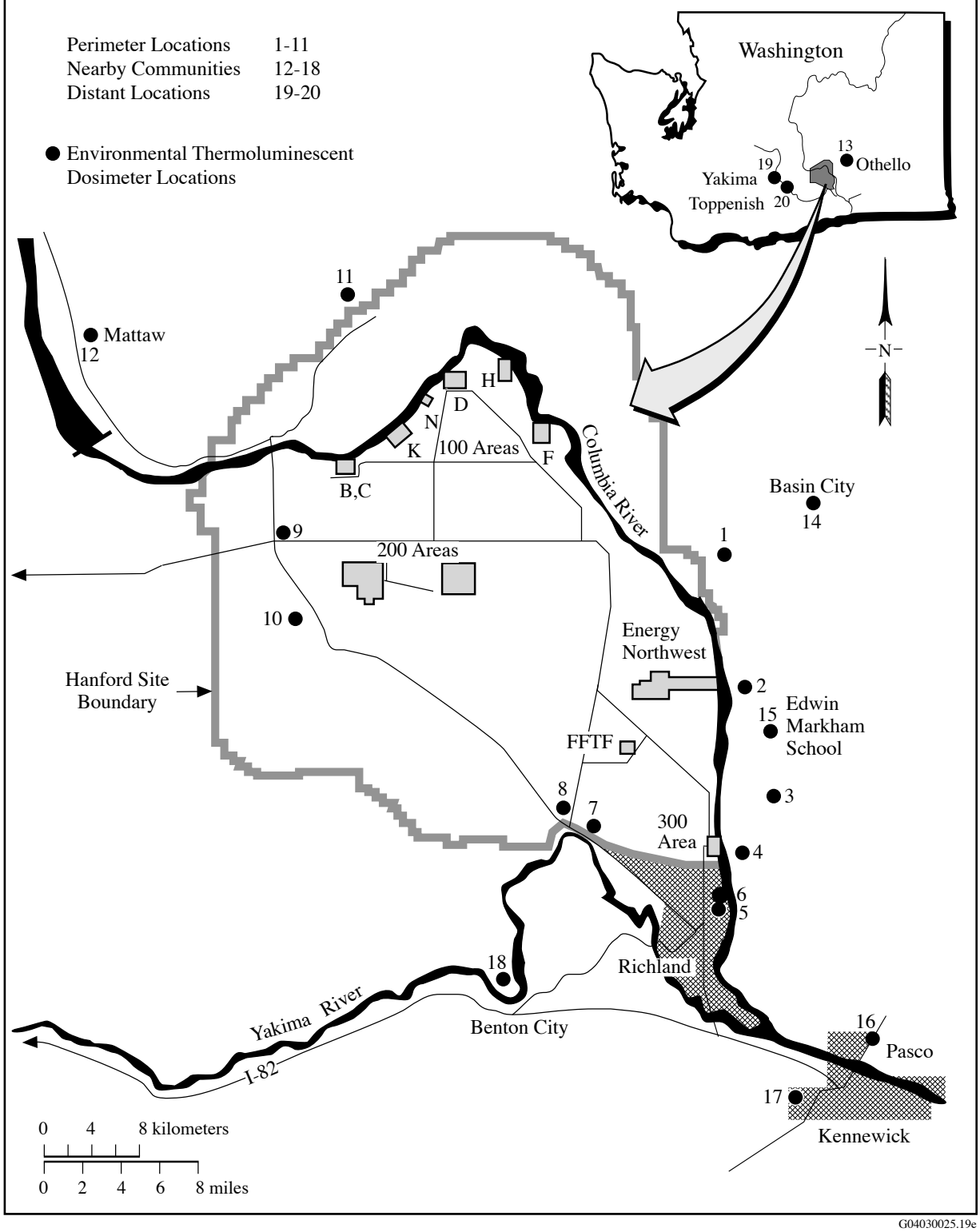


Figure 4.6.2. Community, Distant, and Perimeter Thermoluminescent Dosimeter Locations (and Station Numbers) Around the Hanford Site, 2003 (see Appendix C, Table C.10 for station names)

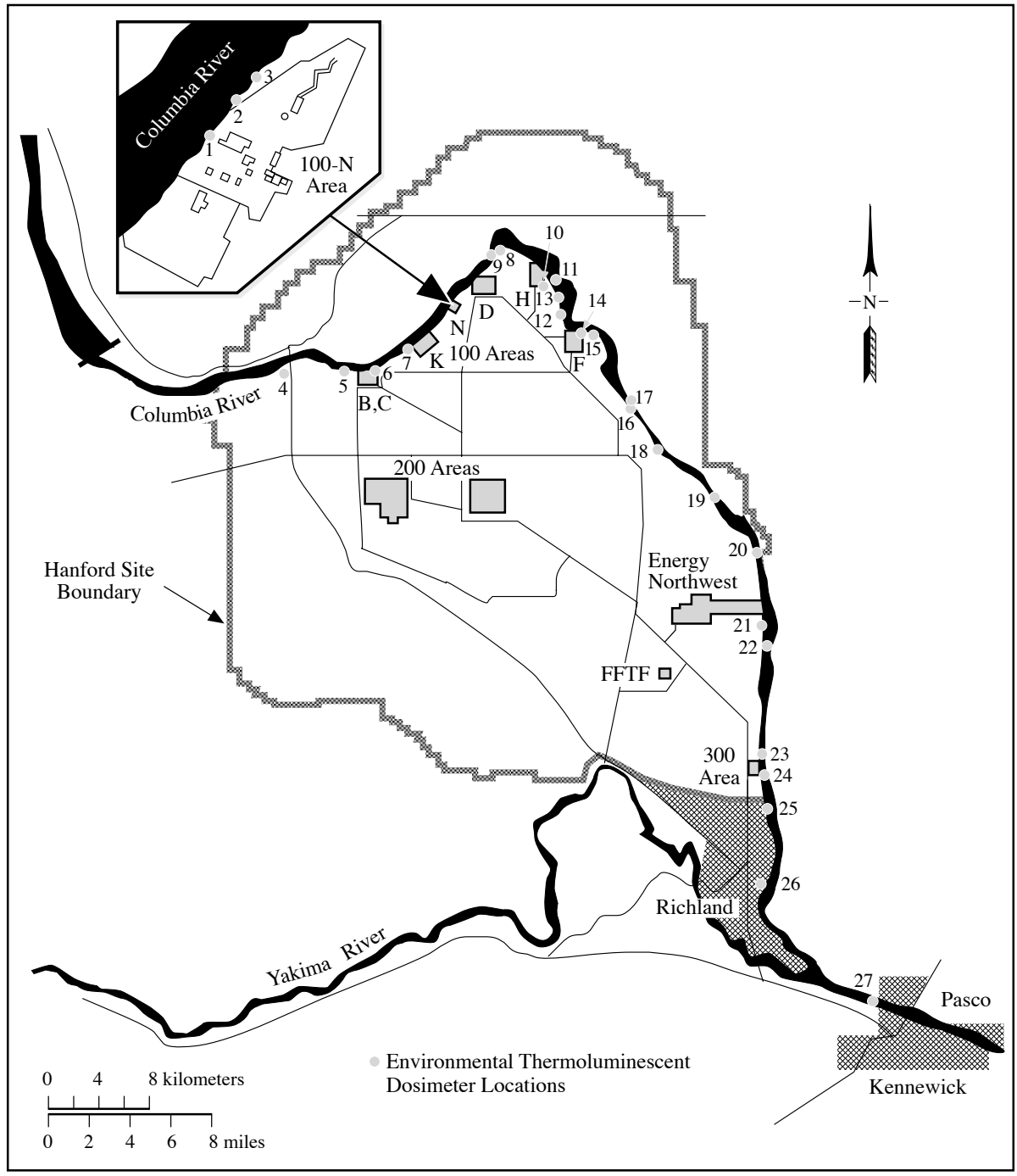


Figure 4.6.3. Hanford Site Surface Environmental Surveillance Project Thermoluminescent Dosimeter Locations (and Station Numbers) Along the Columbia River, 2003 (see Appendix C, Table C.10 for station names)

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 high potential 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 along the Columbia River from the 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 were 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-Mueller meters (Geiger, or GM counters) and Bicron® Microrem meters. Readings were 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. Continuous 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 previously. External dose rates reported in Tables 4.6.1 through 4.6.3 include the maximum annual dose rate (±2 standard deviations) and the average dose rate (±2 standard error of the mean) for all locations within a surveillance zone. Locations were classified (or grouped) based on their location on or their proximity to the Hanford Site.

Onsite External Radiation Results. The average dose rates in all operational areas (Table 4.6.1) were higher than average dose rates measured at distant locations (Table 4.6.2). The highest annual average dose rate measured by Pacific Northwest National Laboratory dosimeters

Table 4.6.1. Dose Rates (mrem/yr[a]) Measured by Thermoluminescent Dosimeters on the Hanford Site, 2003 Compared to Previous 5 Years

		2003		1998-2002		
Location	Map Location[b]	Maximum[c]	Mean[d]	No. of Samples	Maximum[c]	Mean[d]
100 Areas	1 - 4	87 ± 7	81 ± 6	15	88 ± 8	82 ± 3
200 Areas	5 - 13	95 ± 4	87 ± 3	43	98 ± 6	88 ± 1
300 Area	14 - 20	96 ± 8	85 ± 4	31	107 ± 6	84 ± 2
400 Area	21 - 24	86 ± 6	83 ± 2	20	89 ± 7	83 ± 1
600 Area	25 - 33	96 ± 5	86 ± 3	37	128 ± 19	89 ± 3
Combined onsite	1 - 33	96 ± 8	87 ± 3	146	128 ± 19	86 ± 1

(a) Multiply by 10 to convert to μSv/yr.
(b) All station locations are shown on Figure 4.6.2 and are described in Appendix C, Table C.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 a given distance classification (±2 standard error of the mean).

Table 4.6.2. Dose Rates (mrem/yr[a]) Measured by Thermoluminescent Dosimeters at Perimeter and Offsite Locations Around the Hanford Site, 2003 Compared to Previous 5 Years

		2003		1998-2002		
Location	Map Location[b]	Maximum[c]	Mean[d]	No. of Samples	Maximum[c]	Mean[d]
Perimeter	1 - 11	96 ± 3	90 ± 3	55	106 ± 8	90 ± 2
Community	12 - 18	88 ± 5	79 ± 3	39	90 ± 9	79 ± 2
Distant	19 - 20	72 ± 6	72 ± 1	10	75 ± 8	71 ± 1

(a) Multiply by 10 to convert to µSv/yr.
(b) All station locations are shown on Figure 4.6.2 and are described in Appendix C, Table C.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 a given distance classification (±2 standard error of the mean).

Table 4.6.3. Dose Rates (mrem/yr[a]) Measured by Thermoluminescent Dosimeters Along the Shoreline of the Hanford Reach of the Columbia River, 2003 Compared to Previous 5 Years

		2003		1998-2002		
Location	Map Location[b]	Maximum[c]	Mean[d]	No. of Samples	Maximum[c]	Mean[d]
100-N Area shoreline	1 - 3	99 ± 7	94 ± 8	15	152 ± 5	112 ± 10
Typical shoreline	4 - 27	98 ± 5	86 ± 3	109	102 ± 13	87 ± 1
All shoreline	1 - 27	99 ± 7	87 ± 3	124	152 ± 5	90 ± 2

(a) Multiply by 10 to convert to µSv/yr.
(b) All station locations are shown on Figure 4.6.2 and are described in Appendix C, Table C.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 a given distance classification (±2 standard error of the mean).

on the Hanford Site during 2003 (96 ± 8 mrem [0.96 ± 0.08 mSv] was detected at the location on the north side of the 300 Area (location 17 in Figure 4.6.1). The 5-year maximum onsite dose rate (128 ± 19 mrem [1.28 ± 0.19 mSv] per year) was measured during 1999 near the US Ecology low-level waste disposal facility located in the 600 Area, south of the 200 Areas on the Central Plateau.

Offsite and Perimeter External Radiation Results. The average perimeter dose rate was 90 ± 3 mrem (0.90 ± 0.03 mSv) per year in 2003; the maximum was 96 ± 3 mrem (0.964 ± 0.03 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 mrem (1.06 ± 0.08 mSv) per year. The location of the 2003 maximum perimeter dose 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 (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 2003 was 72 ± 1 mrem (0.72 ± 0.01 mSv) per year, which was the same as the average for 2002 (PNNL-14295) and the 5-year average of 71 ± 1 mrem (0.71 ± 0.01 mSv) per year. Onsite and perimeter average dose rates were 15 mrem (0.15 mSv) and 18 mrem (0.18 mSv) per year higher (respectively) than average dose rates measured at distant locations (Figure 4.6.4).

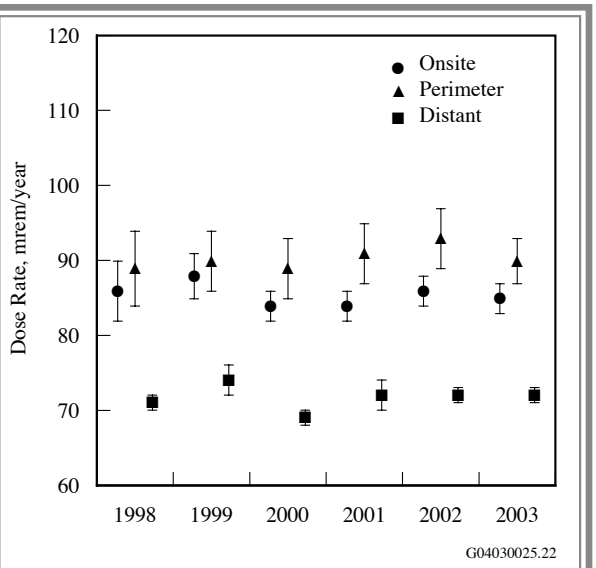


Figure 4.6.4. Annual Average Dose Rates (±2 standard error of the mean) at Onsite, Perimeter, and Distant Locations of the Hanford Site, 1998 through 2003

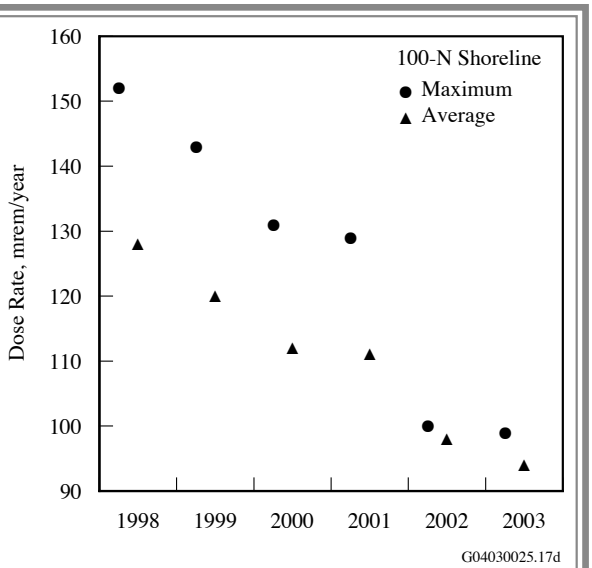


Figure 4.6.5. Maximum and Average External Dose Rates Measured Along the Columbia River at 100-N Area Shoreline Locations on the Hanford Site, 1998 through 2003

Columbia River Shoreline External Radiation Results. During 2003, average dose rates along the Columbia River shoreline near the 100-N Area were approximately 6 mrem (0.06 mSv) per year higher than the average of all other 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 2003 maximum annual 100-N Area shoreline dose rate of 99 ± 7 mrem (0.99 ± 0.07 mSv) is about the same as the maximum of 100 ± 7 mrem (1.00 ± 0.07 mSv) measured in 2002 (PNNL-14295), but is significantly different (i.e., the 95% confidence intervals associated with the two measurements do not overlap) than the 5-year maximum of 152 ± 5 mrem (1.52 ± 0.5 mSv) per year measured during 1998. 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 shore above the high water line but does have boat access to the Columbia River. The dose implications associated with using the Columbia River near the 100-N Area are discussed in Chapter 5.

4.6.2 Radiological Survey Results

During 2003, Bicron® Microrem meters and Geiger counters were used to perform radiological surveys at selected Columbia River shoreline locations. These surveys provided a coarse screening for external radiation fields. The highest dose rate measured with the Bicron® Microrem meter (70 µrem [0.7 µSv] per hour) (approximately 600 mrem per year) 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 the Vernita Bridge (location 4 on Figure 4.6.3) in June. The 70 µrem (0.7 µSv) per hour dose rate is abnormally high, approximately 350% higher than the maximum shoreline survey result reported last year and 700% higher than any other shoreline Bicron® Microrem meter measurement made during 2003. The thermoluminescent dosimeter result for the September 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 (0.004 µSv) per hour, did not agree with the thermoluminescent dosimeter reading obtained at the Vernita Bridge location. 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 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 2003 (Section 7.4). 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 near Toppenish (locations 36, 40, 35, and 44, respectively on Figure 4.1.1). Measurements were collected to determine ambient gamma radiation levels near and downwind of the site and upwind and distant from the site, to display near-continuous exposure rate information to the public living near the station, and for educational information for the teachers who manage the stations.

Data collection systems consisted of computers, data loggers, and modems or radiotelemetry instruments. The computers at Leslie Groves Park and Heritage College were accessed using telephone modems and data were obtained directly from the station. The computers at Edwin Markham Elementary School and Basin City Elementary School were connected by radiotelemetry to a computer at the Hanford Meteorology Station (near the 200-West Area). These data were summarized and posted on the Internet <http://terrassa.pnl.gov:2080/HMS/stamap.htm> (Section 7.4).

Readings at the Leslie Groves Park and Heritage College stations were collected every 5 seconds with a Reuter-Stokes Model RSS-121 pressurized ionization chamber and an average reading was recorded every hour. Data at Basin City and Edwin Markham School were collected every second with a Reuter-Stokes Model RSS-131 pressurized ionization chamber and averaged every 15 minutes. The 15-minute averages were then used to generate a 60-minute average (Table 4.6.4).

Average hourly exposure rates ranged from a maximum of 12.4 μR per hour (26.1 pW/kg per second) at Edwin Markham School during October to a minimum of 2.1 μR per hour (4.4 pW/kg per second) in Leslie Groves Park in November (Table 4.6.4). Monthly mean readings were consistently between 7.6 and 8.8 μR per hour (16.0 and 18.6 pW/kg per second) at the stations near Hanford, and ranged between 7.9 and 8.6 μR per hour (16.7 and 18.1 pW/kg per second) at the distant station (Heritage College). These average exposure rates were similar to exposure rates measured at these locations in past years and by thermoluminescent dosimeters located at or near these locations in 2003 (Table 4.6.5). One μR per hour is approximately equal to 1 microrem per hour.

Table 4.6.4. Exposure Rates[a] Measured by Pressurized Ionization Chambers at Four Locations Around the Hanford Site,[b] 2003

Month		Exposure Rate, µR/h[c] (number of hourly averages)							
		Leslie Groves Park[d]		Basin City[e]		Edwin Markham[e]		Toppenish[d]	
January	Mean	8.76	(744)	7.7	(715)	7.76	(717)	ND[f]	
	Maximum	10.15		9.9		9.7		ND	
	Minimum	8.33		7.3		7.3		ND	
February	Mean	8.75	(672)	7.7	(616)	7.8	(616)	8.29	(544)
	Maximum	10.70		9.6		10.4		9.34	
	Minimum	8.31		7.4		7.4		7.66	
March	Mean	8.63	(744)	7.8	(615)	7.83	(597)	8.20	(742)
	Maximum	9.28		8.5		8.6		9.38	
	Minimum	6.98		7.5		7.5		7.64	
April	Mean	8.63	(720)	7.82	(730)	7.74	(720)	8.36	(721)
	Maximum	9.95		9.7		9.2		9.41	
	Minimum	7.28		7.5		7.4		7.62	
May	Mean	8.49	(744)	7.7	(738)	7.68	(737)	8.13	(708)
	Maximum	10.04		10.0		10.9		9.61	
	Minimum	8.14		7.4		7.4		7.54	
June	Mean	ND		7.73	(680)	7.65	(699)	8.02	(361)
	Maximum	ND		8.7		8.7		9.9	
	Minimum	ND		7.3		7.4		7.5	
July	Mean	ND		7.75	(719)	7.63	(733)	7.86	(714)
	Maximum	ND		8.6		7.9		9.86	
	Minimum	ND		7.5		7.4		7.50	
August	Mean	ND		7.78	(738)	7.71	(742)	7.91	(744)
	Maximum	ND		8.5		8.6		9.6	
	Minimum	ND		7.4		7.3		7.5	
September	Mean	ND		7.73	(653)	7.82	(656)	8.22	(691)
	Maximum	ND		8.2		8.8		10.00	
	Minimum	ND		7.4		7.5		7.48	
October	Mean	8.59	(177)	7.77	(613)	7.88	(636)	8.60	(744)
	Maximum	9.13		8.5		12.4		10.40	
	Minimum	8.21		7.3		7.3		7.50	
November	Mean	8.80	(672)	7.93	(683)	7.87	(58)	8.51	(722)
	Maximum	9.77		8.5		8.0		9.71	
	Minimum	2.08		7.6		7.7		7.89	
December	Mean	8.67	(741)	7.86	(712)	7.61	(316)	8.30	(745)
	Maximum	9.94		9.2		8.7		10.20	
	Minimum	5.11		7.3		7.2		7.64	

(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 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 at Toppenish. Detector removed for re-calibration at Leslie Groves Park.

Table 4.6.5. Quarterly Average Exposure Rates (μR/h[a,b]) Measured by Thermoluminescent Dosimeters at Four Locations Around the Hanford Site,[c] 2003

	Leslie Groves Park[d]	Basin City	Edwin Markham	Toppenish
Quarter Ending				
March	8.50 ± 0.13	8.75 ± 0.21	8.67 ± 0.00	7.79 ± 0.17
June	8.58 ± 0.42	8.83 ± 0.33	8.96 ± 0.29	8.21 ± 0.21
September	8.75 ± 0.17	[e]	8.67 ± 0.25	8.38 ± 0.08
December	8.58 ± 0.17	[e]	9.04 ± 0.75	8.63 ± 0.17

(a) ± 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 map location 26, Figure 4.6.3.
(e) Dosimeter missing.

4.7 References

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5.0 Potential Radiological Doses from 2003 Hanford Site Operations

E. J. Antonio, L. H. Staven, and K. Rhoads

Potential radiological doses to the public and selected biota from Hanford Site operations were evaluated during 2003 to determine compliance with applicable regulations, standards, and U.S. Department of Energy (DOE) limits. The potential sources of radionuclide contamination included gaseous and particulate emissions from stacks and ventilation exhausts, contaminated fugitive dust, liquid effluent from operating wastewater treatment facilities, and contaminated groundwater seeping into the Columbia River. The methods used to calculate the potential doses are presented in Appendix E.

The radiological impact of 2003 Hanford Site operations was assessed in terms of the following criteria:

- Dose to a hypothetical, maximally exposed individual at an offsite location using an all pathways assessment (DOE Order 5400.5; Section 5.0.1).
- Collective dose to the population residing within 80 kilometers (50 miles) of active areas on the Hanford Site (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 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 5.0.4.4).
- 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 2003 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 not possible to separate the contributions from Hanford sources from the contributions from fallout and from naturally occurring uranium and its decay products. As a consequence, offsite doses were estimated using release estimates of individual radionuclides and the GENII computer code (*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-14687, APP. 1. As a comparison, air surveillance data were used to assess the maximum inhalation doses at onsite and offsite monitoring stations.

Radiological doses associated with the water pathway were calculated based on the differences in radionuclide concentrations between upstream and downstream sampling points on the Columbia River. During 2003, tritium, technetium-99, iodine-129, and uranium isotopes were found in the Columbia River downstream of Hanford at higher levels than predicted based on direct discharges from the 100-K Area permitted outfall (Section 4.2 and Appendix C). 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 6.0.3). No direct discharge of radioactive materials from the 300 Area to the Columbia River was reported during 2003.

5.0.1 Maximally Exposed Individual Dose (Offsite Resident)

The maximally exposed individual is a hypothetical person who is postulated to live at a particular location and have a lifestyle that makes it unlikely that any other member of the public would have received a higher radiological dose from Hanford releases during 2003. This individual's exposure pathways were chosen to maximize the combined doses from all reasonable environmental routes of exposure to radionuclides originating from the Hanford Site using an all pathways assessment (DOE Order 5400.5). In reality, it would be unreasonable to assume that such a combination of maximum values would apply to the exposure pathways for any individual in the Hanford environs.

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 2003, the dose assessment determined that the maximally exposed individual was located across the Columbia River (east of the Hanford Site) at Sagemoor (Figure 5.0.1). For the calculation, the following assumptions for this individual was used:

- Was submersed in and inhaled 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 taken 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 2003, the all pathway dose to the maximally exposed individual at Sagemoor was calculated to be 0.06 mrem (0.6 μSv) per year (Table 5.0.1). This dose was

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 the 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.

The 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.

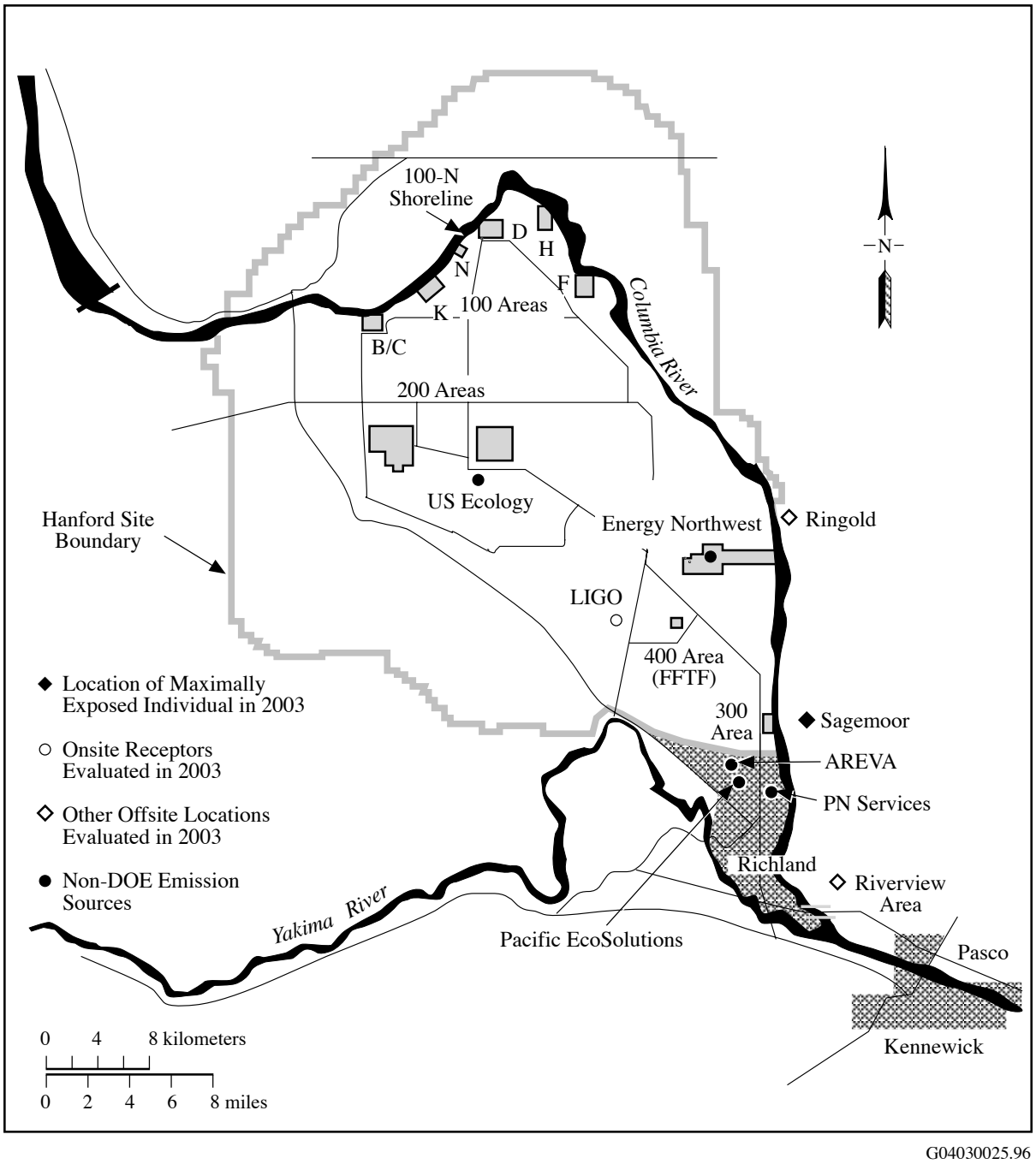

Figure 5.0.1. Locations Important to Dose Calculations at the Hanford Site

Table 5.0.1. Dose to the Hypothetical, Maximally Exposed Individual Residing at Sagemoor from 2003 Hanford Site Operations

		Dose Contributions from Operating Areas, mrem				
Effluent	Pathway	100 Areas	200 Areas	300 Area	400 Area	Pathway Total
Air	External	5.3×10^{-9}	1.7×10^{-7}	6.3×10^{-5}	1.6×10^{-8}	6.3×10^{-5}
	Inhalation	8.4×10^{-6}	6.8×10^{-5}	1.5×10^{-2}	2.5×10^{-6}	1.5×10^{-2}
	Foods	1.4×10^{-7}	8.2×10^{-5}	7.4×10^{-4}	4.8×10^{-6}	8.3×10^{-4}
	Subtotal air	8.5×10^{-6}	1.5×10^{-4}	1.6×10^{-2}	7.3×10^{-6}	1.6×10^{-2}
Water	Recreation	6.2×10^{-7}	1.1×10^{-4}	0.0[a]	0.0	1.1×10^{-4}
	Foods	3.2×10^{-4}	3.1×10^{-2}	0.0	0.0	3.1×10^{-2}
	Fish	2.6×10^{-4}	7.7×10^{-3}	0.0	0.0	8.0×10^{-3}
	Drinking water	0.0	0.0	0.0	0.0	0.0
	Subtotal water	5.8×10^{-4}	3.9×10^{-2}	0.0	0.0	3.9×10^{-2}
Combined total		5.9×10^{-4}	3.9×10^{-2}	1.6×10^{-2}	7.3×10^{-6}	5.5×10^{-2}

(a) Zeros indicate no dose contribution to maximally exposed individual through water pathway.

0.06% of the DOE's all pathway dose limit of 100 mrem (1 mSv) per year (Figure 5.0.2.). The principal pathways contributing to this dose and the percentage of the total dose the pathway represents are listed below:

- Consumption of foods irrigated with water withdrawn downstream of Hanford (56%).
- Consumption of fish from the Columbia River (14.5%).
- Inhalation of air downwind of Hanford (27%).
- Consumption of food products grown downwind of Hanford (1.5%).

5.0.2 Collective Dose

The regional collective dose from 2003 Hanford Site sources was estimated by calculating the radiological dose to the population residing within an 80-kilometer (50-mile) radius of onsite facilities. During 2003, the collective dose calculated for the population was 0.5 person-rem (0.005 person-Sv) per year, slightly higher than the 2002 collective dose (0.3 person-rem [0.003 person-Sv]) per year (Table 5.0.2) (Appendix E, Tables E.5 to E.9). Using the EPA's factor of 0.0006 latent cancer fatalities per person-rem, no fatalities would be expected from the 2003 collective population dose.

Primary pathways contributing to the 2003 collective dose included

- The consumption of water withdrawn from the Columbia River (42%).
- The inhalation of radionuclides (38%) that were released to the air.
- The consumption of foodstuffs (13%) contaminated with radionuclides.

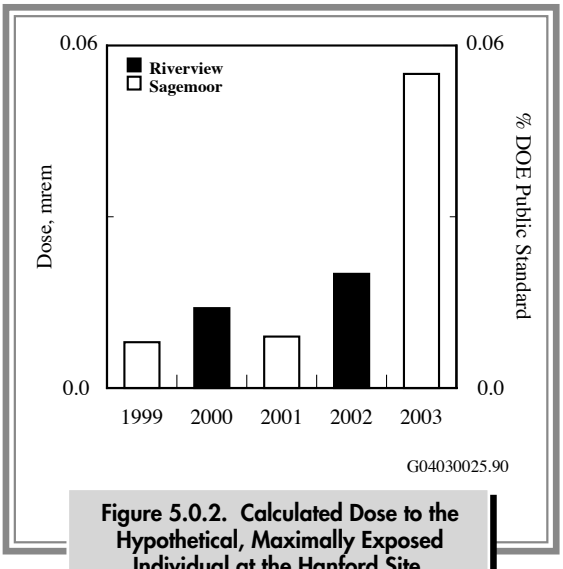

Figure 5.0.2. Calculated Dose to the Hypothetical, Maximally Exposed Individual at the Hanford Site, 1999 through 2003

Table 5.0.2. Collective Dose to the Population from 2003 Hanford Site Operations

		Dose Contributions from Operating Areas, person-rem				
Effluent	Pathway	100 Areas	200 Areas	300 Area	400 Area	Pathway Total
Air	External	8.8×10^{-7}	1.7×10^{-5}	1.1×10^{-3}	8.2×10^{-7}	1.1×10^{-3}
	Inhalation	2.1×10^{-3}	1.0×10^{-2}	1.8×10^{-1}	1.8×10^{-4}	1.9×10^{-1}
	Foods	3.8×10^{-5}	1.2×10^{-2}	5.2×10^{-2}	6.0×10^{-4}	6.5×10^{-2}
	Subtotal air	2.1×10^{-3}	2.2×10^{-2}	2.3×10^{-1}	7.8×10^{-4}	2.6×10^{-1}
Water	Recreation	4.7×10^{-6}	6.3×10^{-4}	0.0[a]	0.0	6.3×10^{-4}
	Foods	3.3×10^{-4}	2.9×10^{-2}	0.0	0.0	2.9×10^{-2}
	Fish	9.7×10^{-5}	2.9×10^{-3}	0.0	0.0	3.0×10^{-3}
	Drinking water	8.0×10^{-4}	2.1×10^{-1}	0.0	0.0	2.1×10^{-1}
	Subtotal water	1.2×10^{-3}	2.4×10^{-1}	0.0	0.0	2.4×10^{-1}
Combined total		3.4×10^{-3}	2.6×10^{-1}	2.3×10^{-1}	7.8×10^{-4}	5.0×10^{-1}

(a) Zeros indicate no dose contribution to the population through the water pathway.

Collective population doses reported for 2003 are based on population data from the 2000 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.

The average estimated individual dose from 2003 Hanford Site operations based on a population of 486,000 within 80 kilometers (50 miles) was 0.001 mrem (10 nSv) per year.

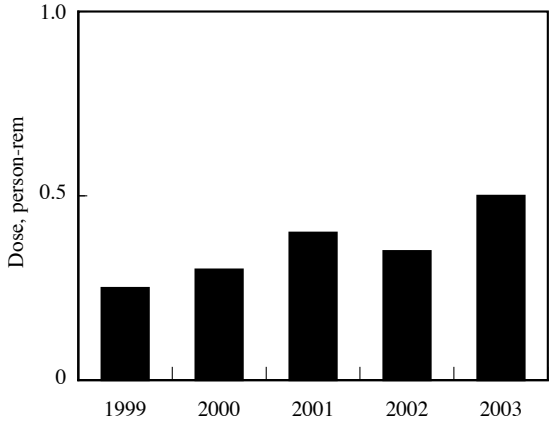

Figure 5.0.3. Collective Dose to the Population within 80 Kilometers (50 Miles) of the Hanford Site, 1999 through 2003

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 and natural radionuclides in the body, nominally approximately 100 mrem (1 mSv) per year (Figure 5.0.4). The estimated average individual dose to members of the public from Hanford Site sources during 2003 was approximately 0.0003% of the estimated annual individual dose received from natural background sources (300 mrem [3 mSv]). The calculated radiological doses from Hanford Site operations in 2003 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 the DOE uses the GENII computer code at Hanford to determine dose to the all-pathways maximally exposed

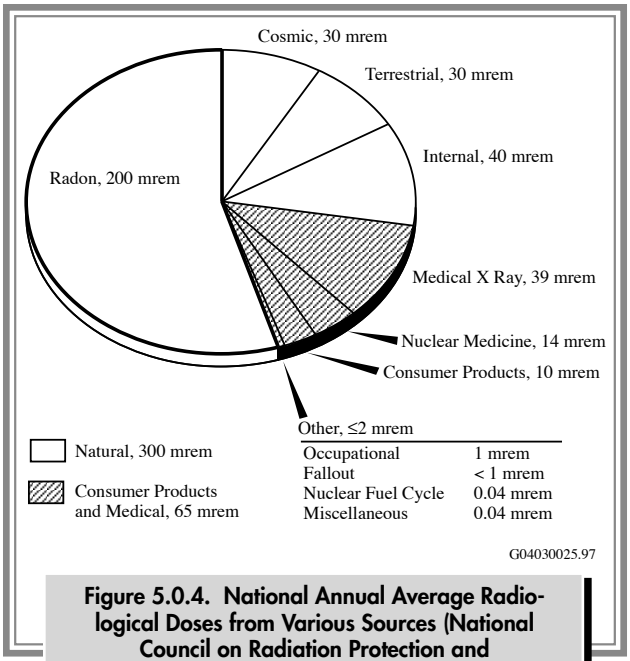

Figure 5.0.4. National Annual Average Radiological Doses from Various Sources (National Council on Radiation Protection and Measurements 1987)

individual, the 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 the EPA that supplies information about atmospheric emissions for the preceding year and their potential offsite dose. For more detailed information about 2003 air emissions on the Hanford Site, refer to the DOE's report to the EPA (DOE/RL-2004-09).

Maximum Dose to an Offsite Maximally Exposed Individual. During 2003, 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, approximately 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 0.022 mrem (0.00022 mSv) per year, which represented less than 0.3% of the EPA standard. This is similar to the offsite individual doses calculated for the EPA in previous years and to the air pathway doses for stack emissions in Table 5.0.1.

Maximum Dose to Non-DOE Workers on the Site. The DOE Richland Operations Office received guidance from the EPA's Region 10 office and 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

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]	0.06 mrem/yr	0.06
EPA - 10 mrem/yr air pathway MEI[d]	0.022 mrem/yr	0.22
Background Dose		
300 mrem/yr average U.S. individual[e]	0.001 mrem/yr	0.0003
144,000 person-rem/yr to population within 80 km (50 mi)	0.5 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).

non-DOE facilities that were outside access-controlled areas on the Hanford Site (those requiring DOE access authorization for entry) were evaluated for the 2003 EPA air emissions report (DOE/RL-2004-09). These locations included the Columbia Generating Station operated by Energy Northwest and the Laser Interferometer Gravitational Wave Observatory (LIGO) operated by the University of California (Figure 5.0.1). Of those locations, an employee at the Columbia Generating Station received the highest dose for non-DOE employees who worked on the Hanford Site. The dose from stack emissions calculated using the CAP-88 code was 0.0035 mrem (0.000035 mSv) per year, assuming full-time occupancy.

EPA guidance does not currently allow for 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 reported for the Columbia Generating Station. In 2003, the estimated doses to non-DOE onsite workers were lower than the doses to offsite individuals for all locations.

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. The DOE and EPA interpreted the regulation to include diffuse and fugitive sources as well as monitored point sources (i.e., stacks). The EPA has not specified or approved standardized methods to estimate air emissions from diffuse sources 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-2004-09). During 2003, the estimated dose from diffuse sources to a maximally exposed individual at a location in the Sagemoor area was calculated using the CAP-88 code to be 0.062 mrem (0.00062 mSv) per year. This is consistent with results for recent years, where the dose from diffuse sources has been greater than the dose from stack emissions because radionuclide emissions from operating Hanford facilities are currently very low. The dose to an onsite non-DOE worker 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 2003 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

Special case dose scenarios that may be of interest include 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 presented 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 2003 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. Use of the Columbia River provides public access to within approximately 100 meters (330 feet) of the N Reactor and supporting facilities at this location. 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.

The highest dose rate along the 100-N Area shoreline during 2003 was approximately 0.011 mrem (0.11 μSv) per hour, or 10% higher than the average dose rate of 0.01 mrem (0.1 μSv) per hour normally observed at other shoreline locations. Therefore, for every hour someone spent near the 100-N Area shoreline during 2003, the external radiological dose received from Hanford operations was approximately 0.001 mrem (0.01 μSv) above the average shoreline dose rate. If an individual had spent 60 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 Sagemoor.

5.0.4.2 Sportsman Dose

Wildlife have access to areas of the Hanford Site that are contaminated with radioactive materials. Hypothetically, wildlife could acquire radioactive contamination and migrate off the site. Wildlife sampling was conducted on the site to estimate the maximum contamination levels that could 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.

Strontium and uranium isotopes were detected in honey samples collected from the East Wahluke Area and the Yakima Valley; however, no difference in strontium-90 concentrations was detected (Section 4.4.5). The East Wahluke area honey sample did have a minute amount of uranium detected (0.004 ± 0.0004 pCi/g). The radiological dose to a person consuming 1 kilogram (2.2 pounds) of the honey containing the maximum measured concentrations of uranium and strontium was calculated to be 0.01 mrem (0.001 mSv). Although honey is not considered wildlife, the consumption of this agricultural product is included here.

The radiological dose to a person consuming 1 kilogram (2.2 pounds) of Canada goose (*Branta canadensis*) breast meat containing the maximum measured concentration of cesium-137 (Section 4.5.1.2) was calculated to be approximately 3 μrem (0.03 μSv). Strontium-90 and cesium-137 were the only radionuclides, possibly of Hanford origin, detected in Canada goose samples during 2003 and strontium-90 was only found in bone samples. Because bone is 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.

The radiological dose to a person consuming 1 kilogram (2.2 pounds) of cottontail rabbit (*Sylvilagus nuttallii*) leg meat containing the maximum concentration of cesium-137 (Section 4.5.1.3) was calculated to be approximately 5 μrem (0.05 μSv). Strontium-90 was found in rabbit bone samples but because bone is 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. Samples of Asiatic clams (*Corbicula fluminea*) and crayfish (*Pacificastus leniusculus*) were also positive for radioactivity (Section 4.52); however, these organisms are not normally consumed by local residents, so a dose calculation for ingestion of these organisms is not reported here.

5.0.4.3 Onsite Drinking Water

During 2003, 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 2003 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 250 working days) would be approximately 0.15 mrem (1.5 μSv). This dose is well below the benchmark drinking water standard of 4 mrem (40 μSv) 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 4.1.1 and 4.1.2). For onsite locations, the exposure period was reduced to 2,000 hours (250 8-hour workdays) 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 average 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 0.066 mrem (0.00066 mSv) at nearby community locations to 0.00000074 mrem (0.0000074 μSv) at the site perimeter. The nearby community results were comparable to doses calculated using a slightly different method associated with the EPA's CAP-88 computer code and reported for the diffuse source calculations (Section 5.0.3).

Table 5.0.4. Calculated Inhalation Doses On and Around the Hanford Site Based on 2003 Average Air Surveillance Data[a]

Radionuclide	Location	Average Air Data (mrem/yr)[b,c]
Tritium	Onsite	9.90×10^{-4}
Iodine-129	Onsite	7.24×10^{-6}
	Perimeter	7.40×10^{-7}
	Distant communities	3.78×10^{-8}
Uranium-234	Nearby communities	3.82×10^{-2}
	Distant communities	2.18×10^{-2}
Uranium-238	Nearby communities	2.82×10^{-2}
	Distant communities	1.91×10^{-2}
Totals	Onsite	9.97×10^{-4}
	Perimeter	7.40×10^{-7}
	Nearby communities	6.64×10^{-2}
	Distant communities	4.10×10^{-2}

(a) Onsite inhalation dose calculations were based on 2,000-hour exposure period and 1.2 m^3/h breathing rate; all offsite inhalation dose calculations were based on a 8,766-hour exposure period and a 0.958 m^3/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.

5.0.5 Doses from Non-DOE Sources

DOE Order 5400.5, Section II, paragraph 7, has a reporting requirement for a combined DOE and other manmade doses that exceeds 100 mrem (1 mSv) per year. During 2003, 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 the site by AREVA; a commercial, low-level, radioactive waste treatment facility operated near the site by Pacific EcoSolutions (formerly Allied Technology Group Corporation); and a commercial decontamination facility operated near the site by PN Services (Figure 5.0.1).

The 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 2003 individual dose from their combined activities was on the order of 0.0023 mrem (0.000023 mSv) per year. Therefore, the combined annual dose from Hanford area non-DOE and DOE sources to a member of the public for 2003 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 limit for dose to 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 were evaluated using the RESRAD-BIOTA computer code (a screening method to estimate radiological doses to aquatic and terrestrial biota). The RESRAD-BIOTA computer code initially compares radionuclide concentrations in soil, water, or sediment measured by routine

surveillance programs to a set of biota concentration guides (e.g., soil or water concentrations that result in a dose rate of 1 rad [10 mGy] per day for aquatic biota or 0.1 rad [1.0 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 mean measured radionuclide concentrations.

For sediment or 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), then the dose guideline has been exceeded and the screening assessment has failed. The second tier of screening, where mean radionuclide concentrations are employed, is then conducted.

The biota concentration guides (DOE-STD-1153-2002) are very different from the DOE derived concentration guides (DOE Order 5400.5) that are used to assess radiological doses to humans. If the estimated screening value exceeds the guideline (Tiers 1 and 2 sum of fractions greater than 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.

Table 5.0.5. Results of RESRAD-BIOTA[a] Screenings at the Hanford Site, 2003

Location	Tier 1 Screen Sum of Fraction	Pass or Fail
100-B Area Spring	0.091	Pass
100-D Area	0.0013	Pass
100-F Area Slough	0.043	Pass
100-F Area Spring	0.073	Pass
100-H Area Spring	0.063	Pass
100-K Area Spring	0.049	Pass
100-N Area	0.0002	Pass
300 Area Springs	0.79	Pass
Hanford Town Site Slough	0.058	Pass
White Bluffs Slough	0.002	Pass
McNary Dam	0.20	Pass
Priest Rapids Dam	0.16	Pass
Richland	0.058	Pass

(a) A screening method to estimate radiological doses to aquatic and terrestrial biota.

During 2003, biota dose assessments were conducted by operational areas (Table 5.0.5) and for special situations.

Maximum concentrations of radionuclides in Columbia River sediment and riverbank spring water were evaluated using the RESRAD-BIOTA computer code. 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 less than 1.0) (Table 5.0.5).

5.0.7 Radiological Dose in Perspective

Two scientific studies (National Research Council 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 recommended 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, for radiation protection purposes, regulatory agencies have prudently assumed that the probability 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 the dose from natural background radiation, which is hundreds of times greater than the dose 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 even suggested that low radiological doses might be beneficial (Sagan 1987). Because cancer may be caused by many agents

other than radon, e.g., genetic defects, immune system suppression, exposure to chemicals, some scientists doubt that the risk from low-level radiation exposure can ever be proven conclusively. In keeping with guidance from the EPA, the DOE uses an occurrence rate of 0.0006 latent cancer fatalities per rem of exposure (EPA 520/1-89-005). Thus, in a population receiving 1,700 person-rem (17 person-Sv), one latent fatal cancer would be predicted to occur. 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). Some activities are considered approximately equal in risk to that from the dose received by the maximally exposed individual from monitored Hanford effluent during 2003 (Table 5.0.7).

Table 5.0.6. Estimated Risk from Various Activities and Exposure[a]

Activity or Exposure Per Year	Risk of Fatality
Smoking 1 pack of cigarettes per day (lung/heart/other diseases)	$3{,}600 \times 10^{-6}$
Home accidents	100×10^{-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)	10×10^{-6}[b]
Flying as an airline passenger (cross-country roundtrip - accidents)	8×10^{-6}[b]
Eating approximately 54 g (4 tbsp) of peanut butter per day (liver cancer)	8×10^{-6}
Pleasure boating (accidents)	6×10^{-6}[b]
Drinking chlorinated tap water (trace chloroform - cancer)	3×10^{-6}
Riding or driving in a passenger vehicle (483 km [300 mi])	2×10^{-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 0.6×10^{-6}
Dose to the maximally exposed individual living near Hanford	0 to 0.02×10^{-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 2003 Maximally Exposed Individual

Driving or riding in a car 8 km (5 mi)
Smoking less than 1/15 of a cigarette
Flying approximately 20 km (12.7 mi) on a commercial airliner
Eating approximately 6 tbsp of peanut butter
Eating one 1.4-kg (48-oz) charcoal-broiled steak
Drinking 8 L (approximately 2.1 gal) of chlorinated tap water
Being exposed to natural background radiation for 96 min in a typical terrestrial location
Drinking approximately 0.14 L (4.8 oz) of wine or 0.4 L (14 oz) of beer

5.0.8 References

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6.0 Groundwater and Vadose Zone

D. R. Newcomer, M. J. Hartman, and R. G. McCain

The U.S. Department of Energy (DOE) has monitored groundwater on the Hanford Site since the 1940s to help determine what chemical and radiological contaminants have made their way into the groundwater. When regulatory requirements for groundwater monitoring increased in the 1980s, some overlap of efforts between various monitoring activities occurred. The DOE established the Groundwater Performance Assessment Project (groundwater project) in 1996 to improve the efficiency of monitoring activities and to assure protection of the public and the environment while improving the efficiency of monitoring activities. The groundwater project was designed to support all groundwater monitoring needs at the site, eliminate redundant sampling and analysis, and establish a cost-effective hierarchy for groundwater monitoring activities. An evaluation of groundwater quality beneath the Hanford Site is documented in an annual groundwater monitoring report (e.g., PNNL-14548).

Plutonium production activities on the Hanford Site produced contaminants that reached the Columbia River by moving down through the vadose zone, into the groundwater, and then into the river. The analysis of groundwater samples helps determine the potential effects that contaminants could have on human health and the environment. The DOE works with regulators, such as the U.S. Environmental Protection Agency (EPA) and Washington State Department of Ecology, to make groundwater cleanup decisions based on sound technical information and the technical capabilities available.

6.0.1 Highlights and Emerging Issues

The DOE's major accomplishments related to groundwater monitoring in 2003, and emerging issues of potential concern, are outlined in the following paragraphs.

6.0.1.1 Groundwater Monitoring Capabilities

Groundwater Sampling – Workers sampled 652 monitoring wells and 48 shoreline aquifer tubes in 2003 to determine the distribution and movement of contaminants in Hanford Site groundwater. Many of the wells were sampled multiple times during the year.

Sample Analyses – One thousand six hundred and twelve samples of Hanford groundwater were analyzed for chromium, 1,170 for nitrate, and 917 for tritium. Other constituents frequently analyzed for included carbon tetrachloride, technetium-99, and uranium, which were analyzed in approximately 580 samples. Summaries that account for the number of all groundwater wells monitored during 2003 according to groundwater interest area and monitoring purpose are provided in Tables 6.0.1 and 6.0.2, respectively.

Adequacy of Monitoring Networks – Groundwater levels in the 200 Areas continued to drop, causing eleven monitoring wells at the Hanford Site to go dry during 2003. Changes in groundwater flow or chemistry also impacted the effectiveness of monitoring networks.

New Wells – The DOE, Washington State Department of Ecology, and EPA agreed to revise a Tri-Party Agreement (Ecology et al. 1989) milestone to allow prioritization of drilling for *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) and *Atomic Energy Act of 1954* wells along with *Resource Conservation and Recovery Act* (RCRA) wells. During 2003, drillers completed seven new RCRA monitoring wells, nine CERCLA wells, and two wells for research on chromate bioremediation.

Table 6.0.1. Summary of Hanford Site Groundwater Performance Assessment Project by Groundwater Interest Area, 2003

	Hanford Site	100-BC-5	100-FR-3	100-HR-3-D	100-HR-3-H	100-KR-4	100-NR-2
Number of wells	700	24	40	67	52	43	37
Number of sampling events	1,749	24	47	277	130	154	58
Number of analyses	20,719	160	354	2,455	801	1,072	988
Number of results	60,510	577	1,407	4,609	1,731	2,776	2,164
Percent of non-detected results	48	42	45	22	27	35	38
	1100-EM-1	**200-BP-5**	**200-PO-1**	**200-UP-1**	**200-ZP-1**	**300-FF-5**	
Number of wells	46	101	82	66	91	51	
Number of sampling events	62	225	171	155	291	155	
Number of analyses	537	5,063	2,952	1,730	3,189	1,418	
Number of results	1,611	12,003	9,004	6,509	11,391	6,728	
Percent of non-detected results	55	46	50	49	50	73	

Table 6.0.2. Summary of Hanford Site Groundwater Performance Assessment Project by Monitoring Purpose,[a] 2003

	Restoration[b]	Waste Management[c]	Environmental Surveillance[d]
Number of wells	433	230	274
Number of sampling events	1,132	681	685
Number of analyses	10,787	11,950	6,831
Number of results	32,509	34,635	19,638
Percent of non-detected results	48	48	47

(a) Because of the co-sampling between groundwater monitoring programs, the wells monitored, sampling events, analyses, results, and non-detectable results overlap between monitoring purposes.
(b) Wells associated with remediation activities.
(c) Wells sampled to determine impacts, if any, to a waste management unit (e.g., RCRA) on groundwater.
(d) Wells sampled to detect impacts, if any, of site operations on groundwater over the entire Hanford Site and adjacent offsite areas.

River Shoreline Monitoring – The DOE monitors aquifer sampling tubes near the Columbia River to track contaminants entering the river. Aquifer sampling tubes are driven into the Columbia River shoreline and used to collect shallow groundwater samples. In late 2003 and early 2004, the DOE installed additional tubes along the river shoreline in the 100-B/C, 100-K, 100-D, 100-H, 100-F, and 300 Areas.

6.0.1.2 Tracking Groundwater Contamination

Site-Wide Tritium Plume – Monitoring in 2003 indicated that the Hanford Site's largest contaminant (tritium) plume is gradually decreasing in size and is not affecting Richland's water-supply wells. The plume is expected to continue to shrink because of dispersion and radioactive decay (half-life of tritium is 12.35 years).

Tritium in the 100-K Area – Tritium concentrations increased in two wells near the KE Basin and in one well near the KW Basin in 2003. However, supporting data indicate that the increases were not due to new leakage from the basins. Investigations of tritium in the vicinity of a burial ground in the 100-K Area indicated the presence of a tritium source in the vadose zone along with an underlying tritium plume in the groundwater.

Chromium in the 100-D Area – Chromium levels continued to increase sharply in the central part of the 100-D Area, between the influences of two interim remedial action systems that operated during 2003. The DOE and the regulators will expand remedial measures to address this change.

Carbon Tetrachloride Plume – A carbon tetrachloride plume beneath the 200-West Area is gradually spreading at the 5-mg/L contour, but the high-concentration portion of the plume appears to be contained. In some monitoring wells, carbon tetrachloride concentrations were higher deep in the aquifer than near the water table. The data indicate that carbon tetrachloride contamination has moved considerable distances downgradient of the source area in deeper parts of the aquifer.

6.0.1.3 Groundwater Operable Units

CERCLA Activities – The groundwater project continued to monitor 11 operable units during 2003 (Figure 6.0.1). Pump-and-treat systems continued to operate at six of the operable units, an in situ remediation system continued to operate at one operable unit, and a soil-gas vapor extraction system continued to operate at one operable unit during 2003 (Figure 6.0.2).

Interim Remedial Actions – Pump-and-treat remediation systems continued to limit the spread of groundwater contamination in the 100 and 200 Areas. Since their inception, remedial measures have treated more than 7 billion liters (1.85 billion gallons) of groundwater to remove carbon tetrachloride, chromium, strontium-90, technetium-99, and uranium. The DOE is evaluating alternative technologies for strontium-90 remediation because no discernable changes in the distribution and concentration of strontium-90 in the aquifer have been observed since the pump-and-treat system began operating in 1995.

Monitored Natural Attenuation – Average trichloroethene concentrations in compliance wells in the 1100-EM-1 Operable Unit (Figure 6.0.1) remained below the 5-µg/L drinking water standard for the third year in a row. This contaminant has been attenuating naturally. Average trichloroethene concentrations also remained below the drinking water standard in the 300-FF-5 Operable Unit, but uranium is slow to attenuate.

CERCLA Sampling and Analysis Plans – The DOE released new plans (DOE/RL-2003-38; DOE/RL-2003-49; DOE/RL-2001-49) for long-term groundwater monitoring in the 100-BC-5, 100-FR-3, and 200-BP-5 Operable Units (Figure 6.0.1) in 2003.

Working Toward Final Remediation Decisions – Final decisions for groundwater remediation have been made only for the 1100-EM-1 Operable Unit. During 2003, the DOE and the regulators began the process to determine what information is needed to make final decisions for the 100-BC-5, 100-FR-3, 200-BP-5, 200-UP-1, 200-ZP-1, 200-PO-1, and 300-FF-5 Operable Units (Figure 6.0.1).

6.0.1.4 Waste Facility Monitoring

RCRA Activities – The groundwater project continued to monitor 24 RCRA sites in 2003 (Figure 6.0.3). Monitoring provided no evidence of new contamination from existing RCRA sites. Seven sites continued to be monitored under assessment programs (i.e., assessment of contaminants that have been detected in groundwater), and two under corrective action (i.e., monitoring during groundwater cleanup activities).

Evaluation of Alternative RCRA Statistical Methods – The groundwater project completed data collection for alternative statistical methods at the 216-B-3 pond and 316-5 process trenches. The alternative statistical methods, which are sensitive to sudden shifts in mean concentrations for each individual well, are used to determine long-term trends.

Other Regulated Units – Four waste disposal sites regulated under state requirements other than the RCRA were monitored in 2003. Monitoring results at the following sites remained within permit limits: 400 Area process ponds, State-Approved Land Disposal Site (located north of 200-West Area), and 200 Area Treated Effluent Disposal Facility (located east of 200-East Area). At the Solid Waste Landfill, specific conductance, pH, chloride, and sulfate exceeded their background threshold levels in one or more samples.

Environmental Restoration Disposal Facility – Concentrations of some constituents of concern were elevated in groundwater beneath this facility in 2003, but reflect migration of contaminant plumes from sources in the 200-West Area. The Environmental Restoration Disposal Facility is located southeast of the 200-West Area.

6.0.1.5 Groundwater Modeling

Site-Wide Groundwater Model – During 2003, development of the site-wide groundwater model focused on calibration based on an alternative conceptual model. The alternative conceptual model defines zones within the

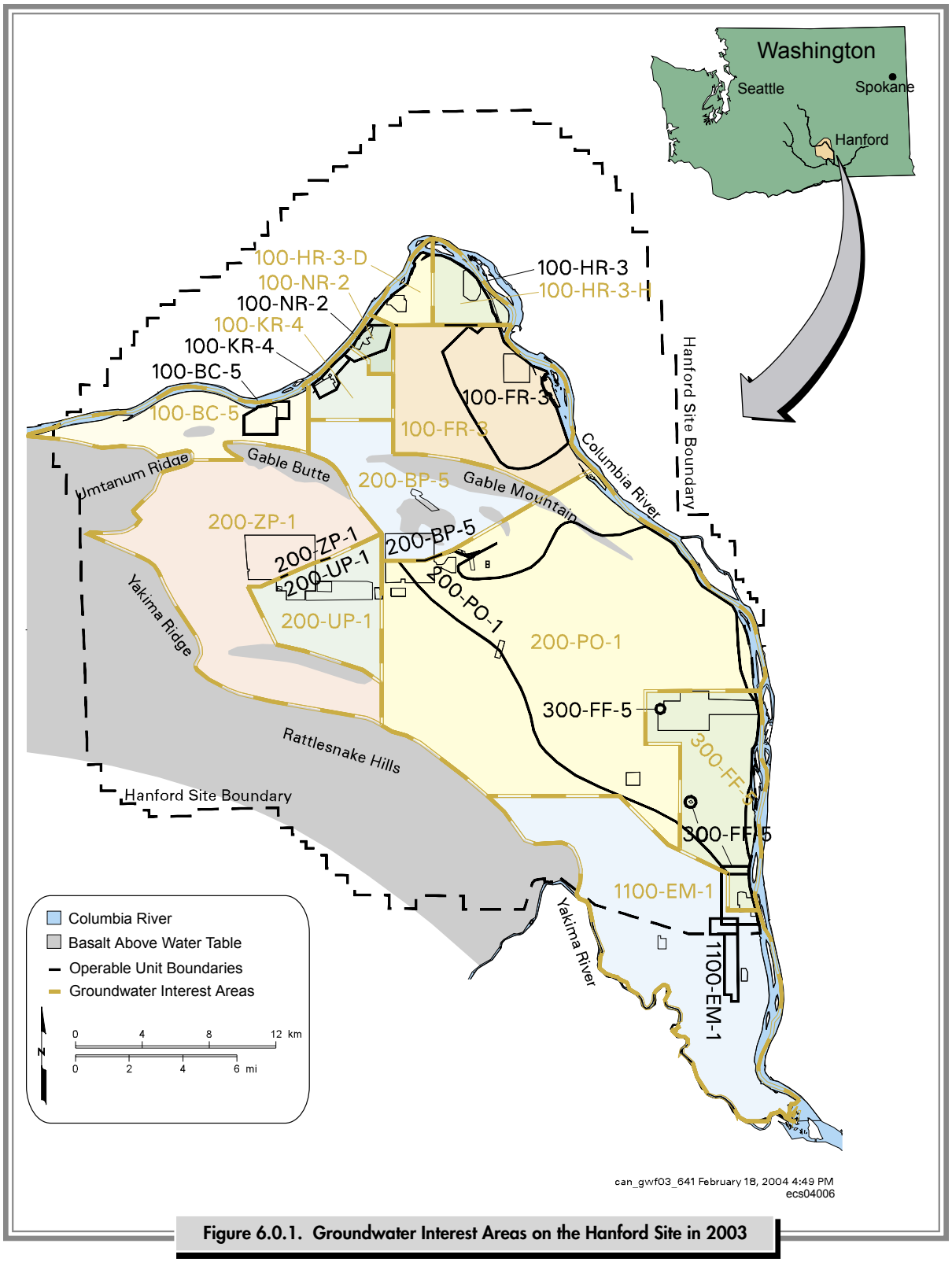

Figure 6.0.1. Groundwater Interest Areas on the Hanford Site in 2003

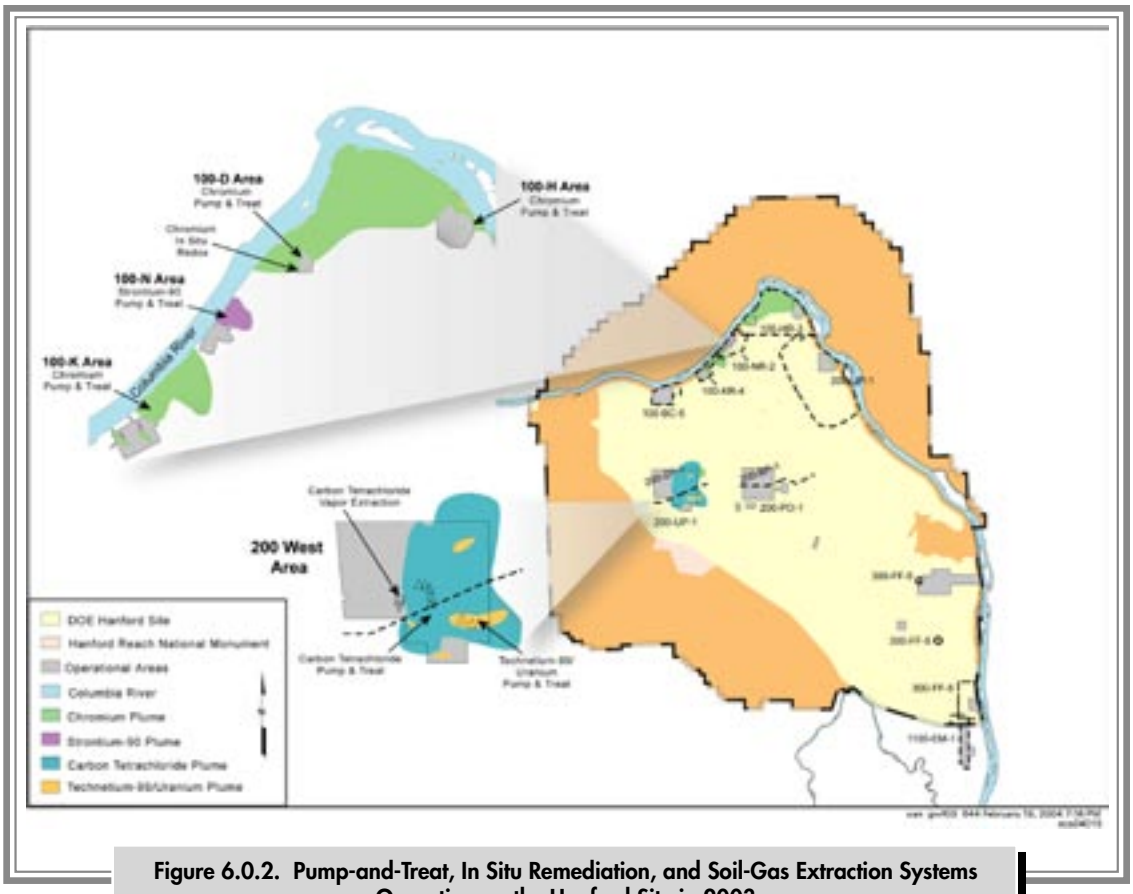

Figure 6.0.2. Pump-and-Treat, In Situ Remediation, and Soil-Gas Extraction Systems Operating on the Hanford Site in 2003

most important transmissive hydrogeologic units based on geologic information, knowledge of depositional environments, aquifer testing information, and hydraulic head responses in wells. The site-wide model was developed to improve predictions of contaminant transport and to evaluate uncertainty in model results.

System Assessment Capability – The System Assessment Capability is an integrated system that links computer models and databases designed to simulate the movement of contaminants from waste sites through the vadose zone and groundwater. The computer models include an atmospheric transport module, a vadose zone module, and groundwater flow and transport module. In 2003, the model was updated; an atmospheric transport module was added and newer versions of groundwater flow and transport modules were incorporated into the system.

6.0.2 Groundwater Flow and Movement

Groundwater in the unconfined aquifer generally flows from west to east across the Hanford Site to discharge areas along the Columbia River. The direction of groundwater flow is inferred from water-table elevations, barriers to flow (e.g., basalt or mud units at the water table), and the distribution of contaminants.

General directions of groundwater flow are illustrated on the map for March 2003 (Figure 6.0.4). Beneath the reactor areas, groundwater flows generally toward the Columbia River. Farther inland, north of Gable Mountain, flow is toward the northeast and east. Groundwater flows eastward beneath the 200 Areas and then flows to the southeast or north through the gap between Gable Butte and Gable Mountain. Groundwater converges on the 300 Area from the northwest, west, and southwest and

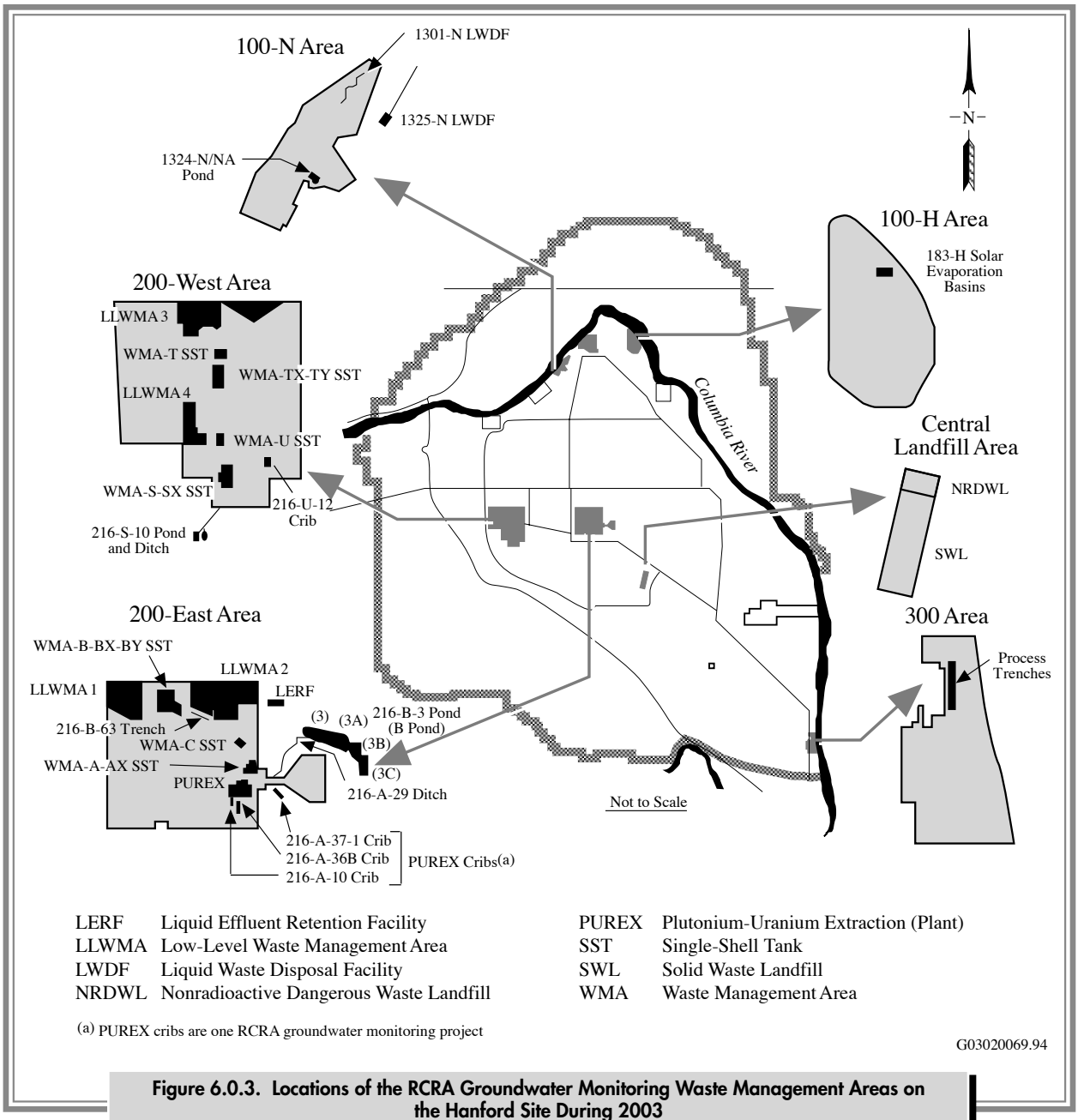

Figure 6.0.3. Locations of the RCRA Groundwater Monitoring Waste Management Areas on the Hanford Site During 2003

discharges into the Columbia River to the east. Groundwater in the Richland North Area flows generally eastward to the Columbia River.

The natural pattern of groundwater flow was altered during the Hanford Site's operating years by the formation of mounds in the water table. The mounds were created by the discharge of large volumes of wastewater to the ground and were present in each reactor area and beneath the 200 Areas. Since effluent disposal decreased significantly in the 1990s, these mounds are disappearing.

East of the 200-East Area, a fine-grained confining unit creates a barrier to movement in the surrounding unconfined aquifer. Beneath this confining unit, the uppermost aquifer is a permeable unit in the Ringold Formation. Groundwater flow in this confined aquifer still is influenced by a recharge mound.

Groundwater in the upper basalt-confined aquifer generally flows from west to east across the Hanford Site, up through the unconfined aquifer, and into the Columbia River. Vertical gradients between the basalt-confined

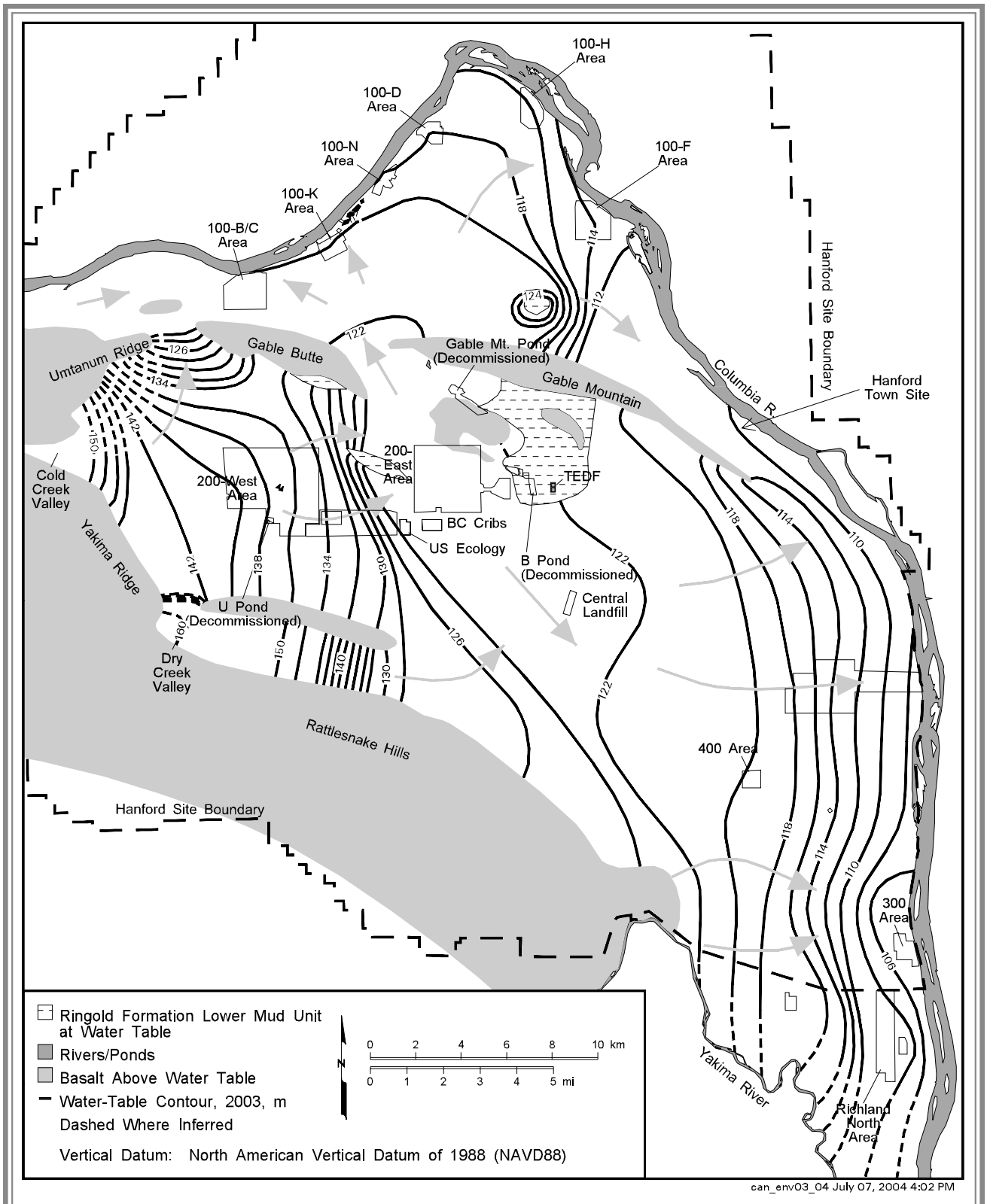

Figure 6.0.4. Water-Table Evaluations and Inferred Flow Direction for the Unconfined Aquifer at the Hanford Site, March 2003

aquifer and the unconfined aquifer are upward on most of the Hanford Site. Therefore, there is little potential for contaminants to migrate from the unconfined aquifer into the basalt-confined aquifer, where it could move offsite. Downward gradients are measured beneath the west portion of the Hanford Site and north and east of the Columbia River.

6.0.3 Groundwater Monitoring and Remediation

This section summarizes results of Hanford Site groundwater monitoring for various requirements, including RCRA and CERCLA monitoring. Progress on groundwater remediation also is summarized.

6.0.3.1 Overview

The DOE has developed a plan (DOE/RL-2002-68) to accelerate cleanup of Hanford's groundwater, which will return it to its beneficial use where practicable or will at least prevent further degradation. Specific results that can be expected using the accelerated plan include (a) remediating waste sites that pose the highest risk to groundwater, (b) shrinking contaminated areas, (c) reducing groundwater recharge, (d) remediating (cleaning up) groundwater, and (e) monitoring groundwater contaminant levels. Figures 6.0.5 and 6.0.6 show the distribution of nine principal groundwater contaminant plumes.

The total area of contaminant plumes with contaminant concentrations exceeding drinking water standards was estimated to be approximately 190 square kilometers (73 square miles) during 2003 (Table 6.0.3). This area occupies 12.5% of the total area of the Hanford Site. The tritium and iodine-129 plumes have the largest areas with concentrations exceeding drinking water standards. The dominant plumes had sources in the 200-East Area and extend toward the east and southeast. Technetium-99 exceeds standards in smaller plumes, one of which has moved northward from the 200-East Area. Uranium is less mobile than tritium, iodine-129, or technetium-99; small plumes are found in the 100-H, 200-East, 200-West, and 300 Areas. Strontium-90 is not very mobile in groundwater, but it exceeds standards in each of the 100 Areas except the 100-D Area. Other radionuclides including cesium-137, cobalt-60, and plutonium are even less mobile in the subsurface and rarely exceed drinking water standards in Hanford Site groundwater.

Nitrate is a widespread contaminant in Hanford Site groundwater, with plumes originating from the 100 and 200 Areas and from offsite industry and agriculture. Carbon tetrachloride forms a large plume beneath the 200-West Area, the most widespread organic contaminant on the Hanford Site. Other organic contaminants include chloroform and trichloroethene. Chromium contamination underlies the 100-K, 100-D, and 100-H Areas. Local plumes of chromium contamination also are present in the 200 Areas.

Contaminant plumes with concentrations exceeding the DOE derived concentration guides occur in isolated areas. The contaminants at levels above the DOE derived concentration guides during 2003 were strontium-90, technetium-99, tritium, and uranium.

Summaries of maximum concentrations for the most widespread contaminants are presented in Table 6.0.4 and by monitoring purpose in Table 6.0.5. 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. 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 6.0.5. A list of drinking water standards for these contaminants is provided in Table 6.0.3.

The following text discusses groundwater contamination, monitoring, and remediation in each of the 11 groundwater operable units and in the confined aquifers.

6.0.3.2 100-BC-5 Operable Unit

The 100-BC-5 Operable Unit includes the groundwater beneath the 100-B/C Area (Figure 6.0.1). Most of the groundwater contamination in this unit is found in the north portion of the area beneath former waste trenches and retention basins. During 2003, tritium and strontium-90 exceeded drinking water standards in several wells. Nitrate and chromium were somewhat elevated, but have been below drinking water standards in recent years.

The EPA approved a new sampling and analysis plan (DOE/RL-2003-38) for this unit at the end of September

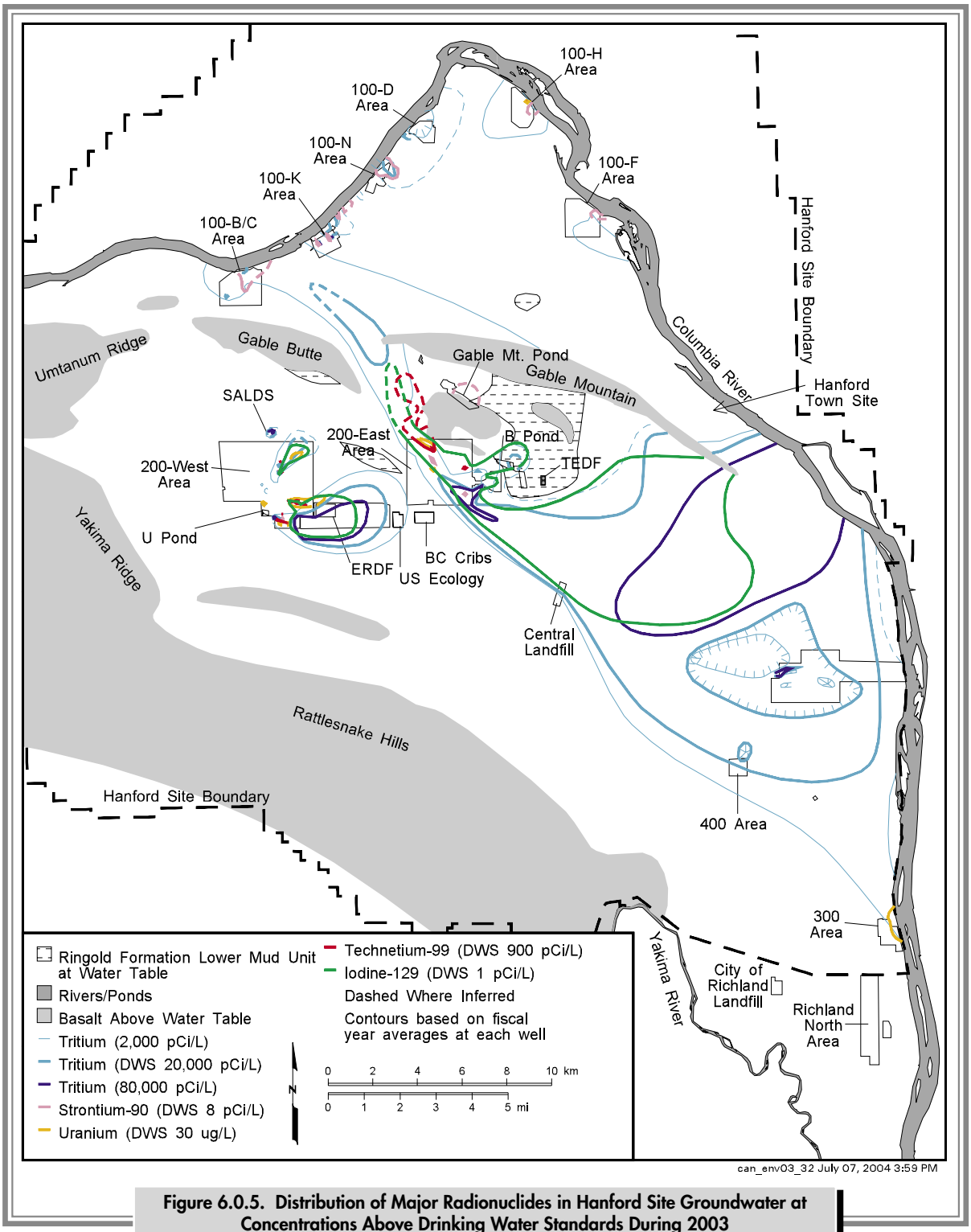

Figure 6.0.5. Distribution of Major Radionuclides in Hanford Site Groundwater at Concentrations Above Drinking Water Standards During 2003

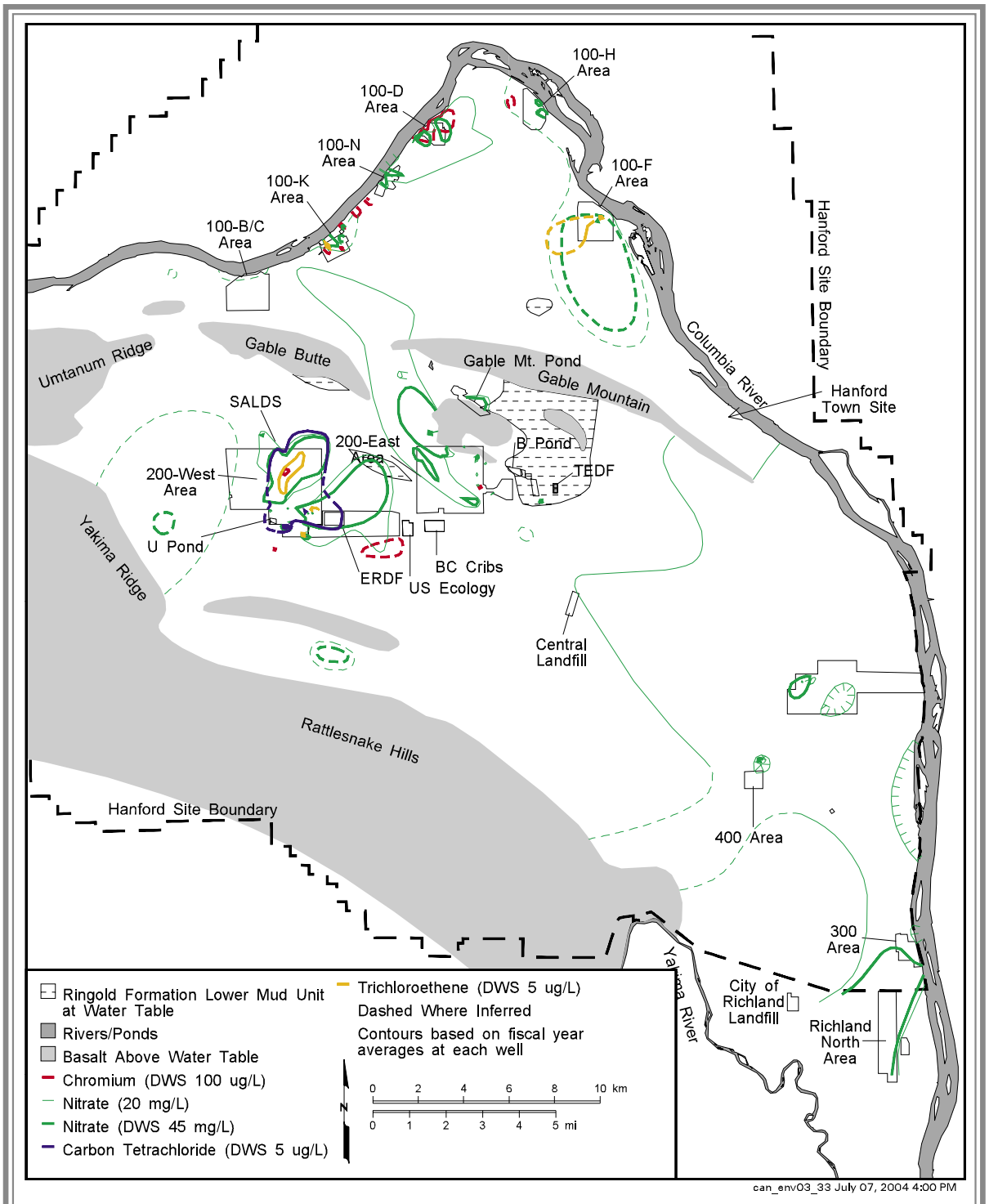

Figure 6.0.6. Distribution of Major Hazardous Chemicals in Hanford Site Groundwater at Concentrations Above Drinking Water Standards During 2003

Table 6.0.3. Areas of Contaminant Plumes on the Hanford Site at Levels Above Drinking Water Standards, 2003

Constituent	Drinking Water Standard	Area (km²)	Constituent	Drinking Water Standard	Area (km²)
Tritium	20,000 pCi/L	136	Filtered chromium	100 µg/L	2.6
Iodine-129	1 pCi/L	75.5	Strontium-90	8 pCi/L	2.6
Nitrate	45 mg/L	36.2	Technetium-99	900 pCi/L	2.3
Carbon tetrachloride	5 µg/L	10.6	Total uranium	30 µg/L	1.4
Trichloroethene	5 µg/L	3.4	Combined plumes		190[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.

Table 6.0.4. Summary of Maximum Contaminant Concentrations in Hanford Site Groundwater by Groundwater Interest Area, 2003

	Hanford Site	100-BC-5	100-FR-3	100-HR-3-D	100-HR-3-H	100-KR-4	100-NR-2
Tritium (pCi/L)	3,620,000	21,900	4,360	25,200	5,750	1,270,000	31,400
Iodine-129 (pCi/L)	36.7	NA[a]	NA	NA	NA	NA	NA
Nitrate (mg/L)	2,160	27.9	104	74.4 N	192	195	228
Carbon tetrachloride (µg/L)	5,500	ND[b]	ND	NA	NA	ND	ND
Trichloroethene (µg/L)	26	NA	19	NA	NA	10	ND
Filtered chromium (µg/L)	5,440	46	97.8	5,440	123	542	168
Strontium-90 (pCi/L)	8,000	98.9	11.3	8.2	29.6	2,270	8,000
Technetium-99 (pCi/L)	188,000	109	NA	ND	485	117	ND
Total uranium (µg/L)	1,190	NA	NA	7.6	54.3	NA	NA

	1100-EM-1	200-BP-5	200-PO-1	200-UP-1	200-ZP-1	300-FF-5
Tritium (pCi/L)	251	27,600	676,000	634,000	2,170,000	3,620,000
Iodine-129 (pCi/L)	ND	5.3	11.9	35.3	36.7	ND
Nitrate (mg/L)	224 C	660 N	125	1,930 N	2,160	134 C
Carbon tetrachloride (µg/L)	ND	ND	0.29	690	5,500	0.35
Trichloroethene (µg/L)	3.1	ND	0.88 J	11	26	4
Filtered chromium (µg/L)	ND	54.9	2,510	209	592	7.3
Strontium-90 (pCi/L)	ND	5,680 B	20.8	35	1.3 B	4
Technetium-99 (pCi/L)	27	9,740	13,100	188,000	14,300 N	319
Total uranium (µg/L)	18 B	554	3.2	1,190	367	178

(a) Not analyzed.
(b) Not detected.
B = Detected at a value less than contract required detection limit.
C = Analyte detected in both the sample and the associated quality control blank.
J = Reported value is an estimate.
N = Spike sample recovery is outside control limits.

Table 6.0.5. Summary of Maximum Contaminant Concentrations in Hanford Site Groundwater by Monitoring Purpose, 2003

	Restoration	Waste Management	Environmental Surveillance
Tritium (pCi/L)	3,620,000	2,170,000	3,620,000
Iodine-129 (pCi/L)	35.3	36.7	6.4
Nitrate (mg/L)	2,160	2,160	660 N
Carbon tetrachloride (µg/L)	5,500	3,400 N	2,200
Trichloroethene (µg/L)	26	15	10
Filtered chromium (µg/L)	5,440	2,510	5,440
Strontium-90 (pCi/L)	8,000	1,200	8,000
Technetium-99 (pCi/L)	18,200	188,000	9,740
Total uranium (µg/L)	1,190	554	276

N = Spike sample recovery is outside control limits.

2003. The new plan, which was implemented at the end of calendar year 2003, revises the monitoring program slightly and calls for the addition of more aquifer sampling tubes to monitor contaminants near the Columbia River. There is no active groundwater remediation in the 100-B/C Area.

6.0.3.3 100-KR-4 Operable Unit

The principal groundwater issues in the 100-KR-4 Operable Unit include (a) chromium contamination associated with past liquid waste disposal to a former infiltration trench near the Columbia River, (b) monitoring near the active fuel storage basins, which have contaminated groundwater in the past with tritium, and (c) tritium associated with a waste burial ground. In addition to chromium and tritium, constituents of concern in this unit include carbon-14, strontium-90, technetium-99, nitrate, and trichloroethene.

CERCLA Interim Action. A pump-and-treat system operates as a CERCLA interim action to reduce the amount of chromium entering the Columbia River at the 100-K Area (Figure 6.0.7). An interim action is a temporary remedy for groundwater cleanup before the final decision is made for cleanup. One new extraction well and one new monitoring well were installed in 2003. Also, an existing monitoring well (well 199-K-126) was converted to an extraction well.

Chromium concentrations appear to be decreasing with time as a result of pump-and-treat operations and the attenuation of the plume by natural processes, such as dispersion. Concentrations remained above the remediation goal (22 µg/L) in most of the compliance wells, however.

K Basins. Tritium concentrations increased sharply during 2003 in several monitoring wells near the 100-K Area basins. The locations of the wells, groundwater flow direction, and concentrations of co-contaminants indicate the increases in tritium were caused by infiltration of water through former waste disposal cribs and do not represent new leakage from the fuel storage basins.

Results of a soil-gas survey conducted near a 100-K Area burial ground during 2003 indicated the presence of tritium in the vadose zone as well as in the underlying groundwater. The data suggest the burial ground is a likely tritium source.

6.0.3.4 100-NR-2 Operable Unit

The primary groundwater contaminant in the 100-N Area is strontium-90, which originated at two former liquid waste disposal cribs. The extent of the strontium-90 plume has changed little in over 12 years; however, concentrations increased during the 1990s because of changing water levels and the end of effluent discharge to the cribs. Tritium also was present in waste discharged to the 100-N Area cribs. Tritium concentrations in groundwater beneath the 100-N Area are declining, and the plume is shrinking. Nitrate, sulfate, and petroleum hydrocarbons also are present in 100-N Area groundwater.

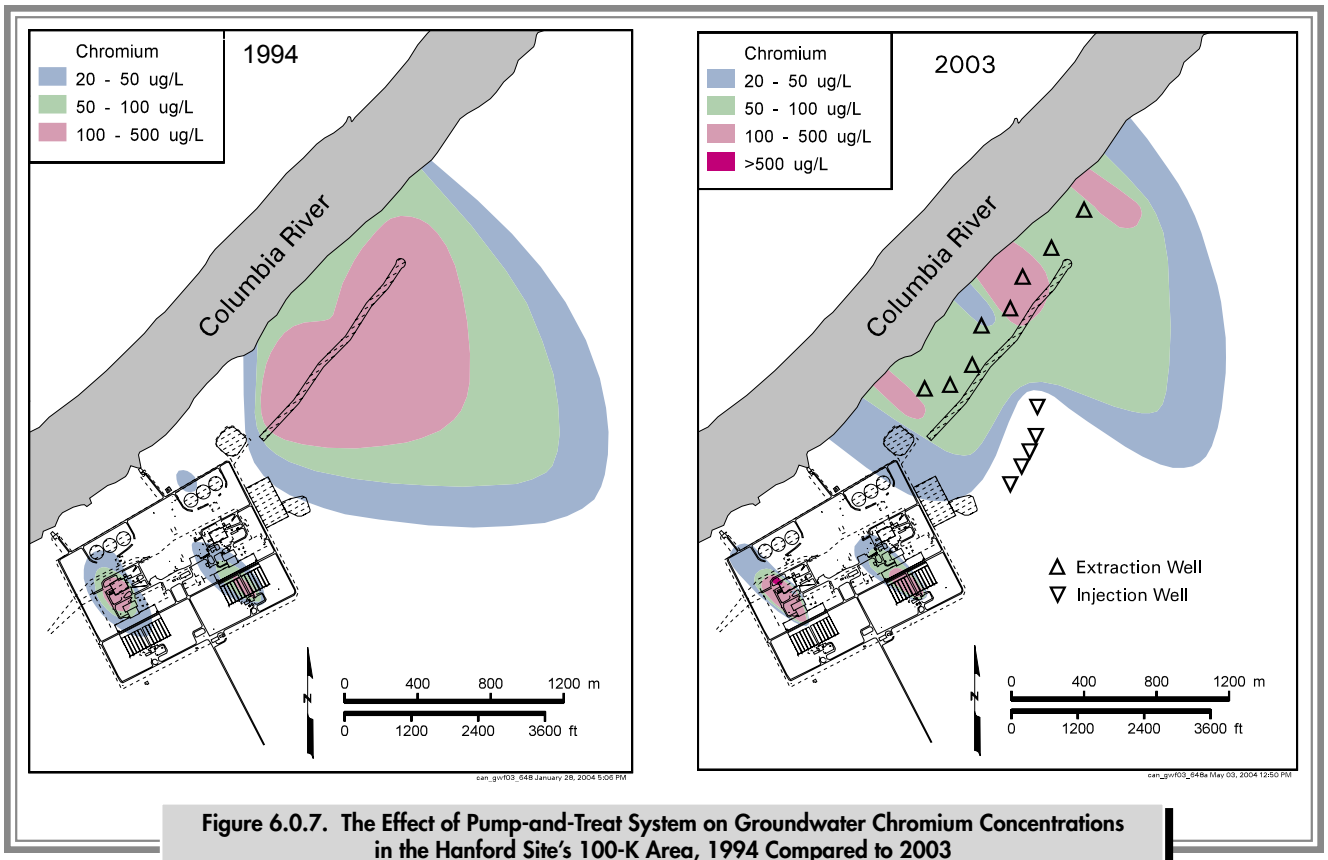

Figure 6.0.7. The Effect of Pump-and-Treat System on Groundwater Chromium Concentrations in the Hanford Site's 100-K Area, 1994 Compared to 2003

CERCLA Interim Action. A pump-and-treat system in the 100-N Area operated to reduce the movement of strontium-90 toward the Columbia River (Figure 6.0.8). Since strontium-90 binds to sediment grains, the pump-and-treat system is not an effective way to remove strontium-90 from the aquifer. Concentrations remained far above the 8 pCi/L (0.3 Bq/L) drinking water standard in most 100-N Area monitoring wells in 2003. The DOE is investigating alternative methods for remediation of the strontium-90 plume in this area.

116-N-1, 116-N-3, 120-N-1, and 120-N-2 (1301-N, 1325-N, 1324-N/NA) Facilities. Four RCRA units are located in the 100-N Area. During 2003, RCRA monitoring indicated that these sites were not contaminating groundwater with non-radioactive, hazardous constituents. However, the former 120-N-1 percolation pond added sulfate, a non-hazardous constituent, to the groundwater.

6.0.3.5 100-HR-3-D Operable Unit

The 100-HR-3 Operable Unit underlies the 100-D and 100-H Areas and the region between. Hexavalent chromium is the primary contaminant of concern in the 100-D Area. The source of this contaminant was sodium dichromate added to reactor cooling water to inhibit corrosion, which was discharged to cribs and ditches. Chromium is distributed in two plumes (north and southwest) that have merged in recent years. Other contaminant plumes in this unit include tritium, nitrate, and sulfate.

CERCLA Interim Actions. The north chromium plume is the target of a pump-and-treat system, which is designed to reduce the amount of chromium entering the Columbia River (Figure 6.0.9). During 2003, concentrations remained above the remediation goal (22 µg/L) in compliance wells. The southwest chromium plume is being remediated with an in situ system that immobilizes chromium in the aquifer. Chromium concentrations downgradient of the remediation system have declined in some wells and Columbia River shoreline aquifer tubes; however, levels remained above the remediation goal (20 µg/L).

During 2003, chromium concentrations increased in the central 100-D Area, bypassing both remediation systems.

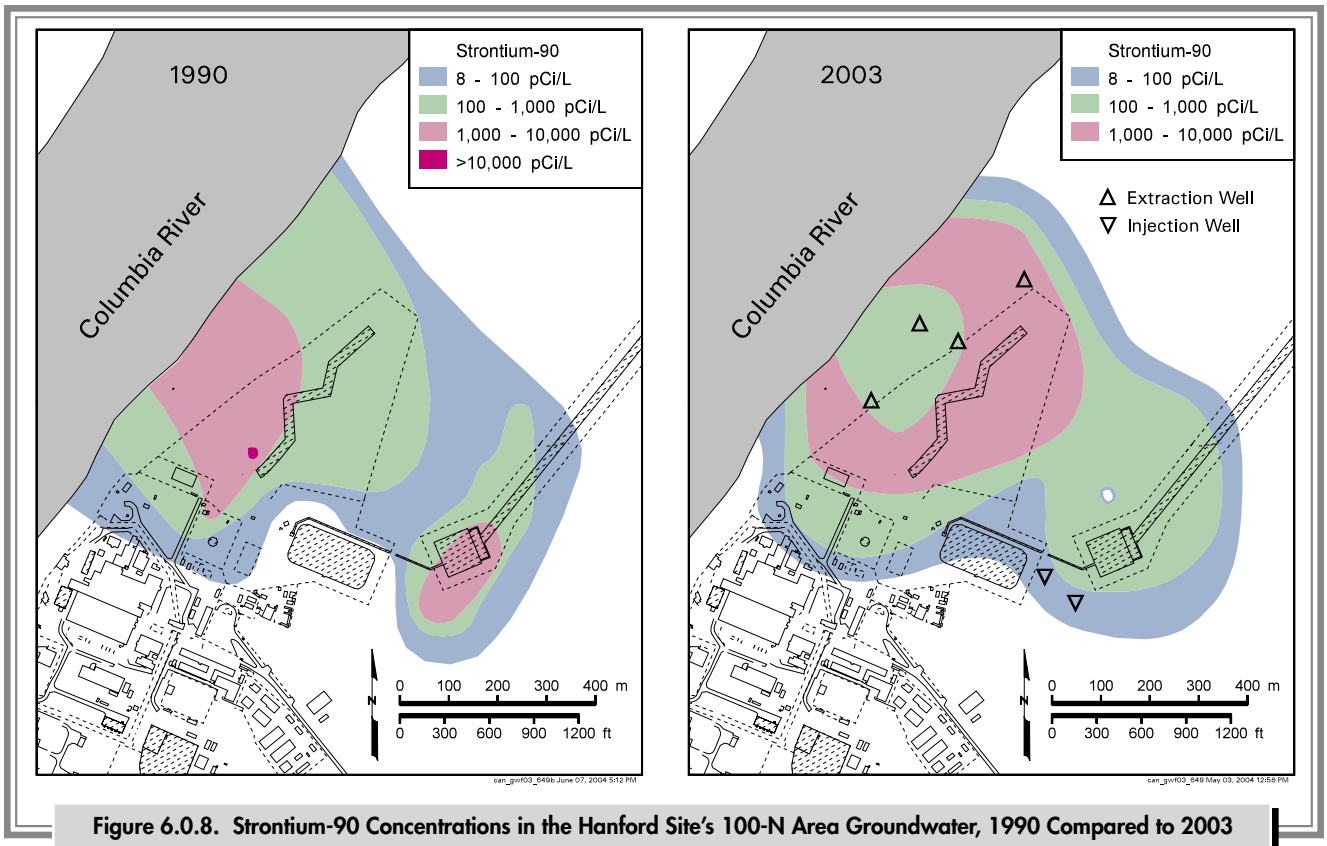

Figure 6.0.8. Strontium-90 Concentrations in the Hanford Site's 100-N Area Groundwater, 1990 Compared to 2003

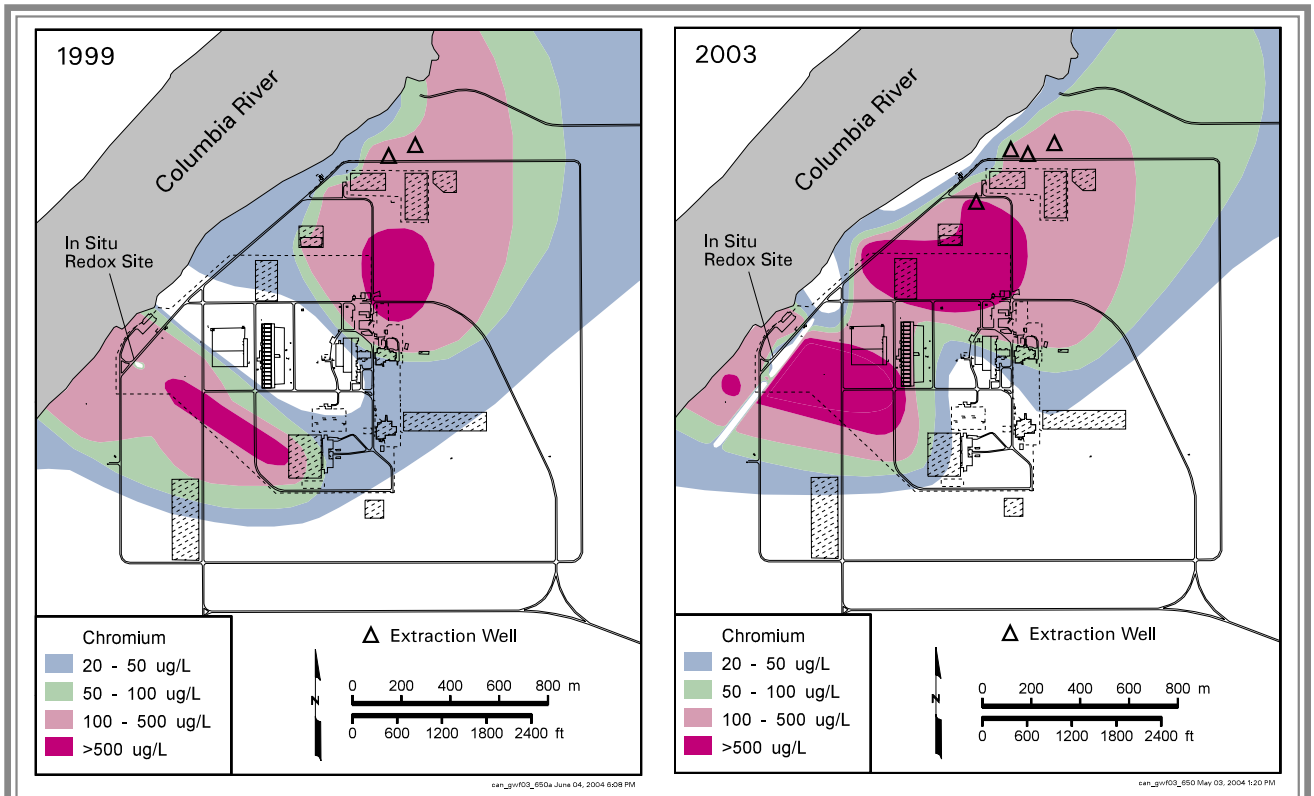

Figure 6.0.9. Chromium Concentrations in Hanford Site's Central 100-D Area Groundwater, 1999 Compared to 2003

The DOE and regulators are working together to expand the remediation systems so they intercept the changing plume.

6.0.3.6 100-HR-3-H Operable Unit

The east part of the 100-HR-3 Operable Unit underlies the 100-H Area. Hexavalent chromium is the primary groundwater constituent of concern, but its plume is smaller and concentrations are lower than in the 100-D Area. Nitrate also is elevated, but concentrations have declined from their peak levels. Strontium-90 exceeds the drinking water standard beneath former waste water retention basins. Technetium-99 and uranium are elevated in a small area.

CERCLA Interim Action. The chromium plume is the target of a pump-and-treat system. Chromium concentrations have decreased in recent years due to remediation and natural processes (Figure 6.0.10). However, concentrations in some compliance wells in 2003 remained above the remediation goal (22 µg/L).

116-H-6 (183-H) Evaporation Basins. These former basins are the only RCRA site in the 100-H Area. Leakage from the basins contaminated groundwater with chromium, nitrate, technetium-99,[(a)] and uranium. The 183-H evaporation basins were closed in 1995. The site is being monitored during the post-closure period to track contaminant trends during the operation of the CERCLA interim action (pump-and-treat system) for chromium.

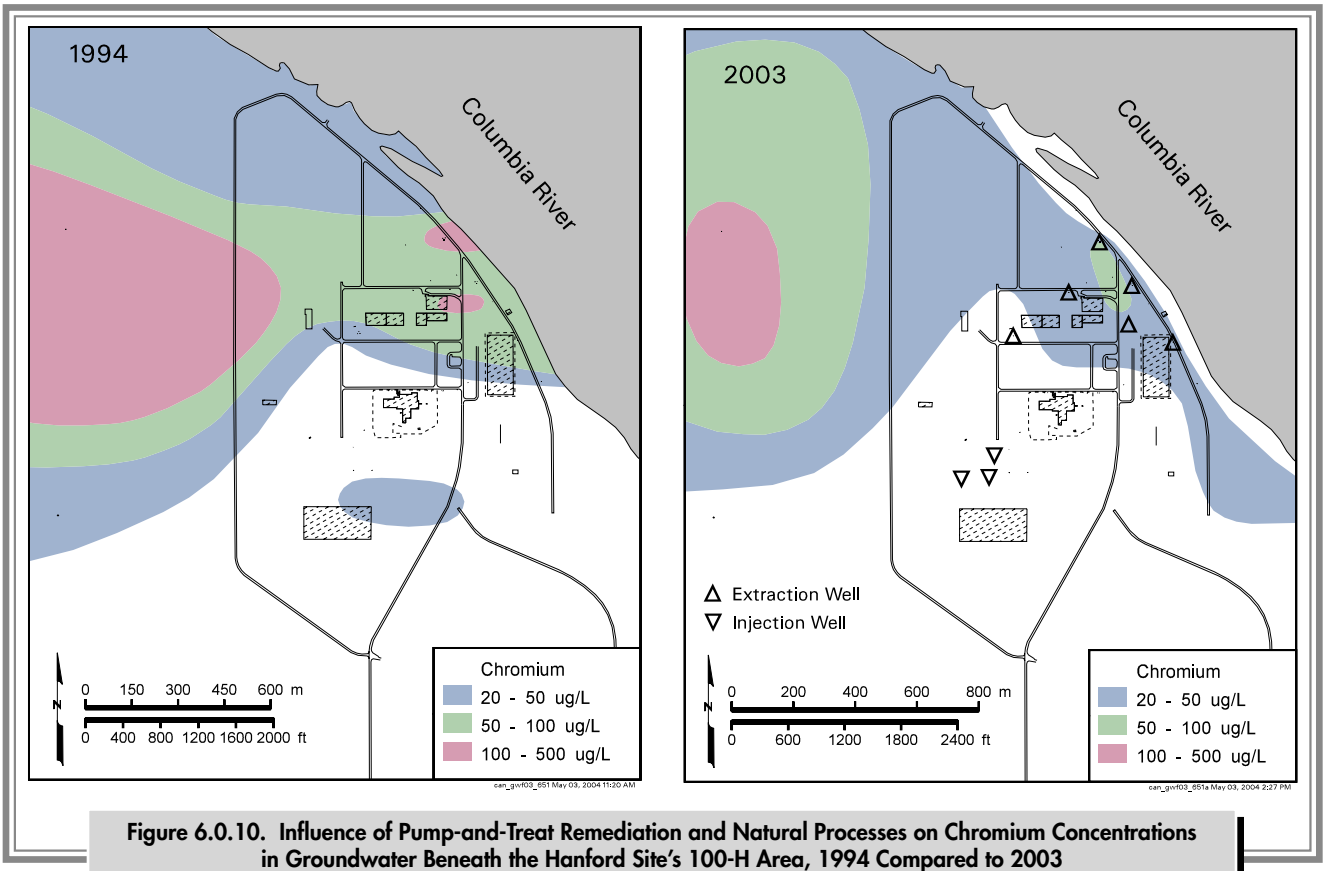

Figure 6.0.10. Influence of Pump-and-Treat Remediation and Natural Processes on Chromium Concentrations in Groundwater Beneath the Hanford Site's 100-H Area, 1994 Compared to 2003

(a) Source, special nuclear, and by-product materials, as defined in the *Atomic Energy Act of 1954*, are regulated at DOE facilities exclusively by the DOE acting pursuant to its *Atomic Energy Act of 1954* authority. These materials are not subject to regulation by the state of Washington. All information contained herein and related to, or describing materials regulated by the *Atomic Energy Act of 1954* and processes in any manner, may not be used to create conditions or other restrictions set forth in any permit, license, order, or any other enforceable instrument. The DOE asserts that pursuant to the *Atomic Energy Act of 1954*, it has sole and exclusive responsibility and authority to regulate source, special nuclear, and by-product materials at DOE-owned nuclear facilities. Information contained herein on radionuclides is provided for process description purposes only.

6.0.3.7 100-FR-3 Operable Unit

Nitrate exceeds the drinking water standard in groundwater beneath much of the 100-F Area and the downgradient region. Other groundwater contaminants in this unit include strontium-90 and trichloroethene.

The EPA approved a new sampling and analysis plan (DOE/RL-2003-49) at the end of September 2003. The new plan, which was implemented in late 2003, revised the monitoring program slightly and called for the addition of more aquifer sampling tubes to monitor contaminants along the shoreline of the Columbia River. There is no active groundwater remediation in the 100-FR-3 Operable Unit (Figure 6.0.1).

6.0.3.8 200-ZP-1 Operable Unit

The 200-ZP-1 Operable Unit encompasses the northern portion of the 200-West Area (Figure 6.0.1). The primary contaminant of concern is carbon tetrachloride, which forms the largest plume of chlorinated hydrocarbons on the Hanford Site. The contamination is principally from past waste disposal associated with the Plutonium Finishing Plant, where organic chemicals were used to process plutonium. Trichloroethene and chloroform also are associated with this plume. Other contaminants include tritium, nitrate, chromium, fluoride, iodine-129, technetium-99, and uranium. There are four RCRA sites, one other regulated unit, and one CERCLA interim action (pump-and-treat system) for groundwater in the 200-ZP-1 Operable Unit.

CERCLA Interim Action. A groundwater pump-and-treat system operated in this operable unit during 2003 to prevent the spread of the central, high-concentration portion of the carbon tetrachloride plume (Figure 6.0.11). The remediation is proving effective, and the plume area at concentrations greater than 4,000 µg/L has shrunk.

Low-Level Burial Grounds Waste Management Areas 3 and 4. Groundwater monitoring under interim status RCRA requirements continued at these waste management areas in 2003. Monitoring results indicate no groundwater contamination attributable to these waste management areas.

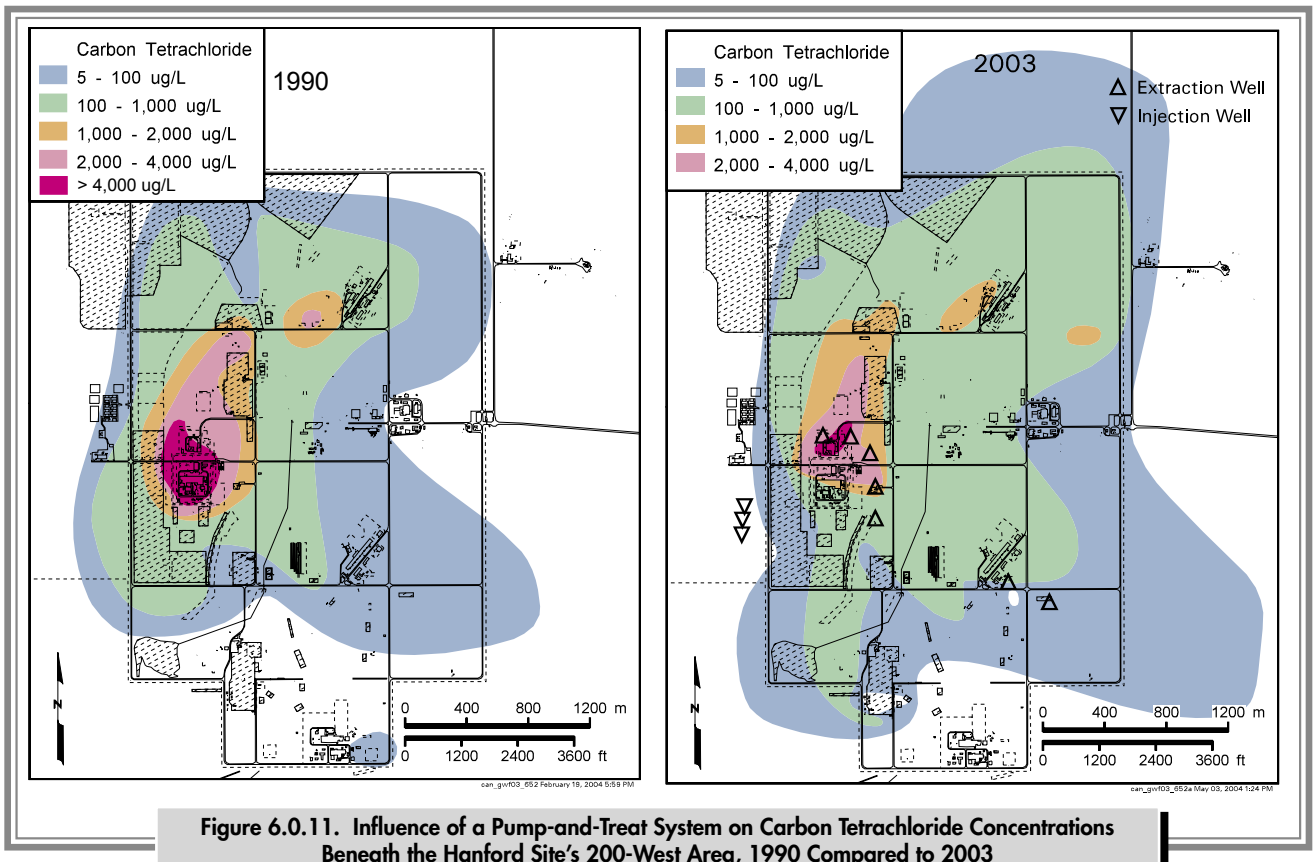

Figure 6.0.11. Influence of a Pump-and-Treat System on Carbon Tetrachloride Concentrations Beneath the Hanford Site's 200-West Area, 1990 Compared to 2003

A downgradient monitoring well for Waste Management Area 4 went dry in 2003. Monitoring networks for Waste Management Areas 3 and 4 contain fewer than the optimal number of wells for monitoring.

The DOE submitted an application in 2002 to incorporate the low-level burial grounds into the Hanford Facility RCRA Permit (Ecology 1994). As part of the application, new groundwater monitoring wells, constituents, and statistical evaluations were proposed in 2003. Workshops with the Washington State Department of Ecology to address this application are in progress.

Waste Management Area T. Results of RCRA groundwater quality assessment monitoring at Waste Management Area T continued to suggest that the waste management area has not contributed to dangerous waste contamination of the uppermost aquifer in this area. Carbon tetrachloride, trichloroethene, chromium, and nitrate are present in groundwater, but the contamination is believed to have originated at other facilities.

Waste Management Area TX-TY. RCRA assessment monitoring at Waste Management Area TX-TY continued in 2003 (Figure 6.0.3). Chromium concentrations were elevated in groundwater; the most likely source is the waste management area. However, other sources of chromium contamination are located nearby. Some nitrate contamination may be from Waste Management Area TX-TY, but other sources nearby clearly have contributed. Carbon tetrachloride and trichloroethene contamination from other sources also is present.

State-Approved Land Disposal Site. This active disposal facility is regulated under a state waste discharge permit. The State-Approved Land Disposal Site is located just north of the 200-West Area. Groundwater beneath this facility is monitored for tritium and 15 other constituents. Concentrations in monitoring wells did not exceed permit enforcement limits during 2003.

6.0.3.9 200-UP-1 Operable Unit

The 200-UP-1 Operable Unit underlies the south 200-West Area (Figure 6.0.1). The primary contaminants of concern in this unit are technetium-99 and uranium. Tritium, iodine-129, and nitrate plumes have origins in this operable unit. Sources of carbon tetrachloride were primarily within the 200-ZP-1 Operable Unit, but the contamination underlies the 200-UP-1 Operable Unit as well.

There are four RCRA sites, one CERCLA interim action (pump and treat), and a CERCLA disposal site in the 200-UP-1 Operable Unit. Monitoring activities are summarized below.

CERCLA Interim Action. A groundwater pump-and-treat system operated to contain the technetium-99 (Figure 6.0.12) and uranium (Figure 6.0.13) plumes near

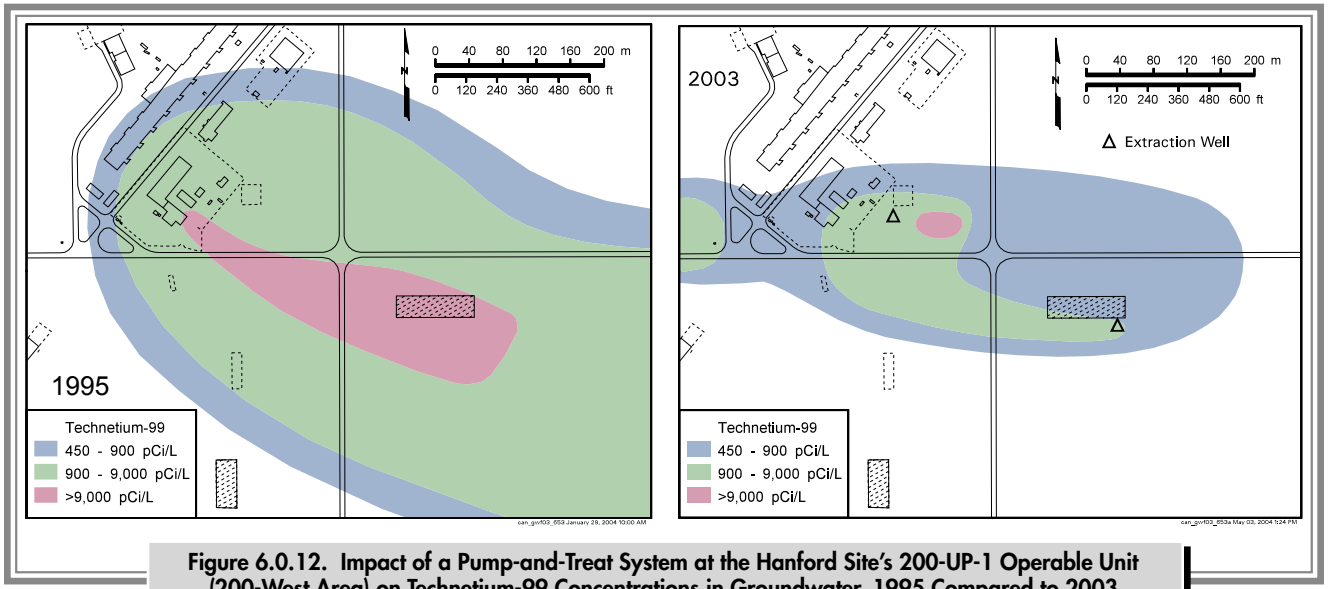

Figure 6.0.12. Impact of a Pump-and-Treat System at the Hanford Site's 200-UP-1 Operable Unit (200-West Area) on Technetium-99 Concentrations in Groundwater, 1995 Compared to 2003

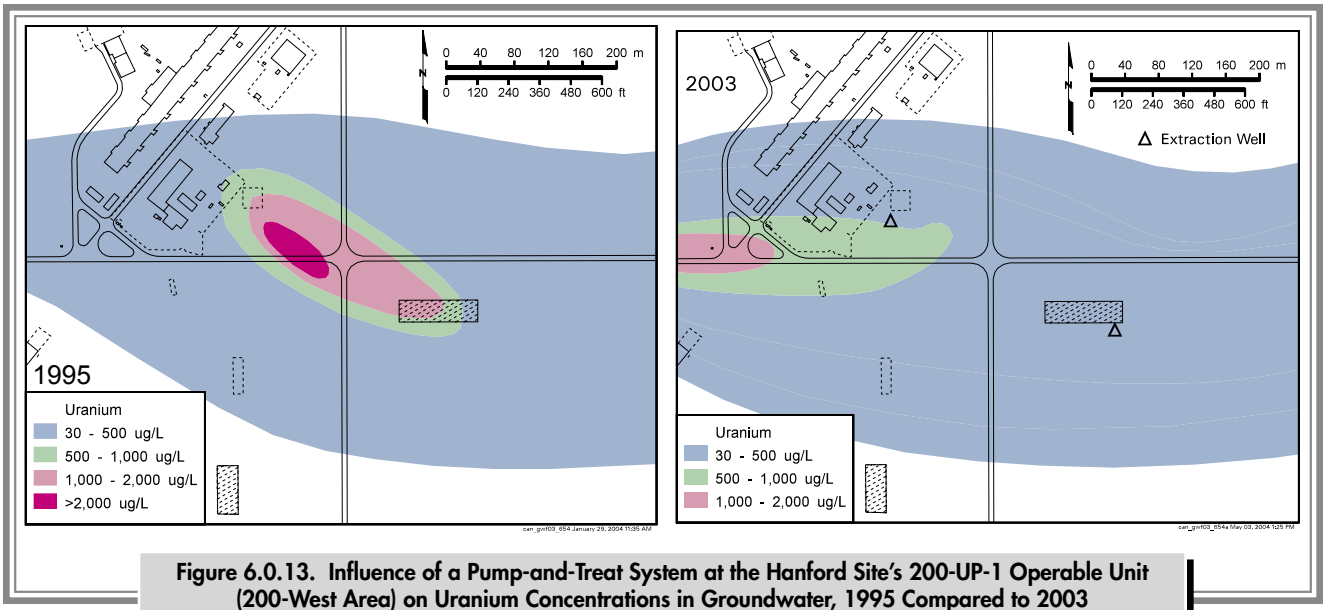

Figure 6.0.13. Influence of a Pump-and-Treat System at the Hanford Site's 200-UP-1 Operable Unit (200-West Area) on Uranium Concentrations in Groundwater, 1995 Compared to 2003

U Plant. During 2003, the high concentration portions of the technetium-99 and uranium plumes (9,000 pCi/L [333 Bq/L]) and 480 µg/L contours, respectively, were contained within the influence of the pump-and-treat system. Although more sampling is required to confirm the trend, technetium-99 concentrations appear to have been reduced to levels below the 9,000-pCi/L (333-Bq/L) remediation goal at all wells in the baseline plume area. The baseline plume area is the area of the plume before the pump-and-treat system began operating. Uranium concentrations remained above the 480-µg/L remediation goal in one well in 2003.

During 2003, one monitoring well in the baseline area went dry, leaving only one monitoring well to track plume behavior. Two wells went dry in another portion of the operable unit. A new monitoring well was installed south of the baseline plume area to replace another dry well.

216-U-12 Crib. RCRA assessment monitoring continued at the 216-U-12 crib in 2003 (Figure 6.0.3). The crib is one of several sources that have contributed to a nitrate plume in the area. Closure of the crib will be coordinated with and conducted under CERCLA regulations. The monitoring network for this crib contains just two useable downgradient wells and no upgradient wells.

216-S-10 Pond and Ditch. Indicator parameter data have not indicated that the 216-S-10 pond and ditch (Figure 6.0.3) have affected groundwater quality in the uppermost aquifer beneath the facility. In 2003, one monitoring well at this facility went dry and a new well was installed. The current RCRA monitoring network consists of only two downgradient wells.

Waste Management Area S-SX. RCRA assessment monitoring continued at Waste Management Area S-SX in 2003 (Figure 6.0.3). Results continued to indicate that an apparent source within each of the S and SX Tank Farms have contaminated groundwater with chromium. Concentrations of nitrate, chromium, and the non-RCRA-regulated constituent technetium-99[(a)] increased significantly during 2003 in one monitoring well. At the request of the Washington State Department of Ecology, the practice of pumping and treating at least 3,785 liters (1,000 gallons) of water from the well after each quarterly sampling event

(a) Source, special nuclear, and by-product materials, as defined in the *Atomic Energy Act of 1954*, are regulated at DOE facilities exclusively by the DOE acting pursuant to its *Atomic Energy Act of 1954* authority. These materials are not subject to regulation by the state of Washington. All information contained herein and related to, or describing materials regulated by the *Atomic Energy Act of 1954* and processes in any manner, may not be used to create conditions or other restrictions set forth in any permit, license, order, or any other enforceable instrument. The DOE asserts that pursuant to the *Atomic Energy Act of 1954*, it has sole and exclusive responsibility and authority to regulate source, special nuclear, and by-product materials at DOE-owned nuclear facilities. Information contained herein on radionuclides is provided for process description purposes only.

was started in March 2003. Data from a vertical sampling study in the same well show that pumped water is a blend of water entering the well from all parts of the screened interval. Therefore, the vertical location of the sample pump intake does not have a significant effect on measured constituent concentrations, as long as the well is purged adequately before a sample is collected.

Waste Management Area U. RCRA assessment monitoring continued at Waste Management Area U in 2003 (Figure 6.0.3). The waste management area has affected groundwater quality with nitrate and possibly chromium. During 2003, nitrate concentrations continued to increase in downgradient wells in the south half of the waste management area.

Environmental Restoration Disposal Facility. Several constituents (tritium, iodine-129, nitrate, and carbon tetrachloride) are present in groundwater at or above drinking water standards, but these results are due to plumes originating from the 200-West Area. Higher concentrations of gross beta and unfiltered chromium were detected in 2003. The causes of these higher concentrations are unknown. Future results will be evaluated to confirm any increasing trends.

6.0.3.10 200-BP-5 Operable Unit

The 200-BP-5 Operable Unit (Figure 6.0.1) includes groundwater beneath the north 200-East Area. A technetium-99 plume extends northward between Gable Mountain and Gable Butte. Other contaminants include uranium, iodine-129, cobalt-60, cyanide, strontium-90, cesium-137, plutonium, tritium, and nitrate.

CERCLA monitoring activities had been interrupted during the past several years in the 200-BP-5 Operable Unit because waste management documentation in support of sampling needed to be developed. Sampling activities resumed in 2003 following approval of new sampling and analysis (DOE/RL-2001-49) and waste control plans (DOE/RL-2003-30). There is no active groundwater remediation in this operable unit.

There are five RCRA sites in the 200-BP-5 Operable Unit. Monitoring activities are summarized below.

Waste Management Area B-BX-BY. Assessment monitoring continued at Waste Management Area B-BX-BY in 2003. Contamination observed in downgradient wells around this waste management area is primarily due to vertical movement of residual waste in the soil under each of the B, BX, and BY Tank Farms.

Waste Management Area C. Waste Management Area C (Figure 6.0.3) continued to be monitored under an interim status indicator evaluation program in 2003. Indicator parameters did not exceed critical mean values. Four new monitoring wells were installed at this waste management area in 2003.

216-B-63 Trench. Results of interim status detection monitoring continued to support the interpretation that the 216-B-63 trench (Figure 6.0.3) has not impacted groundwater with hazardous constituents.

Low-Level Waste Management Areas 1 and 2. Groundwater monitoring under interim status requirements continued at Low-Level Waste Management Areas 1 and 2 in 2003 (Figure 6.0.3). Monitoring results indicated no contaminants in groundwater attributable to these waste management areas.

The DOE submitted an application in 2002 to incorporate these low-level burial grounds into the Hanford Facility RCRA Permit (Ecology 1994). As part of the application, the installation of new groundwater monitoring wells, monitoring of additional constituents, and statistical evaluations were proposed in 2003. Workshops with the Washington State Department of Ecology to address this application are in progress.

Liquid Effluent Retention Facility. A 2001 letter from the Washington State Department of Ecology directed the DOE to discontinue statistical evaluation of groundwater sample results at the Liquid Effluent Retention Facility (Figure 6.0.3) because all but two wells monitoring the facility have gone dry. The DOE has continued to sample the two remaining wells and is exploring alternative approaches to monitoring the facility.

6.0.3.11 200-PO-1 Operable Unit

The 200-PO-1 Operable Unit (Figure 6.0.1) encompasses the south portion of the 200-East Area and a large portion of the Hanford Site extending to the east and southeast. The operable unit includes widespread plumes of tritium,

nitrate, and iodine-129. Concentrations of tritium continued to decline as the plume attenuates naturally due to radioactive decay and dispersion (Figure 6.0.14). Other groundwater contaminants in this unit include strontium-90 and technetium-99, but these are limited to very small areas.

There are six RCRA sites and three other regulated units, respectively, in the 200-PO-1 Operable Unit:

Plutonium-Uranium Extraction Plant Cribs. Three cribs (216-A-10, 216-A-36B, and 216-A-37-1) are monitored jointly at the Plutonium-Uranium Extraction Plant under a RCRA interim status assessment program. The cribs have contributed to widespread groundwater contaminant plumes in the area, including a nitrate plume and plumes containing non-RCRA constituents of tritium and iodine-129.[(a)] The nitrate plume is generally attenuating throughout most of its area, except near the three cribs. During 2003, the concentration of nitrate in monitoring wells at the cribs has either held steady or increased. The cause of the increased nitrate concentrations in recent years is not known. However, it may be related to a smaller contribution of groundwater flow from the B Pond area and a greater contribution of groundwater flow from the northwest. During 2003, one monitoring well at the cribs went dry. An existing well was added to replace the dry well.

Waste Management Area A-AX. Waste Management Area A-AX continued to be monitored under an interim status indicator evaluation program in 2003. Indicator parameters in monitoring wells did not exceed critical

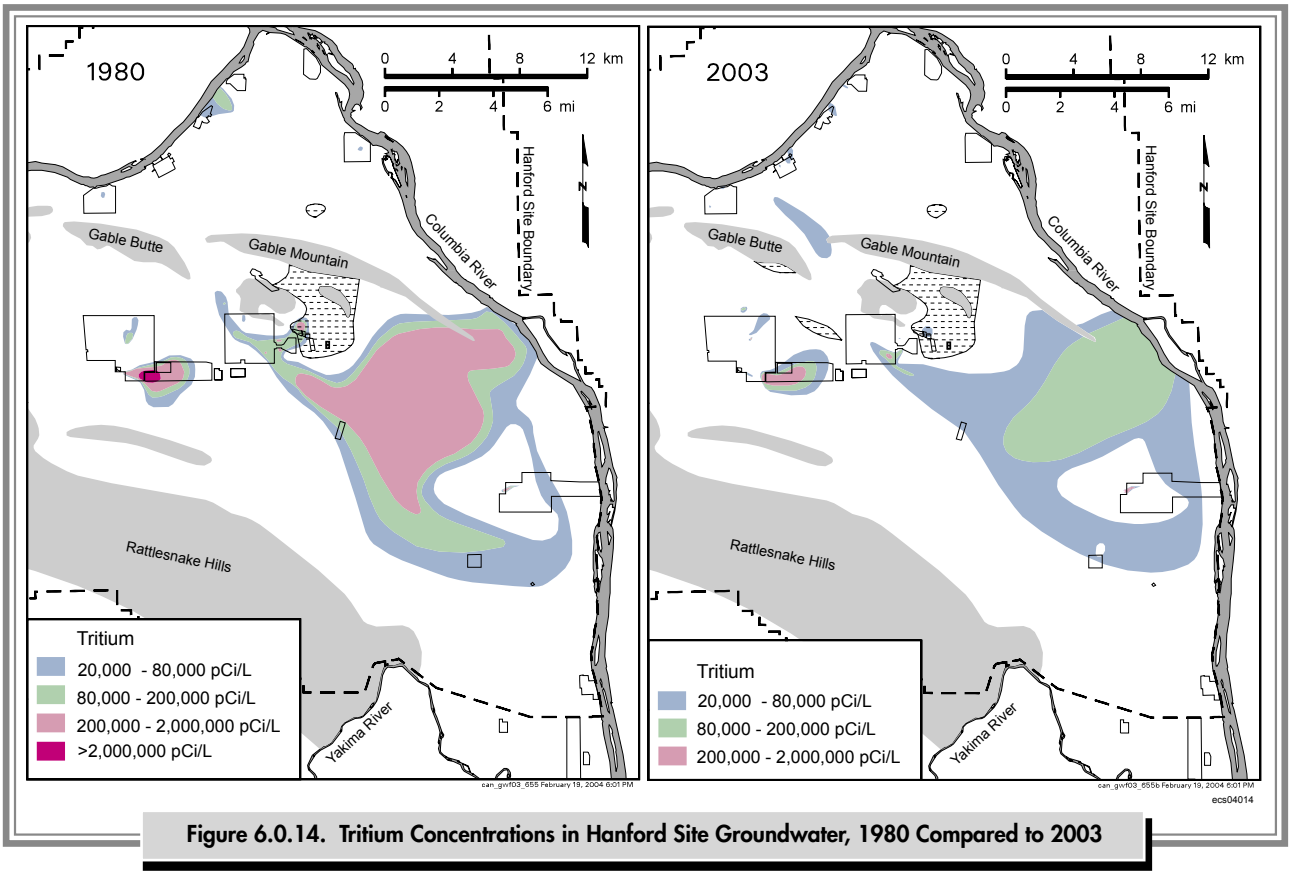

Figure 6.0.14. Tritium Concentrations in Hanford Site Groundwater, 1980 Compared to 2003

(a) Source, special nuclear, and by-product materials, as defined in the *Atomic Energy Act of 1954*, are regulated at DOE facilities exclusively by the DOE acting pursuant to its *Atomic Energy Act of 1954* authority. These materials are not subject to regulation by the state of Washington. All information contained herein and related to, or describing materials regulated by the *Atomic Energy Act of 1954* and processes in any manner, may not be used to create conditions or other restrictions set forth in any permit, license, order, or any other enforceable instrument. The DOE asserts that pursuant to the *Atomic Energy Act of 1954*, it has sole and exclusive responsibility and authority to regulate source, special nuclear, and by-product materials at DOE-owned nuclear facilities. Information contained herein on radionuclides is provided for process description purposes only.

mean values during the year. Two new monitoring wells were installed at this waste management area in 2003.

216-A-29 Ditch. Groundwater beneath the 216-A-29 ditch (Figure 6.0.3) is monitored as required by interim status detection regulations. To date, the ditch has not contaminated groundwater with regulated constituents, although sulfate attributable to manmade sources from the 200-East Area has been detected in two wells.

Integrated Disposal Facility. The Integrated Disposal Facility will be an expandable, lined, RCRA-compliant landfill. This facility is located near the Plutonium-Uranium Extraction Plant (PUREX) in the 200-East Area. Construction is scheduled to begin in 2004. The Part B permit application for this landfill was submitted to the Washington State Department of Ecology and is scheduled to be incorporated into the Hanford Facility RCRA Permit in 2004 (Ecology 1994). Four out of seven monitoring wells scheduled for this facility have already been installed.

216-B-3 Pond. The 216-B-3 pond continued to be monitored in 2003 under a temporary, alternative monitoring plan. During 2001, the Washington State Department of Ecology granted a variance to apply a new approach to groundwater monitoring at this site for a 2-year trial period. The trial approach used statistical methods based on comparisons between all wells instead of the standard upgradient/downgradient concentration comparisons. The constituents selected for the comparisons between all wells were gross alpha, gross beta,[(a)] and specific conductance. The final samples for the trial period were collected in July 2003, and an evaluation of the approach is currently underway.

Nonradioactive Dangerous Waste Landfill. The Nonradioactive Dangerous Waste Landfill is located in the 600 Area, within the footprint of the 200-PO-1 regional plume (Figure 6.0.1). During 2003, seven volatile organic compounds were detected in Nonradioactive Dangerous Waste Landfill monitoring wells. The levels of 1,1,1-trichloroethane, 1,1-dichloroethene, acetone, chloroform, tetrachloroethene, toluene, and trichloroethene were reported to be well below drinking water standards. The source of these volatile organic compounds could either be the Nonradioactive Dangerous Waste Landfill or the Solid Waste Landfill.

Solid Waste Landfill. The Solid Waste Landfill (Figure 6.0.3) is regulated under state dangerous waste regulations. In 2003, specific conductance, pH, chloride, and sulfate exceeded their background threshold levels in one or more groundwater samples collected near this facility. The lower pH apparently is a result of high concentrations of carbon dioxide in the vadose zone resulting from the degradation of sewage material disposed to the Solid Waste Landfill.

200 Area Treated Effluent Disposal Facility. A state waste discharge permit governs groundwater sampling and analysis in the three monitoring wells at the 200 Area Treated Effluent Disposal Facility. The 200 Area Treated Effluent Disposal Facility is located southeast of the B Pond RCRA facility. No permit criteria for constituents in groundwater were exceeded at this facility in 2003. The groundwater monitoring network continues to show that effluent from the facility has not reached the underlying uppermost aquifer, which is confined.

4608 B/C Process Ponds. The 4608 B/C ponds (also called the 400 Area process ponds), are regulated under a state waste discharge permit. Groundwater quality near these ponds met permit conditions in 2003. The permit was modified in 2003, and the requirement for groundwater monitoring at this site ended on October 1, 2003.

6.0.3.12 300-FF-5 Operable Unit

The 300-FF-5 Operable Unit (Figure 6.0.1) is divided into two general regions: the 300 Area and the 300-FF-5 North region, which includes the 618-11 burial ground, the 618-10 burial ground, and the 316-4 cribs.

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Groundwater constituents from 300 Area sources include uranium and volatile organic compounds. The size of the 300 Area uranium groundwater plume is generally consistent from year to year, but concentrations in the plume are variable throughout the year as a result of changes in river stage. A plume of trichloroethene in the 300 Area is attenuating naturally, and average concentrations remained below the drinking water standard in 2003. Trichloroethene contamination in this area is associated with other hydrocarbons (e.g., cis-1,2-dichloroethene). The interim action chosen for the 300-FF-5 Operable Unit includes natural attenuation of the uranium and organic contamination.

Contaminants from the north part of the operable unit include tritium, uranium, various volatile organic compounds, petroleum hydrocarbons, and tributyl phosphate. Tritium concentrations in groundwater near the 618-11 burial ground have decreased in recent years but remained among the highest (3,620,000 pCi/L [134,000 Bq/L]) on the Hanford Site during 2003. This high-concentration contamination is limited to a narrow plume extending approximately 1 kilometer (0.6 mile) to the east of the burial ground.

316-5 Process Trenches. The 316-5 process trenches (a former disposal facility) is the only RCRA site in the 300-FF-5 Operable Unit (Figure 6.0.3). The trenches have contributed to groundwater contamination when they received effluent discharges of dangerous mixed waste in the past. Only two of the contaminants of concern remain above drinking water standards, uranium and cis-1,2-dichloroethene. Groundwater contamination beneath the trenches will be remediated under CERCLA regulations. While the CERCLA interim action (natural attenuation) is in progress, groundwater near the trenches is monitored under a final status, corrective action monitoring program.

6.0.3.13 1100-EM-1 Operable Unit

The 1100-EM-1 Operable Unit (Figure 6.0.1) includes a small, narrow plume of trichloroethene, which is attenuating naturally. Annual average concentrations have remained below the drinking water standard since 2001. Contaminants also flow into the unit from offsite sources (e.g., nitrate from agriculture and industry).

The city of Richland maintains a well field in the 1100-EM-1 groundwater interest area, which includes a much broader area than the operable unit. Wells near the well field are monitored frequently to detect any changes in Hanford contaminants near the city's wells. The tritium plume from the 200-East Area has not been detected in these wells. Low levels of tritium, similar to levels in Columbia River water, continued to be detected.

The selected remedy for cleaning up 1100-EM-1 Operable Unit groundwater is to continue to monitor the natural attenuation of volatile organic compounds.

6.0.3.14 Confined Aquifers

Although most of Hanford's groundwater contamination is in the unconfined aquifer, the DOE monitors wells in deeper aquifers because of the potential for downward migration of contamination and the potential migration of contamination offsite through the basalt-confined aquifer.

The Ringold Formation confined aquifer occurs within fluvial sand and gravel comprising the lowest sedimentary unit of the Ringold formation. It is confined below by basalt and above by the lower mud unit. Groundwater in this aquifer flows generally west to east in the vicinity of the 200-West Area. In the central portion of the aquifer, flow converges on the 200-East Area from the west, south, and east. Groundwater discharges from the confined aquifer into the overlying unconfined aquifer near the 200-East Area.

While effluent disposal was occurring at the B Pond system, groundwater mounding forced groundwater and any associated contamination a limited distance into the Ringold Formation confined aquifer. Groundwater analyses for 2003 at the 200 Area Treated Effluent Disposal Facility continued to demonstrate that the confined aquifer has not been influenced by disposal activities at this facility.

Within the upper basalt-confined aquifer system, groundwater occurs within basalt fractures and joints, interflow contacts, and sedimentary interbeds. Groundwater in the upper basalt-confined aquifer system generally flows from west to east across the Hanford Site toward the Columbia River.

Results of sampling basalt-confined groundwater show that tritium was detected in some wells at very low levels, while

iodine-129, strontium-90, gamma-emitting isotopes, and uranium isotopes were not detected. Cyanide, nitrate, and technetium-99 were elevated in one well in the north part of the 200-East Area, but contaminant migration during well construction is responsible for this contamination. Contaminants on the Hanford Site have not migrated through the upper basalt-confined aquifer system to offsite sample locations south and southeast of the Hanford Site.

6.0.4 Well Installation, Maintenance, and Decommissioning

The Washington State Department of Ecology, EPA, and DOE negotiated an integrated well drilling list that coordinates and prioritizes the requirements of various groundwater monitoring regulations. During 2003, a total of 18 new wells were installed at Hanford. These included seven for RCRA monitoring, nine for CERCLA operable units, and two for research on chromate bioremediation. Two hundred and forty-three wells received maintenance, and 63 wells were decommissioned (filled with grout) because they were no longer needed, were in poor condition, or were in the way of remediation activities.

6.0.5 Modeling

Computer simulations of groundwater flow and contaminant movement help predict future conditions and assess the effects of remediation systems. During 2003, the consolidated groundwater flow and transport site-wide model was calibrated based on an alternative conceptual model that defines zones within the most important transmissive hydrogeologic units.

The System Assessment Capability is an integrated assessment tool that includes several linked computer models designed to simulate the movement of contaminants from waste sites through the vadose zone, groundwater, and Columbia River to receptors. It also incorporates modules that calculate the risks to human health and the environment. During 2003, the System Assessment Capability was updated; an atmospheric transport module was added and newer versions of the groundwater flow and transport modules were added. The three-dimensional "base case" site-wide groundwater model was used in the initial assessment performed during 2002. In 2003, the model grid was refined around the contaminant plume areas.

6.0.6 Vadose Zone

S.M. Stoller Corporation performs geophysical logging at the Hanford Site for both 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.

6.0.6.1 Geophysical Logging in Cased Boreholes at Hanford

Geophysical logging in existing boreholes represents a cost-effective means to obtain subsurface information to support planning for more detailed remedial investigation and/or cleanup activities. All Hanford boreholes contain steel casing, which precludes the use of conventional electromagnetic and seismic (acoustic) logging methods. Radioactivity and nuclear logs can be run in cased holes. The gross gamma log and spectral gamma log are particularly effective in detecting gamma-emitting radionuclides through steel casing, and neutron logging methods can be used to measure moisture content in the vadose zone, or to detect the presence of alpha-emitting radionuclides from neutrons emitted from alpha interactions with elements in the sediment.

"Gross gamma logging" refers to logs in which gamma activity is measured without regard to energy level. Gross gamma logs may use spectral detectors such as the high-purity germanium detector (HPGe), or sodium iodide scintillator, or they may use a simpler detector such as a Geiger-Mueller meter (Geiger counter) tube, which does not differentiate between energy levels. The gross gamma log simply reports the total gamma activity as a function of depth.

"Spectral gamma logging" refers to logs in which gamma energy spectra are collected in the borehole. These systems can use either a semiconductor detector, such as the high-purity germanium detector, or a sodium iodide

scintillator. In a spectral gamma log, individual gamma photons are counted as a function of energy level. This allows radionuclides to be identified and quantified on the basis of gamma activity at specific energy levels. In some cases, generally with a sodium iodide detector, gamma activity may be reported for "windows," which represent specific energy ranges. Most conventional spectral gamma logs are calibrated for naturally occurring radionuclides, primarily potassium-40, thorium-232, and uranium-238. Variations in naturally occurring radionuclides have proven useful in stratigraphic correlation, but many of the assumptions made in conventional spectral gamma logging are not applicable to detection and evaluation of manmade radionuclides. For example, uranium processed for reactor fuel has been chemically separated from its daughter products, and a period on the order of a million years will be required for secular equilibrium to be re-established throughout the decay chain. Processed or manmade uranium, therefore, exhibits few of the gamma rays typically associated with natural uranium. However, manmade uranium-238 can be detected and quantified by measurement of relatively low yield gamma activity associated with protactinium-234, an "early" daughter in the uranium-238 decay series for which secular equilibrium is established relatively quickly. Other manmade radionuclides emit characteristic gamma rays which are detectable with conventional spectral gamma logging equipment, but they may not be recognized by a conventional log evaluation approach. High resolution gamma spectroscopy is necessary to determine net count rates associated with specific gamma lines, from which identification and quantification can be performed.

The spectral gamma logging system, utilizes a cryogenically cooled high-purity germanium detector to detect, identify, and quantify gamma-emitting radionuclides in the subsurface. Identification of naturally occurring and manmade radionuclides is based on detection of gamma rays at characteristic energy levels. Conventional gamma spectroscopy software is used for peak recognition and to determine net counts. A calibration function defines detector response as a function of energy level, and radionuclide concentrations (activity per unit mass of soil) are calculated from net count rates. Correction functions are available for dead time, casing thickness, and water. Tables 6.0.6 and 6.0.7 list commonly encountered natural and manmade radionuclides at the

Table 6.0.6. Naturally Occurring Radionuclides

Radionuclide	Primary Gamma Rays Daughter	Secondary Gamma Rays Daughter
Potassium-40		
Thorium-232	Thallium-208	Lead-212 Thallium-208 Actinium-228
Uranium-238[a]	Bismuth-214	Lead-214 Bismuth-214

(a) Attainment of secular equilibrium between uranium-238 and bismuth-214/lead-214 requires time periods on the order of several million years. Activities of both bismuth-214 and lead-214 are commonly assumed to be equal to the amount of naturally occurring uranium-238. However, these radionuclides are short-term daughter products of radon-222, and accumulations of radon gas inside the casing may temporarily perturb the secular equilibrium between uranium-238 and bismuth-214/lead-214.

Table 6.0.7. Manmade Gamma-Emitting Radionuclides

Radionuclide	Half-Life Years	Typical MDL, pCi/g[a]
Cobalt-60	5.2714	0.15
Ruthenium-106	1.0238	
Antimony-125	2.7582	
Tin-126	1.E+05	
Cesium-134	2.062	
Cesium-137	30.07	0.2
Europium-152	13.542	
Europium-154	8.593	0.2
Europium-155	4.7611	
Uranium-235	7.04E+08	0.6
Protactinium-234 (uranium-238)[b]	4.47E+09	12
Neptunium-237	2.14E+06	
Plutonium-239	24,110	1,300
Americium-241	432.2	5,000

(a) The MDL is affected by variables such as count time, casing thickness, water, shielding, and the presence of other radionuclides. Values shown are for typical logging conditions in a minimally contaminated zone.

(b) Protactinium-234 is a short-term daughter of uranium-238. Secular equilibrium is achieved relatively quickly. Because of the relatively low gamma yield, this peak is not seen when only background levels of naturally occurring uranium-238 are present. Hence, the presence of gamma peaks associated with protactinium-234 without corresponding peaks associated with lead-214 and bismuth-214, is taken as an indication of manmade or chemically processed uranium.

Hanford Site. A variation of the spectral gamma logging system known as the high rate logging system uses a much smaller detector to collect log data in zone of intense gamma radiation. The high rate logging system is used in borehole intervals where the dead time for the spectral gamma logging system exceeds 40%. When used in combination, the spectral gamma logging system and high rate logging system provide a measurement capability from approximately 0.1 to 109 pCi/g (0.0037 to 4 Bq/g) cesium-137.

The neutron moisture logging system utilizes a 50-mCi (1.85-GBq) americium-beryllium source and helium-3 detector. Neutrons generated from the interaction of alpha particles emitted from americium-241 with beryllium bombard the surrounding formation and are scattered back to the detector. In geologic media, the dominant mechanism for neutron scattering is interaction with hydrogen atoms, and the count rate at the detector is a function of the proportion of hydrogen in the formation, which is generally an indication of the moisture content. In the neutron moisture logging system, the detector is located relatively close to the source, so that neutron counts at the detector increase with increasing moisture content. This arrangement provides very good vertical resolution. Calibration functions are available to relate neutron counts to moisture content for 15.24- and 20.32-centimeter (6- and 8-inch) diameter boreholes and a correction function is available for casing thickness. Neutron moisture logging system logs are useful as an indication of in situ moisture content, and for stratigraphic correlation.

The passive neutron logging system has seen limited use at Hanford. This log uses a helium-3 detector to count neutrons originating from the surrounding formation. The most likely sources of neutrons are interactions between alpha particles and elements in the sediment, particularly the interaction between alpha particles and oxygen. This log has been used to qualitatively detect transuranics in the subsurface (BHI-01436).

Another log that shows promise is the neutron capture log. This device bombards the formation with neutrons from a californium-252 source. As the neutrons are scattered by collisions with atoms in the formation, they are slowed and eventually captured. The probably of capture depends on the velocity (energy) of the neutron and the capture cross section of the target atom. When capture occurs, the atom may emit a gamma ray at a characteristic energy level, or it may become unstable and decay, emitting gamma rays as part of the decay process. Gamma rays emitted as a result of the capture process are "prompt" in that they occur immediately after the capture event, whereas gamma rays emitted as a result of decay may occur somewhat later, depending on the decay constant of the new isotope formed by the capture event. The sensitivity of the neutron capture log depends on the capture cross section of the target element and the characteristics of the resulting gamma ray.

6.0.6.2 Vadose Zone Characterization Results

The baseline characterization project for past-practice disposal sites in the Hanford areas is an extension of the Hanford Tank Farms Vadose Zone Project. From 1995 to 2000, spectral gamma logging system logs from 769 existing monitoring boreholes in the single-shell tanks farms were used to develop an understanding of subsurface contamination conditions in the vicinity of the single-shell tanks.

Beginning in 2001, spectral gamma logging system logs are being collected in more than 800 existing boreholes associated with past-practice disposal sites in the Hanford 200 Areas. All available boreholes are logged and log plots and log data reports are prepared for individual boreholes. Log data from a specific area or group of contiguous waste sites are incorporated into a waste site summary report, which also summarizes geologic conditions, waste site construction details, and operational history and provides an evaluation of subsurface contamination conditions. Characterization began in the 200-East Area with a report (GJO-2002-322-TAR) on the 216-B-35 to 216-B-42 trenches (west of the BX Tank Farm). This was followed by reports on the 216-B-8 crib and adjacent sites (GJO-2002-343-TAR); the 216-B-5 injection well and 216-B-9 crib and tile field (GJO-2002-358-TAC); and the 216-B-43 to 216-B-50, 216-B-57, and 216-B-61 cribs (GJO-2003-458-TAC). Logging activities in and around the B-BX-BY Waste Management Area were completed in fiscal year 2003. Currently, a report is being prepared on the B-BX-BY Waste Management Area and adjacent waste sites. This report integrates results from the above reports with previous baseline reports for the B, BX, and BY Tank

Farms. It incorporates log data from 284 boreholes. Cesium-137, cobalt-60, uranium-235 and -238, antimony-125, strontium-90, and europium-152 and -154 were detected. The predominant contaminant was cesium-137, which was measured at a maximum concentration of more than 20 million pCi/g (0.74 MBq/g). This high activity level was observed in boreholes 299-E33-27 (21-02-04) near tank BX-102 and in 299-E33-223 near tank BX-110. Concentrations of cesium-137 greater than 1 million pCi/g (0.37 MBq/g) were found above elevation 525 in the vicinity of the single-shell tank farms and in the vicinity of the BY cribs.

Manmade uranium-238 concentrations as high as 1,000 pCi/g (37 Bq/g) were found in the area east of tank BX-102. Of the 284 boreholes logged in the B-BX-BY Waste Management Area, only 17 encountered detectable amounts of manmade uranium-238. The most extensive area of uranium contamination was found to extend downward and to the northeast from the vicinity of BX-102, intercepting the groundwater in the vicinity of 299-E33-18. Evaluation of historical log data suggests that the uranium plume reached the groundwater in this area between 1991 and 1997. This is consistent with groundwater monitoring results, which show elevated uranium levels beginning in about 1994. Little evidence of subsurface uranium contamination was found in the vicinity of other waste sites for which uranium disposal is assumed.

The maximum concentration of antimony-125 did not exceed 10 pCi/g (0.37 Bq/g). The highest europium-154 concentration encountered was 127 pCi/g (4.7 Bq/g) near tank BX-101.

In general, contamination that appears to be directly associated with a specific waste site or tank was observed at log depths less than 45.7 meters (150 feet) in the immediate vicinity of the waste site. However, most tank farm boreholes and many boreholes associated with the liquid waste sites are less than 45.7 meters (150 feet) in depth, and groundwater occurs at approximately 76.2 meters (250 feet) depth. Hence, the deeper part of the vadose zone is relatively poorly investigated, and the full extent of contamination may not be known. However, borehole evidence of vadose zone contamination extending to groundwater does exist for processed uranium originating from the vicinity of tank BX-102, and for cobalt-60 and cesium-137 originating from the BY cribs. Figures 6.0.15 and 6.0.16 show vadose zone contamination in the B-BX-BY Waste Management Area and vicinity.

S.M. Stoller Corporation also logged selected boreholes in the 200-West Area that were scheduled for decommissioning during fiscal year 2003. These boreholes had been identified in the original database for baseline characterization included in the project management plan. Log data were collected in 23 of the 57 boreholes before they were decommissioned.

In addition to baseline vadose zone characterization activities described above, S.M.Stoller Corporation also provided geophysical logging of new and existing boreholes in support of ongoing remedial investigation activities by other Hanford contractors. These holes are logged as requested and log plots and log data reports are provided to the cognizant engineers. In some cases, shallow boreholes were installed specifically for spectral gamma logging, and the results from these holes were used to identify locations for more detailed investigation.

Spectral gamma logs are also provided for new groundwater monitoring wells before the wells are completed. In addition, the S.M. Stoller Corporation maintains files for boreholes in the Hanford 200 Areas and provides copies of historical logs and log evaluation as requested.

Log data and reports are accessible via the internet at http://www.gjo.doe.gov/programs/hanf/HTFVZ.html.

6.0.6.3 Monitoring Activities in the Single-Shell Tank Farms

The Hanford Tank Farms Vadose Zone Monitoring Project was established in fiscal year 2001 for comprehensive routine monitoring of existing boreholes in Hanford single-shell tank farms. Monitoring is fundamentally different from characterization. Once the nature of contamination is known, the measurements required to detect changes are much simpler to implement. In general, monitoring uses simpler equipment and data analysis methods: the value of monitoring is in detecting changes or trends in successive measurements over time. In most cases, recording total gamma activity at regular intervals is sufficient to demonstrate stability or to detect movement in a particular plume.

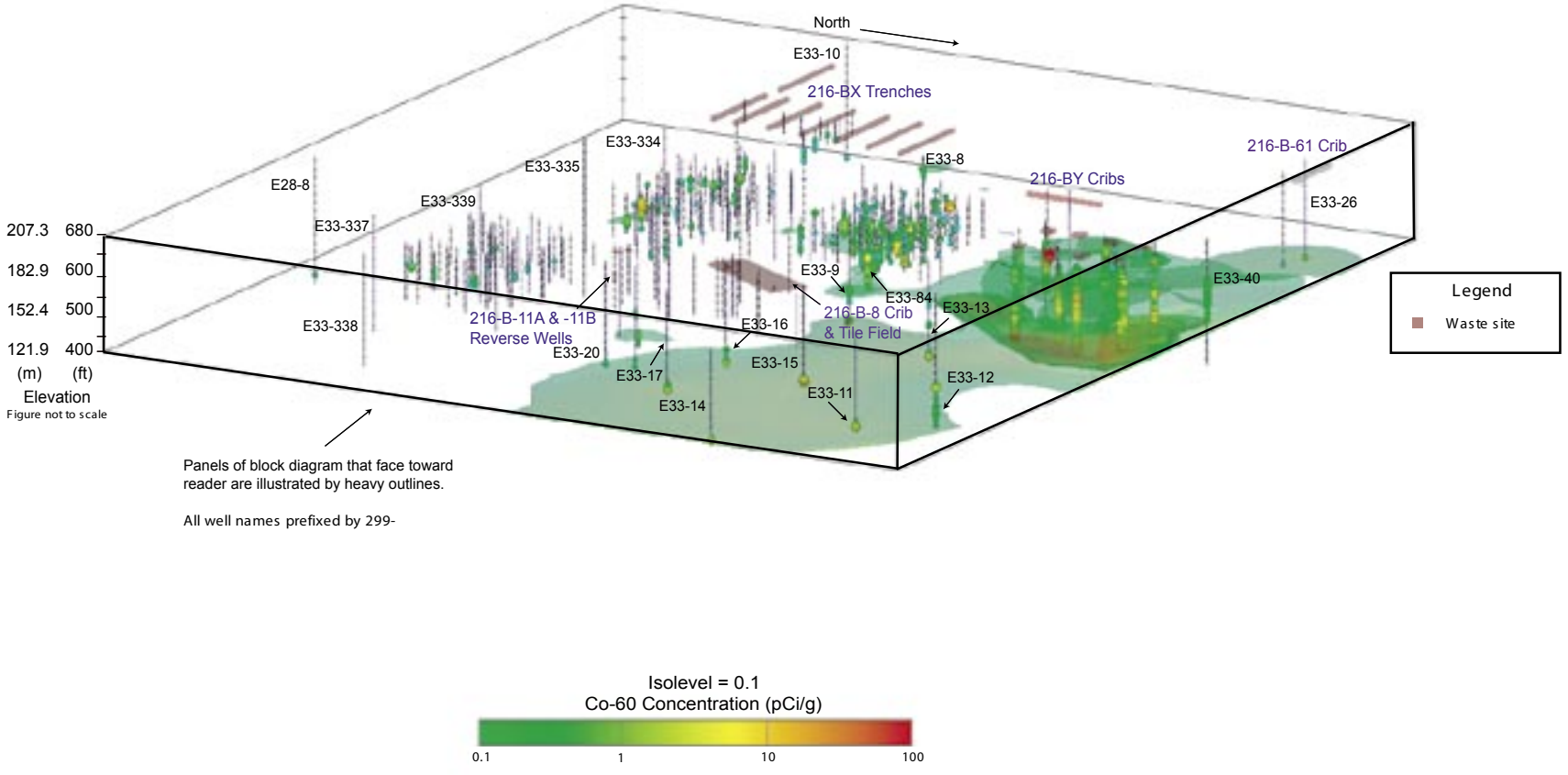

Figure 6.0.15. Cobalt-60 Vadose Zone Contamination in the B-BX-BY Waste Management Area and Vicinity

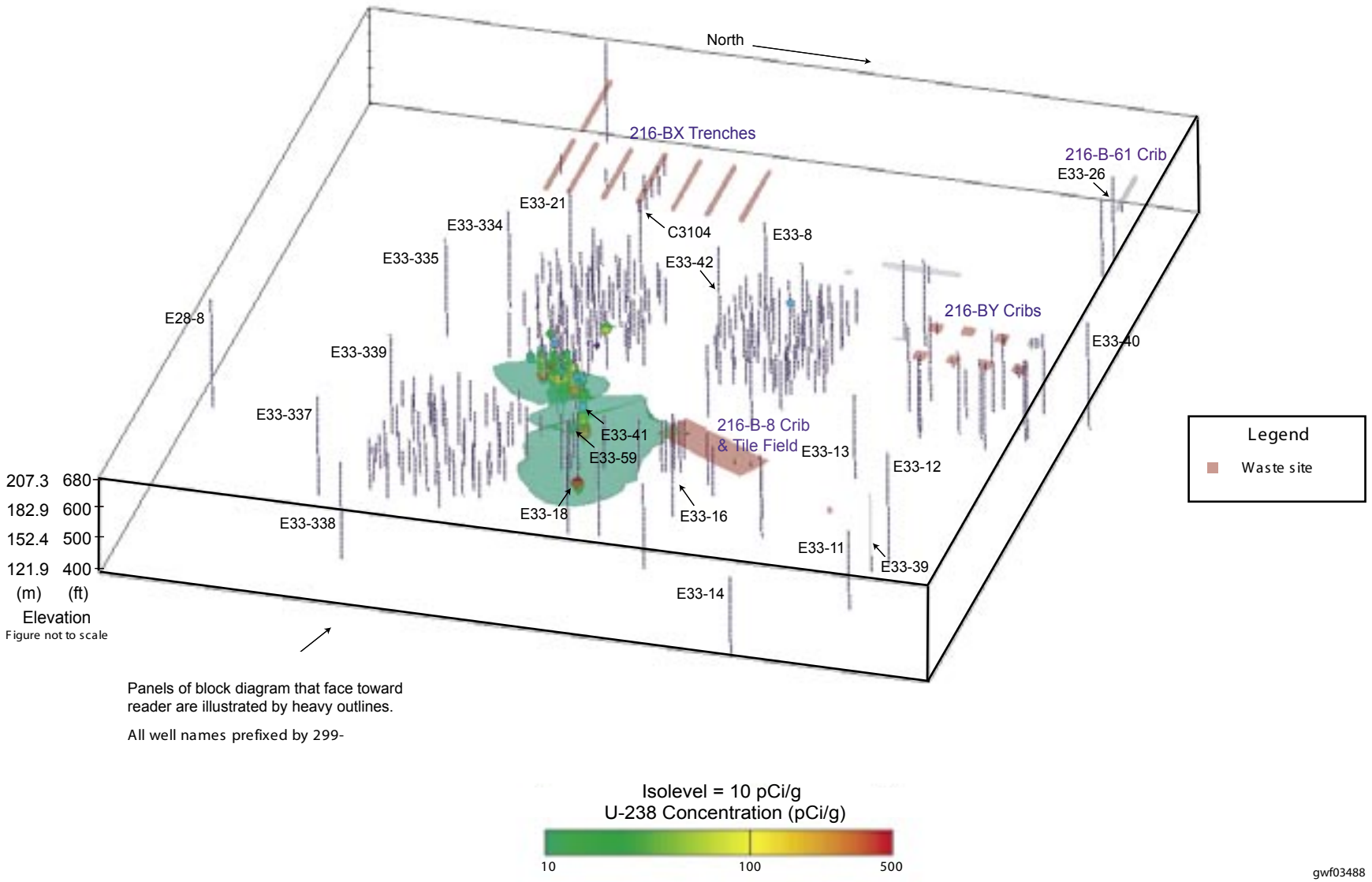

Figure 6.0.16. Uranium-238 Vadose Zone Contamination in the B-BX-BY Waste Management Area and Vicinity

A baseline record of existing contamination associated with gamma-emitting radionuclides in the vadose zone was established between 1995 and 2000. 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.

The logging system used for monitoring is the Radionuclide Assessment System. The Radionuclide Assessment System uses a series of sodium iodide (NaI) scintillation detectors to monitor gamma activity in tank farm boreholes. Three different detector sizes are available to provide a wide range of measurement capability. Although less precise, the Radionuclide Assessment System is a simpler and faster logging system than the high resolution spectral gamma logging system. Measurements collected with the Radionuclide Assessment System can be compared to the baseline data to assess the long-term stability of the radionuclide contaminant profile. When routine monitoring identifies anomalies relative to the baseline, these anomalies may be investigated using the spectral gamma logging system, the High Rate Logging System, and/or the Neutron Moisture Logging System. The High Rate Logging System is also used to collect data in boreholes where the contaminant activity exceeds the working range of the Radionuclide Assessment System instrumentation (greater than about 100,000 pCi/g [3.7 MB/g] cesium-137).

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 fiscal year 2003, monitoring in boreholes associated with individual tanks undergoing retrieval operations was initiated. Retrieval monitoring requirements for specific tanks are under development but include a pre-retrieval baseline measurement, monthly measurements during the retrieval operations, and monthly measurements for six months after retrieval operations cease. Both the Radionuclide Assessment System and Neutron Moisture Logging System measurements are made on a monthly basis, and monthly monitoring is supplemented by manual moisture measurements acquired by CH2M HILL Hanford Group, Inc. personnel over limited depth intervals once or twice per week. During fiscal year 2003, two retrieval projects (tanks C-106 and S-112) were initiated. This required that the Radionuclide Assessment System be diverted from the routine monitoring to retrieval monitoring and resulted in a negative impact on the routine monitoring program as originally set forth in 2001. Deployment of the Neutron Moisture Logging System to support retrieval operations requires an additional logging engineer and reassignment of the system from support for the remedial investigation/feasibility study work conducted by the DOE Richland Operations Office.

A total of 377 (336 routine and 51 retrieval) monitoring events were performed with the Radionuclide Assessment System during fiscal year 2003. In addition, 27 moisture monitoring events were conducted in support of retrieval operations. Results are summarized by tank farm in Table 6.0.8. In the interest of brevity, plots for boreholes will not be included in this report. These logs are available on request, or from the internet at http://www.gjo.doe.gov/programs/hanf/HTFVZ.html.

The Radionuclide Assessment System has proven useful since its inception in fiscal year 2001 in providing a credible monitoring program for the tank farms vadose zone. Evidence of possible contaminant movement has been detected in 29 boreholes in 9 tank farms; 7 were identified this fiscal year. Of these 29 boreholes, data collected from 2 boreholes indicate movement to a degree that can be confirmed over a short time interval. Of the remaining 27 boreholes, it is likely that the elapsed time between monitoring events is not sufficient to detect subtle changes in contaminant profile, suggesting relatively slow movement of contaminants in the vadose zone. In general, intervals where discernable movement of contaminants through the vadose zone is occurring within short periods of time (e.g., less than 1.5 years) appear to be very limited.

Currently only one logging system (the Radionuclide Assessment System) is available to support both routine monitoring and leak detection monitoring for waste

Table 6.0.8. Summary of Tank Farm Monitoring Results

Tank Farm	Boreholes Monitored	Summary of Results
A	28	No significant changes in subsurface contaminant profile
AX	7	No significant changes in subsurface contaminant profile
B	8	No significant changes in subsurface contaminant profile
BX	33	Borehole 21-12-02 showed an abnormal decrease in total and ^{60}Co counts between 12 and 13.7 m (40 and 45 ft) during the most recent monitoring event on September 23, 2003. ^{238}U counts between 41.9 and 45 m (1 scal year 2003 have not confirmed this change.
BY	33	Boreholes 22-07-02, 22-07-05, and 22-08-05 have all shown evidence of possible ^{60}Co movement during previous monitoring events. Monitoring data in these boreholes during fiscal year 2003 failed to provide further evidence of movement.
C	48	Boreholes associated with tank C-106 were monitored several times during fiscal year 2003 in support of the C-106 Waste Retrieval Project. A possible increase of ^{60}Co was identified in borehole 30-06-10 between 37.8 and 38.4 m (124 and 126 ft) on April 23, 2002. Monitoring events conducted in this borehole during fiscal year 2003 showed no further evidence of movement. A definite change in ^{60}Co concentrations was observed in borehole 30-08-02 on September 11, 2002 between 18 and 18.5 m (50 and 61 ft). This appears to be related to a ^{60}Co plume originating between C-108 and C-109, and migrating downward and to the east. Contaminant movement was detected as early as 1999. Subsequent monitoring events during fiscal year 2003 have shown downward movement of ^{60}Co through this interval. This ^{60}Co is not related to recent waste retrieval operations in tank C-106. A possible increase in ^{137}Cs was observed in borehole 30-08-03 from 12.8 and 14.3 m (42 to 47 ft) on January 21, 2003. Subsequent monitoring events did not confirm this change. Five boreholes were logged wi drilling. Beginning in April 2003, three neutron moisture logging system logs were acquired in boreholes around C-106 during the fiscal year. Preliminary results of the moisture measurements le will continue to be monitored during fiscal year 2004 to determine if the increases are due to seasonal fluctuations in moisture or a potential tank leak. Radionuclide Assessment System measurements suggest no increas As of October 2003, it is believed that the observed moisture changes are related to seasonal fluctuations and that no tank leaks associated with the retrieval operations are occurring.
S	28	Boreholes associated with tank S-112 were monitored several times during fiscal year 2003 in support of the S-112 Waste Retrieval Project. These boreholes were also logged several times with the neutron moisture logging system. Eight boreholes located around tank S-102 were monitored in preparation for the S-102 Waste Retrieval Project. An apparent increase in ^{137}Cs concentration was observed in bor scal year 2004. The baseline moisture measurements were acquired during August 2003. Two Radionuclide Assessment System measurements (March and August) have been acquired to support retrieval operations during fiscal year 2003. No changes in activity were observed between the two Radionuclide Assessment System measurements or since the baseline spectral gamma data acquired in 1996. A second pre-retrieval monitoring event is scheduled for January 2004. Currently, baseline moisture logging is planned to be performed in tank S-102 boreholes approximately one month prior to the assess any potential changes in a zone of high gamma flux.

Table 6.0.8. (contd)

Tank Farm	Boreholes Monitored	Summary of Results
SX	49	Borehole 41-02-02 showed evidence of possible ^{137}Cs and/or ^{90}Sr concentration increases between 13 and 16.7 m (43 and 55 ft) during the initial Radionuclide Assessment System monitoring even dence for possible increasing ^{137}Cs concentration increase at 20 m (66 ft). This increase was first identified by the spectral gamma logging system repeat logging in 1999. Borehole 41-15-07 showed a possible ^{137}Cs increase between 17.3 and 18.2 m (57 and 60 ft). This increase was identified during the second monitoring event conducted on February 12, 2003.
T	24	Eight of these boreholes (50 increases and/or contaminant movement in the past. No increases were confirmed in these boreholes during fiscal year 2003. Borehole 50-02-05 indicated an increase during fiscal year 2003. Neutron m drilled in fiscal year 2003. Neut
TX	15	Borehole 51-03-11 showed possible increases in ^{60}Co concentrations at depths of 18.6 and 18.9 m (61 to 62 ft) and from 27.4 and 28.9 m (90 to 95 ft) during the initial monito
TY	9	Borehole 52-03-06 showed an increase in ^{137}Cs concentration between 16.7 and 17.7 m (55 and 58 ft) during the initial monitoring event on May 2, 2002. Subsequent monitoring events have not shown additional increases in ^{137}Cs concentrations. Borehole 52-06-05 continues to show evidence of increasing ^{60}Co concentrations between 39.6 and 44.8 m (130 and 147 ft). Borehole 52-06-07 showed evidence of possible increases between 60.9 and 68.6 m (200 to 225 ft).
U	21	Seven of these boreholes were monitored to support the U-107 Waste Retrieval Project. A special investigation of the boreholes around tank U-107 (U Farm) has been completed. A final report, *Evaluation of Log Data in the Vicinity of Tank U-107* (GJO-2003-427-TAC), summarizing all measurements, was prepared and issued in June nal monitoring event was completed in boreholes around this tank in August 2003. The data from this final event supported the conclusion that there was no apparent change in the gamma-emitting radionuclide distribution in the vicinity of

retrieval operations. This logging system was originally configured for routine monitoring of gamma activity only. The requirement for neutron moisture logging to support retrieval operations has required that an additional logging system be detached from characterization logging and used to run the moisture log. As waste retrieval operations begin in C and S Tank Farms, increasing demands for retrieval support will interfere with the ability to conduct routine monitoring operations in the other tank farms. Efforts are underway to obtain a second monitoring system, configured for concurrent gamma activity and neutron moisture logging. This type of system will streamline logging operations for retrieval support, achieving significant cost savings, as well as freeing the Radionuclide Assessment System for the routine monitoring program.

6.0.7 References

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7.0 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 chapter summarizes activities conducted during 2003 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, and to control invasive and unwanted plant species.

7.1 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.

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 7.1.1 shows the 2003 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.

Real-time and historical data from the Hanford Meteorology Station can be obtained at http://terrassa.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.

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 directions 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 approximately 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 approximately 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.

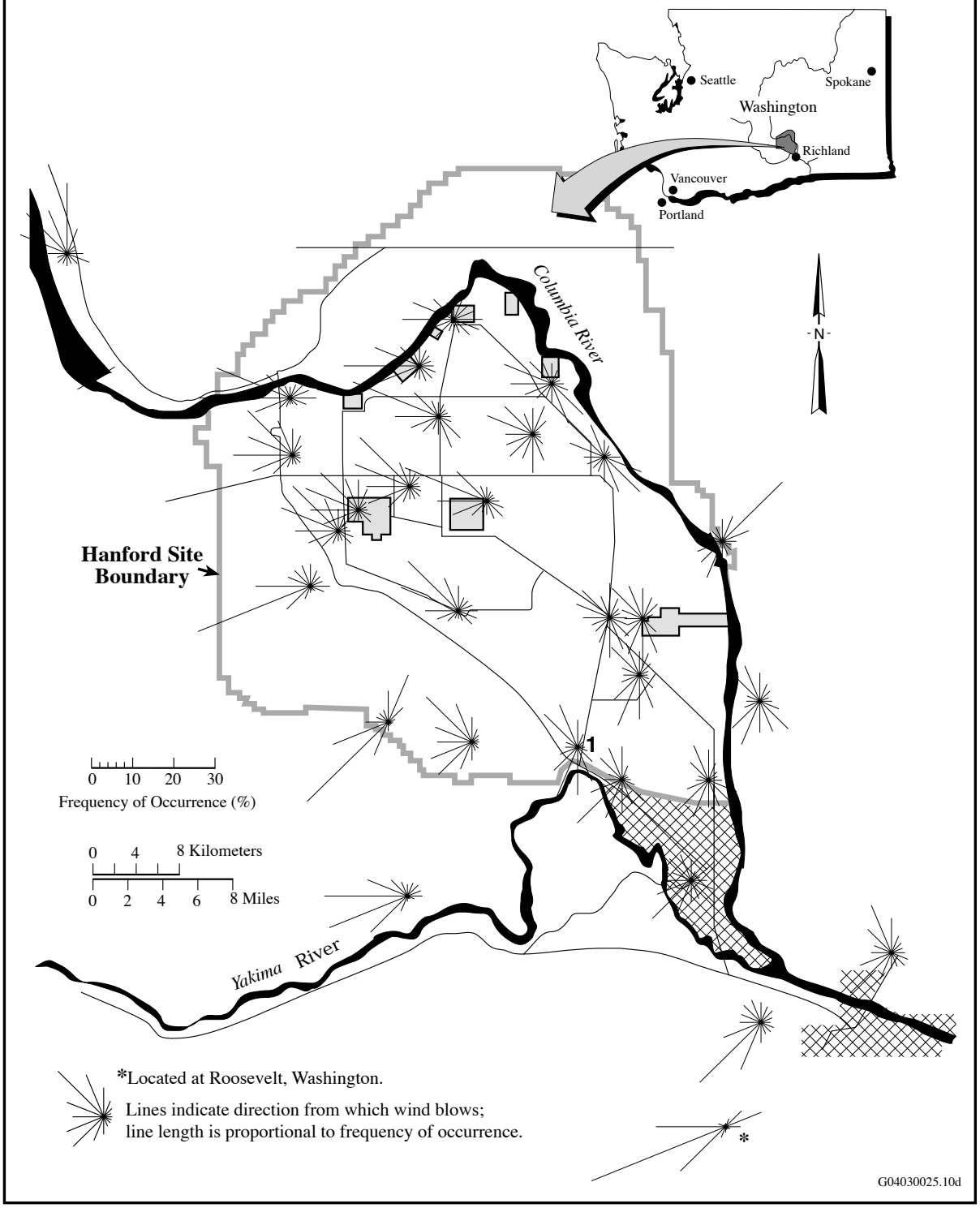

Figure 7.1.1. Hanford Meteorological Monitoring Network Wind Roses, 2003 (measured at a height of 9 meters [30 feet])

7.1.1 Historical Climatological Information

Daily and monthly averages and extremes of temperature, dew point temperature, and relative humidity for 1945 through 2003 are reported in PNNL-14616. From 1945 through 2003, 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 approximately 76%, and lowest during summer, averaging approximately 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.

7.1.2 Results of 2003 Monitoring

Calendar year 2003 was slightly warmer than normal and precipitation was above normal.

The average temperature for 2003 was 13.1°C (55.6°F), which was 1.1°C (2.0°F) above normal (12.0°C [53.6°F]). Nine months during 2003 were warmer than normal; three months were cooler than normal. January had the greatest positive departure, 3.4°C (6.2°F); and November, at 1.3°C (2.3°F) below normal, had the greatest negative departure.

Precipitation during 2003 totaled 20.7 centimeters (8.14 inches), 117% of normal (17.7 centimeters [6.98 inches]). Snowfall for 2003 totaled 22.1 centimeters (8.7 inches) (compared to an annual normal snowfall of 39.1 centimeters [15.4 inches]).

The average wind speed during 2003 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 26.8 meters per second (60 miles per hour) on October 28.

There were two dust storms recorded at the Hanford Meteorology Station during 2003 (March 5 and October 28). There has been an average of five dust storms per year at the Hanford Meteorology Station during the entire period of record (1945-2003).

Table 7.1.1 provides monthly and annual climatological data collected at the Hanford Meteorology Station during 2003.

Table 7.1.1. Monthly and Annual Climatological Data from the Hanford Meteorology Station, 2003

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						Snowfall						Peak Gusts		
	Daily Maximum	Daily Minimum	Monthly	Departure[b]	Highest	Date	Lowest	Date	Total	Departure[b]	Total	Departure[b]	Average	Departure[b]	Average Speed, m/s	Departure[b]	Speed, m/s	Direction	Date
J	6.2	0.4	3.3	+3.4	19.4	26	-5.6	10	4.8	+2.5	1.8	-8.9	86.5	+9.2	2.3	-0.5	17.4	S	2
F	10.2	-1.3	4.4	+1.1	16.7	21	-9.4	25	2.1	+0.4	0	-6.6	66.3	-4.2	3.2	0	23.2	SW	20
M	15.9	3.0	9.4	+1.6	25.0	30	-2.8	24[c]	0.7	-0.8	0	-1.0	55.6	-1.0	4.2	+0.6	23.7	W	5
A	17.9	4.5	11.2	-0.7	25.6	8	-4.4	4	5.7	+4.5	0	- T[d]	55.5	-8.2	3.5	-0.5	21.4	SW	9
M	23.6	8.8	16.2	-0.4	33.9	28	1.1	19	0.2	-1.2	0	0	44.4	+1.4	3.7	-0.3	18.3	W	14
J	30.9	14.1	22.5	+1.8	37.8	28	7.2	21	T[d]	-1.0	0	0	33.3	-6.3	4.1	0	20.1	WNW	18
J	36.3	17.3	26.8	+2.2	42.2	30[c]	11.1	9	0	-0.7	0	0	28.4	-5.0	3.8	-0.1	18.3	WSW	12
A	33.4	15.9	24.7	+0.6	40.0	1	11.7	24	1.2	+0.5	0	0	36.6	+1.0	3.4	-0.2	20.1	WNW	19
S	29.1	12.2	20.7	+1.8	38.9	4	5.0	14	0.6	-0.2	0	0	38.8	-3.5	3.3	0	19.7	WNW	12
O	21.7	6.6	14.1	+2.4	31.2	21	-7.9	31	0.2	-1.1	0	-0.3	49.1	-7.3	3.8	+0.9	26.8	SW	28
N	9.1	-2.7	3.2	-1.3	20.0	18	-10.6	22	0.4	-2.1	T[d]	-5.8	62.9	-10.8	4.4	+1.5	24.1	SW	18
D	3.7	-2.7	0.5	+0.7	10.6	6	-13.3	30	5.0	+2.2	20.3	+5.6	87.0	+6.9	2.5	-0.2	16.1	SSW	6
Y[e]	19.8	6.3	13.1	+1.1	42.2	Jul 30[c]	-13.3	Dec 3	20.7	+2.9	22.1	-17.0	53.7	-0.9	3.5	+0.1	26.8	SW	Oct 28

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) Departu

(c) Latest of several occurrences.

(d) Trace.

(e) Yearly averages, extremes, and totals.

7.2 Ecosystem Monitoring and Compliance

The Hanford Site is a relatively undisturbed area of shrub-steppe (a drought-resistant, shrub and grassland ecosystem) that contains a rich diversity of plant and animal species adapted to the region's semi-arid environment. The Ecological Monitoring and Compliance Project provides data and information to fulfill the 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 and analytical results are used to characterize any potential risk or impact to the biota. Ecological monitoring and ecological compliance support multiple objectives for completion of Hanford's waste management and environmental restoration mission through the following activities:

- 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 help protect 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.

This section provides current inventory, monitoring and survey information for species and communities found on the Hanford Site and presents this information in context with historical data and trend information. Ecological compliance activities and efforts related to inventory and management of threatened and endangered species are also included in this section.

7.2.1 Chinook Salmon

R. P. Mueller

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 Americans. Today, the most important natural spawning area in the mainstem Columbia River for fall Chinook salmon is the free-flowing Hanford Reach (Dauble and Watson 1997). 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 8,800 (Figure 7.2.1). In the early 1990s, redd estimates

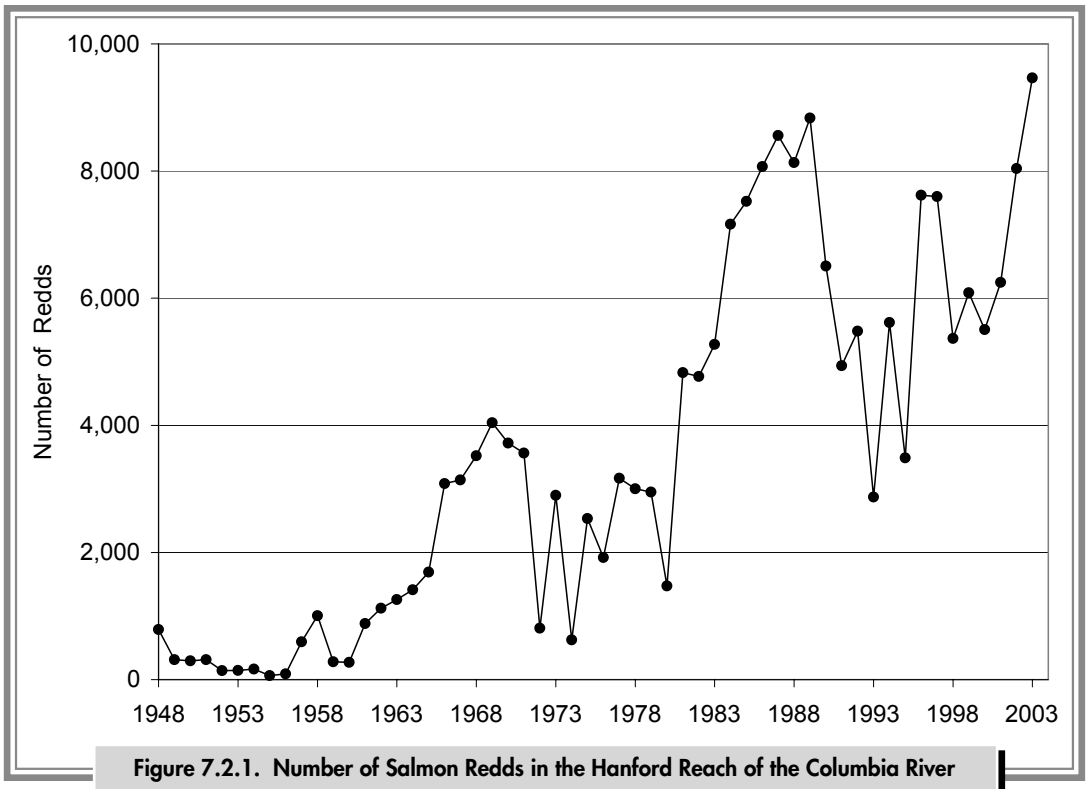

Figure 7.2.1. Number of Salmon Redds in the Hanford Reach of the Columbia River

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 2003, approximately 9,400 redds were observed, an increase of over 1,400 from 2002 and surpassing the peak of approximately 8,800 seen in 1989. The primary spawning areas in the Hanford Reach in 2003 were similar to areas used in previous years (Figure 7.2.2). The general locations of the spawning areas have not changed significantly over the past few years. The majority of redds occur near Locke Island (Areas 4 and 5), Vernita Bar (Area 10), and the areas upstream (Areas 6 and 7) and downstream (Areas 2 and 3) of Locke Island. Aerial surveys do not yield absolute redd counts because environmental conditions such as water depth, water turbidity, and sun angle vary. 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.

7.2.2 Mule Deer

B. L. Tiller and K. D. Hand

The health of resident mule deer (*Odocoileus hemionus*) on Hanford has been routinely monitored to assess onsite environmental quality. In 1993, Tiller et al. (1997) estimated that 15% of resident male mule deer were affected with testicular atrophy, a condition which also results in misshapen antlers and male sterility. Studies revealed no clear link between this condition and contaminants present at Hanford (Tiller et al. 1997).

Since 1994, trends in the population characteristics of mule deer have been monitored using roadside surveys. Population characteristics include number of fawns per 100 does that survive until the fall and male sterility. The survey areas include both upland and riparian environments that occur between the 300 Area to the south and the 100-B/C Area to the north. According to Tiller and Poston (2000), two sub-populations of deer inhabit the roadside survey region, the north region deer (100 Areas) and the south region deer (Hanford town site to the

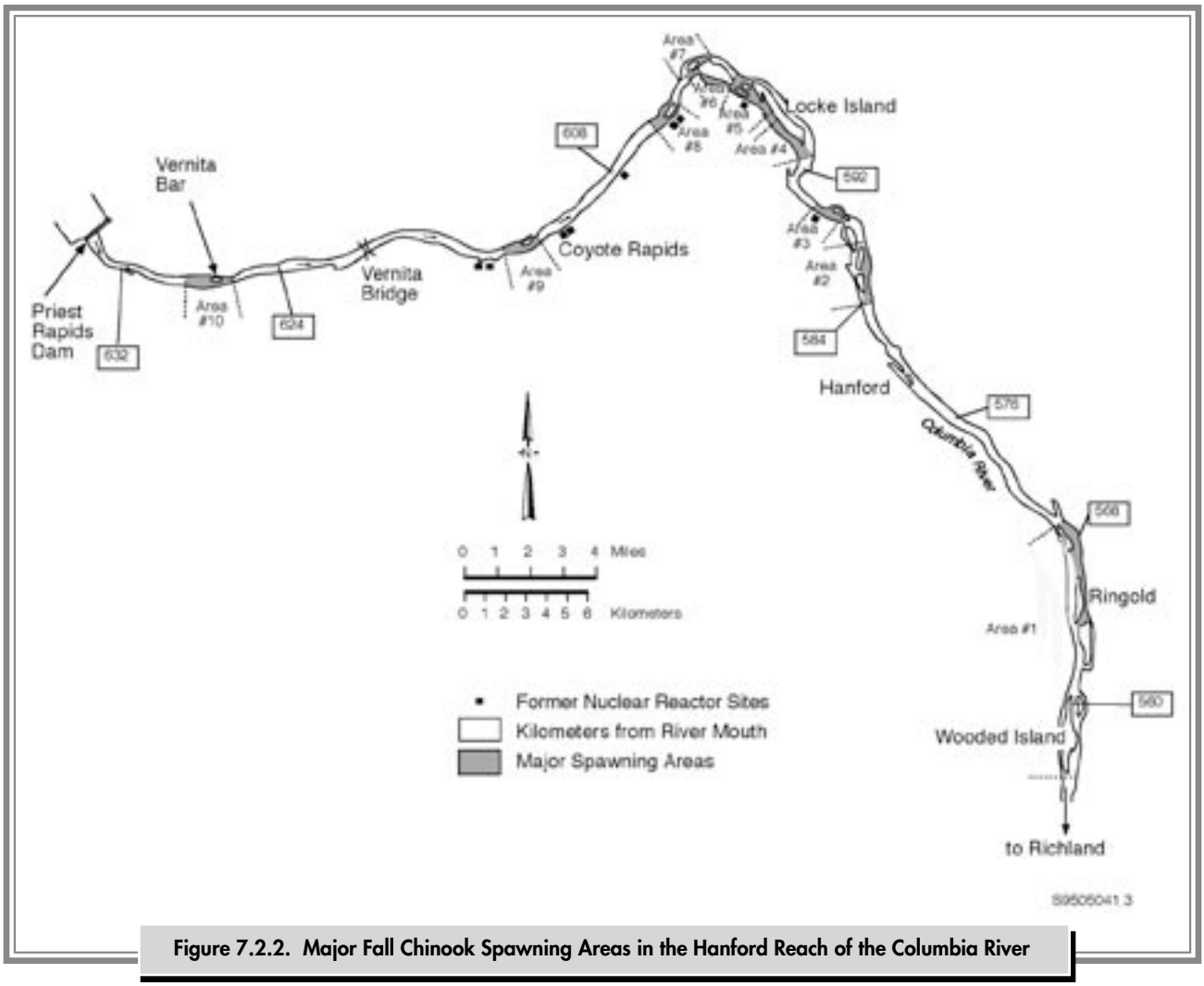

Figure 7.2.2. Major Fall Chinook Spawning Areas in the Hanford Reach of the Columbia River

300 Areas). After the hunting season of 2003, five complete surveys were conducted during November and December 2003 and January 2004; 244 deer were observed noting sex and age. In addition, for male deer, the presence or absence of velvet covered antlers was noted as an indication of their reproductive condition (fertile or sterile).

The data indicate that spatial trends in fawn survival were generally consistent between herds from the north and south regions; however, there appears to be a cyclic pattern over the 9-year survey period (Figure 7.2.3). Survival estimates in 1994 ranged between 20 and 40 fawns born per 100 adult female deer, and then steadily declined to less than 10 fawns per 100 does during 1997. From 1997 through 2000, fawn survival estimates steadily increased before decreasing in 2001. Deer surveys were not conducted during 2002. During 2003, mean fawn to doe survival rate estimates ranged from 47 to 55 fawns per 100 does in herds inhabiting the north and south Hanford Site regions, respectively (Figure 7.2.3). The survival results in 2003 from the deer population in the north region were the second highest in the 10 years of surveys, while estimates for the herd in the south region exceeded the highest documented survival rates.

The long-term trends of male deer with signs of testicular atrophy have also cycled since surveys began in 1994 (Figure 7.2.4). Estimates of the frequency of testicular atrophy in antlered deer (bucks) ranged from 3% to 7% between 1994 and 1997. The frequency of infertile bucks increased substantially during 1998, reaching levels in both the north and south regions similar to those seen during 1992 and 1993 by Tiller et al. (1997). Since 1998, there has been a steady decline in the frequency of this condition in male deer from both regions on the Hanford Site (Figure 7.2.4). During 2003, no bucks were seen with signs of testicular

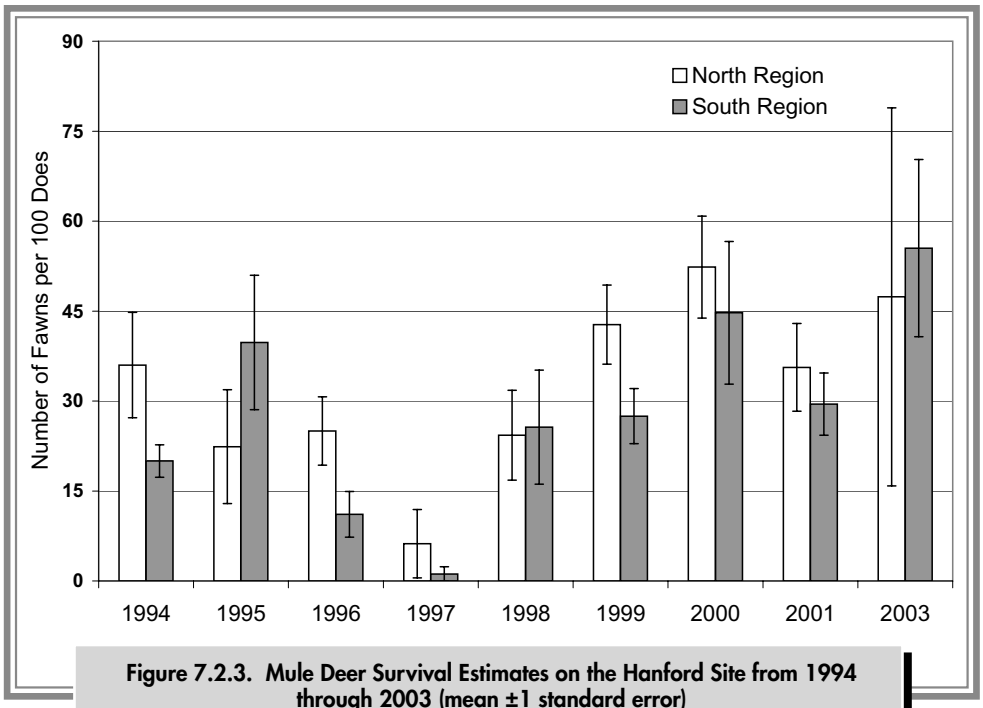

Figure 7.2.3. Mule Deer Survival Estimates on the Hanford Site from 1994 through 2003 (mean ±1 standard error)

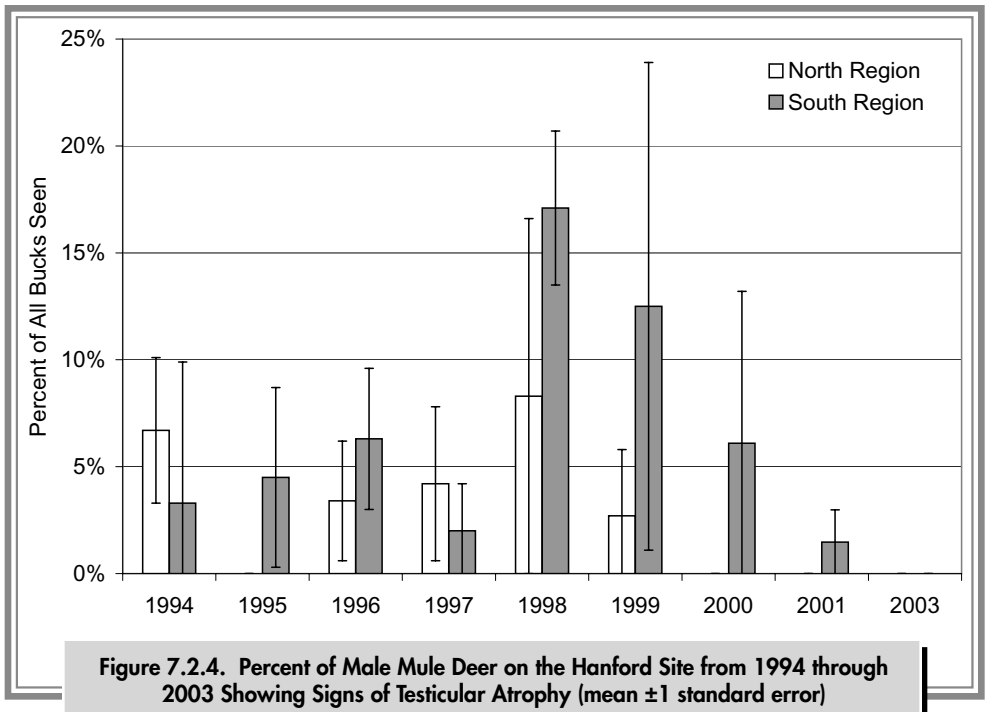

Figure 7.2.4. Percent of Male Mule Deer on the Hanford Site from 1994 through 2003 Showing Signs of Testicular Atrophy (mean ±1 standard error)

atrophy in either the north or south deer herds. Continued roadside surveys to monitor trends of the frequency of testicular atrophy and corresponding demographic and physiological trends of mule deer on the Hanford Site will allow continued evaluation of the health of the deer population.

7.2.3 Breeding Bird Roadside Surveys

W. H. Rickard, M. A. Simmons, S. DeBoer

The shrub-steppe habitat at one time covered approximately 255,000 square kilometers (98,000 square miles) in western North America (Knick et al. 2003). Much of this land has been transformed as a result of agriculture, grazing, and urbanization. Along with the decrease in habitat, the bird species that depend on this habitat have also declined. A large remnant of shrub-steppe habitat currently exists on the Hanford Site and, for the past 16 years, roadside surveys have been used to monitor bird populations on the site. Four survey routes have been monitored that represent distinct vegetation cover types on the Hanford Site (Figure 7.2.5) to determine which species use the site and to evaluate trends in the abundance of shrub-steppe birds. Of particular interest is the status of breeding birds on the site.

Trends were evaluated for the entire avian community as well as for the two most abundant species: Western meadowlarks (*Sturnella neglecta*) and horned larks (*Eremophila alpestris*). A log-linear regression model was used to evaluate the trend in the number of bird species observed during April, May, and June of each year between 1988 and 2003. The analyses revealed a decline in the number of species counted along each of the four transects (Figure 7.2.6). Meadowlarks, one of the most commonly occurring birds in shrub-steppe declined significantly along all four survey routes (Figure 7.2.7), whereas the number of horned larks (another common species) declined significantly on only one route (route A) (Figure 7.2.8). Recent wildfires on the site have eliminated large portions of the shrub habitat and could account for some of the decline. However, meadowlarks and horned larks are often associated with grassland habitats (Knick et al. 2003).

The trends seen at Hanford appear to mirror regional trends and appear to be associated with an overall decline and fragmentation of shrub-steppe habitat (Knick et al. 2003). For example, a general decline in meadowlarks has been noted across much of their range (USGS North American Breeding Bird Survey 1996-2001). Thus, while the Hanford Site continues to act as a refugium (Gray and Rickard 1989), the site cannot compensate for the large-scale habitat changes occurring throughout the Columbia Basin and the west. Results from these monitoring surveys are used for mitigation and land-use planning on the site.

7.2.4 Vegetation Survey and Monitoring

J. L. Downs, K. D. Hand, M. R. Sackschewsky, and R. E. Durham

The Hanford Site contains biologically diverse shrub-steppe plant communities that have been protected from most disturbances, except for fire, for more than 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 (Soll et al. 1999). Plant populations monitored on the site include taxa listed by Washington State as endangered, threatened, or sensitive (Appendix G), and those species 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 on the Hanford Site 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 plant populations of 47 different taxa listed by the Washington Natural Heritage program as endangered, threatened, sensitive, review, or watch list are found at the Hanford Site <http://www.pnl.gov/ecomon/Veg/Habitat.html; PNNL-13688>. The U.S. Fish and Wildlife Service has designated 5 of these 47 taxa (including the two species,

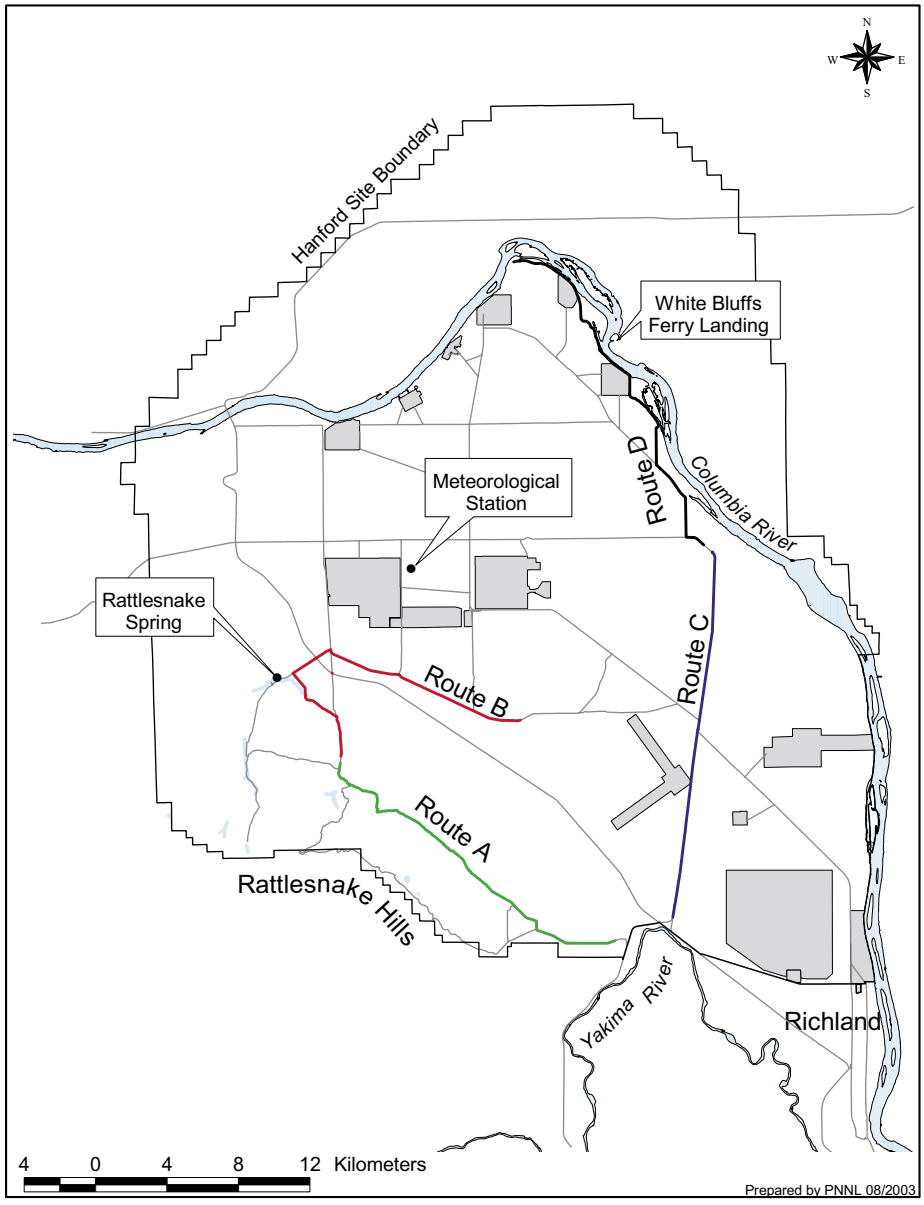

Figure 7.2.5. Roadside Bird Survey Routes on the Hanford Site. Each route passes through a different habitat — route A: bluebunch/wheatgrass community; route B: sagebrush/cheatgrass community; route C: bitterbrush/ cheatgrass community; and route D: old agricultural fields.

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/plantrnk.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.

In 2003, areas where rare annual forbs had been previously documented were resurveyed several times in April and May. No rare forbs were seen during these surveys. During 2004, these locations will be surveyed again as will adjacent habitat to the extent feasible. Occurrences of rare annual

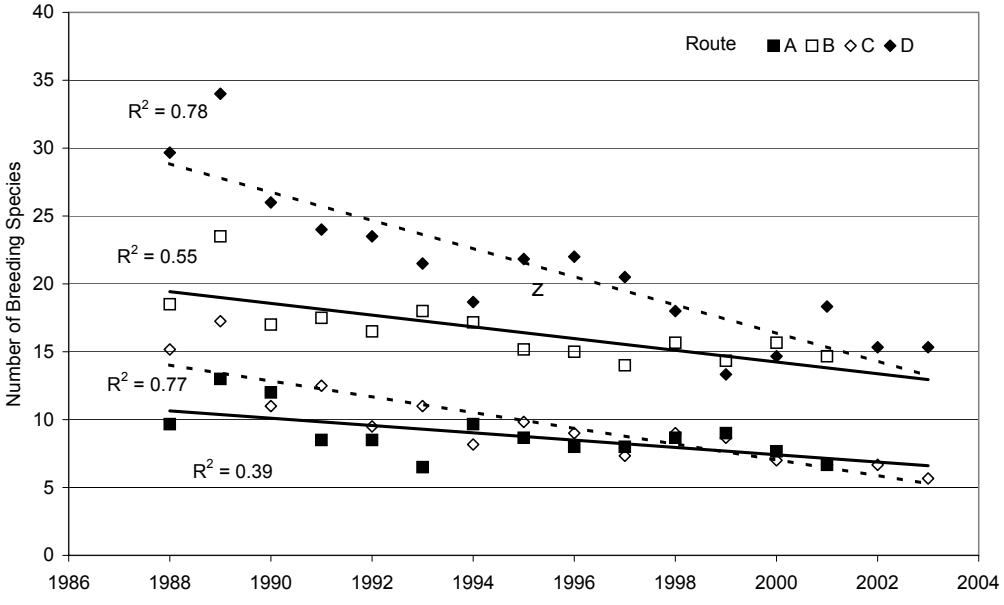

Figure 7.2.6. Species Richness During the Breeding Season Along Four Roadside Routes on the Hanford Site, 1988 through 2003. R^2 refers to the fit of a linear regression through the data. Routes are shown in Figure 7.2.4.

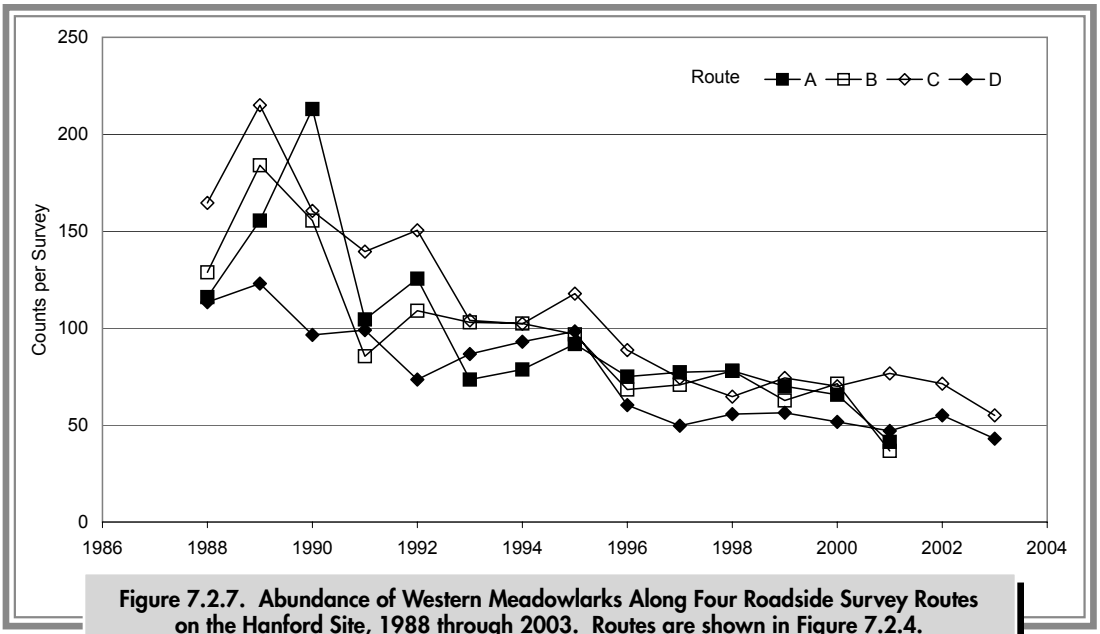

Figure 7.2.7. Abundance of Western Meadowlarks Along Four Roadside Survey Routes on the Hanford Site, 1988 through 2003. Routes are shown in Figure 7.2.4.

plant species can be episodic and variable in location depending on weather conditions and environmental factors that influence seed dispersal.

Rare plant surveys were also conducted along the Columbia River in riparian habitats adjacent to the 100-B/C Area during the summer and early fall months of 2003. These surveys identified several known species including populations of Columbia or persistent sepal yellowcress (*Rorippa columbiae*), toothcup (*Rotala ramosior*), false pimpernel (*Lindernia dubia*), shining flatsedge (*Cyperus rivularis*), and small-flowered hemicarpha (*Lipocarpha aristulata*). Monitoring transects established to examine condition and status of persistent sepal yellowcress along

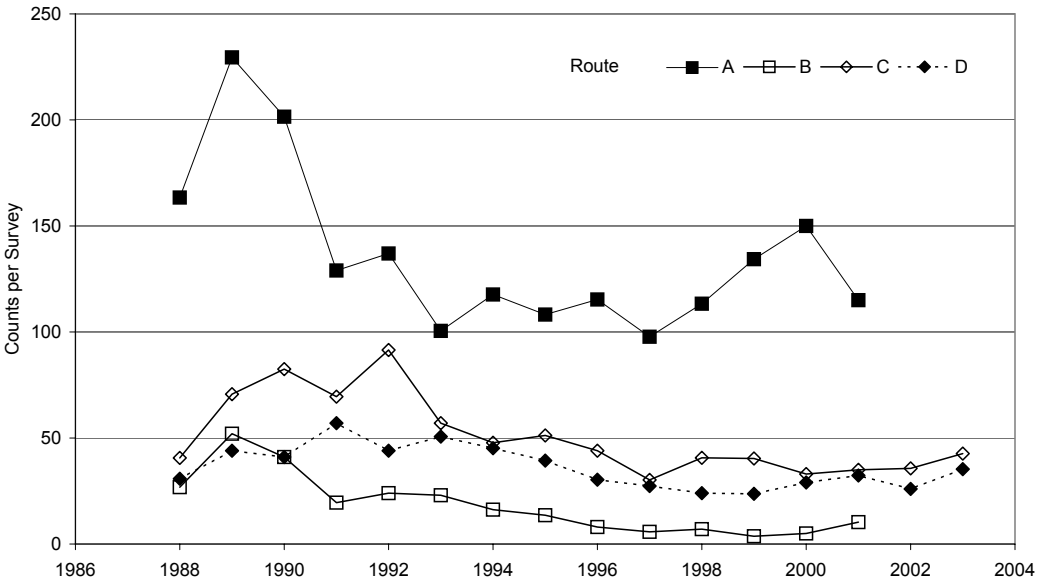

Figure 7.2.8. Abundance of Horned Larks Along Four Roadside Survey Routes on the Hanford Site, 1988 through 2003. Routes are shown in Figure 7.2.4.

the shoreline near 100-F Area and on several islands of the Hanford Reach were not surveyed during 2003 due to high river flows.

In addition to rare plant surveys along the Columbia River shoreline, Ecological Monitoring and Compliance Project personnel, in collaboration with Characterization of Systems tasks under the Groundwater Remediation Program, mapped and described riparian habitats found along the Hanford shoreline of the Columbia River. Vegetation cover types were also mapped on the persistently emergent islands in the Hanford Reach. The mapped vegetation cover types have been classed into landcover/vegetation types (Table 7.2.1; Figure 7.2.9). Each vegetation cover type description includes both the dominant vegetation and other commonly occurring species. In some cases, plant functional types and growth forms related to substrate or geomorphology are used to describe the vegetation association rather than dominant species (e.g., forbs – cobble). The mapped area includes the southern and western shores of the Hanford Reach as well as portions of the Franklin and Grant County and most of the islands that occur within the Hanford Reach.

7.2.5 Ecological Sampling and Impact Evaluations

B. L. Tiller

During 2002 and 2003, sampling of invertebrates, fish, mammals, and birds were initiated as part of an integrated monitoring effort supported by the Ecological Monitoring and Compliance Project and the Surface and Environmental Surveillance Project. Results can be used to describe levels of contaminants in organisms and corresponding measures of biological health. The data also can be used to assist with ecological risk assessments and decisions associated with legacy contamination and cleanup activities and help validate existing cleanup standards at DOE waste sites or develop new standards that reduce costs and simplify cleanup decisions.

Several sets of measurements of biological conditions were obtained in 2003 for organisms inhabiting the near-shore areas of the Columbia River (water less than 2 meters [6.6 feet] deep at low-water levels) near the 100-B/C, 100-K, 100-N, 100-D, 100 H, 100-F Areas, Hanford town site, and 300 Area. Organisms such as Asiatic clams (*Corbicula fluminea*) and crayfish (*Pacificastus leniusculus*) may be exposed to legacy contaminants in these areas.

Table 7.2.1. Current Mapped Extent of Riparian Vegetation Cover Types (hectares) Along the Hanford Shoreline of the Columbia River

Vegetation Cover Type	Cover Type Description	Hectares (acres)	Percent of Mapped Area[a]
Low shrub-forb-cobble association	Vegetation band on unconsolidated cobble adjacent to the "low water mark" with low rhizomatous subshrubs common dogbane (*Apocynum caninum*) and western goldenrod (*Solidago occidentalis*) and scattered herbs	503.15 (1,243)	18.45
Exotic weed	Introduced weedy species such as knapweeds (*Centaurea diffusa* and *Acroptilon repens*), Russian thistle (*Salsola tragus*), and cheatgrass (*Bromus tectorum*)	403.57 (997)	14.80
Wormwood/perennial grass	Perennial *Artemisia* subshrub species including Pacific sagebrush or field sagewort (*Artemisia campestris*), Columbia River wormwood or mugwort (*Artemisia lindleyana*) and prairie or white sagebrush (*Artemisia ludoviciana*)	388.66 (960)	14.26
Cobble	Little to no vegetation	312.77 (773)	11.47
Upland shrub-steppe	Upland areas including Snow buckwheat (*Eriogonum niveum*)/bunchgrass, sagebrush (*Artemisia tridentate*)/ bunchgrass, rabbitbrush (*Chrysothamnus viscidiflorous* or *Ericameria nauseosa*)/bunchgrass, rabbitbrush/cheatgrass, and Antelope bitterbrush (*Purshia tridentate*)/bunchgrass	254.95 (630)	9.35
Riparian wheatgrass association	*Agropyron dasystachyum*/*Agropyron riparium* changed to *Elymus lanceolatus*. Riparian wheatgrass is the dominant species intermixed with other grasses and forbs	177.26 (438)	6.50
Sand dropseed grass association	A subset of the wormwood/perennial grass category where the wormwood component is sparse or missing	128.31 (317)	4.71
Willow	Coyote (*Salix exigue*) patches and small groves scattered along shore with occasional peach leaf willow (*Salix amygdaloides*)	90.85 (224)	3.33
Wormwood/riparian wheatgrass	Perennial *Artemisia* subshrub species with Riparian Wheatgrass as the dominant understory grass	84.60 (209)	3.10
Wild rye association	Great Basin wild rye (*Leymus cinereus*), a large perennial bunchgrass	77.60 (192)	2.85
Reed canary grass	Stands of reed canary grass (*Phalaris arundinaceae*)	73.52 (182)	2.70
Tree association	Clumps or small stands of both native and non-native tree species	44.79 (111)	1.64

Table 7.2.1. (contd)

Vegetation Cover Type	Cover Type Description	Hectares (acres)	Percent of Mapped Area[a]
Wormwood/forb	Low-lying areas, at or below the daily high water mark, with cobble/silty soil. The plant community is comprised of *Artemisia campestris*, *A. lindleyana*, or *A. ludoviciana*, with an understory of *Heterotheca villosa*, *Aster hesperius*, *Coreopsis atkinsoniana*, *Helenium autumnale*, *Bidens frondosa*, and other riparian forbs.	30.65 (76)	1.12
Non-persistent emergent and emergent wetlands	Wetland areas of backwater and sloughs characterized by cattails (*Typha latifolia*), rushes (*Juncus species* and *Scirpus maritimus*), and sedges (*Cyperus* species, *Eleocharis* species, and *Carex* species)	27.46 (68)	1.01
Riparian mosaic	Patchy mosaic of riparian wheatgrass association, forb-cobble, willow, non-persistent emergent wetland, reed canary grass, wormwood/riparian wheatgrass, and exotic weed	26.91 (66)	0.99
Horsetail association	Horsetails (*Equisetum* species) as the dominant cover occurring in topographic lows along the shoreline with silt embedded cobble or some siltation present.	12.77 (31)	0.47
Open sand	Open sand beaches occur in small stretches	9.24 (23)	0.34
Juniper	Characterized by widely spaced junipers (*Juniperus scopularum*) at the transition between riparian and upland cover types	5.80 (14)	0.21
Riparian shrub	Small patches of dense chokecherry (*Prunus virginiana*), currant (*Ribes* sp.), and/or Wood's rose (*Rosa woodsii*). Clematis (*Clematis ligustifolia*) and various forbs or grasses may be present.	3.95 (10)	0.15
Bare Silt	No vegetation	3.11 (8)	0.11
Rock/Road/Outflow	No vegetation	2.30 (6)	0.08

(a) Mapping includes all of the Benton County shoreline from the Verni in the Hanford Reach.

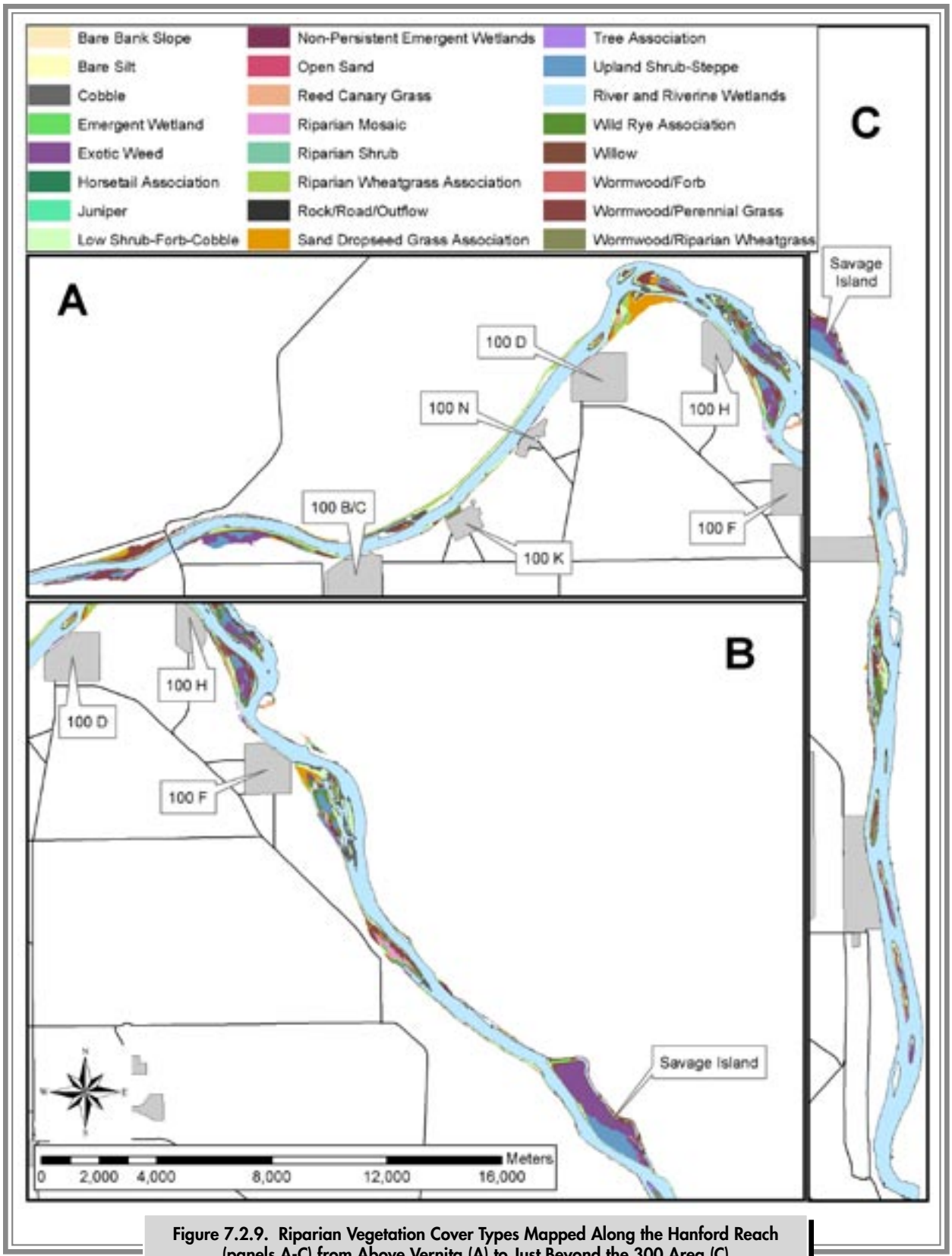

Figure 7.2.9. Riparian Vegetation Cover Types Mapped Along the Hanford Reach (panels A-C) from Above Vernita (A) to Just Beyond the 300 Area (C)

Reference areas located upstream of the Hanford Site operations were also identified and sampled. Information and results obtained from sampling the shoreline area near Hanford Site facilities in subsequent years will be compared with data from the reference locations.

Biological measurements obtained from near-shore indicator species included (1) histological inspection of target organs (radiological and chemical), (2) body condition, (3) relative abundances, and (4) demographic structures. Results for radiological tissue residue levels in clams are discussed in Section 4.5 of this report. Analyses for other species and biological components were still under development when this report was prepared.

7.2.6 Ecological Compliance

M. R. Sackschewsky

DOE policies 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.

Because many projects occur during periods of the year when plants are not growing and 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 visual surveys provide information about habitat types, and species inventories and abundance, which can be used throughout the rest of the year to assess potential impacts. These data are also used to support ecological inventory and data requirements for ecological risk evaluations. Examples of the baseline survey maps are available at http://www.pnl.gov/ecomon/Compliance/comp.html.

A total of 149 ecological compliance reviews were performed during 2003 in support of general Hanford Site activities. An additional 34 reviews were performed in support of environmental restoration activities. The total number of reviews prepared during 2003 (183) was comparable to the number of reviews performed during the previous 2 years (Table 7.2.2).

7.2.6.1 Bald Eagles

B. L. Tiller

Bald eagles (*Haliaeetus leucocephalus*) have wintered along the Hanford Reach for many years. In accordance with DOE's Bald Eagle Site Management Plan (DOE/RL-94-150), limited-access road closures within 800 meters (875 yards) (or within 400 meters [437 yards] out of line of sight) of major perching and roost sites have been in force from November 15 through March 15 since 1994. While these dates generally encompass the arrival and departure times of wintering bald eagles, nest-tending activities and

Table 7.2.2. Ecological Reviews Performed on the Hanford Site, 1997 through 2003

Calendar Year	100 Areas	200 Areas	300 Area	Other[a]	Total
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
2003	36	69	29	49	183
Totals	220	495	217	335	1,266

(a) Includes the 400, 600, 700, Richland North, and former 1100 Areas.

territorial displays in the late 1990s have been observed as early as October with nest occupancy continuing to as late as August. However, all nesting attempts documented along the Hanford Reach have so far been unsuccessful.

During 2003, a pair of adult eagles returned during November to occupy the historical nest site in the vicinity of the former White Bluffs town site. This was the only site occupied by the eagle pair during 2003. Visual surveys revealed the eagles discontinued occupancy of the nest sometime during February or March 2003.

Primary causes of eagle nest abandonment may include (1) adverse weather, (2) food availability, (3) human activity near the nest, and (4) avian predator interactions (hazing and harassment by magpies and ravens). The causes of eagle nest abandonment along the Hanford Reach have not been determined. Food resources do not appear to be limiting as a pair of eagles stayed through August in 1999 (PNNL-13230); thus, some other factor is likely responsible for nest desertion on the Hanford Site. A large buoy was placed in the Columbia River near the nesting site to help minimize all boating activities. During 2001 and 2002, traffic monitors (counts of vehicle passes) were placed at the entrance to the nesting area access road, an area within 400 meters (437 yards) from the major use site for the nesting eagle pair. Vehicle counts were low between November and January and increased dramatically during late February and early March (PNNL-14295).

7.2.6.2 Steelhead

M. R. Sackschewsky

In February 2003, two to three steelhead (*Oncorhynchus mykiss*) redds were discovered near the Columbia River shoreline adjacent to the north end of the 300 Area. Steelhead at this location are considered part of the upper Columbia River Evolutionarily Significant Unit, listed as endangered under the *Endangered Species Act of 1973*.

To address the presence of spawning steelhead near the 300 Area, the DOE prepared a biological evaluation of the potential impact of site characterization and cleanup efforts on steelhead in the Hanford Reach and came to a conclusion that the ongoing characterization and cleanup project activities may affect, but are not likely to adversely affect, upper Columbia River steelhead. This biological evaluation was sent to the National Oceanographic and Atmosphere Administration Fisheries in December 2003. The National Oceanographic and Atmosphere Administration Fisheries concurred with the DOE conclusions in January 2004. The DOE committed to increase monitoring efforts for steelhead redds in the Hanford Reach during 2004 and to limit activities in the vicinity of any redds that are discovered. The results of early monitoring during February 2004 indicated that steelhead had not returned to the redd site at the 300 Area nor were redds observed elsewhere in the Hanford Reach.

7.2.6.3 Sage Sparrow Habitat Suitability Index

M. R. Sackschewsky, C. A. Duberstein, M. A. Simmons, and J. M. Becker

The big sagebrush (*Artemisia tridentata*) communities found on the Hanford Site provide habitat for several sagebrush-obligate species including the sage sparrow (*Amphispiza belli*). The presence of mature big sagebrush (greater than 0.5 meter [1.6 feet] in height with woody branching structure) was one of several factors used to classify land areas into management levels for land use and resource management (DOE/RL-96-32). As part of the *Hanford Site Biological Resource Management Plan*, a preliminary habitat suitability index for breeding sage sparrows was applied to delineate critical habitat areas for sagebrush obligate breeding birds on the Hanford Site based on estimates of big sagebrush canopy cover and grass cover.

Monitoring and analysis efforts in 2003 attempted to better quantify relationships between the presence of breeding and nesting sage sparrows and habitat characteristics. These relationships and ultimately a modified habitat suitability index will be used to support resource management and mitigation planning efforts. Surveys were conducted between March and June 2003. Twenty-four sparrows were detected during 34 surveys. Of those detected, 15 sage sparrow territories were mapped on 10 different transects. An additional six sites were established on transects determined not to have sage sparrows. The monitoring effort in 2003 measured general vegetation characteristics of both the overstory and understory on a total of seventy-nine 10- by 10-meter (32.8- by 32.8-foot) plots (at least three per territory).

Preliminary analysis found all occupied territories contained big sagebrush. Other shrub species occurring in some of the occupied territories included bitterbrush (*Purshia tridentata*) and spiny hopsage (*Grayia spinosa*). Although these shrub mixtures were also present in some of the unoccupied areas, canopy cover was generally lower. Evaluation of the measured vegetation characteristics indicated that, in occupied territories, on average, there was more shrub and bare ground cover, and less annual grass and annual forb cover than unoccupied territories (Figure 7.2.10). However, variability in these habitat components was large, and the statistical analysis (i.e., discriminant function analysis) did not yield an ecologically meaningful distinction between occupied and unoccupied territories. Some of the variability appears to be associated with territory size. Of the 15 territories, 11 were less than 1 hectare (2.5 acres) in size, while 4 were greater than 1.5 hectares (3.7 acres). When habitat characteristics were examined for these two groups, the habitats associated with large territories had fewer shrubs than habitats associated with smaller sage sparrow territories (Figure 7.2.11). While these results are preliminary, it appears that territory size and habitat characteristics, primarily those related to shrubs, are related at a territory scale, and that birds may defend larger territories where shrubs are sparse.

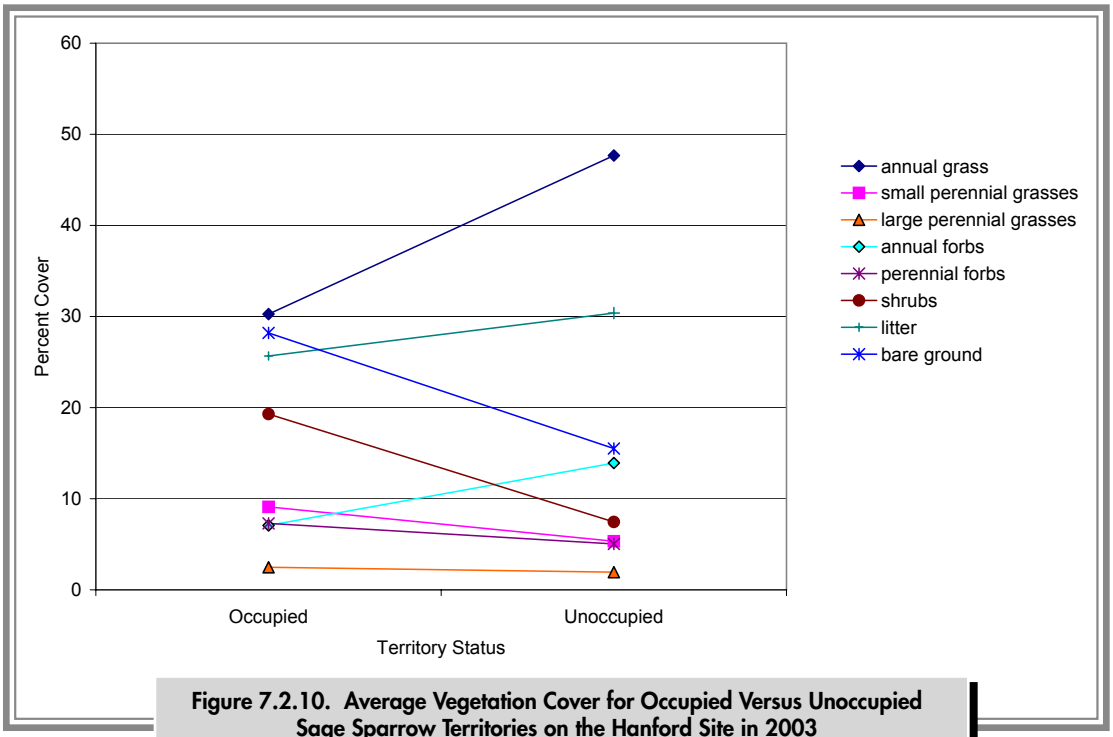

Figure 7.2.10. Average Vegetation Cover for Occupied Versus Unoccupied Sage Sparrow Territories on the Hanford Site in 2003

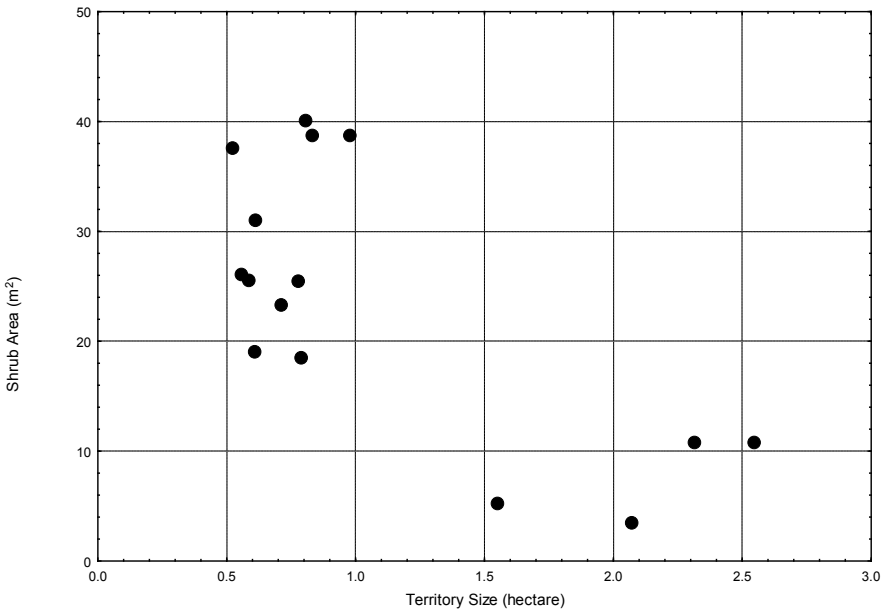

Figure 7.2.11. Total Shrub Area (m^2) for Occupied Sage Sparrow Territories on the Hanford Site in 2003. Shrub area is the sum of sagebrush, bitterbrush, and spiny hopsage.

7.3 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 the DOE for the cultural resources program on the Hanford Site throughout 2003. The U.S. Fish and Wildlife Service also has managed cultural resources on Hanford Site national monument lands since October 1999.

7.3.1 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 the 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 2003 focused on four sites or place categories: Locke Island's erosion, archaeological sites with natural and visitor impact, historic buildings and structures, and Native American sites (i.e., Locke Island).

In summary, a total of 53 archaeological sites, 5 buildings, and 15 cemetery or burial locations were monitored during 2003. Of the 69 findings recorded at these monitored places, some were related to more than one cause. Ninety-three percent were related to natural causes such as animal trailing and digging, wind-caused erosion or aggradations, and water erosion, while 24% of the findings were determined to be human-related. Most of the human-related causes were related to vehicle traffic where sites were exposed in roads and to fishing or duck hunting activities.

7.3.1.1 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 cut bank. During 1994, the 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 2003. The greatest erosion recorded at any one monitoring transect was 1 meter (3.3 feet), as measured perpendicularly from the Columbia River (Figure 7.3.1). This amount of erosion was much less than the 19.6 meters (64.3 feet) of riverbank eroded to the river at a single transect in 1997 during a period of high water flow (PNNL-11970). Four transects showed gains of 0.1 meter (0.3 foot) or less in 2003. One transect showed a barely discernable gain of 0.01 meter (0.03 foot), one transect showed a gain of 0.08 meter (0.26 foot), one transect showed a gain of 0.05 meter (0.16 foot), and one transect showed a gain of 0.1 meter (0.3 foot). These apparent gains were caused by measuring discrepancies and bank separation prior to collapse. The overall reduction in erosion observed since the high water of 1997 (Figure 7.3.2) was likely attributable to the fact that river flows have been lower since 1997, and the fact that the east channel was widened approximately 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).

7.3.1.2 Archaeological Sites

Monitoring archaeological sites for natural and visitor impact began during 1998 and continued during 2003. During 2003, 73 sites were monitored to gather empirical data about the:

- Characteristics of each site (e.g., landform, stratigraphy).
- Processes and changes adversely affecting the site (i.e., riverbank erosion, wind erosion, human visitation).

Monitoring stations established at each archaeological site facilitated the collection of standardized data unique to each site. During 2003, 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.

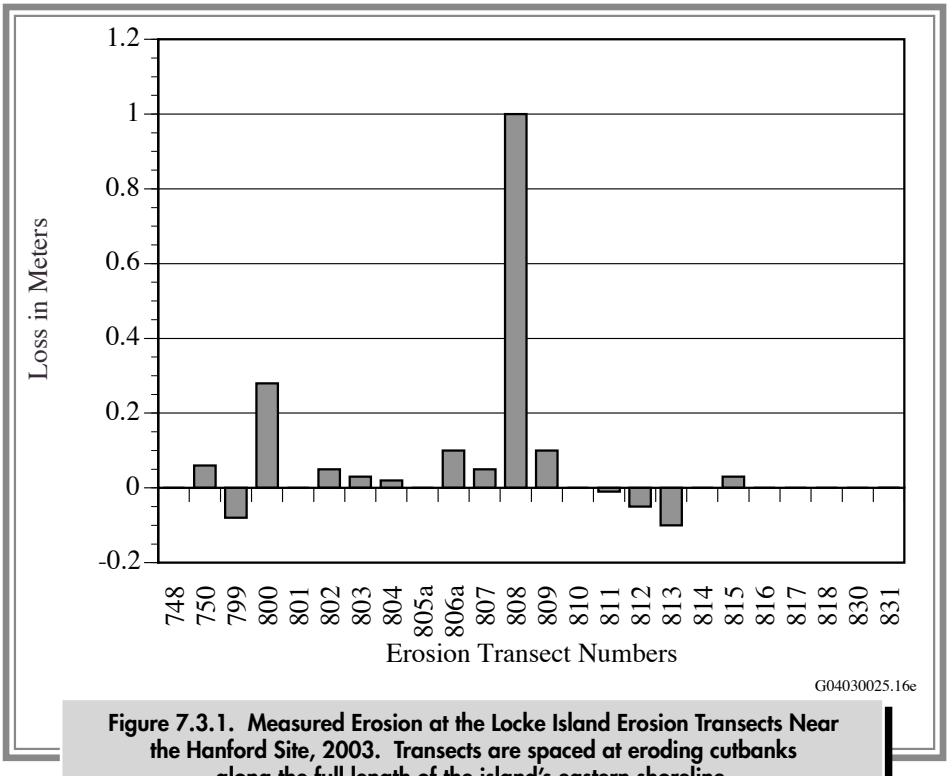

Figure 7.3.1. Measured Erosion at the Locke Island Erosion Transects Near the Hanford Site, 2003. Transects are spaced at eroding cutbanks along the full length of the island's eastern shoreline.

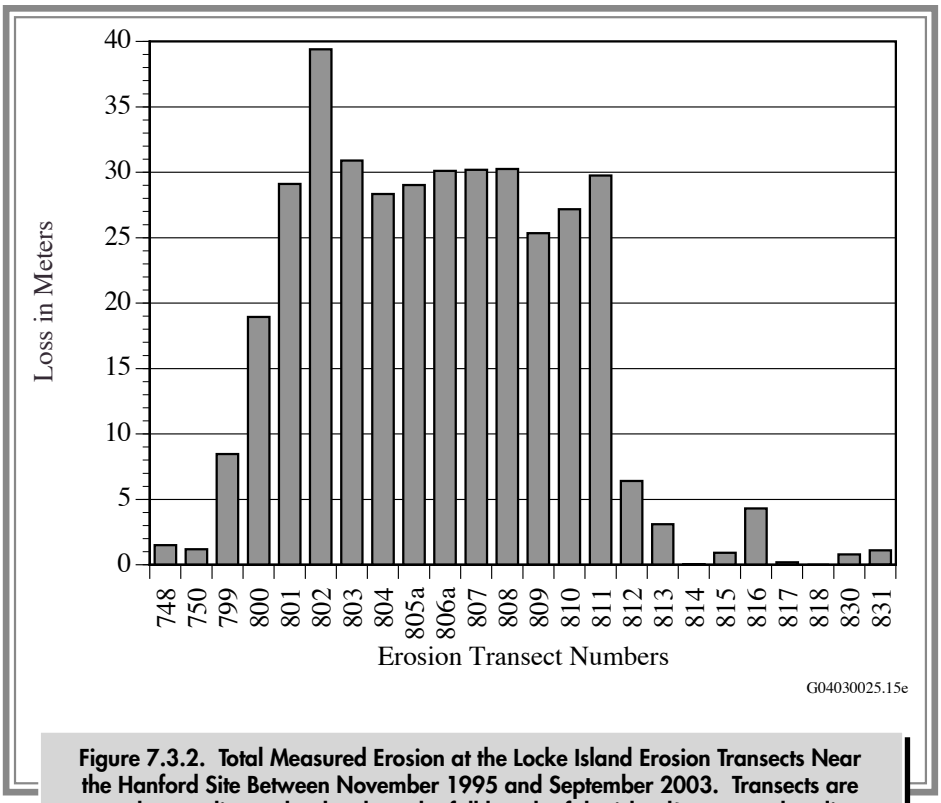

Figure 7.3.2. Total Measured Erosion at the Locke Island Erosion Transects Near the Hanford Site Between November 1995 and September 2003. Transects are spaced at eroding cutbanks along the full length of the island's eastern shoreline.

7.3.1.3 Historic Buildings

Monitoring of historic buildings during 2003 focused on Bruggemann's Warehouse, the only pre-1943 cobblestone structure remaining on the Hanford Site; the First Bank of White Bluffs building; Coyote Rapids Pumping Plant; Hanford town site 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. The DOE and U.S. Fish and Wildlife Service conducted emergency stabilization at the White Bluffs Bank building in 2003 (and early 2004).

7.3.1.4 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 2003, 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 2003. No violations were noted.

7.3.2 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 survey and monitoring efforts for the DOE.

Four Tribal meetings on cultural resources during 2003 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 and cultural reviews dealing with a wide range of topics: mitigation of impact of Bonneville Power Administration road maintenance and upgrade projects along their power line right-of-ways and access roads on the Hanford Site, a radiological survey of the 100-B/C controlled area, an environmental

impact statement for the Tank Closure Project in 200-East and 200-West Areas, the Gable Mountain Management Plan, a U.S. Fish and Wildlife Service comprehensive conservation plan environmental impact statement, the transfer of land from the DOE to the U.S. Fish and Wildlife Service, vehicular access to a cemetery located near the original site of the Environmental Molecular Sciences Laboratory, re-vegetation/stabilization of eroded sand dunes near the 100-F Area, a Hanford Reach National Monument exterior boundary land survey, archaeological testing reports resulting from *National Historic Preservation Act* Section 106 projects (Section 7.3.4), development of alternative Section 106 procedures, 100-K Area remedial actions, updates on *Archaeological Resources Protection Act of 1979* violations, the draft archaeological programmatic agreement and the publishing of 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.

In 2003, one interview was conducted with a Wanapum elder concerning traditional cultural properties on the Hanford Site.

7.3.3 Public Involvement

Public involvement is an important component of a cultural resources management program. To accomplish this, the DOE developed processes 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 the 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 the DOE. These workshop discussions indicated continual strong support for the use of B Reactor as an interpretive facility. In 2003, a public issues exchange workshop/meeting was held. Issues discussed included plans for the stabilization and eventual restoration of the First Bank of White Bluffs building. The DOE drafted an access agreement that allowed the U.S. Fish and Wildlife Service to undertake stabilization and restoration efforts of the historic bank building and assume liability for the use of volunteers. Other issues discussed included the DOE's publishing of the *Hanford Cultural Resources Management Plan* (DOE/RL-98-10); President Bush's Preserve America Executive Order 13287 (68 FR 10635); an update on the preservation status of B Reactor; plans for a 2-day workshop by the Atomic Heritage Foundation devoted to a proposed National Park Service study to establish a Manhattan Project historic park at Hanford, Oak Ridge, and Los Alamos; a draft Hanford Cultural Resources Laboratory's agricultural landscape study at the Hanford Site; and the *Hanford Cultural Resources Laboratory Oral History and Ethnography Task Annual Report* (PNNL-14237) published in 2003.

Since 2000, the public and Tribes provided comments on drafts of the *Hanford Cultural Resources Management Plan* (DOE/RL-98-10). The final draft management plan was submitted to the 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.

During 2003, the 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.

7.3.4 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 that property. The recently modified cultural

resource review process includes two review options. The first option allows the DOE to consider the review process complete if the proposed projects have no potential to affect historic properties. The second option involves notification of the State Historic Preservation Officer, Tribal Nations, and interested parties if a project has potential to affect a historic property.

The Hanford Cultural Resources Laboratory worked closely with the DOE during 2003 to educate Hanford environmental compliance officers on the Section 106 and the cultural resources review processes.

During 2003, Hanford Site contractors requested 142 cultural resource reviews (Figure 7.3.3). A majority of the reviews involved areas that had been previously surveyed or were located on previously disturbed ground. Of the areas reviewed, 2 were monitored during the construction phase, 6 projects required an archaeological survey, and 21 involved proposed building modifications, demolitions, and exemptions from the Programmatic Agreement for the Built Environment (DOE/RL-96-77). 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.

The following are major cultural resources reviews that were completed during 2003:

- Benton County Horn Rapids Park Easement

  This review was initiated in fiscal year 2000 in response to a request by Benton County for three easements from the DOE for utilities at the Horn Rapids Park. The park is located adjacent to *Wanawish*, a Wanapum ethnographic fishing site, recently determined eligible by State Historic Preservation Officer and the DOE as a traditional cultural property. The State Historic Preservation Officer recommended that mitigation agreements be included in a memorandum of agreement. Two newly recorded historic sites on the Hanford Site were determined not eligible to the National Register. The State Historic Preservation Officer and the DOE concurred with these findings. The Hanford Cultural Resources Laboratory and Tribal cultural resource technicians completed shovel testing at another site and determined that the site is not eligible to the National Register. State Historic Preservation Officer, Tribal, and DOE concurrence is pending.

- Well Installations at the 100-KR-4 Pump-and-Treat Project Site

  This review was completed as part of ongoing well installation activities related to the 100-KR-4 Pump-and-Treat Project, which is located in the vicinity of the 100-K Areas. Bechtel Hanford, Inc. had developed a Cultural Resources Treatment Plan (DOE/RL-96-44) for the 100-KR-4 Pump-and-Treat Project in 1996. Following the recommendations of the treatment plan, the Hanford Cultural Resources Laboratory completed excavation of two units. No significant cultural features were located.

- Retrieval, Treatment, and Disposal of Tank Waste and Closure of Single-Shell Tanks (Tank Closure) Environmental Impact Statement

  This review was completed as part of the DOE's proposal to retrieve waste from 149 single-shell tanks and 28 double-shell tanks and close the single-shell tank farms. The Hanford Cultural Resources Laboratory and Tribal cultural resource technicians surveyed approximately 76.9 hectares (190 acres) of land located in and adjacent to the 200 Areas. A small military

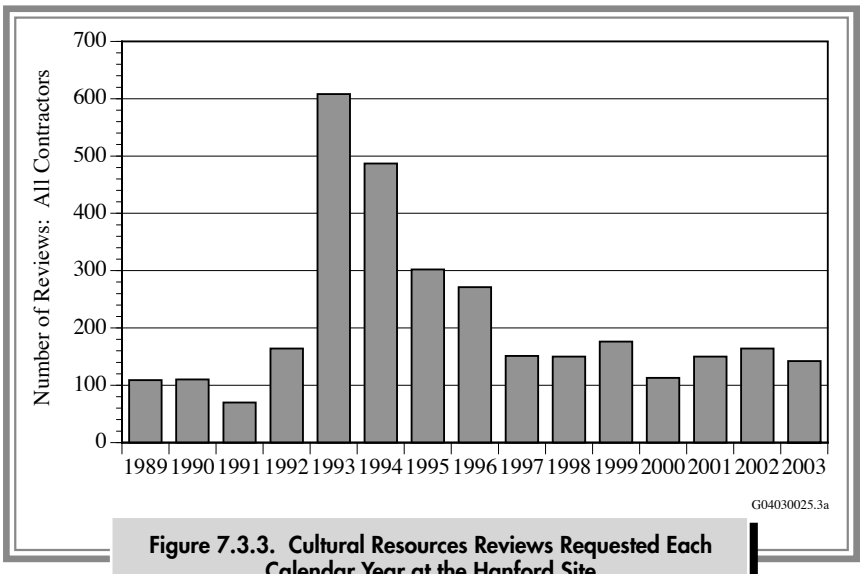

Figure 7.3.3. Cultural Resources Reviews Requested Each Calendar Year at the Hanford Site

refuse pile of cans and coke bottles associated with an antiaircraft artillery site was recorded and determined not eligible to the National Register.

- Blanket Cultural Resources Review of Biological Surveys in Support of the Public Safety and Resources Protection Program

  This review was completed as part of Pacific Northwest National Laboratory's Public Safety and Resource Protection Program environmental monitoring project. To assure that significant cultural resources are not impacted, animal trap placements selected by the Resource Protection Program are to be reviewed by the Hanford Cultural Resource Laboratory and Tribal cultural resource technicians to ensure none of the sites are located in culturally sensitive areas.

- Frequency Modulation Dial Development Use of Trailer on Gable Mountain

  This review was completed as part of a Pacific Northwest National Laboratory experiment to test a system that was developed to detect chemical weapon agents, their precursors, and their degradation products. A portion of this experiment was located on Gable Mountain. The Hanford Cultural Resource Laboratory evaluated the impact of the experiment apparatus on the view of Gable Mountain, an area highly revered by Tribes. To avoid potential impact to Gable Mountain, Tribes and Hanford Cultural Resource Laboratory personnel recommended that a trailer not be located on the mountain during culturally sensitive times or when Tribes themselves are accessing the mountain for spiritual use.

- Bonneville Power Administration Road Improvement Projects along Bonneville Power Administration Line Right-of-Way in various locations in the 600 Area of the Hanford Site

  Three reviews were completed for the Bonneville Power Administration road improvement projects located on the Hanford Site.

  One review covered a portion of the Lower Monumental Ashe power line in the 600 Area near Gable Mountain on the Hanford Site. Hanford Cultural Resource Laboratory and Tribal cultural resource technicians completed a survey of the project area and recommended cultural resource monitoring for Bonneville Power Administration maintenance activities occurring near culturally sensitive areas.

  The second review covered access roads outside of the Bonneville Power Administration's right-of-way and along portions of the Ashe Hanford/Scooteney Tap power line north of Gable Mountain in the 600 Area on the Hanford Site. Hanford Cultural Resource Laboratory and Tribal cultural resource technicians completed a survey of the project area identifying several cultural resources that could be impacted by road improvement activities. A second phase was recommended to evaluate potentially impacted resources against National Register criteria. Bonneville Power Administration agreed to avoid the cultural resources. The Hanford Cultural Resource Laboratory recommended that the site did not meet National Register criteria. A final concurrence from the State Historic Preservation Officer, Tribes, and the Bonneville Power Administration is pending.

  A third review covered Bonneville Power Administration's access roads under the Lower Monumental Hanford/Scooteney Tap power line right-of-way near the former town of White Bluffs and maintenance and improvement activities on access roads outside the right-of-way on the Hanford Site. Hanford Cultural Resource Laboratory and Tribal cultural resources technicians completed a survey of the project area identifying several cultural resources that could be impacted by road improvement activities. National Register eligibility reports are being completed. Consultation with the Tribes is ongoing regarding how to mitigate impact to the site.

7.3.5 Evaluation of Historic Buildings and Structures

Section 110 of the *National Historic Preservation Act* requires that federal agencies undertake a program to identify, evaluate, and nominate historic properties to the National Register of Historic Places and shall use, to the maximum extent feasible, historic buildings or structures available under their ownership. 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 Tribal Nations, and the general public.

During 2003, cleanup and emergency stabilization of the First Bank of White Bluffs building was conducted by the White Bluffs Preservation Coalition, comprised of members of the interested public and staff of the U.S. Fish and Wildlife Service and Pacific Northwest National Laboratory. Restoration activities of the historic bank building are planned for 2004.

Since 1999, the DOE has been evaluating the feasibility of retaining five buildings on the Hanford Site from the pre-Manhattan Project era. Reports about four buildings have been completed: the First Bank of White Bluffs, Hanford town site high school, Coyote Rapids Pumping Plant, and Bruggemann's Warehouse. The existing conditions of the buildings have been assessed and interim actions, conservation needs, immediate stabilization requirements, and cost estimates for stabilization have been identified.

During 2003, one field survey effort was conducted to fulfill Section 110 requirements of the *National Historic Preservation Act* – the Evaluate and Record Farm Sites task. This ongoing effort originated in fiscal year 2001 and is designed to identify all of the farming-related sites on the Hanford Site eligible for listing in the National Register of Historic Places. Although field surveys were conducted, a significant effort was involved in analyzing historic land records, interpreting historic and contemporary aerial photographs, and collecting and analyzing oral histories. During 2003, a total of 32 farm sites near the Hanford and White Bluffs town sites and the China Bar area near Vernita Bridge were visited, covering approximately 283.3 hectares (700 acres). Of this total, 28 were newly recorded sites. Four previously recorded sites were re-visited in an effort to update site forms to current standards. A draft report[(a)] was written and submitted to the DOE for review and comment.

Management activities conducted during 2003 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 (DOE/RL-97-71) to identify, evaluate, and preserve Manhattan Project and Cold War era artifacts. Since Section 110 activities began on the Hanford Site, 506 buildings and structures within the Hanford Site have been documented on historic property inventory forms and are on file at the Hanford Cultural Resources Laboratory (Figure 7.3.4).

During 2003, 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 application of the curation strategy for artifacts and records associated with the Hanford Site Manhattan Project and Cold War Era Historic District also continued during 2003. The strategy is stipulated in the programmatic agreement for the built environment (DOE/RL-96-77), which directs the 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

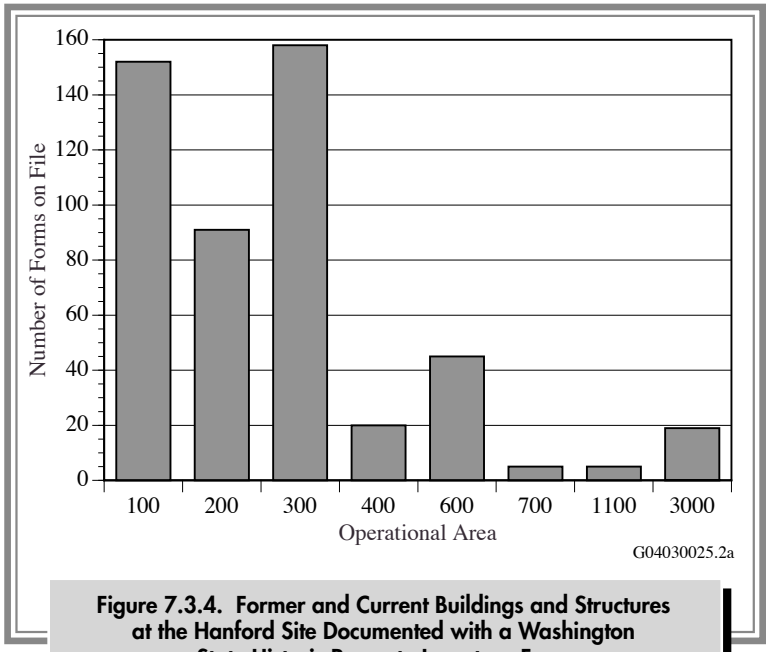

Figure 7.3.4. Former and Current Buildings and Structures at the Hanford Site Documented with a Washington State Historic Property Inventory Form

(a) PNNL-14562, DRAFT submitted to DOE. 2003. *The Hanford and White Bluffs Agricultural Landscape: Evaluation for Listing in the National Register of Historic Places*. DC Stapp, EP Prendergast-Kennedy, DM Woody, and DW Harvey, Pacific Northwest National Laboratory, Richland, Washington.

or educational value as exhibits within national, state, or local museums. The assessments are accomplished by conducting walkthroughs 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 2003, consisting of one facility in the 300 Area and five facilities in the 100-K Area. Industrial artifacts were tagged and recorded by staff from the Hanford Cultural Resources Laboratory to be eventually transferred to the custody of the Columbia River Exhibition of History, Science, and Technology museum in Richland for curation.

During 2003, a team consisting of representatives of the Pacific Northwest National Laboratory, Bechtel Hanford, Inc., and Columbia River Exhibition of History, Science, and Technology undertook an assessment of previously identified artifacts to determine which ones were candidates for permanent curation into the Hanford collection. Besides evaluating their condition and physical integrity, the team established revised criteria for the retention of artifacts as potential museum exhibits. Considerations included dimensions and weight in regard to available storage capacity, level of radiological contamination, and whether a particular artifact was already adequately represented in the collection. Archival photographic recordation was recommended for those artifacts not retained.

The DOE's archaeological collections and associated records continued to be housed in Pacific Northwest National Laboratory's repositories during 2003. The section of the *Hanford Cultural Resources Management Plan* (DOE/RL-98-10) that deals specifically with the curation of archaeological collections was used during 2003 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 2003 of the DOE's archaeological collection holdings in the Pacific Northwest National Laboratory's Sigma V Building repository during 2003. Monthly pest monitoring has indicated that the Pacific Northwest National Laboratory's repository is essentially free of insects.

7.3.6 Education and Research

Educational activities associated with the cultural resources program during 2003 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 the DOE's cultural resources management techniques to professional groups and societies. For Washington State's Archaeology Month in 2003, the Hanford Cultural Resources Laboratory participated in the Tri-Cities Visitors and Convention Bureau's Lewis and Clark Heritage Festival at Sacajewea State Park near Pasco, Washington. The Hanford Cultural Resources Laboratory developed a "Protect the History" interpretive poster for the festival as well as manning a demonstration booth that focused on educating the public about the fragility of the region's archaeological resources.

One cultural resources newsletter, *The Cultural Resources Review*, was written in 2003 by staff of the Pacific Northwest National Laboratory, DOE, and U.S. Fish and Wildlife Service that focused on Hanford histories and cultural resources management issues on the Hanford Site. Articles for the issue included how the Hanford Site was established, site security during the Manhattan Project, and cultural resource management at the Hanford Reach National Monument.

The Pacific Northwest National Laboratory participated in the DOE's Science and Engineering Education 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 2003 as part of *National Historic Preservation Act* Section 106 and 110 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.

7.4 Community Involvement in Environmental Surveillance

R. W. Hanf

During 2003, four teacher-operated radiological air sampling stations operated near the Hanford Site. These stations were located in Basin City, Richland, and Toppenish, Washington, and in north Franklin County at Edwin Markham Elementary School. Each of the stations has a large, lighted display that provides real-time weather and background radiation information to the public as well as general information on station equipment, sample types, and analyses (Figure 7.4.1).

Two teachers from nearby schools were selected to manage each station. The equipment at each location 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 modems. 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 15 minutes <http://terrassa.pnl.gov:2080/HMS/>. The Washington State Department of Transportation and the Pendleton, Oregon, office of the National Weather Service are currently obtaining weather data from these stations. Analytical results for the radiological air samples collected at these stations during 2003 are discussed in this report in Section 4.1. Results of gamma radiation measurements obtained at the stations during 2003 are discussed in Section 4.6 of this report.

Figure 7.4.1. Community Members See Environmental Surveillance in Action at a Community-Operated Environmental Surveillance Station in Richland, Washington

7.5 Biological Control Program

A. R. Johnson, J. G. Caudill, R. C. Roos, J. M. Rodriguez, R. A. Schieffer, and R. K. Woodford

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 taproot 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, birds, mammals) 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.

The control of weeds and pests is an important part of the Biological Control Program. Weeds on industrial sites at Hanford are a threat to accumulate radionuclides, and can be fire hazards and reduce the efficiency of people 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 Operations Sites, 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 also prevents, limits, or removes undesirable animals through the application of chemical, cultural, or mechanical methods.

Noxious weeds are also controlled on the site to prevent their spread. A noxious weed is a legal and administrative category designated by federal or state regulatory agencies (e.g., U.S. Department of Agriculture or Washington State Department of Agriculture). Noxious weeds are nonnative, aggressively invasive, and hard to control. Entire ecosystems can be destroyed unless control measures are taken. Control measures can be mechanical, chemical, or biological; however, biological agents (i.e., natural predators) that will not affect native species are used most extensively on the Hanford Site.

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.

7.5.1 Biological Control During 2003

There were no incidents of offsite contamination by plants or animals during 2003, and all cases of new contamination reported onsite were cleaned up or scheduled for cleanup.

During 2003, 32 incidents of contaminated vegetation occurred on the Hanford Site. This is a decrease of 52% compared to the peak year of 1999 (84), but a two-fold increase over 2002 (16). Severe wind-related soil erosion at one inactive waste disposal site (216-U-10) that was denuded by a wildfire in 2000 resulted in seven cases of contaminated tumbleweeds at this site alone. All contaminated vegetation has been removed from this waste site and the site has been scheduled for revegetation beginning in spring 2004 and continuing through autumn 2004.

Approximately 4,600 hectares (11,400 acres) were again treated with the chemical herbicides Krovar®, Tordon 22K®, or Sahara® to control undesirable vegetation. This is approximately the same land area treated during 2002. Herbicide effectiveness during 2003 was down to approximately 75% compared to approximately 90% during 2002. Approximately 800 hectares (2,000 acres) of burned area west of the 200-West Area continued to provide an effective barrier to protect waste operations and facilities, primarily in the 200-West Area, from tumbleweeds and windblown dust and sand. Approximately 40 hectares (100 acres), including approximately 3.2 kilometers (2 miles) of Contamination Area-posted roadways, were cleaned of windblown tumbleweeds and the roads were reopened after having been closed because of radioactivity detection surveys finding contaminated tumbleweeds that had blown off of nearby low-level burial grounds.

There were approximately 17,000 animal control responses, and approximately 750 trap/bait stations were used to control populations of rodents in and near facilities and offices. Increased vegetation control continued to provide fewer locations for animals to hide and live in critical areas. There were 26 contaminated animals discovered during 2003. This is approximately 57% less than the peak number of 46 in 1999, but is a 2.6-fold increase over the total for 2002 (10).

Flying insects on the Hanford Site were routinely monitored for radiological contaminants. Nineteen of the contaminated animal samples collected in 2003 were related to flying insects (wasps) in the area of the H Reactor decommissioning effort. The wasps were obtaining contaminated mud from the decommissioning site and were using it to construct nests (Section 2.4). The contamination spread was mitigated by changes in decommissioning methods (e.g., physical barriers to wasp access to the contaminated material), increasing radioactivity-condition posting to limit human presence in affected areas, and deploying flying insect traps in the area.

Approximately 62,000 cubic meters (80,000 cubic yards) of windblown non-contaminated tumbleweeds that had accumulated along fences and around facilities were compressed in-place, or in garbage trucks, and burned. Contaminated tumbleweeds were disposed to a designated burial ground dedicated to receiving low-level contaminated waste.

Sites with recurring radioactive contamination events caused by deep-rooted vegetation or burrowing animals were treated with Biobarrier® to prevent further invasion by biota. Biobarrier®, an engineered fabric impregnated with herbicide to stop root penetration and also provide a physical barrier to burrowing animals, was installed at two sites in 2003 totaling approximately 220 square meters (2,400 square feet). Demonstrations have shown this barrier to be an effective tool in preventing the spread of contamination. This brings the total number of sites treated with Biobarrier® since 1999 to 25, totaling 10,230 square meters (110,000 square feet).

7.5.2 Noxious Weed Control Program

Ten plant species, categorized as noxious by the U.S. and Washington State Departments of Agriculture, and found to be replacing native habitats on the Hanford Site, are on a high priority list for control at the Hanford Site. These species are listed below, with a summary of the 2003 control activities. Major populations of noxious weeds on the Hanford Site are illustrated in Figure 7.5.1.

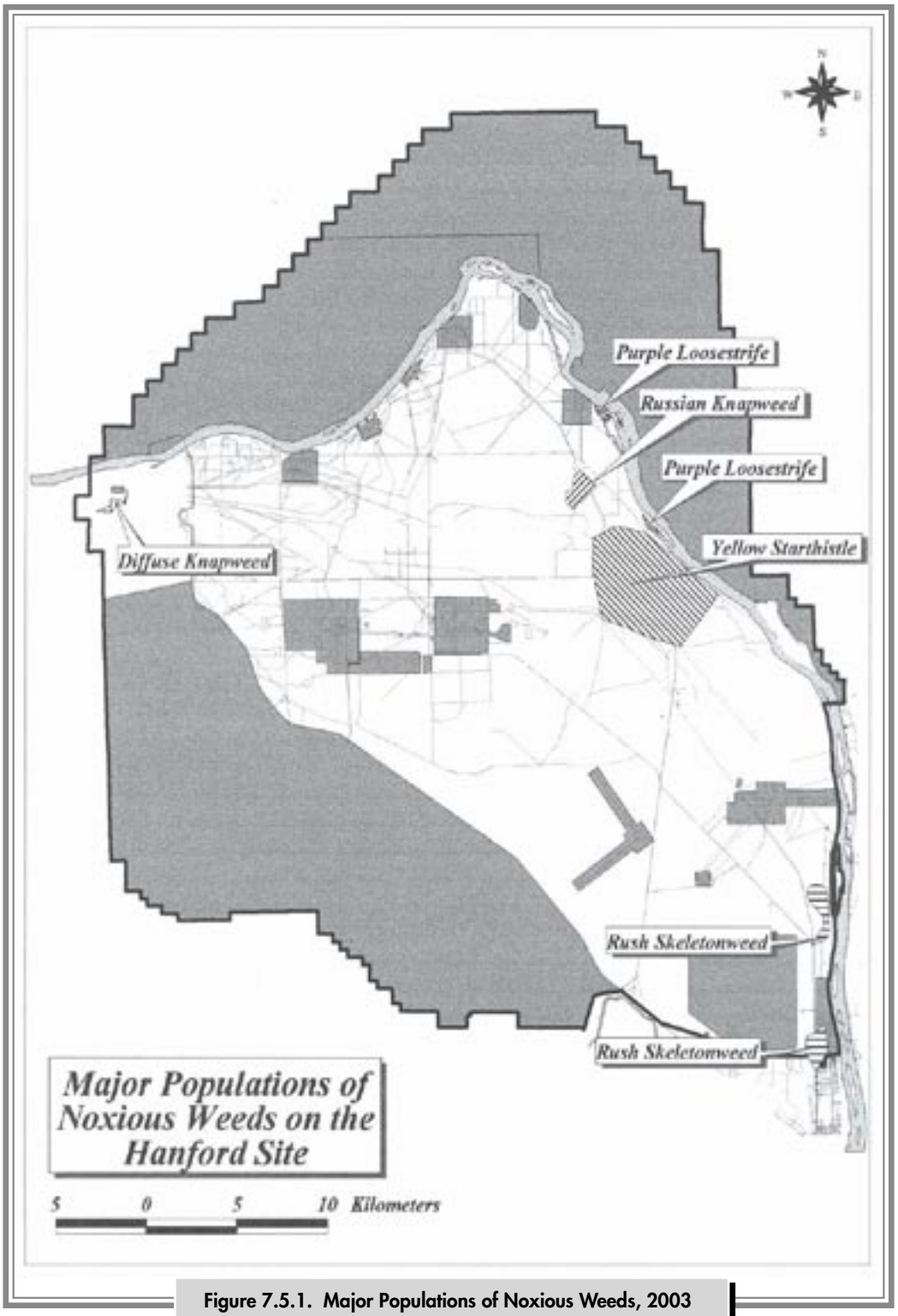

Figure 7.5.1. Major Populations of Noxious Weeds, 2003

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. More than 2,023 hectares (5,000 acres) have been infested, and a seed bank has been established in the soil. Many additional hectares (acres) have scattered starthistle infestation. Applications of aerial herbicides in 1998 and 1999 have been effective, resulting in minimal germination prior to 2003. This minimal germination was controlled primarily through mechanical removal (i.e., pulling by hand). During 2003, however, significant germination was observed indicating that residual action from prior chemical applications was no longer effective. These plants were again controlled by aerial herbicide applications. Biological control organisms, primarily the hairy weevil (*Eustenopus villosus*) and the bud weevil (*Bangasternus orientalis*) were commonly found in starthistle during 2003. It was observed that plants flowering early through mid-summer were heavily infested with weevils. However, plants flowering late in the season showed reduced infestation of the flowering heads indicating that natural predators (i.e., biological control agents) are not totally effective in killing plants or eliminating seed production.

Rush Skeletonweed (*Chondrilla juncea*). Rush skeletonweed is widely scattered over large areas on the Hanford Site. Although areas of dense infestation have largely been eliminated, a considerable population remains as scattered individuals. Populations of skeletonweed have increased on some areas burned in the June 2000 wildfire, both on the Hanford Site proper and on the Fitzner/Eberhardt Arid Lands Ecology Reserve (now managed by the U.S. Fish and Wildlife Service).

During 2003, control of rush skeletonweed concentrated on an area north of the Volpentest Hazardous Materials Management and Emergency Response Training and Education Center (also called HAMMER), which includes the Hanford Patrol Training Academy. Herbicides were aerially applied to approximately 486 hectares (1,200 acres) with a relatively large population of rush skeletonweed. Effectiveness of the spraying will be evaluated in spring 2004.

As in most years, some populations were highly affected by the bio-controls that had been introduced over the past 10 years, and flowering was eliminated. Other populations were less affected, indicating that biological control parameters need to be better understood before relying solely or heavily on this means of weed control.

Medusahead (*Taeniatherum asperum*). Mechanical removal (e.g., pulling by hand) was once again used to control the small population of medusahead on the Central Plateau of the Hanford Site. Plants were pulled before seeds were mature. Monitoring and eradication efforts will continue in 2004 as the plants mature to the point they can be distinguished from neighboring grass species.

Babysbreath (*Gypsophila paniculata*). Efforts to control babysbreath during 2003 concentrated on the main infestation at the former Hanford town site. Although babysbreath is resistant to control by herbicides, herbicides exist that effectively kill the aboveground portions of the plant. Controlling the top of the plant prevents flowering and additional seed production. Killing the top of the plant also depletes energy reserves in the roots until the plant succumbs. The number of these plants on the Hanford Site is relatively small, and control by attrition has proven to be a practical strategy.

Dalmatian Toadflax (*Linaria genistifolia spp. Dalmatica*). During 2003, control of dalmatian toadflax focused on a small population at the 100-B/C Area. The species at Hanford has yielded to past control efforts. Seedlings of this long-lived perennial plant will be eliminated by mechanical removal or chemical treatments as they are identified. Currently, the only extant population of dalmatian toadflax is at the Energy Northwest area, and it is being watched for signs of migration to other parts of the Hanford Site. Security restrictions currently prevent access to the population.

Spotted Knapweed (*Centaurea maculosa*). Most populations of spotted knapweed throughout the Hanford Site have been reduced through mechanical removal and chemical applications to scattered individuals, or seedlings germinating from long-lived seeds. Cooperative work with neighboring landowners continues to eliminate spotted knapweed near the Hanford Site.

Diffuse Knapweed (*Centaurea diffusa*). Aerial applications of herbicide to control diffuse knapweed have been effective in the past. Spot treatment with chemicals and mechanical removal of scattered individuals continued during 2003. The population of diffuse knapweed near

the high water mark of the Columbia River has not been controlled by herbicides due to the biological sensitivity of the area. Biological controls (i.e., parasitic insects) have been established in areas near the Columbia River and are monitored to observe effectiveness in controlling the weed. They are somewhat effective.

Russian Knapweed (*Acroptilon repens*). Biological control (e.g., parasitic insects) of Russian knapweed at Hanford has been tried and success has been poor. This weed's largest population is found along the Columbia River, but small populations are found throughout the site. Chemicals, other biological control agents, and mechanical removal techniques are being developed by federal and state agricultural agencies that may prove 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 on the site 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 are dead.

Purple Loosestrife (*Lythrum salicaria*). Purple loosestrife has established only in sparse populations on the Hanford Site along the south and west shorelines of the Columbia River. Portions of the riverbank and shoreline slews are monitored for purple loosestrife and identified individuals are controlled, with chemicals approved for wetland areas, with biological control agents, and by mechanical removal.

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8.0 Quality Assurance

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Quality assurance and quality control practices encompassed all aspects of Hanford Site environmental monitoring and surveillance programs. This section discusses specific measures taken to ensure 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 perform the following tasks:

- Document instrument calibrations.
- Conduct program-specific activities in the field.
- Maintain groundwater wells to assure representative samples were collected.
- Avoid cross-contamination by using dedicated well sampling pumps.

8.0.1 Environmental Surveillance and Groundwater Monitoring

During 2003, 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 Groundwater Performance Assessment 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.

8.0.1.1 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 U.S. Department of Energy (DOE) Order 414.1B. 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 monitored 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 a significant impact on quality within the project are approved and awarded.

8.0.1.2 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, soil, and biota samples (Table 8.0.1). Eighty-three percent of the field replicate results with the result greater than the minimum detectable activity for 2003 were acceptable. The results were acceptable if the relative percent difference was less than 30% for the sample and duplicate, as specified in the analytical services contract.

Table 8.0.1. Summary of Field Replicate Results for the Surface Environmental Surveillance Project at Hanford, 2003

Medium	Radionuclides	Number of Results Reported for Each Radionuclide	Number Within Control Limits for Each Radionuclide[a]
Water	Gross alpha	1	0
	Gross beta	1	0
	^{7}Be, ^{40}K, ^{60}Co, ^{106}Ru, ^{125}Sb, ^{134}Cs, ^{137}Cs, ^{152}Eu, ^{154}Eu, ^{155}Eu	1	0
	^{90}Sr	2	2
	^{3}H	4	4
	^{234}U, ^{238}U	3	3
	^{235}U	3	0
Soil	Total organic carbon	1	1
Biota	^{7}Be, ^{60}Co, ^{90}Sr, ^{106}Ru, ^{125}Sb, ^{134}Cs, ^{137}Cs, ^{152}Eu, ^{154}Eu, ^{155}Eu	4	0
	^{40}K	4	4

(a) The sample and duplicate results are acceptable if they have a relative percent difference of less than 30% for the sample and duplicate and the result is above the detection limit or minimum detectable activity.

Relative percent difference (RPD) – A measure of the precision of the measurement of a sample (S) and its duplicate (D). The formula is

$$RPD = \left| \frac{S - D}{\left(\frac{S + D}{2} \right)} \right|$$

Samples for the Groundwater Performance Assessment Project were collected by trained staff according to approved and documented procedures (PNNL-14548, Appendix D). Chain-of-custody procedures were followed (EPA 1986). Samples representing full trip blanks and field duplicates were obtained during field operations. Summaries of the 2003 groundwater field quality control sample results are provided in Appendix D of PNNL-14548. The percentage of acceptable field blank and duplicate results during fiscal year 2003 was 96% for field blanks and 98% 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, and the result was greater than five times the minimum detectable activity or method detection limit.

8.0.1.3 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-sanctioned Water Pollution and Water Supply Performance Evaluation Studies conducted by Environmental Resource Associates. 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 by Pacific Northwest National Laboratory. Pacific Northwest National Laboratory submitted additional quality control double-blind spiked samples for analysis.

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 Groundwater Performance Assessment Projects were performed primarily by Severn Trent Laboratories, Inc., Richland, Washington. Severn Trent Laboratories, Inc., Richland, participated in the 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 by Pacific Northwest National Laboratory. Additional information on these quality control efforts is provided in the following sections.

8.0.1.4 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 2003 groundwater samples are provided in PNNL-14548, Appendix D, 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-621). Summaries of the 2003 results are provided in Tables 8.0.2 and 8.0.3. 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).

8.0.1.5 Pacific Northwest National Laboratory Evaluations

In addition to the 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 2003, 295 blind spiked samples were submitted for the Groundwater Performance Assessment Project (PNNL-14548, Appendix D) and 7 samples were submitted for the Surface Environmental Surveillance Project. The samples included air filters, soil, surface water, and vegetation (Table 8.0.4). The results of all water sample non-radiochemistry blind spiked determinations are discussed in Appendix D of PNNL-14548 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.

For all media, 87% of Severn Trent Laboratories, Inc., Richland, radiochemistry blind spiked determinations were within the control limits (±30% of the known value), which indicated acceptable results. Four results for cobalt-60 determined by gamma spectroscopy were outside the acceptable range – one measurement in soil, one in water, and two in vegetation. The fifth result was the measurement of plutonium-238 in soil.

Table 8.0.2. Summary of Laboratory Performance on DOE Quality Assessment Program Samples for the Surface Environmental Surveillance Project at Hanford, 2003

Medium	Radionuclides	Number of Results Reported for Each Radionuclide	Number of Results Within Acceptable Control Limits for Each Radionuclide[a]
Severn Trent Laboratories, Richland, Washington			
Air filter particulate	Gross alpha, gross beta, ^{54}Mn, ^{60}Co, ^{137}Cs, ^{234}U, ^{238}U, ^{238}Pu, ^{239}Pu, ^{241}Am	2	2
	Total uranium	2	1
	^{90}Sr	2	0
Soil	^{40}K, ^{90}Sr, ^{137}Cs, ^{212}Pb, ^{214}Bi, ^{214}Pb, ^{228}Ac, ^{234}Th, ^{234}U, ^{238}U, ^{239}Pu, ^{241}Am, total uranium	2	2
	^{212}Bi	2	1
	^{238}Pu	1	1
Vegetation	^{40}K, ^{60}Co, ^{137}Cs, ^{241}Am, ^{244}Cm	2	2
	^{239}Pu	1	0
Water	^{3}H, ^{60}Co, ^{134}Cs, ^{137}Cs, ^{234}U, ^{238}U, ^{238}Pu, ^{239}Pu, ^{241}Am, total uranium	2	2
	Gross alpha, gross beta	1	1
	^{90}Sr	2	1

(a) Control limits are from EML-621.

Table 8.0.3. Summary of Laboratory Performance on Hanford Site Surface Environmental Surveillance Project Samples by the Environmental Resource Associates Proficiency Testing Program, 2003

Medium	Radionuclides	Number of Results Reported for Each Radionuclide	Number Within Control Limits for Each Radionuclide[a]
Severn Trent Laboratories, Richland, Washington			
Water	Gross alpha, gross beta	5	5
	^{60}Co, ^{89}Sr, ^{90}Sr, ^{134}Cs, ^{137}Cs, ^{226}Ra, ^{228}Ra, total uranium	4	4
	^{89}Sr, ^{90}Sr,	3	3
	^{3}H, ^{65}Zn, ^{133}Ba	2	2
	^{131}I	2	1

(a) Control limits are from NERL-Ci-0045.

Table 8.0.4. Summary of Hanford Site Surface Environmental Surveillance Project Blind Spiked Determinations, 2003

Medium	Radionuclides	Number of Results Reported for Each Radionuclide	Number of Results Within Control Limits for Each Radionuclide[a]
Severn Trent Laboratories, Richland, Washington			
Air Filters	^{60}Co, ^{90}Sr, ^{134}Cs, ^{137}Cs, ^{238}Pu, $^{239/240}$Pu	2	2
	^{125}Sb, ^{238}U	1	1
Soil	^{40}K, ^{137}Cs, ^{238}U, $^{239/240}$Pu	2	2
	^{90}Sr 2	1	
	^{234}U	1	1
	^{60}Co, ^{238}Pu	1	0
Vegetation	^{40}K, ^{137}Cs, $^{239/240}$Pu	2	2
	^{90}Sr 1	1	
	^{60}Co	2	0
Surface Water	^{3}H, ^{137}Cs, ^{238}Pu, $^{239/240}$Pu	2	2
	^{234}U, ^{238}U	1	1
	^{60}Co	2	1

(a) Control limit of ±30%.

8.0.1.6 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, 2001, and 2002. The final intercomparison report for the soil samples from the Hanford Site has not been published yet. Results for uranium-234, uranium-235, uranium-238, and total uranium were determined for three aliquots and reported in PNNL-14295.

8.0.1.7 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 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 predesignated uncertainty multiplier (EPA 520/1-80-012).

Periodically, inspections of services were performed that documented conformance with the 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 2003, an audit of the commercial laboratories supporting the Groundwater Performance Assessment Project was performed by the DOE-sponsored Environmental Management Consolidated Assessment Program and a joint team from Bechtel Hanford, Inc. and Pacific Northwest National Laboratory representatives. The Environmental Management Consolidated Assessment Program evaluated Severn Trent Laboratories, Inc., St. Louis, on May 20 to 22, 2003, Lionville Laboratory on June 24 to 26, 2003, and Severn Trent Laboratories, Inc., Richland, on August 12 to 14, 2003. The scope of the Environmental Management Consolidated Assessment Program audits included the following specific functional areas: (1) quality assurance management systems and general laboratory practices, (2) data quality for organic analyses, (3) data quality for inorganic and wet chemistry analyses, (4) data quality for radiochemistry analyses, (5) hazardous and radioactive materials management, and (6) verification of corrective action implementation from previous audit findings.

The purpose of the joint Bechtel Hanford, Inc. and Pacific Northwest National Laboratory audit conducted on March 18 to 20, 2003, 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. The audit was based on the analytical and quality assurance requirements for both groundwater and multimedia samples as specified in the statement of work. The primary areas of focus were personnel training, procedure compliance, sample receipt and tracking, instrument operation and calibration, equipment maintenance, instrumentation records and logbooks, implementation of Severn Trent Laboratories, Inc.'s quality assurance management plan in accordance with *Hanford Analytical Services Quality Assurance Requirements Document* (DOE/RL-96-68, Volumes 1 and 4), and the implementation of corrective actions for deficiencies identified in previous audits.

A total of 16 findings and 27 observations were noted for the three Environmental Management Consolidated Assessment Program audits, and 7 findings and 6 observations were identified in the joint Bechtel Hanford, Inc. and Pacific Northwest National Laboratory audit. Results of these audits are summarized in Appendix D of PNNL-14548. Corrective actions have been accepted for all the audits and verification of the corrective actions will be performed in future audits. All laboratories have been qualified to continue to provide analytical services for samples generated at DOE sites.

The Surface Environmental Surveillance Project staff visited Severn Trent Laboratories, Inc., Richland, on June 19 and 20, 2003. The scope of the surveillance was to review (1) low-level tritium analysis, (2) uranium analysis, (3) air filter handling, compositing, and storage, (4) identification and control of items, and (5) observe a Surface Environmental Surveillance Project sample in progress. There were no findings or observations noted during the surveillance.

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 Groundwater Performance Assessment Project indicated that each laboratory met the contract specified requirements for each quarter of calendar year 2003 (for the Surface Environmental Surveillance Project) and fiscal year 2003 (for the Groundwater Performance Assessment Project).

8.0.1.8 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 2003. Media that were co-sampled and analyzed for radionuclides included irrigation water, water from 24 locations along and across the Columbia River, water from 12 riverbank springs, water from 2 onsite drinking water locations, and sediment from 25 Columbia River sites from upriver at Priest Rapids Dam downriver to the John Day Dam. Also co-sampled and

analyzed for radionuclides were upwind and downwind samples of whitefish, Canada geese, cottontail rabbits, potato tubers, apples, asparagus, alfalfa, and red and white wines.

The U.S. Food and Drug Administration (FDA) also received co-samples from upwind and downwind sampling locations and analyzed apples, leafy vegetables, potato tubers, and alfalfa for radionuclides (Table 8.0.5). Alfalfa samples from Sunnyside and Riverview had positive results for strontium-90 as reported by the FDA. Duplicate samples from each site did not show positive results. The strontium-90 result from Sunnyside as measured by Pacific Northwest National Laboratory showed agreement with the FDA result. The strontium-90 result from Riverview determined by Pacific Northwest National Laboratory was positive but was not in agreement with the reported value from the FDA.

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 0.99; the highest determined/known exposure ratio was 1.12, with an average of 1.06 ± 0.03 (Table 8.0.6).

8.0.2 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*

Table 8.0.5. Comparison of Co-Sampling Results for Samples Collected Near the Hanford Site, 2003[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	Sunnyside	FDA	<0.002	<0.03	<0.1	<0.03	<200
(stem-leaf)		FDA	0.0011 ± 0.0008	<0.03	<0.1	<0.03	<200
		PNNL	0.038 ± 0.0068	0.0025 ± 0.0055	0.014 ± 0.047	NA[e]	NA
Alfalfa	Sunnyside	FDA	0.0024 ± 0.0014	<0.03	<0.1	<0.03	<200
		FDA	0.0057 ± 0.0016	<0.03	<0.1	<0.03	<200
		PNNL	0.064 ± 0.027	0.007 ± 0.012	-0.041 ± 0.1	NA	NA
Alfalfa	Riverview	FDA	0.0038 ± 0.0016	<0.03	<0.1	<0.03	<200
		FDA	<0.002	<0.03	<0.1	<0.03	<200
		PNNL	0.098 ± 0.027	0.002 ± 0.01	-0.062 ± 0.082	NA	NA
Potato tuber	Sagemoor	FDA	<0.002	<0.03	<0.1	<0.03	<200
		FDA	0.0017 ± 0.0006	<0.03	<0.1	<0.03	<200
		PNNL	0.0026 ± 0.0043	0.0014 ± 0.0044	-0.0082 ± 0.039	NA	NA
Potato tuber	Sunnyside	FDA	<0.002	<0.03	<0.1	<0.03	<200
		FDA	<0.002	<0.03	<0.1	<0.03	<200
		PNNL	0.0094 ± 0.0051	0.0018 ± 0.0041	0.0097 ± 0.036	NA	NA
Apples	Sagemoor	FDA	0.0012 ± 0.0006	<0.03	<0.1	<0.03	<200
		FDA	<0.002	<0.03	<0.1	<0.03	<200
		PNNL	-0.0008 ± 0.0016	0.0040 ± 0.0043	-0.031 ± 0.039	NA	NA
Apples	Riverview	FDA	<0.002	<0.03	<0.1	<0.03	<200
		FDA	<0.002	<0.03	<0.1	<0.03	<200
		PNNL	-0.0012 ± 0.0016	0.0051 ± 0.0055	0.028 ± 0.048	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 8.0.6. Comparison of Pacific Northwest National Laboratory Thermoluminescent Dosimeter Results with Known Exposure, 2003

Quarter	Exposure Date	Known Exposure[a] milliroentgen (mR)	Determined Exposure milliroentgen (mR)	Ratio of Determined/ Known Exposure
1st	February 20, 2003	22 ± 0.82	23.18 ± 0.35	1.05
		17 ± 0.63	18.57 ± 0.89	1.09
		30 ± 1.1	31.4 ± 0.83	1.05
2nd	May 19, 2003	21 ± 0.78	22.17 ± 0.68	1.06
		26 ± 0.97	28.27 ± 0.44	1.09
		18 ± 0.67	17.78 ± 0.25	0.99
3rd	August 14, 2003	29 ± 1.1	30.38 ± 1.01	1.05
		19 ± 0.71	21.31 ± 0.54	1.12
		25 ± 0.93	26.3 ± 0.11	1.05
4th	November 13, 2003	20 ± 0.74	21.06 ± 0.90	1.05
		28 ± 1.0	29.32 ± 1.42	1.05
		24 ± 0.89	24.5 ± 1.02	1.02

(a) Assumed 2 standard deviation error was 3.72%.

Quality Assurance Requirements Document (DOE/RL-96-68). These quality assurance programs complied with DOE Order 414.1B, using standards from the American Society of Mechanical Engineers (ASME NQA-1-1997 Edition) as their basis. The program also adhered to the guidelines and objectives in 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 monitored compliance with the plans. Work such as sample analyses performed through contracts had to meet the requirements of these plans. Suppliers were audited before the contract selection was made for equipment and services that may have significantly affected the quality of a project.

8.0.2.1 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.

8.0.2.2 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 was dependent on the Hanford contractor collecting the samples and contract(s) established between the contractor and the analytical laboratory(s). Table 8.0.7 provides a summary of the Hanford Site's analytical laboratories used for processing effluent monitoring and near-facility monitoring samples in 2003.

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 to analyze samples. Analytical procedural control was assured through administrative procedures. Chemical technologists at the laboratory qualified to perform analyses through formal classroom and on-the-job training.

The participation of the Hanford Site analytical laboratories in the EPA and DOE laboratory performance evaluation programs also served to assure the quality of the data

Table 8.0.7. Hanford Site Laboratories Used by Site Contractors and Types of Effluent Monitoring and Near-Facility Monitoring Samples Analyzed, 2003

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[b]								X
Severn Trent Laboratories, Inc., Richland	X	X	X	X	X			
Radiochemical Processing Laboratory[c]	X	X	X					

(a) Operated by Fluor Hanford, Inc.
(b) Operated by CH2M HILL Hanford (transitioned from Fluor Hanford, Inc. on October 1, 2003).
(c) Operated by Pacific Northwest National Laboratory.

produced. The Waste Sampling and Characterization Facility performance was evaluated in four different laboratory performance studies for 2003. In the EPA Water Pollution Studies #96 and #102 and Soil Studies #43 and #45, 317 different analytes and compounds were submitted to the Waste Sampling and Characterization Facility for analysis. Of the 317 reported analytes, 311 results were acceptable while 6 were unacceptable for a total acceptable rate of 98%. In the DOE Mixed Analyte Performance Evaluation Program studies (MAPEP-02-W10 and MAPEP-03-S10), 84 different radionuclides and analytes were submitted to the Waste Sampling and Characterization Facility for analysis. Of the 84 reported radionuclide analytes, 80 results were acceptable while 4 were unacceptable for a total acceptable rate of 95%. In the National Institute of Standards and Technology Radiochemistry Intercomparison Program study, 8 different radionuclides were submitted to the Waste Sampling Characterization Facility for 40 different analyses. All radionuclide results were acceptable for a total acceptable rate of 100%.

In the DOE Quality Assessment Program, 67 different radionuclides were submitted to the Waste Sampling Characterization Facility for analysis and 61 different radionuclides were submitted to the 222-S Analytical Laboratory. Of the 67 reported radionuclides for the Waste Sampling Characterization Facility, 65 results were acceptable while 2 were unacceptable for a total acceptable rate of 97%. Of the 61 reported radionuclides for the 222-S Analytical Laboratory, 55 results were acceptable while 6 were unacceptable for a total acceptable rate of 90%. Performance results for the DOE Quality Assessment Program and others are presented in Tables 8.0.8 through 8.0.10.

Table 8.0.8. The Hanford Site's Waste Sampling and Characterization Facility[a] Performance on DOE Quality Assessment Program Samples, 2003

Medium		Number of Results Report for Each Radionuclide	Number of Results Within Control Limits for Each Radionuclide
Air filters	^{54}Mn, ^{60}Co, ^{90}Sr, ^{137}Cs, ^{234}U, ^{238}Pu, ^{238}U, ^{239}Pu, ^{241}Am, gross alpha, gross beta	22	22
Soil	^{40}K, ^{90}Sr, ^{137}Cs, ^{234}U, ^{238}U, ^{239}Pu, ^{241}Am	14	13 (^{90}Sr failed once)
Vegetation	^{40}K, ^{60}Co, ^{90}Sr, ^{137}Cs, ^{239}Pu, ^{241}Am, ^{244}Cm	7	7
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 (^{90}Sr failed once)

(a) Onsite laboratory operated by Fluor Hanford, Inc.

Table 8.0.9. The Hanford Site's 222-S Analytical Laboratory[a] Performance on DOE Quality Assessment Program Samples, 2003

Medium	Radionuclide	Number of Results Reported for Each Radionuclide	Number of Results Within Acceptable Limits for Each Radionuclide
Air filters	^{54}Mn, ^{60}Co, ^{90}Sr, ^{137}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, ^{238}Pu, ^{239}Pu, total uranium	11	11
Vegetation	^{60}Co, ^{90}Sr, ^{137}Cs	10	7
Water	^{3}H, ^{60}Co, ^{90}Sr, ^{134}Cs, ^{137}Cs, ^{238}Pu, ^{239}Pu, ^{241}Am, gross alpha, gross beta, total uranium	22	20

(a) Onsite "high-level" radiological laboratory operated by CH2M HILL Hanford, Inc. (Note: These samples are "low-level" environmental activity samples.)

Table 8.0.10. The Hanford Site's 222-S Analytical Laboratory[a] Performance on EPA Laboratory Water Pollution Inorganic and Organic Studies, 2003

Laboratory	Water Pollution Study (WP-99) June 2003 % Acceptable	Water Pollution Study (WP-105) December 2003 % Acceptable
222-S Analytical Laboratory	96[b]	99[c]

(a) Onsite "high-level" radiological laboratory operated by CH2M HILL Hanford, Inc.
(b) Of 103 analytes, 99 were evaluated as acceptable.
(c) Of 166 analytes, 165 were evaluated as acceptable.

8.0.3 References

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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 B.

Scientific Notation

Scientific notation is used 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 follow the International System of Units (SI) and 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.

Radioactivity Units

Much of this report deals with levels of activity (also known as radioactivity) in various environmental media. Activity in this report is usually discussed in units of **curies** (**Ci**), with conversions to **becquerels** (**Bq**), the SI unit, provided (Table A.3). The curie is the basic unit used to describe the amount of activity 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.

Millirem (millisievert) is a term that relates radiological dose and biological effect or risk (to humans). For perspective, a dose of 0.01 millirem (1 millisievert) would have a biological effect roughly the same as received from 1 day's exposure to natural background radiation. An acute (short-term) dose to the whole body of 100 rem (1 sievert) would likely cause temporary radiation sickness in some exposed individuals. An acute dose of over 500 rem (5 sieverts) would soon result in death in approximately 50% of those exposed. 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

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

Symbol	Name
Temperature	
°C	degree Celsius
°F	degree Fahrenheit
Time	
d	day
h	hour
min	minute
s	second
yr	year
Rate	
cfs (or ft^3/s)	cubic foot per second
cpm	counts per minute
gpm	gallon per minute
mph	mile per hour
mR/hr	milliroentgen per hour
mrem/yr	millirem per year
Volume	
cm^3	cubic centimeter
ft^3	cubic foot
gal	gallon
L	liter
m^3	cubic meter
mL	milliliter (1×10^{-3} L)
yd^3	cubic yard

Symbol	Name
Concentration	
ppb	parts per billion
ppm	parts per million
ppmv	parts per million by volume
Length	
cm	centimeter (1×10^{-2} m)
ft	foot
in.	inch
km	kilometer (1×10^{3} m)
m	meter
mi	mile
mm	millimeter (1×10^{-3} m)
µm	micrometer (1×10^{-6} m)
Area	
ha	hectare (1×10^{4} m^2)
km^2	square kilometer
mi^2	square mile
ft^2	square foot
Mass	
g	gram
kg	kilogram (1×10^{3} g)
mg	milligram (1×10^{-3} g)
µg	microgram (1×10^{-6} g)
lb	pound

Table A.2. Conversion Table

Multiply	By	To Obtain
cm	0.394	in.
m	3.28	ft
km	0.621	mi
kg	2.205	lb
L	0.2642	gal
m^2	10.76	ft^2
ha	2.47	acres
km^2	0.386	mi^2
m^3	35.31	ft^3
m^3	1.308	yd^3
pCi	1,000	nCi
µCi/mL	10^9	pCi/L
Ci/m^3	10^{12}	pCi/m^3
mCi/cm^3	10^{15}	pCi/m^3
nCi/m^2	1.0	mCi/km^2
Ci	3.7×10^{10}	Bq
pCi	0.037	Bq
rad	0.01	Gy
rem	0.01	Sv
ppm	1,000	ppb
°C	(°C x 9/5) + 32	°F
oz	28.349	g
ton	0.9078	tonne

Multiply	By	To Obtain
in.	2.54	cm
ft	0.305	m
mi	1.61	km
lb	0.454	kg
gal	3.785	L
ft^2	0.093	m^2
acre	0.405	ha
mi^2	2.59	km^2
ft^3	0.0283	m^3
yd^3	0.7646	m^3
nCi	0.001	pCi
pCi/L	10^{-9}	µCi/mL
pCi/m^3	10^{-12}	Ci/m^3
pCi/m^3	10^{-15}	mCi/cm^3
mCi/km^2	1.0	nCi/m^2
Bq	2.7×10^{-11}	Ci
Bq	27	pCi
Gy	100	rad
Sv	100	rem
ppb	0.001	ppm
°F	(°F -32) ÷ 9/5	°C
g	0.035	oz
tonne	1.1	ton

Table A.3. Names and Symbols for Units of Radioactivity

Symbol	Name	Symbol	Name
Ci	curie	Bq	becquerel (2.7 x 10^{-11} Ci)
mCi	millicurie (1 x 10^{-3} Ci)	kBq	kilobecquerel (1 x 10^{3} Bq)
µCi	microcurie (1 x 10^{-6} Ci)	MBq	megabecquerel (1 x 10^{6} Bq)
nCi	nanocurie (1 x 10^{-9} Ci)	mBq	millibecquerel (1 x 10^{-3} Bq)
pCi	picocurie (1 x 10^{-12} Ci)	GBq	gigabecquerel (1 x 10^{9} Bq)
fCi	femtocurie (1 x 10^{-15} Ci)	TBq	terabecquerel (1 x 10^{12} Bq)
aCi	attocurie (1 x 10^{-18} Ci)		

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 Ci = 3.7 x 10^{10} dps).
1 Becquerel = 1 disintegration/sec (dps).

United States receives an annual dose from exposure to naturally produced radiation of approximately 300 mrem (3 mSv). Medical and dental x-rays and air travel add to this total. Table A.5 includes selected conversions from rems to sieverts.

Table A.5. 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.

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.5 can also be used to convert Grays to rads.

A **roentgen (R)** is a measure of radiation exposure with no SI equivalent. One roentgen is equivalent to a charge release of 258 microcoulombs per kilogram of air.

The names and symbols for units of radiation dose used in this report are listed in Table A.6

Table A.6. Names and Symbols for Units of Radiation Dose or Exposure

Symbol	Name
mrad	millirad (1 x 10^{-3} rad)
mrem	millirem (1 x 10^{-3} rem)
µrem	microrem (1 x 10^{-6} rem)
Sv	sievert (100 rem)
mSv	millisievert (1 x 10^{-3} Sv)
µSv	microsievert (1 x 10^{-6} Sv)
R	roentgen
mR	milliroentgen (1 x 10^{-3} R)
µR	microroentgen (1 x 10^{-6} R)
Gy	gray (100 rad)
mGy	milligray (1 x 10^{-3} rad)

Additional information on radiation and dose terminology can be found in Appendix B. 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

Many of the chemical contaminants discussed in this report are listed in Table A.8 along with their chemical (or elemental) names and their corresponding symbols.

Understanding the Data Tables

Some degree of variability, or uncertainty, is associated with all analytical measurements. This uncertainty is the consequence of random or systematic inaccuracies related to collecting, preparing, 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.

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 two times the standard deviation and the mean result plus two times the standard deviation.

Table A.7. Radionuclides and Their Half-Lives[a]

Symbol	Radionuclide	Half-Life	Symbol	Radionuclide	Half-Life
^{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	1.3×10^{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	1.4×10^{10} yr
^{59}Ni	nickel-59	75,000 yr	U or uranium	natural uranium	[b]
^{60}Co	cobalt-60	5.3 yr	^{233}U	uranium-233	1.59×10^{5} yr
^{63}Ni	nickel-63	100.1 yr	^{234}U	uranium-234	2.4×10^{5} yr
^{65}Zn	zinc-65	243.9 d	^{235}U	uranium-235	7×10^{8} yr
^{85}Kr	krypton-85	10.7 yr	^{237}Np	neptunium-237	2.14×10^{6} yr
^{90}Sr	strontium-90	29.1 yr	^{238}U	uranium-238	4.5×10^{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	2.4×10^{4} yr
^{99}Tc	technetium-99	2.1×10^{5} yr	^{240}Pu	plutonium-240	6.5×10^{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	3.76×10^{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	1.6×10^{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 ^{238}U, thus the half-life is approximately 4.5×10^{9} years.

Table A.8. Elemental and Chemical Constituent Nomenclature

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

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 (e.g., ashed, dried, chemically treated) 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, the mean of mean values (averages) is accompanied by ±2 times the standard error of the calculated mean (or ±2 SEM). Two times the standard error of the mean implies that approximately 95% of the time the next calculated mean will fall somewhere between the reported value minus two times the standard error and the reported value plus two times the standard error.

Median, Maximum, and Minimum Values

Median, maximum, and minimum values are reported in some sections of this report. A median value is the middle value of an odd numbered set and the average of the two central values in an even numbered set. For example, the median value in the odd numbered 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 average with a ± 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,

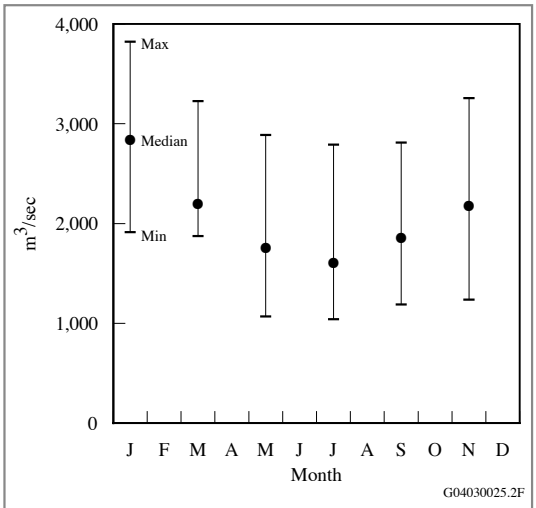

Figure A.1. A Graphical Representation of Maximum, Median (or sometimes average), and Minimum Values

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

Instruments used in the laboratory to measure radioactivity in Hanford Site environmental samples are sensitive enough to measure 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 background radiation level must be subtracted from the total amount of radioactivity measured by an instrument. Because of the randomness of radioactive emissions, the very low activities of some contaminants, or the presence of undesirable materials, 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 Graphs

Graphs are useful when comparing numbers collected at several locations or at one location over time. Graphs often make it easy to visualize differences in data where they exist. However, careful consideration should be given to the scale (linear or logarithmic) and concentration units.

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 or are very close together. 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).

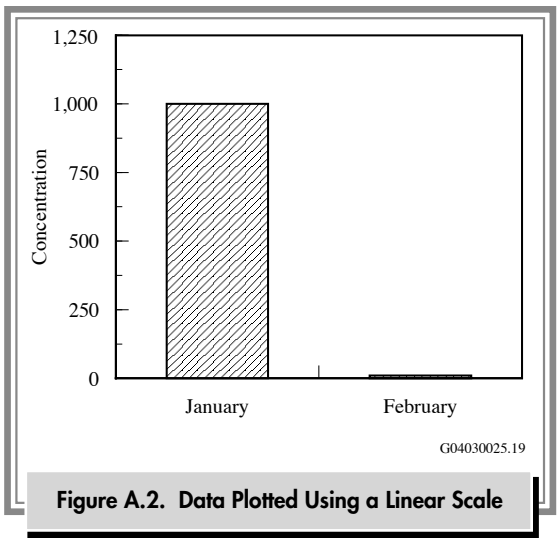

Figure A.2. Data Plotted Using a Linear Scale

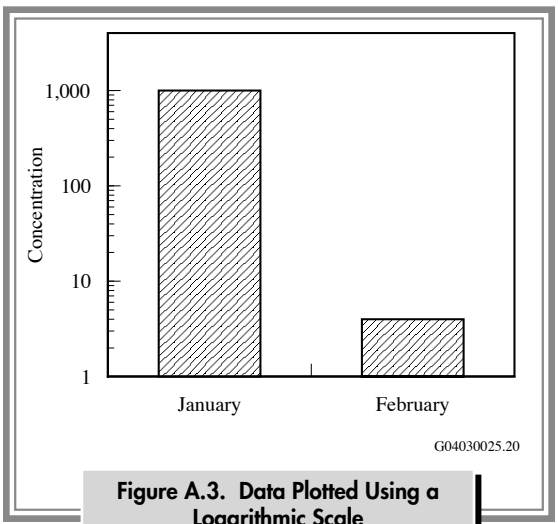

Figure A.3. Data Plotted Using a Logarithmic Scale

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 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 value. The error bars in this report represent a 95% chance that the value is between the upper and lower ends of the error bar and a 5% chance that the true value is either lower or higher than the error bar.[a] For example, in Figure A.4, the first plotted value is 2.0 ± 1.1, so there is a 95% chance that the true value 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 value. These bars provide a quick, visual indication that one value may be statistically similar to or different from another value. If the error bars of two or more values overlap, as is the case with values 1 and 3 and values 2 and 3, the values may be statistically similar. If the error bars do not overlap (values 1 and 2), the values may be statistically different. Values that appear to be very different visually (values 2 and 3) may actually be quite similar when compared statistically.

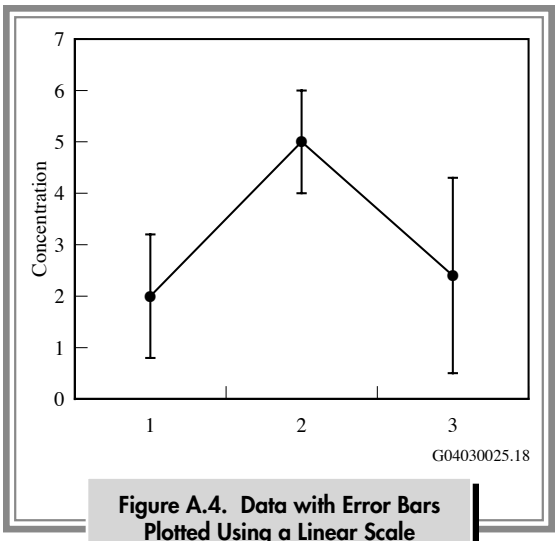

Figure A.4. Data with Error Bars Plotted Using a Linear Scale

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 (Figure A.1).

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. A symbol pointed in the opposite direction (<0.09) would indicate that the number is less than the value presented. A symbol used with an underscore ($\underline{\leq}$ or $\underline{\geq}$) 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, Maryland.

(a) Assuming the data are normally distributed.

Appendix B
Glossary

This glossary contains selected words and phrases used within the context of this report that may not be familiar to the reader. Words appearing in *italic* within a definition are also defined in this glossary.

absorbed dose - Energy absorbed per unit mass from any kind of ionizing *radiation* in any kind of matter. Units: *rad*, which is equal to the absorption of 100 ergs per gram of material irradiated, or *Gray*, which is the International System of Units (SI) equivalent.

activation product - Material made radioactive by *exposure* to *radiation*, principally by neutron radiation as in metals in a nuclear reactor, e.g., cobalt-60 from cobalt-59 in stainless steel.

adsorption - The accumulation of gases, liquids, or solutes on the surface of a solid or liquid.

alpha particle - A positively charged particle comprised of two protons and two neutrons ejected spontaneously from the nuclei of some *radionuclides*. It has low penetrating power and short range. The most energetic alpha will generally fail to penetrate the skin. Alpha particles are hazardous when an alpha-emitting *isotope* is introduced into the body.

anion - A negatively charged ion.

aquifer - Underground sediment or rock that stores and/or transmits 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 *millirem* of background radiation per year.

bank storage - Hydrologic term that describes river water that flows into and is retained in permeable stream banks during periods of high river stage. Flow is reversed during periods of low river stage.

becquerel (Bq) - Unit of activity or amount of a radioactive substance (also *radioactivity*) equal to one nuclear transformation per second (1 Bq = 1 disintegration/s). Another unit of *radioactivity*, the *curie*, is related to the becquerel: 1 Ci = 3.7×10^{10} Bq.

beta particle - A light, negatively charged particle (essentially an electron) 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.

cation - A positively charged ion.

clean closed - A facility is classified as "clean closed" under *Resource Conservation and Recovery Act* 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-sievert*."

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.

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. These structures are no longer used at Hanford.

curie (Ci) - A unit of *radioactivity* equal to 37 billion (3.7×10^{10}) nuclear transformations per second (*becquerels*).

decay - The decrease in the amount of any radioactive material (disintegration) 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). Informally referred to as daughter products. See *radioactivity*.

deep-dose equivalent - The *dose equivalent* at a tissue depth of 1 centimeter from *radiation* 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 *millirem* per year.

detection level (or limit) - Minimum amount of a substance that can be measured with a specified or implied confidence that the analytical result is greater than a specific value (e.g., zero).

dispersion - Process whereby *effluent* is spread or mixed when it is transported by *groundwater*, surface water, or air.

dose equivalent - Product of the *absorbed dose*, a 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*.

dose rate - The rate at which a dose is delivered over time, e.g., *dose equivalent* rate in *millirem* per hour (mrem/h).

dosimeter - Portable device for measuring the accumulated *exposure* or *absorbed dose* from specific types or energies ionizing *radiation* fields.

effective dose - See *effective dose equivalent*.

effective dose equivalent - The sum of products of *dose equivalent* to selected tissues of the body and appropriate tissue weighting factors. The tissue weighting factors put doses to various tissues and organs on an equal basis in terms of health *risk*.

effluent - Liquid waste material released from a facility.

effluent monitoring - Sampling or measuring specific liquid or gaseous *effluent* streams for the presence of pollutants.

emission - Gaseous waste streams released from a facility.

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.

fallout - Typically refers to 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 - Nuclides formed from fissioning. Many fission products are radioactive.

fully institutionalized - To incorporate into a formalized, structured system and be implemented and fully functional.

gamma radiation - High-energy electromagnetic *radiation* (*photons*) originating in the nucleus of decaying *radionuclides*. Gamma radiation is substantially more penetrating than *alpha* or *beta particles*.

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 pores of sand and gravel or in the cracks of fractured rock.

Gray (Gy) - Unit of *absorbed dose* in the International System of Units (SI) equal to 1 joule per kilogram. The common unit of *absorbed dose*, the *rad*, is equal to 0.01 Gy.

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.

institutional controls - Long-term actions or restrictions including monitoring, periodic sampling, access controls, and land use restrictions designed to mitigate any risks posed by contamination following *remediation*. Institutional controls alone may be sufficient to reduce risks posed by low levels of contamination.

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 the same number of protons but a differing number of neutrons.

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.

legacy waste - Waste that was generated prior to termination of Hanford's nuclear materials production mission.

low-level waste - Radioactive waste that is not high-level radioactive waste, spent nuclear fuel, *transuranic waste*, byproduct material, or naturally occurring radioactive material.

maximally exposed individual - A hypothetical member of the public residing near the Hanford Site who, by virtue of location and living habits, would reasonably receive the highest possible *radiation* dose from materials originating from Hanford.

mean (or average) - Average value of a series of measurements. The mean is computed as:

$$\text{mean} = \frac{\Sigma x}{n}$$

where n is the number of measurements and Σx is the sum of all measurements.

median - Middle value in an odd numbered set of results when the data are ranked in increasing or decreasing order or the *average* of two central values in an even number set of results.

millirem - A unit of *radiation dose equivalent* that is equal to one one-thousandth (1/1000) of a *rem*.

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 U.S. Environmental Protection Agency or state designated 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* pathway for radioactive noble gases is direct external dose from the surrounding air.

nuclide - A particular combination of neutrons and protons. A *radionuclide* is a radioactive nuclide.

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 quantum of radiant energy. *Gamma radiation* and x-*radiation* (x-rays) are both comprised of photons of varying energy.

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, metallic element consisting of several *isotopes*. One important *isotope* is ^{239}Pu, which is produced by the *irradiation* of ^{238}U. Routine analysis cannot distinguish between the ^{239}Pu and ^{240}Pu *isotopes*; hence, the term $^{239/240}$Pu as used in this report is symbolic of the presence of one or both of these *isotopes* in the analytical results.

primordial radionuclide - A radioactive material in the earth's crust that has a very long *half-life* and has existed since the beginning of the planet.

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 that from transforming *radionuclides*. For this report, radiation refers to ionizing types of radiation; not radiowaves, microwaves, radiant light, or other types of non-ionizing radiation.

radioactivity - Property possessed by *radioisotopes* of emitting *radiation* (such as alpha, beta, or gamma *photons*) spontaneously in their *decay* process also, the *radiation* emitted.

radioisotope - An unstable *isotope* of an element that *decays* or disintegrates spontaneously, emitting *radiation* (Shleien 1992).

radiologically controlled area - An area to which access is controlled to protect individuals from *exposure* to *radiation* or radioactive and/or hazardous materials.

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 but carbon-12, which is not radioactive is referred to simply as a "*nuclide*."

recruitment - Survival from one life form or stage to the next or from one age class to the next.

redox - A chemical reaction involving oxidation and reduction.

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.

risk-based disposal approval - A written application to the U.S. Environmental Protection Agency intended for the management and disposal of *Toxic Substances Control Act* regulated polychlorinated biphenyl waste not addressed suitably within the regulations. The risk-based disposal approval process is applicable to any person wishing to sample, clean up, or dispose of waste in a manner other than as prescribed in 40 CFR 761. For polychlorinated biphenyl *remediation* waste, the requirements for a risk-based disposal approval are specified in 40 CFR 761.61(c). A written approval from the U.S. Environmental Protection Agency is required before waste management activities are performed.

roentgen (R) - The unit of x-ray or gamma *photon exposure* as 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) - The unit of *dose equivalent* and its varients in the International System of Units (SI). The common unit for *dose equivalent* and its varients, the *rem*, is equal to 0.01 Sv.

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*.

spent fuel - Uranium metal or oxide and its metal container that have been used to power a nuclear reactor and for one reason or another has reached the end of its useful life. 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*.

transuranic element - 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 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 *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.

water table - The top of the *unconfined aquifer*.

wind rose - A diagram showing how often winds of various speeds blow from different directions, usually based on yearly averages.

References

40 CFR 761. U.S. Environmental Protection Agency. "Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions." *U.S. Code of Federal Regulations*.

Shleien, B. (ed.). 1992. *The Health Physics and Radiological Health Handbook, Revised Edition*. Scinta, Inc., Silver Spring, Maryland.

Resource Conservation and Recovery Act. 1976. Public Law 94-580, as amended, 90 Stat. 2795, 42 USC 6901 et seq.

Toxic Substances Control Act. 1976. Public Law 94-469, as amended, 90 Stat. 2003, 15 USC 2601 et seq.

Appendix C
Additional Monitoring Results for 2003

G. W. Patton and E. J. Antonio

This appendix contains additional information on 2003 monitoring results, supplementing the data summarized in the main body of the report. More detailed information is available in PNNL-14687, APP. 1.

Table C.1. Radionuclide Concentrations in Columbia River Water Samples Collected at Priest Rapids Dam, Washington, 2003 Compared to Previous 5 Years

Radionuclide[a]		2003 No. of Samples	2003 Concentration,[b] pCi/L Maximum	2003 Concentration,[b] pCi/L Average	1998-2002 No. of Samples	1998-2002 Concentration,[b] pCi/L Maximum	1998-2002 Concentration,[b] pCi/L Average	Ambient Surface Water Quality Standard, pCi/L
Composite System								
Tritium		12	80 ± 9.0	36 ± 35	58	200 ± 22	39 ± 49	20,000[c]
Alpha (gross)		12	0.94 ± 0.85[d]	0.48 ± 0.56	60	5.6 ± 3.1	0.57 ± 1.5	15[e,f]
Beta (gross)		12	2.5 ± 2.1[d]	0.66 ± 1.8	60	7.7 ± 2.2	0.94 ± 3.3	50[e,f]
Strontium-90		12	0.15 ± 0.047	0.088 ± 0.052	60	0.11 ± 0.038	0.072 ± 0.028	8[c,f]
Technetium-99		12	0.52 ± 0.53	0.094 ± 0.46	60	0.53 ± 0.55[d]	0.0075 ± 0.34	900[c]
Iodine-129		4	0.0000059 ± 0.0000016	0.0000046 ± 0.0000020	20	0.000022 ± 0.0000021	0.0000097 ± 0.000015	1[c]
Uranium-234		12	0.26 ± 0.058	0.22 ± 0.053	60	0.42 ± 0.087	0.23 ± 0.092	--[g]
Uranium-235		12	0.014 ± 0.014[d]	0.0036 ± 0.0094	60	0.025 ± 0.016	0.0062 ± 0.013	--
Uranium-238		12	0.23 ± 0.053	0.17 ± 0.049	60	0.38 ± 0.080	0.19 ± 0.089	--
Uranium (total)		12	0.50 ± 0.080	0.40 ± 0.097	60	0.81 ± 0.12	0.43 ± 0.17	--
Continuous System								
Cobalt-60	P	12	0.0018 ± 0.0012[d]	0.00040 ± 0.0013[d]	52	0.0013 ± 0.0016[d]	0.00026 ± 0.0010	100[c]
	D	12	0.0026 ± 0.0019[d]	0.00092 ± 0.0026[d]	52	0.0040 ± 0.0028[d]	0.00083 ± 0.0030	
Cesium-137	P	12	0.0014 ± 0.0011[d]	0.00033 ± 0.0011[d]	52	0.0032 ± 0.0013	0.00073 ± 0.0016	200[c]
	D	12	0.0027 ± 0.0022[d]	0.00084 ± 0.0026[d]	52	0.0034 ± 0.0021[d]	0.0010 ± 0.0021	
Europium-155	P	12	0.0030 ± 0.0026[d]	0.00043 ± 0.0028[d]	52	0.0032 ± 0.0044[d]	0.00026 ± 0.0021	600[c]
	D	12	0.0054 ± 0.0045[d]	0.0023 ± 0.0043[d]	52	0.012 ± 0.014[d]	0.0013 ± 0.0059	
Plutonium-239/240	P	4	0.000053 ± 0.000037	0.000036 ± 0.000051	20	0.00028 ± 0.00010	0.000046 ± 0.000013	--
	D	4	0.000025 ± 0.000036[d]	0.000021 ± 0.000013[d]	20	0.000055 ± 0.000072[d]	0.000023 ± 0.000039	

(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 deviations of the mean. To convert to the International System of Units, multiply pCi/L by 0.037 to obtain Bq/L.
(c) WAC 173-201A-50 and EPA-570/9-76-003.
(d) Less than the laboratory reported detection limit.
(e) WAC 246-290.
(f) 40 CFR 141.
(g) Dashes indicate no concentration guides available.

Table C.2. Radionuclide Concentrations in Columbia River Water Samples Collected at Richland, Washington, 2003 Compared to Previous 5 Years

Radionuclide[a]		2003 No. of Samples	2003 Concentration,[b] pCi/L Maximum	2003 Concentration,[b] pCi/L Average	1998-2002 No. of Samples	1998-2002 Concentration,[b] pCi/L Maximum	1998-2002 Concentration,[b] pCi/L Average	Ambient Surface Water Quality Standard, pCi/L
Composite System								
Tritium		12	140 ± 14	71 ± 64	58	150 ± 18	72 ± 49	20,000[c]
Alpha (gross)		12	1.6 ± 1.1	0.64 ± 0.93	60	1.8 ± 1.2	0.58 ± 0.76	15[e,f]
Beta (gross)		12	2.8 ± 2.1[d]	0.96 ± 1.8	60	6.6 ± 2.5	0.66 ± 2.8	50[e,f]
Strontium-90		12	0.14 ± 0.035	0.098 ± 0.049	60	0.10 ± 0.037	0.067 ± 0.037	8[e,f]
Technetium-99		12	1.2 ± 0.57	0.28 ± 0.79	60	0.53 ± 0.52	0.026 ± 0.34	900[c]
Iodine-129		4	0.00012 ± 0.0000096	0.000081 ± 0.000065	20	0.00019 ± 0.000022	0.000094 ± 0.000076	1[c]
Uranium-234		12	0.32 ± 0.073	0.28 ± 0.063	60	0.37 ± 0.070	0.26 ± 0.077	--[g]
Uranium-235		12	0.015 ± 0.012	0.0065 ± 0.0086	60	0.024 ± 0.015	0.0084 ± 0.012	--
Uranium-238		12	0.30 ± 0.066	0.22 ± 0.067	60	0.30 ± 0.066	0.21 ± 0.073	--
Uranium (total)		12	0.61 ± 0.093	0.51 ± 0.12	60	0.68 ± 0.093	0.49 ± 0.14	--
Continuous System								
Cobalt-60	P	12	0.0012 ± 0.001[d]	0.00029 ± 0.0010[d]	52	0.0016 ± 0.0011[d]	0.00022 ± 0.0011	100[f]
	D	12	0.0027 ± 0.0038[d]	0.00090 ± 0.0024[d]	52	0.0034 ± 0.0044[d]	0.00074 ± 0.0021	
Cesium-137	P	12	0.0014 ± 0.0012[d]	0.00061 ± 0.0093[d]	52	0.0037 ± 0.0015	0.00075 ± 0.0013	200[f]
	D	12	0.0023 ± 0.0023[d]	0.00084 ± 0.0019[d]	52	0.0031 ± 0.0035[d]	0.00086 ± 0.0020	
Europium-155	P	12	0.0023 ± 0.0028[d]	0.00014 ± 0.0020[d]	52	0.0023 ± 0.0020[d]	0.00029 ± 0.0023	600[f]
	D	12	0.0070 ± 0.0049[d]	0.0021 ± 0.0062[d]	52	0.0077 ± 0.013[d]	0.00086 ± 0.0061	
Plutonium-239/240	P	3	0.000089 ± 0.000046	0.000065 ± 0.000068	20	0.00017 ± 0.000087	0.000030 ± 0.000074	--
	D	4	0.000043 ± 0.000062[d]	0.000019 ± 0.000036[d]	20	0.00016 ± 0.000091	0.000034 ± 0.000094	

(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 deviations of the mean. To convert to the International System of Units, multiply pCi/L by 0.037 to obtain Bq/L.
(c) WAC 173-201A-50 and EPA-570/9-76-003.
(d) Less than the laboratory reported detection limit.
(e) WAC 246-290.
(f) 40 CFR 141.
(g) Dashes indicate no concentration guides available.

Table C.3. Radionuclide Concentrations Measured in Columbia River Water Samples Collected Along Transects of the Hanford Reach, 2003

Transect/Radionuclide	No. of Samples	Concentration,[a] pCi/L Maximum	Concentration,[a] pCi/L Minimum
Vernita Bridge (HRM 0.3)			
Tritium	16	130 ± 25	19 ± 3.9
Strontium-90	16	0.12 ± 0.028	0.062 ± 0.038
Uranium (total)	16	0.52 ± 0.081	0.34 ± 0.068
100-N Area (HRM 9.5)			
Tritium	7	150 ± 26	24 ± 5.5
Strontium-90	7	0.086 ± 0.035	0.058 ± 0.029
Uranium (total)	7	0.52 ± 0.086	0.36 ± 0.062
100-F Area (HRM 19)			
Tritium	6	35 ± 9.2	24 ± 6.8
Strontium-90	6	0.095 ± 0.029	0.075 ± 0.025
Uranium (total)	6	0.54 ± 0.081	0.41 ± 0.065
Hanford Town Site (HRM 28.7)			
Tritium	6	3,400 ± 560	26 ± 7.1
Strontium-90	6	0.090 ± 0.028	0.056 ± 0.020
Uranium (total)	6	0.56 ± 0.084	0.35 ± 0.061
300 Area (HRM 43.1)			
Tritium	6	120 ± 22	33 ± 7.4
Strontium-90	6	0.078 ± 0.026	0.050 ± 0.020
Uranium (total)	6	0.89 ± 0.12	0.42 ± 0.072
Richland (HRM 46.4)			
Tritium	26	140 ± 24	18 ± 3.8
Strontium-90	26	0.10 ± 0.027	0.050 ± 0.029
Uranium (total)	26	1.2 ± 0.16	0.34 ± 0.076

(a) Maximum and minimum values are ± total propagated analytical uncertainty (2-sigma). To convert to the International System of Units, multiply pCi/L by 0.037 to obtain Bq/L.

HRM = Hanford river mile.

Table C.4. Radionuclide Concentrations Measured in Columbia River Water Samples Collected at Near-Shore Locations in the Hanford Reach, 2003

Near-Shore/Radionuclide	No. of Samples	Concentration,[a] pCi/L Maximum	Concentration,[a] pCi/L Minimum
Vernita Bridge (HRM 0.3)			
Tritium	4	33 ± 6.7	22 ± 4.2
Strontium-90	4	0.12 ± 0.028	0.081 ± 0.036
Uranium (total)	4	0.49 ± 0.075	0.36 ± 0.068
100-N Area (HRM 8.4 to 9.8)			
Tritium	6	150 ± 26	29 ± 6.2
Strontium-90	6	0.43 ± 0.075	0.072 ± 0.026
Uranium (total)	6	0.47 ± 0.090	0.38 ± 0.072
100-F Area (HRM 18 to 23)			
Tritium	4	33 ± 8.2	25 ± 7.0
Strontium-90	4	0.094 ± 0.028	0.062 ± 0.024
Uranium (total)	4	0.43 ± 0.070	0.36 ± 0.062
Hanford Town Site (HRM 26 to 30)			
Tritium	5	19,000 ± 1,400	27 ± 7.3
Strontium-90	5	0.073 ± 0.022	0.052 ± 0.019
Uranium (total)	5	1.2 ± 0.16	0.34 ± 0.063
300 Area (HRM 41.5 to 43.1)			
Tritium	5	1,800 ± 210	120 ± 12
Strontium-90	5	0.089 ± 0.027	0.050 ± 0.020
Uranium (total)	5	13 ± 1.5	0.48 ± 0.074
Richland (HRM 43.5 to 46.4)			
Tritium	21	140 ± 25	20 ± 3.9
Strontium-90	21	0.10 ± 0.027	0.051 ± 0.032
Uranium (total)	21	0.80 ± 0.14	0.36 ± 0.075

(a) Maximum and minimum values are ± total propagated analytical uncertainty (2-sigma). To convert to the International System of Units, multiply pCi/L by 0.037 to obtain Bq/L.
HRM = Hanford river mile.

Table C.5. Concentrations (µg/L) of Dissolved Metals in Columbia River Transect and Near-Shore Water Samples Collected Near the Hanford Site, 2003

Location	Metal	No. of Samples	Maximum	Minimum	Average	±2SD[a]
Vernita Bridge	Antimony	16	0.25	0.16	0.19	0.050
	Arsenic	16	0.67	0.51	0.60	0.098
	Beryllium	16	0.066	0.0098	0.042	0.050
	Cadmium	16	0.031	0.014	0.022	0.0082
	Chromium	16	0.27	0.047[b]	0.11	0.15
	Copper	16	0.68	0.34	0.52	0.24
	Lead	16	0.066	0.0090	0.015	0.027
	Nickel	16	0.68	0.40	0.59	0.14
	Selenium	16	0.56	0.080	0.31	0.42
	Silver	16	0.0085	0.004	0.0063	0.0046
	Thallium	16	0.022	0.0090	0.014	0.0083
	Zinc	16	2.2	0.54	1.2	0.96
100-N Area	Antimony	10	0.23	0.18	0.20	0.032
	Arsenic	10	0.58	0.50	0.55	0.046
	Beryllium	10	0.066[b]	0.066[b]	0.066[b]	0
	Cadmium	10	0.028	0.023	0.024	0.0028
	Chromium	10	0.27	0.047	0.070	0.14
	Copper	10	0.73	0.48	0.54	0.14
	Lead	10	0.013	0.011	0.011	0.0017
	Nickel	10	0.61	0.47	0.54	0.093
	Selenium	10	0.50[b]	0.50[b]	0.50[b]	0
	Silver	10	0.0085[b]	0.0085[b]	0.0085[b]	0
	Thallium	10	0.020	0.0099	0.015	0.0065
	Zinc	10	0.99	0.63	0.72	0.22
100-F Area	Antimony	9	0.20	0.16	0.19	0.023
	Arsenic	9	0.62	0.50	0.56	0.075
	Beryllium	9	0.066[b]	0.066[b]	0.066[b]	0
	Cadmium	9	0.026	0.023	0.023	0.0019
	Chromium	9	0.047[b]	0.047[b]	0.047[b]	0
	Copper	9	0.56	0.45	0.51	0.064
	Lead	9	0.012	0.011	0.011	0.0010
	Nickel	9	0.64	0.44	0.51	0.15
	Selenium	9	0.50[b]	0.50[b]	0.50[b]	0
	Silver	9	0.0085[b]	0.0085[b]	0.0085[b]	0
	Thallium	9	0.017	0.0090	0.012	0.0060
	Zinc	9	1.7	0.64	1.0	0.80
Hanford Town Site	Antimony	10	0.21	0.16	0.18	0.037
	Arsenic	10	1.4	0.50	0.66	0.52
	Beryllium	10	0.066[b]	0.066[b]	0.066[b]	0
	Cadmium	10	0.023[b]	0.023[b]	0.023[b]	0
	Chromium	10	0.78	0.047[b]	0.13	0.46
	Copper	10	0.63	0.39	0.49	0.13
	Lead	10	0.011[b]	0.011[b]	0.011[b]	0
	Nickel	10	0.76	0.50	0.60	0.15
	Selenium	10	0.50[b]	0.50[b]	0.50[b]	0
	Silver	10	0.0085[b]	0.0085[b]	0.0085[b]	0
	Thallium	10	0.019	0.0090	0.010	0.0062
	Zinc	10	2.2	0.80	1.4	0.84

Table C.5. (contd)

Location	Metal	No. of Samples	Maximum	Minimum	Average	±2SD[a]
300 Area	Antimony	10	0.20	0.17	0.18	0.023
	Arsenic	10	0.94	0.55	0.67	0.27
	Beryllium	10	0.066[b]	0.066[b]	0.066[b]	0
	Cadmium	10	0.023[b]	0.023[b]	0.023[b]	0
	Chromium	10	0.25	0.047[b]	0.070	0.13
	Copper	10	0.59	0.47	0.51	0.066
	Lead	10	0.090	0.011	0.036	0.067
	Nickel	10	0.84	0.60	0.69	0.15
	Selenium	10	0.50[b]	0.50[b]	0.50[b]	0
	Silver	10	0.0085[b]	0.0085[b]	0.0085[b]	0
	Thallium	10	0.015	0.0090	0.0098	0.0041
	Zinc	10	2.0	1.1	1.5	0.51
Richland	Antimony	39	0.24	0.15	0.18	0.036
	Arsenic	39	1.1	0.37	0.62	0.26
	Beryllium	39	0.066	0.0098	0.042	0.049
	Cadmium	39	0.025	0.012	0.020	0.0070
	Chromium	39	0.40	0.020[b]	0.097	0.16
	Copper	39	1.7	0.38	0.57	0.48
	Lead	39	0.066	0.0062	0.021	0.033
	Nickel	39	0.68	0.49	0.61	0.10
	Selenium	39	0.50	0.068	0.30	0.40
	Silver	39	0.0085	0.004	0.0062	0.0045
	Thallium	39	0.019	0.0090	0.012	0.0064
	Zinc	39	2.0	0.48	1.3	0.90

(a) SD = Standard deviation.
(b) Below detection limit.

Table C.6. Selected U.S. Geological Survey Columbia River Water Quality Data for Vernita and Richland, Washington,[a] 2003

Analysis	Units	Vernita Bridge (upstream)				Richland (downstream)				Washington Ambient Surface Water Quality Standard[b]
		No. of Samples	Median	Maximum	Minimum	No. of Samples	Median	Maximum	Minimum	
Temperature	°C	2	13	19	7.8	2	13	19	7.9	20 (maximum)
Dissolved oxygen	mg/L	2	12.6	12.7	12.6	2	12.0	12.4	11.7	8 (minimum)
Turbidity	NTU[c]	2	2.9	4.0	1.7	2	3.0	3.1	2.9	5 + background
pH	pH units	2	8.0	8.0	8.0	2	8.0	8.2	7.9	6.5 - 8.5
Sulfate, dissolved	mg/L	2	9.0	9.3	8.8	2	9.3	9.4	9.2	--[d]
Dissolved solids, 180°C (356°F)	mg/L	2	84	86	83	2	84	86	81	--
Specific conductance	µS/cm	2	136	139	134	2	140	141	138	--
Total hardness, as $CaCO_3$	mg/L	2	65	66	64	2	64	66	62	--
Alkalinity	mg/L	2	56	59	54	2	58	60	55	
Phosphorus, total	mg/L	2	<0.04	<0.04	<0.03[e]	2	<0.04	<0.04	<0.03[e]	--
Chromium, dissolved	µg/L	2	<0.8	<0.8	<0.8	2	<0.8	<0.8	<0.8	--
Dissolved organic carbon	mg/L	2	1.3	1.4	1.2	2	1.4	1.5	1.3	--
Iron, dissolved	µg/L	2	<10	<10	<8	2	<10	<10	5[e]	--
Ammonia, dissolved, as N	mg/L	2	<0.04	<0.04	<0.04	2	<0.04	<0.04	<0.04	--
Nitrite + nitrate, dissolved, as N	mg/L	2	0.095	0.13	0.06	2	0.095	0.11	0.08	--

(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 C.7. Radionuclide Concentrations in Sediment from the Columbia River Near the Hanford Site and from Columbia River Riverbank Springs Along the Hanford Site, 2003 Compared to Previous 5 Years

		2003			1998-2002		
		No. of	Concentration, pCi/g[a]		No. of	Concentration, pCi/g[a]	
Location	Radionuclide	Samples	Median[b]	Maximum[c]	Samples	Median[b]	Maximum[c]
River Sediment (2003 TOC Value)[d]							
Priest Rapids Dam (11,700 - 12,700 mg/kg)	Cobalt-60	2	0.0018[e]	0.0040 ± 0.011[e]	18	0.0051[e]	0.042 ± 0.041[e]
	Cesium-137	2	0.30	0.32 ± 0.048	18	0.40	0.65 ± 0.086
	Europium-155	2	0.046[e]	0.047 ± 0.034[e]	18	0.049[e]	0.082 ± 0.088[e]
	Plutonium-239/240	2	0.011	0.012 ± 0.0023	18	0.0096	0.015 ± 0.0028
	Strontium-90	2	0.0068	0.010 ± 0.024[e]	18	0.013	0.028 ± 0.028[e]
	Uranium-234	2	0.70	0.73 ± 0.12	18	0.52	0.83 ± 0.14
	Uranium-235	2	0.019	0.022 ± 0.0091	18	0.018	0.037 ± 0.014
	Uranium-238	2	0.62	0.66 ± 0.11	18	0.46	0.73 ± 0.12
White Bluffs Slough (11,800 mg/kg)	Cobalt-60	1		0.027 ± 0.018[e]	5	0.062	0.11 ± 0.024
	Cesium-137	1		0.53 ± 0.072	5	0.58	0.64 ± 0.089
	Europium-155	1		0.045 ± 0.044[e]	5	0.040[e]	0.10 ± 0.034
	Plutonium-239/240	1		0.0069 ± 0.0027	5	0.0050	0.0077 ± 0.0017
	Strontium-90	1		-0.0017 ± 0.020[e]	5	0.0023	0.0082 ± 0.0049
	Uranium-234	1		0.31 ± 0.062	5	0.47	1.6 ± 0.30
	Uranium-235	1		0.015 ± 0.011	5	0.013	0.053 ± 0.016
	Uranium-238	1		0.28 ± 0.056	5	0.38	1.3 ± 0.24
100-F Slough (1,240 mg/kg)	Cobalt-60	1		0.0042 ± 0.013[e]	5	0.010[e]	0.023 ± 0.010[e]
	Cesium-137	1		0.39 ± 0.055	5	0.30	0.36 ± 0.042
	Europium-155	1		0.030 ± 0.031[e]	5	0.040[e]	0.069 ± 0.062[e]
	Plutonium-239/240	1		0.0020 ± 0.0012	5	0.0018	0.0023 ± 0.00054
	Strontium-90	1		0.00018 ± 0.020[e]	5	0.0017	0.0054 ± 0.013[e]
	Uranium-234	1		0.13 ± 0.031	5	0.16	0.31 ± 0.062
	Uranium-235	1		-0.00075 ± 0.0052[e]	5	0.0058	0.011 ± 0.0022
	Uranium-238	1		0.13 ± 0.031	5	0.15	0.29 ± 0.058
Hanford Slough (10,200 mg/kg)	Cobalt-60	1		0.055 ± 0.02	5	0.0099[e]	0.026 ± 0.026[e]
	Cesium-137	1		0.32 ± 0.046	5	0.027	0.16 ± 0.033
	Europium-155	1		0.054 ± 0.035[e]	5	0.058[e]	0.067 ± 0.036[e]
	Plutonium-239/240	1		0.0053 ± 0.0026	5	0.0014	0.0045 ± 0.00093
	Strontium-90	1		0.0058 ± 0.018[e]	5	0.0036	0.0059 ± 0.019[e]
	Uranium-234	1		0.36 ± 0.081	5	0.28	0.53 ± 0.10
	Uranium-235	1		0.021 ± 0.016	5	0.0090	0.017 ± 0.0077
	Uranium-238	1		0.32 ± 0.073	5	0.27	0.47 ± 0.092

Table C.7. (contd)

Location	Radionuclide	2003 No. of Samples	2003 Concentration, pCi/g[a] Median[b]	2003 Concentration, pCi/g[a] Maximum[c]	1998-2002 No. of Samples	1998-2002 Concentration, pCi/g[a] Median[b]	1998-2002 Concentration, pCi/g[a] Maximum[c]
Richland	Cobalt-60	1		0.0066 ± 0.013[e]	5	0.012[e]	0.032 ± 0.023[e]
(1,950 mg/kg)	Cesium-137	1		0.17 ± 0.030	5	0.23	0.24 ± 0.038
	Europium-155	1		0.098 ± 0.036	5	0.035[e]	0.047 ± 0.059[e]
	Plutonium-239/240	1		0.0016 ± 0.00091	5	0.0014	0.0021 ± 0.00056
	Strontium-90	1		-0.0077 ± 0.019[e]	5	0.00065	0.0063 ± 0.0041
	Uranium-234	1		0.22 ± 0.044	5	0.18	0.25 ± 0.053
	Uranium-235	1		0.0062 ± 0.0051	5	0.0096	0.014 ± 0.0080
	Uranium-238	1		0.24 ± 0.047	5	0.19	0.24 ± 0.053
McNary Dam	Cobalt-60	4	0.044[e]	0.062 ± 0.028[e]	22	0.029	0.12 ± 0.042[e]
(8,150 - 10,800 mg/kg)	Cesium-137	4	0.34	0.42 ± 0.083	22	0.36	1.1 ± 0.15
	Europium-155	4	0.070[e]	0.11 ± 0.074[e]	22	0.056[e]	0.13 ± 0.066[e]
	Plutonium-239/240	4	0.0086	0.010 ± 0.0018	22	0.0082	0.032 ± 0.0048
	Strontium-90	5	0.013	0.028 ± 0.026	22	0.020	0.043 ± 0.028
	Uranium-234	4	0.81	1.0 ± 0.18	22	0.76	0.87 ± 0.17
	Uranium-235	4	0.024	0.026 ± 0.012	22	0.022	0.032 ± 0.012
	Uranium-238	4	0.64	0.76 ± 0.14	22	0.61	0.70 ± 0.13
Riverbank Spring Sediment							
100-B Spring	Cobalt-60	1		0.0076 ± 0.012[e]	5	0.0039[e]	0.022 ± 0.013[e]
	Cesium-137	1		0.068 ± 0.023	5	0.075	0.14 ± 0.026
	Europium-155	1		0.095 ± 0.037[e]	5	0.078[e]	0.11 ± 0.072[e]
	Strontium-90	1		0.0068 ± 0.016[e]	5	0.0020[e]	0.0041 ± 0.0083[e]
	Uranium-234	1		0.41 ± 0.077	5	0.26	0.49 ± 0.087
	Uranium-235	1		0.014 ± 0.0080	5	0.014	0.029 ± 0.016
	Uranium-238	1		0.35 ± 0.067	5	0.26	0.41 ± 0.085
100-K Spring	Cobalt-60	1		0.0044 ± 0.0099[e]	1		0.0053 ± 0.013[e]
	Cesium-137	1		0.11 ± 0.024	1		0.10 ± 0.023
	Europium-155	1		0.020 ± 0.029[e]	1		0.057 ± 0.041[e]
	Strontium-90	1		0.017 ± 0.019[e]	1		0.015 ± 0.024[e]
	Uranium-234	1		0.26 ± 0.052	1		0.30 ± 0.065
	Uranium-235	1		0.0091 ± 0.0064	1		0.0085 ± 0.0066
	Uranium-238	1		0.24 ± 0.048	1		0.28 ± 0.060

Table C.7. (contd)

Location	Radionuclide	2003 No. of Samples	2003 Concentration, pCi/g[a] Median[b]	2003 Concentration, pCi/g[a] Maximum[c]	1998-2002 No. of Samples	1998-2002 Concentration, pCi/g[a] Median[b]	1998-2002 Concentration, pCi/g[a] Maximum[c]
100-F Spring	Cobalt-60	1		0.0071 ± 0.012[e]	5	0.016[e]	0.021 ± 0.032[e]
	Cesium-137	1		0.26 ± 0.051	5	0.14	0.20 ± 0.035
	Europium-155	1		0.073 ± 0.033[e]	5	0.042	0.070 ± 0.031
	Strontium-90	1		-0.0016 ± 0.020[e]	5	0.018[e]	0.013 ± 0.032[e]
	Uranium-234	1		0.51 ± 0.095	6	0.51	0.70 ± 0.14
	Uranium-235	1		0.026 ± 0.011	6	0.023	0.060 ± 0.019
	Uranium-238	1		0.45 ± 0.085	6	0.42	0.68 ± 0.074
Hanford Spring	Cobalt-60	0			5	0.039	0.067 ± 0.026
	Cesium-137	0			5	0.20	0.23 ± 0.034
	Europium-155	0			5	0.069[e]	0.10 ± 0.035[e]
	Uranium-234	0			5	0.57	0.75 ± 0.13
	Uranium-235	0			5	0.017	0.024 ± 0.011
	Uranium-238	0			5	0.45	0.60 ± 0.10
300 Area Spring	Cobalt-60	2	0.0039[e]	0.014 ± 0.011[e]	7	0.011[e]	0.020 ± 0.010[e]
	Cesium-137	2	0.10	0.17 ± 0.029	7	0.057	0.27 ± 0.035
	Europium-155	2	0.074[e]	0.083 ± 0.032[e]	7	0.055[e]	0.086 ± 0.035[e]
	Uranium-234	2	1.5	1.5 ± 0.26	13	1.8	11 ± 2.0
	Uranium-235	2	0.059	0.067 ± 0.020	13	0.068	0.38 ± 0.075
	Uranium-238	2	1.4	1.5 ± 0.24	13	1.8	10 ± 1.8

(a) To convert to the International System of 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 C.8. Median Metal Concentrations (mg/kg dry wt.) in Sediment Samples Collected from the Columbia River Near the Hanford Site, 2003

Metal	(n=2) Priest Rapids Dam	(n=4) Hanford Reach[a]	(n=2) McNary Dam	(n=6) Riverbank Springs[b]
Antimony	0.91	0.80	0.81	0.64
Arsenic	9.5	8.4	9.1	6.6
Beryllium	1.6	1.5	1.9	1.5
Cadmium	7.5	1.8	1.6	0.69
Chromium	90	72	72	65
Copper	48	26	32	18
Lead	52	39	26	24
Mercury	0.18	0.035	0.097	0.015
Nickel	44	22	31	21
Selenium[c]	0.48	0.48	0.48	0.48
Silver	0.46	0.32	0.41	0.058
Thallium	1.4	1.1	0.72	0.52
Zinc	543	360	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.
(c) All values were below the detection limit of 0.48 mg/kg dry weight.

Table C.9. Radionuclide Concentrations Measured in Columbia River Water Samples Collected from Riverbank Springs Along the Hanford Site, 2003 Compared to Previous 5 Years

Location/Radionuclide	2003 No. of Samples	2003 Concentration,[a] pCi/L Maximum	2003 Concentration,[a] pCi/L Average	1998-2002 No. of Samples	1998-2002 Concentration,[a] pCi/L Maximum	1998-2002 Concentration,[a] pCi/L Average	Washington State Ambient Surface Water Quality Standard,[b] pCi/L
100-B Area							
Alpha (gross)	3	10 ± 4.2	4.4 ± 10	16	9.4 ± 3.8	2.5 ± 4.2	15
Beta (gross)	3	23 ± 4.8	14 ± 19	16	24 ± 4.5	9.4 ± 11	50
Strontium-90	3	4.0 ± 0.59	1.4 ± 4.5	16	5.7 ± 1.3	0.65 ± 3.5	8
Technetium-99	2	11 ± 0.89	7.3 ± 9.8	7	10 ± 1.4	4.9 ± 6.6	900[c]
Tritium	3	5,800 ± 500	4,700 ± 2,700	16	20,000 ± 870	8,600 ± 10,000	20,000
100-K Area							
Alpha (gross)	6	1.5 ± 1.2[d]	0.76 ± 1.2	19	4.1 ± 2.1	1.6 ± 2.6	15
Beta (gross)	6	10 ± 2.3	6.6 ± 5.2	19	46 ± 7.9	8.5 ± 20	50
Strontium-90	3	2.8 ± 0.41	1.0 ± 3.0	9	3.2 ± 0.72	0.83 ± 2.5	8
Technetium-99	1	0.66 ± 5.2[d]		6	2.3 ± 0.28	0.62 ± 1.9	900[c]
Tritium	6	1,600 ± 210	940 ± 1,400	19	12,000 ± 970	3,100 ± 6,400	20,000
100-N Area							
Alpha (gross)	1	4.9 ± 2.7		6	2.2 ± 1.4	1.6 ± 1.0	15
Beta (gross)	1	9.3 ± 2.4		6	5.9 ± 2.1	4.2 ± 2.9	50
Strontium-90	1	0.041 ± 0.063[d]		6	0.039 ± 0.044[d]	0.016 ± 0.034	8
Tritium	1	10,000 ± 800		6	24,000 ± 1,900	14,000 ± 14,000	20,000
100-D Area							
Alpha (gross)	7	3.8 ± 2.2	0.82 ± 2.7	25	32 ± 9.8	3.5 ± 14	15
Beta (gross)	7	3.8 ± 1.8	1.9 ± 2.0	25	41 ± 7.9	8.3 ± 22	50
Strontium-90	2	0.34 ± 0.061	0.21 ± 0.36	6	5.3 ± 1.3	1.4 ± 3.9	8
Tritium	7	2,600 ± 260	560 ± 1,900	25	9,800 ± 730	3,300 ± 6,900	20,000
100-H Area							
Alpha (gross)	5	20 ± 7.2	5.7 ± 16	32	10 ± 3.7	1.3 ± 3.6	15
Beta (gross)	5	28 ± 5.1	15 ± 22	32	72 ± 8.6	11 ± 29	50
Strontium-90	1	14 ± 2.0		10	14 ± 3.2	4.5 ± 11	8
Technetium-99	2	0.30 ± 0.36[d]	0.27 ± 0.079	10	77 ± 8.7	9.0 ± 48	900
Tritium	5	2,900 ± 290	850 ± 2,400	32	5,500 ± 470	850 ± 2,000	20,000
Uranium (total)	2	2.7 ± 0.32	1.7 ± 2.7	10	9.3 ± 0.70	2.1 ± 2.6	--

Table C.9. (contd)

Location/Radionuclide	2003 No. of Samples	2003 Concentration,[a] pCi/L Maximum	2003 Concentration,[a] pCi/L Average	1998-2002 No. of Samples	1998-2002 Concentration,[a] pCi/L Maximum	1998-2002 Concentration,[a] pCi/L Average	Washington State Ambient Surface Water Quality Standard,[b] pCi/L
100-F Area							
Alpha (gross)	2	4.7 ± 2.7	4.5 ± 0.71	14	6.3 ± 2.8	3.9 ± 3.2	15
Beta (gross)	2	25 ± 4.4	16 ± 26	14	16 ± 3.3	8.6 ± 7.1	50
Strontium-90	2	0.076 ± 0.26[d]	0.067 ± 0.025	14	1.5 ± 0.57	0.21 ± 0.92	8
Tritium	2	800 ± 150	520 ± 780	14	1,500 ± 320	980 ± 940	20,000
Uranium (total)	1	1.5 ± 0.19		6	5.2 ± 0.69	4.0 ± 2.1	--[e]
Hanford Town Site							
Alpha (gross)	2	1.3 ± 1.2[d]	0.98 ± 0.81	11	14 ± 5.9	4.1 ± 6.7	15
Beta (gross)	2	9.4 ± 2.3	8.8 ± 1.5	11	49 ± 7.9	29 ± 16	50
Iodine-129	2	0.14 ± 0.012	0.10 ± 0.12	11	0.41 ± 0.024	0.21 ± 0.18	1
Technetium-99	2	14 ± 1.1	11 ± 7.1	11	120 ± 8.0	83 ± 43	900[c]
Tritium	2	14,000 ± 1,100	14,000 ± 420	11	120,000 ± 8,800	82,000 ± 48,000	20,000
Uranium (total)	2	0.94 ± 0.13	0.88 ± 0.18	11	8.6 ± 1.0	3.7 ± 3.7	--
300 Area							
Alpha (gross)	2	140 ± 36	130 ± 21	11	230 ± 49	87 ± 110	15
Beta (gross)	2	55 ± 10	48 ± 19	11	49 ± 7.9	27 ± 18	50
Iodine-129	2	0.0068 ± 0.00084	0.0058 ± 0.0030	11	0.0067 ± 0.00066	0.0043 ± 0.0034	1
Technetium-99	0			5	16 ± 2.0	12 ± 4.3	900[c]
Tritium	2	10,000 ± 820	10,000 ± 1,000	13	12,000 ± 580	8,600 ± 3,700	20,000
Uranium (total)	2	140 ± 15	120 ± 38	15	210 ± 26	75 ± 98	--

(a) Maximum values are ± total propagated analytical uncertainty. Averages are ±2 standard deviations of the mean. To convert to the International System of 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) WAC 173-201A-50 and EPA-570/9-76-003.
(d) Value below the laboratory reported detection limit.
(e) Dashes indicate no concentration guides available.

Table C.10. Annual Average Dose Rates Measured On and Around the Hanford Site in Calendar Year 2003

Location	Location Number	Annual Average (mrem/yr)[a]
Onsite[b]		
100 B Reactor Museum	1	83 ± 10
100 K Area	2	72 ± 4
100 D Area	3	87 ± 7
100 F Met Tower	4	84 ± 4
N of 200 E	5	92 ± 8
B Pond	6	81 ± 6
E of 200 E	7	91 ± 3
200 ESE	8	86 ± 4
S of 200 E[c]	9	95 ± 4
200 Tel. Exchange	10	82 ± 5
SW of B/C Cribs	11	84 ± 4
200 W SE	12	82 ± 4
Army Loop Camp	13	87 ± 5
3705 Bldg. 300 Area	14	83 ± 5
313 Bldg.	15	96 ± 8
300 Water Intake	16	78 ± 3
300 Southwest Gate	17	79 ± 4
300 South Gate	18	83 ± 8
300 Trench	19	87 ± 6
300 NE	20	86 ± 4
400 E	21	83 ± 3
400 W	22	86 ± 6
400 S	23	82 ± 7
400 N	24	81 ± 3
US Ecology NE Corner	25	86 ± 2
US Ecology SE Corner	26	86 ± 7
US Ecology NW Corner	27	89 ± 5
US Ecology SW Corner	28	96 ± 5
Wye Barricade	29	85 ± 8
WPPSS 1; S of WNP 2	30	86 ± 9
Hanford Townsite	31	81 ± 8
West Lake[c]	32	90 ± 7
LIGO	33	78 ± 20
Perimeter[d]		
Ringold Met Tower	1	94 ± 7
W End of Fir Road	2	93 ± 2
Dogwood Met Tower	3	95 ± 6
Byers Landing	4	96 ± 3
Battelle Complex	5	80 ± 6
WPPSS 4; WPS Warehse	6	81 ± 3
Horn Rapids Substation	7	86 ± 6
Prosser Barricade	8	90 ± 6
Yakima Barricade	9	95 ± 5
Rattlesnake Springs	10	93 ± 7
Wahluke Slope	11	90 ± 3
Community[d]		
Mattawa	12	80 ± 5
Othello	13	74 ± 6
Basin City School[e]	14	77 ± 1
Edwin Markham School	15	77 ± 3
Pasco	16	88 ± 5
Kennewick - Ely Street	17	73 ± 14
Benton City	18	81 ± 11
Distant[d]		
Yakima	19	72 ± 4
Toppenish	20	72 ± 6
Columbia River Shoreline[f]		
Below 100N Outfall	1	99 ± 9
Above Tip 100N Berm	2	84 ± 4
100 N Trench Spring	3	99 ± 7
S End Vernita Bridge[e]	4	76 ± 8
Above 100 B Area	5	86 ± 12
Below 100B Retention Basin	6	98 ± 5
Above 1K Boat Ramp	7	83 ± 10
Below 100 D Area	8	71 ± 12
100-D Island[c]	9	79 ± 6
100 H Area	10	84 ± 9
Lower End Locke Island	11	87 ± 7
White Bluffs Ferry Landing	12	83 ± 11
White Bluffs Slough[c]	13	96 ± 16
Below 100 F	14	82 ± 7
100 F Flood Plain	15	84 ± 3
Hanford Slough	16	95 ± 10
Hanford Powerline Crossing	17	94 ± 6
Hanford Railroad Track	18	91 ± 15
Savage Island Slough	19	79 ± 10
Ringold Island	20	86 ± 15
Powerline Crossing	21	88 ± 14
S End Wooded Island	22	95 ± 8
Island Above 300 Area	23	93 ± 7
Island Near 300 Area	24	91 ± 3
Port of Benton-River[c]	25	85 ± 3
N. Richland[c]	26	75 ± 2
Island Downstream Bateman Island[c]	27	90 ± 7

(a) Average for four quarterly measurements ±2 standard deviations of the dose rate.
(b) All locations are shown on Figure 4.6.1.
(c) Measurements for three calendar quarters only.
(d) All locations are shown on Figure 4.6.2.
(e) Measurements for two calendar quarters only.
(f) All locations are shown on Figure 4.6.3.

References

40 CFR 141. U.S. Environmental Protection Agency. "National Primary Drinking Water Regulations; Radionuclides; Proposed Rule." *U.S. Code of Federal Regulations*.

EPA-570/9-76-003. 1976. *National Interim Primary Drinking Water Regulations*. Office of Water Supply, U.S. Environmental Protection Agency, Washington, D.C.

PNNL-14687, APP. 1. 2004. *Hanford Site Environmental Surveillance Data Report for Calendar Year 2003*. L.E. Bisping, Pacific Northwest National Laboratory, Richland, Washington.

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 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 2003 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. The 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 the DOE, *Clean Air Act*, or drinking water dose standards.

Permits required for regulated releases to water and air have been issued by the EPA under the National Pollutant Discharge Elimination System 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	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	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	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

Radiological Constituent	Primary Maximum Contaminant Level	Interim Drinking Water Standard	Agency[a]	Status
Gross alpha[b]	15 pCi/L (0.56 Bq/L)		DOH,[c] EPA[d]	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]	Final
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]	Final
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]
Radium-226	20 pCi/L (0.74 Bq/L)[d]	3 pCi/L (0.111 Bq/L)[c]	DOH, EPA	Final
Radium-226 and -228	5 pCi/L (0.185 Bq/L)		EPA	Final
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[j]	Final
cis-1,2-Dichloroethene	0.07 mg/L (0.07 ppm)		EPA[j]	Final

(a) DOH = Washington State Department of Health; EPA = U.S. Environmental Protection Agency.
(b) Excluding radon and uranium but including radium-226.
(c) WAC 246-290.
(d) 40 CFR 141.
(e) Beta
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) 40 CFR Parts 9, 141, and 142. 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)[j]	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 $CaCO_3$/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(hardness)] 0.04184) exp(1.128[ln(hardness)]-3.828). Hardness expressed as mg $CaCO_3$/L.
(d) (1.1017 - [ln(hardness)] 0.04184) exp(0.7852[ln(hardness)]-3.490).
(e) (0.960) exp(0.9422[ln(hardness)]-1.464).
(f) (0.960) exp(0.8545[ln(hardness)]-1.465).
(g) (1.4620 - [ln(hardness)] 0.1457) exp(1.273[ln(hardness)]-1.460).
(h) (1.4620 - [ln(hardness)] 0.1457) exp(1.273[ln(hardness)]-4.705).
(i) (0.998) exp(0.8460[ln(hardness)]+3.3612).
(j) (0.997) exp(0.8460[ln(hardness)]+1.1645).
(k) (0.85) exp(1.72[ln(hardness)]-6.52).
(l) (0.978) exp(0.8473[ln(hardness)]+0.8604).
(m) (0.986) exp(0.8473[ln(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(hardness)]+3.688).
(p) (0.860) exp(0.8190[ln(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.

	Effective Dose Equivalent[c]	
	mrem/yr	mSv/yr
Routine public dose	100	1
Potential authorized temporary public dose[d]	500	5

Dose to Native Aquatic Animal Organisms from Liquid Discharges (interim limits from DOE Order 5400.5)

Radioactive material in liquid 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 Parts 9, 141, and 142; WAC 246-290; 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 Parts 9, 141, and 142 (see Table D.2).

Air Pathways Only (limits from 40 CFR 61)

	Effective Dose Equivalent[c]	
	mrem/yr	mSv/yr
Public dose limit at location of maximum annual air concentration as a consequence of routine DOE 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, pCi/L (Bq/L)		Inhaled Air, pCi/m³ (Bq/m³)	
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)
Cobalt-60	5,000	(185)	80	(2.96)
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)
Iodine-129	500	(18.5)	70	(2.59)
Iodine-131	3,000	(111)	400	(14.8)
Cesium-137	3,000	(111)	400	(14.8)
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.

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 storm water 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

has been submitted. A new permit was issued on September 10, 2003, and was effective on October 1, 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.

Permit ST 4509 allows for cooling water, condensate discharges, and miscellaneous discharges from pump leaks, valve wastewater, and tank overflows under controlled conditions. Expired May 1, 2003. An application has been submitted to combine Permits 4508, 4509, and 4510 into a single permit. This combined permit (ST 4511) is expected to be issued in 2004.

Permit ST 4510 covers wastewater discharges associated with industrial storm water under controlled conditions. Expired April 1, 2004.

Permit WAG-50-5180 (General Sand and Gravel) for the Concrete Batch Plant in the 200-East Area.

Permit WAG-50-5181 for Gravel Pit 30 in the 200-East Area.

Permit ST 9240 is a one time limited duration discharge permit (per request) in support of higher volume Waste Treatment Plant construction discharges.

Wildlife Sampling Permits

Scientific Collection Permit 03-029, issued by Washington Department of Fish and Wildlife to Pacific Northwest National Laboratory for 2003; 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. Expires March 31, 2006.

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

State of Washington Department of Ecology P.O. Box 47600 Olympia, WA 92504-7600	U.S. Environmental Protection Agency Region 10 1200 Sixth Avenue Seattle, WA 98101	U.S. Department of Energy Richland Operations Office 825 Jadwin Avenue Richland, WA 99352

References

40 CFR 61. U.S. Environmental Protection Agency. "National Emission Standards for Hazardous Air Pollutants." *U.S. 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)." *U.S. Code of Federal Regulations*.

40 CFR 141. U.S. Environmental Protection Agency. "National Primary Drinking Water Regulations." *U.S. Code of Federal Regulations*.

40 CFR Parts 9, 141, and 142. U.S. Environmental Protection Agency. "National Primary Drinking Water Regulations; Radionuclides; Final Rule." *U.S. Code of Federal Regulations*. 65 FR 76708, December 7, 2000.

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

Measurements

The interaction of radiation with matter results in energy being deposited in that matter. This is why your hand feels warm when it is 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 1 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 to measure radiation absorbed dose is the thermoluminescent dosimeter (TLD). This device absorbs and stores the energy of ionizing radiation within its crystal lattice. By heating the dosimeter material under controlled laboratory conditions, the stored energy is released in the form of light, which is 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.

$$D\ (rad) = X\ (R) * 1.0$$

$$H\ (rem) = D * N * Q$$

Calculations

The radiological dose that the public could have received in 2003 from Hanford Site cleanup 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 rem, or more typically the sub-unit 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.

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

(a) 1 rem (0.01 Sv) = 1,000 mrem (10 mSv).

committed internal dose to obtain the total effective dose equivalent. In this report, the effective dose equivalent is expressed in millirem with the corresponding value in sievert (or millisievert) in parentheses. The transfer factors used for pathway and dose calculations are documented in PNL-6584 and in PNL-3777.

Releases of radionuclides from Hanford Site facilities are usually too small 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 - The Hanford Environmental Radiation Dosimetry Software System*, Version 1.485 (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 RESRAD-BIOTA computer code was used to screen the 2003 radionuclide concentrations in environmental media (water and sediment) for exceeding established biota concentration guides (e.g., soil, sediment, or water concentrations that result in a dose rate of 1 rad per day for aquatic biota or 0.1 rad per day for terrestrial organisms). Both internal and external doses to aquatic, riparian, and terrestrial animals as well as to terrestrial plants are included in the screening process. For analyses with multiple media and multiple radionuclides, a sum of fractions is calculated to account for the contribution to dose from each radionuclide relative to its corresponding biota concentration guide. In the initial screening assessment, one compares maximum measured concentrations to the biota concentration guide. If the sum of fraction does not exceed one, no further analysis is required. However, if the sum of fractions does exceed one, a second analysis is performed using average concentrations. The screening process is further described in *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE-STD-1153-2002).

The computer program, CAP88-PC, was used to calculate an air pathway 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 the 2003 air emissions report (DOE/RL-2004-09).

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 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 Hanford Site 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. Based on experience since 1990, three separate locations (Figure 5.0.1) have been used to assess the dose to the maximally exposed individual: (1) the Ringold area, along the east shoreline of the Columbia River 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. 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 1993 through 1999, 2001, and again in 2003, the hypothetical, maximally exposed individual was located across the Columbia River from the 300 Area at Sagemoor (Figure 5.0.1).

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 contaminated locally grown food products. 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.

Sagemoor 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 Sagemoor, located approximately 1.4 kilometers (0.87 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 Sagemoor 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 Population Doses (person-rem). Regulatory limits have not been established for population doses. However, evaluation of the collective population doses to all residents within an 80-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 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. Approximately 130,000 people in the three cities are assumed to obtain all their drinking water directly from the Columbia River or from wells adjacent to the 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-14687, APP. 1. These distributions are based on 2000 Bureau of the Census data (PNNL-14428). 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-14687, 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 individuals or individuals for whom average parameter values were used.

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-14687, 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 2003 are given in Table E.10.

Table E.1. Food Pathway Parameters Used in Hanford Site Dose Calculations, 2003

Medium	Holdup, d[a] Maximally Exposed Individual	Holdup, d[a] Average Individual	Growing Period, d	Yield, kg/m² (lb/yd²)		Irrigation Rate, L/m²/mo (gal/yd²/mo)	
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, 2003

Medium	Consumption: Maximally Exposed Individual		Consumption: Average Individual	
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	(310 lb/yr)
Fruit	330 kg/yr	(728 lb/yr)	64 kg/yr	(140 lb/yr)
Grain	80 kg/yr	(180 lb/yr)	72 kg/yr	(160 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	(180 lb/yr)	70 kg/yr	(150 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).

Table E.3. Residency Parameters Used in Hanford Site Dose Calculations, 2003

Parameter	Exposure, h/yr: Maximally Exposed Individual	Exposure, h/yr: Average Individual
Ground contamination	4,383	2,920
Air submersion	8,766	8,766
Inhalation[a]	8,766	8,766

(a) Inhalation rates: adult 270 cm^3/s (16.5 $in.^3/s$).

Table E.4. Recreational Parameters Used in Hanford Site Dose Calculations, 2003

Parameter	Exposure, h/yr[a]: Maximally Exposed Individual	Exposure, h/yr[a]: Average Individual
Shoreline	500	17
Boating	100	5
Swimming	100	10

(a) Assumed river-water travel times from 100-N 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.

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 contaminated air. 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.5. Technical Details of Airborne Release Dose Calculations for the 100 Areas of the Hanford Site, 2003

Facility name	100-K Area
Releases (Ci [Bq])	^{90}Sr (9.0 x 10^{-6} [3.33 x 10^{5}]), ^{106}Ru (1.1 x 10^{-6} [4.07 x 10^{4}]), ^{137}Cs (7.5 x 10^{-6} [2.77 x 10^{5}]), ^{238}Pu (3.4 x 10^{-7} [1.26 x 10^{4}]), ^{239}Pu (2.5 x 10^{-6} [9.25 x 10^{4}]), ^{241}Pu (2.3 x 10^{-5} [8.51 x 10^{5}]), ^{241}Am (1.7 x 10^{-6} [6.29 x 10^{4}])
Meteorological conditions	2003 annual average, calculated from data collected at the 100-K Area and the Hanford Meteorology Station from January through December 2003, using the computer code HANCHI
$\overline{X}$/Q'	Maximally exposed individual, 1.8 x 10^{-8} s/m^3 at 53 km (33 mi) SSE; 80-km (50-mi) population, 4.6 x 10^{-3} s/m^3 person-s/m^3
Release height	10-m (33-ft) effective stack height
Population distribution	~482,000 (PNNL-14687, 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

Table E.6. Technical Details of Liquid Release Dose Calculations for the 100-N Area of the Hanford Site, 2003

Facility name	100-N Area
Releases (Ci [Bq])	^{3}H (1.5 x 10^{-2} [5.55 x 10^{8}]), ^{90}Sr (9.4 x 10^{-2} [3.48 x 10^{9}]), ^{238}Pu (3.8 x 10^{-7} [1.4 x 10^{4}]), ^{239}Pu (7.1 x 10^{-6} [2.63 x 10^{5}])
Mean river flow	2,856 m^3/s (100,835 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, 2003

Facility name	200 Areas
Releases (Ci [Bq])	200-East Area ^{60}Co (3.9 x 10^{-8} [1.44 x 10^{3}]), ^{90}Sr (1.2 x 10^{-4} [4.44 x 10^{6}]), ^{129}I (1.4 x 10^{-3} [5.18 x 10^{7}]), ^{137}Cs (6.3 x 10^{-5} [2.33 x 10^{6}]), ^{238}Pu (3.8 x 10^{-8} [1.41 x 10^{3}]), $^{239/240}$Pu (1.7 x 10^{-6} [6.29 x 10^{4}]), ^{241}Am (2.0 x 10^{-6} [7.4 x 10^{4}]) 200-West Area ^{90}Sr (3.0 x 10^{-5} [1.11 x 10^{6}]), ^{137}Cs (1.5 x 10^{-5} [5.55 x 10^{5}]), ^{238}Pu (1.3 x 10^{-6} [4.81 x 10^{4}]), $^{239/240}$Pu (8.3 x 10^{-5} [3.07 x 10^{6}]), ^{241}Pu (7.2 x 10^{-5} [2.66 x 10^{6}]), ^{241}Am (1.4 x 10^{-5} [5.18 x 10^{5}])
Meteorological conditions	2003 annual average, calculated from data collected at the Hanford Meteorology Station from January through December 2003, using the computer code HANCHI
$\overline{X}/Q'$	Maximally exposed individual, 7.6 x 10^{-9} s/m^3 at 32 km (20 mi) SE; 80-km (50-mi) population, 1.1 x 10^{-3} person-s/m^3
Release height	89-m (292-ft) effective stack height
Population distribution	~486,000 (PNNL-14687, 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	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

Table E.8. Technical Details of Airborne Release Dose Calculations for the 300 Area of the Hanford Site, 2003

Facility name	300 Area
Releases (Ci)	^{3}H (as HT)[(a)] (7.8×10^{0} [2.89×10^{11}]), ^{3}H (as HTO)[(a)] (3.5×10^{1} [1.29×10^{10}]), ^{90}Sr (1.3×10^{-6} [4.81×10^{4}]), ^{137}Cs (2.1×10^{-5} [7.77×10^{5}]), ^{220}Rn (2.3×10^{2} [8.51×10^{8}]), ^{234}U (6.3×10^{-11} [2.33×10^{0}]), ^{235}U (4.6×10^{-11} [1.7×10^{0}]), ^{238}Pu (4.9×10^{-9} [1.81×10^{2}]), ^{238}U (3.5×10^{-11} [1.3×10^{0}]), ^{239}Pu (1.1×10^{-7} [4.07×10^{3}]), ^{241}Am (1.3×10^{-8} [4.81×10^{2}])
Meteorological conditions	2003 annual average, calculated from data collected at the 300 Area and the Hanford Meteorology Station from January through December 2003, using the computer code HANCHI
$\overline{X}/Q'$	Maximally exposed individual at residence, 9.0×10^{-7} s/m^3 at 1.4 km (0.87 mi) E; 80-km (50-mi) population, 1.1×10^{-2} person-s/m^3
Release height	10 m (33 ft)
Population distribution	~349,000 (PNNL-14687, 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, 2003

Facility name	400 Area
Releases (Ci [Bq])	^{3}H (as HTO)[(a)] (6.6×10^{-1} [2.44×10^{7}]), ^{137}Cs (4.9×10^{-6} [1.81×10^{5}]), $^{239/240}$Pu (1.4×10^{-7} [5.18×10^{3}])
Meteorological conditions	2003 annual average, calculated from data collected at the 400 Area and the Hanford Meteorology Station from January through December 2003, using the computer code HANCHI
$\overline{X}/Q'$	Maximally exposed individual at residence, 9.0×10^{-8} s/m^3 at 11 km (7 mi) SE; 80-km (50-mi) population, 6.7×10^{-3} person-s/m^3
Release height	10 m (33 ft)
Population distribution	~354,000 (PNNL-14687, 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, 2003

Radionuclide	Average 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)]	7.0 ± 0.3 (259 ± 11.1)	1,680 (62.2)	5.00×10^{-8} (500 pSv/pCi)	8.4×10^{-5} (8.4×10^{-7})
Tritium	3,350 ± 135 (123,950 ± 4,995)	804,000 (22, 748)	6.40×10^{-11} (0.6 pSv/pCi)	5.1×10^{-5} (5.1×10^{-7})
^{226}Ra	0.04 ± 0.03 (1.48 ± 1.11)	9.6 (0.35)	1.3×10^{-6} (0.013 µSv/pCi)	1.3×10^{-5} 1.3×10^{-7}
Total				1.5×10^{-4} (1.5×10^{-6})

(a) Drinking water concentrations are annual averages obtained from quarterly samples taken during 2003.
(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 effective 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 ^{137}Cs for the purposes of this analysis.

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Appendix F
Radionuclides Measured by Gamma Spectroscopy (Gamma Scan)

E. J. Antonio

Gamma rays are a form of high energy electromagnetic radiation that originate from the nucleus of an atom. They have very short wavelengths and can easily penetrate all but the most dense materials. Gamma-emitting radionuclides may be natural in origin, result from Hanford Site operations, or be related to fallout from historic nuclear weapons testing.

Gamma rays can be detected and quantified by inorganic scintillators, which convert energy into visible light. Scintillators may include thallium-activated sodium iodide crystals (NaI[Tl]) or germanium semiconductor detectors and their associated electronics (gamma spectroscopy). A partial list of radionuclides whose activity is measurable using gamma spectroscopy is provided in Table F.1.

Table F.1. Radionuclides Measured by Gamma Spectroscopy

Radionuclide	Symbol	Principal Source
Beryllium-7[(a)]	^{7}Be	Natural - cosmogenic
Sodium-22	^{22}Na	Fission product
Sodium-24	^{24}Na	Fission product
Potassium-40[(a)]	^{40}K	Natural - primordial
Manganese-54	^{54}Mn	Fission product
Cobalt-58	^{58}Co	Fission product
Cobalt-60[(a)]	^{60}Co	Fission product
Iron-59	^{59}Fe	Fission product
Zinc-65	^{65}Zn	Fission 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[(a)]	^{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 in Title 50, Code of Federal Regulations, Part 17 (50 CFR 17); Washington Natural Heritage Program (2004); and Washington Department of Fish and Wildlife (2004).

Threatened or Endangered Species

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. The state of Washington also lists species as threatened or endangered, but such listing does not carry the protection of the federal *Endangered Species Act of 1973*. 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 are listed in Table G.1.

Identification of candidate species can assist environmental planning efforts by providing advance notice of the potential for listing as a threatened or endangered species. This advance notice allows resource managers to alleviate threats and thereby possibly eliminate 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 that alleviate threats to the species. Washington State candidate and sensitive animal species occurring or potentially occurring on the Hanford Site are listed in Table G.2. Plant species potentially found on the Hanford Site that are listed at lower levels than threatened or endangered by Washington State are listed in Table G.3.

Hanford Status

There are one bird species and two fish species known to regularly occur on the Hanford Site on the federal list of threatened and endangered species (Table G.1). One additional fish species (Bull trout [*Salvelinus confluentus*]) has been recorded on the Hanford Site, but is not believed to be resident. 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, 11 species of plants and 5 species of birds have been listed as either threatened or endangered by Washington State. The National Marine Fisheries Service (NMFS 2004) has the responsibility for the federal listing of anadromous fish (i.e., fish which require both saltwater and freshwater to complete a life cycle such as the steelhead [*Oncorhynchus mykiss*] and spring-run Chinook salmon [*Oncorhynchus tshawytscha*]). The U.S. Fish and Wildlife Service has responsibility for all other federally listed species on the Hanford Site.

Several species of animals and plants are listed at the candidate species, sensitive species, or other levels by Washington State. There are 28 state-level candidate species of animals (Table G.2) and 40 plant species of concern occurring or potentially occurring on the Hanford Site (Table G.3).

Table G.1. Federal or Washington State Threatened and Endangered Species that Occur or Potentially Occur on the Hanford Site

Common Name	Scientific Name	Federal	State
Plants			
awned halfchaff sedge	*Lipocarpha (= Hemicarpha) aristulata*		Threatened[a]
desert dodder	*Cuscuta denticulata*		Threatened[a]
Geyer's milkvetch	*Astragalus geyeri*		Threatened[a]
grand redstem	*Ammannia robusta*		Threatened[a]
loeflingia	*Loeflingia squarrosa var. squarrosa*		Threatened[a]
lowland toothcup	*Rotala ramosior*		Threatened[a]
persistent sepal yellowcress	*Rorippa columbiae*	Species of concern[b]	Threatened[a]
rosy pussypaws	*Calyptridium roseum*		Threatened[a]
Umtanum desert buckwheat	*Eriogonum codium*	Candidate[c]	Endangered[d]
White Bluffs bladderpod	*Lesquerella tuplashensis*	Candidate[c]	Threatened[a]
white eatonella	*Eatonella nivea*		Threatened[a]
Fish			
bull trout[e]	*Salvelinus confluentus*	Threatened[a]	Candidate[c]
spring-run Chinook salmon	*Oncorhynchus tshawytscha*	Endangered[d]	Candidate[c]
steelhead	*Oncorhynchus mykiss*	Endangered[d]	Candidate[c]
Birds			
American white pelican	*Pelecanus erythrorhychos*		Endangered[d]
bald eagle[f]	*Haliaeetus leucocephalus*	Threatened[a]	Threatened[a]
ferruginous hawk	*Buteo regalis*	Species of concern[b]	Threatened[a]
sandhill crane	*Grus canadensis*		Endangered[d]
western sage grouse	*Centrocercus urophasianus phaios*	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.
(c)
prepared.
(d) Species in danger of extinction within all or a significant portion or its range.
(e) Reported, but seldom observed on the Hanford Site.
(f) Currently under review for change in status (delisting).

Table G.2. Washington State Candidate and Sensitive Animal Species Occurring or Potentially Occurring on the Hanford Site

Common Name	Scientific Name
Mollusks	
giant Columbia River limpet	*Fisherola* (= *Lanx*) *nuttalli*
giant Columbia River spire snail[a]	*Fluminicola* (= *Lithoglyphus*) *columbiana*
Fish	
bull trout[b,c]	*Salvelinus confluentus*
mountain sucker[c]	*Catastomus platyrhynchus*
leopard dace[c]	*Rhinichthys flacatus*
river lamprey[c]	*Lampetra ayresi*
spring-run Chinook salmon[d]	*Oncorhynchus tshawytscha*
steelhead[d]	*Oncorhynchus mykiss*
Insects	
Columbia River tiger beetle[e]	*Cicindela columbica*
Birds	
burrowing owl[a]	*Athene cunicularia*
common loon[f]	*Gavia immer*
flamulated owl[c]	*Otus flammeolus*
golden eagle	*Aquila chrysaetos*
Lewis woodpecker[c]	*Melanerpes lewisii*
loggerhead shrike[a]	*Lanius ludovicianus*
peregrine falcon[a,f]	*Falco peregrinus*
merlin	*Falco columbarius*
northern goshawk[a,c]	*Accipter gentilis*
sage sparrow	*Amphispiza belli*
sage thrasher	*Oreoscoptes montanus*
western grebe	*Aechmorus occidentalis*
Reptiles	
sagebrush lizard[a]	*Sceloporus graciosus*
striped whipsnake	*Masticophis taeniatus*
Mammals	
black-tailed jackrabbit	*Lepus californicus*
Merriam's shrew	*Sorex merriami*
Townsend's ground squirrel	*Spermophilus townsendii*
Washington ground squirrel[c,g]	*Spermophilus washingtoni*
white-tailed jackrabbit	*Lepus townsendii*

(a) Federal species of concern.
(b) Federal threatened.
(c) Reported, but seldom observed, on the Hanford Site.
(d) Federal endangered.
(e) Probable, but not observed, on the Hanford Site.
(f) State sensitive (i.e., taxa vulnerable or declining) and could become endangered or threatened.
(g) Federal candidate.

Table G.3. Washington State Plant Species of Concern on the Hanford Site

Common Name	Scientific Name	State Listing[a]
annual paintbrush	*Castilleja exilis*	W
annual sandwort	*Minuartia pusilla var. pusilla*	R1
basalt milk-vetch	*Astragalus conjunctus var. rickardii*	W
beaked spike-rush	*Eleocharis rostellata*	S
bristly combseed	*Pectocarya setosa*	W
brittle prickly pear	*Opuntia fragilis*	R1
Canadian St. John's wort	*Hypericum majus*	S
chaffweed	*Centunculus minimus*	R1
Columbia milkvetch	*Astragalus columbianus*	S[b]
Columbia River mugwort	*Artemesia lindleyana*	W
coyote tobacco	*Nicotiana attenuata*	S
crouching milkvetch	*Astragalus succumbens*	W
desert evening-primrose	*Oenothera caespitosa*	S
dwarf evening primrose	*Camissonia (= Oenothera) pygmaea*	S
false pimpernel	*Lindernia dubia anagallidea*	W
fuzzytongue penstemon	*Penstemon eriantherus whitedii*	S
giant helleborine	*Epipactis gigantea*	W
gray cryptantha	*Cryptantha leucophaea*	S[b]
Great Basin gilia	*Gilia leptomeria*	S
hedge hog cactus	*Pediocactus simpsonii var. robustior*	R1
Hoover's desert parsley	*Lomatium tuberosum*	S[b]
Kittitas larkspur	*Delphinium multiplex*	W
medic milkvetch	*Astragalus speirocarpus*	W
miner's candle	*Cryptantha scoparia*	S
mousetail	*Myosurus clavicaulis*	S
Piper's daisy	*Erigeron piperianus*	S
porcupine sedge	*Carex hystericina*	W
Robinson's onion	*Allium robinsonii*	W
rosy balsamroot	*Balsamorhiza rosea*	W
scilla onion	*Allium scilloides*	W
shining flatsedge	*Cyperus bipartitus (rivularis)*	S
small-flowered evening-primrose	*Camissonia (= Oenothera) minor*	S
small-flowered nama	*Nama densum var. parviflorum*	W
smooth cliffbrake	*Pellaea glabella simplex*	W
Snake River cryptantha	*Cryptantha spiculifera (= C. interrupta)*	S
southern mudwort	*Limosella acaulis*	W
stalked pod milkvetch	*Astragalus sclerocarpus*	W
Suksdorf's monkey flower	*Mimulus suksdorfii*	S
Thompson's sandwort	*Arenaria franklinii thompsonii*	R2
winged combseed	*Pectocarya penicillata*	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 federal species of concern

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