September 2006
PNNL-15892

# HANFORD SITE

## ENVIRONMENTAL REPORT

*for* Calendar Year 2005

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**U.S. Department of Energy**
**Hanford Site**

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THE HANFORD SITE ENVIRONMENTAL REPORT FOR CALENDAR YEAR (CY) 2005 (PNNL-15892), RICHLAND, WASHINGTON, SEPTEMBER 2006

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. This report includes information for CY 2005 but also includes some early 2006 information. The purpose of the report is to provide the reader with the most recent information available on 1) environmental monitoring efforts on and around the site, 2) Hanford Site cleanup activities, and 3) the status of the site's compliance with federal, state and local environmental laws and regulations.

The report was prepared for DOE by Pacific Northwest National Laboratory (PNNL) with the support of site contractors and describes programs conducted by PNNL, a research and development laboratory; Fluor Hanford, Inc., the prime contractor for nuclear legacy cleanup; Washington Closure Hanford, LLC, 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 numerous subcontractors at the Hanford Site.

If you have 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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# HANFORD SITE
## ENVIRONMENTAL REPORT

## for Calendar Year 2005
(Including Some Early 2006 Information)


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September 2006


Prepared for the U.S. Department of Energy by
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Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

# Preface

The Hanford Site environmental report is prepared annually for the U.S. Department of Energy (DOE) in accordance with the requirements in DOE Manual 231.1-1A, *Environment, Safety, and Health Reporting Manual*, 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 and public protection programs and efforts. Some historical and early 2006 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, Indian tribes, public officials, regulatory agencies, 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 Project produced this report for the DOE Richland Operations Office. Battelle Memorial Institute (Battelle) operates the Pacific Northwest National Laboratory for DOE. Battelle is a non-profit, independent, contract research institute. Personnel from the Pacific Northwest National Laboratory and Fluor Hanford, Inc. and its subcontractors wrote major portions of the report. Washington Closure Hanford, LLC; Bechtel National, Inc.; CH2M HILL Hanford Group, Inc., and Bechtel Hanford, Inc. and its subcontractors also prepared or provided significant input to selected sections.

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## Report Availability

This report was produced in both paper and electronic formats. The paper formats include this technical report, two supplemental data appendixes, and a less detailed summary report (PNNL-15892-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.

# 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 monitoring programs at the Hanford Site.
- Summarize and discuss monitoring information.
- Discuss the estimated radiation exposure to the public from 2005 Hanford Site activities.
- Discuss activities conducted to assure data quality.

The current mission of the DOE at the Hanford Site includes cleaning up the site and reducing its size. It is the policy of the DOE that all its 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 2005

The site's compliance with federal acts in 2005 is summarized in Table S.1 and discussed in detail in Chapters 3 and 5 of this report.

A key element in Hanford's compliance program is the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement). The Tri-Party Agreement is an agreement among the 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 2005, there were 37 specific Tri-Party Agreement cleanup milestones scheduled for completion: 35 were completed on or before their required due dates, 1 was completed beyond its established due date, and 1 was not yet complete at the end of 2005.

Cleanup activities on the Hanford Site generate radioactive, mixed, and hazardous waste (Chapters 5 and 6). 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 stored or generated on the site or received from off the site in 2005 is provided in Table S.2.

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-shell and double-shell underground waste storage tanks and transuranic waste stored in vaults and on storage pads (see Sections 6.3 and 6.4 for details).

**Table S.1. Status of Compliance with Federal Acts at the Hanford Site in 2005**

| Regulation | What it Covers | 2005 Status |
|---|---|---|
| American Indian Religious Freedom Act, Antiquities Act, Archaeological and Historic Preservation Act, Archaeological Resources Protection Act, Historic Sites, Buildings, and Antiquities Act, National Historic Preservation Act, and Native American Graves Protection and Repatriation Act | Cultural resources. | One hundred ninety cultural resource reviews on the Hanford Site were requested. The DOE determined that 156 were not the type of activities with potential to affect cultural resources and were exempt from review; six requests were exempted by programmatic agreement; seven requests required walk throughs. Twenty-three requests required full reviews. |
| Atomic Energy Act | Management of radioactive materials. | The DOE issued directives, standards, and guidance documents. |
| Clean Air Act | Air quality, including emissions from facilities and from unmonitored sources. | Washington State Department of Health issued two non-compliance documents regarding emissions at the 296-B-28 and 296-P-43 emission units and the 296-S-21 stack at the 222-S Laboratory. |
| Clean Water Act | Discharges to U.S. waters. | The Hanford Site had one National Pollutant Discharge Elimination System Permit, one storm water permit, and several State Waste-water Discharge Permits. There were no permit violations in 2005. |
| Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) | Sites already contaminated by hazardous materials. | Remediation work on these sites followed CERCLA requirements. During 2005, four corrective actions were made: (1) installed new signs on 100 Areas haul roads, (2) evaluated the 300 Area surveil-lance and maintenance program, (3) evaluated the procedure for including deed information in the waste information data system, and (4) evaluated the waste information data system to improve access. |
| 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. |
| Endangered Species Act | Rare species of plants and animals. | Spring Chinook salmon and steelhead are listed as threatened or endangered by the federal government as well as the bald eagle. Western sage grouse and two plants, the Umtanum desert buckwheat and the White Bluffs bladderpod are also proposed as candidate species for federal listing. Additionally, the state of Washington has listed 15 plant species and 5 birds as state threatened or endangered. |
| 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. |
| 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. |
| National Environmental Policy Act | Environmental impact statements for federal projects. | Environmental impact statements and environmental assessments were prepared or conducted as needed. In 2005, the DOE prepared one draft environmental assessment and announced its intention to prepare an environmental impact statement for tank closure to include the Fast Flux Test Facility. |
| Resource Conservation and Recovery Act (RCRA) | Tracking hazardous waste from generator to treatment, storage, or disposal. | The Washington State Department of Ecology identified one non-compliance issue during 2005: An inspection of the 340 facility raised concerns about data and information on the vault tanks. All corrective measures were completed. |
| Safe Drinking Water Act | Drinking water systems operated by the DOE at Hanford. | There were 11 public water systems on the Hanford Site. The systems were monitored for radiological contaminants and all contaminant concentrations in 2005 met the requirements of the Washington State Department of Health. |
| Toxic Substances Control Act | Primarily regulation of chemicals called polychlorinated biphenyls (PCBs). | Non-radioactive waste and radioactive PCB waste in certain categories were disposed of in accordance with 40 CFR 761. The EPA approved the Risk-Based Disposal activities during 2005 for retrieval of waste from single-shell tanks and for North Load-Out Pit sludge from the K Basins project. |

**Table S.2. Hanford Site Waste Summary, 2005**

| Activity | Waste Type | Amount |
|---|---|---|
| Waste generated during onsite cleanup activities | Solid mixed waste | 349,416 kilograms (770,500 pounds) |
| | Radioactive waste | 1.2 million kilograms (2.6 million pounds) |
| Waste received at Hanford from off the site | Solid mixed waste | 190,020 kilograms (419,000 pounds) |
| | Radioactive waste | 83,123 kilograms (183,300 pounds) |
| Waste shipped off the Hanford Site | Hazardous waste | 182,177 kilograms (401,700 pounds) |
| Waste volume pumped from underground single-shell waste storage tanks | Liquid waste | 888,000 liters (234,714 gallons) |
| Waste volume in underground single-shell waste storage tanks at the end of 2005 | Liquid waste | 114.3 million liters (30.2 million gallons) |
| Waste volume evaporated at the 242-A evaporator | Liquid waste | 706,700 liters (186,700 gallons) |
| Waste generated at Hanford and added to underground double-shell waste storage tanks | Liquid waste | 3.7 million liters (969,000 gallons) |
| Waste volume in underground double-shell waste storage tanks at the end of 2005 | Liquid waste | 98.9 million liters (26.1 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. Six significance categories have been established including: OE (operational emergency), R (recurring), 1 (significant impact), 2 (moderate impact), 3 (minor impact), and 4 (some impact).

In 2005, there were no occurrences ranked as significance Category OE, R, 1, or 2 on the Hanford Site (see Section 8.0). There were four Category 3 occurrences with potential environmental implications on the Hanford Site in 2005: (1) Excessive beryllium levels were discovered outside Building 3134. Work was suspended until additional sampling was conducted; when work continued workers were required to wear respiratory protection. (2) An instructor at the Patrol Training Academy accidentally started a brush fire during training exercises. The fire was contained within 3 hours and there was no damage to buildings or personnel. (3) During March 2005, wind storms on the Hanford Site resulted in debris consisting of paper, glass, and cloth being blown outside of posted contamination area in the 300 Area. Technicians conducted surveys and no smearable contamination was detected. (4) During the same March 2005 wind storms, contaminated plastic debris was blown outside of a posted contamination area near the Environmental Restoration Disposal Facility.

There were three Category 4 events during 2005: (1) A radiological air sample collected at the boundary of the 100-N Area and a lapel sample showed elevated levels of airborne contamination. The elevated levels were attributed to demolition of contaminated concrete, inadequate dust suppression techniques, and local meteorology. (2) A grass fire occurred on the Saddle Mountain Unit of the Hanford Reach National Monument on July 5, 2005. The fire was extinguished before midnight that same day. (3) A grass fire occurred on the Wahluke Unit of the Hanford Reach National Monument on August 9, 2005. The fire was contained the next day.

## Pollution Prevention and Waste Minimization

The Pollution Prevention and Waste Minimization Program (Section 9.0) is an organized and continuing effort to reduce the quantity and toxicity of hazardous, radioactive, mixed, and sanitary waste generated 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. Affirmative procurement (the purchase of environmentally preferable products containing recycled material) at the Hanford Site achieved 100% of the 2005 goal.

The Hanford Site met the fiscal year 2005 Secretarial Goals (as defined in a DOE memorandum) for low-level waste, mixed low-level waste, hazardous and sanitary routine waste generation, and recycling (including paper, plastic, cardboard, glass, etc.). In 2005, 3,535 metric tons (3,897 tons) of sanitary and hazardous waste were recycled. This recycled waste included 341 metric tons (376 tons) of office and mixed paper, 787 metric tons (867 tons) of iron/steel, 57 metric tons (63 tons) of non-ferrous metal, and 75 metric tons (83 tons) of appliances and furniture.

The Hanford Site generated 30,593 cubic meters (40,014 cubic yards) of cleanup/stabilization waste (i.e., low-level waste, mixed low-level waste, and hazardous waste), and did not meet the 10% cleanup stabilization goal of 28,028 cubic meters (36,659 cubic yards).

Initiative 297, known as the *Cleanup Priority Act*, was passed by Washington State voters in November 2004. In December 2004, the U.S. Department of Justice sought and received a temporary restraining order from the U.S. District Court that enjoined application or enforcement of the act at Hanford or Pacific Northwest National Laboratory, except to the extent it prohibited import of mixed waste to Hanford. The U.S. Department of Justice filed a motion for summary judgment arguing the *Cleanup Priority Act* is preempted by federal law, violates the principle of sovereign immunity, and burdens the flow of interstate commerce in violation of the U.S. Constitution. In February 2005, the state of Washington asked the federal court to certify five issues for interpretation by the Washington State Supreme Court. The federal court agreed and then prohibited application of the entire initiative, including waste importation prohibitions, until all claims are resolved in both federal and state courts.

## Cleanup Operations

Since cleanup activities began at Hanford in 1996, the primary focus has been on liquid effluent waste sites. After nearly 9 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.

***100 Areas Waste Sites***. Full-scale remediation of waste sites began in the 100 Areas in 1996 and continued in 2005 at the 100-B/C, 100-K, 100-N, 100-D, and 100-F Areas (Section 6.1.3). A total of 843,330 metric tons (929,802 tons) of contaminated soil from 100 Areas remediation activities were disposed at the Environmental Restoration Disposal Facility (near the 200-West Area) during 2005. Pump-and-treat systems operated to help remove contamination from groundwater (Table S.3; Section 10.7.4).

***K Basins Closure Activities***. During 2005, work continued to clean out the K Basins (Section 6.1.3.2). For nearly 30 years, the K Basins contained 2,100 metric tons (2,300 tons) of Hanford N Reactor spent fuel and a small quantity of irradiated single-pass reactor fuel (fuel from older Hanford reactors). During 2005, the K Basins Closure Project made the following progress in cleaning out the K Basins:

- Completed welding multi-canister overpacks holding the dried spent fuel with permanent, "N-Stamped" closure welds (those meeting the highest nuclear quality standards of the American Society of Mechanical Engineers). Nearly 110 multi-canister overpacks were welded in 2005, and the welding subproject finished ahead of schedule.
- Transferred the Canister Storage Building to Fluor Hanford, Inc.'s Waste Storage and Disposal project soon after the welding work finished.

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

| Location | Startup Date | Contaminant | Mass Removed 2005 | Mass Removed – Since Startup |
|---|---|---|---|---|
| 100-D Area (100-DR-5 Pump-and-Treat System) | 2004 | Chromium | 38.8 kilograms (85.4 pounds) | 42.2 kilograms (93 pounds) |
| 100-D and 100-H Areas (100-HR-3 Pump-and-Treat System) | 1997 | Chromium | 33.5 kilograms (74 pounds) | 271.1 kilograms (598 pounds) |
| 100-K Area (100-KR-4 Pump-and-Treat System) | 1997 | Chromium | 25.6 kilograms (56.4 pounds) | 283.2 kilograms (624.3 pounds) |
| 100-N Area (100-NR-2 Pump-and-Treat System) | 1995 | Strontium-90 | 0.15 curies (5.55 gigabecquerels) | 1.78 curies (65.86 gigabecquerels) |
| 200-West Area (200-ZP-1 Pump-and-Treat System) | 1994 | Carbon tetrachloride | 750.6 kilograms (1,655 pounds) | 9,492.3 kilograms (20,927 pounds) |
| 200-West Area (200-UP-1 Pump-and-Treat System) | 1994 | Carbon tetrachloride | 2.0 kilograms (4.4 pounds) | 34.6 kilograms (76.3 pounds) |
| | | Nitrate | 1,255 kilograms (2,761 pounds) | 34,716 kilograms (76,534 pounds) |
| | | Technetium-99 | 2.68 grams (0.006 pound) | 118.9 grams (0.262 pound) |
| | | Uranium | 5.0 kilograms (11.0 pounds) | 211.8 kilograms (467 pounds) |
| Waste Management Area S-SX | 2003 | Technetium-99 | ~0.089 grams (0.003 ounce) | ~0.0034 curies (125.8 megabecquerels) |
| 200-West Area (Soil-Vapor Extraction System) | 1991 | Carbon tetrachloride | 362 kilograms (798 pounds) | 78,710 kilograms (173,524 pounds) |

- Grappled, washed, and loaded out nearly 90 metric tons (100 tons) of debris from both K Basins including over 36 metric tons (40 tons) of fuel racks. The debris was packaged and readied for shipment to Hanford's Environmental Restoration Disposal Facility as low-level nuclear waste. Waste shipments from the K Basins to the Environmental Restoration Disposal Facility were ongoing from June 2005 through the end of the year.
- Continued pumping and containerizing sludge from the K-East Basin. Approximately 57% of the sludge was containerized during 2005.
- Installed new flocculent and settling systems to help quell water turbidity during sludge vacuuming.
- Completed installing all sludge collection tanks (total of 10 tanks) in the K-East and K-West Basins.
- Completed the removal of a small, distinct subset of sludge from one area of the K-East Basin – the North Loadout Pit – and shipped it to T Plant in central Hanford. T Plant began final treatment of that sludge in October 2005 and had finished treating about one-third of the sludge by year's end.
- Permanently sealed the discharge chute of the K-West Basin by filling it with a special cement called grout. Filling the discharge chute with grout sealed the construction joint between the K-West Basin and the K-West Reactor and permanently removed approximately 397,000 liters (105,000 gallons) of contaminated water from the K-West Basin (about 10% of the total water volume).
- Completed 60% of the design for the main portion of the Sludge Treatment System that will treat the bulk of K Basins sludge, and completed 90% of the design of key sub-parts of the system.
- Completed design and installation and began testing a Hose-in-Hose Transfer System that will transfer sludge from the K-East Basin to the K-West Basin – part of the route to the main Sludge Treatment System.

***200 Areas Waste Sites***. Remedial investigations or feasibility studies continued on various facilities in the 200 Areas in preparation for cleanup and closure (Section 6.1.2).

***300 Area Waste Sites***. Remediation continued at the 300-FF-2 Operable Unit. In 2005, 78,054 metric tons (86,057 tons) of contaminated soil from 300 Area remediation were removed and disposed of at the Environmental Restoration Disposal Facility (Section 6.1.4). Remediation of the 300-FF-1 Operable Unit waste sites is complete, including backfill and revegetation.

## Facility Decommissioning

***100 Areas Facilities***. Decontamination and decommissioning activities continued during 2005 in the 100-D, 100-H, and 100-N Areas. The interim safe storage of the H Reactor was completed in 2005. These activities were conducted as non-time-critical removal actions under CERCLA (Section 6.2.4).

Facilities demolished in the 100-N and 100-K Areas during 2005 included the 1900-N water tanks, 1802-N pipe trestle, and 183-KW and 183.1-KW water treatment facilities.

***200 Areas Facilities***. Transition and decommissioning activities continued in the 200 Areas during 2005. Surveillance, maintenance, and decontamination or stabilization of over 500 waste sites including former cribs, ponds, ditches, trenches, unplanned release sites, and burial grounds continued in 2005. Periodic surveillances, radiation surveys, and herbicide applications were performed at these sites and timely responses to identified problems were initiated. The overall objective was to maintain these sites in safe and stable configurations and to prevent contaminants at these sites from spreading in the environment.

***221-U Chemical Processing Facility***. Removal of ancillary facilities at the 221-U Chemical Processing Facility began in November 2004 and demolition of 11 structures was completed in September 2005 (Section 6.2.1.1). The U Plant decontamination and decommissioning project lost its funding due to higher priority needs. Therefore, the CERCLA removal action is on hold until funding is available.

***Plutonium Finishing Plant***. Workers at the Plutonium Finishing Plant complex (Section 6.2.1.2) continued deactivation and transition of the facility. The standards laboratory was brought to low-level waste status, and all of the designated legacy plutonium was removed from processing equipment. Other efforts continued as part of preparation for decommissioning.

***Using the 200 Areas Chemical Separations Plants for Waste Disposal***. The Canyon Disposition Initiative (Section 6.2.1.4) was created to investigate the potential for using the five canyon buildings (B Plant, T Plant, U Plant, PUREX Plant, and REDOX Plant) at the Hanford Site as disposal facilities for Hanford Site remediation waste, rather than demolishing the structures. In September 2005, the EPA issued the 221-U Facility (Canyon Disposition Initiative) record of decision, selecting the close-in-place/collapsed structure alternative. In accordance with the record of decision, process equipment already in the plant will be consolidated into the below-ground plant process cells; the cells, galleries, and void spaces will be backfilled with grout; the exterior walls and roof will be collapsed in place; and the site will be covered with a barrier. No waste will be imported into U Plant as a part of the remedial action. While U Plant remediation is a prototype for the remaining canyon buildings, it is anticipated that remedial action decisions will be reached independently for each of the remaining canyons, taking into account the significant differences between each canyon building.

***300 Area Facilities***. Decommissioning of the 324 and 327 Buildings continued during 2005. Preparations are underway for removal of the remaining waste items, and the buildings are being maintained in surveillance and maintenance mode in compliance with safety and regulatory requirements (Section 6.2.2.1).

The 313 and 314 Buildings were demolished to slab, and the materials were disposed of at the Environmental Restoration Disposal Facility. The slabs and any underlying soil contamination will be part of a future remedial action.

The 309 Plutonium Recycle Test Reactor was shut down in 1969. The facility is being maintained in a surveillance and maintenance mode to comply with safety and regulatory requirements.

***400 Area Facilities – Fast Flux Test Facility***. Decommissioning activities continued at the Fast Flux Test Facility (Section 6.2.3) in 2005. The final 13 interim spent nuclear

fuel storage casks were fabricated and delivered. The remaining fuel was removed from the first of the two sodium filled spent fuel storage vessels. Sixty-nine fueled components were washed and packaged into ten interim storage casks; these components included three assemblies that required disassembly either to identify and isolate failed fuel pins or to facilitate the washing process to fully remove the sodium. Two of the interim storage casks were transferred to the 200 Areas Interim Storage Area while the remainder is stored in the 400 Area Interim Storage Area.

An access hole was drilled through the core support structure in the reactor vessel to insert a suction pump. This was a DOE first-of-kind effort in which a drill bit at the end of a 15.2-meter- (50-foot-) long drive line was used to drill into the stainless steel core support structure that was immersed in molten sodium. The drilling allowed access to molten sodium within the support structure that would not readily drain. Subsequently, approximately 160,000 liters (42,300 gallons) of sodium were pumped from the reactor vessel to the Sodium Storage Facility. In addition, 117,000 liters (31,000 gallons) of sodium were transferred from the Fuel Storage Facility vessel to the Sodium Storage Facility. In total, 849,000 liters (224,200 gallons) of Fast Flux Test Facility sodium are now stored in the Sodium Storage Facility tanks. The sodium has been allowed to cool and solidify in the tanks. About 15% of the original sodium remains in the Fast Flux Test Facility with two-thirds of that in the remaining fuel storage vessel and the remainder characterized as "residual sodium."

## Waste Management

***Solid Waste Management***. Waste management at the Hanford Site in 2005 included the treatment, storage, and disposal of solid waste at many Hanford locations (Section 6.3.3). Onsite solid waste facilities include the Central Waste Complex, Waste Receiving and Processing Facility, T Plant complex, Environmental Restoration Disposal Facility, Radioactive Mixed Waste Disposal Facility, and low-level burial grounds.

Waste is received at the Central Waste Complex (Section 6.3.3.1) 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 generate most of the waste received at the Central Waste Complex. The characteristics of the waste received vary greatly, including low-level, transuranic, or mixed waste, and radioactively contaminated polychlorinated biphenyls (PCBs).

The Central Waste Complex can store as much as 20,796 cubic meters (734,418 cubic feet) of low-level mixed waste and transuranic waste. This capacity is adequate to store the projected volumes of low-level, transuranic, and mixed waste, and radioactively contaminated PCBs to be generated from the activities identified above, assuming on-schedule treatment of the stored waste. Treatment will reduce the amount of waste in storage and make room for newly generated mixed waste. The dangerous waste designation of each container of waste is established at the point of origin based on process knowledge or sample analysis.

There were no defueled reactor compartments from the U.S. Navy (Section 6.3.3.5) shipped to trench 94 in the 200-East Area in 2005. The total number of Navy reactor compartments received to date remains at 114.

Waste destined for the Waste Receiving and Processing Facility (Section 6.3.3.2) 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. This facility, which began operating in 1997, dispositioned and shipped offsite 1,570 cubic meters (55,442 cubic feet) of waste during 2005.

The T Plant complex (Section 6.3.3.3) 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.

During 2005, approximately 921,540 metric tons (1,015,824 tons) of remediation waste was disposed at the Environmental Restoration Disposal Facility (Section 6.3.3.6). Approximately 5.7 million metric tons (6.3 million tons) of remediation waste has been placed in the Environmental Restoration Disposal Facility from initial operations start-up through 2005. The total available expansion area of the Environmental Restoration Disposal Facility site was authorized in the 1995 record of decision to cover as much as 4.1 square kilometers (1.6 square miles).

The Radioactive Mixed Waste Disposal Facility consists of two trenches in the 200-West Area (Section 6.3.3.7). Disposal to the first trench began in September 1999 and the first layer of waste packages has been completed and covered with sand and gravel. The second waste layer has been started. Currently, there are approximately 3,900 cubic meters (137,700 cubic feet) of waste disposed in the first trench. There are approximately 130 cubic meters (4,600 cubic feet) of waste disposed in the second trench, which was opened for operations in July 2004.

During 2005, there were 1,427 cubic meters (1,866 cubic yards) of mixed low-level waste treated or disposed of at the Mixed Low-Level Waste Treatment and Disposal Facility (Section 6.3.3.4).

The low-level burial grounds (Section 6.3.3.8) consist of eight burial grounds located in the 200-East and 200-West Areas, which are used for the disposal of low-level waste and mixed waste (i.e., low-level radioactive waste with a dangerous waste component). The low-level burial grounds have been permitted under a RCRA Part A permit since 1985. Transuranic waste has not been placed in the low-level burial grounds without specific DOE approval since August 19, 1987. On June 23, 2004, the DOE issued a record of decision for the Solid Waste Program at Hanford. Part of the record of decision stated that the DOE will dispose of low-level waste in lined disposal facilities. Only two of the low-level burial ground trenches are lined (trenches 31 and 34); therefore, since that date, all low-level waste as well as mixed low-level waste is being disposed of in these two trenches (Section 6.3.3.7). Disposal of navy reactor compartments (Section 6.3.3.5) in the low-level burial grounds is not affected by this record of decision.

***Liquid Waste Management***. Liquid effluent is managed in facilities that comply with RCRA and state regulations (Section 6.3.4).

The 242-A evaporator (Section 6.3.4.5) 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 more double-shell tanks. The 242-A evaporator completed one campaign during 2005. The volume of waste treated was 1.966 million liters (519,300 gallons), reducing the waste volume by 706,700 liters (186,700 gallons), or approximately 36% of the total volume. The volume of process condensate transferred to the Liquid Effluent Retention Facility for subsequent treatment in the Effluent Treatment Facility was 745,700 liters (197,000 gallons).

The Effluent Treatment Facility (Section 6.3.4.2) in the 200-East Area treats liquid effluent 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 volume of wastewater treated and disposed of in 2005 was approximately 23.8 million liters (6.3 million gallons).

Approximately 38.95 million liters (10.29 million gallons) of liquid waste were stored at the Liquid Effluent Retention Facility at the end of 2005 (Section 6.3.4.1). The volume of wastewater received for interim storage during 2005 was approximately 13.2 million liters (3.49 million gallons). The volume of wastewater transferred to this facility for treatment in 2005 was 23.8 million liters (6.3 million gallons).

The 200 Area Treated Effluent Disposal Facility (Section 6.3.4.3) received 442.8 million liters (117.0 million gallons) of unregulated effluent for disposal in 2005. The major source of this effluent was 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 (Section 6.3.4.4). The wastewater consists of once-through cooling water, steam condensate, and other industrial wastewater. The volume of industrial wastewater treated and disposed of during 2005 was 135.8 million liters (35.88 million gallons).

***Underground Waste Storage Tanks***. 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 the closure of tank farms on the Hanford Site (Section 6.4). During the year, 888,000 liters (234,714 gallons) of waste were pumped from single-shell tanks. At the end of 2005, there were 98.9 million liters (26.1 million gallons) of waste in the double-shell tanks.

***Hanford Waste Treatment and Immobilization Plant (Waste Treatment Plant)***. The Hanford Waste Treatment

and Immobilization Plant (Waste Treatment Plant) is being built on 26 hectares (65 acres) located adjacent to the 200-East Area to treat radioactive and hazardous waste currently stored in 177 underground tanks. Currently, four major facilities are being constructed: a pretreatment facility, a high-level waste vitrification facility, a low-activity waste vitrification facility, and an analytical laboratory. Supporting facilities also are being constructed.

Engineering and construction activities for all facilities progressed in 2005, although technical challenges and funding cuts slowed both design and construction. New seismic design criteria for the pretreatment and high-level waste vitrification facilities, resolution of technical concerns, and reduced funding from Congress slowed the project and changed the work priorities in late 2005. Section 6.5 provides complete information on 2005 activities.

## Effluent Monitoring Program

Effluent monitoring at Hanford has two elements: (1) liquid effluent and airborne emissions monitoring at site facilities and operations and (2) environmental monitoring near facilities and operations that have the potential to discharge, or have discharged, stored, or disposed of radioactive and hazardous materials.

***Liquid Effluent and Airborne Emissions***. Liquid effluent and airborne emissions that may contain radioactive or hazardous constituents are continually monitored 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. These evaluations are also used to assess the effectiveness of effluent treatment and pollution-management practices.

In 2005, the State-Approved Land Disposal Site in the 200 Area was the only facility that discharged radioactive liquid effluent to the ground (Section 10.3). 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.

Radioactive air emissions usually come from a building stack or vent. In 2005, radioactive emission discharge points were located in the 100, 200, 300, 400, and 600 Areas. Table 10.1.1 of this document provides a summary of radionuclides discharged to the atmosphere at the Hanford Site in 2005. Non-radioactive air pollutants from such things as diesel-powered electrical generating plants were also monitored. Table 10.1.2 summarizes the non-radioactive discharges to the air on the Hanford Site during 2005.

***Near-Facility Environmental Monitoring***. Near-facility monitoring (Section 10.0.1.2) is conducted adjacent to DOE facilities and operations on the Hanford Site that have the potential to discharge, or have discharged, stored, or been a disposal site for, radioactive or hazardous contaminants. 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.

Air, soil, vegetation, and biota are routinely sampled near Hanford Site facilities and various radiological and non-radiological measurements are taken. In addition, surface contamination and external radiation levels are monitored. Active and inactive waste disposal sites and the terrain surrounding them are surveyed to detect and characterize radioactive surface contamination. During 2005, there were several locations across the Hanford Site where samples were collected: 88 locations for air samples, 97 locations for soil samples, 62 locations for vegetation samples, and 136 locations where external radiation was measured.

## Public Safety and Resource Protection Projects

Public Safety and Resource Protection Projects (Section 10.0.2) are managed for the DOE Richland Operations Office by Pacific Northwest National Laboratory. Their purposes are to monitor the Hanford environment, provide assurance that the site operates in compliance with applicable environmental regulations, and conduct impact assessments to protect public and worker safety as well as Hanford's significant ecological and cultural resources. Whereas effluent and near-facility environmental monitoring are conducted by the facility operating contractor

or designated subcontractor, environmental surveillance is conducted independent of the operating contractors and subcontractors. These projects include:

- Meteorological and Climatological Services Project.
- Surface Environmental Surveillance Project.
- Ecological Monitoring and Compliance Project.
- Cultural Resources Project.

***Climate and Meteorology***. Meteorological measurements support Hanford Site emergency preparedness, site operations, and atmospheric dispersion calculations (Section 10.16). Activities include weather forecasting and maintaining and distributing climatological data.

The calendar year 2005 average temperature was nearly normal and precipitation was slightly below normal. The average temperature for 2005 was 11.9°C (53.5°F), which was 0.1°C (0.1°F) below normal (12.0°C [53.6°F]). Five months during 2005 were warmer than normal; five months were cooler than normal, and two were normal. March had the greatest positive departure, 1.6°C (2.8°F) above normal; December, at 2.4°C (4.3°F) below normal, had the greatest negative departure.

Precipitation during 2005 totaled 16.2 centimeters (6.39 inches), which is 92% of normal (17.7 centimeters [6.98 inches]). Snowfall for 2005 totaled 30.7 centimeters (12.1 inches), compared to normal snowfall of 39.1 centimeters (15.4 inches).

The average wind speed during 2005 was 3.2 meters per second (7.1 miles per hour), which was 0.2 meter per second (0.5 mile per hour) below normal. The peak gust for the year was 27.3 meters per second (61 miles per hour) on March 16.

Two dust storms were recorded at the Hanford Meteorology Station during 2005. There has been an average of five dust storms per year at the Hanford Meteorology Station during the entire period of record (1945-2005).

***Surface Environmental Surveillance Project***. This project (Section 10.0.2.2) is responsible for measuring the concentrations of radiological and non-radiological contaminants in environmental media onsite in the 600 Area (site-wide) and offsite at perimeter, community, and distance locations and assessing the potential effects of contaminants on the environment and the public. Samples of agricultural products, air, fish and wildlife, soil, surface water and sediment, Columbia River shoreline spring water and river sediment, and vegetation are collected routinely. The samples are analyzed for radionuclides and chemicals including metals and anions. Project monitoring activities focus on routine releases from DOE facilities on the Hanford Site; however, the project also conducts sampling and analysis in response to known unplanned releases and releases from non-DOE operations on and near the site. Monitoring results are provided to the DOE and the public annually through this report series. If elevated contaminant concentrations are found, they are reported to the DOE Richland Operations Office. Environmental monitoring and surveillance results for 2005 are summarized in Table S.4. For detailed discussions of results, refer to the appropriate sections of this report.

***Ecological Monitoring and Compliance Project***. This project (Section 10.0.2.3) supports both activity-specific ecological compliance requirements and site-wide requirements to assure the protection of Hanford's natural resources. Project personnel monitor the abundance, vigor, and distribution of plant and animal populations on the Hanford Site and evaluate the cumulative impact of site operations on these resources. In addition, project staff conduct baseline ecological resource surveys to document the occurrence of protected species, evaluate and document impacts to protected species and habitats, facilitate regulatory compliance, and evaluate fulfillment of DOE natural resource protection responsibilities. These activities are intended to protect the natural resources within the DOE-operated portions of the Hanford Site, including the DOE-managed portion of the Hanford Reach National Monument.

***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 the DOE, makes certain that cultural and historic resources entrusted to the DOE are managed responsibly and in accordance with applicable regulatory requirements.

Cultural resources reviews must be conducted before a federally funded, federally assisted, or federally licensed

**Table S.4. Summary of Contaminant Monitoring On and Around the Hanford Site, 2005**

| | What was Monitored? | The Bottom Line |
|---|---|---|
| Air | Air particles and gases were analyzed for radioactive materials. Air was sampled at 23 site-wide locations on Hanford, 11 perimeter locations, 8 community locations, and in 2 distant communities. In addition, air samples were collected at 88 locations near Hanford Site facilities. | All measurements of radioactive materials in air were below recommended guidelines. In general, radionuclide concentrations near facilities were at or near Hanford Site background levels, which are much less than DOE derived concentration guides but greater than concentrations measured off the site. The data also show that concentrations of certain radionuclides were higher and widely variable within different onsite operational areas. |
| Columbia River Water and Sediment | Columbia River water and sediment samples were collected from multiple sampling points throughout the year. The samples were analyzed for radioactive and chemical materials. Columbia River water quality met the Washington State designation for supporting "noncore salmon/trout" and 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 2005, there was no indication of any deterioration of Columbia River water or sediment quality resulting from operations at Hanford. |
| Columbia River Shoreline Spring Water and Sediment | Groundwater discharges to the Columbia River via surface and subsurface springs. Discharges above the water level of the river are identified as shoreline springs. Samples of spring water and sediment were collected at locations along the Hanford shoreline of the Columbia River. | Samples collected at the springs contained some contaminants at levels above those observed in near-shore river water but similar to local groundwater. However, concentrations in river water downstream of the shoreline springs remained far below federal and state limits. Contaminant concentrations in sediment samples from shoreline springs were similar to background levels, except for uranium at the 300 Area, which was roughly four times background. |
| Food and Farm Products | Samples of alfalfa, asparagus, cherries, honey, leafy vegetables, milk, potatoes, tomatoes, and wine were collected from locations upwind and downwind of the Hanford Site. | Radionuclide concentrations in samples of food and farm products were at normal environmental levels. |
| Fish and Wildlife | Game animals and other animals of interest on the site and along the Hanford Reach and fish from the Columbia River were monitored at onsite locations and three offsite reference locations. Carcass, bone, and muscle samples were analyzed to evaluate radionuclide levels. | Samples of bass, whitefish, geese, lizards, rabbits, mice, invertebrates, and elk 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. |
| Soil | Soil samples were collected at 97 locations near facilities in 2005. Routine radiological monitoring at site-wide and offsite locations was last conducted in 2004. | There were 97 routine soil samples collected onsite near facilities and operations in 2005. In general, radionuclide concentrations in samples collected from or adjacent to waste disposal facilities in 2005 were higher than concentrations measured in distant communities in 2004. There were 20 instances of radiological contamination in soil samples investigated in 2005. Of the 20 locations, 15 were cleaned up. At the remaining locations, the contamination levels did not exceed the radiological control limits for the sites and the soil was left in place. |
| Vegetation | Vegetation samples were collected near Hanford Site facilities in 2005. Vegetation samples were collected at site-wide and offsite locations in 2004. | Concentrations of radionuclides were elevated in vegetation samples near facilities when compared to concentrations in samples from distant communities collected in 2004. |

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 2005, 190 cultural resource reviews were requested. Section 10.15 provides details of these requests.

## Groundwater Performance Assessment Project

This project (Section 10.0.3) is responsible for assessing the distribution and movement of known groundwater contamination (both radiological and chemical) beneath the Hanford Site and for identifying and characterizing potential and emerging groundwater contamination problems.

Groundwater samples were collected from 687 wells and 128 shoreline aquifer tubes to monitor contaminant concentrations. Water levels were measured in several hundred wells on the site to map groundwater movement.

Evaluation of groundwater samples showed that groundwater contaminant plumes are continuing to move from beneath former waste sites to the Columbia River. The total area of radiological and chemical contaminant plumes with contaminant concentrations exceeding drinking water standards was estimated to be approximately 77 square miles during 2005. This area occupies 13% of the total area of the Hanford Site. The tritium and iodine-129 plumes have the largest areas with concentrations exceeding drinking water standards.

## Drinking Water Monitoring Project

This project (Section 10.0.4) conducts radiological monitoring of DOE-owned, contractor-operated drinking water systems. During 2005, Pacific Northwest National Laboratory conducted radiological monitoring of drinking water supplied to Hanford Site facilities by DOE-owned pumps and water treatment facilities. Fluor Hanford, Inc., the site water compliance organization, conducted routine chemical, physical, and microbiological monitoring of onsite drinking water. Individual water systems operated by Fluor Hanford, Inc.; Bechtel; and Washington Closure Hanford, LLC performed process monitoring at the water treatment plants and distribution systems to determine compliance with applicable regulations.

There were 11 systems supplying drinking water to the Hanford Site during 2005. All system were in compliance with drinking water standards for radiological, chemical, and microbiological contaminant levels during 2005. All analytical results are reported routinely to the Washington State Department of Health.

## Biological Control Program

Biological 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 Biological Control Program is responsible for integration of (1) expanded radiological surveillance for contaminated biota and soil, (2) control of undesirable plants and animals, (3) clean up of legacy and new contamination related to biota, and (4) remediation, following cleanup, of sites affected by radioactive contamination spread by plants and animals.

Noxious weeds (Section 10.10.4) are controlled on the site (between State Highway 240 and the Columbia River and along the paved road to the top of Rattlesnake Mountain) to prevent their spread and eliminate populations. Noxious weeds are non-native, aggressively invasive, and hard to control. Control measures can be mechanical, chemical, cultural, or biological. These measures are applied to help ensure that entire native plant communities are not destroyed, thus altering ecosystems.

There are ten plant species on a high priority list for control at the Hanford Site: yellow starthistle, rush skeletonweed, mudusahead, babysbreath, dalmatian toadflax, spotted knapweed, diffuse knapweed, Russian knapweed, saltcedar, and purple loosestrife.

Species such as the domestic pigeon, Northern pocket gopher, house mouse, and deer mouse must be controlled when they become a nuisance, health problem, or contaminated with radioactivity (Section 10.11.5). Biological control personnel responded to approximately 30,000 animal control requests from Hanford employees in 2005. There were approximately 2,300 trap/bait stations used to control populations of animals in and near facilities and offices. There were 20 contaminated animals or animal-related materials discovered during 2005. This is approximately 60% less than the peak number of 46 in 1999, and is the same as the total for 2004.

Flying insects and insect material is also collected during operations on the Hanford Site and tested for radiological contamination. Only one of the contaminated samples found in 2005 related to insects, i.e., a contaminated wasp nest found in a storage container in the 100-H Area.

There were no incidents of offsite contamination by animals during 2005, and all cases of new contamination reported onsite were cleaned up or scheduled for cleanup.

## Potential Radiological Doses from 2005 Hanford Operations

During 2005, the potential radiological doses to the public from Hanford operations were evaluated to determine compliance with pertinent regulations and limits (Section 10.14). The methods used to calculate the potential doses are presented in Appendix E. The potential dose to the offsite maximally exposed individual in 2005 was 0.037 mrem (0.37 μSv) per year. The national average dose from background sources, 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).

## Site Closure Activities

The principal requirements for the control and release of property at Hanford containing residual radioactivity are given in DOE Order 5400.5, *Radiation Protection of the Public and the Environment*. These requirements help assure that property is evaluated; radiologically characterized; and decontaminated before release; the level of residual radioactivity in property to be released is as near background levels as is reasonably practicable and meets DOE authorized limits; and all property releases are appropriately certified, verified, documented, and reported; public participation needs are addressed; and processes are in place to appropriately maintain records. No property with detectable residual radioactivity was released from the Hanford Site in 2005 (Chapter 7).

***Hanford Reach National Monument***. The Hanford Reach National Monument lies within the boundaries of the Hanford Site. Although the DOE maintains administrative control over the land within the monument, the U.S. Fish and Wildlife Service manages about 84% of the monument land (Section 7.0.1.1). In 2001, the DOE Office of Inspector General concluded that 57,900 hectares (143,000 acres) of land within the monument could be transferred to the U.S. Department of Interior without adversely affecting DOE operations on the Hanford Site. Subsequently, the DOE Richland Operations Office entered into negotiations with the U.S. Department of Interior regarding release and transfer of selected portions of the monument from DOE control to the jurisdiction of the U.S. Fish and Wildlife Service. The necessary processes and assessments to make that happen are currently underway.

***Emergency Decontamination Facility***. The Emergency Decontamination Facility (Section 7.0.1.2) maintained next to Kadlec Medical Center in Richland is no longer needed because other decontamination facilities have been constructed. On May 4, 2005, the DOE returned control of the facility to Kadlec Medical Center.

***Columbia River Corridor***. Activities continued during 2005 to clean up the Columbia River Corridor (Section 7.0.2). Although risk assessments are usually done prior to cleanup activities, the regulatory agencies have granted interim records of decision to initiate cleanup first and postpone conducting risk assessments until a later date. In 2005, sampling began on the 100 Areas and 300 Area baseline risk assessment. Planning was initiated for the inter-areas component and the Columbia River component of baseline risk assessments. The Project has created a website to provide information about past and ongoing risk assessments and cleanup activities along the river corridor. The website includes the dates of public involvement opportunities, documents available for review and comment, administrative information, and links to related projects. The website can be found at http://www.washingtonclosure.com/projects/endstate.html.

## 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 (Section 10.18). 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.

Samples are collected and analyzed according to documented standard 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.

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

Leslie Groves Park, Richland: Chuck A. Wagner, Manager, and Dale R. Johns, Alternate Manager

Basin City Elementary School, Basin City: Cliff L. Stevenson, Manager, and Kathy McEachen, Alternate Manager

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

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

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# 1.0 Introduction

R. W. Hanf

This report, published annually since 1958 (http://hanfordsite.pnl.gov/envreport), includes information and summary analytical data that (1) provide an overview of U.S. Department of Energy (DOE) activities at the Hanford Site during calendar year 2005; (2) demonstrate the site's compliance with applicable federal, state, and local environmental laws and regulations, executive orders, and DOE policies and directives; (3) characterize Hanford Site environmental management performance; and (4) highlight significant environmental, public, and worker protection programs.

Specifically, this report provides a short introduction to the Hanford Site, discusses the site mission, and briefly describes the site's various environmental-related programs. Included are sections discussing:

- Site compliance with local, state, and federal environmental laws and regulations.
- Site operations including environmental restoration efforts and cleanup and closure activities.
- Environmental occurrences.
- Effluent and emissions from site facilities.
- Results of onsite and offsite environmental and groundwater monitoring efforts.
- Cultural and biological resource assessments.

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 *Environmental Monitoring Plan, United States Department of Energy Richland Operations Office* (DOE/RL-91-50).

## 1.0.1 Current Site Mission

The primary mission at the DOE's Hanford Site is to accelerate 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 (under construction in 2005), and starting the process of closing the underground waste storage tanks.
3. Accelerating cleanup of other Hanford facilities that are considered 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 speed up the completion of site cleanup, excluding underground waste storage tanks, from 2070 to 2035, and possibly as soon as 2025, and to do so in a cost-effective manner that protects public and worker 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 nuclear materials production, 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** – located on the Central Plateau, approximately 8 and 11 kilometers (5 and 7 miles), respectively, south and west of the Columbia River. The surface of the plateau is approximately 100 meters (328 feet) above the level of the Columbia River and about 85 meters (280 feet) above the underlying water table. These areas contain underground waste storage tanks and house facilities that received and dissolved irradiated fuel and then separated out the plutonium. The 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 was being deactivated and decommissioned during 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. This area includes most of the Hanford Reach National Monument. 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 37253) 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 the shrub-steppe ecosystem that once blanketed the Columbia River Basin. Additional information about the Hanford Reach National Monument can be found in specific subsections in Section 1.0.3, Site Management.
- **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, the Pacific Northwest National Laboratory, and other DOE and contractor facilities, mostly office buildings, generally located in the northern part of the city of Richland.
- **700 Area** (off the site) – an area of DOE administrative buildings in central Richland.
- **Volpentest Hazardous Materials Management and Emergency Response Training and Education Center** (also called HAMMER) – a worker safety-training facility located on the Hanford Site near the city of Richland. It consists of a 32-hectare (80-acre) main site and a 4,000-hectare (10,000-acre) law enforcement and security training site. The facility is owned by DOE, managed by Fluor Hanford, Inc., and is used by site contractors, federal and state agencies, tribal governments, and private industry.

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

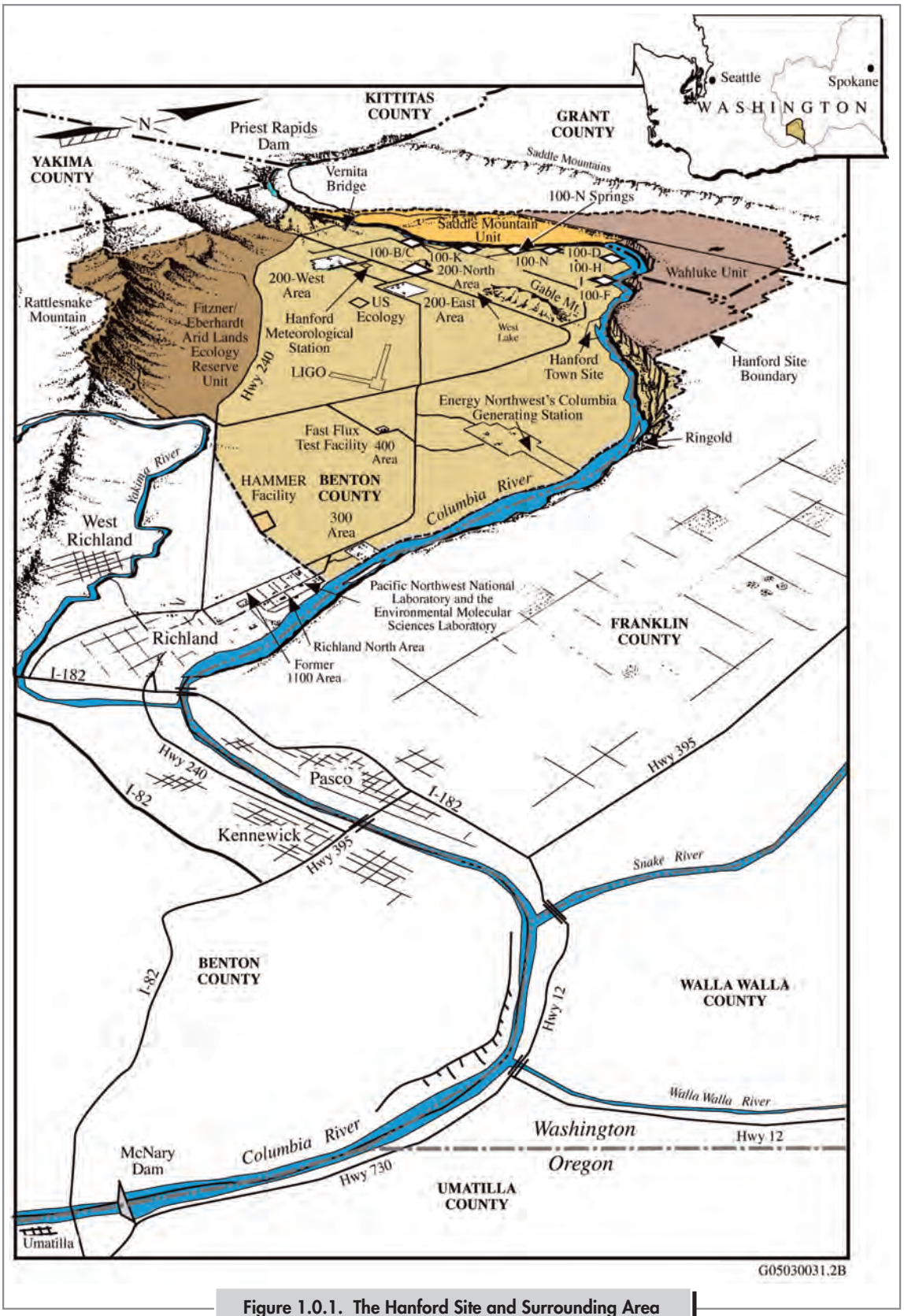


Figure 1.0.1. The Hanford Site and Surrounding Area

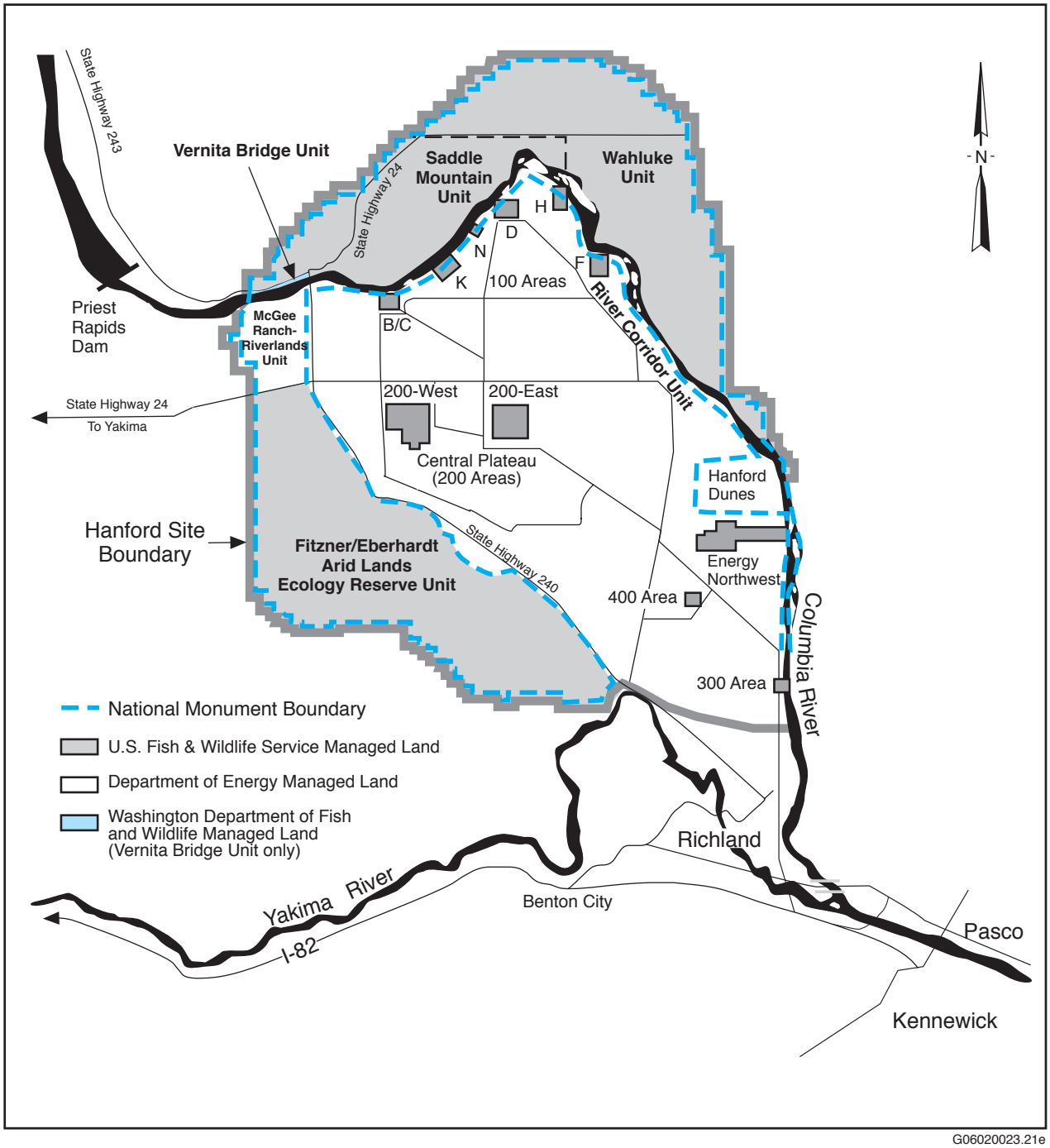


**Figure 1.0.2. Management Units on the Hanford Reach National Monument (Monument boundaries are approximate.)**

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) is located west of the 400 Area and is operated jointly by the California and Massachusetts Institutes of Technology and sponsored by the National Science Foundation.

Near the city of Richland, immediately adjacent to the southern boundary of the Hanford Site, AREVA NP, Inc. operates a commercial nuclear fuel fabrication facility, and Pacific EcoSolutions operates a low-level radioactive waste decontamination, super compaction, and packaging facility.

## 1.0.3 Site Management

DOE's Richland Operations Office and 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; for measuring all discharges to the environment; and for monitoring any potential effluent to assure environmental regulatory compliance. DOE, the U.S. Fish and Wildlife Service, and the Washington Department of Fish and Wildlife each manage portions of the Hanford Reach National Monument.

***The DOE Office of Science***. The Pacific Northwest Site Office of the DOE Office of Science oversees Pacific Northwest National Laboratory, including the Environmental Molecular Sciences Laboratory, to support DOE's Science and Technology programs, goals, and objectives. Pacific Northwest National Laboratory is a DOE facility operated by Battelle Memorial Institute for DOE's national security and energy missions. The core mission is to deliver environmental science and technology in the service of the nation and humanity.

***The DOE Richland Operations Office***. The DOE Richland Operations Office serves as landlord of the Hanford Site and manages legacy cleanup, related research, and other programs. The DOE Richland Operations Office also manages portions of the Hanford Reach National Monument. The portion of the Hanford Reach National Monument administered by the DOE Richland Operations Office included the McGee Ranch-Riverlands Unit (north and west of State Highway 24 and south of the Columbia River), and the Columbia River Corridor Unit, including the Hanford Reach islands in Benton County and a 0.4-kilometer-(0.25-mile-) wide strip of land along the Benton County side of the Hanford Reach shoreline from the Vernita Bridge to just north of the 300 Area. This unit also includes the Hanford dunes area north of Energy Northwest (Figure 1.0.2). During 2005, the principal contractors for the DOE Richland Operations Office, and their respective responsibilities, included the following:

- Bechtel Hanford, Inc. was the environmental restoration contractor for the Hanford Site until late March 2005, when the River Corridor Closure Contract was awarded to Washington Closure Hanford, Inc. During its approximately 11-year tenure at Hanford, Bechtel Hanford, Inc., a subsidiary of Bechtel National, Inc., planned, managed, and executed 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 2005 were CH2M HILL Hanford, Inc. and Eberline Services Hanford, Inc.
- Washington Closure Hanford, LLC, a limited liability company owned by Washington Group International, Bechtel National, and CH2M HILL, Inc. was awarded the River Corridor Closure Contract in March 2005. A protest over the contract award was filed by Fluor Hanford, Inc. in April 2005. This protest halted the transition of work until early June 2005, when the protest was withdrawn and work on the 7-year, $1.9-billion contract began. Washington Closure's work includes placing the remaining deactivated plutonium-production reactors in interim safe storage (also known as cocooning the reactors), continuing with the cleanup of the remaining waste sites located near the Columbia River, demolishing contaminated facilities, and operating the Environmental Restoration Facility. Some of the work that Washington Closure is doing was previously the responsibility of Fluor Hanford, Inc. and the Pacific Northwest National Laboratory. A principal subcontractor to Washington Closure Group was Eberline Services Hanford, Inc.

- Fluor Hanford, Inc. manages the Project Hanford Management Contract. Fluor's responsibilities include integrating work to support cleanup of former DOE nuclear production facilities at the site. In 2005, Fluor Hanford, Inc.'s principal subcontractors were Framatome ANP Inc.; Duratek Federal Services of Hanford, Inc.; and Numatec Hanford Corporation. Other contractors to Fluor Hanford, Inc. included Lockheed Martin Information Technology, and the Fluor Government Group.
- AdvanceMed Hanford was the occupational health contractor on the site in 2005. The company provides occupational medicine and nursing; medical surveillance and evaluations; ergonomics assessment; exercise physiology; case management; psychology counseling and evaluations; fitness-for-duty evaluations; health education; infection control; immediate health care; industrial hygiene; and health, safety, and risk assessment.

***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 2005 and their respective responsibilities included the following:

- Bechtel National, Inc. – Bechtel National, Inc.'s contract mission is to design and build facilities (the Waste Treatment Plant) 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 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.
- Advanced Technologies and Laboratories International, Inc. – This business provides analytical services to site cleanup and restoration contractors. Services include receiving, handling, analyzing, and storing samples, and reporting analytical results to the appropriate contractor.

***U.S. Fish and Wildlife Service***. During 2005, the U.S. Fish and Wildlife Service administered three major management units of the Hanford Reach National 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 (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). 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 more than 60 years.

***Washington Department of Fish and Wildlife***. The Washington Department of Fish and Wildlife manages the Vernita Bridge Unit of the Hanford Reach National Monument, approximately 162 hectares (400 acres) along the north side of the Columbia River, west of the Vernita Bridge, and south of State Highway 243.

Additional information about Hanford Site management and contractors can be found on the Internet at:

- AdvanceMed Hanford – http://www.hanford.gov/?page=65&parent=62
- Advanced Technologies and Laboratories International, Inc. – http://www.atlintl.com/
- Bechtel Hanford, Inc. – http://www.bhi-erc.com/about/
- Bechtel National, Inc. – http://www.bechtel.com
- CH2M HILL, Inc. – http://www.ch2m.com/corporate/
- CH2M HILL Hanford Group, Inc. – http://www.hanfordcleanup.info/
- DOE Office of River Protection – http://www.hanford.gov/orp/
- DOE Office of Science – http://www.er.doe.gov/

- DOE Richland Operations Office – http://www.hanford.gov
- DOE Science and Technology – http://www.energy.gov/sciencetech/
- Duratek Federal Services of Hanford, Inc. – http://www.duratekinc.com/Services/fedservices.asp
- Eberline Services Hanford, Inc. – http://www.eberlineservices.com/page_field.htm
- Environmental Molecular Sciences Laboratory – http://www.emsl.pnl.gov/
- Environmental Restoration Facility – http://web.em.doe.gov/profiles/han.html
- Fluor Hanford, Inc., Project Hanford Management Contract – http://www.fluor.com/ias/gov/projects.asp
- Framatome ANP Inc. – http://www.framatome-anp.com/scripts/us/publigen/content/templates/show.asp?P=482&L=US
- Hanford Reach National Monument – http://www.fws.gov/hanfordreach
  - Fitzner/Eberhardt Arid Lands Ecology Reserve Unit – www.fws.gov/hanfordreach/documents/alefactsheet.pdf
  - Saddle Mountain Unit – www.fws.gov/hanfordreach/documents/saddlemountainfactsheet.pdf
  - Vernita Bridge Unit of the Hanford Reach National Monument – www.fws.gov/hanfordreach/documents/vernitafactsheet.pdf
  - Wahluke Unit – www.fws.gov/hanfordreach/documents/wahlukefactsheet.pdf
- Hanford Tours – http://www.hanford.gov/information/sitetours/?tour=virtual
- Fast Flux Test Facility – http://www.hanford.gov/rl/?page=304&parent=0
- Laser Interferometer Gravitational Wave Observatory (LIGO) – http://www.ligo-wa.caltech.edu/
- Lockheed Martin Information Technology – http://www.hanford.gov/?page=74&parent=62
- Numatec Hanford Corporation – http://www.hanford.gov/?page=75&parent=62
- Pacific Northwest National Laboratory – http://www.pnl.gov/
- Volpentest Hazardous Materials Management and Emergency Response Training and Education Center (HAMMER) – http://www.hammertraining.com/
- Washington Group International – http://www.wgint.com/
- Washington Closure Hanford, LLC – http://www.washingtonclosure.com/

Additional information about the local area and region can be found on the Internet at:

- Bonneville Dam – http://www.nwp.usace.army.mil/op/b/home.asp
- City of Kennewick – http://www.ci.kennewick.wa.us
- City of Pasco – http://www.ci.pasco.wa.us/
- City of Richland – http://www.ci.richland.wa.us/
- Columbia Plateau – http://www.dnr.wa.gov/geology/columbia.htm
- Columbia River Basin – http://www.blm.gov/education/00_resources/articles/Columbia_river_basin/article.html
- Port of Benton – http://www.portofbenton.com/
- Tri-Cities – http://www.visittri-cities.com/
- U.S. Fish and Wildlife Service – http://www.fws.gov/
- Washington Department of Fish and Wildlife – http://wdfw.wa.gov/

Additional information about other companies in the area can be found on the Internet at:

- Battelle Memorial Institute – http://www.battelle.org/
- Energy Northwest, Columbia Generating Station – http://www.energy-northwest.com/generation/cgs/index.php
- US Ecology, Inc. – http://www.americanecology.com/locations/richland/INDEX.ASP
- Pacific EcoSolutions – http://www.pacificecosolutions.com/

## 1.0.4 References

65 FR 37253. 2000. "Establishment of the Hanford Reach National Monument." Proclamation 7319, of June 9, 2000, by the President of the United States of America. *Federal Register*.

DOE/EIS-0222-F. 1999. *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement*. U.S. Department of Energy, Washington, D.C. Accessed on June 12, 2006, at http://www.hanford.gov/doe/eis/hraeis/maintoc.htm.

DOE/RL-91-50, Rev. 3. 2000. *Environmental Monitoring Plan, United States Department of Energy Richland Operations Office*. U.S. Department of Energy, Richland, Washington.

DOE/RL-2002-47, Rev D. 2002. *Performance Management Plan for the Accelerated Cleanup of the Hanford Site*. U.S. Department of Energy, Richland, Washington. Accessed on June 12, 2006, at http:///www.hanford.gov/rl/uploadfiles/Perf_Mang_rl-2002-47.pdf.

# 2.0 Public Involvement at Hanford

A number of federal, state, and local governmental agencies; tribal governments; advisory boards; activist groups; and individuals exercise various roles with respect to the U.S. Department of Energy's (DOE's) mission to safely and efficiently clean up and dispose of waste at the Hanford Site. For example, federal and state agencies exercise a regulatory role over contaminant releases and concentrations of contaminants in various media, and several tribes assure, through a government-to-government relationship with DOE, that treaty rights and other values important to Native Americans are taken into account. The roles of the regulatory agencies, organizations, and the public are described in the following sections.

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

basis for tribal participation in Hanford Site plans and activities. DOE provides financial assistance 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.

## 2.0.2 Consultations and Meetings with Tribes, Interested Parties, and the State Historic Preservation Office

E. P. Kennedy

Federal legislation and policies require programs such as DOE's Cultural and Historic Resources Program to conduct formal consultation with the Washington State Department of Archaeology and Historic Preservation, tribes, and interested parties on cultural resource matters. Specifically, Section 106 of the *National Historic Preservation Act* requires DOE to seek and gather input from tribes and interested parties and obtain concurrence from the Washington State Department of Archaeology and Historic Preservation on the identification of cultural resources, evaluation of the significance of these resources, and assessment of impacts of DOE undertakings on cultural resources. DOE's Cultural and Historic Resources Program routinely conducts formal Section 106 and *National Environmental Policy Act* consultations with the Washington State Department of Archaeology and Historic Preservation, the Confederated Tribes of the Umatilla Indian Reservation, the Confederated Tribes and Bands of the Yakama Nation, the Confederated Tribes of the Colville Reservation, Nez Perce Tribe, and the Wanapum. The program occasionally consults with interested parties that have expressed an interest in cultural resources located on the Hanford Site. These include groups such as the B Reactor Museum Association, White Bluffs Pioneers, Benton County Historical Society, East Benton County Historical Museum, and Franklin County Museum.

The program also holds regular meetings with tribal cultural resources staff of the Confederated Tribes of the Umatilla Indian Reservation, Confederated Tribes and Bands of the Yakama Nation, Confederated Tribes of the Colville Reservation, Nez Perce Tribe, and Wanapum. Discussions focus on cultural resource reviews and issues that concern the protection of cultural resources on the Hanford Site. The program holds meetings with interested parties on an as-needed basis. Section 10.15 further addresses cultural and historic activities.

## 2.0.3 Hanford Natural Resource Trustee Council

D. C. Ward

The President of the United States, by Executive Order 12580, *Superfund Implementation* (52 FR 2923), has appointed the heads of some federal departments to act on behalf of the public as trustees for natural resources when natural resources may be injured, destroyed, lost, or threatened as a result of a release of hazardous substances. For example, the President appointed the Secretary of Energy as the primary trustee for all natural resources located on, over, or under land administered by DOE, including the Hanford Site. Other designated federal trustees for Hanford natural resources include the U.S. Department of the Interior represented by the U.S. Fish and Wildlife Service and the U.S. Department of Commerce represented by the National Oceanic and Atmospheric Administration. The *Comprehensive Environmental Response, Compensation, and Liability Act* (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 by the National Oil and Hazardous Substances Pollution Contingency Plan (55 FR 8666) and Executive Order 12580 (52 FR 2923). 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.

DOE cooperates and coordinates with trustees' assessments, investigations, and planning and with devising and implementing restoration plans. The Hanford trustees signed a Memorandum of Agreement in 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 on the Hanford Site or remediation of those releases. The council has adopted bylaws to direct the process of arriving at consensus agreements.

During 2005, the trustees met as a formal council five times to discuss CERCLA natural resource issues concerning the Central Plateau and Columbia River corridor. Information about the council, including its history and projects, can be found at http://www.hanford.gov/public/boards/nrtc.

During 2005, the trustees:

- Worked with DOE and the River Corridor Closure Contractor (Washington Closure Hanford, LLC) to provide input to complete a sampling and analysis plan for the 100/300 Areas (DOE/RL-2005-42). The information provided by the trustees produced a better plan for the 100 and 300 Areas.
- Were very active in all phases of the Central Plateau Data Quality Objectives process. Workshops were attended and information from DOE and its contractors was shared with the trustees. This interaction helped to focus DOE attention on additional topics of concern for the Central Plateau such as potential polychlorinated biphenyl contamination, selection of Central Plateau reference sites, and collection of additional environmental samples.
- Requested, then supported, efforts by the National Oceanic and Atmospheric Administration to compile a bibliography of information pertaining to past ecological studies and monitoring conducted on the Hanford Site. The National Oceanic and Atmospheric Administration received funding from DOE to conduct this action. With trustees input, the National Oceanic and Atmospheric Administration developed a data compilation matrix, which will be used to determine if there are any data or information gaps concerning Hanford biota for which the various ongoing ecological risk assessments should plan. Preliminary results from this multi-year effort should be available in 2006.
- Developed and justified a budget request to DOE for fiscal year 2006. The budget request was for funds to (1) allow the trustees to provide additional technical support for ecological risk assessments, (2) continue with data and information compilation, and (3) identify and develop plans to integrate ecological risk assessment and potential natural resource injury assessment data requirements.
- Endeavored to be informed on ongoing cleanup efforts at Hanford and the potential impact to natural resources, particularly the biota and the groundwater. In 2005, the trustees attended many workshops and participated in conference calls pertaining to groundwater remediation and natural resource actions at Hanford.

## 2.0.4 Public Participation in Hanford Site Decisions

K. Lutz

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, *Hanford Federal Facility Agreement and Consent Order* (also known as the Tri-Party Agreement, Ecology et al. 1989) activities, *National Environmental Policy Act* public meetings on various environmental impact statements, and other involvement activities. DOE's Office of River Protection and DOE's Richland Operations Office coordinate the planning and scheduling of public participation activities for DOE at the Hanford Site.

During 2005, the Tri-Party Agreement agencies (Section 3.0.1) met with a broad representation of public interests to discuss and develop the end state cleanup vision for the Hanford Site. The end state document (DOE/RL-2005-57) is the primary tool for communicating Hanford's end state vision to DOE, the site contractors, the regulatory agencies, Tribal Nations, and public stakeholders. The document responds to DOE's policy to conduct cleanup to protect human health and the environment and also considers future land uses and risks associated with cleanup decisions.

Information on a Hanford end state workshop held in May 2005 can be found at http://www.hanford.gov/docs/rbes/5-19.cfm.

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 cleanup decisions (Section 3.0.1). The DOE, Washington State Department of Ecology and U.S. Environmental Protection Agency (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, January 2002, is available on the Hanford website located at http://www.hanford.gov under the Public Involvement section.

A mailing list of about 3,300 individuals who have indicated an interest in participating in Hanford Site cleanup decisions is maintained by the Tri-Party Agreement agencies. The mailing list is used to provide information to the public on upcoming cleanup decisions and activities. The mailing is comprised of elected officials, community leaders, special interest groups, news media organizations, and the general public. (To be placed on the mailing list, see Section 3.0.1.)

To inform the public of upcoming public participation opportunities, a newsletter titled *The Hanford Update*, a synopsis of Tri-Party Agreement public involvement activities, is published quarterly and distributed to interested stakeholders and the general public through an established mailing list. In addition, a list of current public involvement opportunities is available on the Hanford website at http://www.hanford.gov/public/calendar/.

Cleanup documents are also made available to the general public through the Tri-Party Agreement's Administrative Record and Public Information Repository located at http://www2.hanford.gov/arpir.

For more information about cleanup activities contact the Tri-Party Agreement agencies at:

| | |
|---|---|
| DOE Richland Operations Office | (509) 376-7501 |
| DOE Office of River Protection | (509) 372-8656 |
| Washington State Department of Ecology's Hanford Cleanup Line | (800) 321-2008 |
| U.S. Environmental Protection Agency | (509) 376-8631 |

## 2.0.5 Hanford Advisory Board

K. Lutz

The Hanford Advisory Board is an independent, nonpartisan, and broadly representative body consisting of a mix of the diverse interests that are affected by Hanford cleanup issues. As set forth in its charter, the primary mission of the board is to provide informed recommendations and advice to DOE, EPA, and the Washington State Department of Ecology on selected major policy issues related to the cleanup of the Hanford Site.

The goal of the board is to develop consensus policy recommendations and advice. When this is not possible, the board will convey its recommendations and advice in a manner that communicates the points of view expressed by all board members.

The board is intended to be an integral component for some Hanford tribal and general public involvement activities, but not to be the sole conduit for those activities. The board assists the agencies in focusing public involvement and makes efficient use of board member's time and energy. Through its open public meetings, advice on agency public involvement activities and the responsibilities of board members to communicate with their constituencies, the board assists the broader public in becoming more informed and meaningfully involved in Hanford cleanup decisions.

In 2005, the board held five 2-day meetings. Members were 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 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/public/boards/hab/.

## 2.0.6 References

52 FR 2923, January 29, 1987. Executive Order 12580, "Superfund Implementation." *Federal Register*.

55 FR 8666. "National Oil and Hazardous Substances Pollution Contingency Plan." *Federal Register*.

*American Indian Religious Freedom Act*. 1978. Public Law 95-341, as amended, 42 USC 1996, 1996 note.

*Archaeological Resources Protection Act*. 1979. Public Law 96-95, as amended, 16 USC 470-470ii.

*Comprehensive Environmental Response, Compensation, and Liability Act*. 1980. Public Law 96-150, as amended, 94 Stat. 2767, 42 USC 9601 et seq. Accessed June 12, 2006, at http://www.epa.gov/region5/defs/html/cercla.htm.

DOE. 2000. *American Indian & Alaska Native Tribal Government Policy*. Office of Congressional & Intergovernmental Affairs, U.S. Department of Energy, Washington, D.C.

DOE/RL-2005-42, Rev. 0. 2006. *100 Area and 300 Area Component of the RCBRA Sampling and Analysis Plan*. U.S. Department of Energy, Richland, Washington.

DOE/RL-2005-57. 2005. *Hanford Site End State Vision*. U.S. Department of Energy, Richland, Washington. Accessed June 12, 2006, at http://www.hanford.gov/docs/rbes/final.cfm.

Ecology - Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy. 1989. *Hanford Federal Facility Agreement and Consent Order*. Document No 89-10, as amended (The Tri-Party Agreement), Olympia, Washington. Accessed June 12, 2006, at http://www.hanford.gov/?page=91&parent=0.

Memorandum of Agreement. 1996. *Memorandum of Agreement Among the United States Department of Energy, United States Department of the Interior, Nez Perce Tribe, State of Oregon, Confederated Tribes of the Umatilla Indian Reservation, State of Washington (including the Departments of Ecology and Fish and Wildlife), and the Confederated Tribes and Bands of the Yakama Indian Nation*. U.S. Department of Energy, Richland Operations Office, Richland, Washington.

*National Environmental Policy Act*. 1969. Public Law 91-190, as amended, 42 USC 4321 et seq.

*National Historic Preservation Act*. 1966. Public Law 89-665, as amended, 16 USC 470 et seq.

*Native American Graves Protection and Repatriation Act*. 1990. Public Law 101-601, as amended, 25 USC 3001 et seq.

Tri-Party Agreement Agencies. 2002. *Hanford Site Tri-Party Agreement Public Involvement Community Relations Plan*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Accessed June 12, 2006, at http://www.hanford.gov/?page=113&parent=91.

# 3.0 Regulatory Oversight at Hanford

K. A. Peterson

Several federal, state, and local regulatory agencies are responsible for monitoring and enforcing compliance with applicable environmental regulations at the Hanford Site. The agencies include the U.S. Environmental Protection Agency (EPA), Washington State Department of Ecology, Washington State Department of Health, and Benton Clean Air Authority. EPA is the primary federal regulatory agency that develops, promulgates, and enforces environmental regulations and standards as directed in statutes enacted by Congress. In some instances, EPA has delegated authority to the state or authorized the state program to operate in lieu of the federal program when the state's program meets or exceeds the EPA's requirements. In other activities, the state program is assigned direct environmental oversight of the U.S. Department of Energy (DOE), as provided by federal law. Where federal regulatory authority is not delegated or only partially authorized to the state, the EPA Region 10 office is responsible for reviewing and enforcing compliance with EPA regulations as they pertain to the Hanford Site. EPA periodically reviews state environmental programs and may directly enforce federal environmental regulations.

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

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. Changes to the agreement have been negotiated to meet the changing conditions and needs of cleanup. All significant changes 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/?page=91&parent=0. To be placed on the mailing list to obtain Tri-Party Agreement information, contact EPA or DOE directly, or call the Washington State Department of Ecology at (800) 321-2008. Requests can be sent to:

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

## 3.0.2 Status of Tri-Party Agreement Milestones

R. D. Morrison

The Tri-Party Agreement (Ecology et al. 1989) commits DOE to achieve compliance with the remedial action provisions of CERCLA and with the treatment, storage, and disposal unit regulations and corrective action provisions of RCRA, including Washington State's implementing regulations (WAC 173-303). From 1989 through 2005, a total of 912 Tri-Party Agreement milestones were completed and 291 target dates were met. During 2005, there were 37 specific cleanup milestones scheduled for completion; 35 were completed on or before their required due dates, 1 was completed beyond its established due date, and 1 was not yet complete at the end of 2005.

## 3.0.3 Approved Modifications to the Tri-Party Agreement

R. D. Morrison

During 2005, 15 negotiated change requests to the Tri-Party Agreement were approved. These approved change requests may be viewed in their entirety in the Tri-Party Agreement Administrative Record at http://www2.hanford.gov/arpir/.

## 3.0.4 Washington State Department of Health

J. A. Bates

The Washington State Department of Health Office of Radiation Protection has regulatory authority to enforce state standards applicable to all sources of ionizing radiation in the state. The Air Emissions and Defense Waste Section of the Office of Radiation Protection enforces the standards and requirements of WAC 246-247, *Radiation Protection – Air Emissions*, issued under the authority of the *Washington Clean Air Act* (RCW 70.94). The regulation includes a requirement for DOE to obtain Washington State Department of Health approval prior to construction of any new or modified source of airborne radionuclide emissions, and a requirement for the Washington State Department of Health to issue and enforce the resulting licenses covering construction and operation. The Washington State Department of Health also conducts a program for inspection of all sources in the state, which may emit airborne radioactive material, to assure the operations and emissions are in compliance with applicable radioactive air licenses and WAC 246-247. The state enforces an as-low-as-reasonably-achievable environmental approach for minimizing airborne emissions to protect public health. Section 5.3.2 provides further information regarding the Washington State Department of Health inspections and enforcement activities on the Hanford Site in 2005.

## 3.0.5 References

*Comprehensive Environmental Response, Compensation, and Liability Act*. 1980. Public Law 96-150, as amended, 94 Stat. 2767, 42 USC 9601 et seq. Accessed June 12, 2006, at http://www.epa.gov/region5/defs/html/cercla.htm.

Ecology - Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy. 1989. *Hanford Federal Facility Agreement and Consent Order*. Document No 89-10, as amended (The Tri-Party Agreement), Olympia, Washington. Accessed June 12, 2006, at http://www.hanford.gov/?page=91&parent=0.

RCW 70.94. *Washington Clean Air Act*. Revised Code of Washington.

*Resource Conservation and Recovery Act*. 1976. Public Law 94-580, as amended, 90 Stat. 2795, 42 USC 6901 et seq. Accessed June 12, 2006, at http://www.epa.gov/region5/defs/html/rcra.htm.

*Superfund Amendments and Reauthorization Act*. 1986. Public Law 99-499, as amended, 100 Stat. 1613, 42 USC 11001 et seq.

Tri-Party Agreement Agencies. 2002. *Hanford Site Tri-Party Agreement Public Involvement Community Relations Plan*. U.S. Department of Energy, Richland Operations Office, Richland, Washington. Accessed June 12, 2006, at http://www.hanford.gov/?page=113&parent=91.

WAC 173-303. "Dangerous Waste Regulations." *Washington Administrative Code*, Olympia, Washington.

WAC 246-247. "Radiation Protection–Air Emissions." *Washington Administrative Code*, Olympia, Washington.

# 4.0 Environmental Program Information

This section provides information on the environmental and chemical management systems on the Hanford Site.

## 4.0.1 Environmental Management Systems

H. T. Tilden II, G. D. Cummins, P. C. Miller, and M. L. Proctor

Contractors at the Hanford Site have established integrated environment, safety, and health management systems as mandated by their contracts with the U.S. Department of Energy (DOE). These systems are intended to protect workers, the public, and the environment by integrating environment, safety, and health considerations into the way work is planned, performed, and improved. The international voluntary consensus standard ISO 14001, *Environmental Management Systems – Specifications with Guidance for Use*, and DOE Order 450.1, *Environmental Protection Program*, were considered during the development of these systems. Basic elements of these management systems include environmental policy, planning, implementation, checking and corrective action, and management review.

DOE verified that several Hanford contractors, and the Pacific Northwest National Laboratory, adequately implemented an integrated environmental, safety, and health management system prior to the implementation date of December 31, 2005, as specified in DOE P 450.4, *Safety Management System Policy*. Implementation dates include CH2M HILL Hanford Group, Inc. (May 2000); Fluor Hanford, Inc. (August 2000); and the Pacific Northwest National Laboratory (1998). The Pacific Northwest National Laboratory obtained ISO 14001:1996 third-party registration of its Environmental Management System in 2002 and was re-registered to the updated ISO 14001:2004 standard in 2005. Based in part on its Environmental Management Systems, Pacific Northwest National Laboratory was accepted into the U.S. Environmental Protection Agency's National Environmental Performance Track program for a 3-year membership beginning in 2004. Washington Closure Hanford, LLC maintains an Environmental Management System that is integrated with the company's Integrated Environment, Safety, and Health Management System. Efforts continued in 2005 to improve these environmental, safety, and health programs.

## 4.0.2 Chemical Management Systems

M. T. Jansky

Hanford Site contractors developed and documented formal systems for the management of chemicals during 1997 that are still in use today. These chemical 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 in 2005 are provided in Section 5.1.1.

## 4.0.3 References

29 CFR 1910, Subpart Z. "Toxic and Hazardous Substances." U.S. Department of Labor, *Code of Federal Regulations*.

DOE Order 450.1. 2003. "Environmental Protection Program." U.S. Department of Energy, Washington, D.C.

DOE P 450.4. 1996. *Safety Management System Policy*. U.S. Department of Energy, The Office of Environment, Safety and Health, Washington, D.C.

ISO 14001. 1996. *Environmental Management Systems–Specifications with Guidance for Use*. American Society for Testing and Materials, West Conshohocken, Pennsylvania.

# 5.0 Compliance Summary

J. P. Duncan

It is the policy of the U.S. Department of Energy (DOE) that all DOE activities at Hanford 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.

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. 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.

# 5.1 Hazardous Materials

This section provides information about federal statutes related to the regulation of hazardous materials at Hanford.

## 5.1.1 Emergency Planning and Community Right-To-Know Act

R. E. Johnson

The *Emergency Planning and Community Right-to-Know Act* requires each state to establish an 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 (quantities that trigger notifications to the state and local emergency response organizations) must identify themselves to the state emergency response commission and local emergency planning committee and periodically provide information to support the emergency planning process. The threshold planning quantities are predetermined amounts established by the state and local authorities. 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*: (1) the *Tier Two Emergency and Hazardous Chemical Inventory* contains information about hazardous chemicals stored at the facility in amounts exceeding minimum threshold levels, and (2) the *Toxic Chemical Release Inventory* contains information about total annual releases of certain toxic chemicals and associated waste management activities.

In early 2005, the Hanford Site issued the *2005 Hanford Site Tier Two Emergency and Hazardous Chemical Inventory* (DOE/RL-2006-15) to the Washington State Department of Ecology's Community Right-To-Know Unit; local emergency planning committees for Benton, Franklin, and Grant Counties; and to both the Richland and Hanford Site fire departments. The *2005 Hanford Site Toxic Chemical Release Inventory* report (DOE/RL-2006-38), which included releases and waste management activities involving the metal lead and the chemical propylene, was provided to the U.S. Environmental Protection Agency (EPA) and the Washington State Department of Ecology. Table 5.1.1 provides an overview of 2005 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 4.0.2). Table 5.1.2 summarizes the information reported, listing the average quantities of the ten hazardous chemicals stored in greatest quantity on the Hanford Site in 2005.

## 5.1.2 Resource Conservation and Recovery Act

M. J. Hartman

The *Resource Conservation and Recovery Act* (RCRA) was enacted during 1976 with the objective of protecting human health and the environment. During 1984, the *Hazardous and Solid Waste Amendments* re-authorized RCRA and imposed new requirements on the management of hazardous

**Table 5.1.1. Emergency Planning and Community Right-to-Know Act Compliance Reporting at the Hanford Site, 2005**

| 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 releases were too small to require action or no releases occurred.
(b) These notifications apply to the Hanford Site but were completed prior to 2005.

**Table 5.1.2. Average Quantity of Ten Hazardous Chemicals[a] Stored on the Hanford Site, 2005**

| Hazardous Chemical | Average Quantity, kg (lb) |
|---|---|
| Argon | 1,600,000 (3,500,000) |
| Mineral oil | 1,200,000 (2,700,000) |
| Sodium | 1,100,000 (2,400,000) |
| Nitrogen | 950,000 (2,100,000) |
| Portland cement | 390,000 (860,000) |
| Diesel fuel (Grades 1 and 2) | 290,000 (630,000) |
| Fly ash (class F) | 180,000 (400,000) |
| Propane | 110,000 (250,000) |
| Sulfuric acid | 44,000 (98,000) |
| Chlorodifluoromethane | 31,000 (68,000) |

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

waste. The most important aspect of RCRA is its establishment of cradle-to-grave management to track hazardous waste from generator to treatment, storage, and disposal. The Washington State Department of Ecology has the authority to enforce RCRA requirements in the state under *Washington Administrative Code* (WAC) 173-303, "Dangerous Waste Regulations." At Hanford, RCRA applies to approximately 70 hazardous waste treatment, storage, or disposal units that have received waste since implementation of the act.

### 5.1.2.1 Hanford Facility RCRA Permit

S. A. Thompson

The Washington State Department of Ecology issued the Hanford Facility RCRA Permit on September 27, 1994 (Ecology 1994). The permit is the foundation for RCRA permitting on the Hanford Site in accordance with provisions set forth in the Tri-Party Agreement (Ecology et al. 1989). The 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 expired on September 27, 2004, and the DOE continues to operate under the old permit, until a new permit is in effect. The Washington State Department of Ecology is working on a draft of the new permit.

### 5.1.2.2 RCRA/Dangerous Waste Permit Applications and Closure Plans

S. A. Thompson

The Hanford Site is considered a single facility for purposes of RCRA and WAC 173-303. The facility encompasses approximately 70 treatment, storage, and disposal units. The Tri-Party Agreement recognized that not all of the units could be issued dangerous waste permits simultaneously, and a schedule was established to submit unit-specific permit applications and closure plans to the Washington State Department of Ecology.

During 2005, 17 revisions to the RCRA Permit Part A Form were submitted to the Washington State Department of Ecology for review and approval. These revisions to the Part A Form, included modifications to information for the former 183-H solar evaporation basins (100-H Area), 216-U-12 crib (300 Area), former 300 Area process trenches, 300 Area Waste Acid Treatment System, inactive 303-M Uranium Oxide Facility (300 Area), 305-B Storage Facility (300 Area), 325 hazardous waste treatment units, 331-C storage unit, former 1301-N Liquid Waste Disposal Facility (100-N Area), former 1324-N surface impoundment (100-N Area), former 1324-NA percolation pond (100-N Area), former 1325-N Liquid Waste Disposal Facility (100-N Area), 242-A evaporator (200-East Area), Liquid Effluent Retention Facility (near the 200-East Area) and 200 Area Effluent Treatment Facility, double-shell tank system (200 Areas) and 204-AR waste unloading station (200-East Area), Plutonium-Uranium Extraction (PUREX) storage tunnels (200-East Area), and Integrated Disposal Facility (200-East Area).

In 2005, three Part B permit applications were submitted to the Washington State Department of Ecology. The submittals included the *Hanford Facility Dangerous Waste Permit Application, Double-Shell Tank System* (DOE/RL-90-39), *Hanford Facility Dangerous Waste Permit Application, Integrated Disposal Facility* (DOE/RL-2003-12) and *Hanford Facility Dangerous Waste Permit Application, 331-C Storage Unit* (Ecology 2005).

### 5.1.2.3 RCRA Groundwater Monitoring

#### M. J. Hartman

RCRA groundwater monitoring is part of the Hanford Site Groundwater Performance Assessment Project (Section 10.7).

New RCRA, *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA), and *Atomic Energy Act* well proposals are reviewed and approved annually as defined under a Tri-Party Agreement milestone. Well needs are integrated and documented via the data quality objectives process. This process integrates the borehole and well data needs of the various Hanford Site regulatory driven projects. Based on results of the data quality objectives process, the Washington State Department of Ecology, EPA, and DOE (the Tri-Parties) annually negotiate an integrated well drilling list that coordinates and prioritizes the requirements of RCRA, CERCLA, and the *Atomic Energy Act* under Tri-Party Agreement (Ecology et al. 1989) Milestone M-24-57. During 2005, drillers completed nine RCRA monitoring wells and eight CERCLA monitoring wells. Ten non-Tri-Party Agreement wells also were installed to support remediation in the 100-D, 100-N, and 100-K Areas.

At the end of 2005, 15 RCRA sites were monitored to detect whether they were contaminating groundwater with hazardous constituents. Eight sites were monitored to assess the extent of known contaminants, and two were monitored to determine the progress of groundwater contamination cleanup activities. Twelve of the sites monitored under RCRA are scheduled for closure under the Hanford Facility RCRA Permit (Ecology 1994). The Liquid Effluent Retention Facility, low-level burial grounds (Waste Management Areas 1 to 4), and planned Integrated Disposal Facility, will receive permits as operating RCRA facilities.

A summary of groundwater monitoring activities for these sites during 2005 is provided in Section 10.7 and more detailed information is available in the *Hanford Site Groundwater Monitoring Report for Fiscal Year 2005* (PNNL-15670).

### 5.1.2.4 RCRA Inspections

#### D. L. Hagel

Hanford Site contractors and DOE worked to resolve notices of violation and warning letters of non-compliance that were received from the Washington State Department of Ecology during 2005. These documents identified conditions that were alleged to be non-compliant with RCRA requirements. The following item summarizes the single RCRA non-compliance document received in 2005.

***Inspection at the 340 Facility***. On March 3, 2005, the Washington State Department of Ecology conducted an inspection regarding Tri-Party Agreement Milestone M-026-01O, *Submit the Land Disposal Restriction (LDR) Report for CY05*. The purpose of the annual Tri-Party Agreement land disposal restrictions report is to provide information on the storage, characterization, and treatment of mixed waste at the Hanford Site. The EPA and Washington State

Department of Ecology consider the annual report equivalent to the site treatment plan required by the *Federal Facility Compliance Act of 1992*.

The focus of the inspection was on a storage assessment that was conducted at the 340 facility as required by the land disposal restriction report. The 340 facility is located in the 300 Area and was used to collect radioactive contaminated laboratory wastewater for transfer by railcar to the double-shell tank system.

The Washington State Department of Ecology letter, dated August 17, 2005, alleged deficiencies in two areas:

1. The assembly and issuance of the land disposal restriction report appears to be viewed as simply an administrative task, particularly in regard to storage assessments and data gap plans for facilities listed in the potential mixed waste section of the report.
2. The data and information provided for the vault tanks within the 340 facility specifically are unacceptable either to meet Tri-Party Agreement Milestone M-026-00 requirements for storage assessments/data gap plans or to provide accurate information about the tanks and their contents.

All corrective measures were completed and documentation was transmitted to the Washington State Department of Ecology. On March 15, 2006, the Washington State Department of Ecology sent a letter to DOE Richland Operations Office concurring that the dispute has been resolved.

## 5.1.3 Washington Administrative Code Groundwater Monitoring

### M. J. Hartman

Groundwater monitoring was required for three regulated, non-RCRA waste facilities in 2005. The 200 Area Treated Effluent Disposal Facility and the State-Approved Land Disposal Site are monitored under state discharge permits (WAC 173-216). The Solid Waste Landfill is monitored for the requirements of WAC 173-304, *Minimum Functional Standards for Solid Waste Handling*. Wells near these facilities were monitored in 2005 for waste constituents specified in the facility permits.

A summary of groundwater monitoring activities for these sites during 2005 is provided in Section 10.7 and more detailed information is available in the *Hanford Site Groundwater Monitoring Report for Fiscal Year 2005* (PNNL-15670).

## 5.1.4 Toxic Substances Control Act

### Hanford Site PCB Technical Team (Point-of-Contact – A. L. Prignano)

Requirements in the *Toxic Substances Control Act* that apply to the Hanford Site primarily involve regulation of polychlorinated biphenyls (PCBs). Federal regulations for use, storage, and disposal of PCBs are found in 40 CFR 761, *Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions*. (Washington State also regulates certain classes of PCBs, not regulated by the *Toxic Substances Control Act*, through WAC 173-303.) Non-radioactive and certain categories of radioactive PCB waste are stored and disposed in accordance with 40 CFR 761. Other radioactive PCB waste remains in storage onsite pending the development of adequate treatment and disposal technologies and capacities. Electrical equipment that might contain PCBs is maintained and serviced in accordance with 40 CFR 761.

To encourage consistent interpretation and implementation of the *Toxic Substances Control Act* PCB regulations throughout the Hanford Site, a *Polychlorinated Biphenyl Hanford Site Users Guide* was drafted in 2001 (DOE 2002). In 2003, this guide was revised to add additional sections on management of PCBs and PCB waste. During 2005, Hanford submitted both the 2004 PCB annual document log (DOE/RL-2005-51) and a 2004 PCB annual report (DOE/RL-2005-52) to EPA as required by 40 CFR 761.180. These two documents describe the PCB waste management and disposal activities taking place at the Hanford Site. The *Framework Agreement for Management of Polychlorinated Biphenyls in Hanford Tank Waste*,[(a)] signed on August 31, 2000, resulted in the EPA,

(a) The agreement is available online at http://yosemite.epa.gov/R10/OWCM.NSF/1931ef1026e96f6f8825651c00804023/ce50d3fe12e371f488256a00006ffa0f!OpenDocument.

Washington State Department of Ecology, and DOE and its Hanford Site contractors working together to resolve the regulatory issues associated with managing PCB waste at the Waste Treatment Plant (now under construction), in the waste tank farms, and at affected waste management units upstream and downstream of the waste tank farms. The flexibility of the 1998 PCB disposal amendments in 40 CFR 761 is used at the Hanford Site to allow necessary storage and to expedite disposal of PCB waste regulated under the *Toxic Substances Control Act*.

In November 2004, a Risk-Based Disposal Approval for retrieval of waste from single-shell storage tanks using double-shell storage tank supernatant, a PCB remediation waste regulated by the *Toxic Substances Control Act*, was submitted to EPA for approval. On June 2, 2005, EPA approved the Risk-Based Disposal Approval. The approval is structured into two phases. Phase I identifies general conditions that apply to the overall strategy and retrieval process, and Phase II identifies tank specific conditions. The approval includes Phase I conditions and Phase II conditions for tank 241-S-102. On August 24, 2005, EPA issued the Phase II approval for tanks 241-C-103 and 241-C-109. Phase II approvals for waste retrieval from the remaining seven tanks identified in the Risk-Based Disposal Approval have not been issued.

In May 2005, DOE submitted a Risk-Based Disposal Approval to EPA Region 10 for the treatment of North Load-Out Pit sludge from the K Basins Project. The North Load-Out Pit sludge is a multi-phasic material, a mixture of liquid and non-liquid phases. Since the phases cannot be separated, the sludge must be managed according to the more stringent (i.e. liquid waste) requirements. Therefore, the Risk-Based Disposal Approval was needed because liquid PCB remediation waste was being solidified to meet radiological treatment standards. In July 2005, EPA approved the Risk-Based Disposal Approval for treatment of North Load-Out Pit sludge at T Plant. EPA found that the treatment of the multi-phasic PCB waste would result in a treated waste form that did not pose an unreasonable risk of injury to human health or the environment. Treatment began at the T Plant complex in October 2005 and is scheduled to end in March 2006.

## 5.1.5 Comprehensive Environmental Response, Compensation, and Liability Act

B. L. Vedder

During 1980, the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) was enacted to address response, compensation, and liability for past releases or potential releases of hazardous substances, pollutants, and contaminants to the environment. During 1986, CERCLA was extensively amended by the *Superfund Amendments and Reauthorization Act*, which made federal facilities subject to the provisions of CERCLA. EPA is the lead regulatory agency responsible for oversight of the DOE's implementation of CERCLA. There is significant overlap between the state RCRA corrective action program (Section 5.1.2) and the CERCLA program. Many waste management units at Hanford 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 (Ecology et al. 1989) 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.

### 5.1.5.1 Hanford Site Institutional Controls Plan

J. P. Sands

Section 4.2 of the *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions* (DOE/RL-2001-41) requires the DOE Richland Operations Office to conduct an annual assessment regarding the performance of the institutional controls (see Appendix B, Glossary) described in the plan. The DOE has recommended in the CERCLA 5-year review that the frequency of review for the institutional controls assessment coincide with the 5-year review. Focused institutional

controls reviews shall continue on an as-needed or required basis. Subsequent 5-year reviews will evaluate whether more frequent reviews for site-wide institutional controls are required. The next revision of the site-wide institutional controls plan will be modified to reflect this new review cycle. This recommendation was based on the first three assessments. Summaries of these assessments follow.

The *2003 Site Wide Institutional Controls Annual Assessment Report for Hanford CERCLA Response Actions* (DOE/RL-2003-37) documented the review of 144 waste sites out of approximately 560 waste sites. The assessment did not result in any major findings. Generally, the institutional controls were found to be implemented and effective with some minor adjustments. The excavation permit process effectively identified waste sites at or near work locations and evaluated excavation activities for potential impact from the waste sites. Security of the groundwater wells was checked during routine and non-routine well maintenance inspections and by the sampling teams. All wells have caps and locks in place to prevent unauthorized access. Two recommendations came out of this assessment and were subsequently adopted:

1. Missing warning signs along the Hanford Site Columbia River shoreline were replaced in order to maintain a consistent 152.4-meter (500-foot) interval between signs.
2. A single strand of fence wire at the Horn Rapids Landfill entrance was repaired.

The *2004 Site Wide Institutional Controls Annual Assessment Report for Hanford CERCLA Response Actions* (DOE/RL-2004-56) documented an evaluation of eight topical areas, including (1) physical assessment of CERCLA waste sites, (2) Hanford human trespass incidents, (3) evaluation efforts of the surveillance and maintenance program, (4) assessment of Hanford Site groundwater use controls, (5) assessment of the Hanford Site excavation process, (6) assessment of property controls for the Hanford Site, (7) assessment of post-cleanup site information, and (8) assessment of deleted portions of national priorities list or transferred properties from DOE ownership. The results of the 2004 assessment indicated that the institutional controls are performing effectively, as designed; however, some observations were identified along with the suggested corrective actions. Four observations and corresponding corrective actions were made in this assessment:

1. Several newly installed haul roads in the 100 Areas were not adequately signed. A corrective action was taken to develop a strategy for maintaining signage on newly installed haul roads.
2. A concern was raised regarding the effectiveness of institutional controls in the 300 Area due to its proximity to the city of Richland. A corrective action was taken to evaluate the 300 Area surveillance and maintenance program as part of the 2005 institutional controls assessment to determine its adequacy.
3. It was observed that there were procedures requiring deed information to be included in the Waste Information Data System, but it was not done. A corrective action was taken to evaluate the procedure for the waste information data system and present a plan to both the EPA and Washington State Department of Ecology for updating the waste information data system procedure.
4. It was observed that the waste information data system database and the administrative record were found to be adequate and effective in identifying institutional control requirements for units in post-closure, when applicable. The regulators expressed concerns over the usability and accessibility of the database to support current and future cleanup decisions. A corrective action was taken for the DOE to evaluate the waste information data system and present a plan to both the EPA and Washington State Department of Ecology to improve access to information.

In 2005, *An Evaluation of the 300 Area Surveillance and Maintenance Program* (DOE/RL-2005-32) documented the evaluation of the effectiveness of the surveillance and maintenance program for 43 facilities in the 300 Area in lieu of formal CERCLA institutional controls. The evaluation indicated that the existing 300 Area surveillance and maintenance program is sufficiently protective of human health and the environment and, therefore, imposing formal institutional controls is unnecessary. No systematic concerns, major physical problems, or significant facility deterioration that could result in a release of hazardous substances to the environment were observed with existing access control.

### 5.1.5.2 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. 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 groundwater or 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. There were no CERCLA reportable spills or releases on or from the Hanford Site during calendar year 2005.

## 5.1.6 Federal Insecticide, Fungicide, and Rodenticide Act

J. M. Rodriguez

The *Federal Insecticide, Fungicide, and Rodenticide Act* is administered by EPA. The standards administered by the Washington State Department of Agriculture to regulate implementation of the act in Washington State include the *Washington Pesticide Control Act* (Revised Code of Washington [RCW] 15.58), *Washington Pesticide Application Act* (RCW 17.21), and rules relating to general pesticide use codified in WAC 16-228, *Pesticide Regulations*. 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.

# 5.2 Air Quality

K. A. Peterson

This section provides information about federal statutes and assessments related to Hanford Site air quality.

## 5.2.1 Clean Air Act

The *Clean Air Act*, the basis for federal air quality regulations, was passed in 1967 and had comprehensive amendments in 1970, 1977, and 1990. In accordance with Section 112 of the *Clean Air Act*, the EPA established the *National Emissions Standards for Hazardous Air Pollutants* (40 CFR 61). The DOE and EPA signed the *Federal Facility Compliance Agreement for Radionuclides NESHAP* (EPA 1994). The agreement provides a 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 agreement were met during 2005, and Hanford Site radiological 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) (see Section 10.1). 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 the Washington State Department of Health. Data for the emission sources are documented annually in the radionuclide air emissions report for the Hanford Site (e.g., DOE/RL-2006-01).

The Washington State Department of Health's Division of Radiation Protection regulates radioactive air emissions statewide through Washington State legislative authority. The Hanford Site operates under state license FF-01 (Appendix D, Table D.1) for air emissions. Conditions specified in the license are incorporated into the Hanford Site air operating permit issued by the Washington State Department of Ecology in July 2001. The permit provides a compilation of applicable *Clean Air Act* requirements both for radioactive and non-radioactive (i.e., toxic and criteria pollutants) emissions. The permit requires the DOE Richland Operations Office to submit periodic compliance reports (e.g., DOE/RL-2006-02) to the Washington State Department of Ecology.

The Washington State Department of Ecology's Nuclear Waste Program regulates air toxic and criteria pollutant emissions from the Hanford Site. The department enforces state regulatory controls for air contaminants as allowed under the *Washington Clean Air Act* (RCW 70.94). The EPA regulates other potential air emission sources under the *Clean Air Act* at the Hanford Site.

At the local level, the EPA delegated the Benton Clean Air Authority as the agency to establish a local oversight and compliance program for asbestos renovation and/or demolitions, adopting EPA's regulation by reference (i.e., the *National Emission Standards for Asbestos* [40 CFR 61, Subpart M]). In addition, the Benton Clean Air Authority regulates open-air burning as an extension of the Washington State Department of Ecology's open-air burning requirements (WAC 173-425).

## 5.2.2 Clean Air Act Enforcement Inspections

Hanford Site contractors and the DOE actively worked toward resolving the notice of correction and/or notice of violation allegation letters from the Washington State Department of Health during 2005. The following paragraphs summarize the two main notices formally received during 2005.

On June 14, 2005, the Washington State Department of Health conducted an inspection of emission unit 296-B-28 in the 200-East Area and unit 296-P-43 in the 200-West Area. These units are associated with operation of the 244B Saltwell Receiver tank and the 241-S-112 underground waste tank, respectively. The purpose of the inspection was to evaluate the emission unit and review calibration records, emission control data, administrative records, sampling records, and emissions monitoring data. As a result, the Washington State Department of Health issued a notice of correction requesting actions to satisfactorily demonstrate closure of the sample exchange, sample handling, and reporting issues identified in the notice of compliance. The DOE Office of River Protection provided a response to the notice of correction letter and transmitted closure information for corrective actions.

On November 17, 2005, a Notice of Violation was received from the Washington State Department of Health regarding the 296-S-21 stack designation at the 222-S Laboratory as a "minor" emission unit based on a miscalculation of the emission unit's potential-to-emit. In their letter, the Washington State Department of Health cites a May 2005 audit of the 296-S-21 stack as the basis for one alleged violation and three corrective measures. The DOE was directed to begin continuous sampling of the stack and to provide a response within 60 days. The DOE Office of River Protection provided a response status letter and a request for an extension to the Washington State Department of Health. The Washington State Department of Health approved the requested extension for response until March 31, 2006.

# 5.3 Water Quality Protection

This section provides information about federal statutes and assessments related to water quality.

## 5.3.1 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 the *EPA Administered Permit Programs: The 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 (Appendix D, Table D.1). 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 2005. The EPA's National Pollutant Discharge Elimination System Storm Water Multi-Sector General Permit WAR05A57F (Appendix D, Table D.1) establishes the terms and conditions under which storm water discharges associated with industrial activity are authorized. This Multi-Sector General Permit for stormwater discharges, issued in October 2000, expired at midnight on October 30, 2005. A new permit to replace it has not been issued. Facilities that obtained coverage under the 2000 Multi-Sector General Permit prior to its expiration are automatically granted an administrative continuance of permit coverage. Fluor Hanford, Inc. is the holder of this permit.

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's treatment facility. Sanitary wastewater in the 200 Areas 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 13,300 to 55,000 liters [3,500 to 14,500 gallons] per day) operate under permits issued by the Washington State Department of Health and treat wastewater from several facilities rather than a single facility (Appendix D, Table D.1).

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 currently holds several state wastewater discharge permits. The Washington State Department of Ecology issued permit ST-4511 combining three permits (ST-4508, ST-4509, and ST-4510) into one permit (Appendix D, Table D.1). During 2005, the Hanford Site had five state waste discharge permits issued by the Washington State Department of Ecology (ST-4500, ST-4501, ST-4502, ST-4507, ST-4511), EPA *National Pollutant Discharge Elimination System* Permit WA-002591-7, and EPA Stormwater Permit WAR05A57F. There were no permit violations during 2005.

## 5.3.2 Safe Drinking Water Act

L. M. Kelly

In 1974, Congress passed the *Safe Drinking Water Act*. The act set up a cooperative program among local, state, and federal agencies to establish drinking water regulations applicable to all public water systems in the United States. States were granted primary responsibility, known as primacy, for administering and enforcing the *Safe Drinking Water Act*. To obtain primacy, states had to meet certain criteria, including adoption of regulations equal to or more stringent than the EPA regulations.

The state of Washington was awarded primacy in 1978. The state Board of Health and the Washington State Department of Health became partners in developing and enforcing state drinking water regulations. The water systems on the Hanford Site were designated as public water systems in 1986 and became formally registered as public systems under the jurisdiction of the Washington State Department of Health in 1987.

The *Safe Drinking Water Act* was amended in 1986, to strengthen the act, and amended again in 1996 (*Safe Drinking Water Act Amendments*). The 1996 amendments represent a national commitment to prepare for future drinking water challenges and assure the sustainable availability of safe drinking water, increase state flexibility, provide for more efficient investments by water systems, give better information to consumers, and strengthen EPA's scientific work, including the use of risk and cost-benefit analysis in setting drinking water standards. The amendments include the development of a number of new drinking water regulations to be published over a period of several years.

A series of these regulations known as the Microbial and Disinfection Byproduct Rules, address acute threats from microbial contamination and chronic threats from disinfectant residuals and byproducts of disinfection. Two of the rules incorporated into the state drinking water regulations, WAC 246-290 – *Public Water Supplies*, became effective in January 2004 (Disinfectants and Disinfection Byproducts Rule, Stage 1), and January 2005 (Long Term 1 Enhanced Surface Water Treatment Rule), impacting Hanford water systems. These rules limit disinfectant residuals and disinfection byproducts in the distribution systems while improving particle removal in the drinking water treatment plants. The affected Hanford systems demonstrated compliance with the new progressively complex requirements during 2004 and 2005.

In 2005, the Wye and Yakima Barricade systems were designated and formally registered as Group B public water systems by the Washington State Department of Health, bringing the total number of public water systems onsite to eleven. To protect the health of consumers using the public water supplies at Hanford, the water systems were monitored during 2005 for microbiological, chemical, physical, and radiological constituents. There were no microbiological detections and all chemical concentrations were well below the maximum contaminant levels established by the EPA. All analytical results for 2005 radiological monitoring are summarized in Section 10.6.

# 5.4 Natural and Cultural Resources

This section provides information about federal statutes and assessments related to ecological compliance and cultural resources at Hanford.

## 5.4.1 Ecological Compliance

M. R. Sackschewsky

DOE policies require that all projects, with 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* and the *Migratory Bird Treaty Act*. It also 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 actions are 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, 100-N and 100-K 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, that can be used throughout the rest of the year to assess the potential impact. 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.

There were 205 reviews preformed during 2005 including 137 ecological compliance reviews to support general Hanford Site activities and 68 reviews for environmental restoration activities.

### 5.4.1.1 Endangered Species Act

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*), steelhead trout (*Oncorhynchus mykiss*), and spring-run Chinook salmon (*Oncorhynchus tshawytscha*) are listed under the *Endangered Species Act* as either threatened or endangered (50 CFR 17, Subpart B) and occur onsite. The DOE has management plans in place for each of these species (DOE/RL-94-150; DOE/RL-2000-27). Other species at Hanford are listed by the Washington Department of Fish and Wildlife as endangered, threatened, or sensitive (see Section 10.12).

### 5.4.1.2 Migratory Bird Treaty Act

The *Migratory Bird Treaty Act* prohibits taking or disturbing specified migratory birds or their feathers, eggs, or nests. Over 100 species of birds that regularly occur on the Hanford Site are protected by the *Migratory Bird Treaty Act*. All Hanford Site projects with a potential to affect federal or state listed species of concern complied with the requirements of this act by using the ecological compliance review process as described in the *Hanford Site Biological Resources Management Plan* (see Section 5.5.1 in DOE/RL-96-32). When applicable, the ecological reviews produced recommendations to minimize adverse impact to migratory birds, such as performing work outside of the nesting season and minimizing the loss of habitat.

## 5.4.2 Cultural Resources

### D. C. Stapp

DOE's policy is to comply with all cultural resource-related laws and regulations (DOE P 141.1). On the Hanford Site, cultural resources are subject to the provisions of the following laws, regulations, and executive orders and proclamations. Laws include the *American Indian Religious Freedom Act*; *Antiquities Act*; *Archaeological and Historic Preservation Act*; *Archaeological Resources Protection Act*; *Historic Sites, Buildings and Antiquities Act*; *National Environmental Policy Act*; *National Historic Preservation Act*; and *Native American Graves Protection and Repatriation Act*. Regulations applicable to cultural resources include *Curation of Federally-Owned and Administered Archaeological Collections* (36 CFR 79), *National Historic Landmarks Program* (36 CFR 65), *National Register of Historic Places* (36 CFR 60) and *Determinations of Eligibility for Inclusion in the National Register of Historic Places* (36 CFR 63), *Native American Graves Protection and Repatriation Act: Final Rule* (43 CFR 10), *Protection of Archaeological Resources* (43 CFR 7), and *Protection of Historic Properties* (36 CFR 800). Executive Orders include Executive Order 11593, *Protection and Enhancement of the Cultural Environment* (36 FR 8921); Executive Order 13007, *Indian Sacred Sites* (61 FR 26771-26772); Executive Order 13287, *Preserve America* (68 FR 10635); and Proclamation 7319, *Establishment of the Hanford Reach National Monument* (65 FR 37253).

See Section 10.15 for details regarding the cultural resources programs on the Hanford Site.

# 5.5 National Environmental Policy Act

M. T. Jansky

The *National Environmental Policy Act* (NEPA) requires preparation of an environmental impact statement for major federal actions with the potential to significantly affect the quality of the human environment. An environmental assessment is prepared when it is uncertain if a proposed action would require the preparation of an environmental impact statement. A supplement analysis is prepared to consider new information developed since issuance of an environmental impact statement and record of decision. The supplement analysis would determine if the federal action is still bounded by the original environmental impact statement and record of decision or if a supplemental environmental impact statement is required.

Additionally, certain types of actions may fall into typical classes that have already been analyzed by DOE and have been determined 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 NEPA environmental assessment or environmental impact statement requirements. Typically, the DOE Richland Operations Office documents more than 20 specific categorical exclusions annually, involving a variety of actions by multiple Hanford Site contractors. In addition, site-wide categorical exclusions are applied to routine, typical actions conducted daily on the Hanford Site. In 2005, there were 20 site-wide categorical exclusions.

NEPA 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), DOE NEPA implementation procedures (10 CFR 1021), and DOE Order 451.1B Change 1, *National Environmental Policy Act Compliance Program – Change 1*. In accordance with the Order, DOE documents prepared for CERCLA projects incorporate NEPA values such as analysis of cumulative, offsite, ecological, and socioeconomic impacts to the extent practicable in lieu of preparing separate NEPA documentation.

## 5.5.1 Recently Issued Environmental Impact Statements

In February 2006, DOE announced its intention to prepare a new environmental impact statement titled *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington* (71 FR 5655). The Washington State Department of Ecology will be a cooperating agency in the preparation of this environmental impact statement. This environmental impact statement will revise, update, and re-analyze groundwater impacts previously addressed in DOE/EIS-0286F; analyze the alternatives for the retrieval, treatment, and disposal of waste from underground waste storage tanks and closure of 149 single-shell underground waste storage tanks; and include the scope of the ongoing *Fast Flux Test Facility Decommissioning Environmental Impact Statement* (DOE/EIS-0364, Notice of Intent issued in 69 FR 50178). Four public scoping meetings are scheduled in February 2006.

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. Projected issuance of the draft environmental impact statement is spring 2006.

## 5.5.2 Recent Environmental Assessments

A draft environmental assessment titled *Sodium Residuals Reaction/Removal and Other Deactivation Work Activities, Fast Flux Test Facility (FFTF) Project, Hanford Site, Richland, Washington* (DOE/EA-1547D) was prepared. A 30-day public comment period was held from February 15 through March 17, 2006. Projected issuance of the final environmental assessment is April 2006.

A draft environmental assessment supporting extended onsite storage of Hanford Site special nuclear material is being prepared. The scope of the environmental assessment includes development and implementation of the necessary capabilities to store and protect the inventory of Hanford Site special nuclear material to the current DOE protection policy. Projected issuance of the draft environmental assessment is March 2006.

# 5.6 Atomic Energy Act

W. M. Glines

The *Atomic Energy Act* was promulgated to assure the proper management of radioactive materials. The act and its amendments have delegated the roles and responsibilities for the control of radioactive materials and nuclear energy primarily to DOE, the Nuclear Regulatory Commission, and EPA. Under the act, DOE regulates the control of radioactive materials under its authority including the treatment, storage, and disposal of low-level radioactive waste from its operations. Sections of the act authorize DOE to set radiation protection standards for itself and its contractors. Accordingly, DOE promulgated a series of regulations (e.g., 10 CFR 820, 10 CFR 830, and 10 CFR 835) and Orders (e.g., DOE Order 435.1 and DOE Order 5400.5) to protect public health and the environment from potential risks associated with radioactive materials. Operations at the Hanford Site are subject to the requirements in these regulations and Orders. In 2005, the following DOE directives or guidance documents potentially impacting the management and control of radioactive materials were issued or underwent significant revision:

- DOE Policy 226.1. "Department of Energy Oversight Policy," June 10, 2005.
- DOE Order 226.1. "Implementation of Department of Energy Oversight Policy," September 15, 2005.
- DOE Order 414.1C. "Quality Assurance," June 17, 2005.
- DOE Guide 414.1-2A. *Quality Assurance Management System Guide for Use with 10 CFR 830 Subpart A, Quality Assurance Requirements, and DOE O 414.1C, Quality Assurance*, June 17, 2005.
- DOE Guide 414.1-4. *Safety Software Guide for Use with 10 CFR 830, Subpart A, Quality Assurance Requirements, and DOE O 414.1C, Quality Assurance*, June 17, 2005.
- DOE Guide 441.1-3A. *Internal Dosimetry Program Guide for Use with Title 10, Code of Federal Regulations, Part 835, Occupational Radiation Protection*, June 11, 2005.
- DOE Guide 441.1-4A. *External Dosimetry Program Guide for Use with Title 10, Code of Federal Regulations, Part 835, Occupational Radiation Protection*, June 11, 2005.
- DOE Guide 450.1-1A. *Implementation Guide for Use with DOE O 450.1, Environmental Protection Program*, October 24, 2005.
- DOE Guide 450.1-9. *Ground Water Protection Programs Implementation Guide for Use with DOE O 450.1, Environmental Protection Program*, May 5, 2005.
- DOE Guide 454.1-1. *Institutional Controls Implementation Guide for Use with DOE P 454.1, Use of Institutional Controls*, October 14, 2005.
- DOE Radiological Control Technical Position 05-01. *Recommended Approaches for Setting Radiological Control Limiting Conditions*, October 27, 2005 (DOE 2005).
- DOE/EH-413/9712. *Cross-Cut Guidance on Environmental Requirements for DOE Real Property Transfers (Update)*, March 2005.

In addition, the following DOE Technical Standards pertaining to the management and control of radioactive materials underwent significant revision in 2005:

- DOE-STD-1120-2005, Volumes 1 & 2. *Integration of Environment, Safety, and Health into Facility Disposition Activities*, April 2005.
- DOE-STD-3020-2005. *Specification for HEPA Filters Used by DOE Contractors*, December 2005.

All of the above documents issued in 2005 may be accessed on the DOE Directives, Regulations, and Standards website at http://www.directives.doe.gov/.

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10 CFR 1021. "Compliance with the National Environmental Policy Act." U.S. Department of Energy, *Code of Federal Regulations*.

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36 CFR 65. "National Historic Landmarks Program." U.S. Department of Labor, *Code of Federal Regulations*.

36 CFR 79. "Curation of Federally-Owned and Administered Archaeological Collections." U.S. Department of Labor, *Code of Federal Regulations*.

36 CFR 800. "Protection of Historic Properties." U.S. Department of Labor, *Code of Federal Regulations*.

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40 CFR 61.92. "Standard." U.S. Environmental Protection Agency, *Code of Federal Regulations*.

40 CFR 61, Subpart H. "National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities." U.S. Environmental Protection Agency, *Code of Federal Regulations*.

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40 CFR 1500-1508. "Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act." Council on Environmental Quality, *Code of Federal Regulations*.

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43 CFR 10. "Native American Graves Protection and Repatriation Regulations." U.S. Department of Labor, *Code of Federal Regulations*.

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# 6.0 Environmental Restoration

J. P. Duncan

This section describes continuing Hanford Site environmental cleanup and decommissioning activities. Included are discussions of project compliance activities, waste management, liquid effluent treatment, revegetation and mitigation, environmental restoration, groundwater protection, and waste storage tank research. Activities, accomplishments, and relevant issues are presented and resolutions are described.

# 6.1 Cleanup Operations

This section describes ongoing cleanup and remediation activities on the Hanford Site.

## 6.1.1 Groundwater Remediation Project

B. H. Ford

The U.S. Department of Energy (DOE) established the Groundwater/Vadose Zone 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 as the Groundwater Remediation Project. 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 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 200 Areas' Waste Site Remedial Actions group within the Groundwater Remediation Project was transferred to the Central Plateau Remediation Project during 2004 and is now designated as the Decontamination and Decommissioning Project. Information on groundwater and vadose zone remediation systems in use in 2005 is summarized in Section 10.7.

## 6.1.2 Waste Site Investigations and Remediation Activities in the 200 Areas

M. E. Todd-Robertson

Remedial investigation/feasibility study activities continued during 2005 at 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 – Environmental Restoration Program* (DOE/RL-98-28). Work was performed at a number of operable unit groups, which were at various stages of the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) remedial investigation/feasibility study process. The following summary provides descriptions of activities that were performed during 2005.

***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 cooling water from facilities such as the Plutonium-Uranium Extraction (PUREX) and B Plants. Sampling was conducted in 2005 as part of the Central Plateau Ecological Risk Assessment task, which supports ecological assessment at all the operable units. The data from these events will be incorporated into the next revision of the feasibility study and proposed plan, planned for fiscal year 2007. Strontium-90, cesium-137, cadmium, mercury, lead, silver, and polychlorinated biphenyls (PCBs) were the major risk contributors identified for human and ecological receptors.

***200-CS-1 Operable Unit***. The 200-CS-1 Operable Unit consists of waste sites that received sewer wastewater containing chemicals from major plant facilities in both the 200-West and 200-East Areas. A remedial investigation/feasibility study work plan (DOE/RL-99-44) was approved during 2000 that defines planned remedial investigation activities at four representative waste sites of the operable unit: the 216-S-10 pond, 216-S-10 ditch, 216-B-63 trench, and 216-A-29 ditch. Fiscal year 2005 activities focused on preparing a feasibility study and proposed plan to be issued to the regulatory agencies in March 2006 (*Hanford Federal Facility Agreement and Consent Order* [Tri-Party Agreement, Ecology et al. 1989] Milestone M-015-39B). Closure plans for the 216-S-10 pond and ditch (DOE/RL-2006-12), 216-B-63 trench (DOE/RL-2006-11), and 216-A-29 ditch treatment, storage, and disposal facilities were also initiated in fiscal year 2005 under Tri-Party Agreement Milestone M-020-39, to be submitted to the regulatory agencies in conjunction with the feasibility study (DOE/RL-2005-63) and proposed plan (DOE/RL-2005-64).

***200-CW-2, 200-CW-4, 200-CW-5, and 200-SC-1 Operable Units***. The 200-CW-2, 200-CW-4, 200-CW-5, and 200-SC-1 consolidated operable unit group consists of waste sites that received cooling water, steam condensate, and chemical sewer waste from facilities in the 200-West Area, including the U Plant, powerhouse and laundry facilities, 242-S evaporator, Plutonium Finishing Plant and associated facilities, Reduction-Oxidation (REDOX) Plant, T Plant, Plutonium-Uranium Extraction (PUREX) Plant, and Waste Encapsulation and Storage Facility. The remedial investigation included pipeline sampling, geophysical logging of shallow drive-point casings, and characterization drilling to the water table. Primary contaminants of concern identified included strontium-90, technetium-99, cesium-137, americium-241, plutonium isotopes, uranium, selenium, PCBs, magnesium, and nitrite. A feasibility study (DOE/RL-2004-24) and proposed plan (DOE/RL-2004-26) was issued to the regulatory agencies in October 2004 (Tri-Party Agreement Milestone M-015-40C). Revisions to the feasibility study and proposed plan are to be initiated in fiscal year 2006.

**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 that received waste associated with uranium recovery activities at the U Plant. The 200-TW-2 Operable Unit consists of waste sites, mostly cribs and trenches that received waste from the decontamination processes at the B Plant and T Plant. The 200-PW-5 Operable Unit waste sites received fission-product-rich wastes that were generated during the fuel-rod enrichment cycle and then released when the fuel elements were decladded or dissolved in sodium hydroxide or nitric acid. Activities were on hold in fiscal year 2005 because emphasis was shifted to preparation of the feasibility study at BC cribs and trenches (the BC cribs and trenches are included in the 200-TW-1 Operable Unit). The regulatory agencies felt the feasibility study for the 200-TW-1, 200-TW-2, and 200-PW-5 Operable Units was too complex and wanted to address a smaller subset of sites through the BC cribs and trenches accelerated remediation project. Revisions to the 200-TW-1, 200-TW-2, and 200-PW-5 Operable Units feasibility study and proposed plan are to be initiated in fiscal year 2007.

***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. The 200-PW-3 Operable Unit waste sites received organic-rich waste from other separation facilities such as the S Plant (REDOX process), A Plant (PUREX process), U Plant (uranium recovery process), and the 201-C Building (hot semiworks process). The 200-PW-6 Operable Unit waste sites received plutonium-rich waste from the Z Plant complex. This operable unit group also includes the carbon tetrachloride plume in the vadose zone that has migrated beyond the boundaries of the waste sites. The work plan for the plutonium/organic-rich operable unit (200-PW-1, 200-PW-3, and 200-PW-6 Operable Units) was approved in 2004 (DOE/RL-2001-01).

A borehole was installed in fiscal years 2003 and 2004 at the 216-Z-9 trench (200-PW-1 Operable Unit); very high levels of plutonium and carbon tetrachloride were found in this borehole. This borehole was drilled as a joint project between the Waste Site Remediation and Groundwater Protection projects. The borehole was drilled to basalt and subsequently completed as a groundwater monitoring well; major contaminants were plutonium and carbon tetrachloride. An initial phase of characterization for carbon

tetrachloride was initiated in 2002, and work has continued on subsequent phases during 2003 through 2005. Activities included passive vapor sampling, sampling of burial ground vent risers, numerical modeling of carbon tetrachloride migration through the vadose zone, assessment of carbon tetrachloride groundwater hot spots for potential carbon tetrachloride sources, vapor and water sampling in existing wells, and soil vapor sampling at waste sites or hot spot areas using direct pushes for vadose zone access. In fiscal year 2005, a borehole was installed to groundwater at the 216-A-8 crib as part of the remedial investigation for the 200-PW-3 Operable Unit to evaluate the potential for organics other than carbon tetrachloride. During fiscal year 2006, a second borehole is planned at the 216-Z-9 trench, and carbon tetrachloride soil vapor samples will be collected from the deep vadose zone at up to 11 locations. The remedial investigation report is planned to be delivered to the regulatory agencies for review in October 2006 (Tri-Party Agreement Milestone M-015-45A).

Field activities to evaluate whether carbon tetrachloride is present as a dense, nonaqueous phase liquid were initiated in 2004 for the DOE Richland Operations Office by Vista Engineering Technologies, LLC and are scheduled to be completed in fiscal year 2006. Activities include drilling and sampling of fine-grained layers such as the Cold Creek Unit, cross-well geophysical surveys, passive soil vapor sampling, and soil vapor sampling at the 216-Z-9 and Z-1A waste sites (200-PW-1 Operable Unit) using direct pushes for vadose zone access. Fluor Hanford, Inc. and Vista Engineering Technologies, LLC work closely to coordinate field activities for the carbon tetrachloride investigation. Vista Engineering Technologies, LLC will prepare the final report on the dense, nonaqueous phase liquid investigation during fiscal year 2006.

***200-PW-2 and 200-PW-4 Operable Units***. Waste sites in the 200-PW-2 Operable Unit received uranium-rich condensate and process waste, primarily from waste streams generated at the U Plant, REDOX Plant, PUREX Plant, 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. In 2005, a borehole was installed at the 216-S-7 crib (200-PW-2 Operable Unit) at the request of the regulatory agencies. The data from this borehole are being incorporated into the feasibility study (DOE/RL-2004-85) and proposed plan (DOE/RL-2004-86), which were initiated in 2005 and are being prepared for submittal to the regulatory agencies in May 2006 (Tri-Party Agreement Milestone M-015-43C). Closure plans for several treatment, storage, and disposal units in these operable units were also initiated in 2005 for coordinated submittal along with the feasibility study and proposed plan (Tri-Party Agreement Milestone M-020-33).

***200-LW-1 and 200-LW-2 Operable Units***. The waste sites in the 200-LW-1 and 200-LW-2 Operable Units received two types of waste: (1) liquid waste resulting from 300 Area process laboratory operations that supported radiochemistry metallurgical experiments and (2) liquid waste resulting mainly from laboratory operations in the 200 Areas that supported the major chemical processing facilities and equipment decontamination at the T Plant. Field work was completed in fiscal year 2005 and consisted of installation of boreholes at four waste sites (216-T-28, 216-S-20, and 216-Z-7). A borehole summary report was completed in fiscal year 2005 (D&D-25461). The remedial investigation report (DOE/RL-2005-61) was initiated in 2005 for submittal to the regulatory agencies in February 2006 (Tri-Party Agreement Milestone M-015-46A). The feasibility study and proposed plan were initiated in fiscal year 2005 and were submitted for review in September 2006 (Tri-Party Agreement Milestone M-015-46B). Contaminants included cesium-137, strontium-90, and plutonium.

***200-MW-1 Operable Unit***. The waste sites in the 200-MW-1 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. The work plan for the 200-MW-1 Operable Unit was approved in 2002 (DOE/RL-2001-65). Field work was initiated in 2004 and consisted of installing boreholes at two sites (216-U-3 and 216-T-33), installing an auger hole at one site (200-E-4), and excavating two test pits at one site (216-T-13). A borehole was attempted at the 216-A-4 crib but has not yet been completed due to unexpectedly high-contamination levels. Drilling was halted, and a new path forward is being evaluated for data collection at that site. A borehole summary report was completed in 2005

(D&D-26572) for all the sites except 216-A-4. The remedial investigation report was initiated in 2005 for submittal to the regulatory agencies in April 2006 (Tri-Party Agreement Milestone M-015-46A). Contamination levels for the sites, besides 216-A-4, were very low. Contaminants at 216-A-4 included plutonium, americium-241, cesium-137, and strontium-90.

***200-UR-1 Waste Group Operable Unit***. The 200-UR-1 Waste Group Operable Unit includes unplanned release sites that generally consist 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 loss of 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. The remedial investigation/feasibility study work plan for the 200-UR-1 Operable Unit was initiated in 2003 and submitted to the regulatory agencies for review in June 2004 fulfilling the requirements of Tri-Party Agreement Milestone M-013-00N (DOE/RL-2004-39).

This operable unit followed a unique path in preparation of the work plan. Because many of the unplanned release sites are shallow sites, the regulatory agencies and the DOE worked on a streamlined process that would allow early cleanup of many of the sites. The work plan follows the remedial investigation/feasibility study action process path for two of the waste sites (BC Controlled Area and West Lake); however, for the rest of the 200-UR-1 sites, an engineering evaluation/cost analysis process under the CERCLA removal action authority was followed. This allows for an early decision to remove these waste sites or close them as no action sites.

***200-SW-1 and 200-SW-2 Operable Units***. The 200-SW-1 Operable Unit includes a number of non-radioactive landfills and dump sites that were created during the construction and operation of the 200 Areas facilities. Although a few sites were excavated engineered structures that were operated in a manner to contain waste releases, most sites were accumulation points for materials not regarded at the time to be potentially hazardous. The 200-SW-2 Operable Unit includes engineered burial grounds that were constructed to receive radioactive waste. The dry-waste burial grounds received all types of miscellaneous radioactive waste, and the industrial burial grounds received large pieces of failed or obsolete equipment from the chemical processing facilities. A remedial investigation/feasibility study work plan for these operable units was submitted for regulatory review during 2004 (DOE/RL-2004-60), fulfilling Tri-Party Agreement Milestone M-13-00O. In 2005, historical research was initiated, a data quality objectives process that focused on further non-intrusive activities was initiated, and surface geophysical surveys of eight burial grounds were completed.

***200-IS-1 and 200-ST-1 Operable Units***. The 200-IS-1 Operable Unit consists primarily of pipelines, diversion boxes, catch tanks, and related structures used to transfer single-shell tank waste within and between the 200 Areas. These facilities are the responsibility of the tank farms (groupings of underground waste-storage tanks) contractor, CH2M HILL Hanford Group, Inc. Five *Resource Conservation and Recovery Act* (RCRA) treatment, storage, and disposal unit tanks belonging to Fluor Hanford, Inc. are also included in this operable unit: the 241-CX-70, 241-CX-71, 241-CX-72, 276-S-141, and 276-S-142 tanks. The 200-ST-1 Operable Unit consists of septic tanks and tile fields that are thought to have potentially received minor quantities of radioactively contaminated liquid waste from showers, floor drains, and janitor sinks. A data quality objectives process was initiated in 2005 to identify characterization needs for completing the remedial investigation/feasibility study process for the pipelines. Planning for field work was initiated in 2005 for four sites that were identified in the original work plan (DOE/RL-2002-14) for a phased characterization approach using direct push techniques or test pits followed by boreholes if deeper contamination was found.

***BC Cribs and Trenches Area***. The BC cribs and trenches area was identified for accelerated closure during 2003. Two boreholes were drilled in this area in fiscal year 2004. Evaluations of these boreholes were included in a feasibility study (DOE/RL-2004-66) and proposed plan (DOE/RL-2004-69) that were submitted to the regulatory

agencies in May 2005. Comment resolution was initiated in fiscal year 2005 and continues in fiscal year 2006.

***Central Plateau Ecological Risk Assessment***. Initiated in 2002, the Central Plateau Ecological Risk Assessment task is designed to evaluate the potential ecological risks associated with Central Plateau waste sites. The information obtained from this assessment will be used to support CERCLA decision making. The task includes compiling existing data and four phases of data collection and evaluation. In fiscal year 2002, a data evaluation report was initiated. In fiscal year 2004, an initial phase of data-quality objectives development and sample planning was conducted, followed by a second phase in fiscal year 2005. Sampling for these phases was conducted in fiscal year 2005 and focused on characterizing background sites, a subset of CERCLA waste sites, and the BC Controlled Area. A third phase of data quality objectives development and sample planning is planned for fiscal year 2006, along with associated sampling areas for which there are no data, and areas outside waste sites. An ecological risk assessment will be performed following the data collection activities to support the remedial investigation/feasibility study process for the Central Plateau; this risk assessment is planned for fiscal year 2007.

## 6.1.3 Cleanup and Remediation Activities in the 100 Areas

This section describes the cleanup and remediation activities occurring within the 100 Areas.

### 6.1.3.1 Remediation of Waste Sites in the 100 Areas

J. W. Donnelly and A. K. Smet

Full-scale remediation of waste sites in the 100 Areas began in 1996. Figure 1.0.1 shows the former 100 Areas reactor areas along the Columbia River. Remediation activities in 2005 were performed in multiple locations in the 100 Areas, including in the 100-B/C, 100-K, 100-N, 100-D, 100-F Areas, and in the 100-IU-2 and 100-IU-6 Operable Units. The 100-IU-2 and 100-IU-6 Operable Units cover areas near the Hanford town site. Remediation activities include sampling to determine if suspected waste sites exceed cleanup objectives, sampling to confirm cleanup objectives have been met, physical excavation operations, waste sorting and segregation, waste sampling, waste treatment, waste disposal, backfill, and revegetation.

Waste sites vary in complexity and types of waste. Typical waste sites include waste burial grounds, liquid effluent waste sites, burn pits, retired septic systems, piping systems, and miscellaneous waste sites. The primary focus early in the cleanup process was to address waste sites receiving liquid waste because those sites generally contain significant quantities of waste and serve as potential sources for groundwater contamination. At the end of 2005, remediation of most of the liquid waste sites had been completed, although backfill and revegetation remains to be completed for some of these sites. As the number of liquid effluent waste sites diminishes, the focus for cleanup is the waste burial grounds and other miscellaneous waste sites. Each of these two waste groups present challenges.

Waste burial grounds require cleanup but also present a significant health and safety risk to workers due to incomplete disposal records and the potential for discovering unknown material disposed from past disposal practices. For example, materials are discovered during cleanup that are unknown and require further characterization, or containers are discovered with no marking or labeling and require further characterization. Characterization of the unknown material is critical to ensure the safety of workers and the proper management of the waste for potential treatment and disposal. Discovery of an unknown material requires additional time and planning to ensure that the proper protective gear is used in the field to characterize the material and to verify that the limits and controls identified in approved authorization documents, required by the DOE, are adequate for the scope of work. If authorization documents do not adequately cover the material discovered, work is stopped until documentation can be revised and work safely restarted. Based on the characterization results, additional waste treatment may be required before disposal.

Miscellaneous waste sites vary in the nature and extent of contamination and are generally smaller sized areas compared to liquid waste sites and burial grounds. Sampling requirements for determining if a miscellaneous waste site requires cleanup or is in compliance with post-cleanup goals

can vary significantly from one waste site to another. Therefore, each site requires a specific sampling instruction. Many of the liquid effluent waste sites and burial grounds were similar and could use a template sampling plan or instruction.

The waste sites in the 100 Areas are authorized for remediation activities through the issuance of records of decision that have been approved by the U.S. Environmental Protection Agency (EPA), DOE, and Washington State Department of Ecology. Additionally, a few waste sites are authorized for closure (i.e., cleanup) through issuance of a closure plan approved by the DOE and Washington State Department of Ecology if the action is performed under RCRA regulation and in accordance with the Hanford Facility RCRA Permit (Ecology 1994). Waste generated from the cleanup of these waste sites is disposed of in the Hanford's Environmental Restoration Disposal Facility located in the 200 Areas. This centralized disposal facility is the primary disposal pathway, but other disposal options are available, if necessary, should the material not meet the waste acceptance criteria for the facility.

During 2005, a total of 843,330 metric tons (929,802 tons) of contaminated soil from the 100 Areas remediation activities were disposed of at the Environmental Restoration Disposal Facility. These included:

- 352,238 metric tons (388,355 tons) from the 100-B/C Area.
- 333,405 metric tons (367,591 tons) from the 100-K Area.
- 114,468 metric tons (126,205 tons) from the 100-N Area.
- 43,209 metric tons (47,651 tons) from the 100-F Area.

Activities in the 100-D Area and the 100-IU-2 and 100-IU-6 Operable Units were not focused on waste site excavation. Therefore, no disposal volumes are reported.

## 6.1.3.2 K Basins Closure Activities

M. S. Gerber

Cleanout of the K Basins was managed throughout 2005 by the K Basins Closure Project. The K Basins are two indoor, concrete pools attached to the now closed K-East and K-West Reactors. For nearly 30 years, they stored 2,100 metric tons (2,300 tons) of Hanford N Reactor spent fuel and a small quantity of slightly irradiated single-pass reactor fuel (fuel from older Hanford reactors). The fuel was removed in a major cleanup project that ended in October 2004. In mid-2004, responsibility for K Basins cleanout passed to the new K Basins Closure Project.

Corrosion of the fuel during the storage years had left behind approximately 53.8 cubic meters (70.4 cubic yards) of sludge. There were 11.2 cubic meters (14.7 cubic yards) in the K-West Basin and 42.6 cubic meters (55.7 cubic yards) in the K-East Basin. Sludge is a non-homogeneous mixture of debris such as windblown sand and environmental particulates, rack and canister corrosion products, fuel cladding pieces, tiny bits of corroded uranium fuel (uranium oxides, hydrates, and hydrides), ion exchange resin beads, PCBs, and/or fission products. Several different forms of sludge exist in the K Basins, depending on the basin, canister type, and pit location where the particular sludge is found. For the purposes of differentiating spent nuclear fuel and debris from sludge, any material that is less than or equal to 0.64 centimeters (0.25 inch) in diameter is considered to be sludge.

In addition, the K Basins contained more than an estimated 268 metric tons (300 tons) of debris (solid nuclear waste) when the fuel removal project ended. The debris included over 200 fuel racks – weighing at least 136 kilograms (300 pounds) apiece – in each basin, pumps, thousands of feet of hoses, structural brackets weighing approximately 91 kilograms (200 pounds) each, hundreds of long-handled tools called pole tools, thousands of canisters and lids that formerly held the fuel, and a variety of other miscellaneous debris. The K-West Basin held more debris than the K-East Basin because the fuel canisters and lids had all been transferred there. The modern Fuel Retrieval System installed in the K-West Basin in the late 1990s to handle and process the fuel, is now debris.

During 2005, the K Basins Closure Project made progress in cleaning out the K Basins as follows:

- Completed welding multi-canister overpacks holding the dried spent fuel with permanent, "N-Stamped" closure

welds (those meeting the highest nuclear quality standards of the American Society of Mechanical Engineers). Nearly 110 multi-canister overpacks were welded in 2005, and the welding subproject finished ahead of schedule.

- Transferred the Canister Storage Building to Fluor Hanford, Inc.'s Waste Storage and Disposal project soon after the welding work finished.
- Grappled, washed, and loaded out nearly 90 metric tons (100 tons) of debris from both K Basins including over 36 metric tons (40 tons) of fuel racks. The debris was packaged and readied for shipment to Hanford's Environmental Restoration Disposal Facility as low-level nuclear waste. Waste shipments from the K Basins to the Environmental Restoration Disposal Facility were ongoing from June 2005 through the end of the year.
- Continued pumping and containerizing sludge from the K-East Basin. Approximately 57% of the sludge was containerized during 2005.
- Installed new flocculent and settling systems to help quell water turbidity during sludge vacuuming.
- Completed installing all sludge collection tanks (total of 10 tanks) in the K-East and K-West Basins.
- Completed the removal of a small, distinct subset of sludge from one area of the K-East Basin – the North Loadout Pit – and shipped it to the T Plant in central Hanford. T Plant began final treatment of that sludge in October 2005 and had finished treating about one-third of the sludge by year's end.
- Permanently sealed the discharge chute of the K-West Basin by filling it with grout. Filling the discharge chute with grout sealed the construction joint between the K-West Basin and the K-West Reactor and permanently removed approximately 397,000 liters (105,000 gallons) of contaminated water from the K-West Basin (about 10% of the total water volume).
- Completed 60% of the design for the main portion of the Sludge Treatment System that will treat the bulk of K Basins sludge, and completed 90% of the design of key sub-parts of the system.
- Completed design and installation and began testing a Hose-in-Hose Transfer System that will transfer sludge from the K-East Basin to the K-West Basin – part of the route to the main Sludge Treatment System.

### 6.1.3.3 Defense Nuclear Facilities Safety Board Related K-Basins Accomplishments, DOE Richland Operations Office

S. M. Hahn

The DOE Richland Operations Office made progress on recommendations from the Defense Nuclear Facilities Safety Board in 2005 and continued to demonstrate DOE's commitment to safely cleaning up the Hanford Site.

The DOE Richland Operations Office completed its commitment to revise the Hanford section of an implementation plan for stabilizing nuclear material identified in Recommendation 2000-1.[(a)] An implementation plan identifies specific actions the DOE intends to take to meet the Board's recommendations which are issued to the Secretary of Energy on issues or circumstances the board determines need to be resolved to ensure adequate protection of the public health and safety. The revised Hanford section to the 2000-1 Implementation Plan modifies K-Basins Closure project commitments and due dates and provides a new cost and schedule baseline. The update to the implementation plan reflects new information on the techniques necessary to safely handle the sludge in the K Basins and appropriate contingency for the risks to the project. The revised implementation plan commitments are completing containerization of bulk sludge from the K Basins; completing transfer of sludge from the K-East Basin; removing containerized sludge from the K-West Basin and treating it to meet applicable waste acceptance criteria by November 30, 2009; and completing the removal of back-flushed filter sludge from the K-East North Load Out Pit.

(a) Letter from SW Bodman (Secretary of Energy, Washington, D.C.) to AJ Eggenberger (Chairman, Defense Nuclear Facilities Safety Board, Washington, D.C.), *Prioritization for Stabilizing Nuclear Materials*, dated November 28, 2005.

Specifically in 2005, the DOE Richland Operations Office and its contractor:

- Started work to remove the remaining radioactive sludge from the K-East and K-West Basins. The approximately 50 cubic meters (65 cubic yards) of sludge consists of fragments of concrete from the basin walls, windblown sand, and fuel-rod corrosion products.
- Retrieved, treated, and containerized the first radioactive sludge from a spent nuclear fuel pool. Approximately 4 cubic meters (5.2 cubic yards) of sludge was retrieved from the K-East Basin North Load Out Pit, pumped into large diameter containers, and transported to the T Plant where specialized equipment is being used to process the material. The large diameter containers are specially engineered steel vessels that are designed to be moved on transport trailers, and hold approximately 1.5 cubic meters (2 cubic yards) of sludge. By the end of November 2005, 33 drums of North Load Out Pit treated sludge were generated.
- Began installation of the hose-in-hose transfer system. As part of the K Basins Closure Project, radioactive sludge will be transferred from K-East Basin to the K-West Basin for containerization. During 2005, installation of the major components for the hose-in-hose transfer system was 100% completed.
- Containerized approximately 82% (34.9 cubic meters [45.6 cubic yards] of the total 42.6 cubic meters [55.7 cubic yards] of K-East Basin sludge.

The DOE Richland Operations Office also completed its commitment related to retrieval of 12 buried drums containing plutonium-238. These drums were safely retrieved, inspected, and relocated from the low-level burial grounds in October 2005.

The DOE Richland Operations Office provided the following 90-day responses to letters from the Defense Nuclear Facilities Safety Board statutory in 2005:

- A briefing on fire response procedures for the Plutonium Finishing Plant.
- A report on the sludge removal delays.
- A briefing on criticality safety issues associated with the Plutonium Finishing Plant.

### 6.1.3.4 Revegetation of 100-F Area and 100-N Area Waste Sites

A. L. Johnson

***100-F Area***. Bechtel Hanford, Inc.'s Remedial Action project initiated remediation of several waste sites within the 100-FR-1 Operable Unit in the 100-F Area in 2000. The remedial action objectives and goals were established by the EPA and Washington State Department of Ecology, in concurrence with the DOE Richland Operations Office and documented in the *Amendment to the Interim Action Record of Decision for the 100-BC-1, 100-DR-1, and 100-HR-1 Operable Units* (EPA/541/R-97/044) and the *Remedial Design Report/Remedial Action Work Plan for the 100 Area* (DOE/RL-96-17). The sites were excavated to the extent required to meet specified soil cleanup levels, the contaminated materials were disposed of at the Environmental Restoration Disposal Facility, and the sites were backfilled with fill from a local borrow source and contoured to match the adjacent area in fall 2003. The backfill material consisted of rocky cobble with some course sand.

The backfilled and re-contoured waste sites and local borrow source were revegetated with a native seed mix in January 2005. The seed mix and seeding rates included Sandberg's bluegrass (*Poa sandbergii*), 22.4 kilograms per hectare (20 pounds per acre); bluebunch wheatgrass (*Agropyron spicatum*), 11.2 kilograms per hectare (10 pounds per acre); thickspike wheatgrass (*Agropyron dasytachyum*), 11.2 kilograms per hectare (10 pounds per acre); Indian ricegrass (*Oryzopsis hymenoides*), 11.2 kilograms per hectare (10 pounds per acre); prairie junegrass (*Koeleria cristata*), 11.2 kilograms per hectare (10 pounds per acre); and needle-and-thread grass (*Stipa comata*), 2.24 kilograms per hectare (2 pounds per acre). Upon the completion of seeding, the entire area was irrigated with 23,400 liters per hectare (2,500 gallons per acre) then mulched with 4.5 metric tons per hectare (2 tons per acre) of grass straw, which was crimped into the soil surface to prevent wind erosion.

Sagebrush plants were grown from seeds collected on the Hanford Site. Fifty-five thousand, sagebrush (*Artemisia tridentata*) seedlings were planted across the remediated waste sites and borrow area.

***100-N Area***. The 116-N-3 crib, trench, and pipeline were remediated to remedial action objectives, remedial action goals, and closure performance standards established by the EPA and Washington State Department of Ecology in concurrence with the DOE Richland Operations Office. The goals and objectives are documented in the *100-NR-1 Interim Remedial Action Record of Decision* (Ecology 2000) and the *Remedial Design Report/Remedial Action Work Plan for the 100-NR-1 Treatment, Storage, and Disposal Units* (DOE/RL-2000-16).

The area in and around the 116-N-3 trench contains unusual depositional features, referred to as giant ripples, created by cataclysmic floods during the late Pleistocene. These features appear as small hills north and east of the N Reactor. Portions of the project area fall within these hills. This area is known as *Mooli Mooli* (little stacked hills) to local Native American Tribes and is significant as an area that contains legends, stories, and spiritual power that remain important to their religion, traditions, and cultural heritage. The 116-N-3 trench was constructed within a portion of *Mooli Mooli*. The hills within the trench construction boundary were removed leaving a flat linear structure within the traditional cultural area. Because of the significance of *Mooli Mooli* to local Native American Tribes, Bechtel Hanford, Inc. remedial action and cultural resources staff, in conjunction with tribal members, developed a backfill re-contour design to restore the previously removed portions of *Mooli Mooli*. Backfill and re-contour operations were initiated in August and continued through the end of December 2004. Revegetation activities on the 116-N-3 area were initiated in mid-January 2005. Revegetation of the trench included broadcast seeding a native grass seed mix consisting of Sandberg's bluegrass, Indian ricegrass, prairie junegrass, bluebunch wheatgrass, thickspike wheatgrass, and needle-and-thread grass with a hydroseeder. Upon the completion of seeding, the entire area was irrigated with 23,400 liters per hectare (2,500 gallons per acre) then mulched with 4.5 metric tons per hectare (2 tons per acre) of grass straw, which was crimped into the soil surface to help hold it in place.

Sagebrush and spiny hopsage (*Grayia spinosa*) tublings were grown on contract with a native plant nursery from seeds collected on the Hanford Site. There were 13,050 seedling shrubs, 11,500 sagebrush, and 1,550 spiny hopsage planted across the remediated waste site and onsite borrow area.

## 6.1.4 Remediation of Waste Sites in the 300 Area

J. W. Donnelly, S. Parnell, and A. K. Smet

Full-scale remediation work began in the 300 Area in 1997 and was focused on the 300-FF-1 Operable Unit waste sites and several 300-FF-2 Operable Unit waste sites. Remediation of the 300-FF-1 Operable Unit waste sites is complete, including backfill and revegetation. These activities were completed in February 2004.

Remediation efforts in 2005 focused on the 300-FF-2 Operable Unit waste sites. The 300-FF-2 Operable Unit record of decision (EPA 2001) authorized remediation activities for the 300-FF-2 Operable Unit. Remediation for the 300-FF-2 Operable Unit began in September 2002. Remediation activities included sampling to determine if suspected waste sites exceeded cleanup objectives, sampling to confirm cleanup objectives were met, physical excavation operations, waste sorting and segregation, waste sampling, waste treatment, waste disposal, backfill, and revegetation.

The waste sites vary in complexity and types of waste. Typical waste sites include waste burial grounds and miscellaneous waste sites. The primary focus early in the cleanup process was to address waste sites in the 300-FF-1 Operable Unit, which were sites containing significant quantities of waste and serving as large potential sources of groundwater contamination. When the 300-FF-1 Operable Unit waste sites were completed, the focus for cleanup switched to waste burial grounds and other miscellaneous waste sites. Each of these two waste groups presents challenges.

Waste burial grounds require cleanup but also present a significant health and safety risk to workers due to incomplete disposal records and the potential for discovering unknown material disposed from past disposal practices. For example, materials are discovered that are unknown and require further characterization, or containers are discovered with no marking or labeling are require further characterization. Characterization is critical to ensure the safety of workers and the proper management of the waste for potential treatment and disposal. Discovery of unknown material requires additional time and planning to ensure the proper protective gear is utilized in the field to characterize

the material and to verify that the limits and controls identified in approved authorization documents, required by DOE, are adequate for the scope of work. If authorization documents do not adequately cover the material discovered, work is stopped until the proper documentation can be revised and work safely restarted. Based on the characterization results, additional waste treatment may be required before disposal.

Significant challenges for remediation are present at the 618-10 and 618-11 burial grounds. In August 2005, these two waste sites were transferred from Fluor Hanford, Inc. to Washington Closure Hanford, LLC. After the sites were transferred, Washington Closure Hanford, LLC began developing a design solution for the sites. The design solution will evaluate removal and packaging technologies and disposal pathways to determine the most cost-effective methods for remediating these waste sites.

The 618-10 burial ground, located just west of Route 4 South, was operated from 1954 to 1963 and is approximately 2.1 hectares (5.2 acres) in size. The 618-11 burial ground, located close to the Energy Northwest nuclear power plant, was operated from 1962 to 1967 and is approximately 3.5 hectares (8.6 acres) in size. Both burial grounds received waste including transuranic material from the 300 Area laboratory facilities. The burial grounds consist of multiple trenches, vertical pipe units, and caissons.

The waste sites in the 300-FF-2 Operable Unit are authorized for remediation activities through the issuance of a record of decision approved by the EPA, DOE, and Washington State Department of Ecology (EPA 2001). Waste generated from the cleanup of these waste sites is disposed of at Hanford's Environmental Restoration Disposal Facility located in the 200 Areas; the Waste Isolation Pilot Plant in Carlsbad, New Mexico; and other disposal facilities approved by the EPA. The Environmental Restoration Disposal Facility is discussed in Section 6.3.3.6.

A total of 78,054 metric tons (86,057 tons) of contaminated soil from the 300-FF-2 Operable Unit was disposed at the Environmental Restoration Disposal Facility in 2005. No waste was shipped to the Waste Isolation Pilot Plant.

## 6.1.5 Remediation of Waste Sites in the Former 1100 Area

In calendar year 2005, additional remediation was necessary at one waste site in the 1100-IU-1 Operable Unit. This waste site was the Horseshoe Landfill located on the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit of the Hanford Reach National Monument. In 1996, this waste site was previously remediated, backfilled, revegetated, and deleted from the National Priorities List in 1996.

Additional sampling in October 1999 and between October 2001 through May 2002 indicated the presence of contaminants above the soil cleanup standards. The DOE obtained approval from the EPA in May 2005 to conduct further soil remediation by issuing a memo-to-file to re-activate the original 1100 Area record of decision (EPA/ROD/R10-93/063).

Excavation operations began in May 2005 and were completed by August 2005. A total of 10,548 metric tons (11,630 tons) of contaminated soil was disposed of at the Environmental Restoration Disposal Facility located in Hanford's 200 Areas. Following excavation, verification sampling was performed, and the cleanup standards were achieved. Backfill was performed from November to December 2005, with revegetation scheduled for early 2006.

# 6.2 Facility Decommissioning Activities

This section provides information about the transition of facilities on the Hanford Site from operation to stabilization, surveillance and maintenance, and decommissioning. Decommissioning activities include the interim safe storage of plutonium production reactors and the decommissioning of ancillary reactor facilities.

## 6.2.1 Facility Decommissioning in the 200 Areas (Central Plateau)

This section provides information about the transition and decommissioning of facilities within the 200 Areas.

### 6.2.1.1 Removal of Ancillary Facilities at the 221-U Chemical Processing Facility

D. L. Klages

The 221-U Chemical Processing Facility (U Plant) ancillary facilities are being decontaminated and demolished as a CERCLA non-time-critical removal action. The facilities are located within the U Plant complex in the 200-West Area and consist of processing, support, and administrative buildings.

The main building associated with the U Plant ancillary facilities is the Uranium Trioxide Facility (224-U), which was used to convert uranyl nitrate hexahydrate solution from the Plutonium-Uranium Extraction (PUREX) Plant into a solid uranium trioxide powder. The Uranium Trioxide Facility's processing schedule was determined by the uranium product inventory buildup at the PUREX Plant. The last operating campaign was completed in June 1993, and deactivation of the facility began shortly thereafter. The Uranium Trioxide Facility is designated as a key facility in the Tri-Party Agreement (Ecology et al. 1989). The majority of the other U Plant buildings and structures were used in support of the uranium trioxide process.

The U Plant ancillary facilities removal action began in November 2004 and demolition of 11 structures was successfully completed in September 2005. The U Plant ancillary facilities decontamination and decommissioning project has lost its funding by DOE due to higher priority needs and limited funding availability. Therefore, the CERCLA removal action for the U Plant ancillary facilities is on hold until additional funding is available.

### 6.2.1.2 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 1990, DOE issued a shutdown order for the plant, and in 1996 authorized deactivation and transition of the plutonium processing portions of the facility in preparation for decommissioning.

Significant accomplishments achieved at the Plutonium Finishing Plant during 2005 included the following:

- Cleaned out contaminated equipment from 53 plutonium processing gloveboxes and "hoods" (open-faced enclosures used for working with plutonium). Thirty-seven of these gloveboxes and hoods were downgraded to low-level waste status. This cleanout work included all of the gloveboxes and hoods in the Plutonium Finishing Plant's standards laboratory; therefore, the laboratory was brought to low-level waste status and closed in July 2005.

- Completed the removal of all of the designated legacy plutonium "held up" in processing equipment in Plutonium Finishing Plant facilities. The amount removed in 2005 totaled just over 50% of the total amount removed. Just under 50% was removed in 2004.
- Continued entries into the highly contaminated Plutonium Reclamation Facility "canyon" area to reactivate the canyon crane and perform decontamination work necessary to use the crane in cleanout work. Deployed a robot named "TRUDY" to capture and remove samples from the Plutonium Reclamation Facility canyon floor. Passed a readiness assessment to remove highly contaminated tanks and vessels attached to the Plutonium Reclamation Facility canyon walls.
- Continued cleanout in four of the five cells beneath the 241-Z Facility.
- Removed the incinerator glovebox in the 232-Z Incinerator building in June 2005 and began cleanout of the highly contaminated "scrubber cell" in the building.
- Decontaminated and packaged for shipment 178 additional "product solution containers" (highly contaminated drums that once held plutonium nitrate) stored beneath the 234-5Z Facility. Combined with the 176 that were decontaminated and packaged in 2004, a total of 354 of 625 product solution containers have been so treated. Three hundred and eighteen of the solutions containers were shipped out of the Plutonium Finishing Plant complex as waste.
- Removed three non-contaminated ancillary buildings within the Plutonium Finishing Plant complex, including the 190,000-liter (50,000-gallon), 43-meter (140-foot) tall, water tower that had stood at the Plutonium Finishing Plant for 56 years.
- Performed characterization entries into the 242-Z Waste Treatment Facility, in preparation for future cleanout. These entries were only the second ones since the facility was contaminated in a major accident in 1976.
- Eliminated the entire Materials Access Area in the main 234-5Z Building.

### 6.2.1.3 Surveillance, Maintenance, and Deactivation Activities in the 200 Areas and on the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit

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 Unit.

Facilities include interim status RCRA treatment, storage, and disposal units awaiting closure, the canyon facilities (PUREX Plant, B Plant, Reduction-Oxidation [REDOX] Plant, and U Plant), two operating major air emission units, and three operating minor emission stacks.

In 2005, the Washington State Department of Health and EPA approved management of the B Plant stack as a minor stack; a public review was conducted because of the significant modification to the site air operating permit. Because of a negative comment received during the public review, and the need to change the B Plant filters sooner than expected, the Washington State Department of Health and EPA rescinded their downgrade approval.

In support of downgrading the PUREX Plant stack to a minor stack, an efficiency test of the stack's deep bed fiberglass filters was conducted and the information was provided to the regulatory agencies. Since approval for the downgrade could not be obtained in time, a lift was installed to meet the new requirement for inspecting and cleaning the sample probe and line on major stacks. This work was done in addition to the normal surveillance and maintenance activities to make certain that the facilities were secure and maintained and did not pose a threat to human health or the environment.

Surveillance, maintenance, and decontamination or stabilization of over 500 waste sites including former cribs, ponds, ditches, trenches, unplanned release sites, and burial grounds continued in 2005. Periodic surveillances, radiation surveys, and herbicide applications were performed at these sites and timely responses to identified problems were initiated. The

overall objective was to maintain these sites in safe and stable configurations and to prevent contaminants at these sites from spreading in the environment.

#### 6.2.1.4 Investigating the Potential for Using the 200 Areas Chemical Separations Plants as Waste Disposal Facilities

J. R. Robertson

The Canyon Disposition Initiative was created to investigate the potential for using the five canyon buildings (B Plant, T Plant, U Plant, PUREX Plant, and REDOX Plant) at the Hanford Site as disposal facilities for Hanford Site remediation waste, rather than demolishing the structures. While planning and sampling activities of the Canyon Disposition Initiative actually began in the mid-1990s, the bulk of the work to prepare the final feasibility study (DOE/RL-2001-11, Rev. 0) was completed in 2001 as the final phase of the CERCLA remedial investigation/feasibility study for disposition of the U Plant. The U Plant was used as the pilot project for the Canyon Disposition Initiative.

In December 2004, the Canyon Disposition Initiative (221-U Facility) final feasibility study (DOE/RL-2001-11, Rev. 1) and the associated proposed plan (DOE/RL-2001-29) were released for public review. These documents examine five alternatives for the remediation of the 221-U facility: (1) no action, (2) full removal and disposal, (3) entombment with internal waste disposal, (4) entombment with internal and external waste disposal, and (5) close-in-place/collapsed structure. In September 2005, EPA issued the 221-U Facility (Canyon Disposition Initiative) record of decision (DOE et al. 2005), selecting the close-in-place/collapsed structure alternative. In accordance with the record of decision, process equipment already in the plant will be consolidated into the below-ground plant process cells; the cells, galleries, and void spaces will be backfilled with grout; the exterior walls and roof will be collapsed in place; and the site will be covered with a barrier. No waste will be imported into U Plant as a part of the remedial action. While U Plant remediation is a prototype for the remaining canyon buildings, it is anticipated that remedial action decisions will be reached independently for each of the remaining canyons, taking into account the significant differences between each canyon building.

### 6.2.2 Decommissioning of Facilities in the 300 Area

J. W. Golden

This section provides information about the transition and decommissioning of facilities within the 300 Area.

#### 6.2.2.1 Deactivation of the 327 and 324 Facilities

Construction of the 327 and 324 Buildings was completed and operations began in 1953 and 1966, respectively. These facilities contain hot cells that were used for radiological research and development work. The facilities were formally transferred to Washington Closure Hanford, LLC from Fluor Hanford, Inc. in August 2005. An engineering evaluation cost analysis was prepared to support demolition of the facilities. It is expected that the action memorandum to implement the recommendation of the cost analysis will be issued in mid-2006.

Significant accomplishments achieved at the 327 Building during 2005 included:

- Initiating equipment and facility preparations for removing remaining waste items to support the 327 Building portion of a Tri-Party Agreement milestone. Activities were proceeding on track for completion ahead of the September 30, 2006, milestone due date.
- Maintaining the 327 Building in surveillance and maintenance mode in compliance with safety and regulatory requirements.

During 2005, the 324 Building was maintained in surveillance and maintenance mode in compliance with safety and regulatory requirements.

#### 6.2.2.2 Status of the 309 Plutonium Recycle Test Reactor Facility

The original 309 Plutonium Recycle Test Reactor Facility mission was to provide an operating test reactor to research and develop nuclear fuel technology during the 1960s. The facility was shut down in 1969. It currently contains a cold replica of the Fast Flux Test Facility Interim Examination and Maintenance Cell (built in 1975), which has been used

by Fast Flux Test Facility staff for training. Facility disposition is to be completed by the contractor managing the River Corridor Closure contract. Activities at the 309 facility during 2005 included surveillance and maintenance activities to maintain compliance with facility and regulatory requirements.

#### 6.2.2.3 Decommissioning of the 313 and 314 Buildings

The 313 and 314 Buildings were used during the 1950s to support uranium metal fuel fabrication development and engineering activities associated with Hanford's production reactors. The 313 Building was used during the 1980s for N Reactor fuel fabrication activities. The 314 Building was used during the 1970s through 1990s for laboratory work. During 2005, the 313 and 314 Buildings were demolished to slab, and the materials were disposed of at the Environmental Remediation Disposal Facility. The slabs and any underlying soil contamination will be addressed as part of a future remedial action.

### 6.2.3 Decommissioning of Facilities in the 400 Area

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 was placed in a standby mode in December 1993. After multiple studies, a final decision was made in 2002 to complete the deactivation of the facility, including removing all nuclear fuel, draining the sodium systems, and deactivating systems and equipment to a low-cost surveillance and maintenance state.

In 2005, the Fast Flux Test Facility continued with deactivation. The final 13 interim spent nuclear fuel storage casks were fabricated and delivered. The remaining fuel was removed from the first of the two sodium filled spent fuel storage vessels. Sixty-nine fueled components were washed and packaged into ten interim storage casks; these components included three assemblies that required disassembly either to identify and isolate failed fuel pins or to facilitate the washing process to fully remove the sodium. Two of the interim storage casks were transferred to the 200 Areas Interim Storage Area while the remainder is stored in the 400 Area Interim Storage Area.

An access hole was drilled through the core support structure in the reactor vessel to insert a suction pump. This was a DOE first-of-kind effort in which a drill bit at the end of a 15.2-meter (50-foot) long drive-line was used to drill into the stainless steel core support structure that was immersed in molten sodium. The drilling allowed access to molten sodium within the support structure that would not readily drain. Subsequently, approximately 160,000 liters (42,300 gallons) of sodium were pumped from the reactor vessel to the Sodium Storage Facility. In addition, 117,000 liters (31,000 gallons) of sodium were transferred from the Fuel Storage Facility vessel to the Sodium Storage Facility. In total, 849,000 liters (224,200 gallons) of Fast Flux Test Facility sodium are now stored in the Sodium Storage Facility tanks. The sodium has been allowed to cool and solidify in the tanks. About 15% of the original sodium remains in the Fast Flux Test Facility with two-thirds of that in the remaining fuel storage vessel and the remainder characterized as "residual sodium."

### 6.2.4 Decommissioning of Facilities in the 100 Areas

J. W. Golden

Decontamination and decommissioning activities continued during 2005 in the 100-K, 100-H, and 100-N Areas. The interim safe storage of the H Reactor was completed in fiscal year 2005. These activities were conducted as non-time critical removal actions under CERCLA.

Facilities demolished in the 100-N and 100-K Areas in 2005 included the 1900-N water tanks, 1802-N pipe trestle, and 183-KW and 183.1-KW water treatment facilities.

# 6.3 Waste Management Operations

This section provides information about liquid and solid waste management on the Hanford Site. The underground single-shell and double-shell waste storage tanks and the status of the Hanford Tank Waste Treatment and Immobilization Plant (Waste Treatment Plant) construction are also discussed.

## 6.3.1 Waste Classifications

L. P. Diediker and D. L. Dyekman

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 underground waste storage 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-2006-13). Dangerous waste is treated, stored, and prepared for disposal at several Hanford Site facilities. Dangerous waste generated at the site also is shipped offsite for disposal or destruction. Some types of dangerous waste, such as used lead acid batteries and used aerosol products (e.g., spray paint), 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.

## 6.3.2 Solid Waste Inventories

L. P. Diediker and D. L. Dyekman

Solid waste program activities are regulated by RCRA and the *Toxic Substances Control Act*, as discussed in Section 5.1.

Solid waste quantities generated onsite or received from offsite and disposed of at the Hanford Site from 2000 through 2005 are shown in Tables 6.3.1 and 6.3.2. Quantities of dangerous waste shipped offsite from 2000 through 2005 are shown in Table 6.3.3.

**Table 6.3.1. Quantities of Solid Waste[a] Generated on the Hanford Site, 2000 through 2005, kg (lb)**

| Waste Category | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|
| Mixed | 441,000<br>(972,500) | 328,500<br>(724,300) | 1,025,000<br>(2,260,100) | 421,000<br>(928,300) | 144,512<br>(318,600) | 349,416<br>(770,500) |
| Radioactive | 700,000<br>(1,543,500) | 1,675,200<br>(3,693,800) | 1,588,000<br>(3,501,500) | 758,000<br>(1,671,400) | 906,591<br>(1,999,000) | 1,188,212<br>(2,620,000) |

(a) Solid waste includes containerized liquid waste.

**Table 6.3.2. Quantities of Solid Waste[a] Received on the Hanford Site from Offsite Sources, 2000 through 2005, kg (lb)**

| Waste Category | 2000 | 2001 | 2002 | 2003 | 20041 | 2005 |
|---|---|---|---|---|---|---|
| Mixed | 1,381<br>(3,045) | 127,000<br>(280,000) | 112,000<br>(247,000) | 667,000[b]<br>(1,470,700) | 255,690[b]<br>(563,800) | 190,020[b]<br>(419,000) |
| Radioactive | 6,958,000<br>(15,342,400) | 4,736,500<br>(10,444,000) | 1,517,000<br>(3,345,000) | 407,000<br>(897,400) | 519,609<br>(1,145,700) | 83,123<br>(183,300) |

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

**Table 6.3.3. Quantities of Dangerous Waste[a] Shipped Off the Hanford Site, 2000 through 2005, kg (lb)**

| Waste Category | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|
| Containerized | 33,200[b]<br>(73,200) | 56,000[b]<br>(123,500) | 78,400[b]<br>(172,900) | 83,500[b]<br>(184,100) | 75,296[b]<br>(166,000) | 71,601[b]<br>(157,900) |
| | 315,500[c]<br>(695,700) | 2,600[c]<br>(5,700) | 3,500[c]<br>(7,700) | 91,800[c]<br>(202,400) | 49,560[c]<br>(109,300) | 61,422[c]<br>(135,400) |
| Bulk Solids | 0 | 0 | 0 | 0 | 0 | 0 |
| Bulk Liquids | 0 | 0 | 50,700<br>(111,800) | 48,400<br>(106,700) | 35,057<br>(77,300) | 49,154<br>(108,400) |
| **Total** | 348,700<br>(768,900) | 59,000<br>(130,100) | 132,500<br>(292,200) | 224,000<br>(493,900) | 159,913<br>(352,600) | 182,177<br>(401,700) |

(a) Does not include *Toxic Substances Control Act* waste.
(b) Dangerous waste only.
(c) Mixed waste (radioactive and dangerous).

## 6.3.3 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 received from offsite sources that are authorized by DOE to ship waste to the site. The following sections contain information regarding specific waste treatment, storage, or disposal locations at Hanford.

### 6.3.3.1 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 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 PCBs.

The Central Waste Complex can store as much as 20,796 cubic meters (734,418 cubic feet) of low-level mixed waste and transuranic waste. This capacity is adequate to store the projected volumes of low-level, transuranic, mixed waste, and radioactively contaminated PCBs to be generated from the activities identified above, assuming on-schedule treatment of the stored waste. Treatment will reduce the amount of waste in storage and make room for newly generated mixed waste. The dangerous waste designation of each container is established at the point of origin based on process knowledge or sample analysis.

### 6.3.3.2 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 radioactive waste and meets disposal requirements is buried onsite. Low-level radioactive waste not meeting 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 determined 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, which began operating in 1997, analyzes, characterizes, and prepares drums and boxes of waste for disposal. The 4,800-square-meter (52,000-square-foot) facility along with two 2,000-square-meter (21,900-square-foot) storage buildings is located north of the Central Waste Complex in the 200-West Area. The facility dispositioned and shipped offsite 1,570 cubic meters (55,442 cubic feet) of waste during 2005.

### 6.3.3.3 T Plant Complex

#### P. W. Martin

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 2005, the following activities occurred at the T Plant complex:

- Numerous containers and boxes of waste were re-packaged, treated, sampled, and characterized to meet waste acceptance criteria and land disposal restriction requirements.
- Air emissions filters were installed on approximately 800 radioactive waste containers at the T Plant complex as part of a venting process to address potential hydrogen gas buildup in the radioactive waste. Following venting, the drums were transferred to the Central Waste Complex and Waste Receiving and Processing Facility (both in the 200-West Area) for storage and eventual shipment to the Waste Isolation Pilot Plat in Carlsbad, New Mexico, for permanent disposal. The T Plant complex was chosen based upon Integrated Safety Management System requirements for contamination control, personnel safety, and reduced costs.

- Treatment of K-East Basin North Load Out Pit sludge began in October 2005 and is scheduled to conclude in May 2006. As of December 31, 2005, 5,027 liters (1,330 gallons) of sludge had been treated, generating ninety-three 208-liter (55-gallon) drums of grouted sludge.
- The weather cap on the T Plant ventilation stack was evaluated in September 2005 and determined to still be in good condition and not in need of replacement even after 63 years of continuous service.
- A new sample probe and sample line were installed on the T Plant ventilation stack in November 2005.
- Three new work stations were set up in the 221-T Canyon Building to repackage transuranic drums and/or process legacy waste.
- T Plant began operations to create a new access to the 221-T Canyon Building via the "head end" facility that is located at the northern endpoint of the Canyon Building. This second access point will facilitate waste movements into the canyon and also speed entry and exit of personnel, thus, increasing work efficiencies while reducing personnel exposures.

### 6.3.3.4 Mixed Low-Level Waste Treatment and Disposal Facility

#### D. E. Nester

During 2005, 1,421 cubic meters (1,858 cubic yards) of mixed low-level waste were treated and/or directly disposed. These included:

- 370 cubic meters (484 cubic yards) of waste, or approximately 1,780 drum equivalents (based on a standard 208-liter [55-gallon] drum), that 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 and trench 31 of the Radioactive Mixed Waste Disposal Facility.
- 200 cubic meters (262 cubic yards) of waste, or approximately 960 drum equivalents (based on a standard 208-liter [55-gallon] drum), that were thermally treated to RCRA land disposal restriction standards at the Pacific EcoSolutions facility located in Richland, Washington, and at Perma-Fix Environmental Services located in Oak Ridge, Tennessee. The treated waste was returned to Hanford and disposed of in trench 34 and trench 31 of the Radioactive Mixed Waste Disposal Facility
- 11 cubic meters (14 cubic yards) of waste, or approximately 53 drum equivalents, that 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.
- 144 cubic meters (188 cubic yards) of waste, or approximately 690 drum equivalents, that 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 by the generators to meet RCRA and state land disposal restrictions.
- 696 cubic meters (910 cubic yards) of waste, or approximately 3,350 drum equivalents, that were shipped from the Central Waste Complex to the Environmental Restoration Disposal Facility where the waste was treated and disposed. The waste was all originally from the 183-H evaporation basins and had been stored in the Central Waste Complex since the late 1980s. Approval to dispose of this waste at the Environmental Restoration Disposal Facility was obtained through an engineering evaluation and cost analysis determination, which was approved in July 2003.

### 6.3.3.5 Disposal of Navy Reactor Compartments

#### S. G. Arnold

There were no defueled U.S. Navy reactor compartments shipped to trench 94 in the 200-East Area during 2005. The total number remains at 114. 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 metric tons (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 metric tons (1,500 tons).

### 6.3.3.6 Environmental Restoration Disposal Facility

M. A. Casbon

The Environmental Restoration Disposal Facility is located near the 200-West Area. The facility began operations during July 1996 and serves as the central disposal site for contaminated waste removed during cleanup operations conducted under CERCLA on the Hanford Site.

To provide a barrier to contaminant migration from the facility, the Environmental Restoration Disposal Facility was constructed to RCRA Subtitle C Minimum Technology Requirements including a double liner and leachate collection system. Remediation waste disposed in the facility includes soil, rubble, or other solid waste materials contaminated with hazardous, low-level radioactive, or mixed (combined hazardous and radioactive) waste.

There are currently six waste cells associated with the Environmental Restoration Disposal Facility site. Initially, cells 1 and 2 were constructed and the placement of waste in these cells is nearly complete. An interim cover has been placed over the parts of cells 1 and 2 that have been brought up to grade. Cells 3 and 4 were later constructed at the site and are currently receiving waste. Construction of cells 5 and 6 has been completed and the cells began receiving waste in January 2005. All six cells are roughly equal in size. During 2005, approximately 921,540 metric tons (1,015,824 tons) of remediation wastes were disposed at the facility. A total of approximately 5.7 million metric tons (6.3 million tons) of remediation wastes have been placed in the Environmental Restoration Disposal Facility from initial operations start-up through 2005. The total available expansion area of the Environmental Restoration Disposal Facility site was authorized in the 1995 record of decision (EPA/ROD/R10-95/100) to cover as much as 4.1 square kilometers (1.6 square miles).

### 6.3.3.7 Radioactive Mixed Waste Disposal Facility

D. E. Nester

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 3,900 cubic meters (137,700 cubic feet) of waste disposed in 3,460 waste packages in trench 34. During the summer of 2004, the first operational layer of waste packages was covered with compacted gravel and soil. The second waste layer was started and continues to be filled.

Trench 31 became operational for disposal during July 2004. Currently, there are approximately 130 cubic meters (4,600 cubic feet) of waste disposed in 170 waste packages in trench 31.

Trenches 31 and 34 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.

These disposal units were originally designated for disposal of mixed low-level waste only; however, beginning in July 2004, disposal of low-level waste in unlined trenches at Hanford ceased, and now Hanford's low-level waste is being disposed of in trenches 31 and 34.

### 6.3.3.8 Low-Level Burial Grounds

D. G. Saueressig

The low-level burial grounds consist of eight burial grounds located in the 200-East and 200-West Areas, which are used for the disposal of low-level waste and mixed waste (i.e., low-level radioactive waste with a dangerous waste component regulated by WAC 173-303). The low-level burial grounds have been permitted under a RCRA Part A permit since 1985.

Three trenches receive mixed waste regulated by WAC 173-303. Trenches 31 and 34 in burial ground 218-W-5 are lined trenches with leachate collection and removal systems (Sections 6.3.3.4 and 6.3.3.7). Trench 94

in burial ground 218-E-12B is used for disposal of defueled navy reactor compartments (Section 6.3.3.5). Low-level waste and transuranic waste have been placed in the other burial grounds. Transuranic waste has not been placed in the low-level burial grounds without specific DOE approval since August 19, 1987. Soil is placed over some of the waste containers to provide radiological protections. The transuranic waste was placed in a manner that allows for retrieval and/or removal in the future.

On June 23, 2004, DOE issued a record of decision (69 FR 39449) for the Solid Waste Program at Hanford. Part of the record of decision stated that DOE will dispose of low-level waste in lined disposal facilities. Only two of the low-level burial ground trenches are lined (trenches 31 and 34); therefore, since that date, all low-level waste as well as mixed low-level waste is being disposed in these two trenches (Section 6.3.3.7). Disposal of navy reactor compartments (Section 6.3.3.5) in the low-level burial grounds is not affected by this record of decision.

Retrieval of suspect-transuranic retrievably stored waste in the 218-W-4C burial ground was initiated in October 2003 in accordance with the Tri-Party Agreement Change Number M-91-03-01. Retrieval of suspect-transuranic retrievably stored waste continues in accordance with Tri-Party Agreement Milestone M-91-40.

A draft revision to the Part B permit application for the low-level burial grounds was submitted to the Washington State Department of Ecology in June 2002. Discussions between the DOE and the state concerning the permit application are ongoing. In addition, the low-level burial grounds are included in a draft remedial investigation/feasibility study work plan completed December 2004 (DOE/RL-2004-60). The plan outlines possible characterization and remediation activities for specified landfills and dump sites at Hanford.

## 6.3.4 Liquid Waste Management

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.

### 6.3.4.1 Liquid Effluent Retention Facility

M. D. Guthrie

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 for a steady flow and consistent 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 operating 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 and bentonite clay barrier, should both 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 2005 was approximately 13.2 million liters (3.49 million gallons). The wastewater received for interim storage during 2005 included approximately 1.88 million liters (497,000 gallons) of RCRA-regulated wastewater (primarily 242-A evaporator process condensate and mixed-waste trench leachate) and approximately 11.3 million liters (2.99 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 originating facility. Approximately 1.65 million liters (436,000 gallons) of wastewater were received from various facilities by tanker trucks. The volume of wastewater transferred to the Effluent Treatment Facility for treatment and disposal during 2005 was 23.8 million liters (6.30 million gallons).

The volume of wastewater being stored in the Liquid Effluent Retention Facility at the end of 2005 was 38.95 million liters (10.29 million gallons). This included 4.09 million liters (1.08 million gallons) of RCRA-regulated wastewater and 34.86 million liters (9.21 million gallons) of CERCLA-regulated wastewater.

### 6.3.4.2 Effluent Treatment Facility

M. D. Guthrie

The Effluent Treatment Facility (200-East Area) treats liquid effluent 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 and 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 2005 was approximately 23.8 million liters (6.30 million gallons). This was primarily CERCLA-regulated wastewater (groundwater from the 200-UP-1 Operable Unit in the 200-West Area and Environmental Restoration Disposal Facility leachate).

### 6.3.4.3 200 Area Treated Effluent Disposal Facility

M. D. Guthrie

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 and all known available and reasonable treatment in accordance with *Submission of Plans and Reports for Construction of Wastewater Facilities* (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 pipelines 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 2005 was 442.8 million liters (117.0 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.

### 6.3.4.4 300 Area Treated Effluent Disposal Facility

M. D. Guthrie

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 and 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 02591-7 [Section 5.4.1]). The volume of industrial wastewater treated and disposed of during 2005 was 135.8 million liters (35.88 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 2005 was 10.14 million liters (2.68 million gallons).

### 6.3.4.5 242-A Evaporator

T. L. Faust

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 waste storage tanks for storage and reduces the potential need for additional double-shell tanks. The 242-A evaporator completed one campaign during calendar year 2005. The volume of waste treated was 1.966 million liters (519,300 gallons), reducing the waste volume by 706,700 liters (186,700 gallons), or approximately a 36% reduction of the total volume. The volume of process condensate transferred to the Liquid Effluent Retention Facility for subsequent treatment in the Effluent Treatment Facility was 745,700 liters (197,000 gallons).

### 6.3.4.6 Status of DOE Order 435.1, Radioactive Waste Management

S. D. Stubblebine

DOE Order 5820.2A, *Radioactive Waste Management*, was issued in 1988. During September 1994, the Defense Nuclear Facilities Safety Board issued *Recommendation 94-2, Conformance with Safety Standards at DOE Low-Level Nuclear Waste and Disposal Sites*, addressing problems with 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 was invalid. The ruling applied to that portion of the order that allows radioactive waste that is incidental to reprocessing to be managed as low-level radioactive waste. Such determination is viewed by the DOE as important to speeding the treatment and reducing associated disposal costs of radioactive liquid wastes generated by the DOE's prior reprocessing of spent nuclear fuel. Under the Order, waste incidental to reprocessing that remains in Hanford waste storage tanks could be disposed of in place as low-level waste rather than being disposed of in a repository as high-level waste. The Natural Resources Defense Council, along with others, challenged the provision as inconsistent with the *Nuclear Waste Policy Act*. The court agreed that part of DOE Order 435.1 was inconsistent with the *Nuclear Waste Policy Act* and held that portion invalid.

DOE appealed this decision to the Ninth Circuit Court of Appeals. The Court of Appeals issued a unanimous decision on November 5, 2004, determining that the case was not ripe for decision and reversed and remanded it to the District Court with instrution to dismiss. In other words, the Ninth Circuit Court of Appeals concluded that since the case did not involve actual application of DOE Order 435.1, there were no facts upon which to determine how DOE would apply the rule, and, therefore, the plaintiffs had filed their action prematurely. Plaintiffs filed petitions with the three-judge panel that decided the case and the full bench of the Ninth Circuit Court of Appeals to grant a re-hearing but these petitions were denied. The District Court of Idaho dismissed the case in accordance with the direction of the Ninth Circuit Court of Appeals on March 6, 2006.

# 6.4 Underground Waste Storage Tanks

Much of the waste stored at Hanford is contained in large underground single-shell (one wall) and double-shell (two walls) tanks. These tanks are located in the 200 Areas; a grouping of tanks is referred to as a tank farm. The single-shell tanks are older, and some are known to have leaked. Liquid in the single-shell tanks is being transferred to double-shell tanks to prevent additional environmental releases. The following sections summarize waste-tank-related activities that took place in 2005.

## 6.4.1 Waste Tank Status

L. P. Diediker and D. L. Dyekman

This section provides information about the 149 single-shell and 28 double-shell tanks on the Hanford Site and activities related to their closure. The quantities of liquid waste generated in 2005 and stored in underground storage tanks are included in an annual dangerous waste report (e.g., DOE/RL-2006-13). Table 6.4.1 is a summary of the liquid waste generated from 2000 through 2005 and stored in underground storage tanks.

### 6.4.1.1 Single-Shell Tanks

J. D. Guberski

The Tri-Party Agreement (Ecology et al. 1989) formally establishes a schedule for interim stabilization, retrieval, and closure of the Hanford 200 Areas waste storage tanks. Interim stabilization is achieved by removing pumpable liquid from a tank; pumpable liquid is that which 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 specified in a Tri-Party Agreement milestone. Waste

**Table 6.4.1. Quantities of Liquid Waste[a] Generated and Stored Within the Tank Farm System on the Hanford Site During 2005 and During Each of the Previous 5 Years, L (gal)**

| Type of Waste | 2000[b] | 2001[b] | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|
| Volume of waste added to double-shell tanks | 8,920,000 (2,357,000) | 2,980,000 (788,000) | 9,280,000 (2,452,000) | 9,710,000 (2,565,000) | 3,316,000 (876,000) | 3,668,000 (969,000) |
| Total volume in double-shell tanks (year end) | 79,630,000 (21,038,000) | 79,980,000 (21,131,000) | 87,683,000 (23,166,000) | 92,693,000 (24,487,000) | 95,275,000 (25,169,000) | 98,943,000 (26,138,000) |
| Volume evaporated at 242-A evaporator | 2,580,000 (682,000) | 2,580,000 (682,000) | 1,578,000 (417,000) | 4,720,000 (1,247,000) | 734,000 (194,000) | 706,700 (186,700) |
| Volume pumped from single-shell tanks[c] | 2,250,000 (595,000) | 590,000 (155,000) | 5,288,000 (1,397,000) | 6,185,000 (1,634,000) | 2,778,000 (734,000) | 888,000 (234,714) |

(a) Quantity of liquid waste is defined as liquid waste sent to double-shell underground storage tanks during these years, rounded to the nearest 1,000. This does not include containerized (e.g., barreled) waste 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 (e.g., barreled) waste included in the solid waste category.
(c) Volume does not include dilution or flush water.

removed from a single-shell tank during stabilization and retrieval activities is transferred to the double-shell tank system.

The Tri-Party Agreement established a September 2004 due date for completion of single-shell tank interim stabilization. CH2M HILL Hanford Group, Inc. concluded its interim stabilization field work approximately 6 months ahead of this schedule. During 2005, CH2M HILL Hanford Group, Inc. continued to collect data to document that tank-specific interim stabilization criteria have been met.

During 2005, CH2M HILL Hanford Group, Inc. continued post-retrieval evaluation of the modified sluicing retrieval technology, used in combination with acid dissolution, for waste retrieval in tank 241-C-106. The use of saltcake dissolution technology, where water is used to dissolve and mobilize tank waste, continued at tank 241-S-112. During 2005, CH2M HILL Hanford Group, Inc. also implemented an additional retrieval technology, the mobile retrieval system, intended for use on solid waste. The mobile retrieval system 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). The articulated mast, coupled with a vacuum retrieval system, was deployed for retrieval of waste in the four C-200 series tanks, the first being tank 241-C-203, followed by tanks 241-C-202 and 24-C-201. Retrieval of tank 241-C-204 is expected to occur in 2006.

### 6.4.1.2 Double-Shell Tanks

J. D. Guberski

The tank farms contain 28 double-shell tanks. Current fill limits give the double-shell tank system a storage capacity of approximately 119 million liters (31.44 million gallons). This storage space is being managed to store waste pending treatment by the Waste Treatment Plant or a supplemental treatment process (i.e., bulk vitrification). At the end of 2005, there were 98.9 million liters (26.1 million gallons) of waste in the double-shell tanks. During 2005, 3.63 million liters (960,000 gallons) of waste were transferred from the single-shell tank system into the double-shell tank system. Waste was received from single-shell tanks 241-C-103, 241-C-203, 241-C-202, 241-S-112, and 241-S-102.

### 6.4.1.3 Tank Farms Projects

C. M. Fetto

***Retrieval of Wastes from Single-Shell Tanks***. The DOE Office of River Protection completed removing all of the pumpable liquids from all single-shell tanks. This activity greatly reduces the potential for leakage from the single-shell tank system.

The DOE Office of River Protection performed waste retrieval on four 208,000-liter (55,000-gallon) single-shell tanks located within the C Tank Farm. These tanks are an older style single-shell tank that have shown signs of leaking in the past. A new vacuum retrieval technology is being used for the first time on these tanks. This retrieval method limits the use of water during retrieval work. Waste retrieval was completed from two tanks (241-C-203 and 241-C-202) during the year. About 22,700 liters (6,000 gallons) of tank waste was transferred to the newer, more robust double-shell tanks. Work on tank 241-C-201 was 28% complete at the end of calendar year 2005, and work on tank 241-C-204 will start in 2006. This technology will be improved while working on these smaller tanks and then deployed on other single-shell tanks that may have leaked in the past.

The DOE Office of River Protection continued to perform bulk waste retrieval on three larger single-shell tanks (241-C-103, 241-S-102, and 241-S-112). These are older style single-shell tanks with capacities from 2.01 to 2.87 million liters (530,000 to 758,000 gallons) and have not shown signs of past leaking. A waste sluicing technology is being used to remove the solid and liquid waste from the tanks. About 4.13 million liters (1.09 million gallons) of tank waste has been transferred to the newer, more robust double-shell tanks. At the end of calendar year 2005, tank 241-S-112 was 96% complete, tank 241-S-102 was 54% complete, and tank 241-C-103 was 10% complete. Construction of the retrieval system in tanks 241-S-102 and 241-C-103 was completed in 2005 and waste retrieval was started. Removal to less than 2.5 centimeters (1 inch) of waste in the tank bottom has been technically challenging. As a result, a remote water lance was developed and deployed in tank 241-S-112 to examine the potential for physically breaking up the dense saltcake at the bottom of the tank. The test of the remote water lance test was successful.

***Integrated Safety Management System in the Tank Farms***. The DOE Office of River Protection conducted its annual line management review of the Integrated Safety Management System. The Integrated Safety Management review evaluated improvements made since the validation reviews (conducted in October 2004 and March 2005), determined the effectiveness of corrective actions, reviewed the work planning/control process, evaluated the Integrated Safety Management self-assessment program, evaluated feedback and improvement processes, and evaluated the contractor's progress towards resolving the tank farm vapor issues.

The review concluded that the Integrated Safety Management system was implemented and, with some exceptions, was effective. Significant progress was made since the October 2004 Integrated Safety Management Improvement Validation Review. Additional improvements are warranted to address deficiencies identified in this review and to fully address previously identified findings. Of particular note, the Integrated Safety Management review identified hazard analysis and work control process deficiencies associated with waste retrieval in tanks 241-C-201, 241-C-202, and 241-C-203. In this case, a detailed project hazard analysis was needed to address all phases of the project in an integrated manner, including the hazards involved in system reconfiguration when moving the retrieval system from tank to tank.

***Double-Shell Waste Tank Integrity***. The double-shell tank corrosion control program is being maintained to protect and evaluate tank condition. The program maintains waste chemistry controls to minimize tank corrosion. The program has been expanded to include improved assessment of double-shell tank corrosion potential and any corrosion impacts. This information will be used to establish more reliable estimates of useful tank life. During 2005, the following activities took place:

- An ultrasonic and visual inspection of the last 4 of 28 double-shell tanks was completed. Inspections were performed using specialized remotely operated equipment to examine wall thickness and detect small pits or cracks potentially caused by corrosion. These tanks have volumes of over 3.8 million liters (1 million gallons) and contain highly radioactive chemical waste.
- An evaluation of corrosion detection and monitoring in double-shell tanks was performed by a panel of experts. Panel recommendations have been incorporated into the corrosion control program. A new in-tank corrosion monitoring probe was designed to provide real time evaluation of corrosion potential and phenomena. The prototype for this probe is in the procurement process.
- Analyses of double-shell tank corrosion resulting from exposure to AN-107 waste were performed by an expert panel and laboratory staff. AN-107 waste is unique in that it appears to be less prone to cause corrosion. Analysis results provided a better understanding of corrosion caused by tank waste and were used to improve monitoring of tank corrosion. The results provided the basis for changing the chemistry control specification, which will reduce the amount of caustic (sodium hydroxide) to be added to the tank in the future, reducing waste treatment costs.
- An analysis of record for double-shell tank system structural integrity was completed. This analysis of record was performed by a registered engineer and was a structural analysis of the tank system. The system includes pumps, pipes, detection equipment, and tanks. New seismic criteria from the Waste Treatment Plant evaluation, as well as Tank Farms Ultrasonic and Visual Testing of double-shell tanks were incorporated into the evaluation. A report will be issued in March 2006 by the independent qualified registered professional engineer to support RCRA permitting.

***Demonstration Bulk Vitrification System***. The Demonstration Bulk Vitrification System is being used to test the suitability of using bulk vitrification for disposal of low-activity waste from underground waste storage tanks. From January to June 2005, design and testing were completed in parallel with early procurement and construction activities. In June 2005, all construction and major procurement activities were halted due to technical issues requiring detailed resolution of increasing costs and schedule durations. Site preparation activities, including site clearing and grading, electrical utility upgrades, excavation, and installation of equipment pads, were completed.

Three full-scale tests using actual in-container vitrification boxes to gather data were performed. These boxes are waste containers that contain refractory materials that allow the

waste to be heated to melting temperatures. Heat loads to various system components, nitrogen oxide generation, and off-gas particulate composition were measured for the Demonstration Bulk Vitrification System design using a six-tank composite low activity waste stimulant (materials that simulate waste found in the tanks that is not radioactive and is used for testing purposes).

***Vapor Issue Resolution***. From October through December 2005, the tank farm contractor's Industrial Hygiene Program has advanced substantially the understanding of tank vapor issues. The following activities were near completion at the close of the year: characterization of tank vapor (the identification of all vapor space chemicals and their concentrations); sampling and analysis of the A-prefix tank farm (e.g., AN, AY, AZ) workplace atmosphere to identify which chemicals represent a hazard to the tank farm worker; completion of a toxicological review by an independent panel of experts; and conducting employee meetings to keep the workforce appraised of progress and plans.

In addition, in October 2005, DOE Office of River Protection industrial hygienists completed a review of the effectiveness of the corrective actions implemented by CH2M HILL Hanford Group, Inc. in response to an investigation conducted by the DOE Office of Independent Oversight and Performance Assurance investigation in April 2004. Based on current progress, CH2M HILL Hanford Group, Inc. is planning to establish respiratory protection requirements in the A-prefix tank farms based on hazards encountered by the worker instead of mandating supplied air respiratory protection. Completion of these corrective actions will likely result in reduced use of supplied air respirators in the A-prefix tank farms starting in mid-April 2006. Workers, however, will be able to select supplied air respiratory protection, even if not required, if they are concerned about their safety.

## 6.4.2 Waste Tank Closure Acceleration

J. D. Guberski

Design of the new bulk vitrification research and development facility began in 2004 and continued throughout 2005. Design completion is expected in 2006. Construction of the site infrastructure and foundations was completed in 2005, with facility construction scheduled for the later part of 2007 after regulatory review of design submittals.

Design and fabrication activities for the disposal of contact-handled transuranic mixed tank waste continued during 2005. Late in 2005, the project was placed in a standby status due to budget constraints.

# 6.5 Hanford Waste Treatment and Immobilization Plant

J. F. Brown

The Hanford Waste Treatment and Immobilization Plant (Waste Treatment Plant) is being built on 26 hectares (65 acres) located adjacent to the 200-East Area to treat radioactive and hazardous waste currently stored in 177 underground tanks. Currently, four major facilities are being constructed: a pretreatment facility, a high-level waste vitrification facility, a low-activity waste vitrification facility, and an analytical laboratory. Supporting facilities also are being constructed.

Engineering and construction activities for all facilities progressed in 2005, although technical challenges and funding cuts slowed both design and construction. New seismic design criteria for the pretreatment and high-level waste vitrification facilities, resolution of technical concerns, and reduced funding from Congress slowed the project and changed the work priorities in late 2005.

During 2005, the following activities were completed:

- Completed structural construction of the low-activity waste vitrification facility with installation of the facility's uppermost structural steel beam at the 21-meter (68-foot) elevation.
- Received 21 process vessels and installed 15 in the pretreatment facility.
- Finished installing, welding, and testing underground radioactive-waste transfer lines between the pretreatment and high-level waste vitrification facilities.
- Installed specialized viewing window frames for the laboratory's 14 hot cell process areas (areas where radioactive samples are processed remotely).
- Completed construction of eight aboveground tanks for diesel fuel storage, water storage, and water treatment, and completed construction of three buildings comprising over 11,000 square meters (120,000 square feet) for offices, warehouses, and workshops.
- Tested for durability two high-level vitrified-waste canisters of different wall-thicknesses. One canister had a 9.5-millimeter (3/8-inch) thick stainless steel wall, while the other was constructed of 3.2-millimeter (1/8-inch) thick stainless steel. Both were dropped 7 meters (23 feet) onto a 2.5-meter (8-foot) thick concrete and steel pad. Post-drop integrity tests showed that both canisters met the durability criteria. By using the thinner-walled canister, which holds more waste, the total number of canisters produced during the life of the facility will be reduced by about 500.

Through the end of 2005, workers at the Waste Treatment Plant had installed the following commodities:

- 128,445 cubic meters (168,000 cubic yards) of concrete.
- 60,655 meters (199,000 feet) of piping.
- 111,557 meters (366,000 feet) of electrical raceway.
- 188 metric tons (207 tons) of ductwork for heating, ventilating, and cooling.
- 29,030 metric tons (32,000 tons) of structural rebar.
- 2,675 metric tons (2,949 tons) of embedded steel plates.
- 7,348 metric tons (8,100 tons) of structural steel.

## Waste Treatment Plant Projects

C. M. Fetto

The Waste Treatment Plant consists of three processing facilities. The Pretreatment Facility prepares tank farm

waste for vitrification through various chemical and physical processes. The High-Level Waste Vitrification Facility contains two melters used to vitrify (turn to glass) tank farm waste for eventual disposal at the National Repository. The Low Activity Waste Vitrification Facility also has two melters, but the tank farm waste vitrified in this facility is disposed in the Integrated Disposal Facility on the Hanford Site. The Waste Treatment Plant also has an analytical laboratory and the supporting infrastructure, called the Balance of Facility.

***Authorization Basis Maintenance Activities***. In 2005, the DOE Office of River Protection approved 18 contractor proposed changes (called amendment requests) to the Authorization Basis. These requests were largely in support of tank waste retrieval activities and preparation for waste feed for the Waste Treatment Plant mission. Significant changes approved or reviewed included (1) the testing of a new retrieval technology; (2) implementation of Defense Nuclear Facilities Safety Board 2002-3, *Requirements for the Design, Implementation, and Maintenance of Administrative Controls*, which required implementation of Specific Administrative Controls within Documented Safety Analysis and Technical Safety Requirement documents; (3) a Preliminary Documented Safety Analysis change to support deployment of a new vitrification technology (Demonstration Bulk Vitrification System); (4) the testing and calibration of a new leak detection device (high resolution resistivity leak detection and monitoring system); (5) review of a Preliminary Documented Safety Analysis to stabilize transuranic waste for storage (Contact Handled Transuranic Mixed Waste Facility); and (6) a Preliminary Documented Safety Analysis for the Interim Disposal Facility.

***Integrated Disposal Facility Construction***. The Integrated Disposal Facility has been designed for disposal of solid low-level waste and mixed low-level waste from the Waste Treatment Plant and other generators. The facility will consist of a single landfill divided lengthwise into two separate, expandable cells, landfill cells 1 and 2. Cell 1 is permitted as a RCRA Subtitle C landfill system and was designed in accordance with the state of Washington Dangerous Waste Regulations (WAC 173-303). The other cell will not receive dangerous and/or hazardous waste and, therefore, will not require a permit. Initially, the Integrated Disposal Facility will hold 163,000 cubic meters (213,000 cubic yards) of material. When completed, the full capacity will be 900,000 cubic meters (1.2 million cubic yards). The Integrated Disposal Facility project is scheduled to be completed in 2006.

***Implementation of Revised Ground Motion***. The seismic design basis for the Waste Treatment Plant was revised as a result of the investigations of the site-specific seismic site response model performed by Pacific Northwest National Laboratory. These investigations led to an increase of up to 38% in the facility seismic load. Bechtel National, Inc. was directed to make the revisions and to incorporate them in the Waste Treatment Plant final design while minimizing the impact to the project. Installation of irreversible structures, such as concrete walls and slabs was halted, except on a case-by-case basis with DOE Office of River Protection approval. While the analysis for the revised seismic load (which was estimated to take approximately 6 months) was being made, Bechtel National, Inc. was also directed to develop interim seismic criteria so that the release of structure and component designs can continue until the final seismic design basis can be completed. Also, in order to minimize the impact of increased seismic loads on the already constructed structures, existing structure designs were reviewed and revised accordingly. The analyses were completed and redesign activities for the facility, equipment, piping, and other distribution systems were initiated.

***Hydrogen Release through Pulse-Jet Mixing and Air Sparging***. Pulse-jet mixers are large columns installed in a number of vessels throughout the Waste Treatment Plant. By alternatively drawing in and discharging air from these columns, the waste in the vessels remains mixed to ensure hydrogen does not build-up in the waste. The mixers also aid in the transfer of the waste out of the vessels. In early fiscal year 2005, the Waste Treatment Plant Project installed a scaled pulse-jet hybrid mixing system in a half-scale lag storage vessel (a high-level waste feed supply tank) in order to confirm that baseline operating parameters and normal vessel operations are adequate, and to demonstrate that vessel operations and near-term accident response scenarios were sufficient to safely mitigate gas holdup and release. The final two reports, documenting the half-scale lag storage test results, and an overview of the entire pulse-jet mixing program are scheduled for release by early in 2006.

Three other pulse-jet mixing-related testing programs are in progress: (1) internal pulse-jet mixer mixing testing is complete and analysis of the results is in progress with initial results expected in early 2006; (2) testing to determine instrument sensitivity, particularly the pressure sensors, is expected to be completed in mid-2006 and will confirm the ability to detect the pressure change characteristics needed for pulse-jet mixing operation control; and (3) a series of small tests is being performed at Savannah River National Laboratory to verify that the addition of an anti-foam agent will not increase the gas hold-up in the vessels. Test results are expected in the summer of 2006.

***Hydrogen Accumulation in Pipes and Ancillary Vessels***. Bechtel National, Inc. has completed a systematic review of potential locations for hydrogen accumulation in pipes and ancillary vessels throughout the Waste Treatment Plant. The locations are in addition to the primary processing vessels, in which the hydrogen build-up is mitigated through the use of spargers, pulse-jet mixing, and air sweeps of vessel headspaces. Similar locations were grouped and analyzed; e.g., the pulse-jet mixing tubes, waste and transfer piping such as recirculation loops, and heat exchangers, including vessel cooling jackets. Generic solutions are under development for each group including controlling solids content, periodically sweeping the vessel, or possibly allowing detonation if adequate safety margins can be demonstrated. The final generic solutions will be formally submitted to DOE Office of River Protection for review and approval in 2006. In parallel, Bechtel National, Inc. has begun identifying the necessary facility design changes, which include the addition of up to 80,000 linear feet of piping in the Pretreatment Facility.

***Black Cell Design Review Oversight***. In the summer of 2005, the DOE Office of River Protection completed the verification of closure of all 36 open items and recommendations from the Black Cell Design Oversight Review performed in 2004. Black cells are facility spaces, that due to high radiation levels, will not be entered throughout the life of the facility. Thus, with the exception of a few specialized components, all equipment in the cells is designed to last for the entire facility mission without maintenance or repairs. In addition to verifying that Bechtel National, Inc. had satisfactorily addressed the open items and recommendations, the DOE Office of River Protection conducted an independent analysis of vessel design to ensure the vessels containing pulse-jet mixers are sufficiently robust to allow for operations beyond the specifications in the contract (e.g., operating at higher solids concentrations or operating pulse-jet mixers for 100% of the time was considered). This analysis assured the DOE Office of River Protection that pulse-jet mixers could be operated 100% of the time if needed. The DOE Office of River Protection has made the commitment to sample for mean particle size, hardness, and size distribution of the incoming waste feed from the tank farms to assure that the erosion allowance for the tanks will not be exceeded.

One additional event occurred that required review of the black cell design. In April 2005, a significant pipe break and leak was detected in a dark cell (similar to a black cell) of the Thermal Oxide Reprocessing Plant at the Sellafield Facility in the United Kingdom. Because the Waste Treatment Plant has a similar approach of not planning any access to dark or black cells, the DOE Office of River Protection and Bechtel National, Inc. jointly reviewed the investigation results from the incident and developed a plan to ensure the lessons learned are incorporated into the design and operations of the Waste Treatment Plant.

***Alternative Ion Exchange Resin Development***. Ion exchange columns are used in the Pretreatment Facility to separate highly radioactive cesium from the low-activity waste stream that is disposed at Hanford. The cesium will be incorporated in the high-level waste stream that is planned to be disposed of at a national repository. SuperLig® 644 cesium ion exchange resin is the removal media being used in the ion exchange columns. There is currently only one producer of this resin, which is expensive and must be replaced after approximately ten regeneration cycles. To reduce the single-supplier risk, Bechtel National, Inc. is developing an alternative resin (resorcinol formaldehyde). Initial testing indicates that the Bechtel resin meets or exceeds project requirements in all areas including hydraulic performance, cesium removal, and resin decontamination prior to disposal. During the last 6 months, multi-cycle testing with a 60.9-centimeter (24-inch) ion-exchange column capable of processing 189-liter (50-gallon) batches (~1/2 scale) was completed and manufacture scale-up to 378.5-liter (100-gallon) batches was successful at both vendor and subcontractor facilities. The Bechtel-developed resin is substantially less expensive

than SuperLig® 644, and data indicate that it can be used for significantly more regeneration cycles than the baseline SuperLig® 644. A Waste Treatment Plant recommendation regarding use of this resin is planned for November 2006.

# 6.6 Scientific and Technical Contributions to Hanford Cleanup

T. Brouns

In 2005, Pacific Northwest National Laboratory and Battelle, which operates the Pacific Northwest National Laboratory for DOE, provided analyses, reviews, testing, and new tools to assist key contractors in preparing the Hanford Site tank waste for treatment and storage. The objective is to turn high-level radioactive liquid and sludge from Hanford's 177 underground storage tanks into durable glass logs and low-activity waste into other glass forms.

Hanford Site tank waste will be separated at the Waste Treatment Plant into a small high-activity fraction and a larger low-activity fraction. Cesium-137 will be separated from the low-activity fraction using an ion exchange resin, SuperLig-644®. Battelle Pacific Northwest Division provided technical support to Bechtel National, Inc. for evaluating the hydraulic performance of an alternative resin, spherical resorcinol formaldehyde. The data from this effort and earlier work provide a basis for making decisions regarding the most suitable formulation to use as an alternative resin. Battelle will also help Bechtel National, Inc. select the best design and operation details for the ion exchange columns if resorcinol formaldehyde is used.

Once the high-activity waste is at the Waste Treatment Plant, it must be mixed to allow potentially flammable gases generated in the waste to be released in a safe and controlled manner. Battelle and the Waste Treatment Plant Pulse Jet Mixer Team provided a large-scale demonstration of the hybrid pulse-jet mixer/air sparging mixing systems and provided performance data for the safe management of potentially flammable gases in the Waste Treatment Plant.

While certain portions of the waste in Hanford's 177 tanks will be vitrified at the Waste Treatment Plant, DOE has given CH2M HILL Hanford Group, Inc. the task of evaluating supplemental treatment processes to immobilize part of the less radioactive or low-activity waste. CH2M HILL Hanford Group, Inc. and their contractor, AMEC Earth and Environmental Inc., are conducting tests to determine if bulk vitrification can be used to supplement the treatment capacity of the Waste Treatment Plant. This process creates large glass blocks, greater than 6.1 meters (20 feet) in length. In 2005, Pacific Northwest National Laboratory supported engineering-scale testing and conducted research to help evaluate the process and product performance of the supplemental treatment technology. The first engineering-scale test with actual radioactive tank waste was completed. Further laboratory testing with radioactive- and non-radioactive-spiked simulants was performed to evaluate process performance.

Pacific Northwest National Laboratory researchers also improved the understanding of technetium migration during bulk vitrification operations to find ways to reduce any small quantity of leachable technetium species not incorporated into the glass and to assess the long-term performance of the waste form. Based on these results, CH2M HILL Hanford Group, Inc. will make decisions on how to accommodate this technetium or adjust the bulk vitrification process.

Chemical vapors from tanks are a concern when retrieving waste from the tanks, as well as during day-to-day operations. Supporting CH2M HILL Hanford Group, Inc.'s efforts to protect its workers, Pacific Northwest National Laboratory researchers conducted chemical and toxicological evaluations to determine which of the hundreds of vapors present in the tank headspaces have been detected at levels of concern and then assigned acceptable occupational exposure guidelines to many of the vapors of concern that lacked national guidelines. Pacific Northwest National Laboratory toxicologists conducted reviews of the available literature and established headspace concentration screening values for

about 600 of the vapors. These efforts helped define the vapor problem and allowed the CH2M HILL Hanford Group, Inc. industrial hygiene staff to develop suitable area monitoring strategies.

Additional information can be found in *Environmental Solutions FY05: PNNL Contributions to CH2M HILL Hanford Group, Inc.* (PNNL-15642) and *Environmental Solutions FY05: Battelle Contributions to the Waste Treatment Plant* (PNWD-3655).

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# 7.0 Site Closure Activities

This section provides information about activities to support Hanford Site cleanup as the U.S. Department of Energy (DOE) moves toward site closure and possible transfer of land to other entities.

## 7.0.1 Radiological Release of Property from Hanford

W. M. Glines

The principal requirements at Hanford for the control and release of property containing residual radioactivity are given in DOE Order 5400.5, *Radiation Protection of the Public and the Environment*. These requirements are designed to make certain that:

- Property is evaluated; radiologically characterized; and, where appropriate, decontaminated before release.
- The level of residual radioactivity in property to be released is as near background levels as is reasonably practicable, as determined through DOE's as low as reasonably achievable process requirements, and meets DOE authorized limits.
- All property releases are appropriately certified, verified, documented, and reported; public participation needs are addressed; and processes are in place to appropriately maintain records.

No property with detectable residual radioactivity was released from the Hanford Site in 2005.

### 7.0.1.1 Radiological Clearance for Release of Selected Hanford Reach National Monument Lands

In June 2000, a Presidential Proclamation (65 FR 37253) created the 78,900-hectare (195,000-acre) Hanford Reach National Monument within the boundaries of the DOE Hanford Site. Although DOE maintains administrative control and jurisdiction over the land within the Hanford Reach National Monument, the Department of Interior's U.S. Fish and Wildlife Service manages about 84% of the land. In July 2001, the DOE Office of Inspector General issued an audit report (DOE/IG-0514). This audit concluded that it was not in DOE's best interest to retain administrative control of all land within the Hanford Reach National Monument and identified approximately 57,900 hectares (143,000 acres) of land within the monument that could be transferred to the Department of Interior without adversely affecting DOE operations at the Hanford Site. The lands identified for transfer included:

1. The Fitzner/Eberhardt Arid Lands Ecology Reserve Unit (a 311-square-kilometer [120-square-mile] tract in the southwestern portion of the Hanford Site).
2. The combined Saddle Mountain Unit (a 130-square-kilometer [50-square-mile] tract located north-northwest of the Columbia River and generally south and east of State Highway 24) and Wahluke Unit (a 225-square-kilometer [87-square-mile] tract located north and east of both the Columbia River and the Saddle Mountain Unit). Together, the Saddle Mountain Unit and the Wahluke Unit are referred to as the North Slope.
3. The McGee Ranch-Riverlands Unit (located on the western portion of the Hanford Site and bordered by State Highway 24, the Columbia River, private land in the Cold Creek Valley, and the Yakima Firing Center).

Subsequently, the DOE Richland Operations Office entered into negotiations with the Department of Interior regarding release and transfer of these selected portions of the Hanford Reach National Monument from DOE control to the jurisdiction of the U.S. Fish and Wildlife Service. In addition to

being consistent with the DOE Office of Inspector General audit report, transfer of these lands would support the primary DOE environmental management mission to remediate and/or release as much of the Hanford Site as possible.

As part of the radiological clearance process for this property, an historical site assessment was performed and documented in PNNL-13989. Staff conducting this site assessment reviewed historical environmental data collected on and around these lands and developed a contaminant transport conceptual model. Interviews were conducted with people who were knowledgeable of past Hanford Site operations that may have contributed to residual contamination on this property.

The historical site assessment (PNNL-13989) concluded that while some activities using radioactive materials had taken place on the selected lands, "In general, the data available indicate that the Hanford Reach National Monument units of interest have very low concentrations of radionuclides. Radionuclide concentrations are very near the analytical detection levels for most media and locations… Further, the data do not indicate a strong likelihood of transport of significant amounts of long-lived radioactive material from Hanford operating areas to national monument lands … The median radionuclide concentrations in each media were generally similar at each unit. In addition, the majority of the observed concentrations on the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit, McGee-Riverlands and North Slope Units were similar to the concentrations observed at reference locations. This implies that atmospheric fallout from above ground weapons testing contributed significantly to the low levels of manmade radionuclides that were measured in the Hanford Reach National Monument environs."

Thus, the expected concentrations of residual radionuclides in the soil on the site are very low, i.e., in the range of background concentrations.

Before control of these lands may be transferred from DOE to the Department of Interior, the DOE Richland Operations Office must verify the presence or absence of residual radioactive contamination on these lands and demonstrate compliance with the requirements of DOE Order 5400.5. For any land with the potential for residual radioactive contamination, DOE Order 5400.5 requires that radiological clearance or release criteria, i.e., authorized limits, be developed and submitted for approval to the applicable DOE Headquarters program office, which for the Hanford Site is the Office of Environmental Management. Authorized limits are defined as levels of residual radioactivity that shall not be exceeded if the property is to be released without restrictions on use resulting from residual radioactivity. Residual radioactivity is defined as any radioactive material that is in or on soil, air, equipment, or structures as a consequence of past DOE operations or activities. Accordingly, authorized limits control the amount of residual radioactivity on property that is released from DOE radiological controls. Specifically, DOE Order 5400.5 states that: "The authorized limits shall be established to (1) provide that, at a minimum, the basic dose limits… will not be exceeded, or (2) be consistent with applicable generic guidelines." Since generic guidelines have not been established for residual radioactivity for the radionuclides of concern for these selected Hanford Reach National Monument lands, the authorized limits were established on the basis of ensuring that the DOE public dose limit of 100 mrem (1 mSv) per year would not be exceeded.

Surface soils were identified as the most significant medium for quantifying potential radiation doses resulting from any residual radioactivity on the selected Hanford Reach National Monument lands. Accordingly, authorized limits, in units of picocuries per gram in soil above background, were required that would result in radiation doses less than 100 mrem (1 mSv) per year to any member of the public. To develop these authorized limits, a radiation dose analysis was conducted based on likely and worst-use scenarios and conditions on the selected Hanford Reach National Monument lands. In accordance with the Presidential Proclamation which created the Hanford Reach National Monument (65 FR 37253), the expected end-use, i.e., likely use scenario, for these Hanford Reach National Monument lands is recreational use. In accordance with the guidance in DOE G 441.1-XX,[a] a dose constraint of 25 mrem (0.25 mSv) per year was applied to this likely use scenario for developing the authorized limits.

(a) DOE G 441.1-XX. Draft. *Implementation Guide - Control and Release of Property with Residual Radioactive Material for Use with DOE 5400.5, Radiation Protection of the Public and the Environment.* U.S. Department of Energy, Washington, D.C.

The worst-use scenario was considered to be a subsistence farmer. This scenario represents the situation in which restrictions that control end-use of these Hanford Reach National Monument lands fail or the actual end-use is different from the expected end-use. The DOE public dose limit of 100 mrem (1 mSv) per year was applied to this worst-use scenario. While the Presidential Proclamation and the expected terms and conditions of the transfer of these selected Hanford Reach National Monument lands to the Department of Interior would preclude such a worst-use scenario, it provides a conservative, bounding scenario to assure that the DOE public dose limit will not be exceeded by an unlikely, future agricultural resident on these selected Hanford Reach National Monument lands.

Accordingly, for the radiation dose analyses used to develop these authorized limits, two types of exposed individuals were identified: (1) recreational users of the Hanford Reach National Monument (likely use scenario at 25 mrem [250 μSv] per year) and (2) agricultural residents (worst-use scenario at 100 mrem [1 mSv] per year). Primary data for these exposure scenarios, including the radionuclides selected for analysis and the parameter values and data used as input to the computer models, were obtained from recent literature and from the historical site assessment. The RESRAD Version 6.21 (ANL/EAD-4) computer program was used as the calculational model for translating these dose values into surface soil concentrations. Soil concentrations were developed for each of the radionuclides of concern, for each of the exposure scenarios, and for several geographical units of the selected Hanford Reach National Monument lands. The final authorized limits (Table 7.0.1) were determined as the most limiting (smallest) soil concentrations for each radionuclide across the scenarios and Hanford Reach National Monument locations.

The request for these authorized limits for the selected Hanford Reach National Monument lands with supporting technical documentation was submitted to the DOE Office of Environmental Management on December 22, 2003. The requested authorized limits were approved on March 1, 2004, subject to reconciliation of comments regarding the application of the DOE public dose limit to the agricultural resident scenario. These comments were reconciled in the final authorized limits request (PNNL-14622) and supporting technical basis document (PNNL-14531).

**Table 7.0.1. Maximum Levels of Radionuclides (Authorized Limits) Allowed in Soil on the Hanford Reach National Monument[a]**

| Radionuclide | Authorized Limit (pCi/g) |
|---|---|
| Cobalt-60 | 11 |
| Strontium-90 | 88 |
| Cesium-134 | 20 |
| Cesium-137 | 46 |
| Europium-152 | 24 |
| Uranium-234 | 2,400 |
| Uranium-235 | 190 |
| Uranium-238 | 770 |
| Plutonium-239 | 480 |
| Plutonium-240 | 480 |
| Americium-241 | 420 |

(a) Approved by the DOE Office of Environmental Management, March 1, 2004.

In order to demonstrate compliance with these approved authorized limits, soil samples must be collected and analyzed in accordance with a DOE-approved sampling and analysis plan. This sampling and analysis plan includes the collection and analyses of soil, assessment of the analytical data against the authorized limits, generation of a final report, and the inclusion of all pertinent data and information into a formal records management system. For purposes of implementing this required sampling, the selected Hanford Reach National Monument lands were divided into two sections: (1) the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit and (2) the remainder of the selected Hanford Reach National Monument lands, i.e., the combined Saddle Mountain Unit and Wahluke Unit and the McGee Ranch-Riverlands Unit. A sampling and analysis plan (PNNL-14633) was developed for the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit. The goal and design criteria of this plan were to collect an adequate number of soil samples to determine if the concentrations of radionuclides of concern in Fitzner/Eberhardt Arid Lands Ecology Reserve soil are below the approved authorized limits with a high degree of statistical confidence, i.e., 99%. The collection and analysis of soil samples from the Fitzner/Eberhardt Arid Lands Ecology Reserve was initiated in 2004 and completed in 2005.

A sampling and analysis plan (PNNL-14950) for the remainder of the selected Hanford Reach National Monument lands has been developed and approved. Soil sampling on these remaining Hanford Reach National Monument lands was conducted in 2005.

### 7.0.1.2 Emergency Decontamination Facility

In October 1965, the former U.S. Atomic Energy Commission, now DOE, signed a 99-year land-lease agreement with the Kadlec Methodist Hospital, now Kadlec Medical Center, for a plot of land adjacent to the hospital. The Hanford Radiosurgery Unit (Building Number 748), later known as the Emergency Decontamination Facility, was subsequently constructed on this leased property. The only major use of the Emergency Decontamination Facility was in 1976 for the treatment and decontamination of a patient who was injured and significantly contaminated with americium-241. Widespread contamination of the Emergency Decontamination Facility occurred as a result of the treatment of this individual.

In 2002, Kadlec Medical Center and the DOE Richland Operations Office entered into discussions regarding the termination of this lease agreement. Kadlec Medical Center wishes to expand its current medical facilities onto the leased property currently occupied by the Emergency Decontamination Facility. Because of the construction of other decontamination facilities at Kadlec Medical Center and on the Hanford Site, maintaining the Emergency Decontamination Facility is no longer necessary or cost-effective. In 2005, as part of the termination of this lease agreement and return of control of the Emergency Decontamination Facility site to Kadlec Medical Center, the DOE Richland Operations Office established radiological release criteria for the Emergency Decontamination Facility site.

The demolition of the Emergency Decontamination Facility was completed in 2005. Demolition debris with the potential to contain residual radioactivity above the established release criteria was disposed in the Envirocare radioactive waste disposal facility in Utah. Remaining demolition debris was recycled or disposed in licensed disposal facilities. Surveys of the Emergency Decontamination Facility site were conducted in accordance with a DOE-approved sampling and analysis plan. The results of these surveys showed no residual radioactivity above the established radiological release criteria. The DOE terminated the lease agreement and returned control of the Emergency Decontamination Facility site to the Kadlec Medical Center on May 4, 2005.

## 7.0.2 River Corridor Baseline Risk Assessment and Long-Term Stewardship

E. T. Feist

Hanford's River Corridor includes the 100 and 300 Areas, which border the Columbia River shoreline. The 100 and 300 Areas include hundreds of contaminated excess facilities, 9 deactivated plutonium production reactors, and nearly 600 liquid and solid waste disposal sites. The DOE's award of the River Corridor Closure Contract to Washington Closure Hanford, LLC in 2005 has allowed cleanup actions to continue in the 100 and 300 Areas with completion in mind. The principal goals of the DOE's River Corridor Closure Contract are to:

- Deactivate, decontaminate, decommission, and demolish excess facilities.
- Place former production reactors in an interim safe and stable condition.
- Remediate liquid and solid waste disposal sites.
- Meet all regulatory requirements.
- Determine the adequacy of the current cleanup criteria in protecting human health and the environment.
- Obtain a proposed "finding of suitability" to transfer Hanford's River Corridor to long-term stewardship.

The last two bullets, which focus on site closure and possible transfer of land to other entities, are being addressed under the River Corridor Closure Contract by the River Corridor Baseline Risk Assessment and Long-Term Stewardship tasks. Ongoing, open communication among the many parties interested in Hanford Site cleanup continued in 2005 as work progressed under the River Corridor Baseline Risk Assessment and Long-Term Stewardship tasks. An internet website, http://www.washingtonclosure.com/Projects/endstate.html, provides current information on the associated activities. The website includes the planned dates of public

involvement opportunities, documents available for review and comment, administrative information, and links to related projects.

### 7.0.2.1 River Corridor Baseline Risk Assessment

J. E. Thomson

The DOE's cleanup plans for the Columbia River corridor are based on the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA). In 1991, the DOE, U.S. Environmental Protection Agency (EPA), and Washington State Department of Ecology (the Tri-Parties) agreed that interim remedial actions in the 100 and 300 Areas would fulfill a "bias for action" approach to CERCLA and could be implemented by relying on streamlined qualitative risk assessments rather than a quantitative baseline risk assessment. Waste site cleanup under interim action records of decision was initiated during the mid-1990s and is planned for completion by Washington Closure Hanford, LLC by 2013. The current focus of Washington Closure Hanford, LLC is on completing the remedial actions so the Tri-Parties can proceed to final CERCLA closeout of the 100 and 300 Areas. A critical step in proceeding toward final CERCLA closeout is a baseline risk assessment, which is now being performed by Washington Closure Hanford, LLC as the River Corridor Baseline Risk Assessment. The River Corridor Baseline Risk Assessment task consists of:

- A baseline risk assessment for the 100 Areas and 300 Area Component, which includes former operational areas (primarily former reactor areas).
- A baseline risk assessment for the Inter-Areas Component, which includes reaches of the Columbia River shoreline area between the former operational areas in the 100 and 300 Areas.
- Risk assessment planning efforts for the Columbia River Component, which includes the Hanford Reach of the Columbia River, as well as downstream reaches of the river to a boundary that has not yet been determined.

The results of these assessments will be used to evaluate the adequacy of cleanup actions within the Columbia River corridor.

The River Corridor Baseline Risk Assessment uses a multi-step process. The process begins by compiling and summarizing the existing data, then using the data quality objectives process to identify both data gaps and unresolved issues through open workshops, and by soliciting and incorporating input from regulatory agencies, the Natural Resources Trustees Council, tribes, and stakeholders. Based on these discussions, sampling analysis plans are developed to collect the data needed to fill the gaps and address the issues. After all necessary data are collected, the risks to human health and the environment are assessed.

A pilot risk assessment study for residual contaminants in the 100-B/C Area (located in the 100 Areas) was initiated in 2002. The assessment initiated and refined a multi-step process for application to the 100 Areas, 300 Area, and Inter-Areas Components. The pilot assessment was completed in 2005 and was immediately followed by sampling of upland, riparian, and near-shore environments for the 100 and 300 Areas Component. Sampling in the 100 and 300 Areas is also planned for 2006 and will include many Columbia River near-shore aquatic sediment, water, and biota, as well as terrestrial soil, groundwater, and biota. Additionally, an evaluation of the effects of contamination on riparian and near-shore environments in the 100-N Area will be completed in 2006 by Pacific Northwest National Laboratory in conjunction with Fluor Hanford, Inc. The results of all these efforts will be incorporated into a draft report for the 100 Areas and 300 Area Component of the River Corridor Baseline Risk Assessment, which is due in 2007.

Adapting methods developed and agreed to by the Tri-Parties and stakeholders for the 100 Areas and 300 Area Component risk assessment, the Inter-Areas risk assessment will be conducted for the riparian and near-shore environments of the river corridor between reactor/operational areas. This risk assessment effort will supplement results from the 100 Areas and 300 Area Component to provide a more complete analysis of residual human health and ecological risk in the river corridor. Results from these baseline risk assessments will be used to develop a source unit remedial investigation report. Recommendations for final cleanup decisions at source units within the river corridor, based in part on the risk assessment results, will be presented by the Tri-Parties to the public for consideration in a river corridor source unit proposed plan in the future.

The third element of the River Corridor Baseline Risk Assessment is the Columbia River Component. The purpose of this component is to identify whether there are areas beyond the boundaries of the Hanford Site that may require additional information to proceed with making risk management decisions. In 2005, work on the Columbia River Component included a compilation and evaluation of existing Columbia River environmental data from locations upstream, downstream, and adjacent to the Hanford Site. Work during 2006 will include compilation of this information that will be provided to the DOE Richland Operations Office and the regulatory agencies for review and approval. Plans to complete a risk assessment work plan are being developed by the DOE Richland Operations Office. Implementation of this work plan is not included in the scope of the River Corridor Closure Contract.

### 7.0.2.2 River Corridor Long-Term Stewardship

J. A. Lerch

The Long-Term Stewardship task focuses on achieving end-state closure and transition of the river corridor to long-term stewardship. Within the River Corridor Closure Contract, key elements of the Long-Term Stewardship work include the preparation of remedial actions reports for each CERCLA operable unit and development of a draft for a long-term stewardship plan that will provide a proposed approach and criteria to be met for long-term stewardship within the river corridor. Results of risk assessment activities, orphan sites evaluations, remedial actions reports, and long-term stewardship plans will provide a basis for closure reviews of the 100 and 300 Areas by independent experts. The independent closure reviews will assure that implemented remedies meet the required action objectives established in the source operable unit records of decision and that no further action is needed to protect human health and the environment. These activities will culminate in development of a long-term stewardship plan that will contain a proposed finding of suitability to transfer in accordance with CERCLA Section 120(h) and the final criteria for long-term stewardship.

Information documenting cleanup and closure activities in the river corridor is maintained in task databases that are managed as part of the Long-Term Stewardship task. Geographical Information Systems contain layered spatial information supporting cleanup operations in the river corridor and long-term stewardship. The Stewardship Information System contains facility and waste site information for the river corridor including process history, location, dimensions, associated structures and sites, cleanup actions, photos, and references. Direct links to site closeout analytical data will also be provided in the database.

## 7.0.3 References

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# 8.0 Environmental Occurrences

B. G. Fritz

Releases of radioactive and regulated materials to the environment are reported to DOE and other federal and state agencies as required by law. The specific agencies notified depend on the type, amount, and location of each event. All occurrences at the Hanford Site are reported to the Occurrence Notification Center. The following sections summarize occurrences that took place during 2005 that could have had an impact on the Hanford environment. The occurrences are arranged according to significance category. Significance categories are assigned based on the nature and severity of the occurrence. The categories include OE (operational emergency), R (recurring), Category 1 (significant impact), Category 2 (moderate impact), Category 3 (minor impact), and Category 4 (some impact). In 2005, there were no environmental occurrences ranked as significance Category OE, R, 1, or 2 on the Hanford Site.

## 8.0.1 Category 3 – Minor Impact

Category 3 occurrences are defined as having a minor impact on safe facility operations, worker or public safety and health, regulatory compliance, or public and business interests. Several Category 3 occurrences with potential environmental implications occurred on the Hanford Site in 2005.

***Discovery of Excessive Beryllium Levels Outside Building 313 in the South Fan Room Building Air Intake (EM-RL-BHI-DND-2005-0002)***. On February 10, 2005, air and surface wipe samples were taken in the air intake fan room of Building 313 in response to concerns raised by an asbestos insulation removal crew. The crew was installing glove bags and double wrapping pipe in preparation for demolition activities. Surface wipe samples were collected and analyzed, and the results were reported on February 16, 2005. Beryllium concentrations above the 0.2-microgram per 100-square-centimeter (15.5-square-inch) limit were found at four of the ten sampling locations. Work activities in the south fan room of Building 313 were immediately suspended. Additional sampling on and around the outside of the building was initiated but no beryllium concentrations above the 0.2-microgram per 100-square-centimeter (15.5-square-inch) limit were found. When work in the building resumed, workers were required to wear respiratory protection.

***Brush Fire East of Range 7, Patrol Training Academy (EM-RL-PHMC-PATROL-2005-0001)***. On June 17, 2005, an instructor at the Patrol Training Academy accidentally started a brush fire when detonating an incendiary device during a training exercise. Initial attempts to contain the fire were not successful, and the Hanford Fire Department responded to the scene. The fire was contained within 3 hours. Approximately 514 hectares (1,270 acres) were burned, with no damage to buildings or personnel.

***Contaminated Debris Blown Beyond Posted Areas by High Winds in the 300 Area Remedial Action Project (EM-RL-BHI-REMACT-2005-0002 & -0004)***. Several wind storms moved across the Hanford Site in late March 2005. One wind storm on March 16, 2005, had gusts to 93 kilometers (58 miles) per hour at the 300 Area meteorological station. This wind storm resulted in debris consisting of paper, glass, and cloth being blown outside of a posted high-contamination area in the 300 Area. The highest contamination levels were found on a piece of glass discovered several meters from the posted area. Measurements were 172,000 disintegrations per minute beta-gamma direct and 1,193 disintegrations per minute smearable alpha.

Thirteen days later on March 29, 2005, another wind storm swept across the Hanford Site. This storm resulted in wind gusts to 66 kilometers (41 miles) per hour at the 300 Area meteorological station. Based on survey results following the previous dust storm, Radiological Control Technicians conducted boundary surveys. Several pieces of contaminated debris were discovered outside of the posted contamination area. The highest radiological survey result measured 89,000 disintegrations per minute direct beta-gamma and 4,000 disintegrations per minute alpha direct. No smearable contamination was detected.

***Contaminated Debris Blown Beyond Posted Areas by High Winds at the Environmental Restoration Disposal Facility (EM-RL-BHI-ERDF-2005-003 & -004)***. Similar to events in the 300 Area, storms on March 16 and March 29, 2005, resulted in contaminated plastic being blown outside posted contamination areas near the Environmental Restoration Disposal Facility. The storms caused wind speeds in excess of 80 kilometers (50 miles) per hour across the Central Plateau on both days. Plastic debris discovered outside of posted contamination areas on March 17 had a contamination level of 82,000 disintegrations per minute per 100 square centimeters (15.5 square inches) total direct beta-gamma. The plastic discovered during surveys outside of posted contamination areas on March 30 had a contamination level of 66,000 disintegrations per minute per 100 square centimeters (15.5 square inches) direct beta-gamma, and 1,088 disintegrations per minute per 100 square centimeters (15.5 square inches) total alpha.

## 8.0.2 Category 4 – Some Impact

Category 4 occurrences are defined as having some impact on safe facility operations, worker or public safety and health, regulatory compliance, or public and business interests. Three Category 4 occurrences with potential environmental implications occurred on the Hanford Site in 2005.

***Elevated Airborne Radioactivity Reading in Non-Airborne Radioactivity Areas (EM-RL-BHI-REMACT-2005-0001)***. A radiological air sample collected at the boundary of the former 116-N-1 crib (100-N Area) and a lapel sample (small personal sampler worn at the lapel) were both collected on January 25, 2005, and showed elevated levels of airborne contamination. The boundary air sample indicated a derived airborne concentration of 1.12 and the lapel sample result was 4.6 derived airborne concentration hours. Both samples were collected from locations not posted as airborne radiation areas. The elevated levels were attributed to demolition of contaminated concrete, inadequate dust suppression techniques, and local meteorology.

***Grass Fire in the Saddle Mountain National Wildlife Refuge (EM-RL-PHMC-FSS-2005-0006)***. A grass fire occurred on the Saddle Mountain Unit of the Hanford Reach National Monument on July 5, 2005. The fire was approximately 600 hectares (1,500 acres) and was extinguished before midnight on July 5, 2005. The Saddle Mountain Unit is on property owned by DOE and managed by the U.S. Fish and Wildlife Service.

***Grass Fire on the Hanford Reach National Monument (EM-RL-PHMC-FSS-2005-0007)***. A grass fire occurred on the Wahluke Unit of the Hanford Reach National Monument in Franklin County on August 9, 2005. The fire burned approximately 280 hectares (700 acres) before being 60% contained early in the morning of August 10, 2005. The Hanford Reach National Monument is on property owned by DOE and managed by the U.S. Fish and Wildlife Service.

# 9.0 Pollution Prevention and Waste Minimization

This section provides information about Hanford Site policies regarding pollution prevention and waste minimization. Initiative 297, a ruling enacted by Washington State voters in November 2004, is also discussed.

## 9.0.1 Pollution Prevention Program

C. E. Marple

DOE Order 450.1, Chg 2, *Environmental Protection Program*, was approved on December 7, 2005. Included in the revised Order are new pollution prevention and environmental stewardship goals. These goals are implemented by Hanford Site contractors, per the Contract Requirements Document for the Order.

The U.S. Department of Energy (DOE) Richland Operations Office is responsible for the Hanford Site pollution prevention program. The office provides program guidance for Hanford Site contractors. Integration activities are managed by Fluor Hanford, Inc. under the Project Hanford Management Contract.

The Hanford Site met the fiscal year 2005 Secretarial Goals for low-level waste, mixed low-level waste, hazardous waste and sanitary routine waste generation, and recycling. In 2005, the program reported recycling 3,535 metric tons (3,897 tons) of sanitary and hazardous waste (Table 9.0.1). Affirmative procurement (the purchase of environmentally preferable products containing recycled material) at the Hanford Site achieved 100% of the 2005 goal.

The Hanford Site generated 30,593 cubic meters (40,014 cubic yards) of cleanup and stabilization goal waste (i.e., low-level waste, mixed low-level waste, and hazardous waste). This volume exceeded the fiscal year 2005 goal of less than 10% of Hanford's total waste volume forecast (10%

**Table 9.0.1. Hanford Site Sanitary and Hazardous Waste Recycled in 2005**

| Waste | Metric Tons | (tons) |
|---|---|---|
| **Sanitary Waste** | | |
| Appliances and furniture | 75 | (83) |
| Computers and electronics | 48 | (53) |
| Computer software | 6 | (7) |
| Diesel fuel | 26 | (29) |
| Engine oils | 68 | (75) |
| Fire extinguishers | 1 | (1) |
| Iron and steel | 787 | (867) |
| Mixed office paper and cardboard | 341 | (376) |
| Non-ferrous metal | 57 | (63) |
| Tires | 15 | (17) |
| Toner cartridges | 10 | (11) |
| Waste to energy[(a)] | 1,543 | (1,701) |
| **Hazardous Waste** | | |
| Antifreeze | 3 | (3) |
| Batteries | 15 | (17) |
| Excess chemicals | 44 | (48) |
| Lamps (fluorescent, sodium, mercury vapor, incandescent) | 3 | (3) |
| Lead | 50 | (55) |
| PCB oil[(b)] | 441 | (486) |

(a) Fuel for power generation.
(b) Less than 50 ppm polychlorinated biphenyl oil burned for energy recovery (Toxic Substance Control).

corresponds to 28,028 cubic meters [36,659 cubic yards]). Accordingly, the Secretarial Goal was not met. Due to changing work scope and other uncertainties, predicting the annual volume of Hanford waste is not precise. Therefore, failure to meet the Secretarial Goal in fiscal year 2005 may be attributed to underestimating the volume.

## 9.0.2 Washington State Initiative 297, The Cleanup Priority Act

M. K. Marvin

Initiative 297, known as the *Cleanup Priority Act*, was passed by Washington State voters in November 2004. The *Cleanup Priority Act* adds a new chapter to the *Mixed Radioactive and Hazardous Waste* (RCW 70.105E) law and addresses a variety of operations at the Hanford Site. Among other things, the act seeks to restrict importing offsite waste to Hanford, set cleanup standards for radioactive releases, and require DOE to pay a new mixed-waste surcharge. In December 2004, the U.S. Department of Justice sought and received a temporary restraining order from the U.S. District Court that enjoined application or enforcement of the act at Hanford or Pacific Northwest National Laboratory, except to the extent it prohibited import of mixed waste to Hanford. The U.S. Department of Justice filed a motion for summary judgment arguing the *Cleanup Priority Act* is preempted by federal law, violates the principle of sovereign immunity, and burdens the flow of interstate commerce in violation of the U.S. Constitution. In February 2005, the state of Washington asked the federal court to certify five issues for interpretation by the Washington State Supreme Court. The federal court agreed and then prohibited application of the entire initiative, including waste importation prohibitions, until all claims are resolved in both federal and state courts. The Washington State Supreme Court provided the requested interpretation of the act in July 2005, after which the parties returned to briefing the federal court. Oral argument on the federal constitutional issues is scheduled before U.S. District Court Judge Alan McDonald on May 23, 2006.

## 9.0.3 References

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RCW 70.105E. *Mixed Hazardous Waste Management*. Revised Code of Washington, Olympia, Washington.

# 10.0 Environmental and Resource Protection Programs

R. W. Hanf

U.S. Department of Energy (DOE) Orders 450.1 and 5400.5 require that environmental monitoring programs be conducted at Hanford to verify protection of the site's environmental and cultural resources, the public, and workers on the site. The monitoring activities support the site's integrated *Safety Management System Policy* (DOE P 450.4) and its component Environmental Management System (see Section 4.0.1). Component systems are tools for achieving site and contractor compliance with environmental, public health, and resource protection laws, regulations, and DOE Orders.

The *Environmental Monitoring Plan, United States Department of Energy, Richland Operations Office* (DOE/RL-91-50) is the mechanism through which monitoring programs and projects are implemented at Hanford. The plan contains the rationale for the required programs and projects including design criteria, sampling locations and schedules, quality assurance requirements, program and project implementation procedures, analytical procedures, and reporting requirements. The early identification of, and appropriate response to, potentially adverse environmental and resource effects associated with DOE operations are assured by:

- Routinely conducting pre-operational environmental characterization and assessment activities.
- Monitoring effluent and emissions.
- Performing environmental monitoring and surveillance (as defined in DOE Order 5400.5 and in Appendix B, Glossary).
- Monitoring cultural resources.
- Performing periodic sampling of Hanford Site drinking water.
- Monitoring and controlling contaminated and undesirable biota.

The objectives of the monitoring programs include:

- Detecting, characterizing, and responding to contaminant releases from Hanford Site DOE facilities and operations.
- Providing data to assess the human health and ecological impact of Hanford-produced contaminants.
- Estimating contaminant dispersal patterns in the environment.
- Characterizing the pathways of exposure to members of the public and biota.
- Characterizing the exposures and doses to individuals, the nearby population, and biota.
- Evaluating potential impact to biota (and the Columbia River) in the vicinity of DOE Hanford Site activities.
- Assuring that environmental monitoring programs are conducted in an integrated fashion to preclude collection of duplicative environmental data.
- Ensuring early identification of, and appropriate response to, the potentially adverse environmental impact associated with DOE operations.
- Promoting long-term stewardship of the Hanford Site's natural and cultural resources.
- Protecting natural and cultural resources.

There are other important reasons for conducting these monitoring activities:

- Complying with local, state, and federal laws and regulations and DOE Orders.
- Confirming site compliance with local, state, and federal laws and regulations and DOE Orders.
- Verifying the efficacy of waste management practices on the Hanford Site.

- Providing information to assure the public that facilities and operations are not adversely affecting people or the environment.
- Answering questions or providing information to stakeholders, activist organizations, and the public.
- Supporting DOE decisions.
- Providing information to support DOE in environmental litigations.

Brief overviews of DOE environmental monitoring programs and projects, the Drinking Water Monitoring Project, and the Biological Control Program are provided in the following sections. The Washington State Department of Health Oversight Monitoring Program is also discussed.

## 10.0.1 Effluent and Near-Facility Environmental Monitoring Programs

Effluent and near-facility environmental monitoring at Hanford consists of (1) liquid effluent and airborne emissions monitoring at site facilities and operations and (2) environmental monitoring near-facilities and operations that have the potential to discharge, or have discharged, stored, or been a disposal site for, radioactive and hazardous materials. Categories of effluent that normally or potentially contain radionuclides or hazardous materials include cooling water, steam condensates, process condensates, and wastewater from laboratories and chemical sewers. Airborne emissions can include both radioactive and non-radioactive particulate, gaseous, and volatilized materials from facility stacks and vents.

### 10.0.1.1 Liquid Effluent and Airborne Emissions Monitoring

Hanford Site contractors perform real-time monitoring of liquid effluent and airborne emissions at each facility to assess the effectiveness of effluent and emissions treatment and control systems, pollution management practices, and to determine facility and site compliance with state and federal regulatory requirements. Information on effluent discharged from site facilities in 2005 is summarized in Section 10.3 and in an annual environmental releases report (e.g., HNF-EP-0527-15). Emissions data for 2005 are summarized in Section 10.1 and in several other reports (e.g., DOE/RL-2006-01).

### 10.0.1.2 Near-Facility Environmental Monitoring

Near-facility environmental monitoring is conducted near DOE facilities and operations on the Hanford Site that have the potential to discharge, or have discharged, stored, or been a disposal site for, radioactive or hazardous contaminants. Monitoring locations are associated with nuclear facilities such as the Canister Storage Building and the 100-K Area fuel storage 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, and 5400.5; DOE Manual 231.1-1A; Title 10, *Code of Federal Regulations*, Part 835 (10 CFR 835) and 40 CFR 61; and *Washington Administrative Code* (WAC) 246-247.

Several types of environmental media are routinely sampled near Hanford Site facilities and various radiological and non-radiological measurements are taken. The media sampled include air, soil, and vegetation. In addition, surface contamination and external radiation levels are monitored. Media samples are collected from known or expected emissions and 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.

Investigations of contaminated biota, soil, and other materials are 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 (e.g., cleanup or construction) sites. Investigations for contaminants are conducted for at least one of the following reasons:

- To follow up surface radiological surveys that had indicated radioactive contamination was present.
- To conduct pre-operational surveys to characterize the radiological and 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.

Contamination incidents investigated in 2005 focused on soil, vegetation, wildlife, and wildlife-related materials. Most materials were surveyed in the field to detect radioactive contamination. Some materials were sampled and the samples were submitted to an analytical laboratory for analysis. Methods for surveying and sampling these contaminated materials are described in *Operational Environmental Monitoring* (DTS-OEM-001). Laboratory analyses results and field survey readings for contamination incidents investigated in 2005 are provided in Appendix 2 of this report (PNNL-15892, APP. 2).

Information on contaminant concentrations or radiation levels measured onsite near facilities and operations during 2005 is summarized in Sections 10.2, 10.9, 10.10, 10.13, and 10.18. Additional data may be found in PNNL-15892, APP. 2. The type and general locations of samples collected for near-facility monitoring during 2005 are summarized in Table 10.0.1. Information on contamination incidents investigated during 2005 is summarized in Sections 10.9, 10.10, and 10.11.

## 10.0.2 Public Safety and Resource Protection Projects

Public Safety and Resource Protection Projects are managed for the DOE Richland Operations Office by Pacific Northwest National Laboratory. Their purposes are to monitor the Hanford environment, provide assurance that the site operates in compliance with applicable environmental regulations, and conduct impact assessments to protect public and worker safety as well as Hanford's significant ecological and cultural resources. The projects obtain environmental information related to public health and environmental effects that is necessary for the DOE to manage environmental risk at Hanford. Whereas effluent and near-facility environmental monitoring are conducted by the facility operating contractor or designated subcontractor, environmental surveillance is conducted independent of the operating contractors and subcontractors.

**Table 10.0.1. Routine Environmental Monitoring Samples and Locations Near Hanford Site Facilities and Operations, 2005**

| Sample Type | Number of Sampling Locations | Operational Area | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 100-B/C | 100-D | 100-F | 100-H | 100-K | 100-N | 200/600 | 300/400 | ERDF[a] |
| Air | 88 | 5 | 2 | 6 | 2 | 13 | 4 | 46[b] | 7 | 3 |
| Soil | 97 | 7 | 0 | 5 | 2 | 6 | 5 | 58 | 13 | 1 |
| Vegetation | 62 | 0 | 0 | 0 | 0 | 0 | 4 | 47 | 11 | 0 |
| External radiation | 136 | 4 | 0 | 0 | 0 | 20 | 14 | 68 | 27 | 3 |

(a) Environmental Restoration Disposal Facility in the 200-West Area.
(b) Includes one station at the Wye Barricade.

The projects include the:

- Meteorological and Climatological Services Project.
- Surface Environmental Surveillance Project.
- Ecological Monitoring and Compliance Project.
- Cultural Resources Project.

Brief overviews of these projects are provided in the following sections.

### 10.0.2.1 Meteorological and Climatological Services Project

The Meteorological and Climatological Services Project provides information to help assure that DOE activities on the Hanford Site, which could be affected by adverse meteorological conditions (e.g., thunderstorms, strong winds, blowing dust, dense fog, and snowstorms), operate in as safe and efficient a manner as possible. Meteorological data are important for planning day-to-day work activities. The project also provides meteorological response in the event of a suspected or actual release of radioactive or hazardous material to the atmosphere so that personnel involved in responding to the event can make appropriate and timely decisions. Meteorological data are also integral to the annual estimates of potential public radiation exposure. Comprehensive climatological data records are maintained for use in a variety of other applications, such as post-accident analysis, dose reconstruction, building designs, and environmental impact assessments. Summary meteorological monitoring data for 2005 and some historical climatological information are provided in Section 10.16.

### 10.0.2.2 Surface Environmental Surveillance Project

The Surface Environmental Surveillance Project is responsible for measuring the concentrations of radiological and non-radiological contaminants in environmental media onsite in the 600 Area (site-wide) and offsite at perimeter, community, and distant locations and assessing the potential effects of these materials on the environment and the public. Samples of agricultural products, air, fish and wildlife, soil, surface water and sediment, Columbia River shoreline seep water and sediment, and vegetation are collected routinely. The samples are analyzed for radionuclides and chemicals, including metals and anions. In addition, ambient external radiation is measured at selected locations on and off the site and ambient gamma radiation levels are monitored at four offsite air sampling locations.

Project monitoring activities focus on routine releases from DOE facilities on the Hanford Site; however, the project also conducts sampling and analysis in response to known unplanned releases and releases from non-DOE operations on and near the site. Monitoring results are provided to the DOE and the public annually through this report series. Unusually high contaminant concentrations, should they occur, are reported to the DOE Richland Operations Office and the appropriate facility managers.

The general requirements and objectives for the Surface Environmental Surveillance Project 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, to monitor potential impacts of contaminants on other biota, and to alert DOE to the possible need for corrective action (DOE Orders 450.1 and 5400.5; DOE/EH-0173T, *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*). The specific objectives of the monitoring activities include:

- Collecting and analyzing samples, reviewing and interpreting analytical data, and maintaining a long-term computer database for trend analysis.
- Determining compliance with applicable environmental quality standards, public exposure limits, and applicable laws and regulations; the requirements of DOE Orders; and the environmental commitments made in environmental impact statements, environmental assessments, safety analysis reports, or other official DOE documents.
- Conducting pre-operational assessments.
- Assessing radiological doses to the public and environment.
- Assessing doses from other local sources.
- Reporting alarm levels and potential doses exceeding reporting limits.
- Determining background levels and site contributions of contaminants in the environment.

- Determining long-term accumulations of site-related contaminants in the environment and predicting trends.
- Characterizing and defining trends in the physical, chemical, and biological conditions of environmental media.
- Determining the effectiveness of treatments and controls in reducing effluents and emissions.
- Determining the validity and effectiveness of models to predict concentrations of pollutants in the environment.
- Detecting and quantifying unplanned releases.
- Identifying and quantifying new environmental quality problems.
- Maintaining the capability to assess the consequence of accidental contaminant releases.
- Providing public assurance and addressing issues of concern to the public, stakeholders, regulatory agencies, and business community.
- Enhancing public understanding of site environmental issues, primarily through public involvement and by providing environmental information to the public.
- Providing environmental data and assessments to assist the DOE and its contractors in environmental management of the site.

Annual reviews are performed to assure the project is aligned with current operations and missions, focused on those contaminants having the greatest contribution to the potential offsite dose, and providing the greatest amount of useful information for the waste management, cleanup, and environmental assessment activities planned or ongoing at Hanford. Site-wide and offsite surveillance is closely related to and coordinated with the Near-Facility Environmental Monitoring Program described in Section 10.0.1.2 and the Groundwater Performance Assessment Project (Section 10.0.3).

Information on contaminant concentrations in project samples collected at site-wide and offsite locations during 2005 is summarized in Sections 10.2, 10.4, 10.5, 10.8, 10.11, 10.13, and 10.14. Other project information is summarized in Sections 10.12, 10.17, and 10.18. More detailed contaminant data are provided in *Hanford Site Environmental Surveillance Data Report for Calendar Year 2005* (PNNL-15892, APP. 1). The types and general locations of samples collected for site-wide and offsite environmental monitoring during 2005 are summarized in Table 10.0.2.

### 10.0.2.3 Ecological Monitoring and Compliance Project

The Ecological Monitoring and Compliance Project has multiple objectives that support both activity-specific ecological compliance requirements and site-wide requirements to assure the protection of Hanford's natural resources. Project personnel monitor the abundance, vigor, and distribution of plant and animal populations on the Hanford Site and evaluate the cumulative impact of site operations on these resources. In addition, project staff perform baseline ecological resource surveys to document the occurrence of protected resources, evaluate and document impacts to protected species and habitats as required by the *National Environmental Policy Act* and the *Endangered Species Act*, facilitate cost-effective regulatory compliance, and assure fulfillment of DOE natural resource protection responsibilities. This project also supports 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*, 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 expansions.
- 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.

Ecosystem and compliance monitoring information for 2005 for plant and animal species and communities found on the Hanford Site is summarized in Sections 10.10 and 10.11.

**Table 10.0.2. Routine Hanford Site Environmental Surveillance Sample Types and Numbers of Sampling Locations, 2005**

| Type | Total Number of Locations | Sampling Locations | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Columbia River | | |
| | | Onsite[a] | Site Perimeter[b] | Nearby[c] | Distant[c] | Upstream[c] | Hanford Reach[b] | Downstream[c] |
| Air | 45 | 24 | 11 | 8[d] | 2[d] | | | |
| Spring water | 19 | | | | | | 18 | 1 |
| Spring sediment | 11 | | | | | | 10 | 1 |
| Columbia River water | 56 | | | | | 5 | 40 | 11 |
| Irrigation water | 2 | | | 2 | | | | |
| Drinking water | 4 | 4 | | | | | | |
| River sediment | 8 | | | | | 2 | 3 | 3 |
| Ponds | 2 | 2 | | | | | | |
| Pond sediment | 1 | 1 | | | | | | |
| Foodstuffs | 8 | | 1 | 4 | 3 | | | |
| Wildlife | 6 | 4 | | | 2 | | | |
| Aquatic biota | 6 | | | | | 2 | 4 | |
| External dose[e] | 82 | 33 | 11 | 7 | 2 | 1 | 25 | 3 |
| External shoreline radiation[f] | 15 | | | | | 1 | 14 | |
| Exposure rate (PIC)[g] | 4 | | | 3[d] | 1[d] | | | |

(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) Measured by thermoluminescent dosimeters.
(f) Measured by handheld survey instruments.
(g) Pressurized ionization chambers.

### 10.0.2.4 Cultural Resources Project

The Cultural Resources Project operates the Hanford Cultural Resources Laboratory for the DOE. Project staff perform baseline cultural resource surveys to document the occurrence of protected resources; evaluate and document impacts to protected resources as required by the *National Historic Preservation Act*, the *American Indian Religious Freedom Act*, and the *Archaeological Resources Protection Act*; facilitate regulatory compliance; and assure fulfillment of DOE cultural resource protection responsibilities. A summary of Hanford Site cultural resource monitoring activities conducted in 2005 is provided in Section 10.15.

## 10.0.3 Groundwater Performance Assessment Project

The Groundwater Performance Assessment Project is responsible for assessing the distribution and movement of existing groundwater contamination (both radiological and chemical) beneath the Hanford Site and for identifying and characterizing potential and emerging groundwater contamination problems. Monitoring activities are conducted to comply with requirements of the *Resource Conservation and Recovery Act* (RCRA), DOE Orders (e.g., 5400.5), and Washington State regulations, as well as requirements for

operational monitoring around retired reactors and chemical-processing facilities, and requirements for environmental surveillance. Groundwater monitoring is also carried out during cleanup investigations under the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA). Groundwater samples were collected from 687 wells and 128 Columbia River shoreline aquifer tubes during 2005. A summary of groundwater monitoring activities and analytical results for 2005 is provided in Section 10.7.

## 10.0.4 Drinking Water Monitoring Project

DOE Order 5400.5 sets the radiation dose limits for persons consuming water from a public drinking water supply operated by the DOE, or by a DOE contractor, to levels equivalent to those mandated by law in 40 CFR 141, *National Primary Drinking Water Regulations; Radionuclides; Proposed Rule* (federal drinking water standards). The U.S. Environmental Protection Agency (EPA) sets legal limits on the levels of certain contaminants in drinking water. State governments, through their health departments and environmental agencies, are expected to accept the major responsibility for administering and enforcing the limits set by the EPA. In the state of Washington, federal drinking water laws are enforced by the Washington State Department of Health through state administrative codes. The Drinking Water Monitoring Project at Hanford conducts radiological monitoring of DOE-owned, contractor-operated drinking water systems. Section 10.6 provides a summary of the radiological monitoring results for 2005 of the Hanford Site drinking water systems.

## 10.0.5 Biological Control Program

Biological 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 Biological Control Program is responsible for integration of (1) expanded radiological surveillance for contaminated biota and soil, (2) control of undesirable plants and animals, (3) clean up of legacy and new contamination related to biota, and (4) remediation, following cleanup, 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, become fire hazards, and reduce the efficiency of people and machines. At Hanford, the control of weeds occurs at tank farms (clusters of underground radioactive waste storage tanks), radioactive waste pumping installations, industrial sites, power stations and along transmission lines, buildings, storage and work areas, and along fence lines. Pest control prevents, limits, or removes undesirable animals through the application of chemical, cultural, or mechanical methods.

Noxious weeds are controlled onsite to prevent their spread and reduce or eliminate their populations. 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 non-native, aggressively invasive, and hard to control. Damage to natural ecosystems and loss of productive agricultural lands can occur unless control measures are taken. Control measures can be mechanical, chemical, or biological. Biological control may include preventive measures or measures in response to existing contamination spread.

Activities to prevent the spread of contamination include radiological surveys, preventive controls (e.g., herbicide spraying), and the placement of engineered 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, and cleaning up and removing the contamination to an approved disposal location.

In some cases, restoration is necessary following cleanup and removal of contamination. Restoration is a common activity on the Hanford Site but has specific meanings and limitations when applied to biological control. Restoration may include soil removal and replacement, revegetation of the soil surface, or placement of engineered barriers to stop biological intrusion (biological barriers). Such restoration on radioactive waste sites is typically performed to prevent reoccurrence of surface radioactive contamination or unwanted biota.

Activities conducted for the Biological Control Program in 2005 are discussed in Sections 10.10 and 10.11.

## 10.0.6 Washington State Department of Health Oversight Monitoring

The Environmental Radiation Section of the Washington State Department of Health conducts an independent oversight program on environmental radiation monitoring conducted by DOE contractors. The contractors are currently the Pacific Northwest National Laboratory and Duratek Federal Services of Hanford, Inc. The main objectives of the Washington State Department of Health oversight program are to verify the quality of contractor monitoring programs and to assure that the programs are adequate to protect the public health.

The objectives of the Washington State Department of Health program are achieved through split sampling with the contractors and independent sampling at contractor sampling sites. Analysis of Washington State Department of Health samples is performed by the Washington State Public Health Laboratory, which provides an independent check on contractor analyses. Each year the Washington State Department of Health compares the measurements of radioactivity in Washington State Department of Health and contractor samples in a quantitative manner to determine the accuracy and reliability of contractor monitoring.

The results of the Washington State Department of Health oversight program are published in the *Hanford Environmental Oversight Program Data Summary Report* (e.g., DOH 320-039).

# 10.1 Air Emissions

L. P. Diediker and D. J. Rokkan

Hanford Site contractors monitor airborne emissions near site facilities to assess the effectiveness of emission treatment and control systems, pollution management practices, and to determine compliance with state and federal regulatory requirements. Measuring devices quantify most facility emission flows, while other emission flows are calculated using process information or fan manufacturer's specifications. For most radioactive air emission units, which are primarily ventilated stacks, sampling is performed either continuously or periodically. Airborne emissions with a potential to contain radioactive materials at prescribed threshold levels are measured for gross alpha and gross beta concentrations, and, as warranted, specific radionuclides. Non-radioactive constituents and parameters are monitored directly, sampled and analyzed, or estimated based upon inventory usage.

Emissions release data are documented in several reports besides this one, all available to the public. For instance, DOE annually submits to EPA and the Washington State Department of Health a report of radionuclide air emissions from the site (DOE/RL-2006-01), in compliance with 40 CFR 61, Subpart H and WAC 246-247.

## 10.1.1 Radioactive Airborne Emissions

Small quantities of tritium (i.e., hydrogen-3), strontium-90, iodine-129, cesium-137, plutonium-238, plutonium-239/240, plutonium-241, americium-241, and several other longer-lived isotopes are released to the environment through state and federally permitted emission points. Distinguishing Hanford-produced radionuclides in the environment is extremely challenging because concentrations in emissions from Hanford Site stacks are comparable to background concentrations of radionuclides that originated from historical atmospheric nuclear weapons testing. Gross alpha and gross beta concentrations in these emissions are on average equivalent to concentrations in the environment, including concentrations at distant locations upwind of Hanford. The cessation of nuclear materials processing operations is largely responsible for the decreasing radiological emissions from the site. Figure 10.1.1 depicts quantities of two longer-lived radionuclides released from the site over the past 11 years.

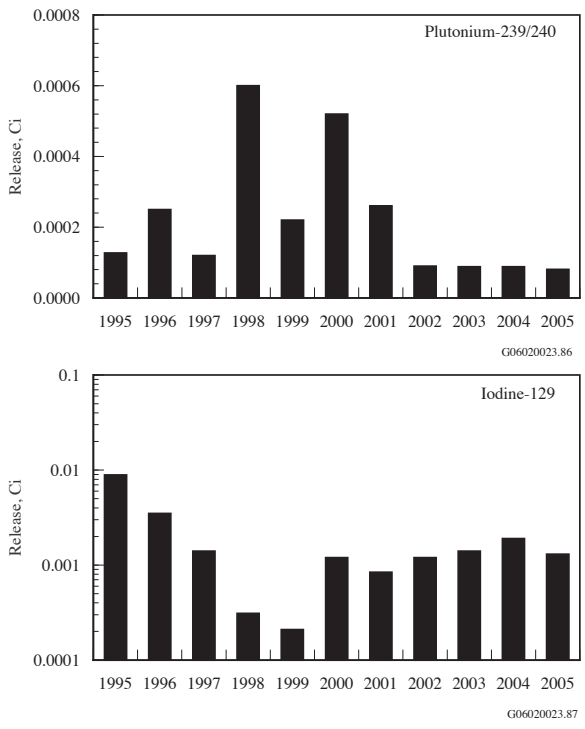



**Figure 10.1.1. Airborne Releases of Selected Radionuclides from the Hanford Site, 1995 through 2005**

Radioactive airborne emissions from Hanford Site activities contain particulate and volatilized forms of radionuclides. Emissions having the potential to exceed 1% of the 10 mrem (100 mSv) per year standard for public dose are monitored continuously.

The continuous monitoring of radioactive emissions involves analyzing samples collected at points of discharge to the environment, usually from a stack but sometimes a vent. Samples are analyzed for gross alpha and gross beta, as well as selected radionuclides. The selection of the specific radionuclides sampled, analyzed, and reported is based on (1) an evaluation of the hypothetical maximum potential of unabated emissions under normal operating conditions 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 emission points when the potential exists for radioactive emissions to exceed normal operating ranges to levels that require immediate personnel alert.

Radioactive emission points are located in the 100, 200, 300, 400, and 600 Areas of the Hanford Site. For 2005, the prime sources of emissions and the number of emission points by operating area are summarized as follows:

- In the 100 Areas, emissions originated predominately from normal evaporation and cleanup activities at two water-filled storage basins (100-K East and 100-K West Fuel Storage Basins [also known as the K Basins], which did contain irradiated nuclear fuel), the Cold Vacuum Drying Facility, and a low-level radiological laboratory in the 1706-KE Building. In the 100 Areas, there were seven radioactive-emission points.
- In the 200 Areas, the primary sources of radionuclide emissions were the Plutonium Finishing Plant, T Plant, Waste Encapsulation and Storage Facility, underground tanks storing high-level radioactive waste, waste evaporators, and inactive Plutonium-Uranium Extraction (PUREX) Plant. In the 200 Areas, a majority of the 52 potential radioactive-emission points were active in 2005.
- The 300 Area primarily has laboratories and research facilities. Primary sources of airborne radionuclide emissions were the 324 Waste Technology Engineering Laboratory, 325 Applied Chemistry Laboratory, 327 Post-Irradiation Laboratory, and 340 Complex Vault and Tanks. In the 300 Area, a majority of the 22 potential radioactive-emission points were active in 2005.
- The 400 Area has the Fast Flux Test Facility, Maintenance and Storage Facility, and Fuels and Materials Examination Facility, all shutdown facilities. Operations and support activities at the Fast Flux Test Facility and Maintenance and Storage Facility released small quantities of radioactive material to the environment. In the 400 Area, five radioactive-emission points were active in 2005.
- The 600 Area has the Waste Sampling and Characterization Facility, at which low-level radiological and chemical analyses are performed on various types of samples (e.g., particulate air filters, liquids, soil, and vegetation). This facility has two radioactive-emission points, both of which were active in 2005. For dose-modeling purposes, emissions from the Waste Sampling and Characterization Facility, which is very close to the east entrance of the 200-West Area, were grouped with emissions reported for the 200-West Area.

A summary of Hanford Site radioactive airborne emissions in 2005 is provided in Table 10.1.1.

## 10.1.2 Non-Radioactive Airborne Emissions

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

In past years, gaseous ammonia has been emitted from the Plutonium-Uranium Extraction (PUREX) Plant, 242-A evaporator, AP Tank Farm, and AW Tank Farm, all located in the 200-East Area. Ammonia emissions are tracked only when activities at these facilities are capable of generating them. During 2005, the 200 Areas tank farms produced reportable ammonia emissions, summarized in Table 10.1.2.

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

**Table 10.1.1. Radionuclides Discharged to the Atmosphere at the Hanford Site, 2005**

| | | Release, Ci[a] | | | | |
|---|---|---|---|---|---|---|
| **Radionuclide** | **Half-Life** | **100 Areas** | **200-East Area** | **200-West Area** | **300 Area** | **400 Area** |
| Tritium (as HT) | 12.3 yr | NM | NM | NM | $1.3 \times 10^{1}$ | NM |
| Tritium (as HTO) | 12.3 yr | NM | NM | NM | $7.6 \times 10^{1}$ | NM |
| Strontium-90 | 29.1 yr | $2.8 \times 10^{-5}$[b] | $3.3 \times 10^{-5}$[b] | $2.2 \times 10^{-5}$[b] | $1.1 \times 10^{-6}$[b] | NM |
| Iodine-129 | 16,000,000 yr | NM | $1.3 \times 10^{-3}$ | NM | NM | NM |
| Xenon-131m | 11.8 d | NM | NM | NM | $1.0 \times 10^{-6}$ | NM |
| Xenon-133 | 5.2 d | NM | NM | NM | $1.3 \times 10^{-7}$ | NM |
| Xenon-135 | 9.1 h | NM | NM | NM | $7.0 \times 10^{-8}$ | NM |
| Cesium-137 | 30 yr | NM | $3.4 \times 10^{-5}$ | $1.4 \times 10^{-6}$ | $8.2 \times 10^{-6}$[c] | $8.9 \times 10^{-6}$[c] |
| Europium-155 | 4.8 yr | ND[f] | ND | $3.9 \times 10^{-8}$ | ND | NM |
| Radon-220 | 55.6 s | NM | NM | NM | $4.3 \times 10^{1}$ | NM |
| Radon-222 | 3.8 d | NM | NM | NM | 1.2 | NM |
| Plutonium-238 | 87.7 yr | $1.6 \times 10^{-6}$ | $5.4 \times 10^{-8}$ | $1.5 \times 10^{-6}$ | ND | NM |
| Plutonium-239/240 | 24,110 yr | $1.2 \times 10^{-5}$[d] | $2.6 \times 10^{-6}$[d] | $6.6 \times 10^{-5}$[d] | $6.9 \times 10^{-8}$[d] | $3.0 \times 10^{-7}$[d] |
| Plutonium-241 | 14.4 yr | $1.3 \times 10^{-4}$ | ND | $6.0 \times 10^{-5}$ | ND | NM |
| Americium-241 | 432 yr | $1.4 \times 10^{-5}$ | $3.7 \times 10^{-6}$ | $1.1 \times 10^{-5}$ | $4.9 \times 10^{-7}$[e] | NM |
| Americium-243 | 7,380 yr | NM | NM | NM | ND | NM |
| Curium-242/244 | 18.1 yr | NM | NM | NM | ND | NM |

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

accordance with the air quality standards established in *General Regulations for Air Pollution Sources* (WAC 173-400). Power plant emissions are calculated from the quantities of fossil fuel consumed, using EPA-approved formulas (*Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources*, AP-42).

Should activities result in chemical emissions in excess of quantities reportable under CERCLA, the release totals are immediately reported to EPA. If the emissions remain stable at predicted levels, they may be reported annually with EPA's permission. Table 10.1.2 summarizes the emissions of non-radioactive pollutants discharged to the atmosphere at Hanford during 2005 (Note: the 100, 400, and 600 Areas have no non-radioactive emission sources of regulatory concern). Table 10.1.2 also includes emission estimates from the carbon tetrachloride vapor extraction work in the 200-West Area. Those emissions are accounted for in the table category of "other toxic air pollutants" and do not require reporting because they are below respective reportable quantities.

**Table 10.1.2. Non-Radioactive Constituents Discharged to the Atmosphere at the Hanford Site, 2005**

| Constituent | Release, kg (lb) | |
|---|---|---|
| Particulate matter-total | 6,500 | (14,000) |
| Particulate matter-10 | 2,800 | (6,200) |
| Particulate matter-2.5 | 1,000 | (2,200) |
| Nitrogen oxides | 12,000 | (27,000) |
| Sulfur oxides | 3,000 | (6,600) |
| Carbon monoxide | 14,000 | (31,000) |
| Lead | 0.47 | (1.0) |
| Volatile organic compounds[a,b] | 14,000 | (30,000) |
| Ammonia[c] | 12,000 | (25,000) |
| Other toxic air pollutants[d] | 6,600 | (14,000) |

(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 and calculated estimates from the 200-East and 200-West Areas tank farms, evaporation losses from fuel dispensing, operation of the 242-A evaporator, 200 Area Effluent Treatment Facility, Central Waste Complex, T Plant complex, and Waste Receiving and Processing 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 200 Area Effluent Treatment Facility, and are produced from burning fossil fuel for steam and electrical generators.
(d) Releases are a composite of calculated estimates of toxic air pollutants, excluding ammonia, from the 200-East and 200-West Areas tank farms, operation of the 242-A evaporator, 200 Area Effluent Treatment Facility, Central Waste Complex, T Plant complex, and Waste Receiving and Processing Facility. Toxic air pollutant emissions, excluding ammonia, are a subset of volatile organic compound emissions and are included in the total of those emissions.

# 10.2 Ambient-Air Monitoring

B. G. Fritz and C. J. Perkins

Atmospheric releases of radioactive materials from Hanford Site facilities and operations to the surrounding region are potential sources of human exposure. At the Hanford Site, radioactive constituents in air are monitored onsite near facilities and operations, at site-wide locations away from facilities, and offsite around the perimeter of the site and in nearby and distant communities. Information about these ambient-air monitoring efforts, including detailed descriptions of air sampling and analysis techniques is provided in DOE's environmental monitoring plan for the Hanford Site (DOE/RL-91-50). Brief summaries of the ambient-air monitoring objectives and the projects that support them can be found in this report in Section 10.0.

Comparing measured radionuclide concentrations from locations on and around the Hanford Site to concentrations measured at upwind locations 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. Complete listings of all radiological analytical results summarized in the following sections are reported separately (PNNL-15892, APP. 1; PNNL-15892, APP. 2).

In addition to the radiological monitoring networks, a small non-radiological air-monitoring system is operated onsite. This system measures atmospheric particulate matter (dust) concentrations at a few locations on the Hanford Site. Results are primarily used for scientific studies in an attempt to better understand windblown dust on and around the Hanford Site.

## 10.2.1 Ambient-Air Monitoring Near Facilities and Operations

C. J. Perkins

During 2005, a network of continuously operating samplers at 88 locations across the site (Table 10.2.1) (sampling locations illustrated in PNNL-15892, APP. 2) was used to monitor radioactive materials in air near Hanford Site facilities and operations. Air samplers were located primarily at or within approximately 500 meters (1,500 feet) of sites and/or facilities having the potential for, or a history of, environmental releases. The samplers were predominantly located in the prevailing downwind direction. Samples were collected according to a schedule established before the 2005 monitoring year. Airborne particle samples were collected at each 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

**Table 10.2.1. Monitoring Locations and Analyses for Ambient-Air Monitoring Samples Collected Near Hanford Site Facilities and Operations, 2005**

| Site | Number of Samplers | EDP Code[a] | Analyses: Biweekly | Analyses: Composite[b] |
|---|---|---|---|---|
| 100-B/C Area field remediation project | 5 | N464, N465, N466, N496, N497 | Gross alpha, gross beta | Gamma, $^{90}$Sr, Pu-iso, U-iso |
| 105-D interim safe storage project (100-D Area) | 1 | N523 | Gross alpha, gross beta | Gamma, $^{90}$Sr, Pu-iso, U-iso |
| 105-DR interim safe storage project (100-D Area) | 1 | N492 | Gross alpha, gross beta | Gamma, $^{90}$Sr, Pu-iso, U-iso |
| 100-F Area field remediation project | 6 | N519, N520, N521, N552, N553, N558 | Gross alpha, gross beta | Gamma, $^{90}$Sr, Pu-iso, U-iso |
| 105-H interim safe storage project (100-H Area) | 2 | N524, N525 | Gross alpha, gross beta | Gamma, $^{90}$Sr, Pu-iso, U-iso |
| 100-K Area spent nuclear fuels | 8 | N401, N402, N403, N404, N476, N477, N478, N479 | Gross alpha, gross beta | Gamma, $^{90}$Sr, Pu-iso, U-iso, $^{241}$Pu, $^{241}$Am |
| 100-KR-1 field remediation project (100-K Area) | 3 | N528, N529, N530 | Gross alpha, gross beta | Gamma, $^{90}$Sr, Pu-iso, U-iso |
| 118-KR-1 field remediation project (100-K Area) | 3 | N403, N534, N535 | Gross alpha, gross beta | Gamma, $^{90}$Sr, Pu-iso, U-iso |
| 100-NR-1 field remediation and 100-N D4 projects (100-N Area) | 4 | N102, N103, N106, N526 | Gross alpha, gross beta | Gamma, $^{90}$Sr, 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 | Gamma, $^{90}$Sr, Pu-iso, U-iso |
| Canister Storage Building (200-East Area) | 2 | N480, N481 | Gross alpha, gross beta | Gamma, $^{90}$Sr, Pu-iso, U-iso, |
| Integrated Disposal Facility (200-East Area) | 1 | N532 | Gross alpha, gross beta | Gamma, $^{90}$Sr, Pu-iso, U-iso |
| 200-West Area | 23 | N155, N161, N165, N168, N200, N304, N433, N441, N442, N449, N456, N457, N554, N555, N956, N963, N964, N965, N966, N974, N975, N987, N994 | Gross alpha, gross beta | Gamma, $^{90}$Sr, Pu-iso, U-iso |
| U Ancillary decontamination and demolition project (200-West Area) | 2 | N550, N551 | Gross alpha, gross beta | Gamma, $^{90}$Sr, Pu-iso, U-iso |
| 300 Area decontamination and demolition project | 1 | N557 | Gross alpha, gross beta | Gamma, $^{90}$Sr, Pu-iso, U-iso |
| 300-FF-2 field remediation project (300 Area) | 6 | N130, N527, N546, N547, N548, N549, | Gross alpha, gross beta | Gamma, $^{90}$Sr, Pu-iso, U-iso |
| Environmental Restoration Disposal Facility | 4 | N482, N517, N518, N963 | Gross alpha, gross beta | Gamma, $^{90}$Sr, Pu-iso, U-iso |
| 600 Area | 1 | N981 | Gross alpha, gross beta | Gamma, $^{90}$Sr, Pu-iso, U-iso |

(a) EDP Code = Sampler location code. See PNNL-15892, APP. 2.
(b) Gamma spectroscopy, strontium-90, isotopic plutonium ($^{238}$Pu, $^{239/240}$Pu), and isotopic uranium ($^{234}$U, $^{235}$U, and $^{238}$U).

each location. Composite samples were routinely analyzed for gamma-emitting isotopes, strontium-90, plutonium-238, plutonium-239/240, uranium-234, uranium-235, and uranium-238, and at locations associated with processing spent nuclear fuel, americium-241, and plutonium-241 (Table 10.2.1).

Figure 10.2.1 shows the annual average air 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; Appendix D, Table D.2) are dose-based reference values that are used as indexes of performance. The concentration guides are concentrations that would result in a dose of 100 mrem (1 mSv) per year under conditions of continuous exposure. The 2005 data indicate a large degree of variability. Air samples collected from locations 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 and widely variable within different onsite operational areas. Naturally occurring radionuclides beryllium-7 and potassium-40 were routinely identified. Appendix C, Table C.1 shows the annual average and maximum concentrations of radionuclides in air samples collected near facilities and operations during 2005. A complete listing of the 2005 near-facility ambient-air monitoring results can be found in PNNL-15892, APP. 2. Concentrations of radionuclides in air in the 300 and 400 Areas, near some onsite remediation projects, and offsite at distant locations were collected by Pacific Northwest National Laboratory personnel. Results for Pacific Northwest National Laboratory air samples are summarized in Section 10.2.2.

At the remedial action project site in the 100-B/C Area, ambient air monitoring was conducted at five locations in 2005. The radionuclides uranium-234 and uranium-238 were consistently detected, while strontium-90, uranium-235, and plutonium-239/240 were detected in 30% or less of the composited samples.

In concert with the resumption of field remediation activity at the 100-F Area, air monitoring was conducted at six locations beginning in March 2005. Similar to results observed during earlier remediation activity at this location (March 2000 through April 2003), uranium-234 was detected consistently in approximately 85% of the samples. Strontium-90 was not detected in 2005, unlike the previous remediation campaign in which the isotope was detected in approximately 50% of the samples.

During 2005, air monitoring continued at four locations associated with the interim safe storage of the reactor buildings in the 100-D/DR and 100-H Areas. The quarterly analytical results from these air samples showed radionuclide concentrations and frequencies of detection consistent with results observed over the past 5 years. Uranium-234 and uranium-238 were consistently detected (in 70% of the samples). Plutonium-239/240, strontium-90, and uranium-235 were detected in approximately 20% of the quarterly composite samples.

The airborne contaminant levels in the 100-K Area were similar to those measured over the previous years. Ambient-air monitoring was conducted at eight 100-K Area locations during 2005 (four stations each at the 100-K East and 100-K West Areas). Uranium-234 and uranium-238 were detected in approximately 90% of the composite samples obtained during 2005. Plutonium-239/240 was detected in about half of the composite samples, while americium-241, uranium-235, and strontium-90 were detected in approximately 25% of the samples.

Air sampling to support the 118-K-1 Field Remediation Project (100-K Area) was intermittently conducted at two new and one pre-existing locations during 2005. Sampling was performed in conjunction with project activity and the initial term was from mid-February through mid-March 2005. Monitoring resumed in November and was conducted continuously through the end of the year. Uranium-234 and uranium-238 were detected in approximately 67% of the samples, while strontium-90 and plutonium-239/240 were detected in approximately 50% and 33% of the samples, respectively.

Beginning in July 2005, decontamination and decommissioning activities in the 100-K Area prompted the use of air monitoring data from three nearby existing air sampling

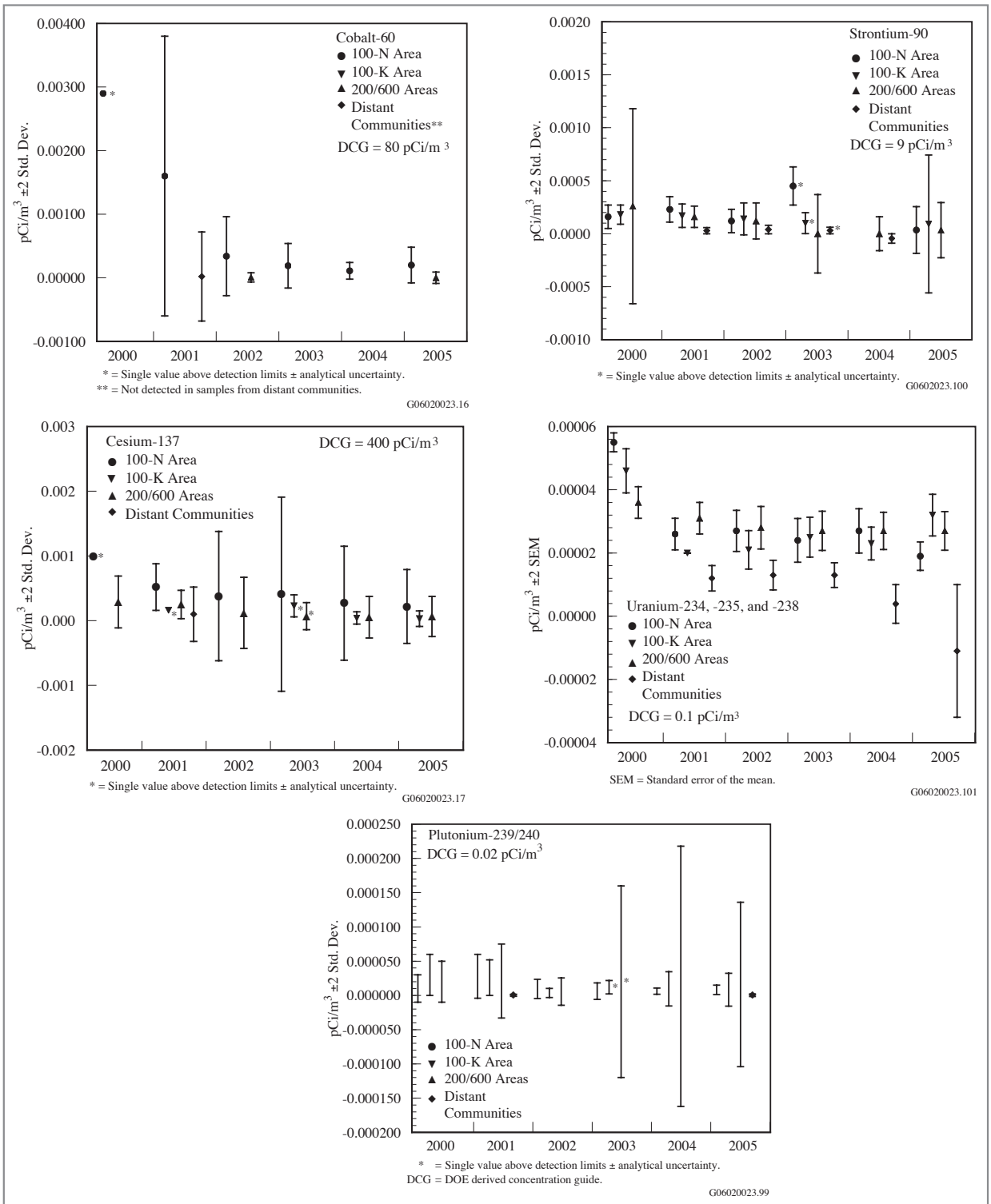



**Figure 10.2.1. Average Concentrations of Selected Radionuclides in Ambient-Air Samples Collected on the Hanford Site Near Facilities and Operations Compared to Those Collected in Distant Communities, 2000 through 2005. Radionuclide concentrations below analytical detection limits are not shown. As a result of figure scale, some uncertainties (error bars) are concealed by the point symbol.**

stations. Air sampling results obtained from two near-facility stations and one Pacific Northwest National Laboratory air sampling station indicated that only uranium-234 and uranium-238 were detected consistently (100% of the samples) and their concentrations were similar to those measured in previous years.

Air sampling continued in 2005 at three locations at the 100-KR-1 remedial action site (100-K Area). Uranium-234 and uranium-238 were detected in approximately 90% of the composite samples obtained during 2005. Uranium-235 and plutonium-239/240 were detected in approximately 33% and 50% of the samples, respectively.

Analytical results from four ambient-air sampling locations at the 100-NR-1 remedial action project site and 100-N Area surveillance and maintenance and transition project site (both in the 100-N Area) in 2005 were similar to those measured in previous years. Uranium-234 and uranium-238 were detected in approximately 80% of the composite samples. Cesium-137 and plutonium-239/240 were detected in approximately 50% of the samples, while cobalt-60 was detected in 75% of the samples.

Air sampling was conducted at 20 locations in the 200-East Area during 2005. Radionuclide levels measured in the 200-East Area ambient air composite samples in 2005 were similar to those measured over the previous years. Uranium-234 and uranium-238 were detected in 90% of the samples and uranium-235 was detected in approximately 33% of the samples. Cesium-137, plutonium-239/240, and strontium-90 were detected in less than 20% of the samples.

Air sampling was conducted at 25 locations in the 200-West Area during 2005. Generally, radionuclide levels measured in the 200-West Area were similar to results for previous years. Uranium-234 and uranium-238 were detected in approximately 85% of the samples. Plutonium-239/240 was detected in approximately 30% of the samples and uranium-235 in less than 25%.

Air sampling in support of decontamination and decommissioning activities in the 300 Area was initiated at one new location in February 2005. Results from the quarterly composited samples showed that only uranium-234 and was detected with any consistency (100% of the samples).

Remediation work in the 300-FF-2 Operable Unit (located near the 300 Area) during 2005 was conducted at several locations at different times, and as a result, six ambient-air monitoring stations were intermittently employed during the year. Uranium-234 and uranium-238 were detected in approximately 70% of the samples and uranium-235 in approximately 30% of the samples. The highest uranium-234, uranium-235, uranium-238, and plutonium-239/240 concentrations observed in near-facility air samples during 2005 were from a 2-week sample collected during August at one of the two sampling stations (N548) at the 316-4/600-259 remediation site. At both sampling stations, the total alpha and total beta concentrations during the same sample period were slightly higher than concentrations observed previously at these locations. It is difficult to draw firm conclusions about the uranium and plutonium results from such short-duration air samples, and the elevated concentrations may be more closely associated with the low sample volumes than with the project activities. The uranium concentrations were less than 1% of the DOE derived concentration guide and the plutonium-239/240 result was approximately 3% of the DOE derived concentration guide. The 316-4/600-259 remediation site (familiarly known as "Little Egypt") is located in the northern portion of the 300-FF-2 Operable Unit project, approximately 6.6 kilometers (4.1 miles) northwest of the 300 Area.

The air sampling network at the Environmental Restoration Disposal Facility (200-West Area) used two established samplers for upwind monitoring (one near-facility sampler and one Pacific Northwest National Laboratory sampler, station #13 at the 200 W SE location) (Section 10.2.2) and three air samplers at the facility that provided downwind coverage. The 2005 analytical results were comparable to those obtained in 2004. Uranium-234 and uranium-238 were detected in 100% of the near-facility composite samples and plutonium-239/240 was detected in approximately 38%.

## 10.2.2 Site-Wide and Offsite Ambient-Air Monitoring

B. G. Fritz

During 2005, airborne radionuclide samples were collected by 44 continuously operating samplers. The sampling

stations were grouped into four location classifications: site-wide (onsite) (23 stations), perimeter (11 stations), community (8 stations), and distant (2 stations) (Figure 10.2.2 and Table 10.2.2). Four of the stations were community-operated environmental surveillance stations (Section 10.17) that were managed and operated until October 2005 by local schoolteachers as part of a 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 boundary, with emphasis on the prevailing downwind directions to the south and east of the site. 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.

### 10.2.2.1 Collection of Site-Wide and Offsite Ambient-Air Samples and Analytes Tested

Samples were collected according to a schedule (PNNL-15003) established before the monitoring year and analyzed for up to eight analytes (Table 10.2.2). Airborne particle samples were collected biweekly at each location 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 compositing procedure results in a 12-week-average concentration. 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 cartridge containing a charcoal adsorbent material. Samples were collected monthly and combined to form quarterly composite samples for each location.

Atmospheric water vapor was collected for tritium analysis at 21 locations by continuously drawing air through multi-column samplers containing adsorbent silica gel. The water-vapor samplers were exchanged every 4 weeks to prevent loss of the sample as a result of breakthrough (i.e., over saturation). 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.

### 10.2.2.2 Ambient-Air Monitoring Results for Site-Wide and Offsite Samples

All sample results showed very low radiological concentrations in air during 2005. All concentrations were below the DOE derived concentration guide (Appendix D, Table D.2) for each radionuclide analyzed (Table 10.2.3). The derived concentration guides are concentrations that would result in a 100 mrem (1 mSv) per year dose under conditions of continuous exposure. A more conservative dose standard is the EPA Clean Air Act standard of 10 mrem (100 µSv) per year from airborne radiological material. All radionuclide concentrations in air samples collected in 2005 were less than the DOE derived concentration guide values and the EPA standards. Therefore, no air samples were collected in 2005 with concentrations high enough to result in a 10-mrem (100-µSv) annual dose.

Gross alpha concentrations were essentially the same at all site-wide and offsite locations during 2005 (Figure 10.2.3). There were no statistically significant (two-sample means t-test, 95% confidence level) differences in the average gross alpha concentrations measured at the different distant classes. The highest gross alpha concentration for 2005

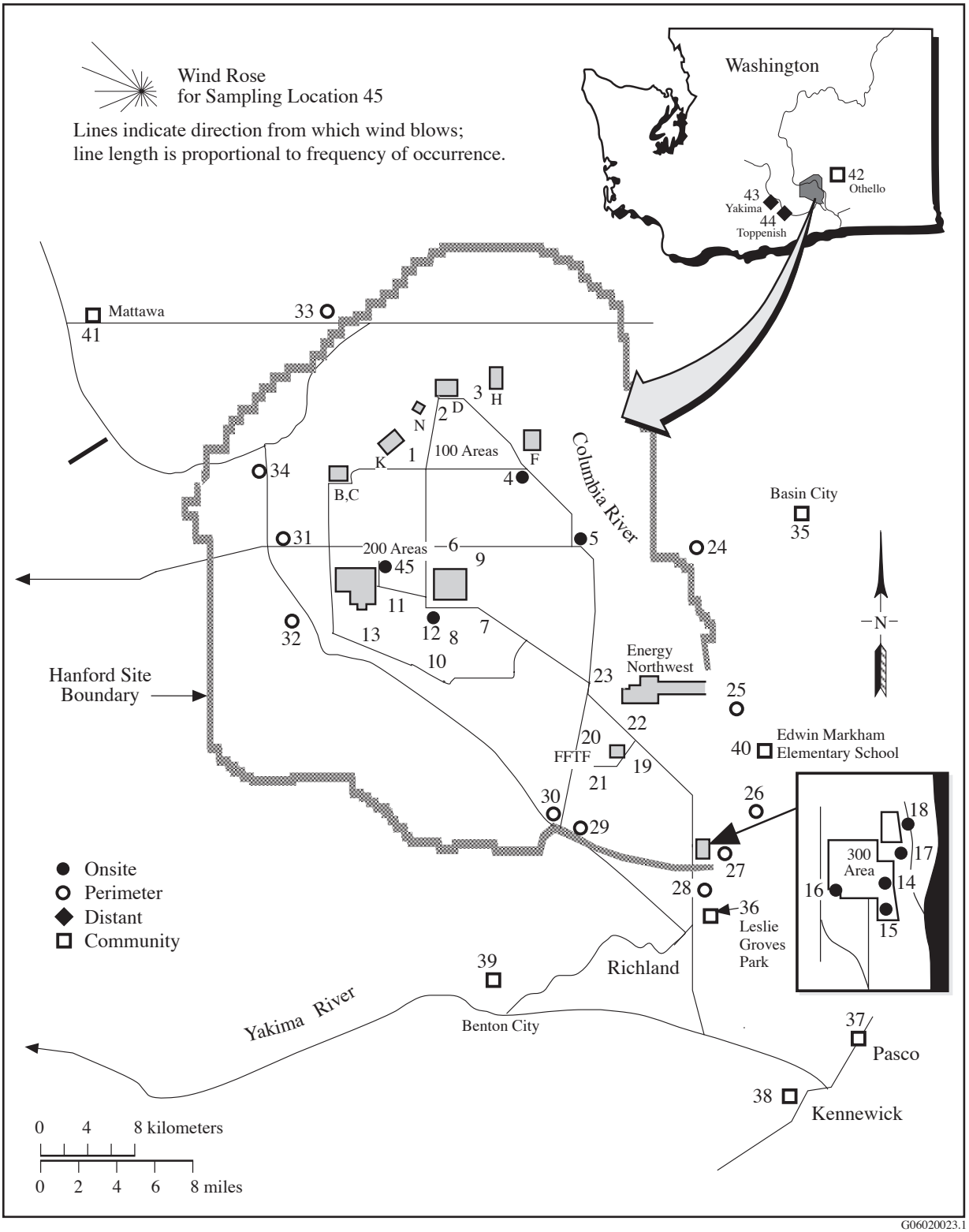



**Figure 10.2.2. Hanford Site-Wide and Offsite Ambient-Air Sampling Locations During 2005 (see Table 10.2.2 for location names)**

**Table 10.2.2. Site-Wide and Offsite Ambient-Air Sampling Locations, Sample Composite Groups, and Analytes, 2005**

| Map[a] Location | Sampling Location | Analytes[b] | Composite Group | Analytes[c] |
|---|---|---|---|---|
| **Site-Wide (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 10.2.2. (contd)**

| Map[a] Location | 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 10.2.2.
(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 10.2.2.3.

was observed at a site-wide location near the 400 Area (6,300 aCi/m$^3$ [230 µBq/m$^3$]). The average gross alpha concentrations observed in individual location groups during 2005 were slightly higher than the 5-year average concentrations observed in the groups from 2000 through 2004 (Table 10.2.3).

Gross beta concentrations in air peaked during the winter months in 2005 (Figure 10.2.4), repeating a pattern of natural radioactivity fluctuations (Eisenbud 1987). The annual average gross beta concentration at site-wide locations during 2005 was slightly higher than at the distant locations. The difference was small and not statistically significant (two-sample means t-test, 95% confidence level). The average gross beta concentrations reported for 2005 were slightly higher than concentrations measured from 2000 through 2004 (Table 10.2.3). However, the differences were not statistically significant (two-sample means t-test, 95% confidence level).

In 2004, gross beta concentrations appeared to be inversely proportional to the average wind speed over the sampling period, i.e., as wind speed increased, concentrations decreased. This pattern was evident again in 2005. Section 10.2.2.4 describes sampling done in 2005 and early 2006 to explore this relationship.

Tritium concentrations measured at all locations during 2005 were similar, but slightly lower than average values reported for 2000 through 2004 (Table 10.2.3). The annual average 300 Area, perimeter, and community concentrations were higher than the average concentration measured at the

**Table 10.2.3. Airborne Radionuclide Concentrations in the Environs of the Hanford Site, 2005 Compared to Previous Years**

| Radionuclide (approximate detection limit) | Location Group[a] | 2005 No. of Samples | 2005 No. of Detections[b] | 2005 Maximum[c] | 2005 Average[d] | 2000-2004 No. of Samples | 2000-2004 No. of Detections[b] | 2000-2004 Maximum[c] | 2000-2004 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 (1.0 pCi/m$^3$) | 300 Area | 78 | 64 | 7.6 ± 1.5 | 2.2 ± 3.0 | 381 | 363 | 23 ± 2.1 | 5.3 ± 7.7 | 100,000 |
| | Site-wide | 65 | 40 | 8.6 ± 0.88 | 1.3 ± 2.5 | 323 | 260 | 16 ± 2.4 | 3.2 ± 5.5 | |
| | Perimeter | 79 | 54 | 8.2 ± 1.6 | 1.8 ± 3.3 | 376 | 299 | 74 ± 10 | 4.9 ± 14 | |
| | Nearby communities | 37 | 23 | 15 ± 1.3 | 2.1 ± 5.3 | 193 | 161 | 61 ± 8.5 | 5.3 ± 15 | |
| | Distant communities | 26 | 8 | 5.8 ± 0.80 | 0.85 ± 2.3 | 127 | 74 | 24 ± 3.8 | 2.6 ± 6.1 | |
| Gross beta (0.001 pCi/m$^3$) | Site-wide | 589 | 589 | 0.14 ± 0.027 | 0.018 ± 0.027 | 3,037 | 3,028 | 0.084 ± 0.014 | 0.016 ± 0.019 | No standard |
| | Perimeter | 284 | 284 | 0.075 ± 0.012 | 0.018 ± 0.026 | 1,408 | 1,406 | 0.074 ± 0.012 | 0.016 ± 0.018 | |
| | Nearby communities | 207 | 207 | 0.074 ± 0.012 | 0.018 ± 0.025 | 1,042 | 1,040 | 0.056 ± 0.0094 | 0.016 ± 0.019 | |
| | Distant communities | 52 | 52 | 0.062 ± 0.010 | 0.015 ± 0.022 | 274 | 273 | 0.059 ± 0.010 | 0.015 ± 0.018 | |
| | | | | 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$^3$) | Site-wide | 589 | 410 | 6,300 ± 3,300 | 640 ± 950 | 3,011 | 2,040 | 3,900 ± 1,200 | 580 ± 890 | No standard |
| | Perimeter | 284 | 206 | 5,000 ± 1,400 | 690 ± 1,100 | 1,408 | 994 | 5,100 ± 1,300 | 570 ± 860 | |
| | Nearby communities | 108 | 84 | 2,200 ± 780 | 720 ± 870 | 551 | 411 | 6,300 ± 1,700 | 660 ± 1,100 | |
| | Distant communities | 52 | 32 | 3,600 ± 1,200 | 610 ± 1,300 | 244 | 176 | 5,500 ± 1,900 | 570 ± 1,100 | |
| Strontium-90 (70 aCi/m$^3$) | Site-wide | 44 | 0 | 18 ± 63 | -42 ± 130 | 204 | 39 | 1,300 ± 280 | 19 ± 220 | 9,000,000 |
| | Perimeter | 28 | 0 | 9.6 ± 26 | -48 ± 100 | 140 | 10 | 110 ± 64 | -1.5 ± 90 | |
| | Nearby communities | 16 | 0 | 5.4 ± 14 | -71 ± 130 | 80 | 7 | 160 ± 62 | 7.2 ± 110 | |
| | Distant communities | 8 | 0 | 15 ± 65 | -71 ± 160 | 40 | 2 | 300 ± 100 | -4.5 ± 150 | |
| Iodine-129 (0.01 aCi/m$^3$) | Site-wide | 4 | 4 | 23 ± 3.4 | 20 ± 4.0 | 19 | 19 | 26 ± 2.6 | 18 ± 9.4 | 70,000,000 |
| | Perimeter | 8 | 8 | 0.83 ± 0.055 | 0.47 ± 0.40 | 38 | 38 | 0.89 ± 0.066 | 0.48 ± 0.47 | |
| | Distant communities | 4 | 4 | 0.035 ± 0.0032 | 0.023 ± 0.018 | 19 | 19 | 0.22 ± 0.015 | 0.052 ± 0.091 | |
| Plutonium-238 (3 aCi/m$^3$) | Site-wide | 44 | 1 | 4.3 ± 3.9 | 0.16 ± 2.5 | 204 | 14 | 13 ± 3.9 | 0.12 ± 2.5 | 30,000 |
| | Perimeter | 28 | 0 | 4.6 ± 4.5 | 0.35 ± 2.4 | 140 | 0 | 1.7 ± 2.4 | -0.14 ± 1.2 | |
| | Nearby communities | 16 | 0 | 1.3 ± 2.4 | -0.24 ± 2.7 | 80 | 1 | 3.7 ± 3.6 | 0.030 ± 1.6 | |
| | Distant communities | 8 | 0 | 2.0 ± 4.6 | -0.25 ± 2.0 | 40 | 0 | 0.98 ± 1.4 | -0.39 ± 1.2 | |
| Plutonium-239/240 (3 aCi/m$^3$) | Site-wide | 43 | 9 | 100 ± 19 | 4.4 ± 32 | 204 | 46 | 36 ± 6.4 | 1.5 ± 7.7 | 20,000 |
| | Perimeter | 28 | 1 | 6.7 ± 4.6 | 0.76 ± 3.0 | 140 | 5 | 5.2 ± 2.5 | 0.25 ± 1.8 | |
| | Nearby communities | 16 | 1 | 3.0 ± 6.7 | 0.55 ± 2.8 | 80 | 4 | 3.2 ± 4.6 | 0.39 ± 1.5 | |
| | Distant communities | 8 | 0 | 2.2 ± 4.6 | 0.37 ± 2.0 | 40 | 0 | 2.4 ± 3.0 | 0.19 ± 1.6 | |

## Table 10.2.3. (contd)

| Radionuclide (approximate detection limit) | Location Group[a] | 2005 No. of Samples | 2005 No. of Detections[b] | 2005 Maximum[c] aCi/m³[g] | 2005 Average[d] aCi/m³[g] | 2000-2004 No. of Samples | 2000-2004 No. of Detections[b] | 2000-2004 Maximum[c] aCi/m³[g] | 2000-2004 Average[d] aCi/m³[g] | Derived Concentration Guide[e] aCi/m³[g] |
|---|---|---|---|---|---|---|---|---|---|---|
| Uranium-234 | Site-wide | 32 | 0 | 50 ± 260 | -5.3 ± 43 | 160 | 135 | 150 ± 52 | 20 ± 46 | 90,000 |
| (10 aCi/m³) | Perimeter | 16 | 0 | 24 ± 240 | -14 ± 31 | 80 | 68 | 140 ± 32 | 23 ± 51 | |
| | Nearby communities | 12 | 0 | -0.70 ± 240 | -20 ± 18 | 60 | 50 | 58 ± 21 | 20 ± 40 | |
| | Distant communities | 8 | 0 | -9.5 ± 250 | -23 ± 15 | 40 | 32 | 34 ± 14 | 11 ± 32 | |
| Uranium-235 | Site-wide | 32 | 0 | 0.69 ± 9.1 | -1.2 ± 2.3 | 160 | 1 | 6.5 ± 8.5 | 0.17 ± 3.2 | 100,000 |
| (10 aCi/m³) | Perimeter | 16 | 0 | 1.5 ± 14 | -1.5 ± 2.7 | 80 | 0 | 4.3 ± 4.7 | 0.43 ± 3.2 | |
| | Nearby communities | 12 | 0 | 0.36 ± 15 | -2.3 ± 2.9 | 60 | 0 | 6.1 ± 8.1 | 0.015 ± 4.0 | |
| | Distant communities | 8 | 0 | 0.41 ± 16 | -2.4 ± 3.0 | 40 | 0 | 7.0 ± 9.3 | -0.43 ± 4.4 | |
| Uranium-238 | Site-wide | 32 | 29 | 120 ± 35 | 21 ± 51 | 160 | 147 | 160 ± 37 | 22 ± 41 | 100,000 |
| (10 aCi/m³) | Perimeter | 16 | 13 | 62 ± 17 | 17 ± 33 | 80 | 77 | 140 ± 32 | 27 ± 40 | |
| | Nearby communities | 12 | 10 | 32 ± 12 | 14 ± 18 | 60 | 58 | 52 ± 16 | 23 ± 22 | |
| | Distant communities | 8 | 4 | 29 ± 14 | 11 ± 18 | 40 | 39 | 28 ± 11 | 17 ± 14 | |
| Cobalt-60 | Site-wide | 48 | 0 | 470 ± 510 | 9.1 ± 500 | 248 | 1 | 3,800 ± 2,500 | 88 ± 910 | 80,000,000 |
| (1,200 aCi/m³) | Perimeter | 32 | 0 | 350 ± 700 | -6.2 ± 610 | 169 | 0 | 910 ± 740 | -1.2 ± 780 | |
| | Nearby communities | 28 | 0 | 1,100 ± 1,000 | -59 ± 820 | 146 | 0 | 1,800 ± 3,600 | 70 ± 920 | |
| | Distant communities | 8 | 0 | 380 ± 800 | -61 ± 690 | 42 | 0 | 730 ± 1,000 | 90 ± 580 | |
| Cesium-137 | Site-wide | 48 | 0 | 940 ± 1,500 | 9.4 ± 550 | 248 | 3 | 3,500 ± 1,500 | 13 ± 750 | 400,000,000 |
| (1,000 aCi/m³) | Perimeter | 32 | 0 | 520 ± 520 | -74 ± 590 | 169 | 2 | 4,600 ± 1,300 | 94 ± 970 | |
| | Nearby communities | 28 | 0 | 730 ± 700 | 44 ± 660 | 146 | 0 | 2,100 ± 3,100 | 36 ± 710 | |
| | Distant communities | 8 | 0 | 200 ± 820 | -83 ± 440 | 42 | 0 | 530 ± 520 | -16 ± 560 | |

(a) Location groups are identified in Table 10.2.2.
(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.2).
(f) 1 pCi = 0.037 Bq.
(g) There are 1 million attocuries (aCi) in 1 picocurie (pCi).

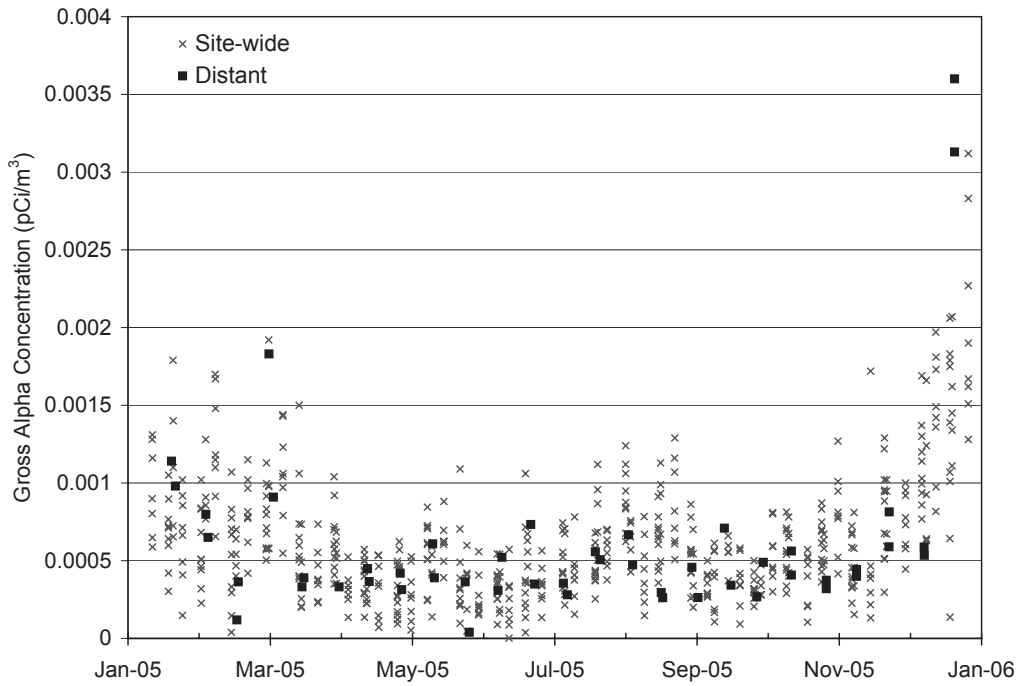



**Figure 10.2.3. Gross Alpha Concentrations in Airborne Particulate Samples Collected at Hanford Site-Wide and Distant Locations During 2005 (1 pCi = 0.037 Bq)**

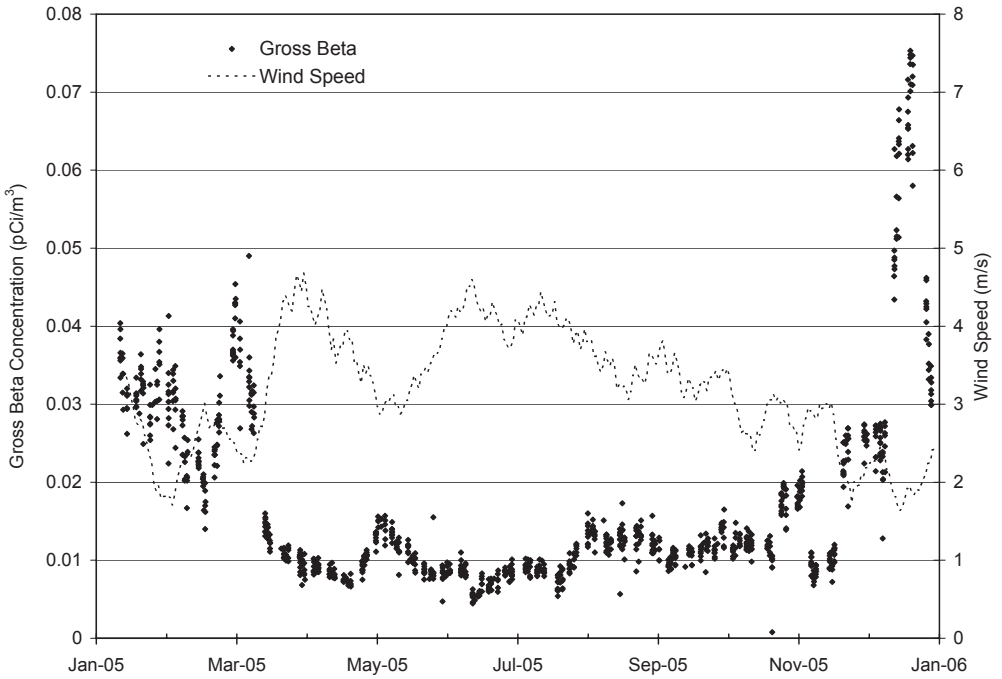



**Figure 10.2.4. Gross Beta Concentrations in Airborne Particulate Samples for all Hanford Site-Wide and Offsite Sampling Locations in 2005 and Continuous 14-day Average Wind Speeds at the Hanford Meteorology Station (1 pCi = 0.037 Bq)**

distant locations, although the differences were not statistically significant (two-sample means t-test, 95% confidence level). The sample with the highest tritium concentration measured during 2005 (15 pCi/m$^3$ [0.56 Bq/m$^3$]) was collected at the Leslie Groves Park sampling location in Richland (location 36 on Figure 10.2.2) during December. This concentration was 0.015 % of the DOE derived concentration guide for tritium (Appendix D, Table D.2).

Iodine-129 analyses were performed on samples collected at a site-wide location downwind of the Plutonium-Uranium Extraction (PUREX) Plant, at two downwind perimeter locations, and at a distant location (Yakima) in 2005 (Table 10.2.2). Concentrations measured site-wide during 2005 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 10.2.5). Concentration differences between these locations were statistically significant and indicated a Hanford Site source. Site-wide and perimeter concentrations observed in 2005 were consistent with the levels observed from 2000 through 2004 (Table 10.2.3). Site-wide air concentrations of iodine-129 were influenced by minor emissions (Table 10.1.1) from the Plutonium-Uranium Extraction (PUREX) Plant and possible releases from waste storage tanks and cribs. The annual average iodine-129 concentration observed at the downwind perimeter in 2005 (0.47 aCi/m$^3$ [0.017 µBq/m$^3$]) was 0.0000007% of the DOE derived concentration guide (70 million aCi/m$^3$ [2.6 Bq/m$^3$]).

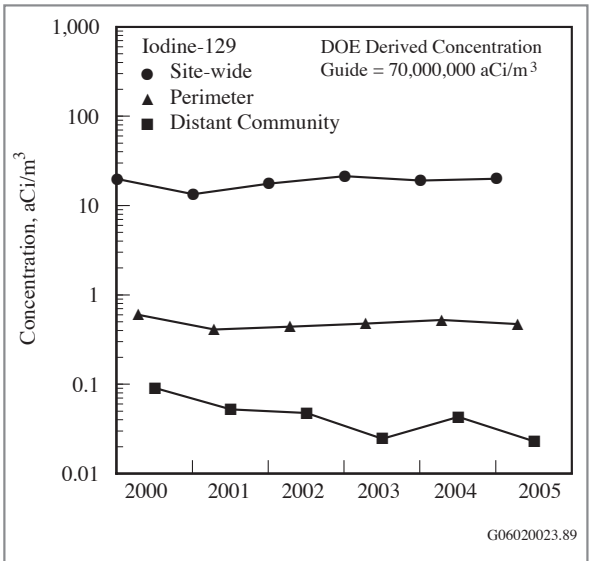



**Figure 10.2.5. Iodine-129 Concentrations in Hanford Site-Wide and Offsite Ambient-Air Samples, 2000 through 2005 (1 aCi = 0.037 µBq)**

Plutonium-238 was detected in one site-wide composite sample during 2005 (Table 10.2.3). The maximum reported plutonium-238 concentration in 2005 was 4.6 aCi/m$^3$ (0.17 µBq/m$^3$), or 6,500 times below the DOE derived concentration guide for plutonium-238 (30,000 aCi/m$^3$ [1,100 µBq/m$^3$]).

The annual average plutonium-239/240 concentration in air samples collected in 2005 at site-wide locations was 4.4 aCi/m$^3$ (0.16 µBq/m$^3$). Of the 43 site-wide samples analyzed for plutonium-239/240, 9 had detectable concentrations (Table 10.2.3). Six of the nine detectable plutonium-239/240 concentrations were from samples collected in and near the 300 Area, which may have been affected by ongoing cleanup activities. The maximum Hanford Site plutonium-239/240 air concentration (100 aCi/m$^3$ [3.7 µBq/m$^3$]) was observed during the first quarter of 2005 at the 300 NE sampling location (Figure 10.2.2). This sampling period included the time period covering a Category 3 environmental occurrence at the 300 Area Remediation Project (see Section 8.0.1). This event may have contributed to the maximum plutonium-239/240 air concentration measured in 2005. This maximum reported concentration was 0.5% of the DOE derived concentration guide (20,000 aCi/m$^3$ [730 µBq/m$^3$]) for plutonium-239/240.

Average isotopic uranium concentrations (uranium-234, uranium-235, and uranium-238) in airborne particulate matter in 2005 were lower than average concentrations measured from 2000 through 2004 for all location groups (Table 10.2.3). The 2005 annual average uranium-238 concentration for the site perimeter was 17 aCi/m$^3$ (0.63 µBq/m$^3$), which is 0.02% of the DOE derived concentration guide (100,000 aCi/m$^3$ [3,700 µBq/m$^3$]). The site-wide and perimeter uranium-238 average concentrations were not different than the distant concentrations by a statistically significant amount (two-sample means t-test, 95% confidence level). Similar to plutonium-239/240, the highest measured uranium-238 concentration was measured at the 300 Trench sampling location (Figure 10.2.2) during the first quarter of 2005. This sampling period included the time period when a Category 3 environmental

occurrence at the 300 Area Remediation Project occurred (see Section 8.0.1). This concentration (120 aCi/m$^3$ [4.4 µBq/m$^3$]) was only 0.12% of the DOE derived concentration guide for uranium-238.

Ninety-six airborne-particulate samples were analyzed for strontium-90 in 2005 (Table 10.2.3). No samples had detectable concentrations.

Gamma spectroscopy was conducted on all quarterly composite samples collected in 2005. Naturally occurring beryllium-7 and potassium-40 were routinely identified. The potential Hanford-origin gamma-emitting radionuclides cobalt-60 and cesium-137 were not detected in any air samples collected in 2005.

### 10.2.2.3 Monitoring of Airborne Particulate Matter on the Hanford Site

Airborne particulate matter (dust) is one of EPA's criteria pollutants. 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 $PM_{2.5}$). The EPA's National Primary and Secondary Ambient Air Quality Standards (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 15 µg/m$^3$ for an 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 Hanford Site 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 (dust) concentrations in air. In 2005, particulate monitoring was done at the Hanford Meteorological Station (location 45, Figure 10.2.2 and Table 10.2.2) using a tapered element oscillating microbalance. 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 10.2.6 illustrates the daily average $PM_{10}$ concentrations recorded at the Hanford Meteorology Station during 2005 for all time periods when the instrument was operating. The instrument operated 73% of the time during 2005. Although Hanford Site measurements are not used to determine compliance with air quality standards (Section 5.3.1), EPA standards were not exceeded at the measurement locations on the Hanford Site. The observed annual average $PM_{10}$ concentration at the Hanford Meteorology Station during 2005 (11 µg/m$^3$) was well below the EPA annual average standard (50 µg/m$^3$). Daily average $PM_{10}$ concentrations on the Hanford Site were higher than the EPA 24-hour average standard once during 2005 (March 16) (Figure 10.2.6), but EPA policy allows exemptions for natural events that result in high particulate matter concentrations, such as windstorms. Wind speeds on March 16, 2005, exceeded 27 meters per second (61 miles per hour).

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 2005 were well below the proposed EPA standards for $PM_{2.5}$ (15 µg/m$^3$ annual average, 65 µg/m$^3$ 24-hour average). The measured annual average $PM_{2.5}$ concentration at the Hanford Meteorology

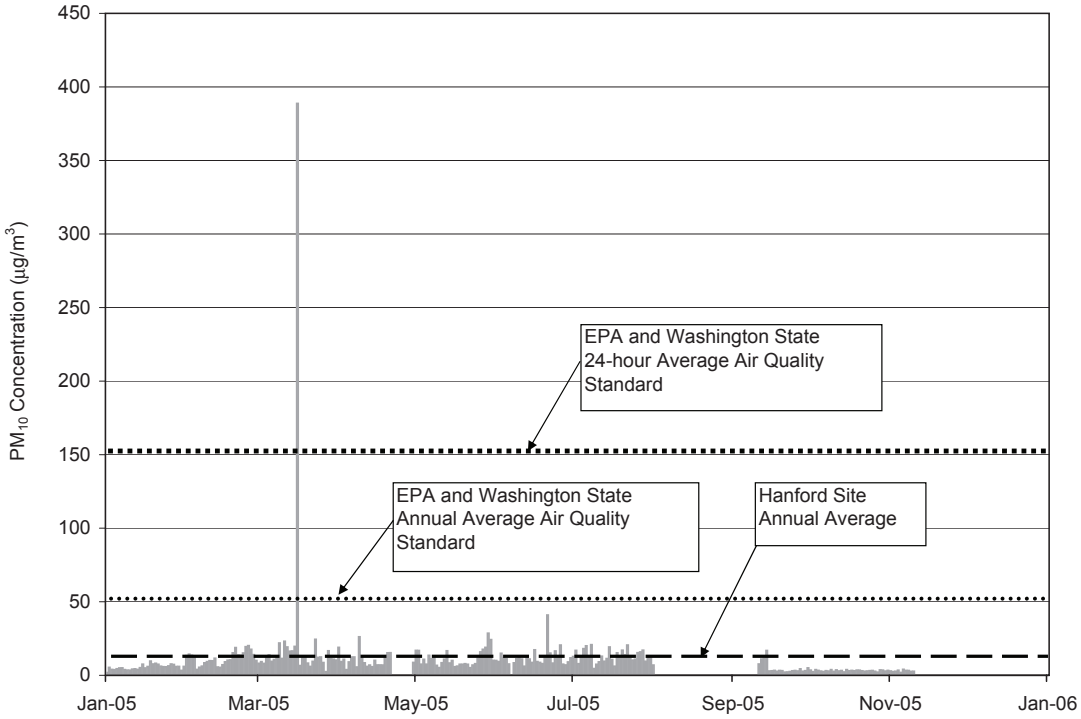



**Figure 10.2.6. Daily Average $PM_{10}$ Particle Concentrations at the Hanford Meteorology Station, 2005**

Station during 2005 was 5.3 µg/m$^3$, while the highest 24-hour average concentration observed was 27 µg/m$^3$.

## 10.2.2.4 Relationship Between Measurements of Gross Beta, Radon, and Lead-210

In 2004, it was noted that gross beta concentrations appeared to be inversely proportional to the average wind speed over the sampling period (PNNL-15222). This pattern was evident again in 2005 (Figure 10.2.4) and is similar to other research that has observed a negative correlation between wind speed and the concentrations of radon and radon decay products (Duenas et al. 2003; Ho and Measday 2005; Marcazzan et al. 2003; Winkler et al. 2001). This indicates that a majority of the gross beta activity observed in site-wide and offsite air samples may consist of radon decay products. Therefore, ambient radon monitoring at a single location (Prosser Barricade) was conducted from October 2005 through January 2006. Ambient radon concentrations were monitored with a Femto-TECH® CRM-510LP radon monitor. The Prosser Barricade sampling location was chosen because it is a local sampling location that is not too close to anthropogenic radon emissions (Central Hanford and the 300 Area - see Section 10.1). It appeared that the radon concentrations were generally higher during periods of low wind speed (Figure 10.2.7).

In addition to the ambient radon monitoring, six multi-day high volume particulate samples were collected and analyzed by gamma spectroscopy for lead-210, a radon decay product. During December 2005, the concentrations of radon, gross beta, and lead-210 were all higher than during November 2005 or January 2006 (Figure 10.2.8). Weather during December 2005 was dominated by a temperature inversion, as evidenced by the warmer temperatures on top of Rattlesnake Mountain (1,070-meter [3,510-foot] elevation) relative to temperatures at the Prosser Barricade sampling location (Figure 10.2.9). This inversion most likely accounted for the elevated radon, lead-210, and gross beta concentrations during December 2005. The data indicate that the fluctuations in gross beta concentrations observed on the Hanford Site during winter months are likely attributable to changing concentrations of radon decay products.

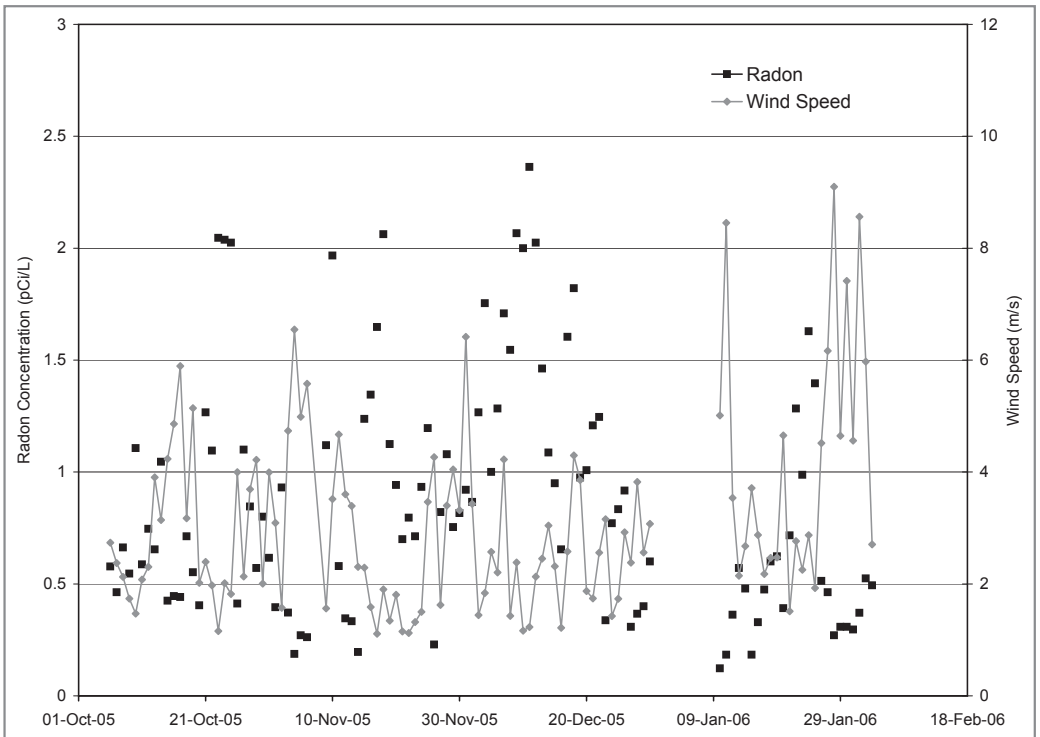



**Figure 10.2.7. Daily Average Radon Concentrations and Wind Speeds Measured at the Hanford Site's Prosser Barricade Sampling Location, October 2005 through January 2006**

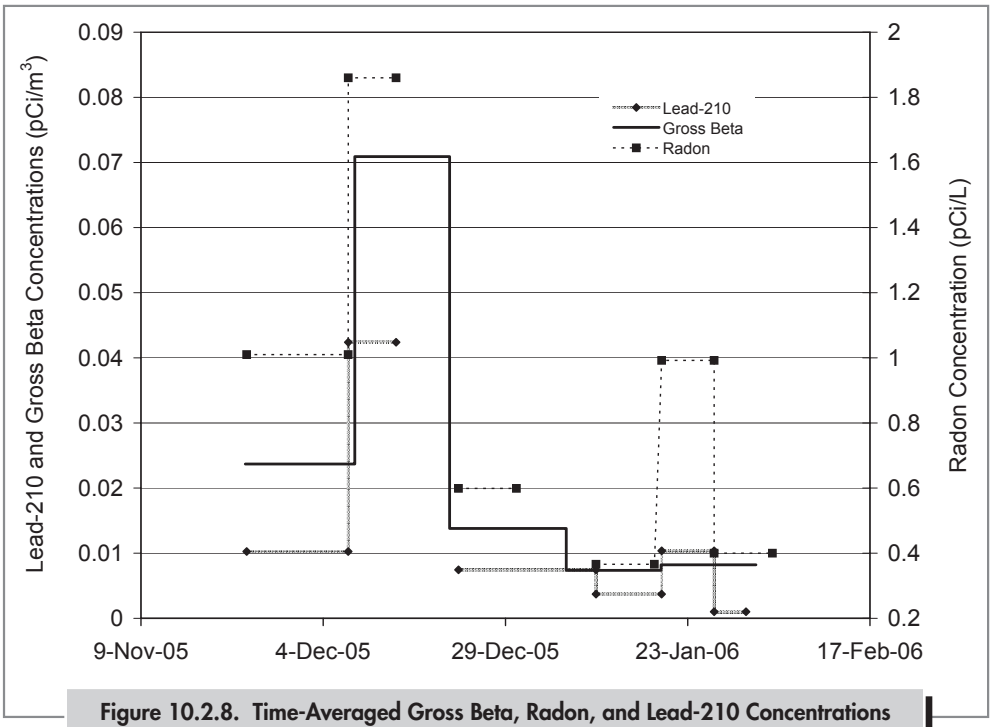



**Figure 10.2.8. Time-Averaged Gross Beta, Radon, and Lead-210 Concentrations Measured at the Hanford Site's Prosser Barricade Sampling Location, November 2005 through January 2006**

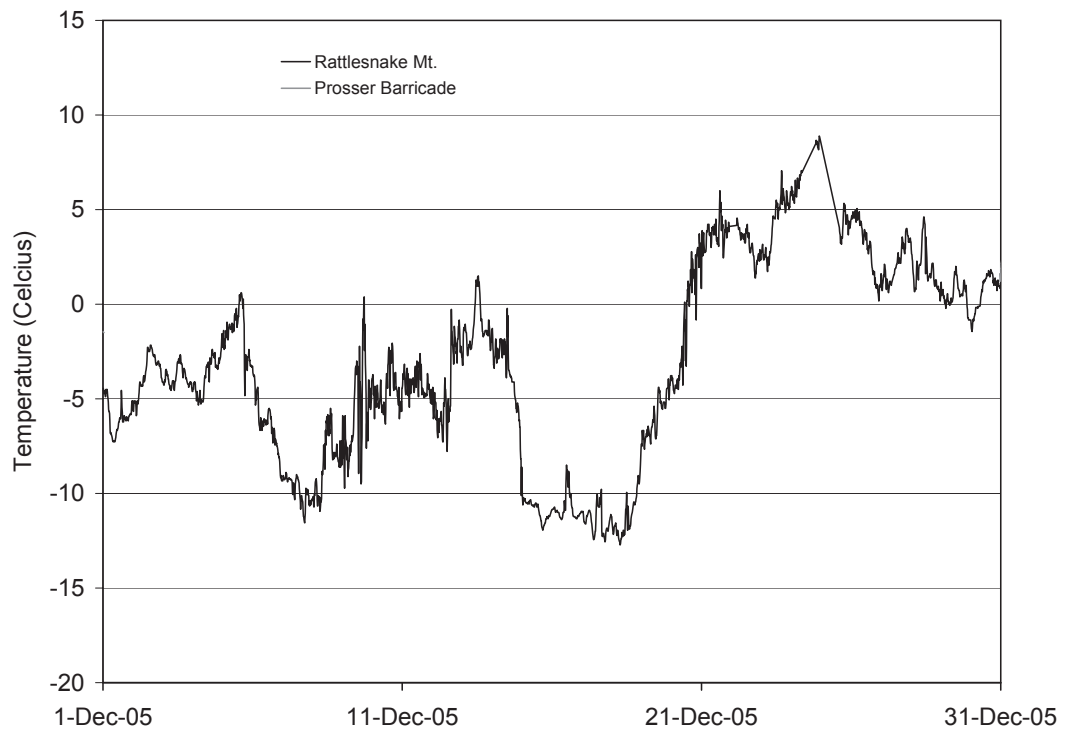



**Figure 10.2.9. Temperatures on Rattlesnake Mountain (1,070-meter [3,510-foot] elevation) and at the Hanford Site's Prosser Barricade Sampling Location (150-meter [492-foot] elevation). Warmer temperatures on Rattlesnake Mountain indicate a temperature inversion.**

# 10.3 Liquid Effluents from Hanford Site Facilities

L. P. Diediker and D. J. Rokkan

Liquid effluents are discharged from some facilities at the Hanford Site. Effluent streams are sampled for gross alpha and gross beta concentrations, as well as for concentrations of selected radionuclides.

Contaminant data from liquid effluent sampling and analyses are reported to the DOE annually in an environmental releases report (HNF-EP-0527-15). This report also includes summaries of monitoring results on liquid effluents discharged to the Columbia River, which are regulated by the National Pollutant Discharge Elimination System permit and reported quarterly to the EPA, and liquid effluent discharges to the soil, which are regulated by WAC 173-216 and reported quarterly to the Washington State Department of Ecology.

## 10.3.1 Radionuclides in Liquid Effluent

During 2005, only facilities in the 200 Areas discharged radioactive liquid effluent to the ground, which all went to a single location, the 616-A crib, also known as the State-Approved Land Disposal Site. A summary of radioactive liquid effluent is provided in Table 10.3.1. Table 10.3.2 summarizes data on radionuclides in liquid effluent released from the 100 Areas to the Columbia River, the sources of which include secondary cooling water used at the K Basins and shoreline seepage of groundwater that has passed near the retired 116-N-1 and 116-N-3 cribs in the 100-N Area. Figure 10.3.1 depicts quantities of tritium released to the ground and strontium-90 released to the Columbia River over the past 11 years.

**Table 10.3.1. Radionuclides in 200 Areas Liquid Effluent Discharged to the State-Approved Land Disposal Site at the Hanford Site, 2005**

| Radionuclide | Half-Life | Release, Ci[(a)] |
|---|---|---|
| Tritium | 12.3 yr | 2.3 |

(a) 1 Ci = $3.7 \times 10^{10}$ becquerels.

**Table 10.3.2. Radionuclides in Liquid Effluent from the 100 Areas Discharged to the Columbia River, 2005**

| Radionuclide | Half-Life | Release, Ci[(a)] |
|---|---|---|
| Tritium | 12.3 yr | $7.5 \times 10^{-3}$ |
| Strontium-90 | 29.1 yr | $5.0 \times 10^{-2}$ |
| Antimony-125 | 2.8 yr | $4.7 \times 10^{-3}$ |
| Cesium-137 | 30 yr | $4.1 \times 10^{-3}$ |
| Europium-152 | 13.5 yr | $8.5 \times 10^{-3}$ |
| Europium-154 | 8.6 yr | $3.5 \times 10^{-3}$ |
| Plutonium-238 | 87.7 yr | $5.3 \times 10^{-6}$ |
| Plutonium-239/240 | 24,110 yr | $2.7 \times 10^{-6}$ |

(a) 1 Ci = $3.7 \times 10^{10}$ becquerels.

## 10.3.2 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 (40 CFR 122) and the state waste discharge permits (WAC 173-216) for the

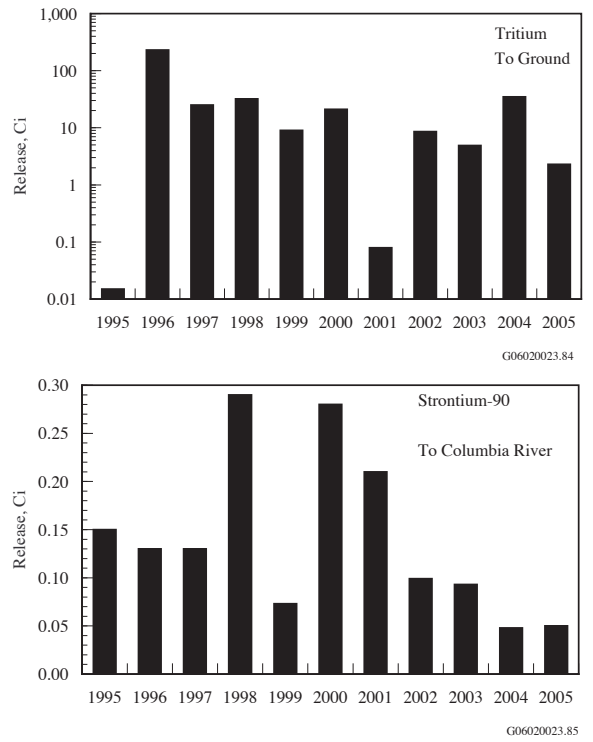



**Figure 10.3.1. Liquid Releases of Selected Radionuclides from the Hanford Site, 1995 through 2005**

site. Should chemicals in liquid effluent exceed quantities reportable under CERCLA, the release totals are immediately reported to the EPA. If chemical levels in effluent remain stable at predicted levels, they may, with the EPA's permission, be reported annually. Section 5.3.1 provides a synopsis of the National Pollutant Discharge Elimination System and state waste discharge permit.

# 10.4 Surface-Water and Sediment Monitoring

G. W. Patton

Samples of surface water and sediment on and near the Hanford Site were collected and analyzed to determine the concentrations of radiological and chemical contaminants from Hanford in the aquatic environment. Surface-water bodies monitored included the Columbia River, onsite ponds, and offsite irrigation sources (Figure 10.4.1). Aquatic sediment monitoring was conducted for the Columbia River and one onsite pond. Tables 10.4.1 and 10.4.2 summarize the sampling locations, types, frequencies, and analyses included in surface-water and sediment monitoring during 2005. This section describes the monitoring efforts and summarizes the results for these aquatic environments. Detailed analytical results are reported in PNNL-15892, APP. 1.

## 10.4.1 Monitoring of 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 portion 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 11 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 (the first dam upstream from the ocean) that remains unimpounded.

River flow through the Hanford Reach fluctuates significantly and is controlled primarily by operations at upstream dams. 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 2005, the Columbia River had below normal flow; the average daily flow rate downstream of Priest Rapids Dam was 2,970 cubic meters (105,000 cubic feet) per second. The peak monthly average flow rate occurred during July (3,875 cubic meters [137,000 cubic feet] per second) (Figure 10.4.2). The lowest monthly average flow rate occurred during September (1,980 cubic meters [69,900 cubic feet] per second). Daily flow rates varied from 1,210 to 5,180 cubic meters (42,700 to 183,000 cubic feet) per second during 2005. 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

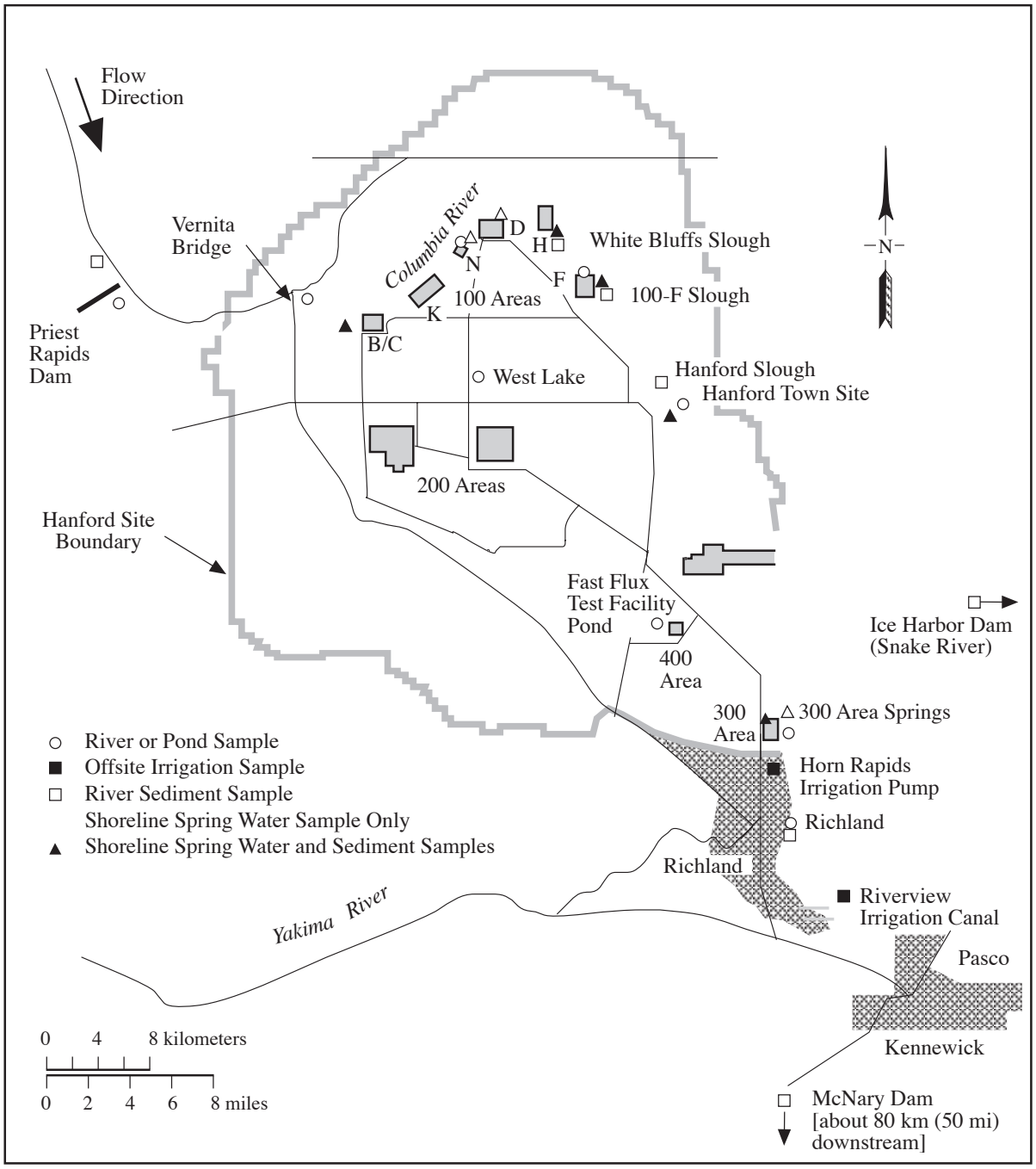



**Figure 10.4.1. Surface-Water and Sediment Sampling Locations On and Around the Hanford Site, 2005**

**Table 10.4.1. Surface-Water Surveillance On and Near the Hanford Site, 2005**

| Location | Sample Type | Frequency | Analyses |
|---|---|---|---|
| **Columbia River - Radiological** | | | |
| Priest Rapids Dam and Richland | Cumulative | M Comp[a]<br>Q Comp[d] | Alpha, beta, low $^{3}H$,[b] $^{90}Sr$, $^{99}Tc$, U[c]<br>$^{129}I$ |
| | Particulate (filter) | M Cont[e]<br>Q Cont[f] | Gamma energy analysis<br>Pu[g] |
| | Soluble (resin) | M Cont<br>Q Cont | Gamma energy analysis<br>Pu |
| Vernita Bridge and Richland | Grab (transects) | Quarterly | low $^{3}H$, $^{90}Sr$, U |
| 100-F, 100-N, and 300 Areas, and Hanford town site | Grab (transects) | Annually | low $^{3}H$, $^{90}Sr$, U |
| **Columbia River - Chemical** | | | |
| Vernita Bridge and Richland[h] | 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, Fe, $NH_3$, $NO_3$ + $NO_2$ |
| | Grab (transects) | Quarterly | Metals (filtered and unfiltered), anions |
| | Grab (transects) | Annually | VOA |
| 100-F, 100-N, and 300 Areas and Hanford town site | Grab (transects) | Annually | Metals (filtered and unfiltered), anions |
| **Onsite Ponds** | | | |
| West Lake[i] | 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 |

(a) M Comp indicates river water was collected hourly and composited monthly for analysis.
(b) Low $^{3}H$ = Low-level tritium analysis (10-pCi/L detection limit), which includes an electrolytic preconcentration.
(c) U = Isotopic uranium-234, uranium-235, and uranium-238.
(d) Collected hourly and composited for quarterly analysis.
(e) 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.
(f) 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.
(g) Pu = Isotopic plutonium-238 and plutonium-239/240.
(h) Numerous water quality analyses are performed by the U.S. Geological Survey under contract to Pacific Northwest National Laboratory.
(i) Because of high concentrations of suspended sediment, West Lake water is analyzed for tritium, all other analytes are for sediment samples.

Comp = Composite.
Cont = Continuous.
M = Monthly.
Q = Quarterly.
VOA = Volatile organic compounds.

fluctuations measured at the 300 Area are approximately half the magnitude of those measured near the 100 Areas because of the effect of the pool behind McNary Dam (PNL-8580) and the relative distance of each area from Priest Rapids Dam. The width of the river varies from 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 10.3). 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 5.3.1). In addition to permitted direct discharges of liquid effluent from Hanford facilities, contaminants in groundwater from past operational

**Table 10.4.2. Columbia River Sediment Surveillance, 2005**

| Location[a] | Frequency | Analyses |
|---|---|---|
| **Columbia River** | | River sediment analyses included gamma energy analysis, $^{90}Sr$, U,[b] Pu,[c] metals, SEM/AVS, and total organic carbon |
| 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 | Annually | |

(a) See Figure 10.4.1.
(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.
SEM/AVS = Simultaneously extracted metals and acid volatile sulfide.

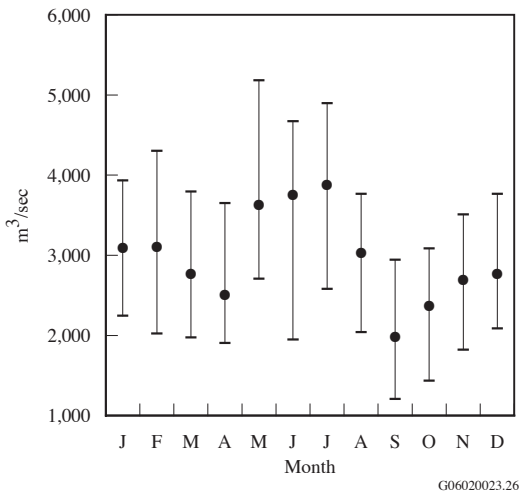



**Figure 10.4.2. Average, Maximum, and Minimum Columbia River Flow Rates at Priest Rapids Dam, Washington, 2005**

discharges to the ground seep into the river (DOE/RL-92-12; PNL-5289; PNL-7500; WHC-SD-EN-TI-006; Section 10.5 of this report).

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.3). In 2003, the Washington State Department of Ecology revised the surface-water quality standards and submitted them to EPA for approval in July 2003 (WAC 173-201A). Under the submitted surface water quality standards, the Class A (Excellent) designated uses criteria will be replaced with separate designations for aquatic life uses, recreational uses, water supply uses, and miscellaneous uses. For the Columbia River downstream from Grand Coulee Dam, the aquatic life designation will be "salmon and trout spawning, noncore rearing, and migration," which provides for the protection of spawning, noncore rearing, and migration of salmon and trout, and other associated aquatic life. The recreational uses designation for the Columbia River downstream from Grand Coulee Dam will be "primary contact," which provides for activities that may involve complete submersion by the participant. The entire Columbia River will be designated for all water supply and miscellaneous uses by the state of Washington.

### 10.4.1.1 Collection of Columbia River Water Samples and Analytes of Interest

During 2005, Columbia River water samples were collected from fixed-location monitoring stations at Priest Rapids Dam and Richland, Washington, and from cross-river transects and near-shore locations near the Vernita Bridge, 100-N Area, 100-F Area, Hanford town site, 300 Area, and the city of Richland, Washington (Figure 10.4.1). 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 10.4.4.

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 10.4.1). 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 facility effluent controls and monitoring systems, and determining compliance with applicable water quality 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.3 and D.4). Unless otherwise noted in this section, the statistical tests for differences are paired sample comparisons and two-tailed t-tests, with 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. 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 2005 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 transects and near-shore locations were sampled quarterly during 2005. 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 2005 were analyzed for both radiological and chemical contaminants (Table 10.4.1). Specific 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 water quality monitoring for potential Hanford contaminants conducted by the Pacific Northwest National Laboratory, water quality monitoring for basic parameters (e.g., pH, dissolved oxygen, turbidity) 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 the Vernita Bridge and Richland (Appendix C, Table C.2). Sample analyses were performed at the U.S. Geological Survey laboratory in Denver, Colorado, for numerous physical parameters and chemical constituents.

### 10.4.1.2 Radiological Results for Columbia River Water Sample Analyses

***Fixed Location Samples***. Results of the radiological analyses of Columbia River water samples collected at Priest Rapids Dam and Richland, Washington, during 2005 are reported in PNNL-15892, APP. 1 and summarized in Appendix C (Tables C.3 and C.4). These tables also list the maximum and average concentrations of selected radionuclides detected in Columbia River water in 2005 and for the previous 5 years. All individual radiological contaminant concentrations measured in Columbia River water during 2005 were less than 1/25 of DOE derived concentration guides (DOE Order 5400.5, Appendix D, Table D.2). DOE derived concentration guides are based on a 100-mrem (1-mSv) per year standard; dividing by 25 allows for more direct comparison of the 4-mrem (0.04-mSv) per year standard used for drinking water, and Washington State ambient surface-water quality criteria (WAC 173-201A and 40 CFR 141; Appendix D, Tables D.4 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 2005, 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 Site facilities. Tritium and uranium occur naturally in the environment, in addition to being present in Hanford Site effluent.

The 2005 average gross alpha and gross beta concentrations measured upstream and downstream of the Hanford Site were similar to those observed during recent years (Figures 10.4.3 and 10.4.4). 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)

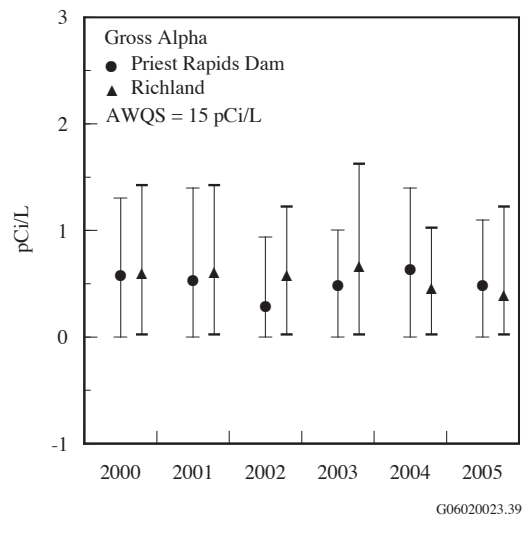



**Figure 10.4.3. Annual Average Gross Alpha Concentrations (±2 standard deviations) in Columbia River Water Upstream and Downstream of the Hanford Site, 2000 through 2005 (AWQS = ambient water quality standard)**

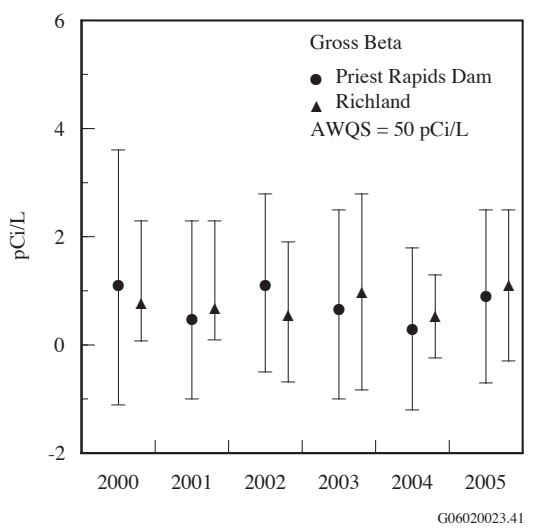



**Figure 10.4.4. Annual Average Gross Beta Concentrations (±2 standard deviations) in Columbia River Water Upstream and Downstream of the Hanford Site, 2000 through 2005 (AWQS = ambient water quality standard)**

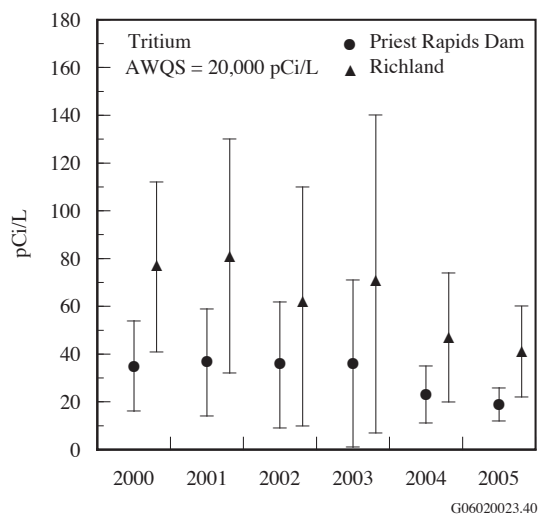



**Figure 10.4.5. Annual Average Tritium Concentrations (±2 standard deviations) in Columbia River Water Upstream and Downstream of the Hanford Site, 2000 through 2005 (AWQS = ambient water quality standard)**

minimum detectable concentrations, respectively. The average gross alpha and gross beta concentrations in Columbia River water at Richland during 2005 were less than the Washington State ambient surface-water quality criteria of 15 and 50 pCi/L (0.56 and 1.9 Bq/L).

The 2005 annual average tritium concentrations[(a)] 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 10.4.5). However, 2005 average tritium concentrations[(a)] in Columbia River water collected at Richland were only 0.21% of the Washington State ambient surface-water quality criterion of 20,000 pCi/L (740 Bq/L). Onsite sources of tritium entering the river included groundwater seepage and direct discharge from the 100-K Area permitted outfall (Section 10.3). Tritium concentrations measured at Richland, while representative of river water used by the city of Richland (first municipal water source downstream from Hanford) 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 water intake. This plume is not completely mixed within the river at Richland. Sampling along cross-river transects at Richland during 2005 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.

The average strontium-90 levels measured in Columbia River water collected upstream and downstream of the Hanford Site during 2005 were similar to those reported previously (Figure 10.4.6). Both upstream and downstream values had larger standard deviations from the means for 2005 compared to previous years. 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.

(a) Data only available from January 1, 2005 through August 31, 2005.

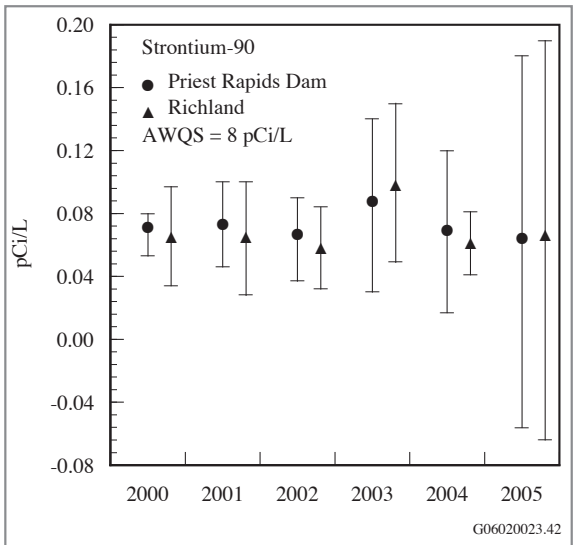



**Figure 10.4.6. Annual Average Strontium-90 Concentrations (±2 standard deviations) in Columbia River Water Upstream and Downstream of the Hanford Site, 2000 through 2005 (AWQS = ambient water quality standard)**

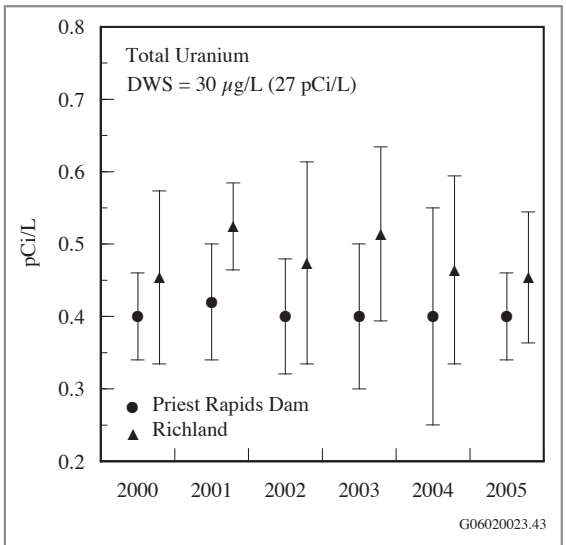



**Figure 10.4.7. Annual Average Total Uranium Concentrations (±2 standard deviations) in Columbia River Water Upstream and Downstream of the Hanford Site, 2000 through 2005 (DWS = drinking water standard)**

Despite the Hanford Site source, there were no statistical differences between monthly strontium-90 concentrations at Priest Rapids Dam and Richland. Average strontium-90 concentrations in Columbia River water at Richland were less than 0.8% of the Washington State ambient surface-water quality criterion (8 pCi/L [0.30 Bq/L]).

Annual average total uranium concentrations (i.e., the sum of uranium-234, uranium-235, and uranium-238) observed in water samples collected upstream and downstream of the Hanford Site during 2005 were similar to those observed during recent years (Figure 10.4.7). Monthly total uranium concentrations measured at Richland during 2005 were statistically higher (for a one-tailed paired t-test) 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 shoreline springs at the 300 Area in the past (Section 10.5; 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 directly applicable to uranium. However, total uranium levels in the river during 2005 were well below the EPA drinking water standard of 30 μg/L (approximately 27 pCi/L [1.0 Bq/L], Appendix D, Table D.4).

The average iodine-129 concentration in Columbia River water measured downstream of the Hanford Site at Richland was extremely low during 2005 (0.0049% of the Washington State ambient surface-water quality criterion of 1 pCi/L [0.037 Bq/L]) and similar to levels observed during recent years (Figure 10.4.8). 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 10.4.8.

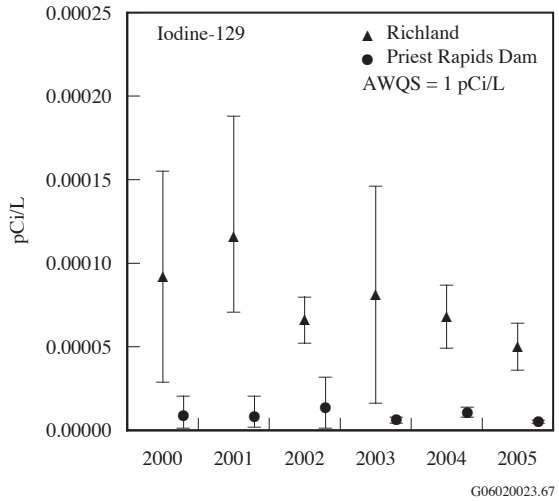



**Figure 10.4.8. Annual Average Iodine-129 Concentrations (±2 standard deviations) in Columbia River Water Upstream and Downstream of the Hanford Site, 2000 through 2005 (AWQS = ambient water quality standard)**

Plutonium-239/240 concentrations for filtered river water samples at Richland were extremely low during 2005. All plutonium concentrations for dissolved fractions were reported as undetected by the analytical laboratory. Plutonium concentrations for material collected on the filters were above the detection limits in two of four samples at both locations, with maximum concentrations of 0.000043 ± 0.000028 pCi/L [0.0000016 ± 0.0000010 Bq/L] at Richland and 0.00012 ± 0.000046 pCi/L [0.0000044 ± 0.0000017 Bq/L] at Priest Rapids Dam. The average minimum detectable concentrations were 0.00002 pCi/L (0.00000074 Bq/L) for the particle fraction and 0.0001 pCi/L (0.0000037 Bq/L) for the dissolved fraction. All concentrations and detection limits were well below the DOE derived concentration guide of 30 pCi/L (1.1 Bq/L) (Appendix D, Table D.2). No Washington State ambient surface-water quality criterion exists for plutonium-239/240. Statistical comparisons for dissolved plutonium concentrations at Priest Rapids Dam and Richland were not performed because most of the concentrations were below the reported minimum detectable concentrations and the samples with detectable results were higher at Priest Rapids Dam than at Richland.

***Columbia River Transect and Near-Shore Samples.*** 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 2005 are presented in Appendix C (Tables C.5 and C.6) and PNNL-15892, APP. 1. Results for samples collected between September and December 2005 were not all available at the time of printing. 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 (including tritium through August 2005) than applicable Washington State ambient surface-water quality criteria.

Tritium concentrations measured along Columbia River transects at the Vernita Bridge and the 100-N Area during September 2005 and at the Richland pump house during June 2005 are depicted in Figure 10.4.9. The transect at the Vernita Bridge is the most upstream location. Stations 1 and 10 are located along the Benton County and Grant/Franklin Counties shorelines, respectively. The 100-N 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 in the river 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 fixed-location monitoring station in Richland, illustrating the conservative bias (i.e., overestimate) of the fixed-location monitoring station. For samples collected in 2005 with available results, the highest tritium concentration measured in cross-river transect water was 95 ± 9.5 pCi/L (3.5 ± 0.35 Bq/L) (Appendix C, Table C.5), which was detected along the shoreline at the Richland pump house.

Tritium results for near-shore water samples collected in 2005 were only available for some samples at the time of printing. The spatial and temporal extent of the data available was not sufficient for an analysis of the tritium concentrations in near-shore water.

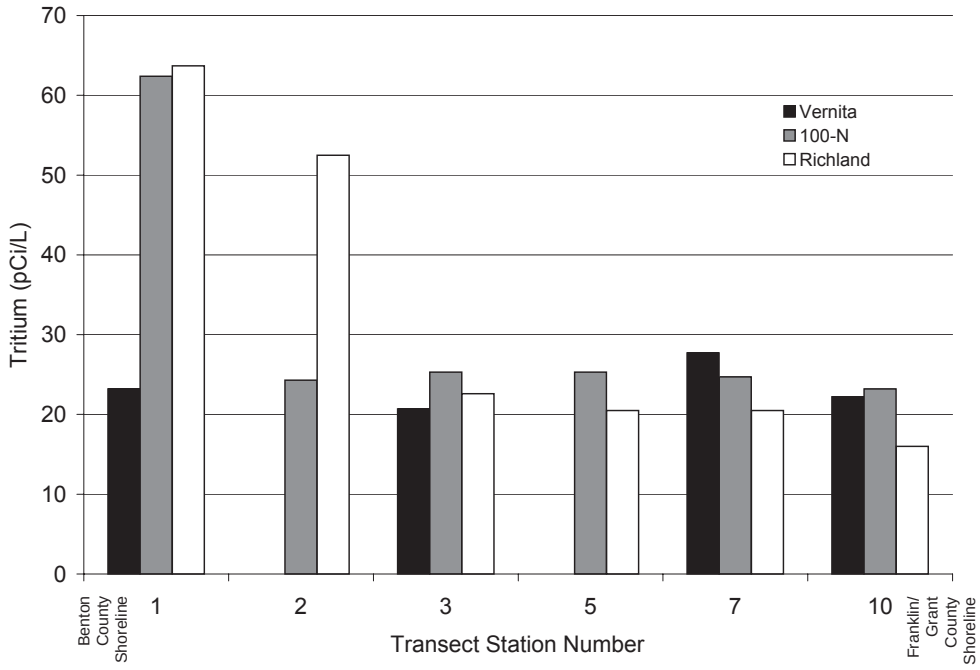



**Figure 10.4.9. Tritium Concentrations in Cross-River Transect Water Samples from the Hanford Reach of the Columbia River, September 2005. The ambient water quality standard for tritium is 20,000 pCi/L (740 Bq/L).**

During 2005, 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 where slightly elevated strontium-90 concentrations were measured in some samples obtained at near-shore locations. The maximum strontium-90 concentration was 0.19 ± 0.052 pCi/L (0.0069 ± 0.0019 Bq/L) for a Vernita Bridge water sample collected in June 2005. 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 2005 were elevated along the Benton and Franklin County shorelines for the 300 Area and Richland transects. The highest total uranium concentration was measured for the Richland transect at Hanford river marker #43.5 which is at the southern boundary of the 300 Area on the Benton County shoreline (1.5 ± 0.23 pCi/L [0.056 ± 0.0085 Bq/L]) (Appendix C, Table C.6; PNNL-15892, APP. 1). Elevated uranium concentrations on the Franklin County side of the river likely resulted from groundwater seepage and water from irrigation return canals that had elevated uranium levels from the use of phosphate fertilizers, which contain some uranium (PNL-7500).

### 10.4.1.3 Chemical and Physical Water Quality Results for Columbia River Water Samples

The Pacific Northwest National Laboratory and the U.S. Geological Survey (under contract to the Pacific Northwest National Laboratory) compiled chemical and physical water quality data for the Columbia River during 2005. 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 introduced upstream from the Hanford Site.

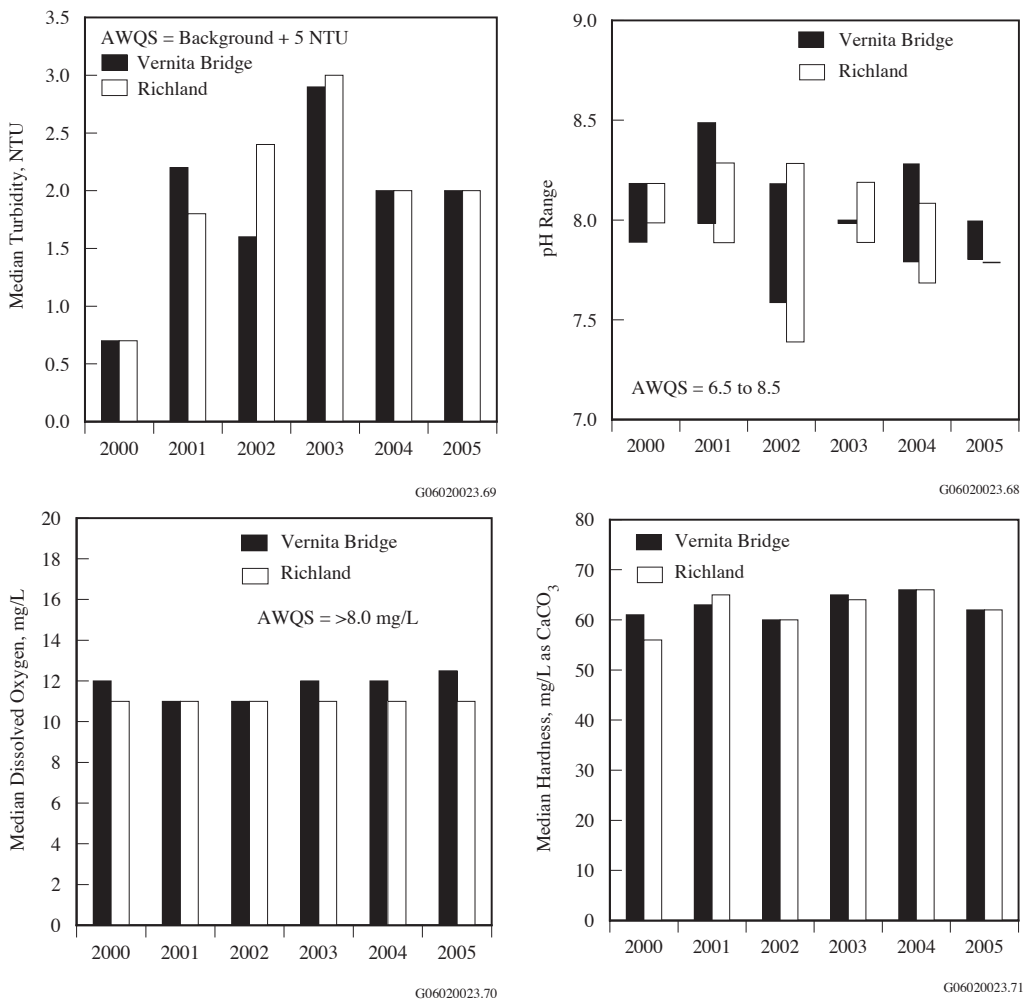
***Pacific Northwest National Laboratory Samples***. Results of chemical sampling conducted by the Pacific Northwest National Laboratory along transect and near-shore locations of the Columbia River at the Vernita Bridge, 100-F Area, 100-N Areas, Hanford town site, 300 Area, and Richland are provided in PNNL-15892, APP. 1. The concentrations of metals and anions observed in river water during 2005 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, copper, lead, mercury, 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. 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.5). Increased water hardness (i.e., primarily higher concentrations of calcium and magnesium ions) can reduce the toxicity of some metals by limiting their absorption into aquatic organisms. Criteria for Columbia River water were calculated using a total hardness of 47 mg/L as calcium carbonate, the lowest 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 2005 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 for the protection of aquatic life (Appendix C, Table C.7 and Appendix D, Table D.5). 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.5).

For samples collected on the cross-river transects, concentrations of nitrate and sulfate measured near the Hanford shoreline transect samples were elevated at the 100-F Area (near Hanford river marker #22), the Hanford town site, the 300 Area, and the Richland shoreline. Elevated nitrate concentrations at the Hanford town site shoreline are from the 200 Areas' contaminated groundwater plume, while elevated levels at the 300 Area appear (based on groundwater contaminant contours) to be from agricultural areas to the south. 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 withdrawn 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; U.S. Geological Survey Circular 1144). Average chloride, nitrate, and sulfate results were higher for quarterly concentrations at the Richland transect compared to the Vernita Bridge transect. The concentrations of volatile organic compounds in Columbia River water samples (e.g., chlorinated solvents, and benzene) were below the analytical laboratory's required detection limits for all samples, with no indication of a Hanford source.

***U.S. Geological Survey Samples***. Figure 10.4.10 illustrates U.S. Geological Survey Columbia River water quality data for samples collected at the Vernita Bridge and Richland for 2000 through 2005. Results for 2005 are also tabulated in PNNL-15892, APP. 1 and summarized in Appendix C (Table C.2). These results have been published by the U.S. Geological Survey (e.g., WA-05-1). The 2005 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 2005, 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.3).

## 10.4.2 Monitoring of Columbia River Sediment

As a result of past operations at the Hanford Site, large amounts of radioactive and non-radioactive materials were




AWQS = Washington State Ambient Water Quality Standard; NTU = Nephelometric turbidity unit.

**Figure 10.4.10. U.S. Geological Survey Water Quality Measurements for the Columbia River Upstream and Downstream of the Hanford Site, 2000 through 2005**

discharged to the Columbia River (PNWD-2223). Upon release to the Columbia River, some of these materials were deposited on the riverbed as sediment, particularly in upstream areas near downstream dams. The concentrations of the radioactive materials decreased as they underwent radioactive decay. Fluctuations in the river flow, as a result of the operation of upriver 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 and metals and other non-radioactive contaminants from mining and agricultural activities (Beasley et al. 1981; BNWL-2305; PNL-8148; PNL-10535; Cox et al. 2004). Periodic sediment sampling is necessary to confirm that concentrations remain low and to assure that no significant changes in concentrations have occurred. 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 Columbia River surface sediment have been decreasing as a result of radioactive decay and the deposition of uncontaminated material on top of the older sediment, which occurs in the reservoirs of the dams located downstream of Hanford (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 (Sections 5.4.1 and 10.3) and via contaminated groundwater seepage (Section 10.5).

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 reservoirs behind dams located upstream of the site and from White Bluffs Slough on the Hanford Reach.

### 10.4.2.1 Collection of Columbia River Sediment Samples and Analytes of Interest

During 2005, 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 submerged (some Hanford Reach sampling locations may not be submerged during extremely low river stage) (Figure 10.4.1 and Table 10.4.2). Sampling locations were documented using a global positioning system.

Samples were collected upstream of Hanford Site facilities from the Priest Rapids Dam reservoir (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 in the reservoir above Ice Harbor Dam (the first dam on the Snake River upstream of the river mouth) to assess Snake River input. Sediment samples also were collected along the Hanford Reach of the Columbia River, 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 in the reservoirs behind McNary and Priest Rapids Dams consisted of two stations spaced approximately equidistant on a transect line crossing the Columbia River; the samples were collected near the boat-exclusion buoys immediately upstream of each dam. All other monitoring sites consisted of a single sampling location. Samples were collected using a clam-shell style sediment dredge. The sampling method is 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 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 contaminants discharged from site facilities, and reviews of contaminant concentrations observed in Hanford Site groundwater monitoring wells located near the river.

### 10.4.2.2 Radiological Results for Columbia River Sediment Sample Analyses

Radionuclides consistently detected in river sediment adjacent to and downstream of the Hanford Site during 2005 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-15892, 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 2005 were similar to those reported for previous years (Appendix C, Table C.8), and there were no obvious differences between locations. The only unusual values for sediment samples for 2004 and 2005 have been for cesium-137 at the White Bluffs Slough, which were roughly 3 to 4 times higher than values from the previous years. Median, maximum, and minimum concentrations of selected radionuclides measured in Columbia and Snake River sediment (2000 through 2005) are presented in Figure 10.4.11.

### 10.4.2.3 Chemical Results for Columbia River Sediment Sample Analyses

Detectable amounts of most metals were found in all river sediment samples (Figure 10.4.12; Appendix C, Table C.9;

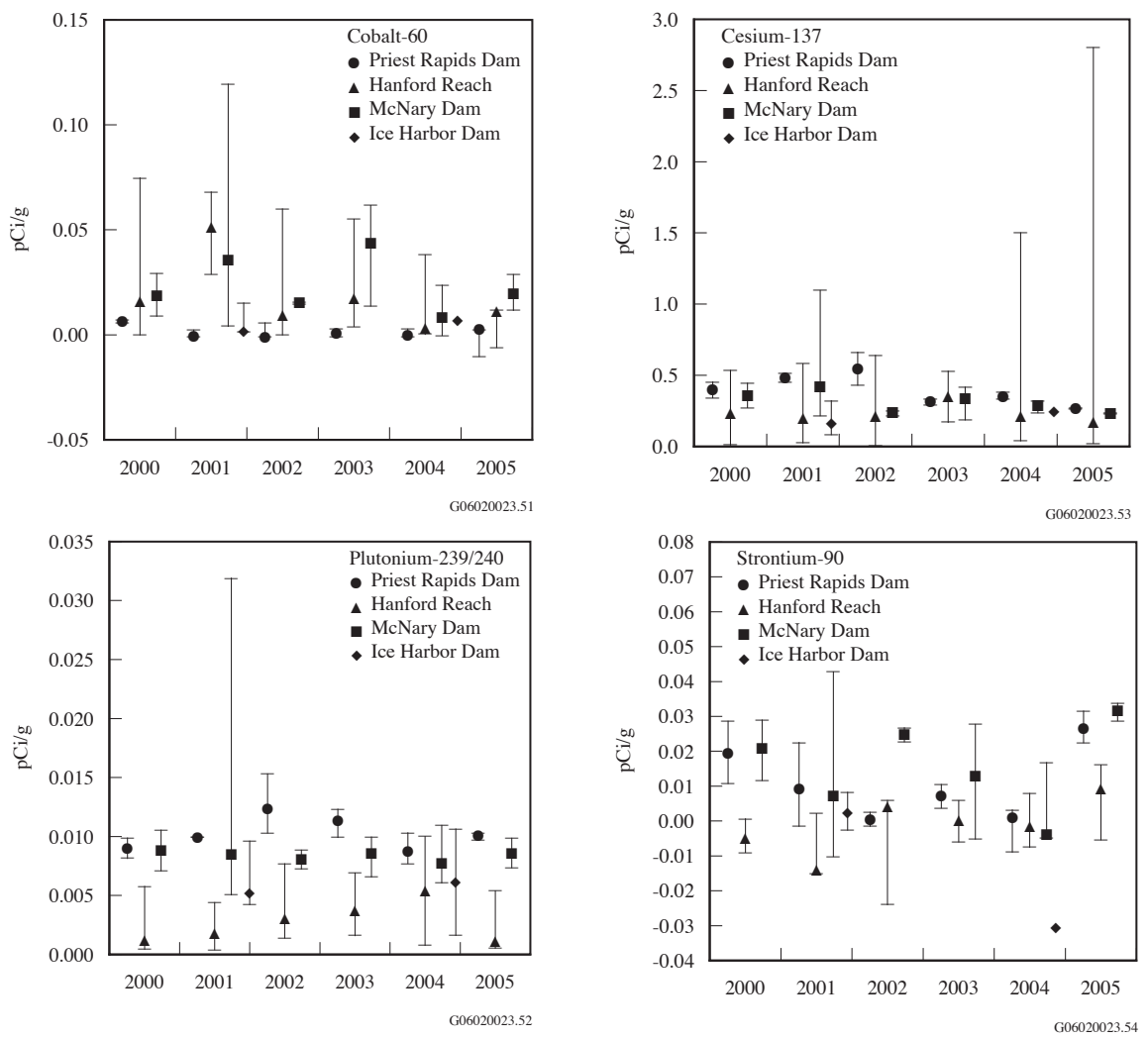



**Figure 10.4.11. Median, Maximum, and Minimum Concentrations of Selected Radionuclides Measured in Columbia River and Snake River Sediment, 2000 through 2005. All 2001 through 2004 results for cobalt-60 (except for Hanford Slough, 2003, and White Bluffs Slough, 2004) and 2002 through 2004 results for strontium-90 were below detection limits.**

PNNL-15892, APP. 1). Maximum and median concentrations of most metals were higher for sediment collected in the reservoir upstream of Priest Rapids Dam compared to either Hanford Reach or McNary Dam sediment. The concentrations of cadmium, mercury, and zinc had the largest differences between locations. Currently, there are no Washington State freshwater sediment quality criteria for comparison to the measured values.

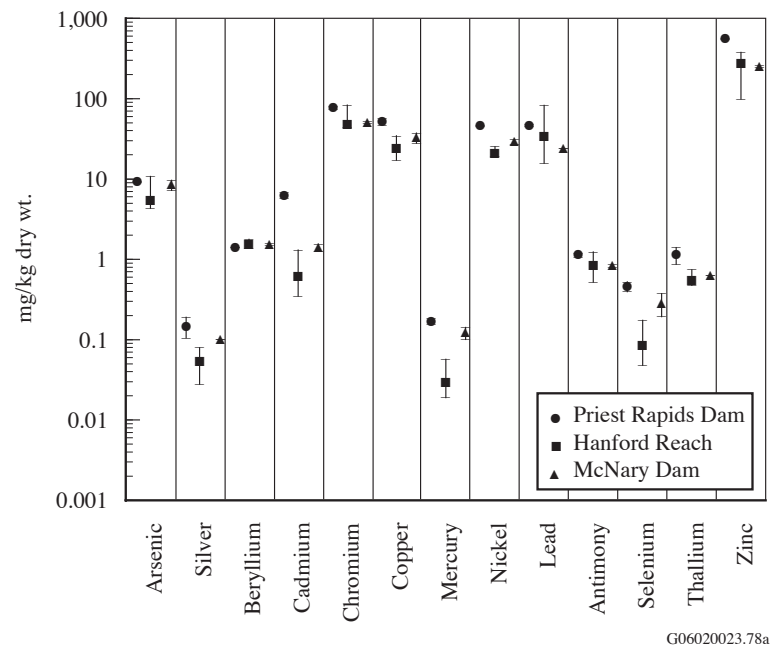



**Figure 10.4.12. Median, Maximum, and Minimum Concentrations of Selected Metals Measured in Columbia River Sediment (Washington and Oregon), 2005**

Since 1997 (no samples were collected in 2001), 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 acid volatile sulfide and metals. 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. These metals readily bind to sulfides and form metal sulfide precipitates, which are typically very insoluble, and this limits the amount of dissolved metal available in the sediment pore water. The SEM/AVS ratios are an indicator of potential sediment toxicity (DeWitt et al. 1996; Hansen et al. 1996; PNNL-13417). 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 pore water will be low. For a suite of divalent metals, the sum of the simultaneously extracted metals must be considered, with the assumption that the metal with the lowest solubility will be the first to combine with the acid volatile sulfide.

The SEM/AVS results for the sediment collected during 2005 from the Priest Rapids Dam and McNary Dam reservoirs were similar to results from previous years (Figure 10.4.13). Locations where sediment is deposited 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 2005, the acid volatile sulfide values in sediment from the Priest Rapid Dam reservoir had concentrations ranging from 6.1 to 13 µmol/g. Sediment from the McNary Dam reservoir had lower concentrations of acid volatile sulfide, with values ranging from 0.05 to 1.0 µmol/g. SEM/AVS molar ratios for sediment from the Priest Rapids Dam reservoir, Hanford Reach, and McNary Dam reservoir were above 1.0, indicating a potential for some dissolved metals to be present in the sediment pore water. For all locations, zinc was the primary metal present.

Overall results from 1997 through 2005 reveal that acid volatile sulfide concentrations in sediment from the Priest Rapids Dam reservoir are generally higher than concentrations in sediment from the Hanford Reach and the McNary Dam reservoir. 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 pore water concentrations of cadmium, copper, lead, and mercury. In Priest Rapids Dam sediment, average zinc values were of similar magnitude as the average acid volatile sulfide concentrations. In McNary Dam sediment, the average zinc concentrations were higher than the available mean acid volatile sulfide pool, indicating the

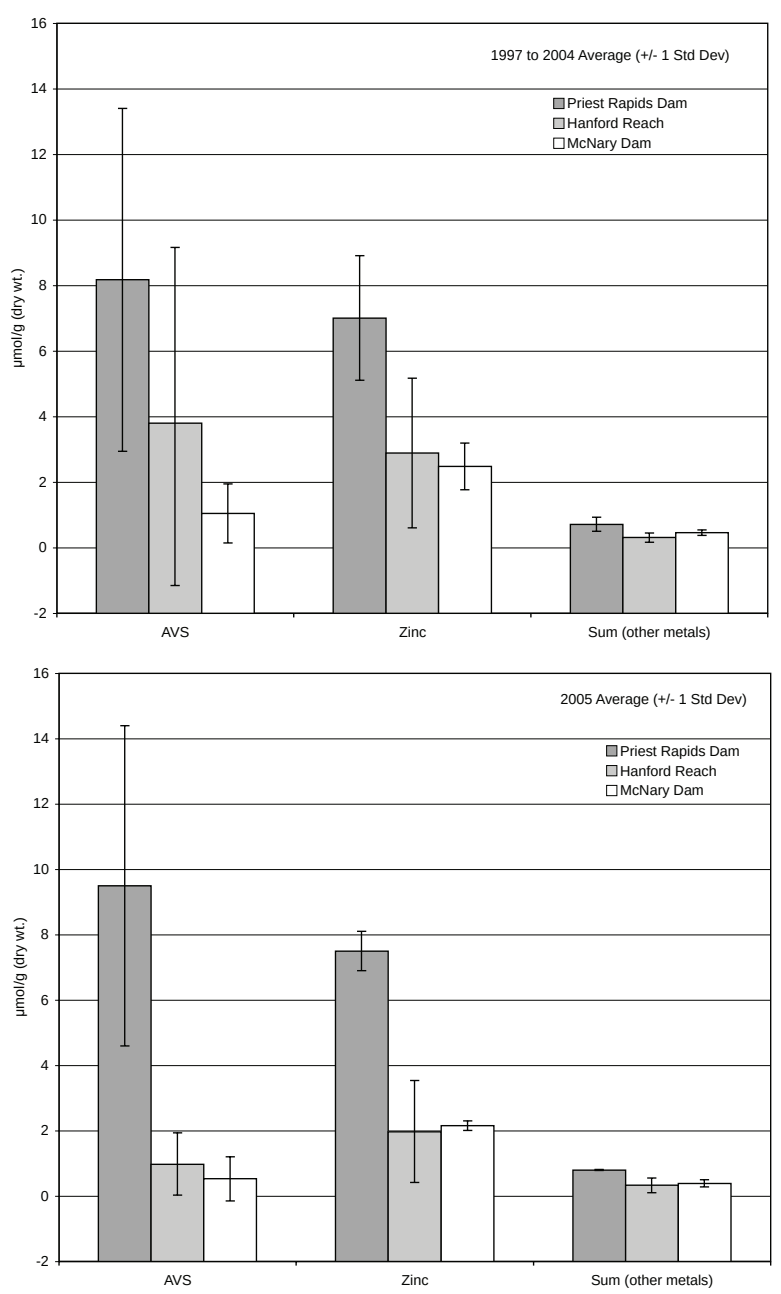



**Figure 10.4.13. Average Acid Volatile Sulfide/Simultaneously Extracted Zinc and Sum of Simultaneously Extracted Cadmium, Copper, Lead, Nickel, and Mercury in Columbia River Sediment, 1997 through 2004 Compared to 2005 Data**

potential for zinc and possibly other dissolved metals to be present in the sediment pore water.

## 10.4.3 Monitoring of Onsite Pond Water and Sediment

Two onsite ponds, West Lake and the Fast Flux Test Facility pond (Figure 10.4.1), located near facilities in various stages of remediation, were sampled periodically during 2005. The ponds were inaccessible to the public and, therefore, did not constitute a direct offsite environmental impact during 2005. 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 it is influenced by precipitation and changing water-table elevations that are related to the discharge of water to the ground in the 200 Areas. The water level in West Lake fluctuates and changes from standing water in winter and spring to nearly dry in summer and fall.

### 10.4.3.1 Collection of Pond Water and Sediment Samples and Analytes of Interest

During 2005, 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 as well as gamma-emitting radionuclides. The groundwater table in the 200-East Area has dropped in recent years

(Section 10.7), 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, uranium-234, uranium-235, and uranium-238 because of the high sediment load; thus, sediment samples were submitted for these analytes. Radionuclides were chosen for analysis based on their presence in local groundwater and their potential to contribute to the overall radiation dose to biota that frequent the ponds.

### 10.4.3.2 Radiological Results for Pond Water and Sediment Sample Analyses

All radionuclide concentrations in onsite pond water samples were less than applicable DOE derived concentration guides (DOE Order 5400.5; Appendix D, Table D.2) and Washington State ambient surface-water quality criteria (WAC 173-201A; 40 CFR 141; PNNL-15892, APP. 1; Appendix D, Tables D.3 and D.4).

Figure 10.4.14 shows the annual gross beta and tritium concentrations in Fast Flux Test Facility pond water from 2000 through 2005. Median levels of both constituents have remained stable in recent years. The median tritium concentration in Fast Flux Test Facility pond water during 2005 was 14% of the Washington State ambient surface-water quality criterion of 20,000 pCi/L (740 Bq/L). The sources of contaminants in the pond water are groundwater contaminant plumes from the 200 Areas that have migrated to wells near the Fast Flux Test Facility that supply water to facility operations.

Tritium concentrations in West Lake water during 2005 were similar to those observed in the past (Figure 10.4.15). The median concentration of tritium in West Lake water in 2005 was 0.8% of the Washington State ambient surface-water quality criterion level (20,000 pCi/L [740 Bq/L]) and reflected groundwater concentrations in the area.

Samples of West Lake sediment in 2005 had the following ranges of detectable values:

- Gross alpha – 5.3 to 13 pCi/g (0.20 to 0.48 Bq/g).
- Gross beta – 20 to 29 pCi/g (0.74 to 1.1 Bq/g).

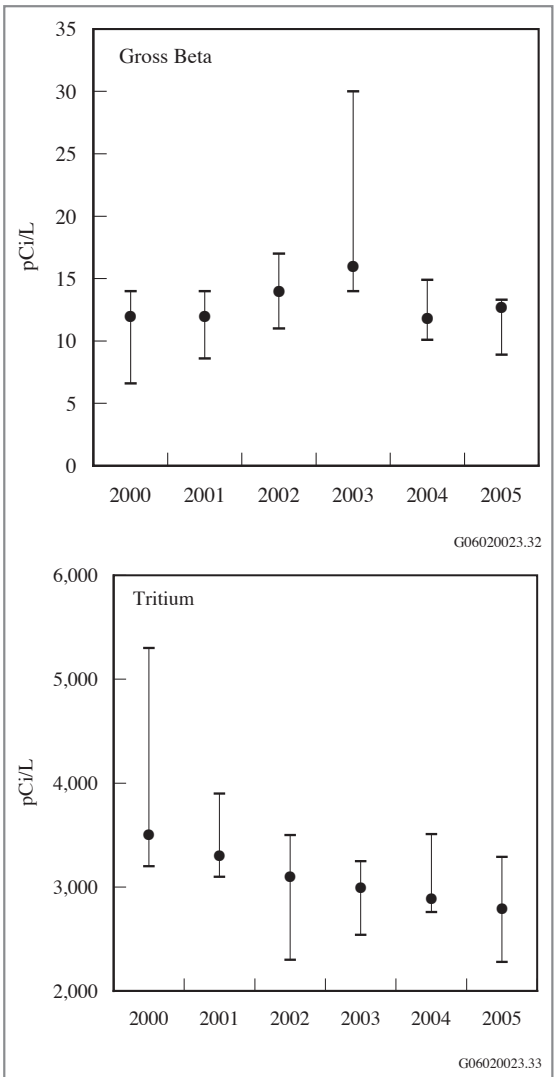



**Figure 10.4.14. Median, Maximum, and Minimum Gross Beta and Tritium Concentrations in Water Samples from the Fast Flux Test Facility Pond on the Hanford Site, 2000 through 2005**

- Potassium-40 – 15 to 17 pCi/g (0.56 to 0.63 Bq/g).
- Strontium-90 – 0.27 to 0.72 pCi/g (0.010 to 0.027 Bq/g).
- Cesium-137 – 0.84 to 1.7 pCi/g (0.031 to 0.063 Bq/g).
- Uranium-234 – 0.65 to 7.7 pCi/g (0.024 to 0.28 Bq/g).
- Uranium-235 – 0.019 to 0.32 pCi/g (0.00070 to 0.0012 Bq/g).
- Uranium-238 – 0.59 to 7.2 pCi/g (0.022 to 0.27 Bq/g).

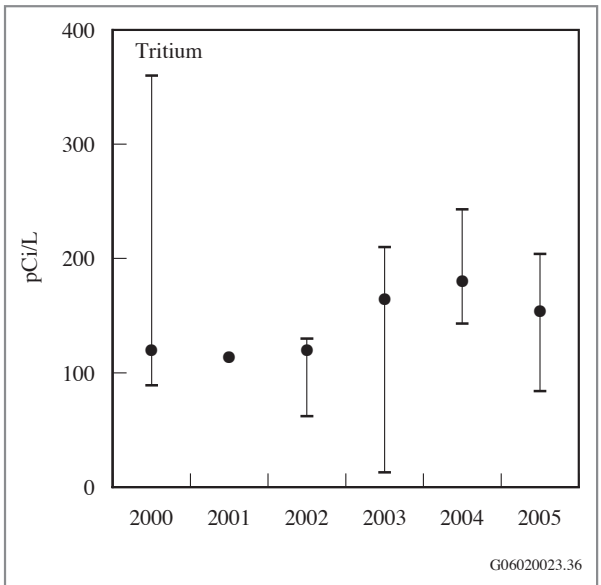



**Figure 10.4.15. Median, Maximum, and Minimum Concentrations of Tritium in Water Samples from West Lake on the Hanford Site, 2000 through 2005**

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

## 10.4.4 Monitoring of Offsite Irrigation Water

During 2005, 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 10.4.1). 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 (Section 10.14).

### Collection, Analysis, and Results for Offsite Irrigation Water Samples

Water from the Riverview irrigation canal and the Horn Rapids irrigation pumping station was sampled three times during the 2005 irrigation season. Unfiltered samples were analyzed for gross alpha, gross beta, gamma emitters, tritium, strontium-90, uranium-234, uranium-235, and uranium-238. During 2005, radionuclide concentrations measured in irrigation water were at the same levels detected in the Columbia River upstream of the Hanford Site (PNNL-15892, APP. 1). All radionuclide concentrations were below their respective DOE derived concentration guides and Washington State ambient surface-water quality criteria (DOE Order 5400.5; WAC 173-201A; 40 CFR 141).

# 10.5 Columbia River Shoreline Springs Monitoring

G. W. Patton

Samples of Columbia River shoreline spring water and associated sediment were collected along the Hanford Reach and analyzed to determine the potential impact of radiological and chemical contaminants from Hanford on the public and the aquatic environment. Sections 10.5.1 and 10.5.2 discuss the results for Columbia River shoreline spring water and sediment samples.

## 10.5.1 Water Monitoring at Columbia River Shoreline Springs

The Columbia River is the 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 shoreline springs. Routine monitoring of shoreline 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 shoreline groundwater-sampling tubes (aquifer tubes) (Section 10.7; PNNL-14444).

Shoreline 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 inclusion of the 100-N Area as the predominant area is no longer valid because of declining water-table elevations in response to the cessation of liquid waste discharges to the ground from Hanford Site operations and the pump-and-treat systems that are being used to decontaminate groundwater at the 100-N Area. In recent years, it has become increasingly difficult to locate shoreline springs in the 100-N Area.

The presence of shoreline springs also varies with river stage (river-level height). 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 upriver dams. As water levels fluctuate, groundwater levels and, thus, the presence of shoreline springs in the Hanford Reach vary. In addition, at the 300 Area the water levels are influenced by the height of the McNary Dam pool. Water flows into the Hanford Site aquifer (as bank storage) as the river stage rises and then discharges from the aquifer in the form of shoreline springs 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 aquifer 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 discharges and contaminant concentrations, as well as variations in aquifer thickness, porosity, and plume concentrations, it is difficult to accurately estimate the volume of contaminated groundwater discharging to the Columbia River within the Hanford Reach. Studies of shoreline 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.

### 10.5.1.1 Collection of Water Samples from Columbia River Shoreline Springs and Analytes of Interest

Routine monitoring of selected shoreline springs was initiated during 1988. Currently, shoreline spring water samples are collected for contaminant monitoring and to support groundwater operable unit investigations (DOE/RL-91-50). Tables 10.5.1 and 10.5.2 and Figure 10.4.1 summarize the sampling locations, types, frequencies, and analyses included in shoreline springs monitoring during 2005. This section describes the monitoring efforts and summarizes the results for these aquatic environments. Detailed analytical results are reported in PNNL-15892, APP. 1. Analytes of interest for samples from shoreline 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.

The majority of samples collected during 2005 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, uranium-234, uranium-235, and uranium-238. Most samples were analyzed for metals and anions. Samples from selected locations were analyzed for volatile organic compounds. All analyses were conducted on unfiltered samples, except for metals analyses, which were conducted on both filtered and unfiltered samples (Appendix C, Table C.10; PNNL-15892, APP. 1).

**Table 10.5.1. Shoreline Springs Water Monitoring at the Hanford Site, 2005**

| Springs Locations | Sample Type | Frequency | Analyses |
|---|---|---|---|
| 100-K Area | Grab | Annually | Alpha, beta, $^{3}H$, $^{90}Sr$, $^{99}Tc$, gamma energy analysis, metals (filtered and unfiltered), anions, VOA |
| 100-H Area | Grab | Annually | Alpha, beta, $^{3}H$, $^{90}Sr$, $^{99}Tc$, U,[a] gamma energy analysis, metals (filtered and unfiltered), anions |
| 100-D Area | Grab | Annually | Alpha, beta, $^{3}H$, $^{90}Sr$, U, gamma energy analysis, metals (filtered and unfiltered), anions |
| 100-B Area | Grab | Annually | Alpha, beta, $^{3}H$ |
| 100-N Area | Grab | Annually | Alpha, beta, $^{3}H$, $^{90}Sr$, 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 |
| Hanford town site | Grab | Annually | Alpha, beta, $^{3}H$, $^{129}I$, $^{99}Tc$, 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) U = Isotopic uranium-234, uranium-235, and uranium-238.
VOA = Volatile organic compounds.

### 10.5.1.2 Radiological Results for Water Samples from Columbia River Shoreline Springs

**Table 10.5.2. Hanford Reach Shoreline Springs Sediment Monitoring, 2005**

| Springs Locations[a] | Frequency | Analyses |
|---|---|---|
| 100-H Area | Annually | Gamma energy analysis, $^{90}$Sr, U,[b] metals |
| 100-F Area | Annually | Gamma energy analysis, $^{90}$Sr, U,[b] metals |
| Hanford town site | Annually | Gamma energy analysis, $^{90}$Sr, U,[b] metals |
| 300 Area | Annually | Gamma energy analysis, $^{90}$Sr, U,[b] metals |

(a) See Figure 10.4.1.
(b) U = Isotopic uranium-234, uranium-235, and uranium-238 analyzed by low-energy photon analysis.

Contaminants of Hanford origin continued to be detected in water from shoreline springs entering the Columbia River along the Hanford Site during 2005. Tritium, strontium-90, technetium-99, iodine-129 (2005 data pending), uranium-234, uranium-235, and uranium-238 were detected in spring water (Appendix C, Table C.10). All radiological contaminant concentrations measured in shoreline springs during 2005 were less than applicable DOE derived concentration guides (DOE Order 5400.5; Appendix D, Table D.2).

Figure 10.5.1 depicts concentrations of selected radionuclides in 300 Area shoreline spring water (spring 42-2 and spring DR 42-2) from 2000 through 2005. Concentrations of radionuclides in 300 Area shoreline springs in 2005 were similar to concentrations measured in previous years. Concentrations of radionuclides in shoreline spring water vary over the years with changes in the degree of river water and groundwater mixing (i.e., bank storage effect). The elevated tritium levels measured in 300 Area shoreline springs are indicators of the contaminated groundwater plume from the 200 Areas (Section 5.9 in PNL-10698).

Concentrations of selected radionuclides in shoreline spring water near the Hanford town site (spring 28-2) from 2000 through 2005 are provided in Figure 10.5.2. Annual fluctuations in these values reflect the influence of bank storage during the sampling period.

Gross beta concentrations in shoreline spring water at the 100-D Area, 100-K Area, 100-H Area, 100-F Area, Hanford town site, and 300 Area were elevated compared to other shoreline spring water locations.

Tritium concentrations varied widely with location. The highest tritium concentration measured in shoreline springs was at the Hanford town site (39,000 ± 2,800 pCi/L [1,400 ± 100 Bq/L]), which was above the Washington State ambient surface-water quality criterion of 20,000 pCi/L (740 Bq/L) (WAC 173-201A; 40 CFR 141), followed by 12,000 ± 920 pCi/L (440 ± 34 Bq/L) in the 300 Area, and 10,000 ± 2,300 pCi/L (370 ±85 Bq/L) in the 100-D Area. Tritium concentrations in all shoreline spring samples (expect for the 100-K Area) were elevated compared to the 2005 Columbia River concentrations at Priest Rapids Dam.

Samples from shoreline springs were analyzed for strontium-90 in the 100-B, 100-K, 100-N, 100-D, 100-H, and 100-F Areas. The highest strontium-90 concentration detected in shoreline spring water was at the 100-K Area (2.7 ± 0.41 pCi/L [0.10 ± 0.015 Bq/L]). This value was 34% of the ambient surface-water quality criterion of 8 pCi/L (0.30 Bq/L). Groundwater at the 100-N Area has historically had the highest strontium-90 concentrations; however, since 1997, no visible shoreline springs have been observed along the shoreline where strontium-90 concentrations in groundwater are elevated.

Samples from shoreline springs in the 100-K Area, 100-N Area, 100-H Area, 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 (33 Bq/L) (Appendix D, Table D.4). The highest technetium-99 concentration was found in shoreline spring water from the Hanford town site (40 ± 2.4 pCi/L [1.5 ± 0.089 Bq/L]).

Samples from shoreline springs at the Hanford town site and 300 Area were collected in 2005 and submitted to a laboratory for iodine-129 analyses. However, analysis results

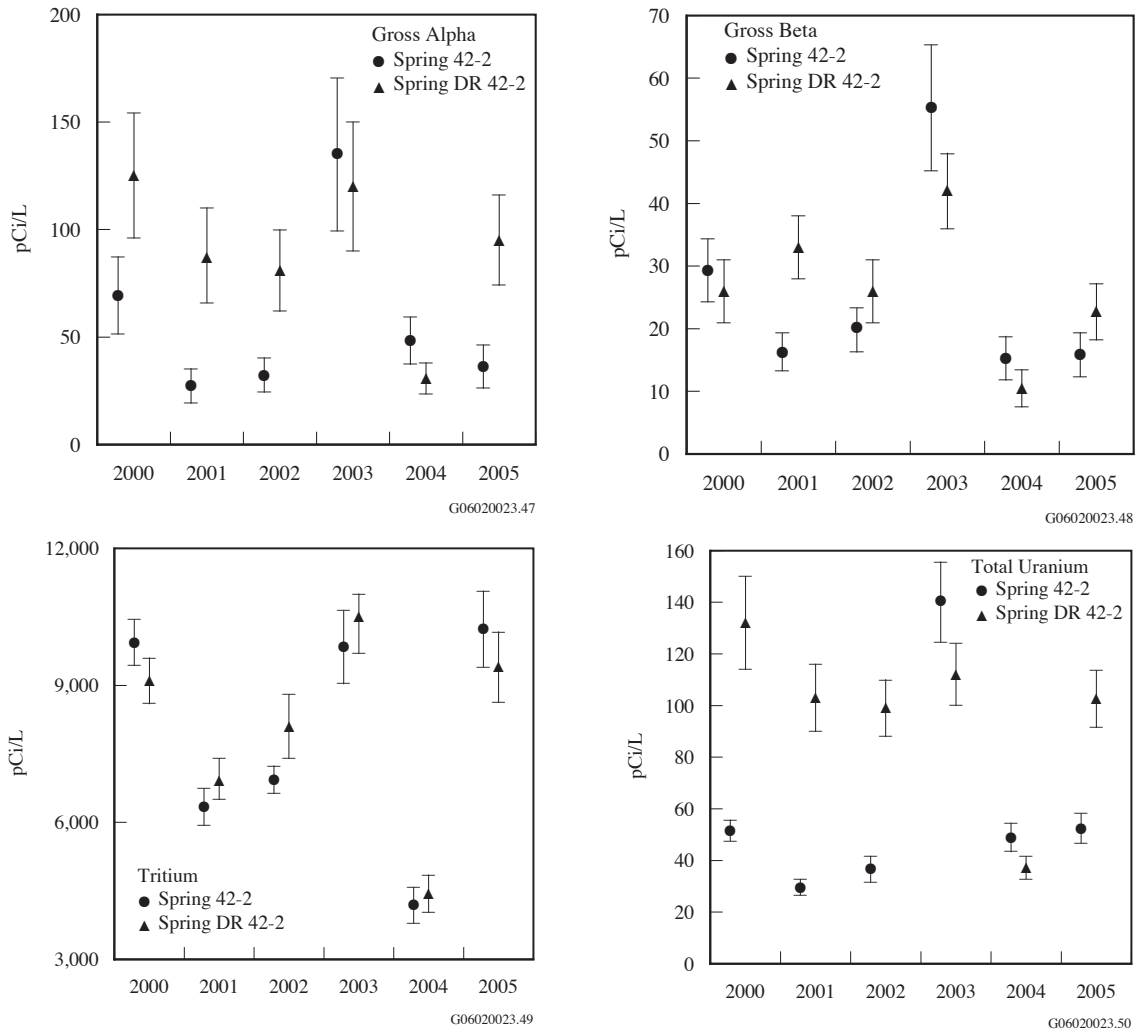



**Figure 10.5.1. Concentrations (results ±2 total propagated analytical uncertainty) of Selected Radionuclides in Water from Columbia River Shoreline Springs Near the Hanford Site's 300 Area, 2000 through 2005. Multiple samples were collected for 300 Area shoreline springs in 2001; the results are for the May 10, 2001 sampling event. Note: DR refers to downriver, thus DR 42-2 is a spring located downriver from Hanford Mile Marker 42-2.**

will not be available until August 2006. These results will be reported in the 2006 Hanford Site environmental report. From 2000 through 2004, the highest concentration was measured in a water sample from the Hanford town site spring (0.25 ± 0.022 pCi/L [0.0093 ± 0.00081 Bq/L]). This Hanford town site value was roughly 74,000 times higher than the 2005 average concentration measured at Priest Rapids Dam (0.0000034 ± 0.00000094 pCi/L [0.00000012 ± 0.000000034 Bq/L]) but was below the surface-water quality criterion of 1 pCi/L (0.037 Bq/L) (Appendix D, Table D.4).

Uranium was monitored in shoreline spring water samples from the 100-D Area, 100-H Area, 100-F Area, Hanford town site, and 300 Area in 2005 (Figure 10.4.1). The highest total uranium level was found in 300 Area spring water (100 ± 11 pCi/L [3.7 ± 0.41 Bq/L] or approximately 110 ± 12 µg/L), which was collected 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 (95 ± 21 pCi/L

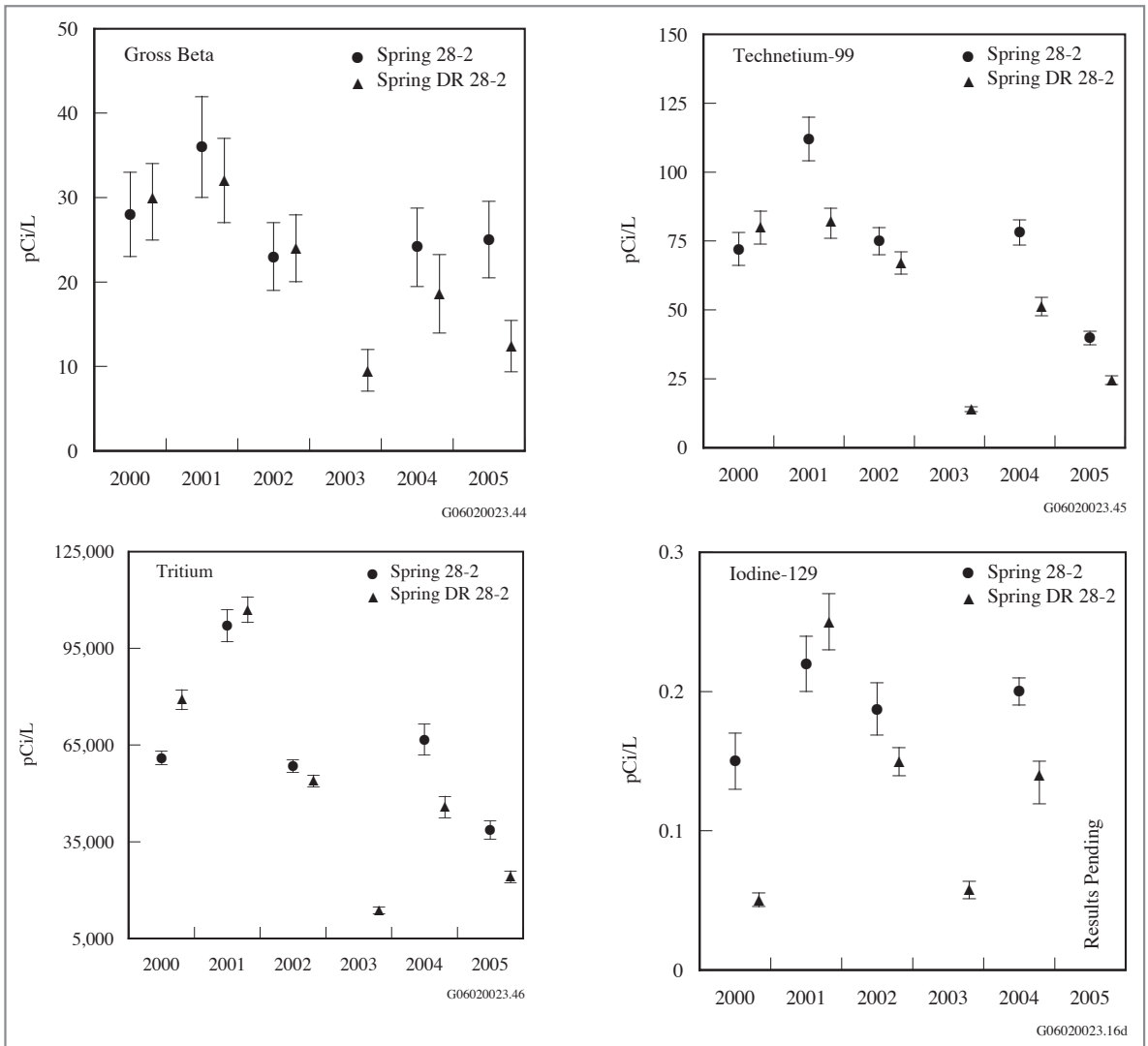



**Figure 10.5.2. Concentrations (results ±2 total propagated analytical uncertainty) of Selected Radionuclides in Columbia River Shoreline Springs Water at the Hanford Town Site (Spring 28-2 and Spring 28-2 DR), 2000 through 2005. As a result of figure scale, some uncertainties (error bars) are concealed by the point symbol. Note: DR refers to downriver, thus DR 28-2 is a spring located downriver from Hanford Mile Marker 28-2.**

[3.5 ± 0.78 Bq/L]), which exceeded the Washington State ambient surface water quality criterion of 15 pCi/L (0.56 Bq/L) (Appendix D, Table D.4). Elevated uranium concentrations exist in the unconfined aquifer beneath the 300 Area in the vicinity of former uranium fuel fabrication facilities and inactive waste sites. The increase in uranium concentrations in 2003 samples from shoreline spring 42-2 was 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 shoreline 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 shoreline spring water from 2000 through 2005 parallel uranium and are likely associated with its presence. Concentrations of radionuclides in 300 Area shoreline springs in 2005 were similar to concentrations measured in previous years and varied with the bank storage effect.

### 10.5.1.3 Chemical Results for Water Samples from Columbia River Shoreline Springs

Hanford-origin contaminants continued to be detected in water from shoreline springs entering the Columbia River along the Hanford Site during 2005. Metals and anions (chloride, fluoride, nitrate, and sulfate) were detected in spring water. Concentrations of volatile organic compounds were near or below their detection limits in all samples. Trichloroethene was detected (1.4 µg/L) in one sample from the 300 Area and was the only analyte detected at all shoreline spring sampling locations. Trichloroethene has been consistently detected at low concentrations in 300 Area shoreline spring water.

Concentration ranges of selected chemicals measured in shoreline spring water during 2003 through 2005 are presented in Table 10.5.3. For most locations, the 2005 chemical sample results were similar to those reported previously (PNNL-14687). Nitrate concentrations were highest in spring water samples from the 100-F Area. Dissolved chromium concentrations were highest in the 100-D and 100-K Areas' shoreline springs. Hanford groundwater monitoring results for 2005 indicated similar contaminant concentrations in shoreline areas (Section 10.7, Figure 10.7.6).

The ambient surface-water quality criteria for cadmium, copper, lead, nickel, silver, and zinc are total-hardness dependent (WAC 173-201A; Appendix D, Table D.5). For comparison purposes, spring-water criteria were calculated using the same 47-milligram calcium carbonate per liter hardness given in Appendix D, Table D.5. The concentrations of most metals measured in water collected from springs along the Hanford Site shoreline during 2003 through 2005 were below Washington State ambient surface-water chronic toxicity levels (WAC 173-201A). However, concentrations of dissolved chromium in 100-B, 100-K, 100-N, 100-D, 100-H, and 100-F Areas' shoreline spring water were above the Washington State ambient surface water chronic toxicity level (Appendix D, Table D.5) and above the acute toxicity level at the 100-B, 100-K, 100-D, and 100-H Areas. Arsenic concentrations in shoreline spring water were well below the Washington State ambient surface-water chronic toxicity level, 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.5). Nitrate concentrations at all spring water locations were below the drinking water standard (Appendix D, Table D.4).

## 10.5.2 Monitoring Columbia River Shoreline Springs Sediment

Sampling of sediment from shoreline springs began during 1993 at the Hanford town site and 300 Area. Sampling of shoreline springs sediment in the 100-B, 100-K, and 100-F Areas began during 1995. Substrates at sampling locations of shoreline springs in the 100-N, 100-D, and 100-H Areas consist predominantly of large cobble and are unsuitable for sampling.

### Radiological Results for Sediment Samples from Columbia River Shoreline Springs

During 2005, sediment samples were collected at shoreline springs in the 100-F, 100-H, and 300 Areas and the Hanford town site. No sediment was available for sampling at the 100-B and 100-K Area locations because the springs that were scheduled for sampling were not flowing during the scheduled sampling time. Results for 2005 samples were similar to those observed for previous years (PNNL-15892, APP. 1; Appendix C, Table C.11). Beryllium-7, potassium-40, cesium-137, and uranium isotopes were the only radionuclides reported above the minimum detectable concentrations. During 2005, radionuclide concentrations in shoreline spring sediment were similar to those observed in Columbia River sediment, with the exception of the 300 Area where uranium concentrations were roughly four times 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-14687).

Concentrations of metals in shoreline spring sediment samples during 2005 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.

**Table 10.5.3. Concentration Ranges for Selected Chemicals in Water Monitoring Samples from Columbia River Shoreline Springs at the Hanford Site, 2003 through 2005**

| | 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** | | 7 | 4 | 5 | 6 | 5 | 3 | 8 | 7 |
| **Dissolved Metals (µg/L)** | | | | | | | | | |
| Antimony | NA | 0.11 - 0.31 | 0.13 - 0.29 | 0.16 - 0.46 | 0.17 - 0.30 | 0.13 - 0.27 | 0.17 - 0.22 | 0.15 - 0.26 | 0.18 - 0.26 |
| Arsenic | 190 | 0.60 - 1.6 | 0.35 - 1.4 | 1.5 - 2.7 | 0.54 - 2.5 | 0.35 - 2.9 | 1.4 - 1.7 | 0.99 - 3.7 | 1.2 - 5.6 |
| Cadmium | 0.59 | 0.0056 - 0.024 | 0.012 - 0.023 | 0.015 - 0.030 | 0.014 - 0.062 | 0.011 - 0.040 | 0.018 - 0.051 | 0.010 - 0.023 | 0.016 - 0.029 |
| Chromium | 10[b] | 5.1 - 18 | 0.97 - 42 | 6.0 - 14 | 10 - 57 | 0.76 - 33 | 3.3 - 14 | 0.52 - 2.7 | 1.5 - 5.0 |
| Copper | 6 | 0.23 - 0.51 | 0.37 - 0.45 | 0.22 - 0.43 | 0.36 - 0.82 | 0.40 - 0.52 | 0.31 - 1.1 | 0.29 - 0.88 | 0.30 - 0.45 |
| Lead | 1.1 | 0.0040 - 0.60 | 0.0040 - 0.18 | 0.0091 - 0.23 | 0.016 - 0.29 | 0.011 - 0.40 | 0.0082 - 0.36 | 0.0040 - 0.14 | 0.0040 - 0.35 |
| Nickel | 83 | 0.79 - 1.6 | 0.60 - 1.3 | 0.85 - 1.7 | 1.3 - 6.4 | 0.76 - 1.5 | 1.1 - 1.7 | 0.72 - 1.4 | 0.90 - 2.1 |
| Silver | 0.94[c] | 0.0017 - 0.0097 | 0.0017 - 0.0085 | 0.0017 - 0.0085 | 0.0017 - 0.0085 | 0.0017 - 0.010 | 0.0017 - 0.0040 | 0.0017 - 0.0040 | 0.0017 - 0.0085 |
| Thallium | NA | 0.0054 - 0.0098 | 0.0079 - 0.015 | 0.0057 - 0.0090 | 0.0090 - 0.024 | 0.0054 - 0.017 | 0.011 - 0.011 | 0.0073 - 0.019 | 0.0040 - 0.016 |
| Zinc | 55 | 0.14 - 1.2 | 0.43 - 3.1 | 1.2 - 1.6 | 1.2 - 3.0 | 1.4 - 2.5 | 0.66 - 3.2 | 0.54 - 2.6 | 0.78 - 1.9 |
| **No. of Samples** | | 4 | 4 | 5 | 6 | 5 | 3 | 8 | 7 |
| **Total Recoverable Metals (µg/L)** | | | | | | | | | |
| Chromium | 96[d] | 8.4 - 20 | 1.2 - 41 | 9.4 - 14 | 11 - 69 | 0.89 - 63 | 10 - 30 | 0.88 - 5.4 | 1.8 - 9.6 |
| Mercury | 0.012 | 0.00038 - 0.00047 | 0.00075 - 0.018 | 0.00046 - 0.00094 | 0.00047 - 0.028 | 0.00071 - 0.041 | 0.0076 - 0.012 | 0.00081 - 0.0052 | 0.00080 - 0.047 |
| Selenium | 5 | 0.50 - 1.3 | 0.10 - 0.50 | 0.50 - 0.85 | 0.10 - 2.4 | 0.10 - 0.74 | 0.68 - 1.5 | 0.45 - 1.7 | 1.2 - 3.8 |
| **No. of Samples** | | 5 | 3 | 2 | 6 | 5 | 3 | 8 | 8 |
| **Anions (mg/L)** | | | | | | | | | |
| Nitrate | 45[e] | 0.59 - 2.4 | 0.028 - 2.8 | 2.7 - 4.0 | 0.41 - 2.6 | 0.56 - 6.9 | 2.6 - 7.2 | 0.47 - 4.9 | 1.7 - 5.8 |

(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) Drinking water standard (WAC 246-290).
NA = Not available.

# 10.6 Radiological Monitoring of Hanford Site Drinking Water

R. W. Hanf and L. M. Kelly

During 2005, Pacific Northwest National Laboratory conducted radiological monitoring of drinking water supplied to Hanford Site facilities by DOE-owned pumps and water treatment facilities. Fluor Hanford, Inc., the site water compliance organization, conducted routine chemical, physical, and microbiological monitoring of onsite drinking water. Individual water systems operated by Fluor Hanford, Inc.; Bechtel; and Washington Closure Group performed process monitoring (includes chemical and physical sampling) at the water treatment plants and distribution systems to determine compliance with applicable regulations.

WAC 246-290 requires that all drinking water analytical results be reported routinely to the Washington State Department of Health. Radiological results for Hanford Site drinking water samples are reported to the state through this annual environmental report and through an annual supplemental data compilation (e.g., PNNL-15892, APP. 1). Process monitoring reports are provided directly to the state each month by the contractor responsible for operating the water system. Chemical, physical, and microbiological data are reported to the state directly by the state-accredited laboratory performing the analyses and to Fluor Hanford, Inc. but are not published.

All DOE-owned drinking water systems on the Hanford Site were in compliance with drinking water standards for radiological, chemical, and microbiological contaminant levels during 2005. Contaminant concentrations measured during the year were similar to those observed in recent years (see Section 4.3 in PNNL-14687 and Section 8.6 in PNNL-15222).

## 10.6.1 Hanford Site Drinking Water Systems

During 2005, drinking water was supplied to DOE facilities on the site by eleven DOE-owned, contractor-operated, public water systems (Table 10.6.1). Two systems, one at the Wye Barricade and one at the Yakima Barricade, were designated as Group B water systems by the Washington State Department of Health in 2005 (a Group B system serves an average non-residential population of less than 25 for 60 or more days within a calendar year). These systems consisted of holding tanks that were supplied with water trucked from the 200-West Area water treatment plant. Ten of the 11 systems used water from the Columbia River. One system in the 400 Area used groundwater from the unconfined aquifer beneath the site. Fluor Hanford, Inc. operated nine of the systems. Bechtel Hanford, Inc. operated one system in the 100-N Area until August, when it was turned over to Washington Closure Hanford. The system in the 300 Area, a system that distributed water supplied by the city of Richland, was operated by Fluor Hanford, Inc. until August, when it was turned over to Washington Closure Hanford. In addition to the 300 Area, the city of Richland provided drinking water to the Richland North Area, and the Hazardous Materials Management and Emergency Response (HAMMER) Training and Education Center in 2005.

## 10.6.2 Hanford Site Drinking Water Treatment Facilities

Raw water was treated at four DOE-owned water treatment facilities in the 100-K, 100-N, 200-West, and 400 Areas (Figure 10.6.1). Water for the 100-K, 100-N, and 200-West

**Table 10.6.1. Hanford Site Drinking Water Systems and Systems Operators**

| System[a] | Operator |
|---|---|
| 200-West Area | Fluor Hanford, Inc. |
| 100-K Area | Fluor Hanford, Inc. |
| 100-N Area | Washington Closure Hanford[b] |
| 300 Area | Washington Closure Hanford[c] |
| 400 Area | Fluor Hanford, Inc. |
| 200-East Area | Fluor Hanford, Inc. |
| 100-B Area | Fluor Hanford, Inc. |
| 251-West | Fluor Hanford, Inc. |
| 609 Fire Station | Fluor Hanford, Inc. |
| Wye Barricade | Fluor Hanford, Inc. |
| Yakima Barricade | Fluor Hanford, Inc. |

(a) 400 Area system water from 400 Area groundwater wells. Water for all other systems from the Columbia River.
(b) Operated by Bechtel Hanford, Inc. until August 2005.
(c) Operated by Fluor Hanford, Inc. until August 2005.

Areas facilities was obtained from the Columbia River. Water treated in the 400 Area was pumped from wells. The 400 Area continued to use well 499-S1-8J (P-16) as the primary drinking water supply well and wells 499-S0-8 (P-14) and 499-S0-7 (P-15) as backup sources. The three wells furnished water to a common header that supplied three above-ground storage tanks. The backup well with the lowest tritium level, as demonstrated by sampling and analysis, was considered the primary backup water supply. During 2005, backup well 499-S0-7 was not used as a drinking water source. Backup well 499-S0-8 supplied 95,382 liters (25,200 gallons) to the distribution system in June and 204,390 liters (54,000 gallons) in December. During both of these months, the primary well was off line for a short time for maintenance.

## 10.6.3 Collection of Drinking Water Samples and Analytes of Interest

Samples at all four drinking water treatment facilities were collected and analyzed quarterly for radiological contaminants. All were samples of treated water collected before the water was distributed for general use. Drinking water in the 300 and Richland North Areas and at the HAMMER training and education center 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 the city's river water intake. The Columbia River is the primary source of the city of Richland's drinking water. The radiological analytical results for these river water samples are summarized in Section 10.4 and tabulated in Appendix C (Table C.4). The city of Richland also monitors its water for radiological and chemical contaminants, and for general water quality. As a community water system, the city is required to annually report monitoring results and characterize the risks (if any) from exposure to contaminants in the water, in what is known as a Consumer Confidence Report. The reports are mailed to all consumers as an insert with a monthly utility bill. Results are also made available on the city of Richland's web page (http://www.ci.richland.wa.us/RICHLAND/Utilities/index.cfm?PageNum=15).

## 10.6.4 Radiological Results for Hanford Site Drinking Water Samples

Drinking water samples collected for radiological analysis were analyzed for gross alpha, gross beta, tritium, strontium-90, iodine-131, radium-226, and radium-228. Results for radiological monitoring of Hanford Site drinking water during 2005 are summarized in Table 10.6.2. Individual analytical results are reported in PNNL-15892, 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). Maximum contaminant levels for gross alpha (excluding uranium and radon) and radium-226 and radium-228 (a combined total) are 15 pCi/L (0.56 Bq/L) and 5 pCi/L (0.18 Bq/L), respectively. The maximum allowable annual average limit for tritium is 20,000 pCi/L (740 Bq/L) (40 CFR 141; WAC 246-290). These concentrations are assumed to produce a total body or organ dose of 4 mrem/yr (0.04 mSv/yr). 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).

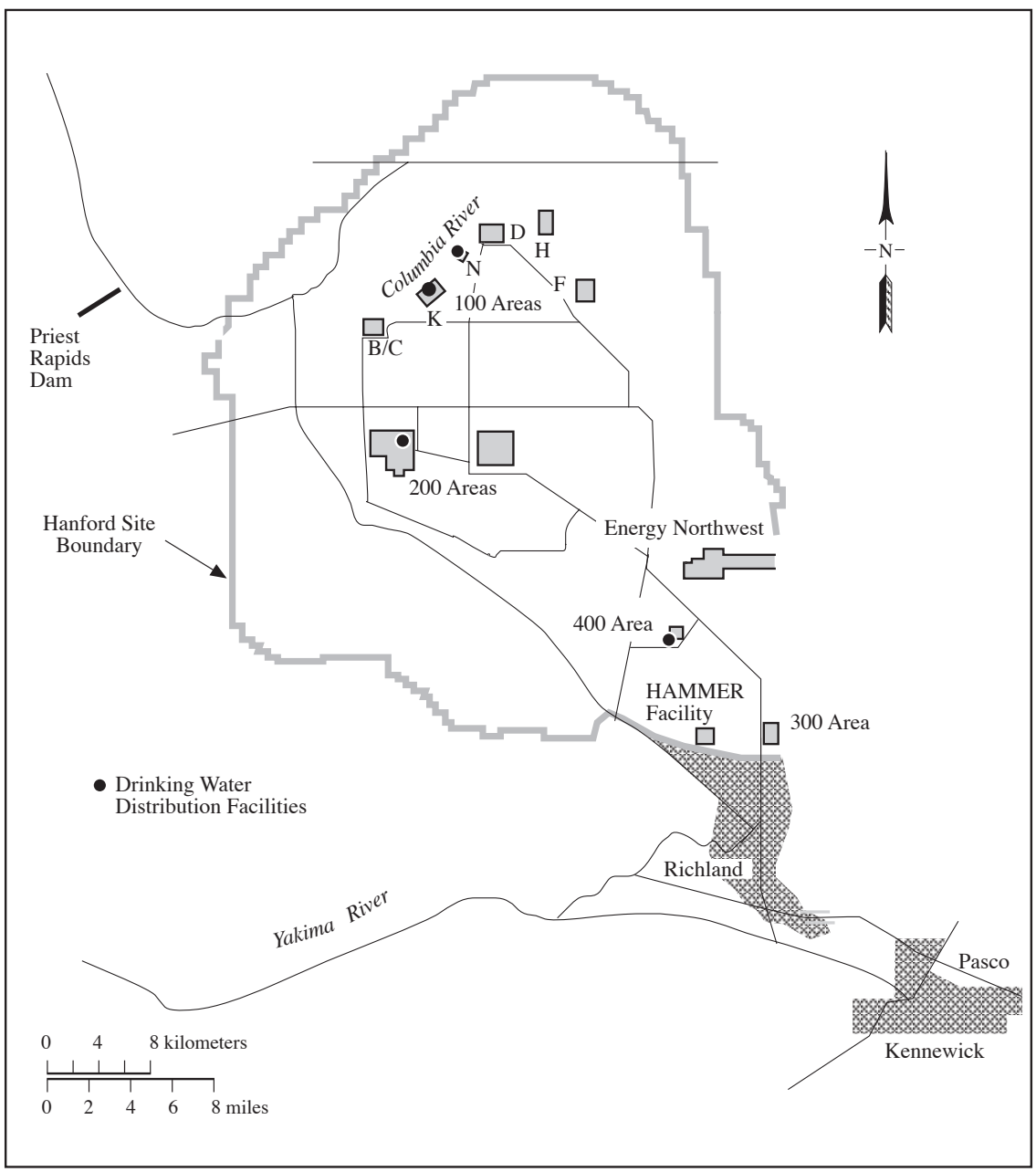



**Figure 10.6.1. Hanford Site Drinking Water Distribution Facilities and Sampling Locations, 2005**

During 2005, annual average concentrations of all monitored radionuclides in Hanford Site drinking water were below state and federal maximum allowable contaminant levels. All gross beta and tritium results for river water samples were below their minimum detectable concentrations, as were radium-228 results for 2 of 12 river water samples and alpha results for 11 of 12 samples tested. Federal law states that all community systems designated by Washington State as utilizing waters contaminated by effluents from nuclear facilities must sample for iodine-131. However, there is currently no DOE source for this contaminant at Hanford. All river and well water iodine-131 results were also below their respective minimum detectable concentrations (i.e., concentrations were too low to measure). Radium-226 was

**Table 10.6.2. Annual Average Concentrations (pCi/L)[a] of Selected Radiological Constituents in Hanford Site Drinking Water, 2005**

| Constituent | No. of Samples Analyzed From Each Location | Systems: 100-K Area | 100-N Area | 200-West Area | 400 Area | Standards |
|---|---|---|---|---|---|---|
| Gross alpha[b] | 4[c] | 0.15 ± 0.90[d] | 0.59 ± 0.71[d] | 0.61 ± 1.27 | 0.17 ± 1.33[d] | 15[e,f] |
| Gross beta[b] | 4[g] | 0.20 ± 1.75[d] | 0.59 ± 1.43[d] | 0.62 ± 1.59[d] | 6.37 ± 2.00 | 50[f] |
| Tritium | 1[h] | -26.3 ± 92[d,i] | -140 ± 86[d,i] | 60.5 ± 96[d,i] | 3,097 ± 918[c] | 20,000[f] |
| Strontium-90 | 1[h] | 0.02 ± 0.04[d,i] | 0.04 ± 0.04[i] | 0.03 ± 0.04[d,i] | -0.08 ± 0.04[d,i] | 8[e,f] |
| Iodine-131[b] | 4[c] | -0.09 ± 0.42[d] | 0.04 ± 0.74[d] | 0.01 ± 0.77[d] | -0.17 ± 0.69[d] | 3[j] |
| Radium-226[b] | 4[c] | 0.09 ± 0.04 | 0.08 ± 0.18 | 0.11 ± 0.22 | 0.08 ± 0.18 | combined |
| Radium-228[b] | 4[c] | 0.83 ± 0.47 | 0.73 ± 0.68 | 1.02 ± 1.41 | 0.74 ± 0.59 | 5[f] |

(a) Multiply pCi/L by 0.037 to convert to Bq/L.
(b) Annual average ±2 times the standard deviation.
(c) Samples were 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 were collected monthly, composited, and analyzed quarterly.
(h) Samples were collected quarterly, composited, and analyzed annually.
(i) Single result ± the total propagated analytical error.
(j) EPA-570/9-76/003.

detected in six of twelve river water samples. Strontium-90 was only detected in one of three river-water samples analyzed for strontium. Gross beta was found in all four 400 Area well water samples, radium-226 was found in one of the four well water samples analyzed, and radium-228 was measured in three of four well water samples. Neither gross alpha nor strontium-90 were detected in 400 Area well water samples (Table 10.6.2).

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 all 400 Area drinking water wells. During 2005, 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 10.6.3; Figure 10.6.2).

**Table 10.6.3. Tritium Concentrations (pCi/L)[a] in Hanford Site 400 Area Drinking Water Wells, 2005[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) |
|---|---|---|---|
| January 12, 2005 | 2,420 ± 210 | 2,650 ± 220 | 10,300 ± 510 |
| April 13, 2005 | 2,830 ± 300 | 2,760 ± 300 | 13,200 ± 710 |
| July 14, 2005 | 2,760 ± 290 | 2,880 ± 290 | 12,800 ± 720 |
| October 20, 2005 | 3,240 ± 300 | 2,980 ± 290 | 9,790 ± 570 |

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

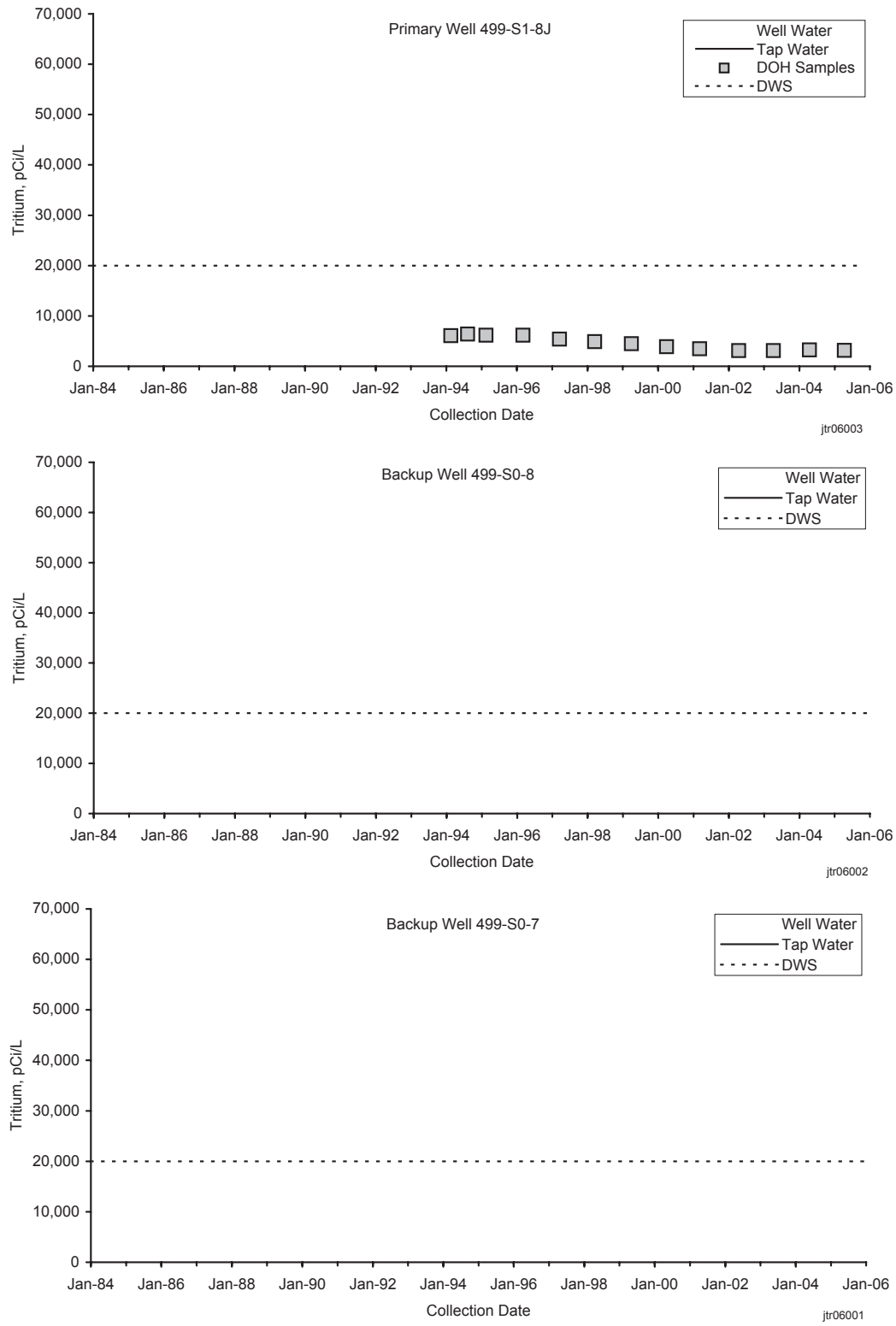



**Figure 10.6.2. Tritium Concentrations in Drinking Water from Three Wells in the Hanford Site's 400 Area, 1984 through 2005. (DOH = Washington State Department of Health, DWS = drinking water standard). Multiply pCi/L by 0.037 to convert to Bq/L.**

# 10.7 Groundwater Monitoring

D. R. Newcomer and M. J. Hartman

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. An evaluation of groundwater quality of the Hanford Site is documented in an annual groundwater monitoring report (e.g., PNNL-15670).

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 regulatory agencies, such as the EPA and Washington State Department of Ecology, to make groundwater-cleanup decisions based on sound technical information and the technical capabilities available.

## 10.7.1 Groundwater Monitoring Highlights and Emerging Issues

***Number of Wells Sampled in 2005***. Workers sampled 687 monitoring wells and 128 shoreline aquifer tubes in 2005 to determine the distribution and movement of contaminants in Hanford Site groundwater. Many of the wells were sampled multiple times during the year.

***Number of Sample Analyses in 2005***. A total of 2,428 samples of Hanford groundwater were analyzed for chromium, 1,517 for nitrate, and 1,068 for tritium. Other constituents frequently analyzed for included carbon tetrachloride (735 samples), technetium-99 (909 samples), and uranium (941 samples). Summaries that account for the number of all groundwater wells monitored and the number of analyses performed on samples from the wells during 2005 according to groundwater interest area and monitoring purpose are provided in Tables 10.7.1 and 10.7.2, respectively.

***100-N Pump-and-Treat Alternatives***. DOE has operated a pump-and-treat system to contain and clean up groundwater contaminated with strontium-90 at the 100-N Area since 1994. Like most of the groundwater remedial actions undertaken at the Hanford Site in the 1990s, the 100-N Area pump-and-treat system was intended as an interim measure, designed as part of DOE's accelerated cleanup strategy. With additional research and characterization, an alternative cleanup method will be employed to support 100-N Area remediation. Laboratory studies of strontium-90 sequestration by apatite (a natural mineral) continued during 2005. Favorable results for one approach led to the decision to implement a treatability field test that includes a 91-meter (298-foot) barrier to be installed in 2006. The goal is to create a permeable, reactive barrier by injecting apatite-forming chemicals near the Columbia River shoreline, which will capture strontium-90 as groundwater flows through.

***300-FF-5 Operable Unit Phase III Feasibility Study***. Because the uranium plume beneath the 300 Area has not decreased in concentration as rapidly as predicted by earlier remedial investigations, DOE continued a detailed investigation of the natural processes that cause the plume to persist and the residual sources that may supply uranium to the plume. Potential treatment technologies that would result in lowering plume concentrations are being evaluated.

***Rebound Study at 200-UP-1 Operable Unit***. The 200-UP-1 pump-and-treat system was an interim action designed to contain the high concentration portions of the technetium-99 and uranium plumes in the 200-West Area. Following 18 months with technetium-99 and uranium

**Table 10.7.1. A Summary of the Hanford Site Groundwater Performance Assessment Project by Groundwater Interest Area, 2005**

| | 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 and aquifer tubes | 815 | 16 | 28 | 103 | 59 | 55 | 66 |
| Number of sampling events | 2,688 | 16 | 30 | 372 | 271 | 283 | 281 |
| Number of analyses | 26,994 | 143 | 256 | 2,630 | 966 | 1,448 | 2,819 |
| Number of results | 85,886 | 458 | 1,037 | 4,727 | 1,948 | 3,566 | 6,799 |
| Percent of non-detected results | 48 | 37 | 42 | 20 | 21 | 32 | 38 |
| | **1100-EM-1** | **200-BP-5** | **200-PO-1** | **200-UP-1** | **200-ZP-1** | **300-FF-5** | |
| Number of wells | 44 | 105 | 97 | 76 | 95 | 71 | |
| Number of sampling events | 72 | 253 | 235 | 317 | 370 | 188 | |
| Number of analyses | 550 | 5,614 | 4,094 | 3,037 | 3,816 | 1,626 | |
| Number of results | 1,698 | 13,753 | 13,345 | 13,579 | 17,579 | 7,397 | |
| Percent of non-detected results | 58 | 40 | 48 | 58 | 58 | 67 | |

**Table 10.7.2. A Summary of the Hanford Site Groundwater Performance Assessment Project by Monitoring Purpose,[a] 2005**

| | Restoration[b] | Waste Management[c] | Environmental Surveillance[d] |
|---|---|---|---|
| Number of wells | 516 | 246 | 299 |
| Number of sampling events | 1,797 | 882 | 991 |
| Number of analyses | 14,275 | 13,789 | 8,456 |
| Number of results | 46,854 | 43,318 | 25,385 |
| Percent of non-detected results | 51 | 47 | 47 |

(a) Because of the co-sampling among groundwater monitoring programs, the wells monitored, sampling events, analyses, results, and non-detectable results overlap among monitoring purposes.
(b) Wells associated with remediation activities.
(c) Wells sampled to determine impact, if any, to a waste management unit (e.g., RCRA) on groundwater.
(d) Wells sampled to detect impact, if any, of site operations on groundwater over the entire Hanford Site and adjacent offsite areas.

concentrations below remedial action goals, and with approval of the Washington State Department of Ecology, DOE turned off the extraction well pumps and initiated a rebound study in January 2005. The goal of the rebound study is to assess the effectiveness of the pump-and-treat system and to evaluate whether concentrations of key constituents will remain below remedial action goals under natural groundwater flow conditions. Future actions at the pump-and-treat site will be based on the results of the rebound study.

***K-West Reactor Chromium Plume***. In 1998, chromium concentrations in groundwater near the K-West Reactor began to rise. Evidence is building that the plume has reached the Columbia River shoreline. Planning is underway to add this plume to the interim remedial action that is currently addressing chromium in the vicinity of the 100-K Area trench.

***K-East Basin***. DOE has removed nuclear fuel from the K-East fuel storage basin, is removing radioactive sludge, and is planning to demolish the basin and excavate contaminated sediments. As part of the demolition process, a large excavation will be made north of the K-East Reactor building to provide access for heavy equipment. The excavation will require removal of two or three groundwater monitoring wells. A strategy to provide groundwater monitoring capability during and after demolition will be developed during 2006.

***Vertical Distribution of Contaminants in the 200-West Area***. In recent years, depth-discrete sampling in existing

wells, and sampling during drilling of new wells, have provided new information on how carbon tetrachloride concentrations change with depth in the unconfined aquifer. At some locations in the carbon tetrachloride plume, the highest concentrations are at depths of up to 45 meters (147 feet) below the water table.

***Technetium-99 at Waste Management Area T.*** Technetium-99 concentrations in wells east of Waste Management Area T, in the 200-West Area, continued to increase. A groundwater sample collected during drilling at 10 meters (33 feet) below the water table had the highest technetium-99 concentration (181,900 pCi/L [6,730 Bq/L]) on the Hanford Site in 2005. The maximum nitrate concentration in the well was 590 mg/L, at approximately the same depth. Additional wells are being installed to delineate the deeper contamination and an investigation is being planned to evaluate sources, transport, and possible remediation alternatives for the contamination.

***Technetium-99 at Waste Management Area A-AX.*** Technetium-99 concentrations continued to exceed the drinking water standard (900 pCi/L [33 Bq/L]) in a well downgradient of these tank farms in the 200-East Area. The source or sources of this contamination is unknown. Data from two wells installed in 2005 will help define contaminant distribution. In addition, exceedance of the critical mean value[(a)] for specific conductance has resulted in the waste management area moving from detection to assessment monitoring under RCRA.

***Uranium Plume in Northwest 200-East Area.*** A uranium plume occurs beneath and to the east of the BY Tank Farm. The maximum concentration in 2005 was 454 µg/L (0.454 parts per million). The contamination is present in a narrow northwest-southeast band and concentrations are increasing. The leading interpretation is that the plume originated from a past tank leak.

***CERCLA Five-Year Review.*** The second 5-year review of records of decision for remedial actions under CERCLA started during 2005, with completion scheduled in 2006. DOE is conducting the review in coordination with the EPA, which is responsible for certifying the review. The purpose of the review is to evaluate the implementation and performance of the remedies in order to determine if they are protective of human health and the environment.

## 10.7.2 Groundwater Flow

Groundwater in the unconfined aquifer generally flows from west to east across the Hanford Site and discharges at locations 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 2005 (Figure 10.7.1). Groundwater enters the Hanford Site from recharge areas to the west and eventually discharges to the Columbia River. Hydrologists estimate that the total discharge of groundwater from the Hanford Site aquifer to the Columbia River is in the range 1.1 to 2.8 cubic meters (39 to 99 cubic feet) per second. This rate of discharge is very small compared to the average flow of the river, approximately 3,400 cubic meters (120,000 cubic feet) per second. Consequently, Hanford Site groundwater becomes indistinguishable in the river within a short distance of its discharge location.

In the part of the Hanford Site north of Gable Mountain and Gable Butte, groundwater flows generally northeast or east toward the Columbia River, except beneath the 100-B/C, 100-K, 100-N, and 100-D Areas where groundwater flows north and northwest toward the river. South of Gable Mountain and Gable Butte, groundwater flows toward the east and southeast. The water table beneath the 200-East Area is relatively flat because of the presence of highly permeable sediment of the Hanford formation at the water table. Groundwater enters the vicinity of the 200-East Area from the west and divides, with some migrating to the north through Gable Gap and some moving southeast toward the central part of the site. In the south part of the Hanford Site, groundwater converges on the 300 Area from the northwest, west, and southwest.

(a) Critical means are statistical values used for upgradient/downgradient comparisons at interim status RCRA sites. Exceeding a critical mean value for an indicator parameter may signify that a release from the site has occurred.

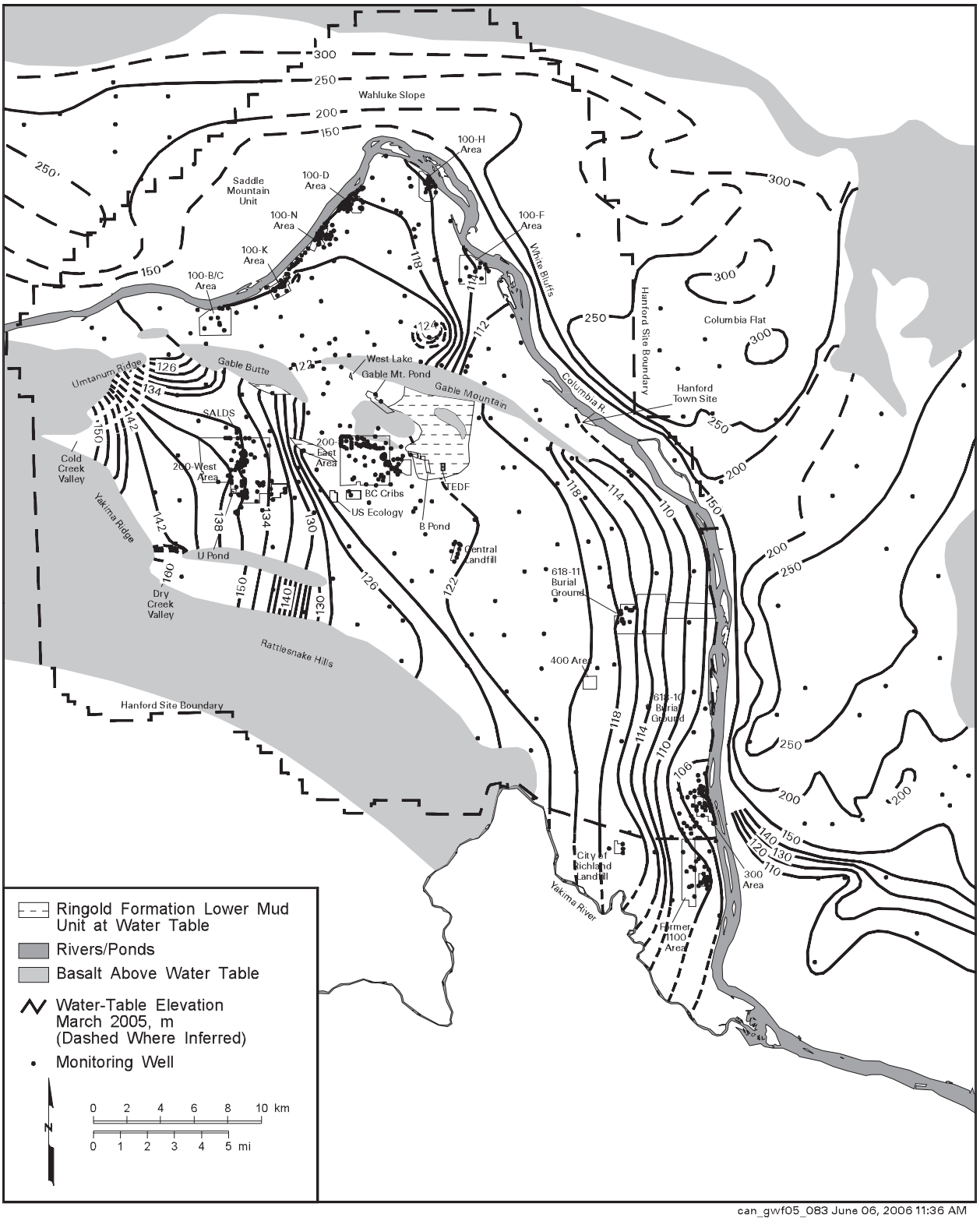



**Figure 10.7.1. Water-Table Elevations and Inferred Flow Direction for the Unconfined Aquifer at the Hanford Site, March 2005**

The natural pattern of groundwater flow was altered during the Hanford Site's operating years by water-table mounds. 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 have dissipated in the reactor areas and have declined considerably in the 200 Areas.

Groundwater flow is currently altered where extraction or injection wells are used for pump-and-treat systems or where wastewater is discharged to the land surface. Extraction wells in the 100-K, 100-N, 100-D, 100-H, and 200-West Areas capture contaminated water from the surrounding areas. Water flows away from injection wells, which are located upgradient of the contaminant plumes so the injection increases the hydraulic gradient toward the extraction wells. Wastewater is discharged to the ground at the State-Approved Land Disposal Site, north of the 200-West Area, affecting groundwater flow locally.

East of the 200-East Area, a fine-grained confining unit creates a barrier to groundwater 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 locally confined aquifer still is influenced by a residual recharge mound.

## 10.7.3 Groundwater Monitoring and Remediation

CERCLA-related groundwater monitoring continued at 11 operable units during 2005 (Figure 10.7.2). Monitoring continued in 2005 at 24 RCRA units (or waste management areas) on the Hanford Site (Table 10.7.3 and Figure 10.7.3).

### 10.7.3.1 Overview

The DOE has developed a plan to clean up the Hanford Site's groundwater, which will return it to its beneficial use where practicable or will at least prevent further degradation (DOE/RL-2002-68). Under the accelerated plan, DOE will (a) remediate high-risk waste sites, (b) shrink the contaminated area, (c) reduce natural and artificial recharge at selected locations, (d) remediate groundwater, and (e) monitor groundwater. Figures 10.7.4 and 10.7.5 show the distribution of nine principal groundwater contaminant plumes.

The total area of radiological and chemical contaminant plumes with contaminant concentrations exceeding drinking water standards was estimated to be approximately 200 square kilometers (77 square miles) during 2005 (Table 10.7.4). This area occupies approximately 13% 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. Extensive tritium and iodine-129 plumes are also present in the 200-West Area. Technetium-99 concentrations exceed the drinking water standard in plumes within both the 200-East and 200-West Areas. One technetium-99 plume has moved northward from the 200-East Area. Uranium is less mobile than tritium, iodine-129, or technetium-99; plumes are found in the 200-East, 200-West, and 300 Areas. Strontium-90 is not very mobile in groundwater, but strontium-90 concentrations exceed the drinking water standard in the 100 Areas (except the 100-D Area), the 200-East Area, and beneath the former Gable Mountain Pond. Other radionuclides, including cesium-137, cobalt-60, and plutonium, are even less mobile in the subsurface and exceed drinking water standards in a few wells.

Nitrate is a widespread chemical contaminant in Hanford Site groundwater; plumes originate from the 100 and 200 Areas and from offsite industry and agriculture. Carbon tetrachloride, the most widespread organic contaminant on the Hanford Site, forms a large plume beneath the 200-West Area. Other organic contaminants include chloroform, found in 200-West Area, and trichloroethene. Trichloroethene plumes are found in the 100-K, 100-F, and 200-West Areas. Chromium contamination underlies portions of the 100-K, 100-D, and 100-H Areas. Local plumes of chromium contamination also are present in the 200 Areas, particularly the north part of 200-West Area.

Summaries of maximum concentrations in Hanford Site groundwater for the most widespread contaminants are presented by groundwater interest area in Table 10.7.5 and by monitoring purpose in Table 10.7.6. The purpose for which monitoring was conducted are divided into restoration, waste management, and environmental surveillance. Restoration refers to wells associated with groundwater remediation activities, including pump-and-treat systems and innovative technology demonstrations. Waste management refers to

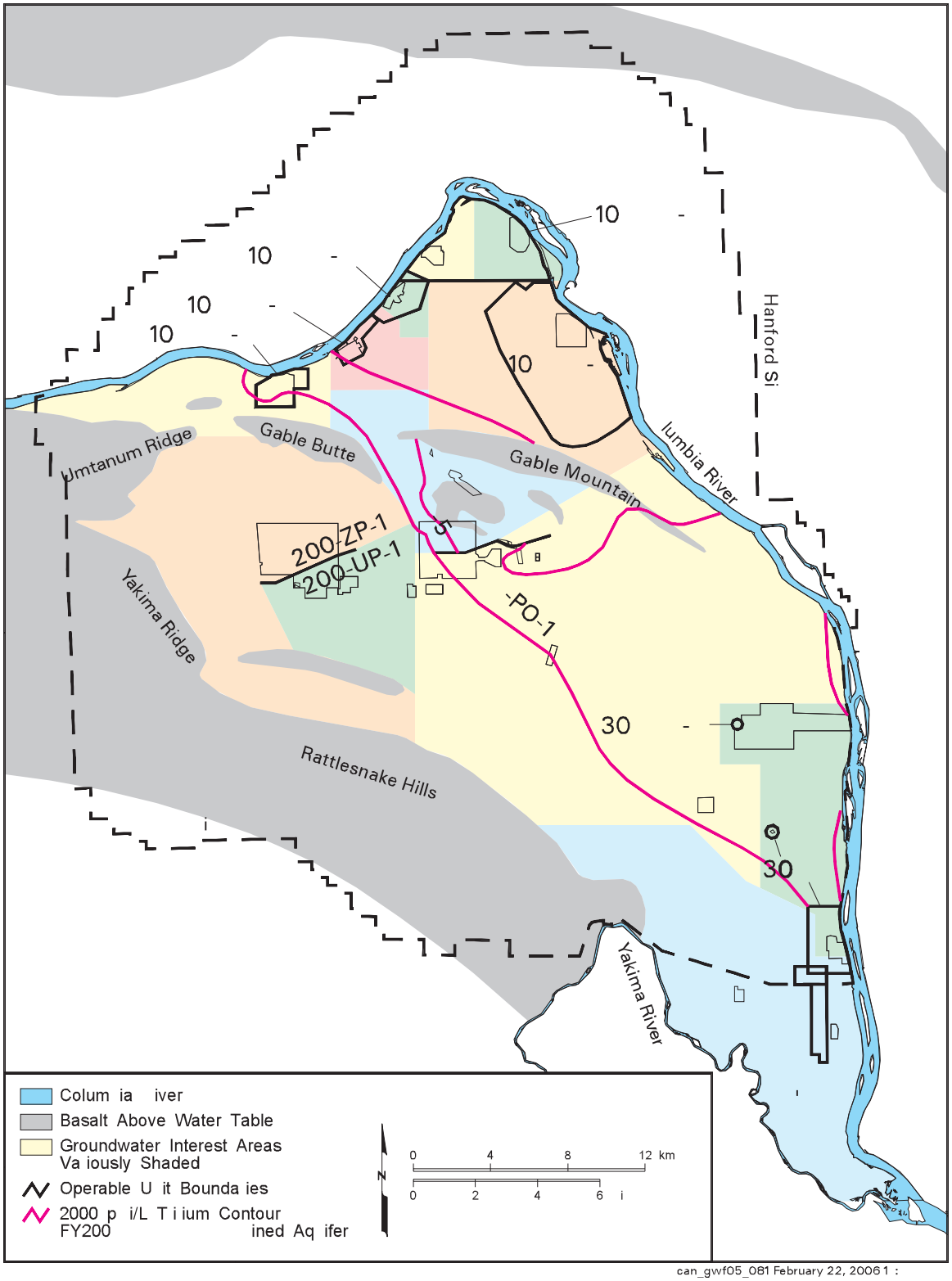



**Figure 10.7.2. Groundwater Interest Areas on the Hanford Site in 2005**

**Table 10.7.3 Regulated Units Requiring Groundwater Monitoring on the Hanford Site, 2005**

| Site or Waste Management Area | Type of Monitoring Program | Regulated Under | 2005 Highlights |
|---|---|---|---|
| | **RCRA Regulated Units** | | |
| 116-N-1 (1301-N) facility | Final status detection | WAC 173-303-400; 40 CFR 265.93(b) | Continued detection[a] |
| 116-N-3 (1325-N) facility | Final status detection | WAC 173-303-400; 40 CFR 265.93(b) | Continued detection[a] |
| 120-N-1, 120-N-2 (1324-N/NA) facilities | Final status detection | WAC 173-303-400; 40 CFR 265.93(b) | Continued detection[a] |
| 116-H-6 (183-H) evaporation basins | Final status corrective action | WAC 173-303-645(11)(g) | Monitoring during CERCLA interim action; chromium, nitrate, technetium-99, uranium |
| 216-A-29 ditch | Interim status detection | WAC 173-303-400; 40 CFR 265.93(b) | Continued detection[a] |
| 216-B-3 pond | Interim status detection | WAC 173-303-400; 40 CFR 265.93(b) | Continued detection[a] |
| 216-S-10 pond and ditch | Interim status detection | WAC 173-303-400; 40 CFR 265.93(b) | Continued detection;[a] only two shallow and one deep downgradient wells remain |
| 216-U-12 crib | Interim status assessment | WAC 173-303-400; 40 CFR 265.93(d) | Continued assessment; new plan; network modified |
| 316-5 process trenches | Final status corrective action | WAC 173-303-645(11)(g) | Monitoring during CERCLA natural attenuation interim action; uranium and organics |
| Integrated Disposal Facility | Establishing background | WAC 173-303-645 | Planned facility; seven of eight wells in place |
| Liquid Effluent Retention Facility | Interim status detection | WAC 173-303-400; 40 CFR 265.93(b) | Insufficient wells; no statistical comparisons |
| Low-Level Waste Management Area 1 | Interim status detection | WAC 173-303-400; 40 CFR 265.93(b) | Continued detection[a] |
| Low-Level Waste Management Area 2 | Interim status detection | WAC 173-303-400; 40 CFR 265.93(b) | Continued detection;[a] north wells dry; no unconfined aquifer |
| Low-Level Waste Management Area 3 | Interim status detection | WAC 173-303-400; 40 CFR 265.93(b) | No statistical comparisons until background re-established |
| Low-Level Waste Management Area 4 | Interim status detection | WAC 173-303-400; 40 CFR 265.93(b) | Continued detection;[a] three wells installed |
| Nonradioactive Dangerous Waste Landfill | Interim status detection | WAC 173-303-400; 40 CFR 265.93(b) | Continued detection[a] |
| PUREX cribs | Interim status assessment | WAC 173-303-400; 40 CFR 265.93(d) | Continued assessment; iodine-129, nitrate, tritium |
| SST Waste Management Area A-AX | Interim status detection | WAC 173-303-400; 40 CFR 265.93(b) | Began assessment monitoring based on specific conductance |
| SST Waste Management Area B-BX-BY | Interim status assessment | WAC 173-303-400; 40 CFR 265.93(d) | Continued assessment; nitrate, nitrite, technetium-99, uranium |
| SST Waste Management Area C | Interim status detection | WAC 173-303-400; 40 CFR 265.93(b) | Continued detection[a] |
| SST Waste Management Area S-SX | Interim status assessment | WAC 173-303-400; 40 CFR 265.93(d) | Continued assessment; chromium, technetium-99; one well installed |

**Table 10.7.3 (contd)**

| Site or Waste Management Area | Type of Monitoring Program | Regulated Under | 2005 Highlights |
|---|---|---|---|
| SST Waste Management Area T | Interim status assessment | WAC 173-303-400; 40 CFR 265.93(d) | Continued assessment; technetium-99, nitrate, chromium; two wells installed |
| SST Waste Management Area TX-TY | Interim status assessment | WAC 173-303-400; 40 CFR 265.93(d) | Continued assessment; chromium, nitrate, technetium-99; one well installed |
| SST Waste Management Area U | Interim status assessment | WAC 173-303-400; 40 CFR 265.93(d) | Continued assessment; nitrate, technetium-99 |
| **Other Regulated Units** | | | |
| 200 Area Treated Effluent Disposal Facility | Compliance with permit | WAC 173-216 | No influence on upper aquifer |
| Environmental Restoration Disposal Facility | Similar to RCRA detection | EPA/ROD/R10-95/100 | No impact on groundwater |
| State Approved Land Disposal Site | Compliance with permit | WAC 173-216 | No permit limits exceeded |
| Solid Waste Landfill | Compliance with permit | WAC 173-304 | Five constituents exceeded background or standards; low levels of organics |

(a) Analysis of RCRA CIP provided no evidence of groundwater contamination with hazardous constituents from the unit.
CIP = Contamination indicator parameters.
CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act*.
CFR = *Code of Federal Regulations*.
EPA = U.S. Environmental Protection Agency.
PUREX = Plutonium-Uranium Extraction Plant.
RCRA = *Resource Conservation and Recovery Act*.
ROD = Record of decision.
SST = Single-shell tank.
WAC = *Washington Administrative Code*.

wells sampled to determine impacts, if any, of a waste management unit (e.g., RCRA facility) on groundwater. Environmental surveillance refers to wells sampled to detect impacts, if any, on site operations on groundwater over the entire Hanford site and adjacent offsite areas. 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 10.7.6. A list of drinking water standards for these contaminants is provided in Table D.4 in Appendix D.

The following text discusses groundwater contamination, monitoring, and remediation for each of the 11 groundwater operable units and in the confined aquifers.

### 10.7.3.2 Groundwater Monitoring Results for the 100-BC-5 Operable Unit

The 100-BC-5 Operable Unit includes the groundwater beneath the 100-B/C Area (Figure 10.7.2). Most of the groundwater contamination is found in the north portion of the area, beneath former waste trenches and retention basins. In 2005, tritium and strontium-90 concentrations exceeded drinking water standards in several wells. The tritium concentration in one well in the northeast 100-B/C Area increased sharply to 161,000 pCi/L (5,957 Bq/L) in 2005, but the reason for the increase is not known. Nitrate and chromium were somewhat elevated, but have been below drinking water standards in recent years.

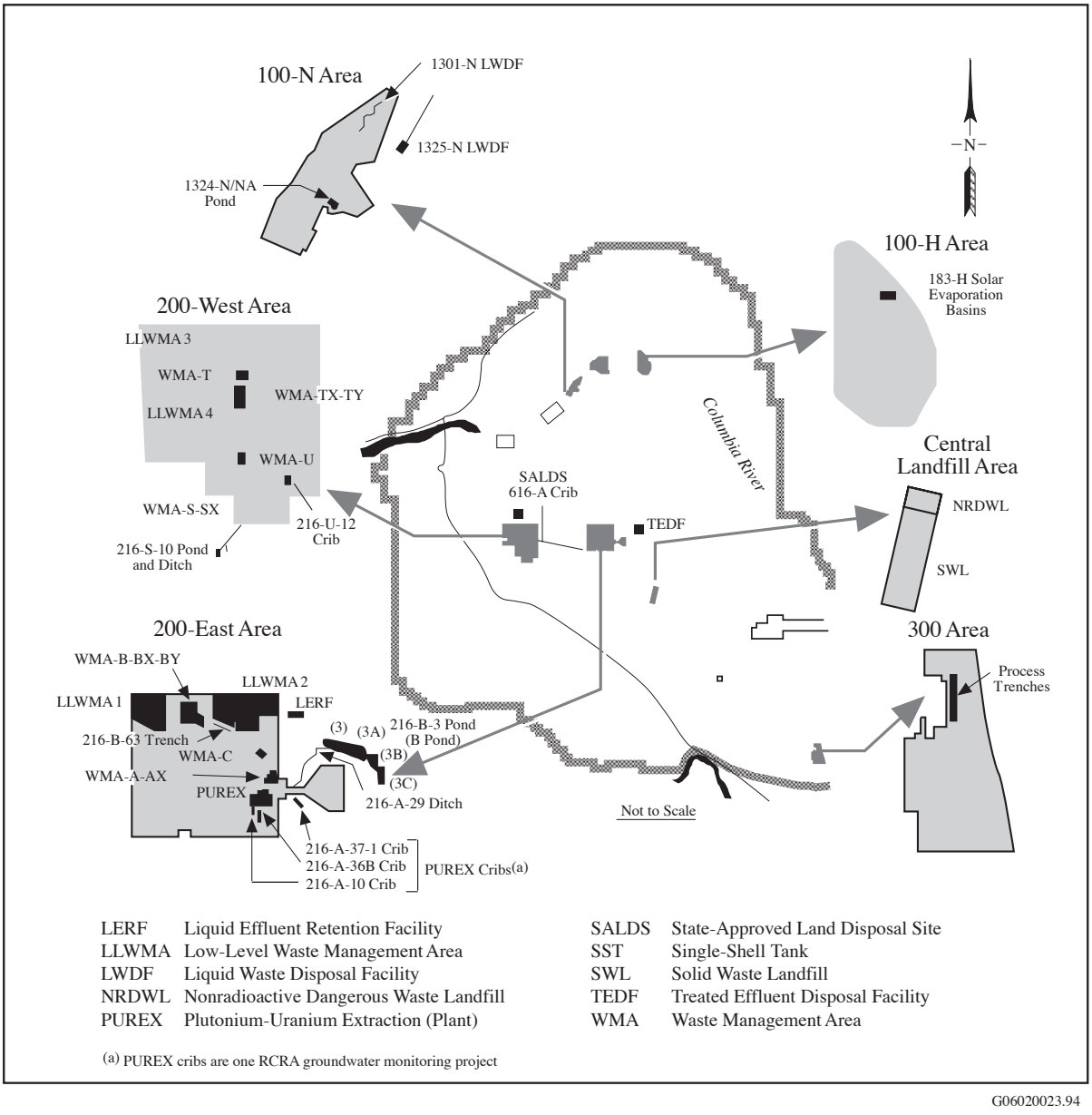



**Figure 10.7.3. Locations of the Regulated Waste Management Units on the Hanford Site During 2005**

A record of decision has not yet been developed for the 100-BC-5 Operable Unit, and no active remediation of groundwater is underway. Monitoring contaminant conditions has continued since the initial remedial investigation and while waste site remedial actions are conducted. Results of a pilot project risk assessment were published in draft form in 2005, which will serve as a prototype for risk assessments in the other reactor areas. The pilot risk assessment characterized the potential risks to human health and the environment under the cleanup standards implemented in remedial actions performed to date.

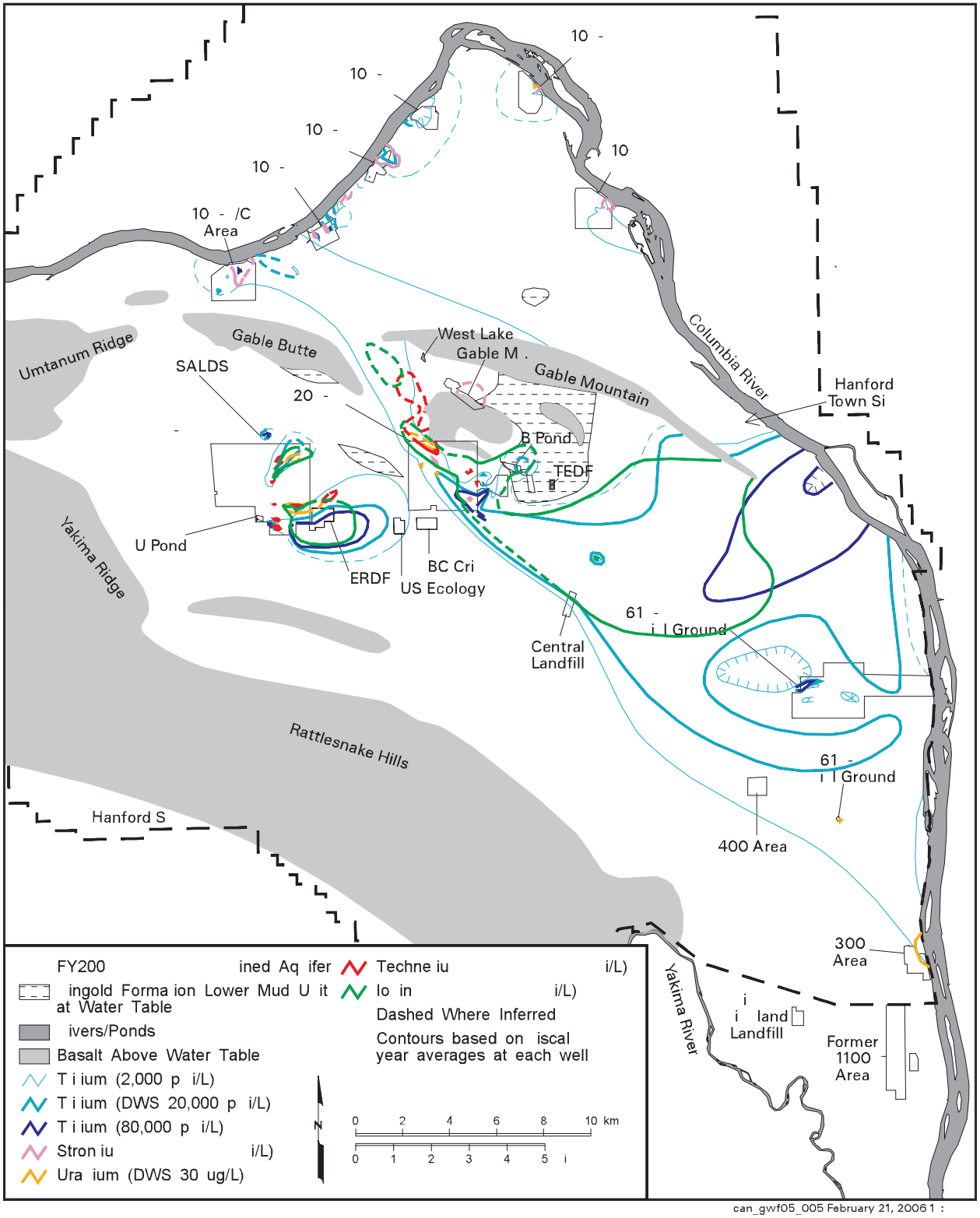



**Figure 10.7.4. Distribution of Major Radionuclides in Hanford Site Groundwater at Concentrations Above Drinking Water Standards During 2005**

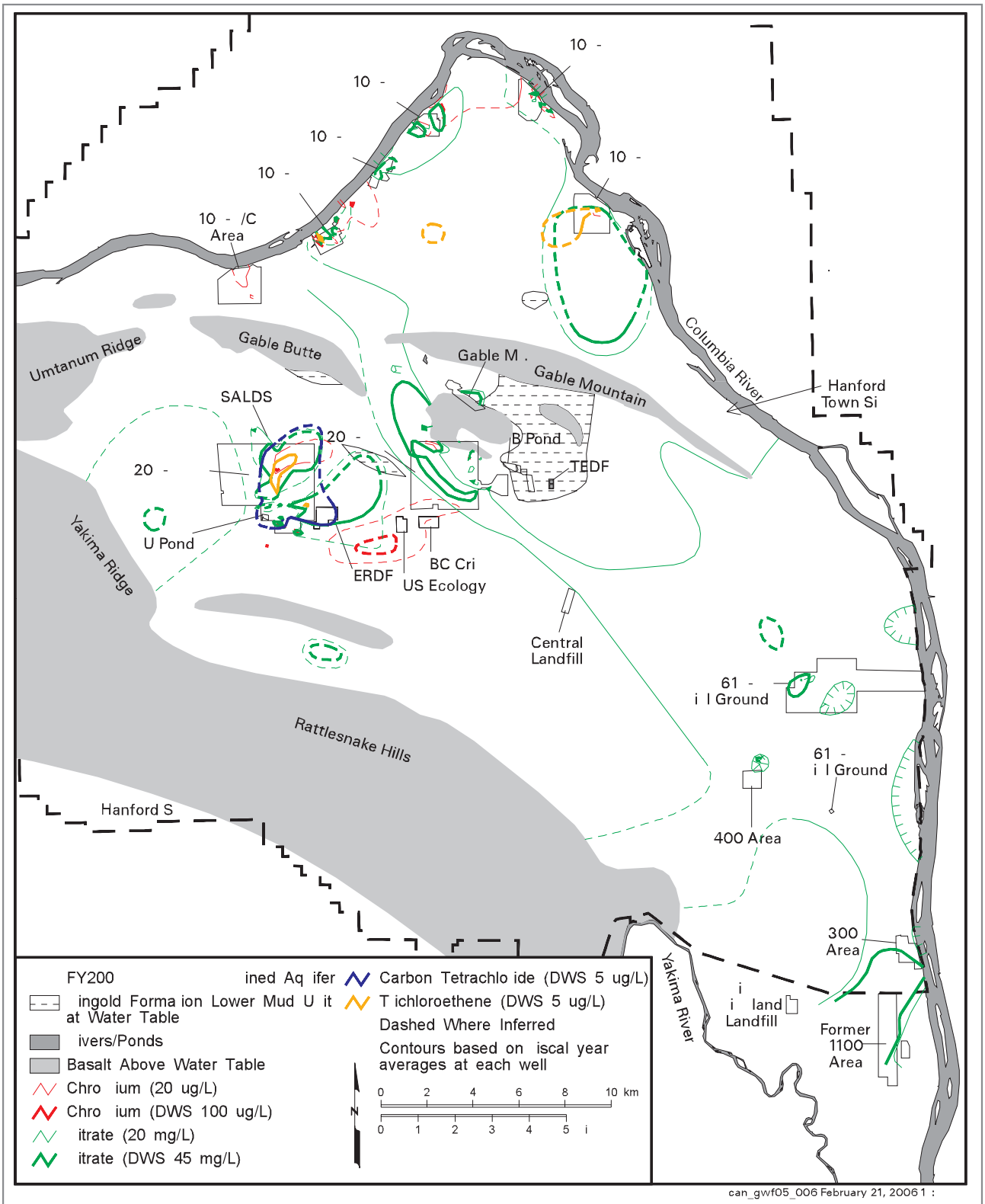



**Figure 10.7.5. Distribution of Major Hazardous Chemicals in Hanford Site Groundwater at Concentrations Above Drinking Water Standards During 2005**

**Table 10.7.4. Areas of Contaminant Plumes on the Hanford Site at Levels Above Drinking Water Standards, 2005**

| Constituent | Drinking Water Standard | Area ($km^2$) | Constituent | Drinking Water Standard | Area ($km^2$) |
|---|---|---|---|---|---|
| Tritium | 20,000 pCi/L | 135.5 | Dissolved chromium | 100 µg/L | 2.0 |
| Iodine-129 | 1 pCi/L | 75.4 | Strontium-90 | 8 pCi/L | 2.4 |
| Nitrate | 45 mg/L | 43.3 | Technetium-99 | 900 pCi/L | 2.5 |
| Carbon tetrachloride | 5 µg/L | 10.8 | Total uranium | 30 µg/L | 1.4 |
| Trichloroethene | 5 µg/L | 3.8 | Combined plumes | | 199[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 10.7.5. Summary of Maximum Contaminant Concentrations in Hanford Site Groundwater by Groundwater Interest Area, 2005**

| | 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) | 2,240,000 | 161,000 | 19,800 | 32,500 | 4,980 | 2,240,000 | 28,500 |
| Iodine-129 (pCi/L) | 30.1 | NA | NA | NA | NA | NA | NA |
| Nitrate (mg/L) | 3,540 | 27.9 | 124 | 77 | 514 | 340 | 308 |
| Carbon tetrachloride (µg/L) | 5,300 | NA | ND | NA | NA | ND | ND |
| Trichloroethene (µg/L) | 36 | NA | 14 | NA | NA | 3.5 | ND |
| Dissolved chromium (µg/L) | 2,550 | 52 | 83.3 | 2,550 | 117 | 538 | 181 |
| Strontium-90 (pCi/L) | 9,710 | 45.8 | 48.6 | 9 | 40 | 3,140 | 9,710 |
| Technetium-99 (pCi/L) | 137,000 | NA | NA | ND | 1,510 | 376 | ND |
| Total uranium (µg/L) | 479 | NA | 14.5 | 5.08 | 90 | 8.13 | 0.863 |
| | **1100-EM-1** | **200-BP-5** | **200-PO-1** | **200-UP-1** | **200-ZP-1** | **300-FF-5** | |
| Tritium (pCi/L) | 361 | 118,000 | 552,000 | 1,020,000 | 1,890,000 | 1,650,000 | |
| Iodine-129 (pCi/L) | ND | 4.95 | 9.2 | 30.1 | 26.1 | ND | |
| Nitrate (mg/L) | 239 | 1,890 | 134 | 1,490 | 3,540 | 99.2 | |
| Carbon tetrachloride (µg/L) | 0.81 | 0.64 | 0.36 | 470 | 5,300 | 1.4 | |
| Trichloroethene (µg/L) | 2.3 | ND | 0.93 | 9.1 | 36 | 3.6 | |
| Dissolved chromium (µg/L) | ND | 53.1 | 43.7 | 1,750 | 769 | 16.1 | |
| Strontium-90 (pCi/L) | NA | 3,900 | 20.5 | 26.8 | 2.6 | 3.31 | |
| Technetium-99 (pCi/L) | 23.4 | 17,500 | 8,580 | 137,000 | 46,800 | 44.5 | |
| Total uranium (µg/L) | 21.6 | 711 | 25.8 | 479 | 183 | 192 | |

NA = Not analyzed.
ND = Not detected.

### 10.7.3.3 Groundwater Monitoring Results for the 100-KR-4 Operable Unit

**Table 10.7.6. Summary of Maximum Contaminant Concentrations in Hanford Site Groundwater by Monitoring Purpose, 2005**

| | Restoration | Waste Management | Environmental Surveillance |
|---|---|---|---|
| Tritium (pCi/L) | 1,650,000 | 1,890,000 | 2,240,000 |
| Iodine-129 (pCi/L) | 30.1 | 26.1 | 7.86 |
| Nitrate (mg/L) | 3,540 | 3,540 | 877 |
| Carbon tetrachloride (µg/L) | 5,300 | 4,400 | 3,100 |
| Trichloroethene (µg/L) | 36 | 19 | 12 |
| Dissolved chromium (µg/L) | 2,550 | 1,750 | 2,550 |
| Strontium-90 (pCi/L) | 9,710 | 1,360 | 9,710 |
| Technetium-99 (pCi/L) | 14,600 | 137,000 | 14,600 |
| Total uranium (µg/L) | 479 | 711 | 357 |

The principal groundwater issues in the 100-KR-4 Operable Unit, which includes the 100-K Area, include (a) remediation of groundwater beneath a large liquid-waste disposal trench, (b) tracking plumes from other past-practices sites, and (c) monitoring groundwater near the K-East and K-West fuel storage basins. Interim remedial action involves a pump-and-treat system that removes chromium from groundwater beneath the trench and injects the treated water back into the aquifer at a location farther from the river.

***Interim Remedial Action***. A pump-and-treat system is being used to remove hexavalent chromium from the aquifer beneath the large liquid waste disposal trench. Approximately 271 kilograms (597 pounds) of chromium have been removed since startup in 1997. Although the mapped extent of contamination has remained fairly constant during the past 10 years, the area of highest concentrations (>100 µg/L) has decreased markedly. The concentration goal for the interim remedial action is 22 µg/L in groundwater near the Columbia River.

Four new wells were installed adjacent to one of the pump-and-treat extraction wells, and a field test involving injection of calcium polysulfide was performed during the summer and fall of 2005. The calcium polysulfide acts to reduce hexavalent chromium in the aquifer by converting it to the less toxic and less mobile trivalent form. This method is a potential alternative to pump-and-treat systems for cleanup of groundwater contaminated by hexavalent chromium.

In 1998, chromium concentrations in groundwater near the K-West Reactor began to rise. From their previous trend at approximately 160 µg/L, concentrations increased to approximately 500 µg/L in a relatively short period of time and remained high in 2005. Although an exact source for this chromium has not been identified, it is most likely related to past sodium dichromate handling. Evidence is building that the K-West Reactor chromium plume has reached the Columbia River shoreline. That evidence includes chromium in groundwater at a newly installed well located between the reactor and the river, and at shoreline aquifer tubes. Planning is underway to add this plume to the interim remedial action that is currently addressing chromium in the vicinity of the liquid waste disposal trench.

***Monitoring Past-Practices Waste Sites***. Other contaminants of potential concern in the 100-KR-4 Operable Unit are carbon-14, nitrate, strontium-90, trichloroethene, and tritium. These contaminants are associated with waste disposal and facility operations that occurred during the operating years of the K-East and K-West Reactors (1955 to 1971). While levels remain above drinking water standards, risks to the river ecosystem are low, so the DOE and regulatory agencies have deferred decisions regarding remedial actions until source remedial actions are complete. Some recent variability in tritium concentrations near the K-West Reactor is believed to be caused by remobilization of contaminants held in the vadose zone.

***Monitoring at the K Basins***. The K-East and K-West fuel storage basins are integral parts of each reactor building. Since the late 1970s, they have been used to store irradiated fuel from the last run of N Reactor, as well as miscellaneous fuel fragments recovered from cleanup at other reactor areas. The DOE has removed the fuel and is currently removing radioactive sludge from K-East Basin. Following sludge removal, the K-East Basin will be demolished. As part of

the demolition process, a large excavation will be made on the north (river) side of the reactor building to provide access for the heavy equipment that will be used to divide the concrete basin into transportable sections. The excavation will require removal of two or three monitoring wells. A strategy to provide groundwater monitoring capability during and after the demolition activities will be developed during 2006. Demolition of K-West Basin will follow work at K-East Basin.

### 10.7.3.4 Groundwater Monitoring Results for the 100-NR-2 Operable Unit

The primary groundwater contaminant of concern in the 100-NR-2 Operable Unit, which contains the 100-N Area, is strontium-90, which originated at two liquid waste disposal cribs. In 2005, data from new shoreline aquifer tubes enabled the DOE to refine the interpretation of strontium-90 distribution near the Columbia River shore. A tritium plume also originated at the 100-N Area cribs. Tritium concentrations in groundwater are declining, and the plume is shrinking. Nitrate, sulfate, and petroleum hydrocarbons also are present in 100-N Area groundwater.

***Interim Remedial Action***. A pump-and-treat system in the 100-N Area operates as a CERCLA interim action to reduce the movement of strontium-90 toward the Columbia River. Although the pump-and-treat system may have reduced groundwater flux to the river, it is not an effective way to remove strontium-90, which binds to sediment grains in the aquifer. Therefore, the DOE is evaluating alternative treatment methods. Laboratory studies of strontium-90 sequestration by apatite continued during 2005. Favorable results for one approach led to the decision to implement a treatability field test and install a 91-meter (298-foot) barrier in 2006. The goal is to create a permeable, reactive barrier near the shoreline that will capture strontium-90 as groundwater flows to the river through a treatment zone created by injection of apatite-forming chemicals.

***Monitoring at the 116-N-1, 116-N-3, 120-N-1, and 120-N-2 (also known as 1301-N, 1325-N, and 1324-N/NA) Facilities***. The 116-N-1, 116-N-3, 120-N-1, and 120-N-2 waste sites are former liquid waste disposal facilities located in the 100-N Area. During 2005, the sites remained in RCRA detection monitoring programs. *Atomic Energy Act* and CERCLA monitoring continued to track strontium-90 and tritium plumes from the 116-N-1 and 116-N-3 sites and sulfate from the former 120-N-1 pond.

### 10.7.3.5 Groundwater Monitoring Results for the 100-HR-3-D Operable Unit

The 100-HR-3 Operable Unit underlies the 100-D and 100-H Areas and the region between. The informally named 100-HR-3-D groundwater interest area comprises the west part of the 100-HR-3 Operable Unit, which includes the 100-D Area. Chromium is the primary contaminant of concern in groundwater beneath the 100-D Area. A principal cause for this contamination was the routine discharge of reactor coolant, which contained sodium dichromate as a corrosion inhibitor, to ground disposal facilities, such as trenches. A second cause was periodic spillage and leakage of sodium dichromate stock solution to the ground. Chromium is distributed in two plumes. Other contaminant plumes include tritium, nitrate, and sulfate.

***Interim Remedial 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. In 2005, chromium concentrations remained above the remediation goal (22 μg/L) in compliance wells. A second pump-and-treat system intercepts groundwater in the central 100-D Area near the river shoreline. The southwest chromium plume is being remediated with a permeable barrier that immobilizes chromium in the aquifer. Chromium concentrations downgradient of the barrier have declined in some wells and aquifer tubes and were below the remediation goal (20 μg/L for this plume) in two of seven compliance wells in 2005. Four new wells were installed in 2005 as part of an investigation into the apparent breakthrough of a portion of the barrier.

### 10.7.3.6 Groundwater Monitoring Results for the 100-HR-3-H Operable Unit

The east part of the 100-HR-3 Operable Unit, informally called the 100-HR-3-H groundwater interest area, underlies the 100-H Area. Chromium is the primary contaminant

of concern, but the 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 (8 pCi/L) beneath former retention basins, and technetium-99 and uranium are elevated in a small area.

***Interim Remedial Action***. The chromium plume is the target of a pump-and-treat system (Figure 10.7.6). The remediation in the 100-H Area has removed 42 kilograms (92 pounds) of chromium from the aquifer, which represents most of the amount estimated to be in the aquifer before remediation began. The extraction and injection networks were modified in 2005 to respond to the changing plume and to further reduce the remaining chromium mass.

***Monitoring at the 116-H-6 (183-H) Evaporation Basins***. The 116-H-6 Evaporation Basins are former basins that comprise the only RCRA site in the 100-H Area. Leakage from the basins contaminated groundwater with chromium, nitrate, technetium-99, and uranium. The site is monitored during the post-closure period to track contaminant trends during the operation of the CERCLA interim action for chromium. Nitrate, technetium-99, and uranium concentrations increased sharply in a well northeast of the former basins in 2005.

### 10.7.3.7 Groundwater Monitoring Results for the 100-FR-3 Operable Unit

Nitrate concentrations in groundwater exceed the drinking water standard beneath much of the 100-F Area and the downgradient region. Other groundwater contaminants include strontium-90 and trichloroethene.

A record of decision has not yet been developed for the 100-FR-3 Operable Unit (Figure 10.7.2), and no active remediation of groundwater is underway. Monitoring of contaminant conditions has continued since the initial remedial investigation and while waste site remedial actions are conducted.

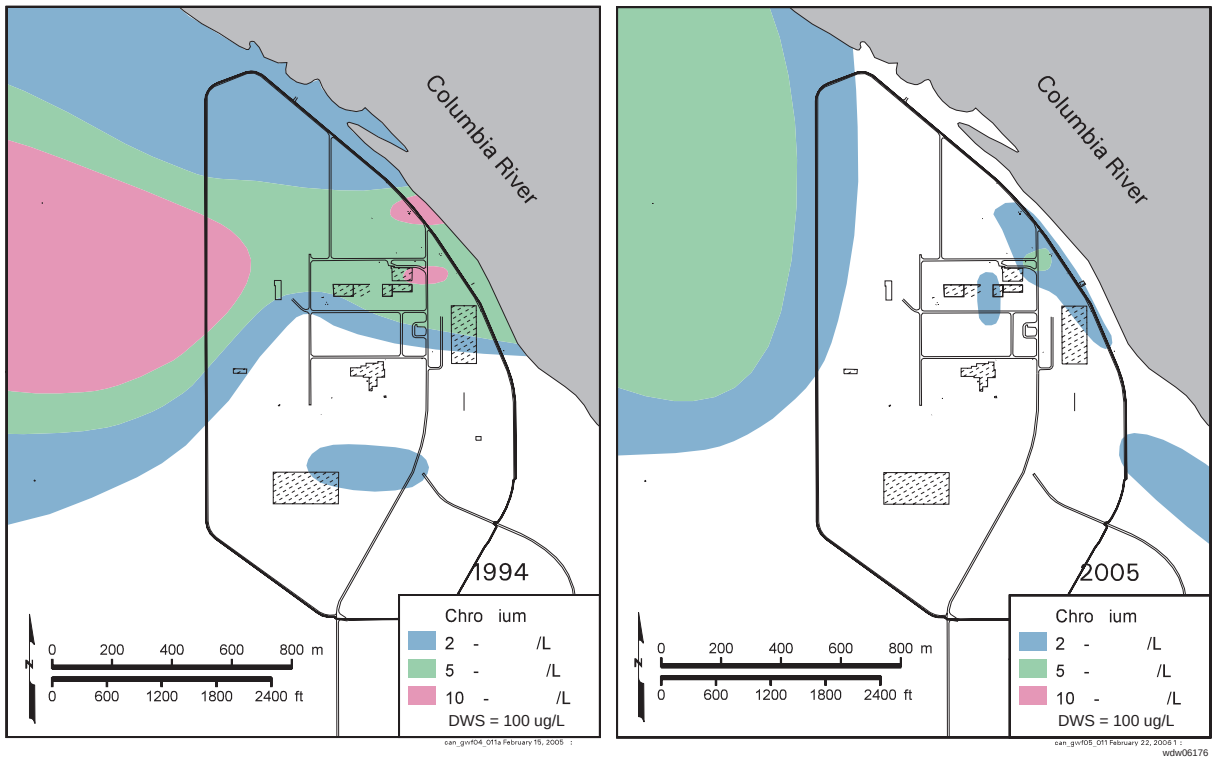



**Figure 10.7.6. Influence of Pump-and-Treat Remediation and Natural Processes on Chromium Concentrations in Groundwater Beneath the Hanford Site's 100-H Area, 1994 Compared to 2005**

### 10.7.3.8 Groundwater Monitoring Results for the 200-ZP-1 Operable Unit

The 200-ZP-1 Operable Unit encompasses the north portion of the 200-West Area (Figure 10.7.2). The primary contaminant of concern is carbon tetrachloride, which forms the largest plume of chlorinated hydrocarbons on the Hanford Site and is the target of an interim remedial action. The carbon tetrachloride contamination had sources associated with waste disposal from the Plutonium Finishing Plant, where organic chemicals were used to process plutonium. Trichloroethene and chloroform also are associated with this plume. Other contaminants in the 200-ZP-1 Operable Unit include tritium, nitrate, chromium, fluoride, iodine-129, technetium-99, and uranium.

The distribution of carbon tetrachloride is complex because of its potential to migrate as a dense, non-aqueous phase liquid, in the gaseous state, and dissolved in water. Data from depth-discrete sampling have shown the maximum concentrations of carbon tetrachloride at some locations were up to depths of 45 meters (147 feet) below the water table. In other locations, the maximum was located closer to the water table.

The 200-ZP-1 Operable Unit contains one CERCLA interim action for groundwater, one remediation system for the vadose zone, four facilities monitored under RCRA (in conjunction with CERCLA and *Atomic Energy Act*), and one state-permitted unit.

***Interim Remedial Action***. Since 1994, the DOE has operated an interim action pump-and-treat system to prevent carbon tetrachloride from spreading. The remediation system was extended to the north in 2005, beyond the capture zone of the former system, to capture carbon tetrachloride contamination at levels above 2,000 µg/L (2.0 parts per million).

***Soil-Vapor Extraction***. Soil vapor is extracted from the vadose zone and treated to remove carbon tetrachloride. As of October 2005, approximately 78,600 kilograms (173,000 pounds) of carbon tetrachloride have been removed from the vadose zone since extraction operations started in 1991.

***Monitoring at Waste Management Areas 3 and 4 (Low-Level Burial Grounds)***. RCRA groundwater monitoring continued under interim status requirements in 2005 to determine whether the burial grounds have affected groundwater. Two wells went dry at Low-Level Waste Management Area 3 in 2005. In 2006, three downgradient wells will be installed in the south part of the area. The changing flow direction has left Low-Level Waste Management Area 3 without any upgradient wells. Until new upgradient wells are installed and background conditions are established, statistical evaluations of indicator parameters have been suspended. Three new wells were installed for Low-Level Waste Management Area 4 in 2005, and more are planned for 2006.

***Monitoring at Waste Management Area T***. RCRA assessment monitoring continued at Waste Management Area T in 2005 (Figure 10.7.3; Table 10.7.3). The waste management area has introduced technetium-99 and other tank waste contaminants to the uppermost aquifer in the area. Additional contamination from other facilities is present in groundwater beneath the waste management area. Two new wells were installed in 2005 and another is planned for 2006. Unexpectedly high concentrations of contaminants were found in groundwater samples collected during drilling of one of the new wells. The maximum technetium-99 concentration was 181,900 pCi/L (6,730 Bq/L) at a depth of 10 meters (33 feet) below the water table. The concentration decreased with depth, but concentrations at the bottom of the well remained in the 20,000 to 30,000 pCi/L (740 to 1,110 Bq/L) range. Nitrate and chromium concentrations also were elevated in the new well. Another new well was installed farther downgradient, and technetium-99 concentrations were lower, but still far above the drinking water standard.

***Monitoring at Waste Management Area TX-TY***. RCRA assessment monitoring continued at Waste Management Area TX-TY in 2005 (Figure 10.7.3; Table 10.7.3). Sources in the waste management area have contaminated groundwater with chromium and other tank waste constituents. The presence of other nearby sources of contamination makes source origins uncertain for some contaminants. Technetium-99, iodine-129, nitrate, and tritium exceed drinking water standards in groundwater beneath the area. One new well was installed in 2005 to sample below the

water table. Groundwater flow beneath Waste Management Area TX-TY is changing due to the operation of the 200-ZP-1 pump-and-treat remediation system. In particular, greater volumes of water are being pumped south of Waste Management Area TX-TY because replacement extraction wells have increased the pumping capacity and monitoring wells west of the waste management area were converted to extraction wells in 2005.

***Monitoring at the State-Approved Land Disposal Site***. This active liquid waste disposal facility is regulated under a state waste discharge permit. Groundwater is monitored for tritium and 15 other constituents. Concentrations of all constituents considered in the permit did not exceed enforcement limits during 2005.

### 10.7.3.9 Groundwater Monitoring Results for the 200-UP-1 Operable Unit

The 200-UP-1 Operable Unit underlies the south portion of 200-West Area (Figure 10.7.2). The primary contaminants of concern are technetium-99 and uranium. Tritium, chromium, iodine-129, and nitrate plumes also have sources in this operable unit. Carbon tetrachloride in the 200-UP-1 Operable Unit originated from sources in the 200-ZP-1 Operable Unit.

Depth-discrete sampling during well installation shows that carbon tetrachloride, chloroform, and trichloroethene concentrations generally increase with depth in the east part of the operable unit. Farther west, depth-discrete sampling showed peak carbon tetrachloride concentrations shallower in the aquifer.

There are four facilities monitored under RCRA (in conjunction with CERCLA and the *Atomic Energy Act*) in this unit, one CERCLA interim action, and a CERCLA disposal site. Monitoring activities are summarized in the following paragraphs.

***Interim Remedial Action***. A groundwater pump-and-treat system operated near U Plant to contain the technetium-99 and uranium plumes there. In January 2005, groundwater extraction ceased and a rebound study was initiated to determine if contaminant concentrations will remain below the remedial action goal under natural groundwater flow conditions. At the end of 2005, (8 months into the rebound study), technetium-99 and uranium concentrations remained below the remedial action objectives but continued to exceed drinking water standards.

***Monitoring at Waste Management Area S-SX***. RCRA assessment monitoring continued at Waste Management Area S-SX in 2005 (Figure 10.7.3; Table 10.7.3). Groundwater beneath this waste management area is contaminated with nitrate, chromium, and technetium-99 attributed to two general source areas within the waste management area. Technetium-99, nitrate, and chromium concentrations in well 299-W23-19 increased in 2005, indicating that a pulse of contamination has entered the aquifer beneath the tank farm. This well continued to be purged at least 3,785 liters (1,000 gallons) after each quarterly sampling event, as the Washington State Department of Ecology requested in 2003. One well was installed in 2005, and sample results indicate the contaminant plume at the south end of the waste management area is wider than previously thought. Three wells will be installed in 2006.

***Monitoring at Waste Management Area U***. RCRA assessment monitoring continued at Waste Management Area U in 2005 (Figure 10.7.3; Table 10.7.3). This waste management area has been identified as the source of a small contaminant plume that is limited to the downgradient (east) side of the site. Plume constituents of interest include nitrate and technetium-99. During 2005, technetium-99 concentrations exceeded the drinking water standard (900 pCi/L [33 Bq/L]) for the first time since 1993.

***Monitoring at the 216-U-12 Crib***. RCRA assessment monitoring continued at the 216-U-12 crib in 2005 (Figure 10.7.3; Table 10.7.3). The crib is one of several sources that have contributed to nitrate and technetium-99 plumes in the area. Closure of the crib (i.e., cleanup and stabilization) will be coordinated to meet both RCRA and CERCLA requirements. The monitoring network at this crib was revised in late 2005 to include one upgradient and three downgradient wells. An additional upgradient well is proposed for installation in 2006.

***Monitoring at the 216-S-10 Pond and Ditch***. The 216-S-10 facility continued to be monitored under a RCRA interim status detection program in 2005 (Figure 10.7.3; Table 10.7.3). The current RCRA monitoring network at

this facility consists of only two shallow downgradient wells and one deeper downgradient well, because other wells have gone dry. Three new wells will be installed in conjunction with the 200-UP-1 Operable Unit in 2007.

***Monitoring at the Environmental Restoration Disposal Facility***. This facility is a low-level, mixed waste facility where waste from surface remedial actions on the Hanford Site is disposed. The site is designed to meet RCRA standards, although it is not permitted as a RCRA unit. Results of groundwater monitoring continued to indicate that the facility has not adversely impacted groundwater quality.

### 10.7.3.10 Groundwater Monitoring Results for the 200-BP-5 Operable Unit

The 200-BP-5 Operable Unit includes groundwater beneath the north 200-East Area (Figure 10.7.2). Technetium-99 and tritium plumes extend northward between Gable Mountain and Gable Butte. Uranium forms a narrow plume that extends northwest of the 200-East Area. Nitrate forms a plume that extends to the north and probably originated from multiple sources within the 200-East Area. Other contaminants include cesium-137, cobalt-60, cyanide, iodine-129, nitrate, nitrite, plutonium, strontium-90, sulfate, and uranium.

Groundwater monitoring under CERCLA continued in 2005. There is no active groundwater remediation in this operable unit, and final remediation decisions are yet to be made. One new well was installed near the gap between Gable Mountain and Gable Butte in 2005. This well is located above a topographic high on the basalt surface where the aquifer is very thin.

Five facilities in the 200-BP-5 Operable Unit are monitored under RCRA in conjunction with CERCLA and the *Atomic Energy Act*. Monitoring activities are summarized in the following paragraphs.

***Monitoring at Waste Management Area B-BX-BY***. A RCRA assessment continued at Waste Management Area B-BX-BY in 2005 (Figure 10.7.3; Table 10.7.3). Contaminants include uranium, technetium-99, and nitrate. Concentrations of these contaminants continued to increase in 2005.

***Monitoring at Waste Management Area C***. Waste Management Area C continued to be monitored under an interim status RCRA detection program in 2005 (Figure 10.7.3; Table 10.7.3). RCRA indicator parameters did not exceed critical mean values. However, nitrate, technetium-99, and sulfate are elevated in the groundwater near the waste management area. Concentrations of sulfate in upgradient wells indicate an upgradient source. Although high levels of technetium-99 have been observed upgradient in the past, the plume is currently affecting only downgradient wells at levels above the drinking water standard (900 pCi/L [33 Bq/L]).

***Monitoring at 216-B-63 Trench***. The 216-B-63 trench continued to be monitored under an interim status detection monitoring program in 2005 (Figure 10.7.3).

***Monitoring at Low-Level Waste Management Areas 1 and 2***. Low-Level Waste Management Areas 1 and 2 continued to be monitored under RCRA interim status requirements in 2005 (Figure 10.7.3; Table 10.7.3). Specific conductance continued to exceed its critical mean value at Low-Level Waste Management Area 1, and total organic carbon continued to exceed its critical mean value in an upgradient well at Low-Level Waste Management Area 2. However, both exceedances were reported previously and neither appears to indicate contamination from these waste management areas. Most wells in the north part of Low-Level Waste Management Area 2 are dry, and the water table has dropped below the top of the subsurface basalt layer.

***Monitoring at the Liquid Effluent Retention Facility***. A 2001 letter from the Washington State Department of Ecology directed the DOE to discontinue RCRA statistical evaluation of groundwater sample results at the Liquid Effluent Retention Facility because all but two wells have gone dry, and a 1999 variance to allow the DOE to operate the remaining wells in the network expired. The DOE has continued to sample the two remaining wells but is not conducting statistical analyses of the results. The DOE and Washington State Department of Ecology are exploring alternative approaches to environmental monitoring to comply with hazardous waste regulations.

## 10.7.3.11 Groundwater Monitoring Results for the 200-PO-1 Operable Unit

The 200-PO-1 Operable Unit encompasses the south portion of the 200-East Area and a large portion of the Hanford Site extending to the east and southeast (Figure 10.7.2). The operable unit is contaminated with plumes of tritium, nitrate, and iodine-129 that exceed drinking water standards. Concentrations of tritium continued to decline as the plume attenuates naturally due to radioactive decay and dispersion (Figure 10.7.7). Other contaminants include strontium-90 and technetium-99, but these are limited to very small areas near cribs or tank farms.

CERCLA groundwater monitoring continued in this unit in 2005, and the sampling and analysis plan was revised (DOE/RL-2003-04). Currently, no active groundwater remediation is occurring in this operable unit and final remediation decisions are yet to be made.

Groundwater is monitored at eight regulated waste sites in the 200-PO-1 Operable Unit. Water supply wells in the 400 Area, which falls within the footprint of the 200-PO-1 Operable Unit, also are monitored.

***Monitoring at the Integrated Disposal Facility***. The Integrated Disposal Facility will be an expandable, lined, RCRA-compliant landfill. Construction began in September 2004. The DOE submitted a Part B RCRA permit application to the Washington State Department of Ecology, and it will be incorporated into the Hanford Facility RCRA Permit after approval. The facility is scheduled to receive its first waste in early 2007. Two wells were installed in 2005, bringing the total to three upgradient wells and four downgradient wells, and groundwater sampling began in 2005. One new well remains to be installed at a future date when required by facility expansion.

***Monitoring at the Plutonium-Uranium Extraction (PUREX) Plant Cribs***. Three cribs (216-A-10, 216-A-36B,

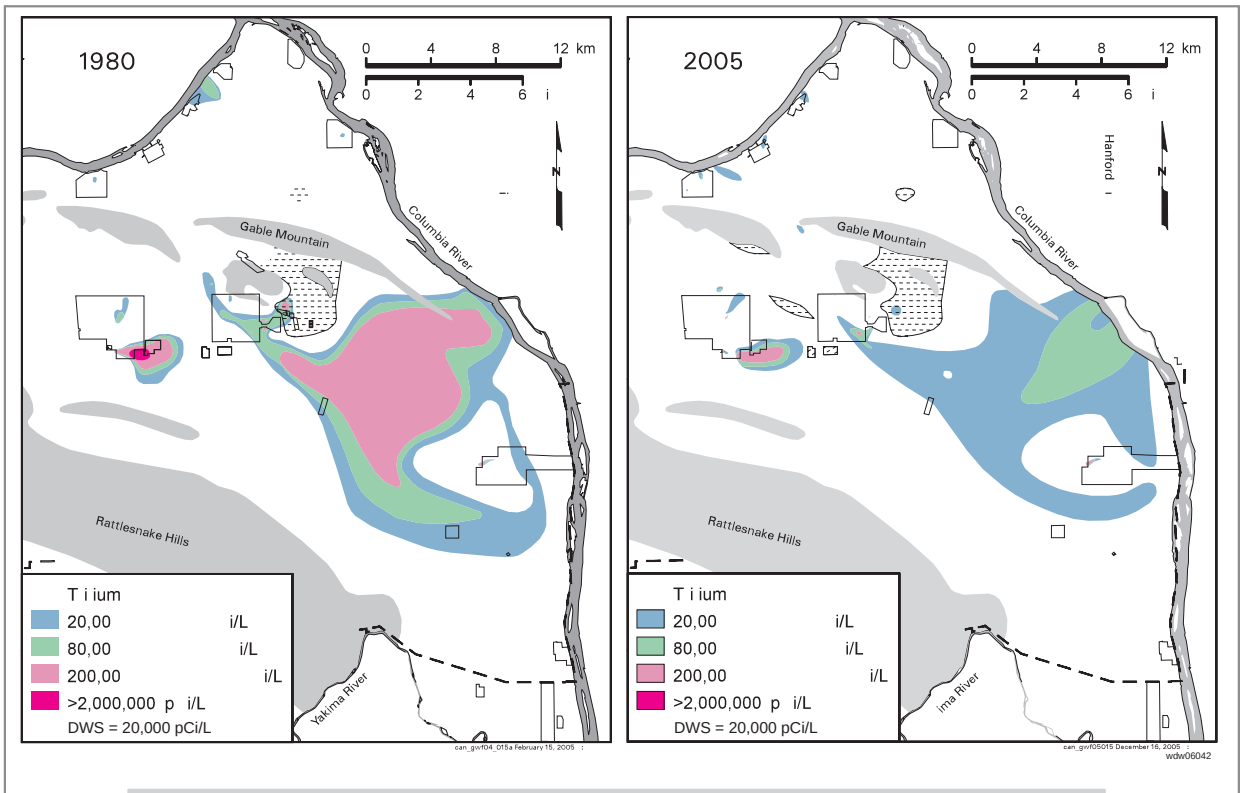



**Figure 10.7.7. Tritium Concentrations in Hanford Site Groundwater, 1980 Compared to 2005**

and 216-A-37-1) are monitored jointly at the Plutonium-Uranium Extraction (PUREX) Plant under a RCRA interim status assessment program, CERCLA, and the *Atomic Energy Act*. The cribs have contributed to widespread contaminant plumes in the area, including nitrate, tritium, and iodine-129. The nitrate and tritium plumes are generally attenuating throughout most of their area. However, in recent years the concentration of nitrate in near-field wells at the Plutonium-Uranium Extraction (PUREX) Plant cribs has either held steady or increased.

***Monitoring at Waste Management Area A-AX***. Based on results for 2005 sampling and analysis, Waste Management Area A-AX began RCRA assessment monitoring in 2005. Specific conductance in a downgradient well exceeded the critical mean value. Contributing constituents included calcium, nitrate, sodium, and sulfate. Technetium-99 concentrations continued to exceed the drinking water standard (900 pCi/L [33 Bq/L]) in the same well. Data from two wells installed in 2005 will help define contaminant distribution.

***Monitoring at the 216-A-29 Ditch***. The groundwater beneath the 216-A-29 ditch (Figure 10.7.3; Table 10.7.3) continued to be monitored as required by RCRA interim status detection regulations. Except for specific conductance, RCRA indicator parameters in downgradient wells did not exceed critical mean values in 2005. Specific conductance continued to exceed its critical mean value in downgradient wells as groundwater quality returns to ambient conditions in response to the cessation of effluent disposal at B Pond. Groundwater quality beneath the ditch closely resembles regional patterns.

***Monitoring at the 216-B-3 Pond***. The groundwater beneath the 216-B-3 pond continued to be monitored in 2005 as required by RCRA interim status detection regulations.

***Monitoring at the 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. No permit criteria for constituents in groundwater were exceeded in 2005. The groundwater monitoring network continues to show that effluent from the facility is not taking a direct route to the uppermost aquifer, which is confined.

***Monitoring at the 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 10.7.3; Table 10.7.3). Interim status detection monitoring continued in 2005.

***Monitoring at the Solid Waste Landfill***. The Solid Waste Landfill is adjacent to the Nonradioactive Dangerous Waste Landfill (Figure 10.7.3; Table 10.7.3) and is regulated under state solid waste regulations. As in previous years, some downgradient wells showed higher chemical oxygen demand, chloride, coliform bacteria, specific conductance, and sulfate, and lower pH than upgradient wells in 2005. Some of these constituents may be related to past disposal of sewage materials to the Solid Waste Landfill.

***Monitoring at the 400 Area Water Supply Wells***. Three water supply wells provide drinking water and emergency supply water for the 400 Area. Because the 400 Area lies in the path of the site-wide tritium plume, the wells are routinely monitored for tritium. The main water supply well is completed deep in the unconfined aquifer and has tritium levels below the drinking water standard. Two backup wells are shallower and have detectable tritium levels, but tritium concentrations in all samples were below the drinking water standard in 2005.

### 10.7.3.12 Groundwater Monitoring Results for the 300-FF-5 Operable Unit

The 300-FF-5 Operable Unit includes three geographic regions: the 300 Area, the 618-11 burial ground region, and the 316-4 cribs and 618-10 burial ground region (Figure 10.7.2). The latter region is referred to informally as "300-FF-5 North." The operable unit is currently regulated under a record of decision (EPA/ROD/R10-96/143) that calls for continued monitoring of groundwater conditions and institutional controls on the use of groundwater as an interim action, until source remedial actions are complete. The operable unit includes groundwater associated with a former liquid waste disposal site regulated under a RCRA final status, corrective action monitoring program.

***Status of Interim Remedial Actions***. Contaminants of concern in 300 Area groundwater are uranium, trichloroethene, and cis-1,2-dichloroethene. Monitoring and plume

characterization activities indicate relatively constant or gradually decreasing levels of these contaminants. Uranium is the primary contaminant of concern and remains above the drinking water standard (30 µg/L) beneath part of the 300 Area.

Groundwater downgradient of the 618-11 burial ground is contaminated by a high-concentration tritium plume, whose origin is believed to be irradiated material in the burial ground. Concentrations at a well adjacent to the burial ground have decreased from >8 million pCi/L (296,000 Bq/L) in 2000 to 1.65 million pCi/L (61,050 Bq/L) in 2005.

At the 316-4 cribs and 618-10 burial ground waste sites, uranium and tributyl phosphate are contaminants of potential concern. Both are associated with the 316-4 cribs, which were removed in 2004. Results of research involving uranium isotopes suggest that there also may be a uranium source from the 618-10 burial ground, where concentrations of uranium exceeded the drinking water standard in 2005 in one well. Tributyl phosphate concentrations were elevated for a brief period in early 2004, along with uranium, during the period when crib removal actions were underway. Since then, concentrations have remained very low.

***300-FF-5 Operable Unit Phase III Feasibility Study***. A new Tri-Party Agreement milestone for the 300-FF-5 Operable Unit was proposed in early 2005 for the delivery of both a Phase III Feasibility Study report for remediation technology alternatives and a draft proposed plan by May 2007. A work plan (DOE/RL-2005-41) was prepared that describes these additional efforts, which include updated computer simulations of groundwater flow and uranium transport, an update to human health and ecological risk assessment in the 300 Area, a limited field investigation (DOE/RL-2005-47) involving multiple characterization boreholes, and an assessment of potential remediation technologies for uranium.

***Monitoring at the 316-5 Process Trenches***. This liquid waste disposal site, monitored under RCRA, was the last in the 300 Area to receive uranium-bearing effluent, with discharges ending in the early 1990s (Figure 10.7.3; Table 10.7.3). The trenches have undergone two phases of remedial action (1991 and 1995), which included removal of contaminated soil and operational structures, and backfilling with clean soil. Uranium currently exceeds the drinking water standard in wells downgradient from the waste site, although concentrations appear to be decreasing with time. Cis-1,2,dichloroethene concentrations exceed the standard at only one downgradient well that is completed near the bottom of the aquifer.

### 10.7.3.13 Groundwater Monitoring Results for the 1100-EM-1 Operable Unit

The 1100-EM-1 Operable Unit is located in the south part of the Hanford Site (Figure 10.7.2). Trichloroethene was the primary contaminant of concern. Contaminants also flow into the area from offsite sources (e.g., nitrate from agriculture and industry).

***Selected Remedial Action***. The final remedy selected for 1100-EM-1 Operable Unit groundwater was monitored natural attenuation of volatile organic compounds. Concentrations of trichloroethene have remained below the drinking water standard since 2001.

Wells in the city of Richland well field are monitored to detect any Hanford contaminants near these wells. The tritium plume originating from sources in the 200-East Area has not been detected in these wells. Low levels of tritium, similar to Columbia River water, continued to be detected.

The city of Richland monitors groundwater quarterly for chemical constituents at their Horn Rapids Sanitary Landfill. The landfill is located in the central portion of the 1100-EM-1 groundwater interest area adjacent to the south boundary of the Hanford Site. Chlorinated hydrocarbons were detected in city landfill monitoring wells between approximately 1 and 1.5 kilometers (0.6 and 0.9 mile) south of the Hanford Site boundary at levels above their respective drinking water standards during 2005.

### 10.7.3.14 Groundwater Monitoring Results for the 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 appears to converge into the 200-East Area from the west, south, and east. Groundwater likely discharges from the confined aquifer to the overlying unconfined aquifer where the confining mud unit has been removed by erosion.

While effluent disposal was occurring at the former B Pond system, east of the 200-East Area, groundwater mounding forced groundwater a limited distance into the Ringold Formation confined aquifer. Groundwater analyses for 2005 at the 200 Area Treated Effluent Disposal Facility continued to demonstrate isolation of the confined aquifer from current disposal activities.

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 generally flows from west to east across the Hanford Site, up through fractures or other pathways in the confining layers, into the unconfined aquifer, and into the Columbia River. Vertical gradients between the basalt-confined aquifer and the unconfined aquifer are upward on most of the Hanford Site. Downward gradients are measured in the west portion of the Hanford Site, near the former location of B Pond, and north and east of the Columbia River.

Tritium continued to be detected at low levels in some basalt-confined wells. One elevated tritium concentration near the 200-East Area is associated with intercommunication between the upper basalt-confined aquifer and the overlying unconfined aquifer. Iodine-129, strontium-90, gamma-emitting isotopes, and uranium isotopes were not detected above their minimum detection limits in the upper basalt-confined aquifer. Cyanide, nitrate, and technetium-99 were elevated in an upper basalt-confined aquifer well in the northwest part of the 200-East Area. Migration of high-salt waste from the vadose zone or unconfined aquifer during well construction is responsible for this contamination.

## 10.7.4 Groundwater and Vadose Zone Remediation

The overall objectives of groundwater and vadose zone 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.

### 10.7.4.1 Groundwater Remediation Using Pump-and-Treat Systems and In Situ Redox Manipulation Technology

G. G. Kelty, D. B. Erb, and R. O. Mahood

Six pump-and-treat systems continued to operate at five 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 2005 (Figure 10.7.8). A second pump-and-treat system (DR-5) was installed at the 100-HR-3 Operable Unit in 2004 to treat contaminated groundwater in the central part of the 100-D Area. Summary descriptions of groundwater remediation activities are provided in the following paragraphs. A summary of groundwater remediation activities at the Hanford Site is provided in Table 10.7.7.

***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 ecosystem of the Hanford Reach. Low levels of chromium may be 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 parts per million) of chromium (WAC 173-201A). Chromium concentrations exceeding 600 µg/L (0.6 parts per million) have been measured in the pore water 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.

***100-KR-4 Operable Unit***. A pump-and-treat system is being used to remove chromium from the aquifer beneath a large, liquid-waste disposal trench in the 100-KR-4 Operable Unit.

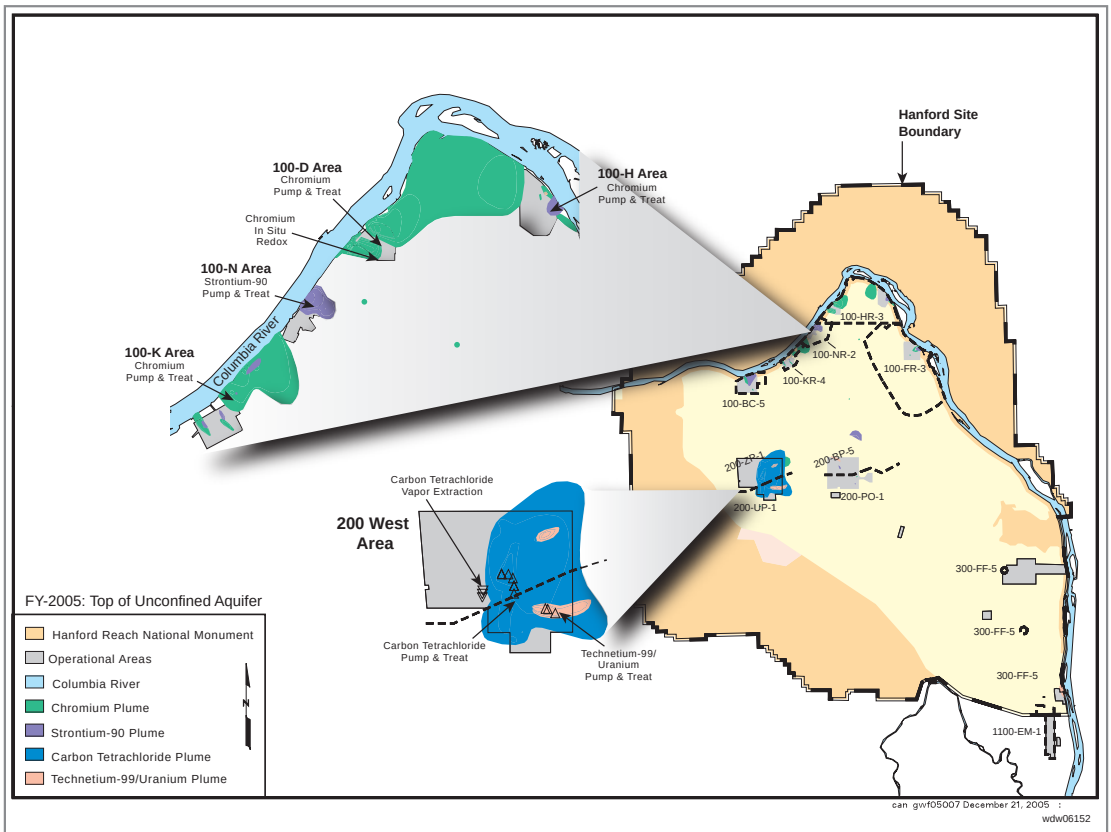



**Figure 10.7.8. Pump-and-Treat, In Situ Remediation, and Soil-Gas Extraction Systems Operating on the Hanford Site in 2005**

The purpose of the interim action is to reduce the amount of chromium entering the Columbia River at the 100-K Area (Figure 10.7.9). During 2005, the 100-KR-4 pump-and-treat system treated 529.5 million liters (139.9 million gallons) of groundwater and removed 25.6 kilograms (56.4 pounds) of chromium. Total chromium removed since operations began in 1997 is 283.2 kilograms (624.3 pounds) through treatment of 3.36 billion liters (887.6 million gallons) of water. Treated groundwater is re-injected into the aquifer upgradient from the 100-KR-4 extraction wells. The areal extent of the plume has remained fairly constant during the past 10 years; however, the central portion of the plume has been treated to nearly the remedial action goal, and the area of highest concentration has decreased markedly. The interim remedial action concentration goal for groundwater near the Columbia River is 22 µg/L (0.022 parts per million) chromium. A second pump-and-treat system is currently being planned for the area downgradient of the K-West Reactor where chromium concentrations range from about 500 µg/L (0.5 parts per million) near the K-West Reactor to about 44 µg/L (0.044 parts per million) at the river shoreline.

***100-HR-3 Operable Unit Pump-and-Treat Systems.*** 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/ROD/R10-96/134), full-scale pump-and-treat systems were constructed in the 100-D, 100-H, and 100-K Areas (Figure 10.7.8). The objective of these systems is to remove chromium contamination from the groundwater and, thus, prevent or reduce the movement of chromium to the Columbia River.

During 2005, 325.6 million liters (86 million gallons) of groundwater were treated by a pump-and-treat system that consists of extraction wells in the 100-D and 100-H Areas, a treatment system in the 100-H Area, and injection wells

**Table 10.7.7. Summary of Groundwater Remediation Activities at the Hanford Site, 2005**

| Remedial Action Site | Startup Date | Progress from Startup through December 2005 | Progress for 2005 |
|---|---|---|---|
| 100-K Area<br>100-KR-4 Pump-and-Treat | 1997 | Decreases chromium to river; 283.2 kilograms (624.3 pounds) chromium removed. | 25.6 kilograms (56.4 pounds) chromium removed |
| 100-N Area<br>100-NR-2 Pump-and-Treat | 1995 | Diverts strontium-90 from river; 1.78 curies (65.8 gigabecquerels) strontium-90 removed. | 0.15 curies (5.55 gigabecquerels) strontium-90 removed |
| 100-D Area and 100-H Area<br>100-HR-3 Pump-and-Treat | 1997 | Decreases chromium to river; 271.1 kilograms (598 pounds) chromium removed. | 33.5 kilograms (74 pounds) chromium removed |
| 100-D Area<br>100-HR-3 In Situ Redox | 1999 | Decreases chromium concentration downgradient of barrier. | |
| 100-D Area<br>100-DR-5 Pump-and-Treat | 2004 | Decreases chromium to river; 42.2 kilograms (93 pounds) chromium removed. | 38.8 kilograms (85.4 pounds) chromium removed |
| 200-West Area<br>200-ZP-1 Pump-and-Treat | 1994 | Prevents high-concentration portion of carbon tetrachloride plume from spreading; 9,492.3 kilograms (20,927 pounds) removed. | 750.6 kilograms (1,655 pounds) carbon tetrachloride removed |
| 200-West Area<br>Soil-Vapor Extraction | 1991 | Prevents carbon tetrachloride movement to groundwater; 78,710 kilograms (173,524 pounds) removed from vadose zone. | 362 kilograms (798 pounds) carbon tetrachloride removed |
| 200-West Area<br>200-UP-1 Pump-and-Treat | 1994 | Decreases migration of contaminants; 118.9 grams (0.262 pound) technetium-99 and 211.8 kilograms (467 pounds) uranium removed. | 5.0 kilograms (11.0 pounds) uranium removed<br>2.68 grams (0.006 pound) technetium-99 removed |
| | | 34.6 kilograms (76.3 pounds) carbon tetrachloride removed. | 2.0 kilograms (4.4 pounds) carbon tetrachloride removed |
| | | 34,716 kilograms (76,534 pounds) nitrate removed. | 1,255 kilograms (2,761 pounds) nitrate removed |
| Waste Management Area<br>S-SX Well 299-W23-19<br>Pump-and-Treat | 2003 | ~0.0034 curies (125.8 megabecquerels) technetium-99 removed. | ~0.089 grams (0.003 ounce) technetium-99 removed |
| 300-FF-5 Natural Attenuation | NA | Average trichloroethene concentrations below target level; uranium concentrations above target level. | |
| 1100-EM-1 Natural Attenuation | NA | Average trichloroethene concentrations below 5 µg/L (0.005 ppm) since 2001. | |

NA = Not applicable.

in the 100-H Area. This system removed approximately 33.5 kilograms (73.9 pounds) of chromium from the groundwater in 2005. Since 1997, more than 2.59 billion liters (684.2 million gallons) of groundwater have been treated, with 271.1 kilograms (598 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. Since 2005, the well configuration in the pump-and-treat system has been modified in an attempt to accelerate cleanup. For example, three previous compliance wells have been converted to extraction wells, and injection has been moved closer to the remaining plume above the remedial action objective.

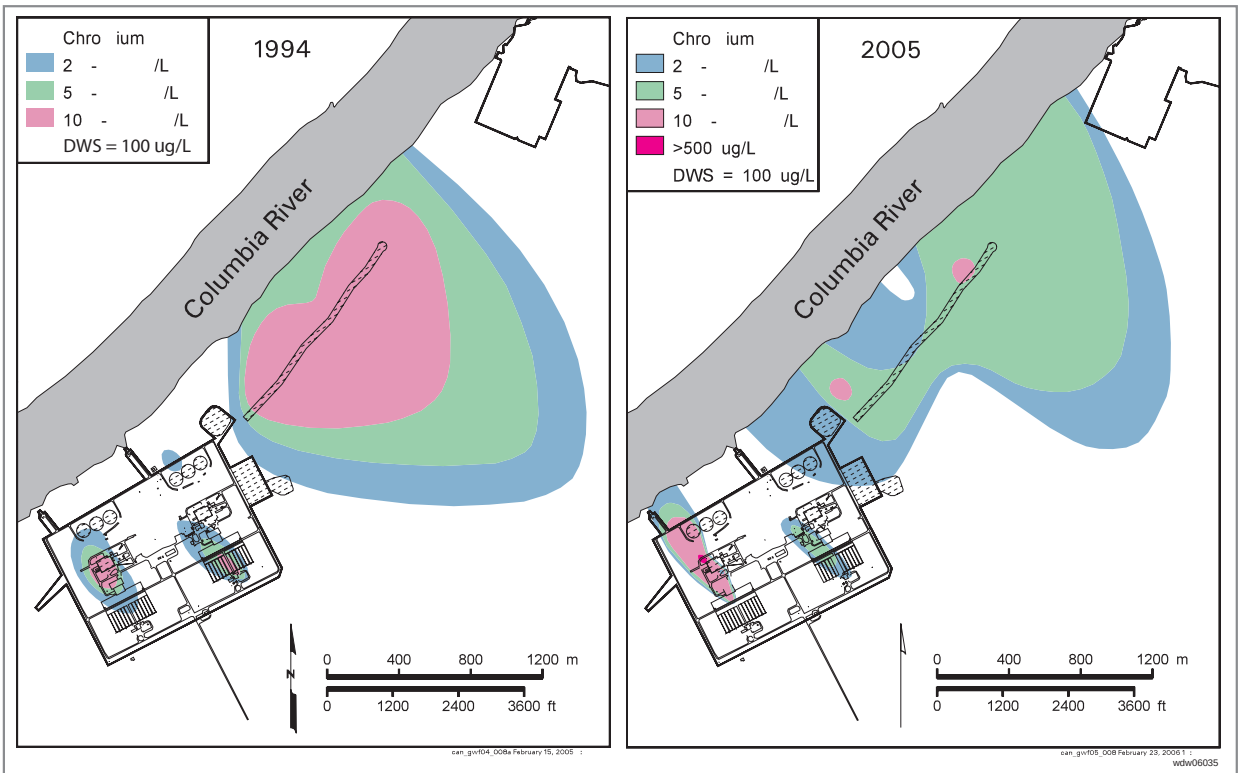



**Figure 10.7.9. The Effect of Pump-and-Treat System on Groundwater Chromium Concentrations in the Hanford Site's 100-K Area, 1994 Compared to 2005**

A second, 189-liter (50-gallon) per minute, ion exchange pump-and-treat system, 100-DR-5, was brought on line in the 100-D Area in June 2004 to intercept groundwater in the central 100-D Area near the Columbia River shoreline, where chromium concentrations had increased in recent years (Figure 10.7.10). Water is extracted at three downgradient wells at a combined rate of approximately 142 liters (37.5 gallons) per minute, treated, and re-injected into an upgradient well. To date, 50.4 million liters (13.3 million gallons) of water have been extracted and an estimated 42.2 kilograms (93.0 pounds) of chromium removed. This system is designed to capture a recently identified lobe of the chromium plume that is not contained by either the existing 100-D Area pump-and-treat system or an in situ redox manipulation barrier.

***100-HR-3 Operable Unit In Situ Redox Manipulation***. 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 to a chromic-ferric hydroxide complex. This is accomplished by injecting sodium dithionite, 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, 2002, and 2003. The barrier is now 680 meters (2,230 feet) long and approximately 15 meters (48 feet) wide and consists of 65 injection wells.

Monitoring has shown that chromium concentrations in wells along the barrier axis are, generally, less than 20 µg/L (0.02 parts per million) in the southwestern half of the barrier. Along the northeastern half of the barrier there are 19 barrier wells where concentrations exceed 30 µg/L (0.03 parts per million). The maximum concentration in

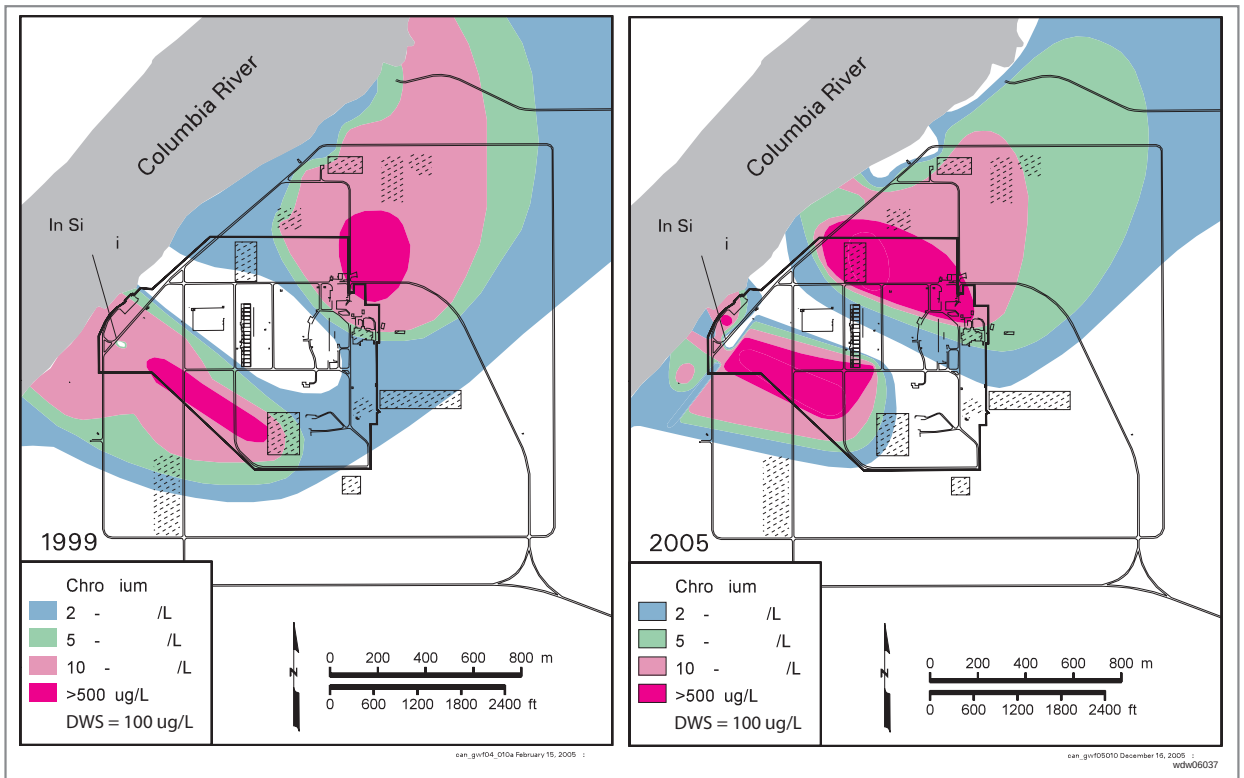



**Figure 10.7.10. Chromium Concentrations in Hanford Site's Central 100-D Area Groundwater, 1999 Compared to 2005**

these wells is 1,090 µg/L (1.09 parts per million). Compliance wells to the west of the barrier still have high concentrations ranging from 9 to 894 µg/L (0.009 to 0.89 parts per million).

During 2005, four new wells were installed as part of the investigations of the premature loss of reductive capacity (breakdown) of the barrier, which is evident along the northeastern half. The studies indicate that nitrate in the groundwater will decrease the predicted life of the barrier to 10 years, a decrease of 47%. The studies also indicate that breakdown may be a consequence of high-permeability oxidized sediment near the water table. Treatment of the barrier with micron-scale native iron particles injected with a shear-thinning polymer is currently being evaluated to restore the treatment capacity of the barrier.

***Bioremediation Research***. The DOE conducted field tests near the 100-H Area in 2004 to demonstrate the feasibility of a remediation technology to immobilize hexavalent chromium in the aquifer. The natural microbial population was successfully stimulated during the initial field tests in 2004. In 2005, geophysical surveys, a pumping test, and groundwater monitoring were conducted to assess the remediation technology. The results indicate that chromium concentrations at the field site decreased and remained below upgradient chromium concentrations.

***Strontium-90***. 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 groundwater levels caused by fluctuating Columbia River levels. A pump-and-treat system in the 100-N Area operates as a CERCLA interim action to reduce the movement of strontium-90 toward the Columbia River (Figure 10.7.11).

The pump-and-treat system creates a hydraulic barrier to flow, thereby, decreasing groundwater flow into the Columbia River. Approximately 105 million liters (27.7 million gallons) of water were processed during 2005. During that period, 0.15 curies (5.55 gigabecquerels) of strontium-90

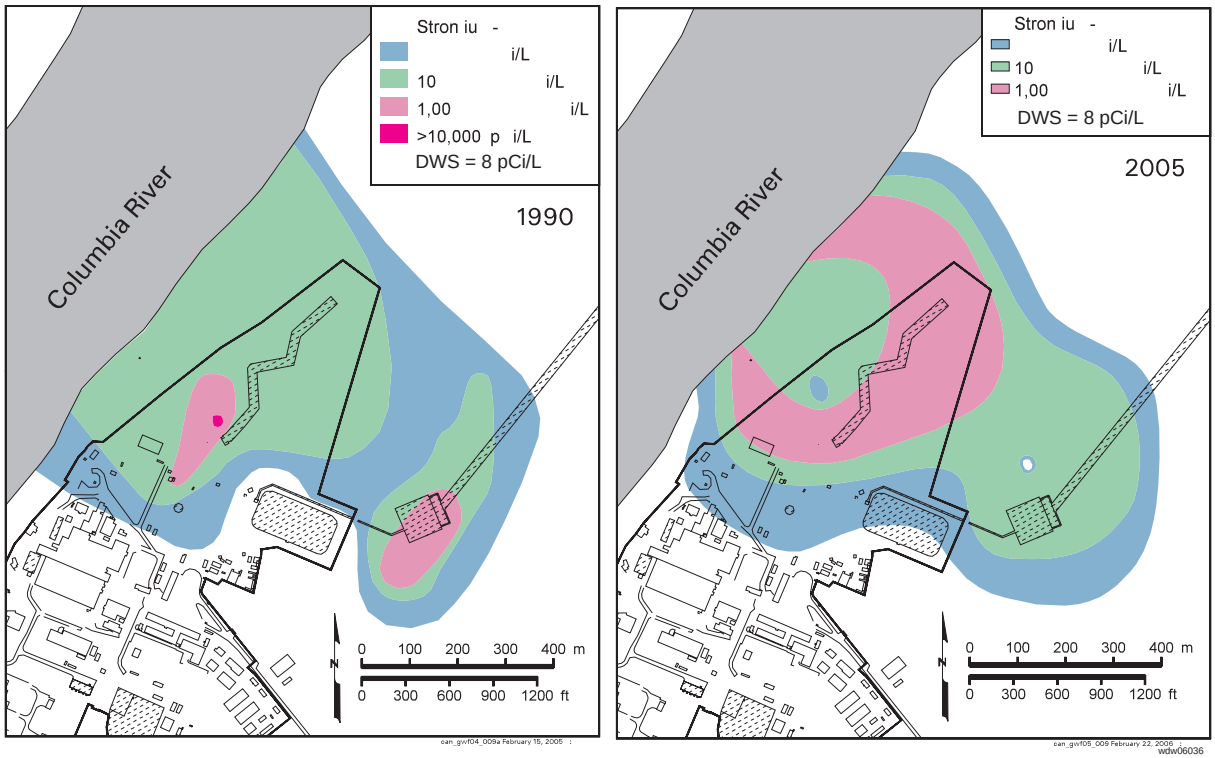



**Figure 10.7.11. Strontium-90 Concentrations in the Hanford Site's 100-N Area Groundwater, 1990 Compared to 2005**

were removed from the groundwater. More than 1.132 billion liters (299 million gallons) of groundwater have been processed since the system began operation in 1995, removing 1.78 curies (65.8 gigabecquerels) of strontium-90. Concentrations remained far above the 8-pCi/L (0.3-Bq/L) drinking water standard in 2005.

Pump-and-treat technology has proven to be an ineffective way to remediate strontium-90 contamination because strontium-90 binds to sediment grains. DOE is considering alternative technologies for remediating the strontium-90 plume in this area. DOE has developed a treatability test plan to evaluate the effectiveness of one technology, sequestration, where chemicals injected into the aquifer immobilize strontium-90 so it does not flow with the groundwater into the Columbia River. The plan includes a contingency provision for a permeable reactive barrier installation to meet the same objective if sequestration fails. The test will also evaluate phytoremediation to enhance strontium-90 recovery along the Columbia River shoreline. Phytoremediation is a technology that uses plants to remove (take up) contaminants from groundwater. The DOE has recommended temporarily suspending operation of the pump-and-treat system while they collect data to evaluate the alternative technologies. Sampling frequency was increased along the Columbia River shoreline in anticipation of suspending the pump-and-treat operations. Three new monitoring wells and new aquifer tubes along the 100-N Area shoreline of the Columbia River were installed to collect baseline data. The DOE also recommends monitoring natural attenuation for that portion of the plume that is not expected to reach the Columbia River.

***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) (Figure 10.7.12). The 200-ZP-1 pump-and-treat system operated as a pilot-scale treatability test from 1994 to 1996, with full-scale Phase II operations beginning in 1996. A total of 2.86 billion liters (755.3 million gallons) of groundwater have been processed since startup, removing 9,492.3 kilograms (20,927 pounds) of carbon tetrachloride. During 2005,

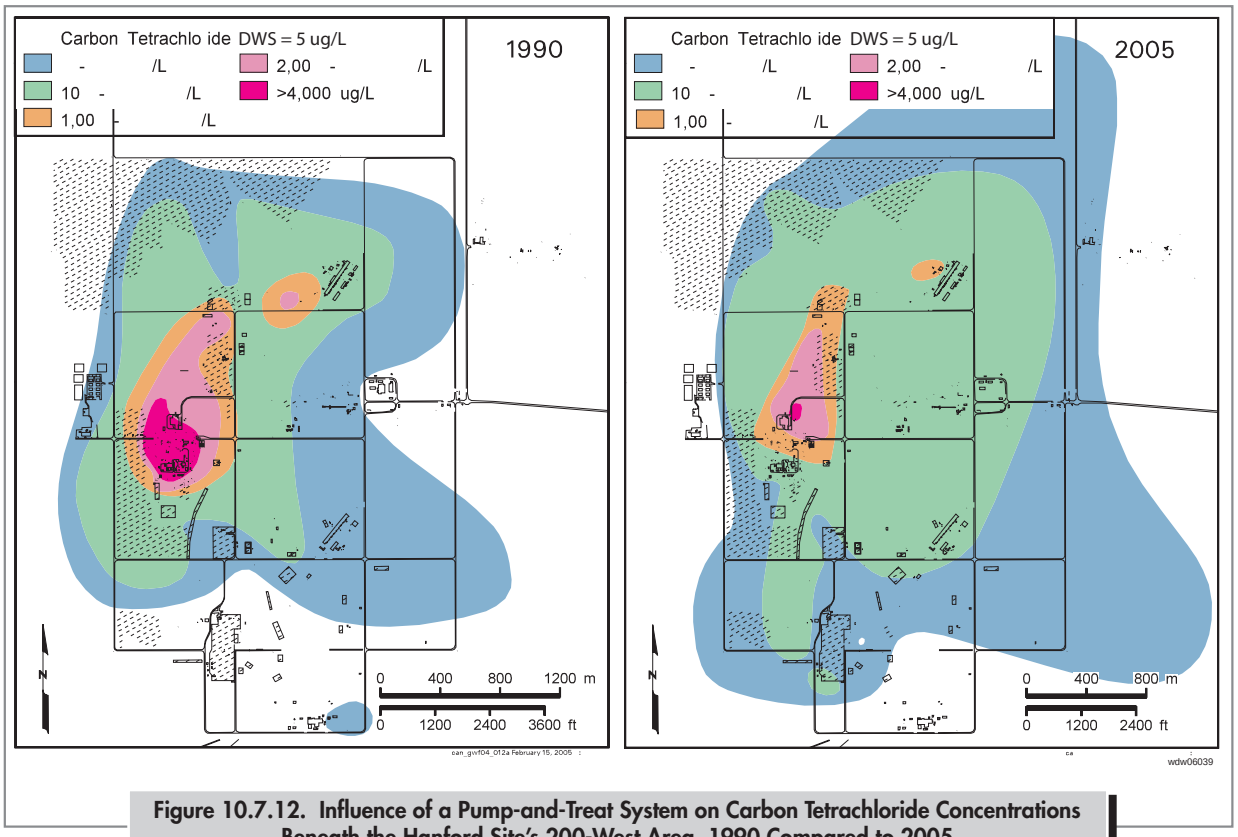



**Figure 10.7.12. Influence of a Pump-and-Treat System on Carbon Tetrachloride Concentrations Beneath the Hanford Site's 200-West Area, 1990 Compared to 2005**

354.6 million liters (93.7 million gallons) of groundwater were treated, removing 750.6 kilograms (1,655 pounds) of carbon tetrachloride.

The volume of water treated in 2005 increased due to the conversion of four existing monitoring wells into extraction wells in July. The wells are located west of the TX/TY Tank Farm and are intended to treat the northern >2,000-µg/L (2.0 parts per million) plume. The four wells increased the average extraction rate to 1,098 liters (290 gallons) per minute, and ranged from 946 to 1,230 liters (250 to 325 gallons) per minute. Prior to adding the new wells, the total extraction rate averaged 732.4 liters (193.5 gallons) per minute.

Carbon tetrachloride concentrations have declined at the baseline plume wells but have remained above the 2,000-µg/L (2.0 parts per million) remedial action objective for the four new extraction wells. At the same time, increasing concentrations of technetium-99, tritium, and nitrate have been observed at two of the wells. At 900 pCi/L (41 Bq/L), well 299-W15-765 has equaled the 900-pCi/L (33-Bq/L) maximum contaminant level for technetium-99. Well 299-W15-44 has also increased; however, at 630 pCi/L (24 Bq/L), remains below the maximum contaminant level for technetium-99. The increases were anticipated as technetium-99, tritium, nitrate, chromium, and iodine-129 groundwater plumes are reported on the east side of the TX/TY Tank Farms.

Since the start of Phase II operations, technetium-99 has been recognized as a minor contaminant in the treatment process. It passes through the treatment system and is re-injected into the aquifer. Unintentionally, it acts as a tracer allowing tracking of the injection water front toward the extraction wells.

Carbon tetrachloride concentrations at monitoring wells between the injection and extraction wells have decreased while technetium-99 concentrations have increased to around 130 to 160 pCi/L (5 to 6 Bq/L), indicating sweeping of the carbon tetrachloride plume. Actions are under way to evaluate the potential impact of the increasing technetium-99 concentrations on operations and in the groundwater.

***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 into early 2005, at which time it was suspended to conduct a rebound study. The contaminant plumes include 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 plumes. 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 Areas 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 until January 26, 2005, producing at rates of 189 liters (50 gallons) per minute. Three extraction wells were used during the year. By January 26, 2005, the Effluent Treatment Facility had treated 4.0 million liters (1.06 million gallons) of groundwater with another 26.4 million liters (6,970,000 gallons) in temporary storage prior to treatment. Groundwater treatment in calendar year 2005 removed 2.68 grams (0.006 pound) of technetium-99, 5.0 kilograms (11.0 pounds) of uranium, 2.0 kilograms (4.4 pounds) of carbon tetrachloride, and 1,255 kilograms (2,761 pounds) of nitrate. To date, the system has treated 853.4 million liters (225.4 million gallons) of water, removing 118.9 grams (0.262 pound) of technetium-99 and 211.8 kilograms (467 pounds) of uranium.

The rebound study is assessing the effectiveness of remediation on the aquifer. With the pumps turned off, groundwater levels, flow rates, and contaminant concentrations can re-equilibrate. Sampling can then determine if enough contamination has been removed to prevent future exceedances above the remedial action objective. The rebound test started on January 25, 2005 and continued through January 25, 2006.

The rebound study started with two weekly sampling events immediately following shutdown of the pump-and-treat system, and was followed by monthly sampling at ten wells within and around the baseline plume area (Figures 10.7.13 and 10.7.14). Technetium-99 and uranium were sampled for monthly while carbon tetrachloride and nitrate were sampled for quarterly. Trend plots were constructed for each analyte and tracked for the year (Figures 10.7.15 through 10.7.18). Two new wells drilled in August-September 2005 were added to sampling in October 2005.

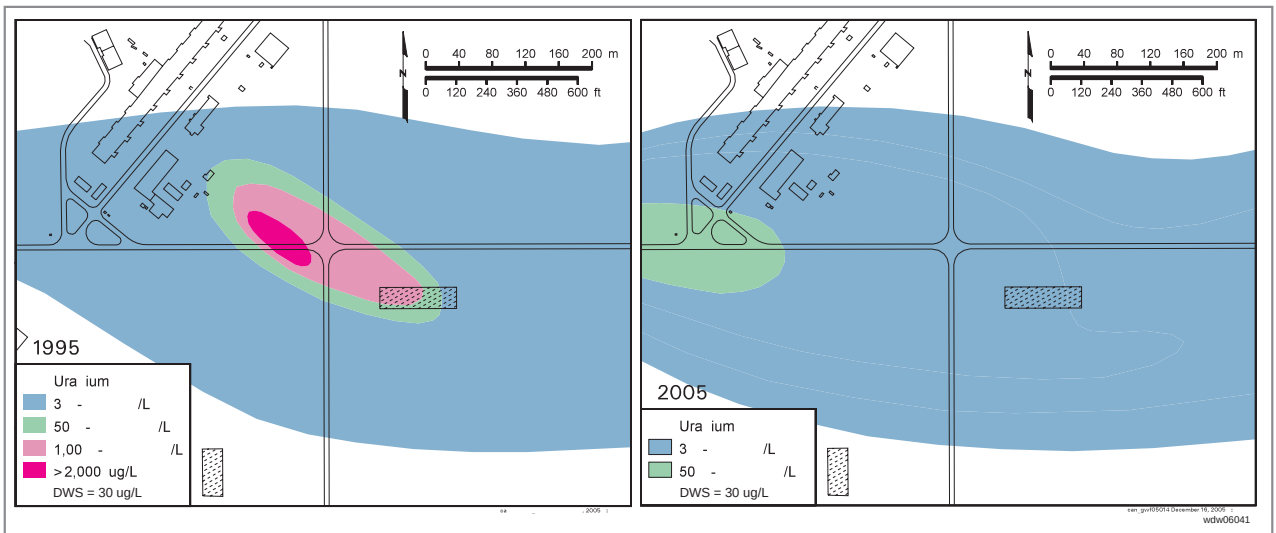



**Figure 10.7.13. Influence of a Pump-and-Treat System on Uranium Concentrations at the Hanford Site's 200-UP-1 Operable Unit (200-West Area), 1995 Compared to 2005**

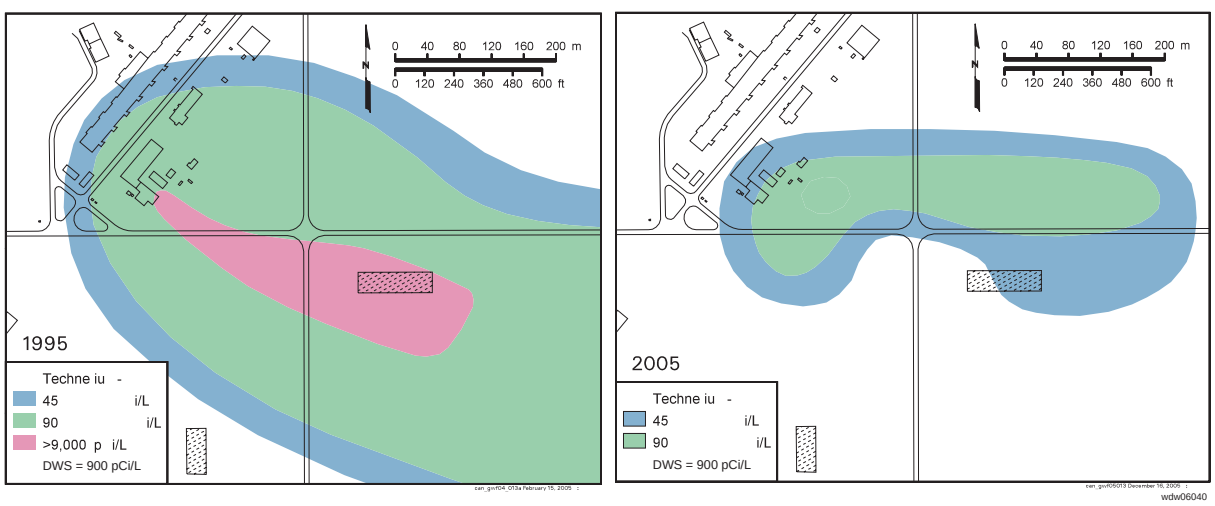



**Figure 10.7.14. Impact of a Pump-and-Treat System on Technetium-99 Concentrations at the Hanford Site's 200-UP-1 Operable Unit (200-West Area), 1995 Compared to 2005**

For all but one well, technetium-99 concentrations did not increase above 3,000 pCi/L (111 Bq/L), and seven of the ten wells trended below the 900-pCi/L (33-Bq/L) maximum contaminant level. Well 299-W19-36 concentrations briefly spiked to 14,500 pCi/L (536 Bq/L), then declined to 1,930 pCi/L (71 Bq/L) at the end of the test. Well 299-W19-43 increased from 989 to 2,920 pCi/L (36 to 108 Bq/L) over the year.

Uranium concentrations remained below the 480-µg/L (0.48 parts per million) remedial action objective at all wells. Concentrations at 299-W19-36 reached 479 µg/L (0.479 parts per million) in early March 2005 but then declined to 300 µg/L (0.3 parts per million) before increasing to a closing value of 442 µg/L (0.442 parts per million). Three of the wells remained below the 48-µg/L (0.048 parts per million) maximum contaminant level.

Carbon tetrachloride trends at the ten wells consistently exceeded the 5-µg/L (0.005 parts per million) maximum contaminant level with most wells ranging between 6 and 240 µg/L (0.006 and 0.24 parts per million). One well, 699-38-70B, located outside the 200-West fence (not shown on Figure 10.7.13) ranged between 300 and 520 µg/L (0.3 and 0.52 parts per million) for calendar year 2005.

The highest nitrate concentrations were measured at well 299-W19-43. Concentration in this well increased sharply to 1,180,000 µg/L (1,180 parts per million) in February and continued increasing to 1,740,000 µg/L (1,740 parts per million) by January 2006. The levels are similar to the 1,930,000 µg/L (1,930 parts per million) encountered when the well was first sampled in January 2003. Nitrate trends at other monitoring wells are above the 45,000-µg/L (45 parts per million) maximum contaminant level but four downgradient wells were below the maximum contaminant level.

At the conclusion of the rebound study, a letter report will be prepared to report the results and help decide a future course for the 200-UP-1 pump-and-treat system.

Elevated concentrations of technetium-99 were observed at a well in the 200 Areas that was drilled in 2002 at the S-SX Tank Farm. The high values led to an agreement that this well should be extensively purged during sampling. The Washington State Department of Ecology and DOE agreed that, for each quarterly sample, more than 3,785 liters (1,000 gallons) of water should be contained and taken to the Effluent Treatment Facility for treatment. After completing a field evaluation and pipe extension modification, purging and treatment were implemented starting in March 2003 (RPP-10757). During 2003, and prior to the first purging, technetium-99 concentrations peaked at 188,000 pCi/L (6,956 Bq/L) at the S-SX Tank Farm then began a steep decline. In 2005, concentrations began increasing, ranging between 62,300 and 137,000 pCi/L (2,305 and 5,069 Bq/L). Through 2005, at least 42,790 liters

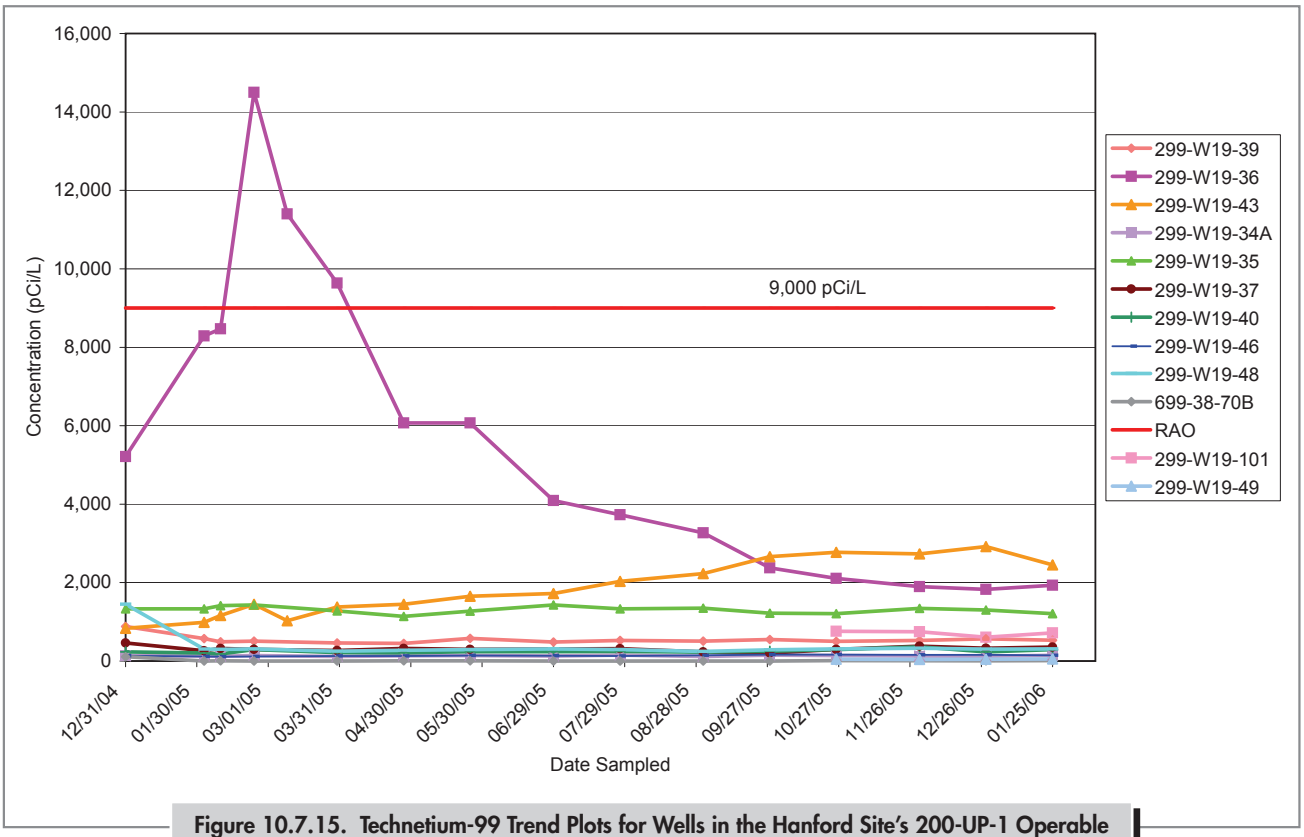



**Figure 10.7.15. Technetium-99 Trend Plots for Wells in the Hanford Site's 200-UP-1 Operable Unit Rebound Study (RAO = remedial action objective)**

(11,304 gallons) of water have been treated at the Effluent Treatment Facility, yielding 0.00337 curies (125 megabecquerels) of technetium-99. Further actions will depend on how concentrations change in the future.

### 10.7.4.2 Vadose Zone Remediation Using Soil-Vapor Extraction Systems

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 2005. 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 2005; the other two systems are no longer operational. In 2005, 362 kilograms (798 pounds) of carbon tetrachloride were removed. Since operations began, soil-vapor extraction has removed 78,710 kilograms (173,524 pounds) of carbon tetrachloride from the vadose zone. 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 2005.

## 10.7.5 Well Installation, Maintenance, and Decommissioning

The DOE installs new wells when needed for monitoring or characterization, maintains wells to repair problems, and decommissions wells that are no longer needed. The

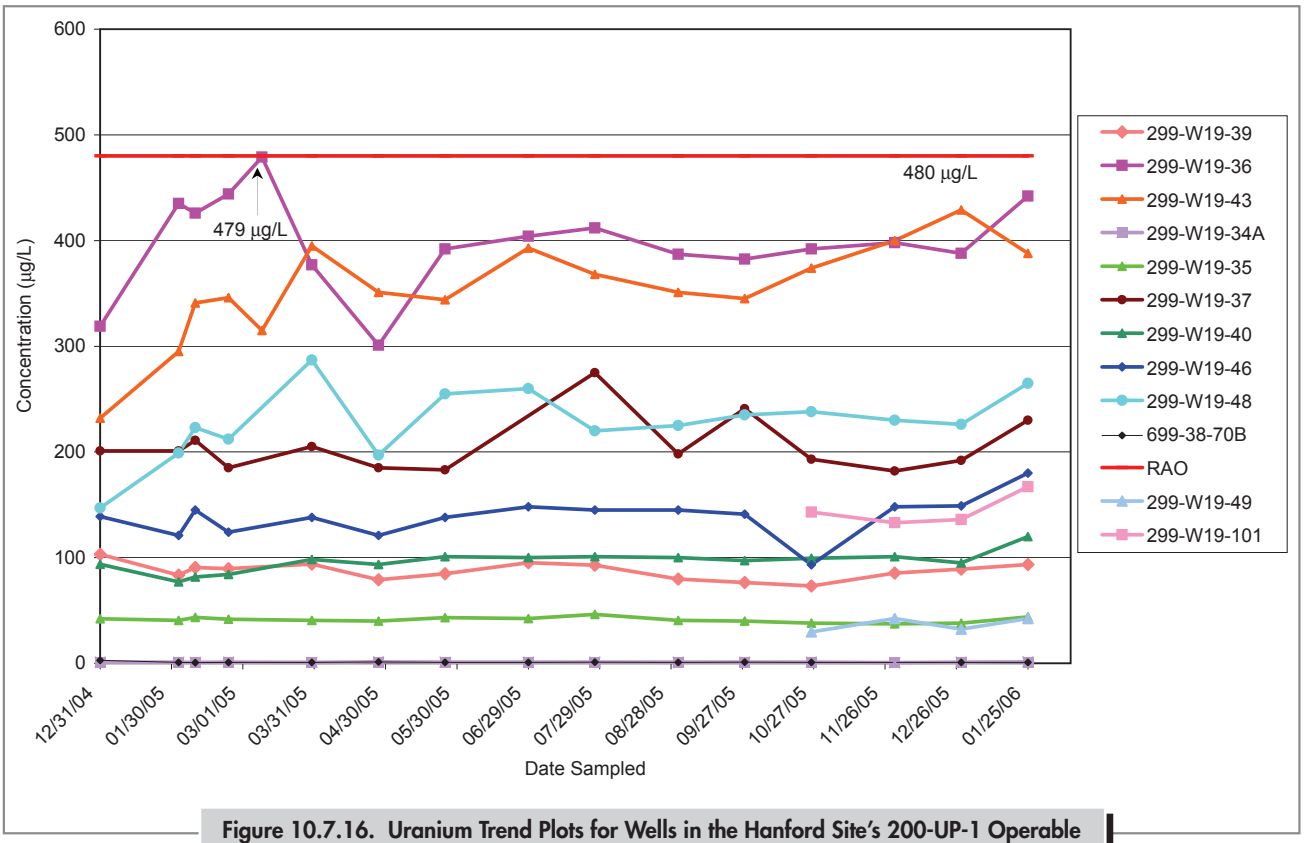



**Figure 10.7.16. Uranium Trend Plots for Wells in the Hanford Site's 200-UP-1 Operable Unit Rebound Study (RAO = remedial action objective)**

Washington State Department of Ecology, EPA, and DOE worked together to develop a prioritized list of new wells needed to meet requirements of various groundwater monitoring regulations. Twenty-seven new monitoring wells were installed during calendar year 2005.

Approximately 3,975 permanent wells have been identified within the Hanford Site. Many of these have been decommissioned (sealed with grout) because they were no longer needed; were in poor condition; were in the path of intended remediation or construction activities; or posed an environmental, safety, or public health hazard. During 2005, 1,382 wells were in use and 115 wells were decommissioned.

## 10.7.6 Groundwater Modeling

M. D. Freshley

***New Science and Technology***. The Groundwater Remediation Project includes a science and technology effort to provide data, tools, and scientific understanding to make remediation and site closure decisions. These activities are accomplished under the Remediation and Closure Science Project. During 2005, the Remediation and Closure Science Project focused on documenting estimates of radionuclide inventories in past-practice waste-disposal sites, continuing to update conceptual models for key waste sites, and performing biological uptake studies for key contaminants.

***Soil Inventories***. During 2005, update of the Soil Inventory Model was completed and documented. A report (RPP-26744) summarizing both the radionuclide inventories in past-practice waste-disposal sites and tank leaks was published jointly with CH2M HILL Hanford Group, Inc.

***Conceptual Model Updates***. At the Hanford Site, conceptual models are used to describe subsurface contamination and key processes impacting contaminant migration. Efforts to update conceptual models for waste sites and vadose zone and groundwater contamination continued to focus on the 300 Area, 100-N Area, carbon tetrachloride transport

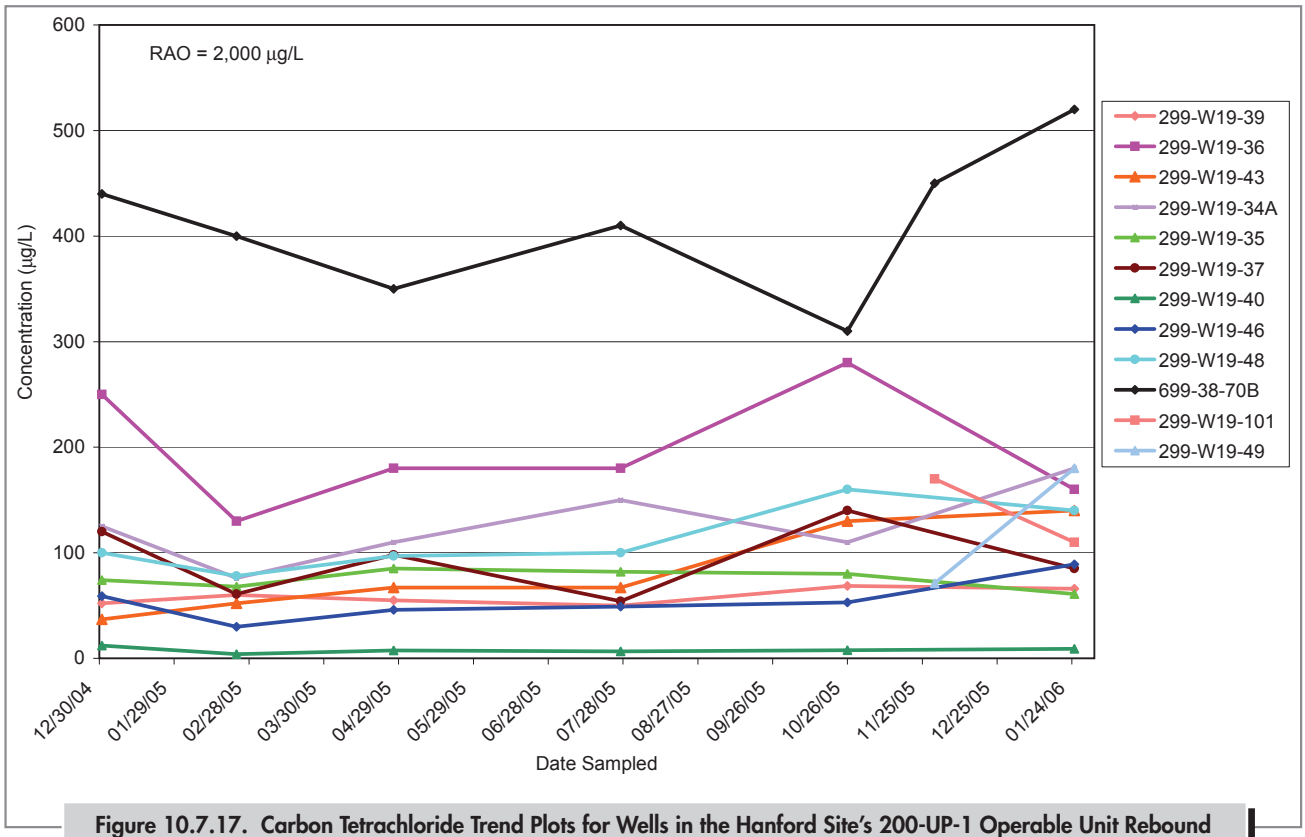



**Figure 10.7.17. Carbon Tetrachloride Trend Plots for Wells in the Hanford Site's 200-UP-1 Operable Unit Rebound Study (RAO = remedial action objective)**

in Hanford sediment, and the 216-B-26 trench in the 200 Areas. During 2005, a report (PNNL-15121) was published summarizing the results of scientific investigations of uranium geochemistry in the 300 Area.

The experimental results documented in the report collectively provide scientific explanations of why the 300 Area uranium plume has been slow to disperse. These results also provide the basis for reactive transport models to forecast future behavior.

Progress continued on evaluation of sediment samples from three boreholes drilled in the 100-N Area along the Columbia River during fiscal year 2004. These samples are being evaluated in the laboratory to provide data for a reactive transport model of strontium-90 at the 100-N Area. This model will be used to evaluate remediation alternatives to the pump-and-treat system that has been operating in the 100-N Area.

A theory being developed to describe residual non-aqueous phase liquid carbon tetrachloride was updated during 2005. Experiments were completed to evaluate wettability (ability of soil to retain fluids) of carbon tetrachloride and intermediate-scale experiments with residual carbon tetrachloride to measure dissolution rates in the vadose zone. The experimental results are being incorporated into the Subsurface Transport Over Multiple Phases (STOMP) code to improve predictions of remedial actions.

Conceptual and numerical models of the 216-B-26 trench were completed incorporating new theories that better explain the amount of lateral spreading from heterogeneities (variations in soil properties) and anisotropy (preference of flow to occur in one direction over another). The results are published in PNNL-14907. The 216-B-26 modeling approach was used to simulate moisture flow and contaminant transport and predict the extent of lateral spreading of technetium-99. These simulations of flow and transport modeling are being used to assist with remedial design.

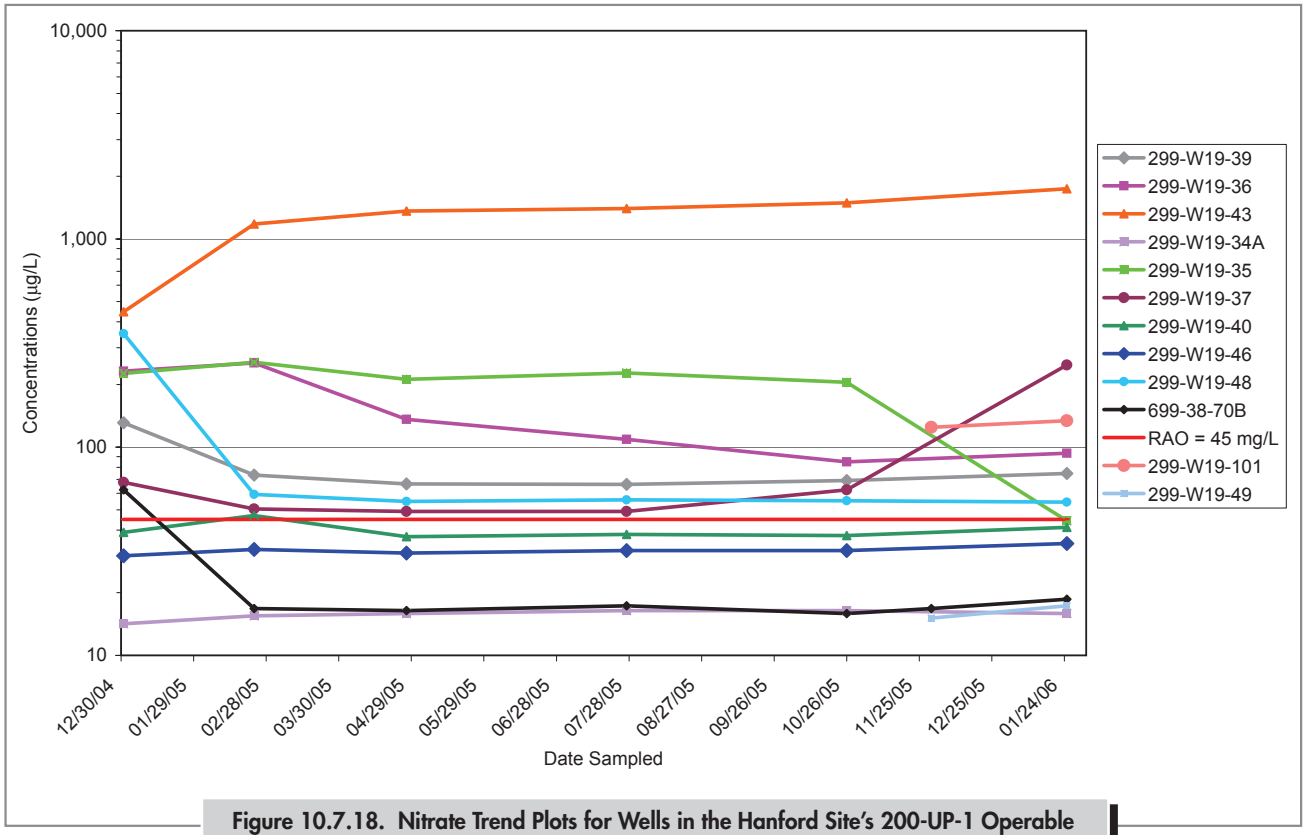



**Figure 10.7.18. Nitrate Trend Plots for Wells in the Hanford Site's 200-UP-1 Operable Unit Rebound Study (RAO = remedial action objective)**

***Biological Uptake of Uranium***. During 2005, the Remediation and Closure Science Project completed the first two studies of uranium uptake by periphyton, indicating that maximum uptake occurred between 3 and 6 days, followed by a downward trend for the higher concentrations. These results may suggest negative response by periphyton to uranium uptake at higher concentrations. Additional uptake experiments being conducted during fiscal year 2006 will resolve this question.

***Remediation Support***. During 2005, the Remediation and Closure Science Project completed installation of 14 aquifer tubes in the 100-N Area, including a configuration to provide a vertical profile at the center of the strontium-90 plume in groundwater and a horizontal survey parallel to the river to the edge of the shoreline rip rap. The horizontal survey parallel with the shoreline shows the distribution of strontium-90 along the 100-N Area river shoreline and results coincide with the high concentrations from monitoring clams. The survey included a vertical profile of the center of the plume. These data will be used in remediation design. The Remediation and Closure Science Project also conducted integrated sampling of monitoring networks in the 300 Area, including groundwater, shoreline springs, river tubes, and near-shore river water. This sampling, performed in collaboration with the Groundwater Performance Assessment Project, was the most comprehensive project sampling event since 2001.

## 10.7.7 Groundwater Remediation Project: Strategic Planning, Public Involvement, and Database Management

T. W. Fogwell

During 2005, the Groundwater Remediation Project continued to closely align the scope of project work with similar site-wide DOE work and align the project with Hanford Site

end-state goals and remedial actions. Throughout the year, Groundwater Remediation Project personnel worked closely with the DOE and Hanford regulatory agencies to characterize, protect, remediate, and monitor Hanford Site groundwater. Project staff continued to coordinate and perform scientific research and technical development to support decision-making activities at Hanford and to manage Hanford's modeling and assessment capabilities aimed at cleaning up groundwater. The Integration Management team organized and coordinated several scientific and technology workshops that resulted in better scientific methods and technological advances being applied to the remediation of the Hanford Site. Also, the Data Access Network prototype was demonstrated. This tool allows for efficient retrieval and visualization of much of the data pertinent to writing reports and other documents at the Hanford Site.

***Strategic Planning***. The Groundwater Remediation Project team worked throughout 2005 to complete work in the project's master plan, *Hanford's Groundwater Plan: Accelerated Cleanup and Protection* (DOE/RL-2002-68). 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) and to update a more detailed *Plan for Central Plateau Closure* (CP-22319).

***Public Involvement***. During 2005, open meetings, held the first Monday of every month, gave the public, Tribal Nations, regulatory agencies, DOE, and other stakeholders an opportunity to discuss and resolve issues and identify upcoming events. Groundwater Remediation 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. The project's internet website (http://www.hanford.gov/cp/gpp/) provided information about the project's missions, a calendar of upcoming events, and links to a variety of valuable resources.

***Database Management***. The Groundwater Remediation Project manages several Hanford Site environmental databases. The Hanford Environmental Information System, as managed by the Groundwater Remediation Project, provides and integrates environmental databases. The environmental databases are required by the Tri-Party Agreement (Ecology et al. 1989).

The Hanford environmental databases include the Hanford Environmental Information System, Hanford Well Information Data System, Waste Information Data System, and Hanford Geographic Information System. These databases document and track the progress of Hanford Site cleanup. The Hanford Environmental Information System contains the date, time, location, and results from samples taken during activities such as field investigations and groundwater monitoring. The Hanford Well Information Data System contains the details (well history, survey information, as-built information, well construction, and well maintenance records) of the wells and boreholes on the site. The Waste Information Data System tracks the waste sites from discovery through cleanup. The Hanford Geographic Information System keeps track of the locations for waste sites, wells and boreholes, and other sampling site locations. Each of the databases is supported by several software applications for entering or retrieving information.

Database integration supports the sample and data management needs of the Groundwater Remediation Project and waste site remediation. Additionally, the Sample and Data Management Group provides support to Pacific Northwest National Laboratory and the Liquids Effluent Monitoring Information System, and support is currently being planned for the Plutonium Finishing Plant. Sample and data management personnel track samples and data from approval of a sample authorization form to loading of the analytical results from the laboratories into the Hanford Environmental Information System database. The project-specific database stores the data taken from the pump-and-treat and in situ redox manipulation facilities managed by the Groundwater Remediation Project. The data in the Hanford Environmental Information System and the project-specific databases are used by engineers and scientists to prepare the reports required by records of decision and Tri-Party Agreement milestones.

The virtual library portion of database integration makes available the information needed to estimate contamination migration and impact across the Hanford Site. In addition to providing easier user access to the Hanford Environmental Information System, the virtual library includes inventory, geophysical, geochemical, hydrological, and other relevant data. Much of the existing information of this nature is currently scattered throughout several sources, some of which

are not available across the Hanford Site. In addition, Fluor Hanford, Inc. and Pacific Northwest National Laboratory generate new information from their science and characterization activities. Key portions of this information are made available through the virtual library. The Data Access Network relies on some of the capabilities to facilitate access to appropriate databases.

# 10.8 Food and Farm Products Monitoring

R. W. Hanf

Food and farm products, including asparagus, cherries, leafy vegetables, milk, potatoes, tomatoes, alfalfa, honey, and wines, were collected routinely during 2005 at places around the Hanford Site (Figure 10.8.1) and samples were analyzed to monitor concentrations of radiological contaminants. Samples were obtained from:

- Locations generally downwind (east and southeast) of the site where airborne emissions or contaminated dust from the Hanford Site would potentially be deposited.
- Other locations generally upwind of and distant from the site to provide information on reference (background) contaminant levels.
- Farms irrigated with water taken from the Columbia River downstream of the site.

Results of sample analyses are used to assess the amounts of Hanford Site contaminants in food and farm products by: (1) comparing analytical results obtained from like samples collected from the same regions over long periods of time, (2) comparing analytical results from samples collected at downwind locations to results from samples obtained from generally upwind or distant locations, and (3) comparing analytical results from samples collected in areas irrigated with water withdrawn from the Columbia River downstream from the Hanford Site to analytical results from samples obtained from locations irrigated with water from other regional sources.

The concentrations of most radionuclides in food and farm product samples in 2005 were below levels that could be detected by the analytical laboratories. However, some contaminants potentially from Hanford (strontium-90, tritium) were found at low levels in some samples. These findings are discussed in the following sections. Data for naturally occurring potassium-40 and beryllium-7 are included to show the amounts of these natural materials in food products relative to concentrations of materials potentially from Hanford. Radiological doses associated with possible Hanford-produced contaminants that were detected are discussed in Section 10.14.

## 10.8.1 Collection of Food and Farm Product Samples

Some food and farm product samples are collected each year on quarterly or annual schedules. Others may only be sampled every 2 or 3 years. The rationale for sampling and analyzing some media more frequently than others is discussed in the Hanford Site Environmental Monitoring Plan (DOE/RL-91-50). The types and number of samples scheduled for collection in any given year are documented in the annual *Hanford Site Surveillance Master Sampling Schedule* (e.g., PNNL-15003). Typically, enough crop material for two samples is collected at each location. A portion of this material is submitted to a laboratory for analysis and the other portion is archived at Pacific Northwest National Laboratory in the event that the analytical laboratory needs additional material for confirmatory or follow-up analyses. Table 10.8.1 shows the products, sampling locations and frequencies, types of analyses, and numbers of samples collected and analyzed for radioactive contaminants during 2005. Most samples were obtained from commercial producers. Leafy vegetables and tomatoes were obtained from residential gardens because commercial growers could not be located.

## 10.8.2 Milk

During 2005, milk samples were obtained quarterly from three dairies in the East Wahluke sampling area and from

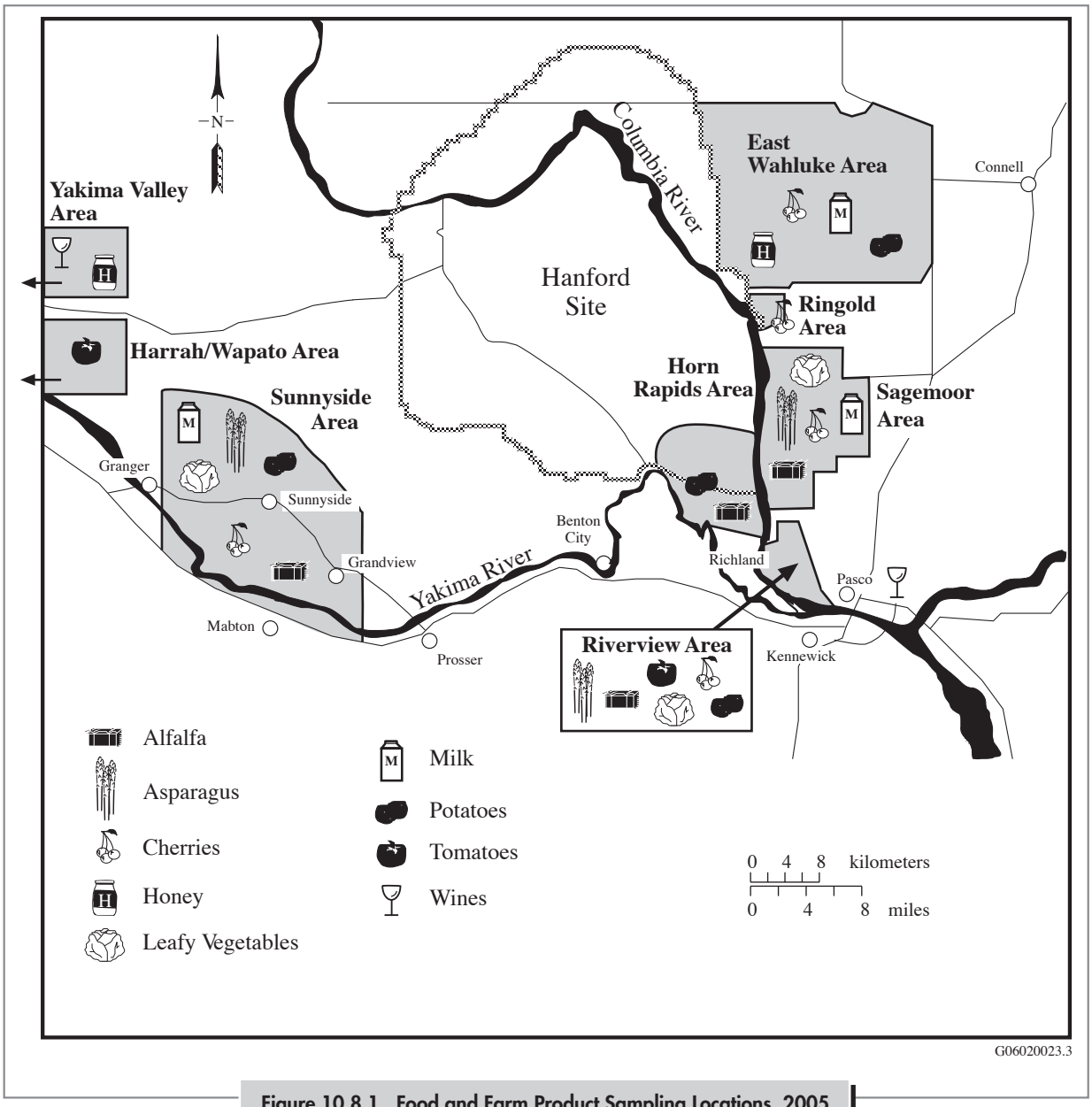



**Figure 10.8.1. Food and Farm Product Sampling Locations, 2005**

one in the Sunnyside sampling area. Quarterly samples were also obtained from a single dairy in the Sagemoor sampling area during the first three quarters of the calendar year and from two dairies during the last quarter of the year (Figure 10.8.1). The Sagemoor and East Wahluke sampling areas are located near the site perimeter and could potentially be affected by airborne contaminants from Hanford. The Sunnyside area is a reference location generally upwind of the site. If milk was obtained from more than one dairy within a sampling area, the milk samples were combined and the combined (composite) sample was analyzed. All samples were analyzed for gamma-emitting radionuclides, strontium-90, and tritium. Twice each year, additional milk was obtained from each area to monitor for iodine-129 (Table 10.8.1). Milk sampling was conducted because Hanford-produced radionuclides have the potential to move through the air-pasture-cow-milk or water-pasture-cow-milk food chains to humans. However, in recent years, the levels of Hanford-produced radiological contaminants in milk samples have diminished, and concentrations in samples obtained from

**Table 10.8.1. Sampling Locations, Frequencies, and Analyses Performed for Food and Farm Products Sampled Around the Hanford Site, 2005[a]**

| | Number of Locations | | | Types of Analyses and Number of Samples Analyzed | | | | |
|---|---|---|---|---|---|---|---|---|
| Product | Upwind | Downwind | Sampling Frequency | $^{3}H$ | Gamma | $^{90}Sr$ | $^{129}I$ | U |
| Alfalfa | 2 | 2 | BE | 0 | 5 | 5 | 0 | 0 |
| Asparagus | 1 | 2 | A | 0 | 3 | 3 | 0 | 3 |
| Cherries | 1 | 4 | TE | 0 | 5 | 5 | 0 | 0 |
| Honey | 1 | 1 | BE | 0 | 2 | 2 | 0 | 2 |
| Leafy vegetables | 1 | 2 | A and BE | 0 | 3 | 3 | 0 | 0 |
| Milk | 1 | 2 | Q and SA | 13 | 14 | 14 | 0 | 0 |
| Potatoes | 2 | 2 | A and TE | 0 | 4 | 4 | 0 | 0 |
| Tomatoes | 1 | 1 | A | 0 | 2 | 2 | 0 | 0 |
| Wine | 2 | 2 | A | 8 | 8 | 0 | 0 | 0 |

(a) Products may include multiple varieties for each category.
A = Annually.
BE = Biennially.
Q = Quarterly.
SA = Semiannually.
TE = Triennially.

dairies located downwind of the site are now similar to levels measured in samples obtained from the dairy located generally upwind of the site.

**Strontium-90** – Strontium-90 was not detected in any of the milk samples collected in 2005.

**Tritium** – Tritium was detected in all milk samples collected in 2005. Concentrations ranged from a maximum of 173 pCi/L (6.4 Bq/L) in a Sagemoor area sample to 17.6 pCi/L (0.6 Bq/L) in an East Wahluke area sample. Annual average concentrations for the three sampling areas were 88 pCi/L (3.2 Bq/L) for Sagemoor (n=6), 39 pCi/L (1.4 Bq/L) for East Wahluke (n=4), and 47 pCi/L (1.7 Bq/L) for Sunnyside (n=3). These concentrations are within the range of concentrations measured in these areas historically. In past years, tritium concentrations in Sagemoor area milk samples have been consistently higher than concentrations in samples from the East Wahluke and Sunnyside sampling areas (PNNL-14687). A reason for this has been proposed that suggests a relationship between tritium concentrations in Columbia River water used for irrigation in the Sagemoor area during past years and concentrations in groundwater used by some Sagemoor area dairies (PNNL-13910). While there is no standard for tritium in milk, the health-based standard for tritium in drinking water is an annual average of 20,000 pCi/L (740 Bq/L).

**Iodine-129** – Milk samples collected in 2005 were provided to an analytical laboratory for iodine-129 analyses but the analyses were not completed in time to include a data summary in this report.

**Cesium-137** – There were no manmade gamma emitters (including cesium-137) detected in milk samples collected and analyzed in 2005 (PNNL-15892, APP. 1).

**Potassium-40** – Potassium-40 is a naturally occurring radionuclide that is found in soil and in fertilizers applied to soil. It is the predominant radionuclide in foods and human tissues (Eisenbud 1987). Potassium-40 was detected in all milk samples collected in 2005. Concentrations ranged from a maximum of 1,520 pCi/L (56.2 Bq/L) in a Sagemoor area sample to a minimum of 729 pCi/L (26.9 Bq/L) in a Sunnyside area sample. Average concentrations for the individual areas were 1,330 pCi/L (49.2 Bq/L) for the Sagemoor area; 1,215 pCi/L (44.9 Bq/L) for the East Wahluke area; and 1,000 pCi/L (37 Bq/L) for the Sunnyside area.

**2004 Tritium Data** – Tritium data for the majority of the 2004 milk samples were received from the analytical laboratory too late to include in the 2004 site environmental report (PNNL-15222). Fourteen samples were submitted for analysis in 2004, but only 11 were analyzed. Eight samples collected early in the year were sent to one laboratory and six samples collected during the remainder of the year were sent to another laboratory. The Pacific Northwest National Laboratory halted work at the first laboratory because analyses and data were not provided in a timely manner.

Both laboratories used sensitive analytical methods to detect low levels of tritium, but the methods differed. The first laboratory used stable isotope analysis by gas source isotope ratio mass spectrometry. The second laboratory used an electrolytic enrichment technique. Results from both laboratories were similar for most samples.

Tritium was detected in all of the samples analyzed, and one sample from the Sagemoor sampling area that was analyzed at the first laboratory had a slightly elevated tritium concentration (229.5 ± 4.5 pCi/L [8.5 ± 0.16 Bq/L]). A re-analysis of this sample to confirm the result was not possible because of the work stoppage and change in laboratories just discussed. Of the other ten samples analyzed, five were from the Sagemoor area, three were from the Wahluke area, and two were from the Sunnyside area. The highest tritium concentration measured in these samples (65.8 ± 7.2 pCi/L [2.4 ± 0.2 Bq/L]) was seen in a sample from the Sunnyside area. This concentration was within the range of concentrations measured in milk in past years (PNNL-14687). While there is no standard for tritium in milk, the health-based standard for tritium in drinking water is an annual average of 20,000 pCi/L (740 Bq/L).

## 10.8.3 Asparagus

Samples of asparagus shoots were collected in the spring from commercial fields in the Riverview, Sagemoor, and Sunnyside sampling areas (Figure 10.8.1). Samples were analyzed for gamma-producing radionuclides, strontium-90, and uranium isotopes (Table 10.8.1). The only radionuclide detected in the samples was naturally occurring potassium-40. Concentrations of potassium-40 in all samples were less than 3 pCi/g (0.11 Bq/g) wet weight.

## 10.8.4 Cherries

Samples of cherries were collected in the spring from the Riverview, Sagemoor, East Wahluke, Ringold, and Sunnyside sampling areas (Figure 10.8.1). Samples were analyzed for gamma-producing radionuclides and strontium-90 (Table 10.8.1). The only radionuclide found in measurable quantities was naturally occurring potassium-40. Concentrations of potassium-40 in all samples were low (<3 pCi/g [0.11 Bq/g] wet weight).

## 10.8.5 Leafy Vegetables

Samples of leafy vegetables were collected during the summer from the Sagemoor, Riverview, and Sunnyside sampling areas (Figure 10.8.1). Leafy plants are sampled to monitor the potential deposition of airborne contaminants on agricultural food products. The Riverview area was also sampled because crops in this area were irrigated with Columbia River water withdrawn at places downstream of the Hanford Site. All samples were analyzed for gamma-producing radionuclides and strontium-90 (Table 10.8.1). Low concentrations (<3 pCi/g [0.11 Bq/g] wet weight) of naturally occurring potassium-40 were detected in the samples collected from all three areas.

## 10.8.6 Potatoes and Tomatoes

Samples of potatoes and tomatoes were collected from both upwind and downwind sampling areas (Figure 10.8.1) during the growing season. All samples were analyzed for gamma-emitting radionuclides and strontium-90. Tomato samples were also monitored for tritium (Table 10.8.1). The only radionuclide detected in the samples was naturally occurring potassium-40. Concentrations of potassium-40 in all samples were less than 5 pCi/g [0.185 Bq/g] wet weight.

## 10.8.7 Alfalfa

Samples of alfalfa were collected during the spring from the Sagemoor, Riverview, Sunnyside, and Horn Rapids sampling areas (Figure 10.8.1). Each sample was analyzed for gamma-emitting radionuclides and strontium-90

The only radionuclide potentially of Hanford origin detected in 2005 alfalfa samples was strontium-90, which was measured in the Sagemoor area and Sunnyside area samples. The maximum strontium-90 concentration (0.09 ± 0.07 pCi/g [0.003 ± 0.002 Bq/g]) was measured in Sunnyside. Naturally occurring potassium-40 was detected in all samples at an average concentration of 23.9 pCi/g (0.88 Bq/g). Beryllium-7, another naturally occurring radionuclide, was measured in four of the five samples analyzed. All concentrations were less than 2 pCi/g (0.07 Bq/g).

## 10.8.8 Honey

Two samples of honey were collected for radiological analysis in 2005. One was obtained from a producer in Yakima, who maintained hives in the Yakima area, and the other was from a beekeeper in Pasco, who had hives in the Franklin County area north of Pasco. All of the honey was produced in 2005. Samples were monitored for gamma-emitting radionuclides, uranium, plutonium, and strontium-90. The only radionuclide detected in both samples was naturally occurring potassium-40, at very low levels (<1 pCi/g [<0.037 Bq/g]).

## 10.8.9 Wines

Samples of a red wine and a white wine were obtained from a winery in the vicinity of Pasco and a winery near Yakima. The wines were produced from 2005 vintage grapes that were harvested in the fall from vineyards located just north of Pasco (downwind of the site) and just east of Yakima (generally upwind of the site) (Figure 10.8.1). Each wine was divided (split) into two samples and all eight samples were analyzed for gamma-emitting radionuclides and tritium (Table 10.8.1).

**Cesium-137** – There were no manmade gamma emitters (including cesium-137) detected in wine samples collected and analyzed in 2005 (PNNL-15892, APP. 1).

**Potassium-40** – Potassium-40, a naturally occurring gamma emitter, was measured in all wine samples collected in 2005. Concentrations in all samples ranged from 120 to 1,070 pCi/L (4.4 to 39.6 Bq/L). The average concentration for all samples was 652 pCi/L (24.1 Bq/L).

**Tritium** – All wine samples are generally analyzed each year for low levels of tritium using an electrolytic enrichment process and a liquid scintillation counter. However, tritium analyses on 2005 samples were not completed in time to include a data summary in this report.

# 10.9 Soil Monitoring

The following sections summarize soil monitoring efforts conducted on and around the Hanford Site in 2005. Radiological monitoring of soil is conducted onsite near facilities and operations, onsite away from facilities and operations (site-wide), and offsite at perimeter and distant locations and in nearby communities. Contaminant concentration data are used to:

- Determine the effectiveness of effluent monitoring and controls within facilities.
- Assess the adequacy of containment at waste disposal sites.
- Detect and monitor unusual conditions.
- Provide information on long-term radionuclide contamination trends in soil at undisturbed locations.

Soil samples have been collected on and around the Hanford Site for more than 50 years. Consequently, a large number of data documenting onsite and offsite levels of manmade radionuclides in Hanford Site soil exists. These data provide a baseline against which unplanned releases can be compared. For further information about these monitoring efforts, the programs that support them, and their purposes see Section 10.0 and DOE/RL-91-50.

## 10.9.1 Soil Monitoring Near Hanford Site Facilities and Operations

R. M. Mitchell

Soil samples are collected near facilities and operations to evaluate long-term trends in the environmental accumulation of radioactive materials and to detect potential migration and deposition of facility emissions. Contamination in soils can occur as the result of direct deposition from facility emissions, resuspension and movement of contaminants from radiologically contaminated surface areas, uptake of contaminants into plants whose roots contact below-ground waste, or translocation of buried waste by intruding animals.

### 10.9.1.1 Soil Sampling Near Hanford Site Facilities and Operations

Soil 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. The number and locations of soil samples collected during 2005 are summarized in Table 10.9.1. Only radionuclides with concentrations consistently above analytical detection

**Table 10.9.1. Number and Location of Soil Samples Collected Near Hanford Site Facilities and Operations, 2005**

| | Operational Area | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Number of Samples | 100-B/C | 100-F | 100-H | 100-K | 100-N | 200-West[a] | 200-East | 600 | 300 | 400 |
| 97 | 7 | 5 | 2 | 6 | 5 | 28 | 14 | 17 | 12 | 1 |

(a) Includes one sample collected at the Environmental Restoration Disposal Facility.

limits are discussed in this section. A comprehensive presentation of the analytical data from these samples can be found in PNNL-15892, APP. 2.

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. Soil samples were sieved in the field to remove rocks and plant debris and dried in the laboratory prior to analysis to remove residual moisture.

Hanford Site samples were analyzed for radionuclides expected to occur in the areas sampled (i.e., gamma-emitting radionuclides [Appendix F, Table F.1], strontium-90, uranium isotopes, and/or plutonium isotopes). The analytical results from Hanford Site samples were compared to concentrations of radionuclides measured in samples collected offsite in previous years at various sampling locations in Grant, Yakima, Walla Walla, Adams, Benton, and Franklin Counties (Figure 10.9.1). These comparisons were used to differentiate concentrations of Hanford-produced contaminants from levels resulting from natural sources and worldwide fallout.

Soil sampling results can be compared to the accessible soil concentrations (WHC-SD-EN-TI-070) developed specifically for use at the Hanford Site. These concentration values for radionuclides were established to ensure 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 foods, including animal products. The accessible soil concentration values are based on a radiation dose estimate scenario (WHC-SD-EN-TI-070) in which 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. These concentrations apply specifically to the Hanford Site with respect to onsite waste disposal operations and cleanup, decontamination, and decommissioning activities. A partial listing of these values is presented in Table 10.9.2 (see PNNL-15892, APP. 2 for a complete listing of concentrations).

### 10.9.1.2 Analytical Results for Soil Samples Collected Near Hanford Site Facilities and Operations

Some degree of variability is always associated with the collection and analysis of environmental samples. Therefore, variations in sample concentrations from year to year are expected. In general, radionuclide concentrations in soil samples collected from or adjacent to waste disposal facilities in 2005 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 2005 were higher within different operational areas when compared to concentrations measured in distant communities in previous years. Generally, the predominant radionuclides detected were activation and fission products in the 100-N Area, fission products in the 200 and 600 Areas, and uranium in the 300 and 400 Areas.

Cobalt-60, strontium-90, cesium-137, plutonium-239/240, and uranium were detected consistently in 2005 samples. Concentrations of these radionuclides were elevated near and within facility boundaries when compared to historical concentrations measured offsite at distant communities. Figure 10.9.1 shows the average concentrations of selected radionuclides in soil samples collected during 2005 and the preceding 5 years. Some individual levels demonstrate a high degree of variability, though overall trends are stable.

**Table 10.9.2. Accessible Soil Concentration Limits (pCi/g[a] dry wt.) for Selected Radionuclides**

| | $^{60}$Co | $^{90}$Sr | $^{137}$Cs | $^{234}$U | $^{235}$U | $^{238}$U | $^{239/240}$Pu |
|---|---|---|---|---|---|---|---|
| Accessible soil[b] concentration limits (WHC-SD-EN-TI-070) | 7.1 | 2,800 | 30 | 630 | 170 | 370 | 190 |

(a) To convert to international metric system units, multiply pCi/g by 0.037 to obtain Bq/g.
(b) Hanford soil that is not behind security fences.

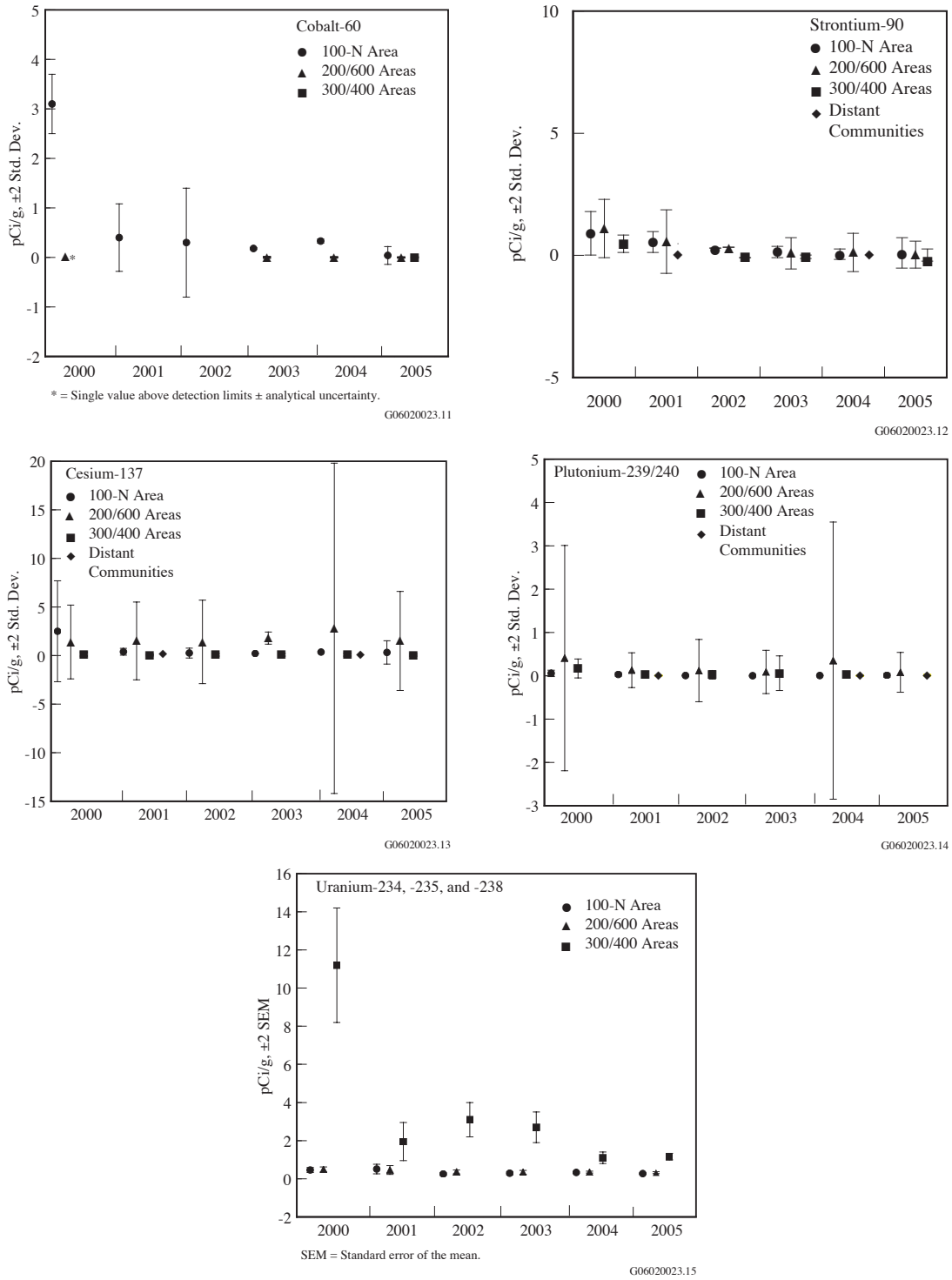



**Figure 10.9.1. Average Concentrations of Selected Radionuclides in Soil Samples Collected on the Hanford Site Near Facilities and Operations Compared to Those Collected in Distant Communities, 2000 through 2005. Radionuclide concentrations below analytical detection limits are not shown. As a result of figure scale, some uncertainties (error bars) are concealed by the point symbol.**

Table 10.9.3 provides a summary of selected radionuclides detected in near-facility soil samples collected and analyzed in 2005. The average and maximum results are reported for the six primary operational areas of interest along with comparative data for the preceding 5 years. Complete listings of radionuclide concentrations for all soil samples collected during 2005, as well as sampling location maps, can found in PNNL-15892, APP. 2.

Two routine soil samples were collected near waste disposal facilities in the 100-N Area in 2005. The average radionuclide concentrations detected in the samples collected from the 100-N Area are presented in Table 10.9.3, along with the averages for concentrations measured from 2000 through 2004 for trend comparisons. Cobalt-60, strontium-90, cesium-137, plutonium-239/240, and uranium-235 averages were somewhat lower than in preceding years, while averages for other radionuclides remained comparable.

Samples were collected from 14 locations in the 200-East Area in 2005. Average concentrations were comparable or somewhat lower than results reported for the previous years. Radionuclide levels for strontium-90, cesium-137, plutonium-238, plutonium-239/240, and uranium-238 were greater than those measured off the Hanford Site in previous years.

Twenty-eight locations were sampled in the 200-West Area in 2005. Of these, a single sample was collected at the Environmental Restoration Disposal Facility near the 200-West Area to determine the effectiveness of contamination controls (Table 10.9.1). Values reported for all radionuclides were comparable to historical ranges. Again, radionuclide levels reported for strontium-90, cesium-137, plutonium-238, plutonium-239/240, and uranium-238 were greater than those measured at distant communities in previous years.

Soil samples were collected from 12 locations in the 300 Area. Based on the summary data provided in Table 10.9.3, concentrations of uranium-234, uranium-235, and uranium-238 isotopes in 300 Area samples were lower than in previous years. These uranium concentrations did remain higher than those measured in the 100 and 200 Areas. The higher uranium levels were expected due to uranium releases to the environment during past fuel fabrication operations in the 300 Area.

A single soil sample is collected annually from the 400 Area. The average cesium-137 and uranium-235 concentrations measured in 2005 were lower than average concentrations measured in prior years.

A total of 17 soil samples were collected from the 600 Area, which consists of locations on the plateau surrounding the 200-East and 200-West Areas. As indicated in Table 10.9.3, average results reported for cesium-137, plutonium-238, plutonium-239/240, and strontium-90 were lower that averages reported for previous years. All calendar year 2005 results for cobalt-60 results were less than analytical detection limits. Average radionuclide concentrations for cesium-137, plutonium-238, and plutonium-239/240 were greater than those measured off the Hanford Site.

For non-routine soil sampling in support of the environmental restoration contractor projects in 2005, seven soil samples were collected at the remedial action project in the 100-B/C Area, five at the 100-F Area remedial action project, two at the 100-H Area site, and four at the 100-KR-1 and two at the 118-KR-1 remedial action projects in the 100-K Area. Analytical results from each of these locations were comparable to those observed at other near-facility sampling locations at Hanford. Table 10.9.4 provides a summary of selected analytical results for samples from these sites. All of the 2005 data are provided in PNNL-15892, APP. 2.

With regard to areas proximal to waste disposal facilities, cesium-137 and plutonium-239/240 were the radioisotopes most frequently detected in the routine soil samples; 97% and 42%, respectively. This agrees closely with the results reported for soil samples collected site-wide during 2004 (see Section 8.9.2 in PNNL-15222). In 2005, there was a slight reduction in average concentrations of both of these radionuclides in the 600 Area compared to historical levels. However, average cesium-137 and plutonium-239/240 levels were greater at locations near waste disposal facilities than those measured off the Hanford Site.

### 10.9.1.3 Investigations of Radioactive Contamination in Soil Near Hanford Site Facilities and Operations

S. M. McKinney and R. M. Mitchell

Investigations for radioactive contamination in soil were conducted in and near operational areas to monitor the

**Table 10.9.3. Concentrations of Selected Radionuclides (pCi/g dry wt.)[a] in Near-Facility Soil Samples, 2005 Compared to Previous Years**

| | | 2005 | | | | 2000-2004 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Number of | | | | Number of | | | |
| Radionuclide | Hanford Area | Samples | Detections[b] | Average[c] | Maximum[d] | Samples | Detections[b] | Average[c] | Maximum[d] |
| $^{60}Co$ | 100-N | 2 | 2 | 0.19 ± 0.27 | 0.32 ± 0.034 | 8 | 7 | 0.38 ± 0.73 | 0.99 ± 0.077 |
| | 200-E | 14 | 0 | 0.0012 ± 0.0085 | 0.0062 ± 0.011 | 73 | 0 | -0.00020 ± 0.0077 | 0.0099 ± 0.0076 |
| | 200-W[e] | 28 | 0 | 0.0014 ± 0.0072 | 0.0090 ± 0.0097 | 137 | 3 | 0.0012 ± 0.031 | 0.18 ± 0.020 |
| | 300 | 12 | 0 | -0.00012 ± 0.0072 | 0.0083 ± 0.0063 | 75 | 0 | -0.00034 ± 0.0052 | 0.0073 ± 0.0073 |
| | 400[f] | 1 | 0 | Not applicable | -0.0011 ± 0.0067 | 5 | 0 | 0.00071 ± 0.0043 | 0.0036 ± 0.0061 |
| | 600 | 17 | 0 | 0.00070 ± 0.0077 | 0.012 ± 0.013 | 81 | 2 | 0.000063 ± 0.0098 | 0.013 ± 0.013 |
| $^{137}Cs$ | 100-N | 2 | 2 | 0.21 ± 0.22 | 0.32 ± 0.059 | 8 | 6 | 0.41 ± 1.2 | 1.9 ± 0.25 |
| | 200-E | 14 | 14 | 1.6 ± 6.1 | 12.0 ± 2.0 | 73 | 72 | 2.2 ± 7.1 | 17 ± 3.0 |
| | 200-W[e] | 28 | 28 | 2.0 ± 5.6 | 13.0 ± 2.4 | 137 | 134 | 1.7 ± 3.7 | 9.0 ± 1.4 |
| | 300 | 12 | 10 | 0.053 ± 0.11 | 0.22 ± 0.044 | 75 | 64 | 0.078 ± 0.16 | 0.41 ± 0.066 |
| | 400[f] | 1 | 1 | Not applicable | 0.019 ± 0.0098 | 5 | 5 | 0.038 ± 0.084 | 0.12 ± 0.022 |
| | 600 | 17 | 16 | 0.43 ± 1.4 | 3.2 ± 0.52 | 81 | 79 | 1.3 ± 13.0 | 61.0 ± 9.7 |
| $^{238}Pu$ | 100-N | 2 | 0 | 0.0070 ± 0.032 | 0.023 ± 0.034 | 8 | 0 | -0.0022 ± 0.015 | 0.0075 ± 0.028 |
| | 200-E | 14 | 0 | 0.0074 ± 0.043 | 0.046 ± 0.036 | 73 | 1 | 0.0045 ± 0.032 | 0.047 ± 0.039 |
| | 200-W[e] | 28 | 2 | 0.0063 ± 0.039 | 0.038 ± 0.038 | 137 | 5 | 0.0067 ± 0.051 | 0.22 ± 0.066 |
| | 300 | 12 | 1 | 0.018 ± 0.089 | 0.16 ± 0.061 | 75 | 1 | 0.0019 ± 0.031 | 0.042 ± 0.037 |
| | 400[f] | 1 | 0 | Not applicable | 0.0038 ± 0.035 | 5 | 0 | -0.00012 ± 0.018 | 0.011 ± 0.021 |
| | 600 | 17 | 1 | 0.0089 ± 0.042 | 0.076 ± 0.039 | 81 | 3 | 0.035 ± 0.32 | 1.2 ± 0.25 |
| $^{239/240}Pu$ | 100-N | 2 | 0 | 0.0029 ± 0.020 | 0.013 ± 0.012 | 8 | 2 | 0.0091 ± 0.015 | 0.027 ± 0.015 |
| | 200-E | 14 | 3 | 0.012 ± 0.025 | 0.046 ± 0.023 | 73 | 30 | 0.014 ± 0.030 | 0.064 ± 0.029 |
| | 200-W[e] | 28 | 22 | 0.11 ± 0.59 | 1.6 ± 0.42 | 137 | 118 | 0.24 ± 1.6 | 8.5 ± 1.6 |
| | 300 | 12 | 3 | 0.015 ± 0.035 | 0.055 ± 0.026 | 75 | 25 | 0.047 ± 0.21 | 0.73 ± 0.15 |
| | 400[f] | 1 | 0 | Not applicable | 0.0019 ± 0.0066 | 5 | 0 | 0.0044 ± 0.0048 | 0.0075 ± 0.010 |
| | 600 | 17 | 9 | 0.091 ± 0.39 | 0.70 ± 0.20 | 81 | 46 | 0.25 ± 2.7 | 0.12 ± 3.1 |
| $^{90}Sr$ | 100-N | 2 | 0 | -0.19 ± 0.40 | 0.0090 ± 0.090 | 8 | 1 | 0.027 ± 0.37 | 0.37 ± 0.23 |
| | 200-E | 14 | 0 | -0.012 ± 0.30 | 0.20 ± 0.20 | 73 | 39 | 0.40 ± 1.1 | 2.8 ± 0.56 |
| | 200-W[e] | 28 | 6 | 0.12 ± 0.68 | 1.3 ± 0.29 | 137 | 72 | 0.42 ± 1.3 | 3.8 ± 0.76 |
| | 300 | 12 | 0 | -0.12 ± 0.26 | 0.15 ± 0.24 | 75 | 18 | 0.13 ± 0.57 | 1.0 ± 0.30 |
| | 400[f] | 1 | 0 | Not applicable | -0.051 ± 0.51 | 5 | 1 | 0.017 ± 0.50 | 0.41 ± 0.21 |
| | 600 | 17 | 1 | -0.096 ± 0.28 | 0.28 ± 0.20 | 81 | 23 | 0.17 ± 0.65 | 1.1 ± 0.25 |

**Table 10.9.3. (contd)**

| | | 2005 | | | | 2000-2004 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Number of | | | | Number of | | | |
| Radionuclide | Hanford Area | Samples | Detections[b] | Average[c] | Maximum[d] | Samples | Detections[b] | Average[c] | Maximum[d] |
| $^{234}U$ | 100-N | 2 | 2 | 0.13 ± 0.000043 | 0.13 ± 0.048 | 8 | 8 | 0.19 ± 0.11 | 0.26 ± 0.065 |
| | 200-E | 14 | 14 | 0.14 ± 0.061 | 0.20 ± 0.068 | 73 | 73 | 0.18 ± 0.10 | 0.36 ± 0.083 |
| | 200-W[e] | 28 | 28 | 0.16 ± 0.10 | 0.30 ± 0.090 | 137 | 137 | 0.18 ± 0.10 | 0.47 ± 0.10 |
| | 300 | 12 | 12 | 0.60 ± 1.6 | 2.5 ± 0.65 | 75 | 75 | 2.2 ± 13.0 | 43.0 ± 8.2 |
| | 400[f] | 1 | 1 | Not applicable | 0.12 ± 0.043 | 5 | 5 | 0.15 ± 0.073 | 0.20 ± 0.052 |
| | 600 | 17 | 17 | 0.16 ± 0.11 | 0.32 ± 0.096 | 81 | 81 | 0.21 ± 0.25 | 0.99 ± 0.20 |
| $^{235}U$ | 100-N | 2 | 1 | 0.0045 ± 0.013 | 0.011 ± 0.010 | 8 | 4 | 0.016 ± 0.017 | 0.029 ± 0.015 |
| | 200-E | 14 | 12 | 0.016 ± 0.015 | 0.029 ± 0.017 | 73 | 41 | 0.015 ± 0.019 | 0.055 ± 0.029 |
| | 200-W[e] | 28 | 17 | 0.014 ± 0.014 | 0.033 ± 0.019 | 137 | 89 | 0.015 ± 0.015 | 0.035 ± 0.021 |
| | 300 | 12 | 9 | 0.041 ± 0.095 | 0.16 ± 0.054 | 75 | 61 | 0.13 ± 0.74 | 2.4 ± 0.53 |
| | 400[f] | 1 | 0 | Not applicable | 0.0082 ± 0.0082 | 5 | 4 | 0.017 ± 0.017 | 0.026 ± 0.017 |
| | 600 | 17 | 10 | 0.012 ± 0.0089 | 0.022 ± 0.019 | 81 | 56 | 0.020 ± 0.029 | 0.086 ± 0.033 |
| $^{238}U$ | 100-N | 2 | 2 | 0.12 ± 0.020 | 0.13 ± 0.047 | 8 | 8 | 0.18 ± 0.094 | 0.25 ± 0.062 |
| | 200-E | 14 | 14 | 0.15 ± 0.065 | 0.23 ± 0.074 | 73 | 73 | 0.19 ± 0.10 | 0.38 ± 0.087 |
| | 200-W[e] | 28 | 28 | 0.15 ± 0.092 | 0.32 ± 0.096 | 137 | 137 | 0.19 ± 0.11 | 0.43 ± 0.099 |
| | 300 | 12 | 12 | 0.60 ± 1.7 | 2.6 ± 0.68 | 75 | 75 | 2.3 ± 13.0 | 44.0 ± 8.4 |
| | 400[f] | 1 | 1 | Not applicable | 0.13 ± 0.045 | 5 | 5 | 0.15 ± 0.085 | 0.22 ± 0.057 |
| | 600 | 17 | 17 | 0.15 ± 0.097 | 0.28 ± 0.084 | 81 | 81 | 0.20 ± 0.23 | 0.97 ± 0.20 |

(a) 1 pCi = 0.037 Bq.
(b) Number of samples with measurable concentrations of contaminant.
(c) Average ± two standard deviations of all samples analyzed.
(d) Maximum ± analytical uncertainty.
(e) Includes one sample collected at the Environmental Restoration Disposal Facility.
(f) Average cannot be calculated from a single sample.

**Table 10.9.4. Radionuclide Concentrations (pCi/g[a] dry wt.)[b] in Environmental Restoration Contractor Field Remediation Projects' Soil Samples, 2005**

| Site | Sample Location[c] | Sample Date | $^{60}$Co | $^{90}$Sr | $^{137}$Cs | $^{234}$U | $^{238}$U | $^{239/240}$Pu |
|---|---|---|---|---|---|---|---|---|
| ERDF | D146 | 05/18/2005 | -0.0042 ± 0.006 | 0.10 ± 0.19 | 0.14 ± 0.024 | 0.16 ± 0.056 | 0.15 ± 0.053 | 0.01 ± 0.009 |
| 100-B/C Area | D150 | 06/14/2005 | 0.0018 ± 0.007 | -0.29 ± 0.29 | 0.026 ± 0.014 | 0.15 ± 0.051 | 0.13 ± 0.044 | 0.00 ± 0.008 |
| | D153 | 01/27/2005 | 0.0018 ± 0.007 | -0.16 ± 0.36 | 0.25 ± 0.048 | 0.14 ± 0.053 | 0.15 ± 0.056 | 0.006 ± 0.013 |
| | D153 | 06/14/2005 | 0.0051 ± 0.010 | -0.083 ± 0.26 | 0.24 ± 0.042 | 0.13 ± 0.048 | 0.13 ± 0.047 | 0.11 ± 0.041 |
| | D160 | 06/14/2005 | 0.002 ± 0.006 | 0.056 ± 0.23 | 0.41 ± 0.068 | 0.13 ± 0.047 | 0.14 ± 0.049 | 0.015 ± 0.015 |
| | D161 | 01/27/2005 | -0.008 ± 0.008 | 0.23 ± 0.37 | 0.13 ± 0.023 | 0.13 ± 0.051 | 0.11 ± 0.044 | 0.004 ± 0.014 |
| | D161 | 06/14/2005 | 0.0001 ± 0.001 | -0.180 ± 0.25 | 0.36 ± 0.059 | 0.11 ± 0.043 | 0.12 ± 0.046 | 0.016 ± 0.013 |
| | D165 | 01/27/2005 | -0.0048 ± 0.006 | 0.004 ± 0.037 | 0.12 ± 0.022 | 0.092 ± 0.037 | 0.086 ± 0.034 | 0.011 ± 0.012 |
| 100-F Area | D154 | 06/14/2005 | 0.0026 ± 0.007 | -0.24 ± 0.24 | 0.11 ± 0.024 | 0.085 ± 0.036 | 0.091 ± 0.036 | 0.003 ± 0.005 |
| | D155 | 06/14/2005 | 0.0048 ± 0.006 | 0.27 ± 0.26 | 0.19 ± 0.033 | 0.097 ± 0.039 | 0.120 ± 0.046 | 0.002 ± 0.020 |
| | D168 | 06/14/2005 | -0.0038 ± 0.011 | 0.32 ± 0.29 | 0.20 ± 0.035 | 0.095 ± 0.036 | 0.091 ± 0.035 | 0.004 ± 0.01 |
| | D169 | 06/14/2005 | 0.015 ± 0.008 | 0.066 ± 0.26 | 0.25 ± 0.046 | 0.086 ± 0.034 | 0.100 ± 0.038 | 0.002 ± 0.004 |
| | D170 | 06/14/2005 | 0.006 ± 0.006 | -0.28 ± 0.28 | 0.053 ± 0.013 | 0.14 ± 0.049 | 0.130 ± 0.047 | 0.009 ± 0.01 |
| 100-H Area | D151 | 06/14/2005 | 0.0006 ± 0.006 | -0.24 ± 0.24 | 0.43 ± 0.07 | 0.075 ± 0.031 | 0.140 ± 0.048 | 0.013 ± 0.013 |
| | D152 | 06/14/2005 | 0.0013 ± 0.006 | -0.30 ± 0.30 | 0.22 ± 0.038 | 0.16 ± 0.046 | 0.130 ± 0.040 | 0.006 ± 0.009 |
| 118-K-1 | D166 | 02/17/2005 | 0.0036 ± 0.007 | -0.081 ± 0.53 | 0.10 ± 0.022 | 0.18 ± 0.059 | 0.160 ± 0.053 | 0.009 ± 0.01 |
| (100-K Area) | D167 | 02/17/2005 | 0.0079 ± 0.011 | -0.05 ± 0.5 | 0.19 ± 0.035 | 0.19 ± 0.055 | 0.210 ± 0.059 | 0.017 ± 0.015 |
| 100-KR-1 | D162 | 06/14/2005 | -0.0045 ± 0.007 | -0.25 ± 0.25 | 0.32 ± 0.059 | 0.18 ± 0.059 | 0.140 ± 0.049 | 0.008 ± 0.01 |
| (100-K Area) | D162 | 10/28/2005 | -0.0036 ± 0.008 | -0.32 ± 0.45 | -0.0004 ± 0.004 | 0.17 ± 0.059 | 0.170 ± 0.058 | -0.002 ± 0.011 |
| | D163 | 06/14/2005 | 0.012 ± 0.009 | -0.018 ± 0.18 | 0.32 ± 0.055 | 0.16 ± 0.056 | 0.150 ± 0.053 | 0.011 ± 0.01 |
| | D163 | 10/28/2005 | 0.020 ± 0.011 | 0.67 ± 0.48 | 0.16 ± 0.032 | 0.11 ± 0.042 | 0.110 ± 0.040 | 0.012 ± 0.012 |
| 100-NR-1 | D156 | 06/14/2005 | 0.014 ± 0.006 | -0.22 ± 0.22 | 0.092 ± 0.018 | 0.088 ± 0.036 | 0.096 ± 0.038 | -0.014 ± 0.014 |
| (100-N Area) | D158 | 06/14/2005 | 0.079 ± 0.012 | -0.42 ± 0.42 | 0.13 ± 0.026 | 0.15 ± 0.057 | 0.180 ± 0.063 | 0.011 ± 0.012 |
| | D159 | 06/14/2005 | 0.35 ± 0.038 | 0.83 ± 0.29 | 3.2 ± 0.55 | 0.12 ± 0.049 | 0.110 ± 0.046 | 0.019 ± 0.014 |
| Accessible Soil Concentration[d] | | | 7.1 | 2,800 | 30 | 630 | 370 | 190 |

(a) 1 pCi = 0.037 Bq.
(b) ± total analytical uncertainty.
(c) Sampling location code. See PNNL-15892, APP. 2.
(d) Hanford soil that is not behind security fences.
ERDF = Environmental Restoration Disposal Facility (200-West Area).

presence or movement of radioactive materials around areas of known or suspected contamination or to verify radiological conditions at specific project sites. All samples collected during investigations were field surveyed for alpha and beta/gamma radiation and some samples were analyzed at a laboratory to identify specific radionuclides. Most samples were disposed of without being analyzed. Generally, the predominant radionuclides in samples from the 100 and 200 Areas were strontium-90, cesium-137, and plutonium-239/240. Uranium-234, uranium-235, and uranium-238 were usually found in 300 Area samples.

During 2005, there were 20 instances of radiological contamination in soil samples collected during investigations. Of the 20, 14 were identified as speck contamination. One of the soil samples was submitted for radioisotopic analysis. Of the 20 locations, 15 were cleaned up, and the contaminated soil was disposed of onsite in burial grounds. At the remaining locations, the contamination levels did not exceed the radiological control limits for the sites and the soil was left in place. The number of soil investigation contamination incidents, range of radiation dose levels, and radionuclide concentrations in 2005 were generally within historical values (WHC-MR-0418).

The number and general locations of soil contamination incidents investigated during 2005 are summarized in Table 10.9.5. The number of contamination incidents investigated in 2005 and during the previous 11 years are provided in Table 10.9.6.

**Table 10.9.5. Number and Location of Soil Contamination Incidents Investigated Near Hanford Site Facilities and Operations, 2005**

| Location | Number of Incidents |
|---|---|
| 200-East Area | |
| tank farms | 5 |
| burial grounds | 1 |
| cribs, ponds, and ditches | 0 |
| fence lines | 0 |
| roads and railroads | 1 |
| unplanned release sites | 1 |
| underground pipelines | 2 |
| miscellaneous | 1 |
| 200-West Area | |
| tank farms | 4 |
| burial grounds | 0 |
| cribs, ponds, and ditches | 0 |
| fence lines | 0 |
| roads and railroads | 0 |
| unplanned release sites | 0 |
| underground pipelines | 0 |
| miscellaneous | 0 |
| Cross-site transfer line | 1 |
| 200-North Area | 0 |
| 100 Areas | 3 |
| 300 Area | 0 |
| 400 Area | 0 |
| 600 Area | 1 |
| former 1100 Area | 0 |
| **Total** | **20** |

**Table 10.9.6. Annual Number of Soil Contamination Incidents Investigated Near Hanford Site Facilities and Operations, 1994 through 2005**

| Year | Number of Incidents | Year | Number of Incidents |
|---|---|---|---|
| 1994 | 94 | 2000 | 25 |
| 1995 | 73 | 2001 | 20 |
| 1996 | 37 | 2002 | 22 |
| 1997 | 51 | 2003 | 30 |
| 1998 | 41 | 2004 | 19 |
| 1999 | 42 | 2005 | 20 |

## 10.9.2 Soil Monitoring at Site-Wide and Offsite Locations

B. G. Fritz

Soil monitoring provides information on long-term contamination trends and baseline environmental radionuclide activities at undisturbed locations both on and off the Hanford Site (DOE/RL-91-50). Soil samples have been collected on and around the Hanford Site for more than 50 years. Consequently, a large database exists that documents onsite and offsite levels of manmade radionuclides in soil at specific locations. This database contains baseline data against which analysis results from unplanned contaminant releases from the Hanford Site can be compared. Routine radiological monitoring of soil at site-wide (onsite away from facilities and operations) and offsite locations was last conducted in 2004 (Section 8.9 in PNNL-15222) and is scheduled to be done again in 2007.

# 10.10 Vegetation Monitoring

Vegetation monitoring and control activities conducted on and around the Hanford Site in 2005 are summarized in the following sections. The sections include discussions on surveys and monitoring of Hanford Site plant populations, monitoring contaminants in perennial vegetation growing near facilities and operations on the site, and control of contaminated or unwanted vegetation on the site. Surveys and monitoring of plant populations are conducted to assess the abundance, vigor or condition, and distribution of populations and species. These data can be integrated with contaminant monitoring results and used to help characterize potential risks or impact to biota. Radiological monitoring of vegetation near onsite facilities and operations is done to determine the effectiveness of effluent monitoring and controls within facilities, to assess the adequacy of containment at waste disposal sites, and to detect and monitor unusual conditions. Site-wide and offsite vegetation samples (not collected in 2005 but scheduled for collection in 2007) are analyzed for information on atmospheric deposition of contaminants in uncultivated areas offsite and around operational areas onsite. These data provide a baseline against which unplanned releases can be compared. Vegetation management activities help to prevent, limit, or clean up contaminated plants or undesirable plant species. For further information about these monitoring and control efforts, the programs that support them, and their purposes, see Section 10.0 in this report or DOE/RL-91-50.

## 10.10.1 Plant Communities and Population Surveys on the Hanford Site

J. L. Downs, K. D. Hand, M. R. Sackschewsky, R. E. Durham, and R. K. Zufelt

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 (PNL-8942; PNNL-13688; Soll et al. 1999). Plant populations monitored on the site include taxa listed by Washington State as endangered, threatened, or sensitive (Section 10.12), 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.

### 10.10.1.1 Vegetation Cover Types and Habitats

Monitoring of the plant communities and cover types on the Hanford Site focuses on two main objectives: mapping the distribution and extent of major plant cover types on

the uplands and riparian areas on the site, and conducting periodic surveys to assess whether community composition and structure are changing. Mapping the distribution and extent of vegetation on the site provides important information on potential and existing habitats of sensitive or rare species as well as provides information regarding the presence of receptor species. The spatial data for upland habitats were updated to reflect changes in vegetation following the 24 Command Wildland Fire in 2000 (DOE/RL-2000-63). Spatial information for the riparian vegetation cover types was updated during 2003 and 2004 to provide a continuous map of the Benton County shoreline of the Hanford Reach. During 2005, further work was conducted to update the vegetation cover type information for the 100 Areas, 200 Areas, and 300 Area to better describe the current status of vegetation within the area boundaries. Numerous activities associated with cleanup including excavation, remediation, and restoration have influenced the vegetation inside the areas and at their fenced boundaries. Revisions of the vegetation cover type maps for these areas were accomplished using color aerial photography and ground surveys. Information from these surveys were also used to update maps depicting areas with highly valued biological resources (http://www.pnl.gov/ecomon/Veg/Veg.html). Periodic surveys of the frequency, cover, and number of species found on permanent monitoring plots provide information on trends or changes in species diversity, presence of invasive and key species, and the overall condition of the plant community and available habitat (see Section 10.11.1.3).

### 10.10.1.2 Rare Plant Monitoring

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, 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 habitats.

In June 2004, a population of coyote tobacco, *Nicotiana attenuata*, was discovered in a disturbed, open sand dune adjacent to the 618-10 burial ground, approximately 3.2 kilometers (2 miles) southeast of the 400 Area. A total of approximately 30 individual plants were found at that time, and the habitat in the vicinity of the population was designated a rare plant protection area to help conserve the population while cleanup of the 618-10 burial ground proceeds. The site was inspected several times during 2005 and no living plants were found. The disappearance of coyote tobacco from this area is presumably due to below normal rainfall during the year. Between January and May 2005, there were 5.9 centimeters (2.33 inches) of precipitation compared to 11.4 centimeters (4.5 inches) between January and May 2004 (normal for that period is 5.9 centimeters [3.12 inches]).

During September 2005, monitoring transects originally established to examine the condition and status of persistent sepal yellowcress (*Rorippa columbiae*) were revisited along the Columbia River shoreline near the 100-F Area. No specimens were located along the original transects. However, nearly 130 individual plants, in clumps of 5 to 40 individuals, were found nearby and up the river bank from the original population. Data that describe trends in plant numbers and the timing of growth for this species are of interest because large variations in population numbers have been observed. These variations are believed to be related to river-level fluctuations that inundate habitat for this species during a large part of the growing season. Additional data were gathered in 2005 to investigate this relationship by employing a survey grade real-time global positioning system to map the location and elevation of each plant clump found along the Columbia River shoreline near the 100-F Area.

## 10.10.2 Vegetation Monitoring Near Hanford Site Facilities and Operations

R. M. Mitchell

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 and potential migration of radioactive material. Contamination in vegetation can occur as the result of surface deposition of radioactive materials from other radiologically contaminated sources and/or by absorption of radionuclides by the roots of vegetation growing on or near waste disposal sites.

The number and location of vegetation samples collected near facilities and operations during 2005 are summarized in Table 10.10.1. Only those radionuclides with concentrations consistently reported above analytical detection limits are discussed in this section. A comprehensive presentation of the analytical data from these samples can be found in PNNL-15892, APP. 2.

### 10.10.2.1 Vegetation Sampling Near Hanford Site Facilities and Operations

Each sample (approximately 500 grams [16.1 ounces]) consisted of new-growth leaf cuttings taken from the available brushy, deep-rooted species (e.g., sagebrush and/or rabbitbrush) at a sampling location. Often, the sample consisted of a composite of several like members of the sampling site plant community to avoid decimation of any individual plant through overharvesting. Vegetation samples were dried prior to analyses and analytical results were reported on a dry weight basis.

Samples were analyzed for the radionuclides expected to occur in the areas sampled (i.e., gamma-emitting radionuclides [cobalt-60 and cesium-137], strontium-90, uranium isotopes, and/or plutonium isotopes). Selected analytical results were compared to concentrations in samples collected during 2004 by Pacific Northwest National Laboratory at offsite sampling locations in Yakima, Benton, and Franklin Counties (PNNL-15222; PNNL-15222, APP. 1). Comparisons can be used to determine the differences between contributions from site operations and remedial action sites and contributions from natural sources and worldwide fallout.

### 10.10.2.2 Analytical Results for Vegetation Samples Collected Near Hanford Site Facilities and Operations

Some degree of variability is always associated with the collection and analysis of environmental samples. Therefore, variations in sample concentrations from year to year are expected. In general, radionuclide concentrations in vegetation samples collected from, or adjacent to, waste disposal facilities in 2005 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 2005 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 and 600 Areas, and uranium in the 300 and 400 Areas.

Strontium-90, cesium-137, plutonium-238, plutonium-239/240, and uranium were detected consistently in samples taken in 2005. Concentrations of these radionuclides were elevated near and within facility boundaries compared

**Table 10.10.1. Number and Location of Vegetation Samples Collected Near Hanford Site Facilities and Operations in 2005**

| Number of Samples | Operational Area | | | | | |
|---|---|---|---|---|---|---|
| | 100-N | 200-East | 200-West | 300 | 400 | 600 |
| 62 | 4 | 9 | 22 | 10 | 1 | 16 |

to concentrations measured at distant communities. Figure 10.10.1 shows the average concentrations in vegetation samples collected near onsite facilities and operations during 2005 and the preceding 5 years and results for 2004 at distant communities. The results demonstrate a high degree of variability.

Table 10.10.2 provides a summary of selected radionuclides, which were detected in vegetation samples collected and analyzed in 2005 and/or in previous years. The average and maximum results are reported for the six primary waste facility/operational areas of interest along with comparative data for the preceding 5 years. A complete listing of radionuclide concentrations, as well as sampling location maps can found in PNNL-15892, APP. 2.

Four vegetation samples were collected at locations in the 100-N Area in 2005. Analytical results from these samples were generally lower than those observed in 100-N Area samples collected in previous years, with the exception of strontium-90, which remained essentially unchanged. The levels of strontium-90 in 100-N Area samples were higher than levels found in samples from the 200, 300, and 400 Areas. The radionuclide levels measured in 100-N Area vegetation in 2005 were greater than those measured in samples from distant communities in 2004.

Samples were collected from nine locations in the 200-East Area in 2005. Analytical results were somewhat lower or comparable to results reported for the previous years. Radionuclide levels for strontium-90, cesium-137, plutonium-238, plutonium-239/240, and uranium-238 were greater than those measured off the Hanford Site in 2004.

Twenty-two locations were sampled in the 200-West Area in 2005. Values reported for strontium-90, cesium-137, and plutonium isotopes were somewhat lower than those reported for previous years, while uranium concentrations were comparable to historical ranges. Again, radionuclide levels reported for strontium-90, cesium-137, plutonium-238, plutonium-239/240, and uranium-238 were greater than those measured at distant communities. Additionally, the maximum value reported for plutonium-239/240 (0.012 ± 0.006 pCi/g [0.0004 ± 0.0002 Bq/g]) for the 200-West Area was higher than the maximum site-wide value (0.0077 ± 0.0013 pCi/g [0.003 ± 0.00005 Bq/g]) collected east of the 200-West Area gate and reported by Pacific Northwest National Laboratory (see Section 8.10.3 in PNNL-15222) for the 2004 vegetation samples.

Vegetation samples were collected from ten locations in the 300 Area. Based on the summary data provided in Table 10.10.2, concentrations of uranium isotopes were somewhat lower than historical data, except for uranium-235, which was essentially the same. Uranium concentrations were higher than those measured in the 100 and 200 Areas. Additionally, the average value reported for uranium-238 (0.026 ± 0.06 pCi/g [0.001 ± 0.002 Bq/g]) in the 300 Area was higher than the maximum site-wide value (0.018 ± 0.001 pCi/g [0.0007 ± 0.00004 Bq/g]) reported by Pacific Northwest National Laboratory for the 2004 vegetation samples (see Section 8.10.3 in PNNL-15222). The higher uranium levels were expected due to uranium releases to the environment during past fuel fabrication operations in the 300 Area.

A single vegetation sample is collected annually from the 400 Area. In 2005, reported radionuclide concentrations were within the ranges of historical data.

A total of 16 vegetation samples were collected from the 600 Area, which consists of locations on the 200 Areas plateau surrounding the 200-East and 200-West Areas. As indicated in Table 10.10.2, results reported for strontium-90 and plutonium-239/240 isotopes were lower that those reported for previous years, while those for other radionuclides were similar to historical levels. Radionuclide levels for cesium-137, plutonium-238, and plutonium-239/240 were greater than those measured off the Hanford Site in 2004.

### 10.10.2.3 Investigations of Radioactive Contamination in Vegetation Near Hanford Site Facilities and Operations

S. M. McKinney and R. M. Mitchell

Investigations for radioactive contamination in vegetation were conducted in and near operational areas to monitor the presence or movement of radioactive materials around areas of known or suspected contamination or to verify radiological conditions at specific project sites. All samples collected during investigations were field surveyed for alpha

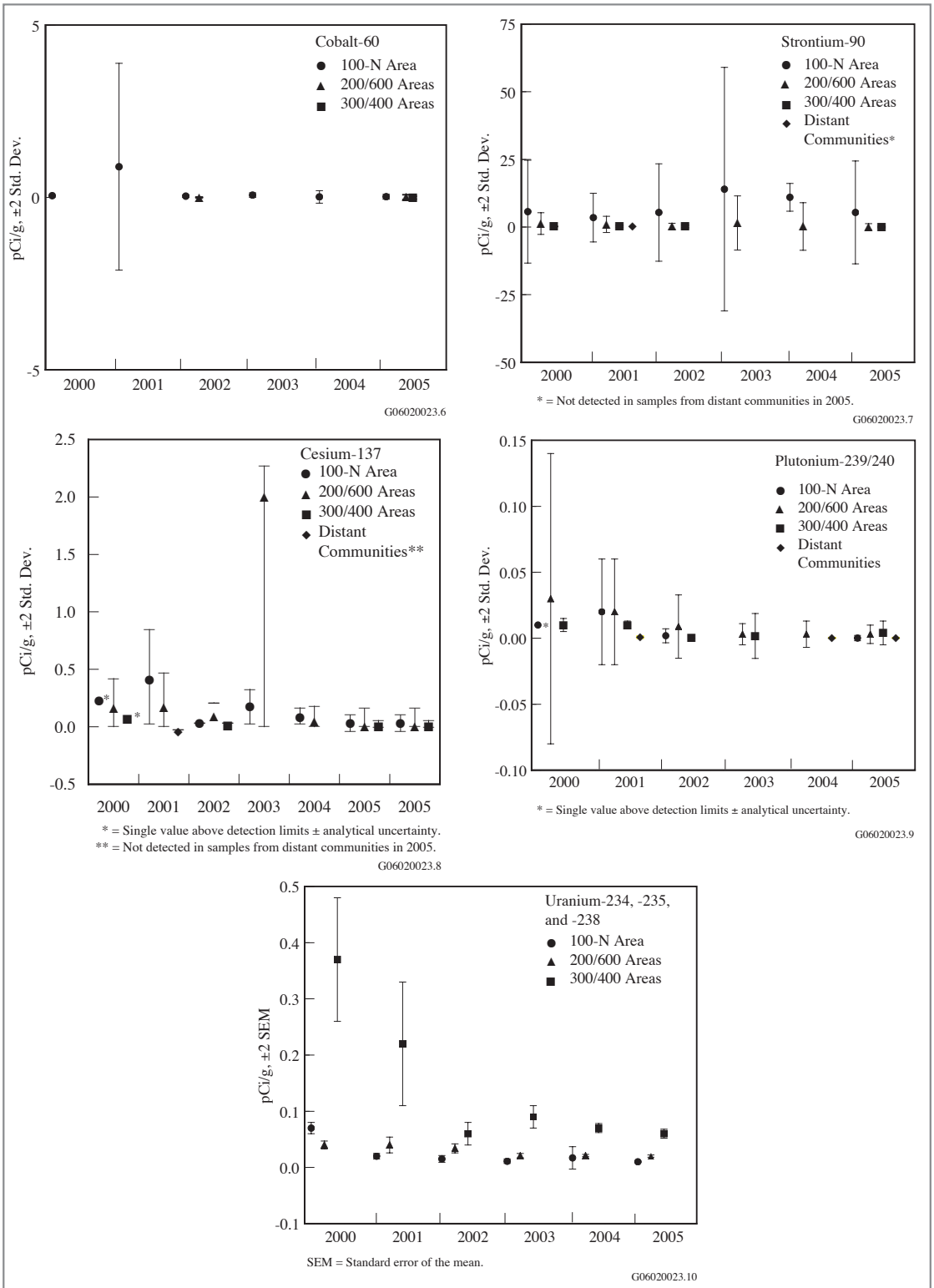



**Figure 10.10.1. Average Concentrations of Selected Radionuclides in Vegetation Samples Collected Near Hanford Site Facilities and Operations Compared to Those Collected in Distant Communities, 2000 through 2005. Radionuclide concentrations below analytical detection limits are not shown. As a result of figure scale, some uncertainties (error bars) are concealed by the point symbol.**

**Table 10.10.2. Concentrations of Selected Radionuclides (pCi/g dry wt.)[a] in Near-Facility Vegetation Samples, 2005 Compared to Previous Years**

| | | 2005 | | | | 2000-2004 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Number of | | | | Number of | | | |
| Radionuclide | Hanford Area | Samples | Detections[b] | Average[c] | Maximum[d] | Samples | Detections[b] | Average[c] | Maximum[d] |
| $^{60}$Co | 100-N | 4 | 0 | 0.023 ± 0.070 | 0.079 ± 0.089 | 31 | 9 | 0.17 ± 1.3 | 3.8 ± 0.33 |
| | 200-East | 9 | 0 | -0.0055 ± 0.050 | 0.036 ± 0.22 | 50 | 0 | 0.0061 ± 0.055 | 0.098 ± 0.24 |
| | 200-West | 22 | 0 | 0.013 ± 0.073 | 0.096 ± 0.099 | 118 | 1 | 0.0075 ± 0.14 | 0.72 ± 3.1 |
| | 300 | 10 | 0 | -0.0082 ± 0.041 | 0.015 ± 0.040 | 71 | 0 | -0.00064 ± 0.033 | 0.041 ± 0.044 |
| | 400 | 1 | 0 | -0.0084 ± 0.0 | -0.0084 ± 0.036 | 4 | 0 | -0.0047 ± 0.016 | 0.0051 ± 0.019 |
| | 600 | 16 | 0 | 0.0041 ± 0.068 | 0.095 ± 0.077 | 78 | 0 | 0.0016 ± 0.039 | 0.059 ± 0.094 |
| $^{137}$Cs | 100-N | 4 | 0 | 0.0064 ± 0.070 | 0.062 ± 0.047 | 31 | 8 | 0.088 ± 0.33 | 0.71 ± 0.16 |
| | 200-East | 9 | 1 | 0.047 ± 0.17 | 0.25 ± 0.29 | 50 | 19 | 0.082 ± 0.27 | 0.80 ± 0.30 |
| | 200-West | 22 | 3 | 0.036 ± 0.13 | 0.24 ± 0.16 | 118 | 51 | 0.17 ± 1.3 | 6.0 ± 4.3 |
| | 300 | 10 | 0 | -0.015 ± 0.037 | 0.0068 ± 0.044 | 71 | 2 | 0.0033 ± 0.041 | 0.071 ± 0.045 |
| | 400 | 1 | 0 | -0.017 ± 0.0 | -0.017 ± 0.039 | 4 | 0 | 0.0031 ± 0.012 | 0.0088 ± 0.020 |
| | 600 | 16 | 0 | 0.011 ± 0.083 | 0.14 ± 0.14 | 78 | 17 | 0.039 ± 0.14 | 0.44 ± 0.10 |
| $^{238}$Pu | 100-N | 4 | 0 | -0.000055 ± 0.0058 | 0.0041 ± 0.0049 | 31 | 0 | 0.012 ± 0.089 | 0.25 ± 0.25 |
| | 200-East | 9 | 0 | -0.0022 ± 0.017 | 0.0073 ± 0.018 | 50 | 2 | 0.0019 ± 0.020 | 0.033 ± 0.017 |
| | 200-West | 22 | 2 | 0.00092 ± 0.0092 | 0.010 ± 0.0061 | 118 | 1 | 0.0018 ± 0.024 | 0.096 ± 0.044 |
| | 300 | 10 | 0 | 0.0043 ± 0.0071 | 0.011 ± 0.019 | 71 | 2 | 0.0025 ± 0.017 | 0.050 ± 0.017 |
| | 400 | 1 | 0 | 0.0048 ± 0.0 | 0.0048 ± 0.020 | 4 | 0 | -0.00072 ± 0.0097 | 0.0051 ± 0.015 |
| | 600 | 16 | 0 | 0.0035 ± 0.021 | 0.024 ± 0.021 | 78 | 1 | 0.0022 ± 0.017 | 0.026 ± 0.016 |
| $^{239/240}$Pu | 100-N | 4 | 0 | 0.00014 ± 0.0021 | 0.0014 ± 0.0028 | 31 | 5 | 0.0035 ± 0.027 | 0.055 ± 0.018 |
| | 200-East | 9 | 1 | 0.00063 ± 0.0074 | 0.0051 ± 0.0047 | 50 | 5 | 0.0033 ± 0.012 | 0.040 ± 0.014 |
| | 200-West | 22 | 7 | 0.0042 ± 0.0043 | 0.010 ± 0.0058 | 118 | 49 | 0.012 ± 0.046 | 0.22 ± 0.051 |
| | 300 | 10 | 2 | 0.0040 ± 0.0092 | 0.016 ± 0.010 | 71 | 9 | 0.0019 ± 0.0069 | 0.013 ± 0.0074 |
| | 400 | 1 | 0 | 0.0012 ± 0.0 | 0.0012 ± 0.0024 | 4 | 0 | 0.0013 ± 0.0040 | 0.0045 ± 0.0054 |
| | 600 | 16 | 1 | 0.0014 ± 0.0066 | 0.0059 ± 0.0058 | 78 | 17 | 0.0048 ± 0.018 | 0.052 ± 0.017 |
| $^{90}$Sr | 100-N | 4 | 1 | 5.4 ± 19.0 | 22.0 ± 3.3 | 31 | 20 | 6.4 ± 31.0 | 68.0 ± 8.2 |
| | 200-East | 9 | 3 | 0.070 ± 0.42 | 0.42 ± 0.15 | 50 | 30 | 1.0 ± 3.9 | 12.0 ± 1.8 |
| | 200-West | 22 | 4 | 0.27 ± 1.6 | 3.3 ± 0.66 | 118 | 53 | 0.73 ± 8.7 | 25.0 ± 3.8 |
| | 300 | 10 | 0 | 0.0045 ± 0.22 | 0.15 ± 0.14 | 71 | 19 | 0.079 ± 0.40 | 0.88 ± 0.18 |
| | 400 | 1 | 0 | 0.17 ± 0.0 | 0.17 ± 0.14 | 4 | 2 | 0.088 ± 0.19 | 0.17 ± 0.10 |
| | 600 | 16 | 0 | 0.0040 ± 0.16 | 0.15 ± 0.14 | 78 | 28 | 0.32 ± 1.5 | 4.8 ± 0.72 |

**Table 10.10.2. (contd)**

| Radionuclide | Hanford Area | 2005 Number of Samples | 2005 Number of Detections[b] | 2005 Average[c] | 2005 Maximum[d] | 2000-2004 Number of Samples | 2000-2004 Number of Detections[b] | 2000-2004 Average[c] | 2000-2004 Maximum[d] |
|---|---|---|---|---|---|---|---|---|---|
| $^{234}U$ | 100-N | 4 | 1 | 0.0050 ± 0.0023 | 0.0062 ± 0.0055 | 31 | 22 | 0.014 ± 0.040 | 0.12 ± 0.088 |
| | 200-East | 9 | 5 | 0.011 ± 0.011 | 0.022 ± 0.011 | 50 | 42 | 0.012 ± 0.013 | 0.041 ± 0.015 |
| | 200-West | 22 | 20 | 0.012 ± 0.0087 | 0.027 ± 0.012 | 118 | 98 | 0.017 ± 0.019 | 0.054 ± 0.017 |
| | 300 | 10 | 10 | 0.033 ± 0.068 | 0.13 ± 0.035 | 71 | 68 | 0.082 ± 0.39 | 1.4 ± 0.27 |
| | 400 | 1 | 0 | 0.0066 ± 0.0 | 0.0066 ± 0.0064 | 4 | 4 | 0.013 ± 0.0064 | 0.016 ± 0.0083 |
| | 600 | 16 | 11 | 0.0092 ± 0.0080 | 0.017 ± 0.0095 | 78 | 63 | 0.013 ± 0.015 | 0.036 ± 0.013 |
| $^{235}U$ | 100-N | 4 | 0 | 0.0026 ± 0.0034 | 0.0046 ± 0.0051 | 31 | 4 | 0.0060 ± 0.022 | 0.063 ± 0.063 |
| | 200-East | 9 | 2 | 0.0033 ± 0.0045 | 0.0057 ± 0.0049 | 50 | 8 | 0.0034 ± 0.0052 | 0.011 ± 0.0073 |
| | 200-West | 22 | 4 | 0.0036 ± 0.0034 | 0.0069 ± 0.0055 | 118 | 38 | 0.0042 ± 0.0057 | 0.015 ± 0.0078 |
| | 300 | 10 | 2 | 0.0034 ± 0.0040 | 0.0068 ± 0.0051 | 71 | 38 | 0.0084 ± 0.022 | 0.075 ± 0.023 |
| | 400 | 1 | 0 | 0.0036 ± 0.0 | 0.0036 ± 0.0043 | 4 | 2 | 0.0036 ± 0.0049 | 0.0073 ± 0.0057 |
| | 600 | 16 | 3 | 0.0040 ± 0.0071 | 0.013 ± 0.0084 | 78 | 20 | 0.0040 ± 0.0064 | 0.014 ± 0.0080 |
| $^{238}U$ | 100-N | 4 | 4 | 0.0058 ± 0.0036 | 0.0088 ± 0.0056 | 31 | 16 | 0.0089 ± 0.025 | 0.073 ± 0.066 |
| | 200-East | 9 | 4 | 0.0083 ± 0.0064 | 0.014 ± 0.0078 | 50 | 40 | 0.010 ± 0.010 | 0.024 ± 0.011 |
| | 200-West | 22 | 19 | 0.0095 ± 0.0098 | 0.025 ± 0.012 | 118 | 106 | 0.014 ± 0.018 | 0.060 ± 0.027 |
| | 300 | 10 | 10 | 0.026 ± 0.060 | 0.11 ± 0.031 | 71 | 63 | 0.076 ± 0.39 | 1.4 ± 0.27 |
| | 400 | 1 | 1 | 0.0041 ± 0.0 | 0.0041 ± 0.0038 | 4 | 4 | 0.0088 ± 0.0080 | 0.015 ± 0.0079 |
| | 600 | 16 | 9 | 0.0083 ± 0.011 | 0.025 ± 0.012 | 78 | 61 | 0.010 ± 0.012 | 0.024 ± 0.011 |

(a) 1 pCi = 0.037 Bq.
(b) Number of samples with measurable concentrations of contaminants.
(c) Average ± two standard deviations.
(d) Maximum ± analytical uncertainty.

and beta/gamma radiation and some samples were analyzed at a laboratory to identify specific radionuclides. Most samples were disposed of without being analyzed. Generally, the predominant radionuclides in samples from the 100 and 200 Areas were strontium-90, cesium-137, and plutonium-239/240. Uranium-234, uranium-235, and uranium-238 were usually found in 300 Area samples.

During 2005, radiological contamination was found in 65 vegetation samples collected during investigations. Sixty-two samples were tumbleweeds (Russian thistle) or tumbleweed fragments, three samples were crested wheatgrass, and one sample was listed as vegetation. Only one sample (crested wheatgrass) was analyzed for specific radionuclides. Samples not sent to the laboratory for analysis were disposed of onsite in burial grounds. A discussion of vegetation control efforts at Hanford during 2005 is provided in Section 10.10.4.

The number and general locations of vegetation contamination incidents investigated during 2005 are summarized in Table 10.10.3. The numbers of contamination incidents investigated in 2005 and during the previous 11 years are provided in Table 10.10.4.

| Location | Number of Incidents |
|---|---|
| 200-East Area | |
| tank farms | 14 |
| burial grounds | 8 |
| cribs, ponds, and ditches | 1 |
| fence lines | 4 |
| roads and railroads | 1 |
| unplanned release sites | 2 |
| underground pipelines | 8 |
| miscellaneous | 0 |
| 200-West Area | |
| tank farms | 9 |
| burial grounds | 0 |
| cribs, ponds, and ditches | 11 |
| fence lines | 0 |
| roads and railroads | 0 |
| unplanned release sites | 3 |
| underground pipelines | 1 |
| miscellaneous | 0 |
| Cross-site transfer line | 1 |
| 200-North Area | 0 |
| 100 Areas | 1 |
| 300 Area | 0 |
| 400 Area | 0 |
| 600 Area | 1 |
| Former 1100 Area | 0 |
| **Total** | **65** |

## 10.10.3 Vegetation Monitoring at Site-Wide and Offsite Locations

B. G. Fritz

Monitoring of rabbitbrush and sagebrush leaves and stems provides information on atmospheric deposition of radioactive materials in uncultivated areas and at site-wide locations that could potentially be affected by contaminants from Hanford Site operations. Vegetation samples have been collected on and around the Hanford Site for more than 50 years. Data from these samples are maintained in a database to document onsite and offsite levels of manmade radionuclides in vegetation at specific locations. This database holds baseline data against which data from unplanned contaminant releases from the Hanford Site can be compared. Collection of vegetation samples at site-wide and offsite locations was last conducted in 2004 (Section 8.10 in PNNL-15222) and is scheduled to be done again in 2007.

**Table 10.10.4. Annual Number of Vegetation Contamination Incidents Investigated Near Hanford Site Facilities and Operations, 1994 through 2005**

| Year | Number of Incidents | Year | Number of Incidents |
|---|---|---|---|
| 1994 | 39 | 2000 | 66 |
| 1995 | 39 | 2001 | 31 |
| 1996 | 21 | 2002 | 16 |
| 1997 | 46 | 2003 | 32 |
| 1998 | 51 | 2004 | 60 |
| 1999 | 85 | 2005 | 66 |

## 10.10.4 Vegetation Control Activities

A. R. Johnson, R. C. Roos, J. G. Caudill, J. M. Rodriguez, and R. A. Schieffer

Vegetation control at Hanford consists of cleaning up contaminated plants that can be a threat to workers or the

public (i.e., either safety, health, or radiation protection), controlling or preventing the growth or re-growth of plants in contaminated or potentially contaminated areas on the site, and monitoring and removing unwanted (noxious) plant species.

### 10.10.4.1 Waste Site Remediation and Revegetation during 2005

Small sites with recurring radioactive contamination events caused by deep-rooted vegetation or burrowing animals were covered with Biobarrier® to prevent further invasion by biota. Biobarrier® is an engineered fabric impregnated with herbicide used to stop root penetration and serve as a physical barrier to burrowing insects. It was installed at seven sites in 2005 that totaled approximately 1,600 square meters (approximately 17,000 square feet). Tests at Hanford have shown this barrier is effective in preventing the spread of contamination. This brings the total number of sites at Hanford covered with Biobarrier® since 1999 to 32, with a total area of approximately 13,000 square meters (138,000 square feet).

Larger areas, including entire waste sites, were reseeded with bunchgrass to inhibit the growth of deep-rooted vegetation (e.g., tumbleweed). There were approximately 120 hectares (330 acres) overseeded with bunchgrass seed in 2005, including the 216-U-10 interim stabilized pond (i.e., filled and seeded with bunchgrass), the 216-Z-11 interim stabilized ditch, and along roads on the peripheries of waste sites and operational areas.

### 10.10.4.2 Noxious Weed Control

Noxious weeds are controlled on the site (between State Highway 240 and the Columbia River and along the paved road to the top of Rattlesnake Mountain) to prevent their spread and eliminate populations. 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 non-native, aggressively invasive, and hard to control. Entire native plant communities can be destroyed, altering ecosystems, unless control measures are taken. Control measures can be mechanical, chemical, cultural, or biological.

Ten plant species are on a high priority list for control at the Hanford Site. These species are described in the following paragraphs along with a summary of the 2005 control activities.

***Yellow Starthistle*** (*Centaurea solstitialis*). Yellow starthistle represents the most rapidly expanding weed infestation in the western United States. Since 1995, yellow starthistle has been the highest priority weed for Hanford's noxious weed control program because starthistle has the potential to invade virtually the entire Hanford Site, with dramatic impact to the ecology of the Hanford Site and neighboring lands.

Control measures for starthistle have included spot treatments and broadcast herbicide applications by ground equipment and aerial sprayers, biological control, and hand weeding in critical locations. Major populations near the Hanford town site have been reduced to scattered individual plants, mostly near live trees where aerial herbicide applications were not made. A sustained dry spell beginning in the middle of January 2005 killed most starthistle seedlings. The subsequent reduction in flowering and seed production was estimated at over 90%. With little-to-no plants or flowers produced during the year, populations were difficult to locate for control. One additional aerial herbicide application is scheduled for 2006. It is hoped that following the application, no additional aerial applications will be necessary for control of yellow starthistle on the Hanford Site. Individual plants or small populations will be treated with spot applications as they are identified.

Yellow starthistle seeds are known to remain viable for 10 years in the soil. The small number of seedlings that are found over much of the area of infestation indicates that the seed bank is being exhausted. Careful control efforts over the next few years should see yellow starthistle on the Hanford Site changed from a major infestation to a monitoring and eradication effort.

Biological control agents for yellow starthistle are widely distributed across the area of infestation. They have been highly effective during the early part of the flowering season. However, the adult phase of the control agent's annual life cycle is completed before the end of the flowering season. Consequently, flowers opening late in the season are largely spared the effects of insect predation.

***Rush Skeletonweed*** (*Chondrilla juncea*). Rush skeletonweed is scattered over large areas on the Hanford Site. Areas of dense rush skeletonweed infestation have largely been eliminated. Nevertheless, considerable rush skeletonweed remains as scattered individual plants. Populations of rush skeletonweed have increased on some areas burned in the 24 Command Wildland Fire in June 2000.

In 2005, control of rush skeletonweed focused on individuals scattered across the Hanford Site. Aerial applications of herbicide in 2004 and earlier have nearly eliminated surface growth of rush skeletonweed in the major population north of the Volpentest Hazardous Materials Management and Emergency Response (HAMMER) Training and Education Center. The deep and extensive root system of rush skeletonweed makes it very difficult to eliminate. The area north of the HAMMER facility will be monitored for sprouts emerging from roots remaining in the ground. It is expected that at least one additional aerial application will be needed to reduce the population of rush skeletonweed to the level that ground applications will be able to control the infestation.

Biological control agents are commonly found in rush skeletonweed on the Hanford Site. However, they have not significantly reduced plant populations.

***Medusahead*** (*Taeniatherum asperum*). Only one plant of medusahead was discovered in 2005. The area will continue to be monitored for several years to assure that the seed bank has been exhausted.

***Babysbreath*** (*Gypsophila paniculata*). Efforts to control babysbreath in 2005 concentrated on the main infestation (about 30 hectares [75 acres]) at the Hanford town site. Babysbreath is resistant to control by herbicides; however, the above-ground portion of the plant can be killed by some herbicides. By using these herbicides, flowering and population growth can be prevented. It is hoped that plants will ultimately be killed by continually removing the top portions through herbicide use.

***Dalmatian Toadflax*** (*Linaria genistifolia ssp. Dalmatica*). 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. Few plants continue to sprout. Sprouts and seedlings of the long-lived perennial plant will be eliminated as they are identified. No biological controls have been released at Hanford for dalmatian toadflax.

***Spotted Knapweed*** (*Centaurea maculosa*). Spotted knapweed at Hanford has been controlled so that sprouts or seedlings are rare. No sprouts or seedlings were found in 2005. The site will continue to be monitored for several years to be sure that viable seeds and roots have been eliminated from the soil. Cooperative efforts with neighboring landowners continues to eliminate spotted knapweed near the Hanford Site. No biological controls have been released specifically for spotted knapweed. Most biological controls for diffuse knapweed are also effective for spotted knapweed.

***Diffuse Knapweed*** (*Centaurea diffusa*). Aerial applications for control of diffuse knapweed have been effective in the past. Spot treatment of scattered individuals continues. The population of diffuse knapweed near the high water mark of the Columbia River has not actively been controlled by herbicides due to the biological sensitivity of the area. Biological controls are established and are monitored to observe effectiveness in controlling the weed.

***Russian Knapweed*** (*Acroptilon repens*). Biological controls for Russian knapweed are limited, and success in the arid climate of Hanford has been poor. Chemicals and techniques are being developed that promise to be effective with this difficult-to-control species.

***Saltcedar*** (*Tamarix spp.*). Several individual plants of saltcedar are found on the Hanford Site. Most are remaining from ornamental plantings near homes in the early part of the previous century. A few populations are the result of natural seed dispersal. Most individual plants south and west of the Columbia River have been eliminated. Those remaining alive continue to be treated with herbicide and will be monitored until they no longer show signs of life.

***Purple Loosestrife*** (*Lythrum salicaria*). Portions of the Columbia River riverbank and slews on the Hanford Site are monitored for purple loosestrife, and identified plants are controlled. Biological controls are effective for purple loosestrife; however, the population at Hanford is too small to sustain biological controls.

# 10.11 Fish and Wildlife Monitoring

The following sections summarize wildlife-related monitoring activities conducted on and around the Hanford Site in 2005. Included is information on surveys and monitoring of Hanford Site animal populations, discussions of selected species that occur at Hanford and are protected by state and federal laws and regulations, results of activities to measure levels of Hanford-produced contaminants in fish and wildlife tissues, and activities to manage organisms that might affect workers or have become radiologically contaminated.

Wildlife populations at Hanford are monitored to assess the abundance, condition, and distribution of populations of selected species. Data collection and analyses are integrated with contaminant monitoring efforts, and analytical results may be used to help characterize potential risks or impact to biota. They may also be used to support objectives for completing Hanford's waste management and environmental restoration missions. Information on threatened, endangered, and sensitive wildlife species is collected so the DOE can determine site compliance with the requirements of applicable state and federal laws and regulations.

This section provides current information on ecological monitoring of key animal species and populations found on the Hanford Site as well as results of contaminant monitoring. Population monitoring (Section 10.11.1) focuses on species of interest including fish and wildlife potentially hunted offsite and used for food, as well as special status species listed by Washington State or the U.S. Fish and Wildlife Service as threatened or endangered. Habitat and species characterization efforts (Section 10.11.2) target the near shore and riparian areas along the Columbia River. These habitats are important because of the potential for exposure to groundwater contaminants that are intersecting the river. A third area of interest includes ecological and contaminant monitoring of animal and plant populations on 35 long-term monitoring plots (Section 10.11.3) spread across Hanford. Data collected from surveys of these plots are used to evaluate both spatial and temporal site-wide population trends.

Fish and wildlife that inhabit the Columbia River and Hanford Site are routinely monitored for contaminants (Section 10.11.4) because they could potentially be exposed to Hanford-produced materials and be adversely affected, and because contaminated animals could be harvested and consumed by members of the public. When discovered, pest organisms are removed and disposed of to eliminate possible impact to worker safety and health and to control the spread of radioactive contamination (Section 10.11.5). For further information about these monitoring and pest control efforts and the programs that support them, see Section 10.0 of this report or DOE/RL-91-50.

## 10.11.1 Population Monitoring

Four fish and wildlife species on the Hanford Site are monitored annually by the Ecological Monitoring and Compliance Project: fall Chinook salmon (*Oncorhynchus tshawytscha*), steelhead (*Oncorhynchus mykiss*), bald eagles (*Haliaeetus leucocephalus*), and mule deer (*Odocoileus hemionus*). These species are of special interest to the public and to stakeholders. Monitoring consists of estimating numbers of fall Chinook salmon redds, surveying for steelhead redds, assessing bald eagle nesting, and conducting an inventory of mule deer. The species are monitored to assess abundance, condition, and distribution. All have the potential to be impacted by Hanford operations and yearly monitoring provides baseline data for ecological assessments.

## 10.11.1.1 Chinook Salmon

R. P. Mueller

Chinook salmon are an important resource in the Pacific Northwest; they are caught commercially and for recreation. Salmon are also of cultural importance to Native American tribes. Today, the most important natural spawning area in the main stem Columbia River for the fall Chinook salmon is found in 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 main stem 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 main stem Columbia River also have contributed to the increased number of redds found in the Hanford Reach.

The number of fall Chinook salmon redds in the Hanford Reach is estimated by aerial surveys. Over the years, the number of redds has increased from less than 500 in the early 1950s to a high in 2003 of nearly 9,400 (Figure 10.11.1). In the early 1990s, redd estimates declined to approximately one-third of the 1989 peak. The number of redds peaked again in 1996 and 1997 and then declined before starting to rise again in 2001. From 2001 to 2005, counts have been fairly consistent and have averaged approximately 8,000 redds per year.

The peak redd count for fall Chinook salmon in the Hanford Reach during the fall of 2005 was estimated at 7,890. This count was slightly lower than the 2004 count of 8,470 and near the 2000–2004 five-year average of 7,550. The main spawning areas in 2005 were similar to those in 2004 and, in the order of abundance were: the Vernita Bar (Area 10), Locke Island complex (Areas 4 and 5), areas upstream (Area 7) and downstream (Area 2) of Locke Island, and the Ringold area (Area 1) (Figure 10.11.2). The general locations of the spawning areas have not changed significantly over the past few years.

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

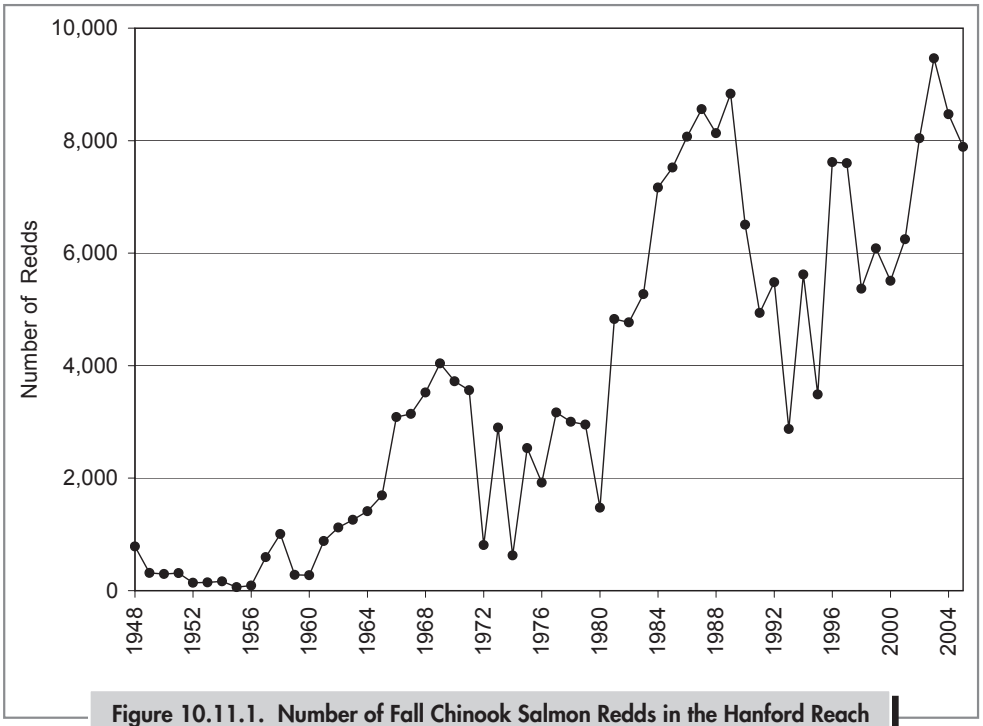



**Figure 10.11.1. Number of Fall Chinook Salmon Redds in the Hanford Reach of the Columbia River**

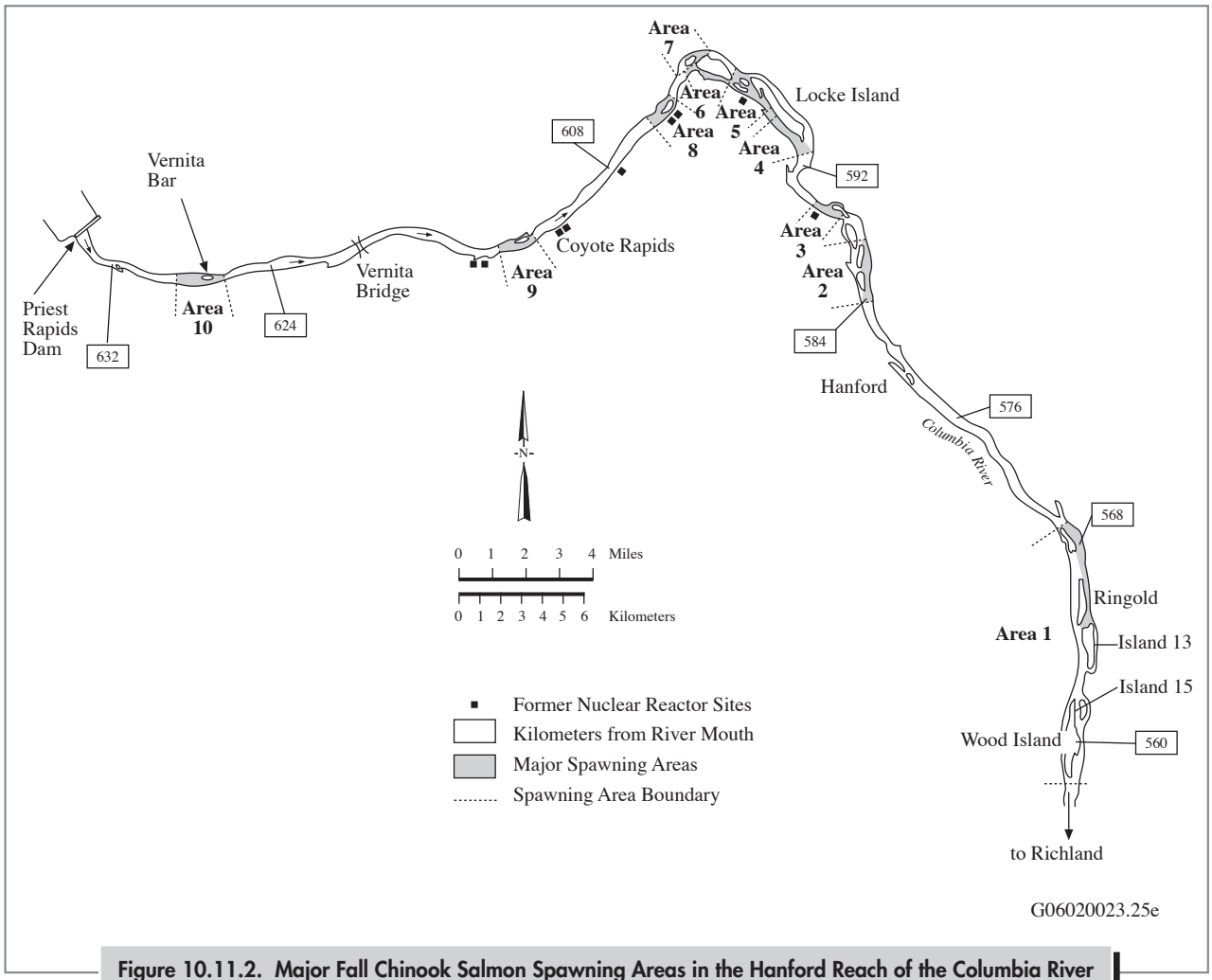



**Figure 10.11.2. Major Fall Chinook Salmon Spawning Areas in the Hanford Reach of the Columbia River**

correlated with adult salmon escapement estimates obtained by state and federal agencies within the Columbia River Basin (http://www.streamnet.org).

## 10.11.1.2 Steelhead

### R. P. Mueller

Steelhead within the Hanford Reach are part of the upper Columbia River Evolutionarily Significant Unit, and are listed as Endangered under the *Endangered Species Act* (NMFS 1997). In 2003, two steelhead redds were discovered near the 300 Area prompting establishment of a monitoring effort directed specifically at locating any steelhead redds in the Hanford Reach. In April 2005, two aerial surveys were conducted along the Columbia River from north Richland to the Vernita Bridge. During these surveys, two regions having characteristics associated with steelhead redds were found along the Franklin County shoreline within Area 1 (Figure 10.11.2); one was near Island 13 (river kilometer 566) and the second near Island 15 (river kilometer 562). These areas were also inspected with a boat-deployed video camera and approximately four steelhead redds were found near the Island 15 site but none at the Island 13 site. The 300 Area was extensively surveyed during 2005, but no indication of spawning activity was observed. No other areas within the survey area were identified as having characteristics associated with steelhead redds.

## 10.11.1.3 Bald Eagles

### R. E. Durham, C. A. Duberstein, and M. R. Sackschewsky

Bald eagles have wintered along the Hanford Reach for many years. In accordance with DOE's *Bald Eagle Site Management Plan for the Hanford Site, South-Central Washington* (DOE/RL-94-150), limited-access road closures within 800 meters (875 yards) of major perching and roost sites and within 400 meters (437 yards) of out of line-of-sight major perching and roost sites are put in force from November 15 through March 15. No Hanford worker access is allowed within 800 meters (875 yards) of an occupied bald eagle nest site once occupancy is determined. This area closure is not subject to any time constraints but remains in effect until the nest site is no longer occupied. The period from November 15 through March 15 generally encompasses the arrival and departure times of wintering bald eagles. However, nest-tending activities and territorial displays in the past have been observed as early as October with nest occupancy continuing to as late as August.

A pair of adult bald eagles returned during November 2005 to occupy the historical nest site in the vicinity of the former White Bluffs town site. As of March 15, 2006, bald eagles were still being observed onsite; however, the historical nest site was no longer occupied by a bald eagle pair. Biweekly surveys of other potential nest areas began in January 2006 and will continue throughout the nesting season or until bald eagles are no longer observed onsite.

Primary causes of eagle nest abandonment may include (1) adverse weather, (2) food availability, (3) human activity near the nest site, and (4) avian predator interactions (such as hazing and harassment by magpies and ravens). The causes of eagle nest abandonment along the Hanford Reach have not been determined.

## 10.11.1.4 Mule Deer

### K. D. Hand and J. A. Stegen

Population characteristics of mule deer on the Hanford Site have been monitored since 1994. Roadside surveys are conducted from mid-November to mid-January to assess age and sex ratios and the frequency of testicular atrophy in males. The survey route extends from near the 300 Area in the south to the 100-B/C Area in the north and is divided at the Hanford town site into north and south regions. Tiller and Poston (2000) found that there is little overlap in the home ranges of deer occupying these two regions.

Six surveys were conducted between mid-November 2005 and early-January 2006. A combined total of 559 deer observations were made over the six repeated surveys, which included multiple observations of the same animals in some cases. Individual animals were identified according to sex and age class (fawn or adult). For male deer, the presence of misshapen, velvet-covered antlers was used as an indicator of testicular atrophy.

Trends in the ratios of fawns to does over time can be used to monitor changes in mule deer population size and health. Data from the 2005–2006 surveys show a pattern of fawn-to-doe ratios that was similar to that observed in 2004. In 2005, the north region fawn-to-doe mean estimate was 27 fawns per 100 does while the south region mean estimate was 22 fawns per 100 does (Figure 10.11.3). These estimates are similar to those from 2004 when the mean estimates were 20 and 24 fawns per 100 does for the north and south regions, respectively. Hanford fawn-to-doe ratios for all survey years (1994–2005) are weighted averages, using the total number of fawns and does seen per survey as the weighting factors.

In the early 1990s, testicular atrophy and sterility were observed in some male mule deer on the Hanford Site (Tiller et al. 1997; PNNL-11518). Extensive investigation found no clear cause for these conditions (Tiller et al. 1997). Testicular atrophy in male mule deer is associated with abnormal antler growth manifest as misshapen, velvet-covered antlers, which can be observed in field surveys. The frequency of misshapen antlers in mule deer has ranged from a high of 17% in 1998 to a low of 0% in 2003 (Figure 10.11.4). The decrease from 1998 through 2003 was reversed in 2004 with 12.5% of the north region and 5% of the south region male deer affected. Data from the 2005–2006 surveys again show a decrease with only 2.9% of male deer in both the north and south regions affected. However, because small sample sizes may not fully reflect population conditions, these frequency estimates need to be interpreted with caution. Table 10.11.1 shows the total number of bucks observed and the number with antler abnormalities observed during roadside surveys between 1994 and 2005.

*

*No data collected.

**Figure 10.11.3. Estimates of the Number of Fawns per 100 Mule Deer Does in the Post-Hunting Period (winter) on the Hanford Site from 1994 through 2005 (mean ±1 standard error)**

*

*No data collected.

**Figure 10.11.4. Percent of Male Mule Deer on the Hanford Site from 1994 through 2005 Showing Signs of Abnormal Antler Growth (mean ±1 standard error)**

**Table 10.11.1. Total Number of Bucks and Number of Bucks Showing Signs of Antler Abnormality Observed in Hanford Site Roadside Surveys from 1994 through 2005**

| | North Region | | South Region | |
|---|---|---|---|---|
| Year | Total Number of Bucks | Number of Bucks with Antler Abnormality | Total Number of Bucks | Number of Bucks with Antler Abnormality |
| 1994 | 30 | 2 | 90 | 3 |
| 1995 | 19 | 0 | 22 | 1 |
| 1996 | 29 | 1 | 16 | 1 |
| 1997 | 24 | 1 | 51 | 1 |
| 1998 | 12 | 1 | 70 | 12 |
| 1999 | 37 | 1 | 80 | 10 |
| 2000 | 37 | 0 | 33 | 2 |
| 2001 | 50 | 0 | 68 | 1 |
| 2002 | ND | ND | ND | ND |
| 2003 | 11 | 0 | 17 | 0 |
| 2004 | 64 | 8 | 40 | 2 |
| 2005 | 71 | 2 | 68 | 2 |

ND = No data.

## 10.11.2 Habitat and Species Characterizations

Another aspect of ecological monitoring of the Hanford Site is characterizing habitats and associated species. This information is used to evaluate the biological resources on the Hanford Site and provide the data necessary to identify critical and priority habitats for special status species or communities and to establish mitigation criteria. These data can be integrated with contaminant monitoring data to assess potential impacts of Hanford contaminants to individuals and populations. Characterization tasks in 2005 involved an inventory of amphibian breeding habitats, sampling and describing aquatic macroinvertebrate communities, and evaluating mitigation criteria for sage sparrow (*Amphispiza belli*) habitat.

### 10.11.2.1 Amphibians

#### J. M. Becker and B. F. Miller

Amphibians may serve as key indicators of aquatic environmental health in ecological assessments (Welsh and Ollivier 1998; OEPA 2002; Collins and Storfer 2003). Before 2003, relatively little information existed on amphibian distributions and breeding sites along the Columbia River shoreline. Since 2003, Pacific Northwest National Laboratory personnel have conducted surveys along the Benton County shoreline of the Hanford Reach to locate potential and actual breeding sites and identify the amphibian species that use them. Amphibian breeding sites may occur in slough and backwater areas that are continuously inundated, or in temporary pools that lie within the main river channel that are flooded periodically by discharges from Priest Rapids Dam upstream.

Fifteen permanent and temporary pools were identified and surveyed during summer months in 2003, 2004, and 2005. These included eight shoreline pools, five pools in sloughs or backwater areas, and two pools in upland borrow pits adjacent to the 100-B/C Area. Larvae (egg masses and/or tadpoles) and adults of three amphibian species were found within or around these pools. Two species are native to the Columbia Basin: the Woodhouse's toad (*Bufo woodhousii*) (a Washington State monitor species thought to occur only within the Columbia Basin of the Pacific Northwest [Washington Herp Atlas 2002]), and the Great Basin spadefoot toad (*Spea intermontana*). The bullfrog (*Rana catesbeiana*) is an introduced species. Survey results indicated that Woodhouse's toads occupied the greatest number of pools over the three summer periods and were the most abundant species along the Hanford Reach, followed by the bullfrog and

Great Basin spadefoot toad (Table 10.11.2). Use of pools by Woodhouse's and Great Basin spadefoot toads appeared to be variable between years whereas use by bullfrogs increased (Table 10.11.2). Annual variations in the number of pools used by these species may be due to their proximity to and opportunistic use of existing and newly created (temporary) pools. Predation by bullfrogs may also cause variation in breeding and reproduction. Bullfrogs are known to consume other amphibians and are suspected of having displaced native amphibian species in other areas of the Pacific Northwest (Corkran and Thoms 1996; Environmental News Network 2000). Results from these surveys will be used to guide monitoring of habitat use and relative abundance of amphibian species along the Hanford Reach of the Columbia River.

Many environmental factors cause malformations in developing frogs and toads, including contaminant exposure, parasites and predators, ultraviolet light, and viral infections (Welsh and Ollivier 1998; Collins and Storfer 2003). In 2005, a pilot study was conducted to evaluate malformation rates in Woodhouse's toads at two Hanford Reach slough/backwater pools. Juvenile Woodhouse's toads were examined for spine, snout, eye, limb, foot, and toe malformations just after completing metamorphosis, while they were exiting the pools. The rate of malformations was relatively low in both pools, ranging from 1% to 2.6%. Accepted background malformation rates for amphibian generally range from 0% to 2% (Fort et al. 1999; Gardiner and Hoppe 1999; Pfeiffer 1999; Burkhart et al. 2000; Harris et al. 2001; Trust and Tangermann 2002).

## 10.11.2.2 Aquatic Macroinvertebrate Surveys

R. P. Mueller

The aquatic macroinvertebrate community in the Hanford Reach has been studied sparingly over the past 10 to 20 years (The Nature Conservancy 2003). From 2003 to 2005, periodic sampling of macroinvertebrate communities in the Hanford Reach was conducted by Pacific Northwest National Laboratory scientists in association with ecological risk assessments near Hanford Site facilities. Samples were usually collected using small-meshed kick-nets and by hand picking organisms from the substrates near the shoreline. The results of the sampling show that the macroinvertebate community has low diversity and species richness compared to smaller streams and is primarily composed of caddisfly and dipteran (midge, gnat, and fly) species. Species densities are generally greatest in the fall and early winter, when most macroinvertebrate eggs hatch.

A Shannon-Weiner Diversity Index was used to compare the diversity of benthic (bottom dwelling) communities sampled along the Hanford Reach. The Shannon-Weiner Diversity Index is a commonly used biotic index combining data on the number of species (richness) and the relative abundance of each species (evenness) in the sampled community. Higher index values are associated with communities that have high species richness (i.e., many taxa) and the abundance of each taxon is similar. Values for the index generally fall between zero and four with values less than one indicative of low richness and evenness that may be a result of environmental

**Table 10.11.2. Amphibian Species Observed in Pools Along the Shoreline of the Hanford Reach of the Columbia River from 2003 through 2005**

| | | Species,[a] Year, and Number of Pools Occupied | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Woodhouse's Toad | | | Great Basin Spadefoot Toad | | | Bullfrog | | |
| Pool Type | Number of Pools Surveyed | 2003 | 2004 | 2005 | 2003 | 2004 | 2005 | 2003 | 2004 | 2005 |
| Shoreline | 8 | 5 | 2 | 1 | 3 | 0 | 1 | 1 | 3 | 1 |
| Slough | 5 | 3 | 4 | 3 | 1 | 1 | 2 | 1 | 3 | 3 |
| Borrow pit | 2 | 2 | 1 | 1 | 2 | 1 | 2 | 1 | 0 | 2 |
| **Total** | **15** | **10** | **7** | **5** | **6** | **2** | **5** | **3** | **6** | **6** |

(a) Larvae (egg masses/tadpoles and/or adults).

perturbations. Values greater than three are indicative of robust communities and a "healthy" stream (Krebs 1994). However, this description is based on small streams with more organic input and may not best describe the overall health of larger rivers like the Columbia River. Other factors such as river level fluctuations, flow, and water temperatures influenced by flow rate, water stagnation, and geomorphology (potential pooling of water) might also influence the diversity in near-shore zone communities of the Columbia River.

At all sampling locations from the Vernita Bridge to the 300 Area, the macroinvertebrate community was dominated by midges and caddisfly larvae. Midges made up the majority of the community in the spring while caddisflies were dominant in the fall. The mean Shannon-Weiner Indexes ranged from 0.87 near the Vernita Bridge to 1.41 at the 100-N Area (Figure 10.11.5). The low value for the index reflects the limited number of taxa found at most sampling sites (median = 5) and the dominance of a few taxa.

## 10.11.2.3 Sage Sparrow Habitat Study

### C. A. Duberstein, M. A. Simmons, and M. R. Sackschewsky

Sage sparrows nest almost exclusively in sagebrush communities (Petersen and Best 1985; Rotenberry and Wiens 1989). On the Hanford Site, the presence of sage sparrows is used as an indicator of high quality habitat. The *Hanford Site Biological Resources Management Plan* (BRMaP; DOE/RL-96-32) quantified quality sage sparrow habitat as having sagebrush cover greater than 10% and annual grass cover (primarily cheatgrass [*Bromus tectorum*]) less than 25%. These standards are part of the mitigation criteria for areas that may be impacted during cleanup activities. Mitigation involves either preserving an area or substituting another area and restoring that area so that it meets the habitat standards set for sage sparrow.

In 2003, a 3-year study was started to evaluate the habitat standards set forth in the management plan to determine if these standards were adequate to protect sage sparrow habitats

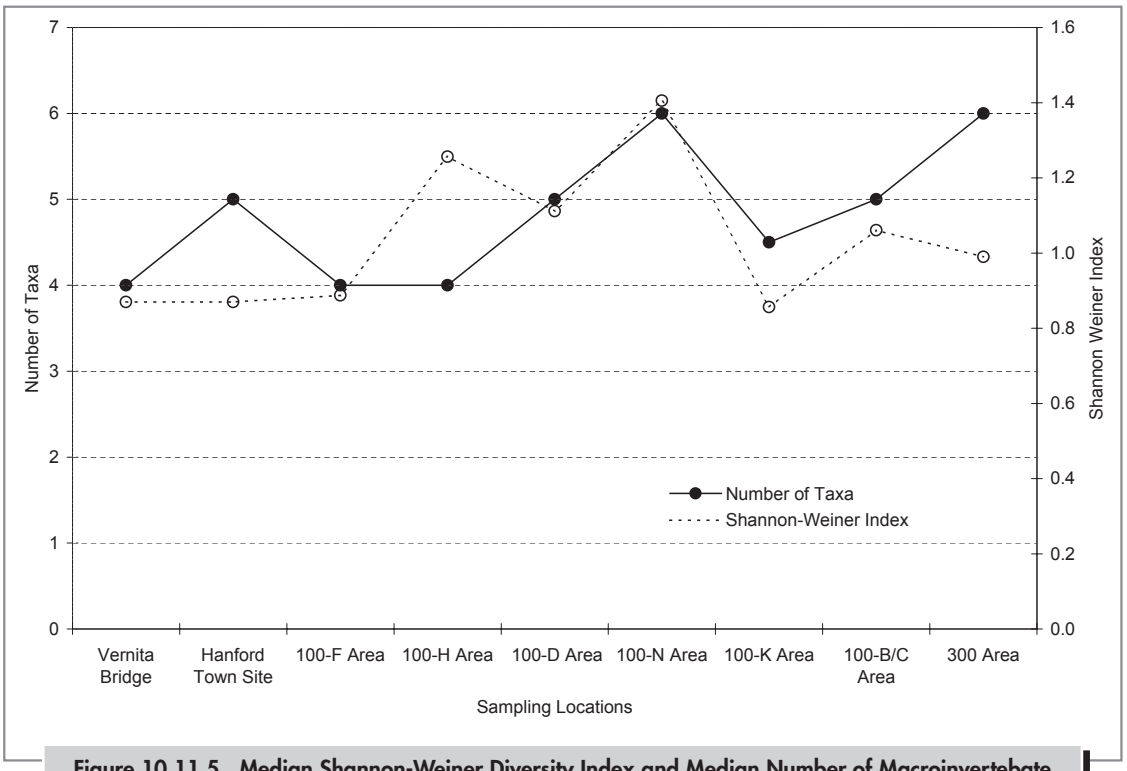



**Figure 10.11.5. Median Shannon-Weiner Diversity Index and Median Number of Macroinvertebate Taxa Collected throughout the Hanford Reach of the Columbia River, 2003–2005**

on the Hanford Site. Three tasks were identified: (1) quantify habitat characteristics (e.g., sagebrush cover, annual grass cover, amount of bare ground) of sage sparrow territories on the Hanford Site between State Highway 240 and the Columbia River, (2) develop a computer model showing the relationship between these habitat characteristics and sage sparrow territory size, and (3) collect additional data on sage sparrow density to test this relationship. The new relationship will be used to evaluate existing habitats on the Hanford Site for mitigation and protection of the sage sparrows and their habitat.

During fiscal years 2003 and 2004, the first two tasks were completed. Sage sparrow territories and vegetative features of the territories were measured, and a model was developed relating vegetative features to territory size. The resulting model related sage sparrow territory size to sagebrush cover, annual grass and forb cover, burn history, and patchiness. The last variable is a measure of the number and size of shrub patches. These four habitat characteristics define four general habitat types: (1) mature/undisturbed, (2) mature/disturbed, (3) recovering/undisturbed, and (4) recovering/disturbed. Mature and recovering refer to the amount of sagebrush cover, burn history, and patchiness, with a mature habitat having more cover, a longer time, in years, since the last fire, and larger continuous areas of sagebrush (i.e., less patchiness). A recovering habitat would be one that had burned more recently, has less sagebrush cover, and many small patches of sagebrush (i.e., more patchiness). Disturbance is a function of annual grass and forb cover with undisturbed sites having less annual grass and forb cover than disturbed sites.

From the work in fiscal years 2003 and 2004, smaller sage sparrow territories were consistently found in habitats characterized as mature/undisturbed. The largest sage sparrow territories were in recovering/disturbed habitats. All of these habitat types support sage sparrow territories; however, given trends noted in the data, mature/undisturbed habitats should support a higher density of birds than recovering/disturbed habitats.

To evaluate the assumed relationship between habitat type and density, in 2005, we measured male sage sparrow density and habitat attributes at 20 locations on central Hanford. Because males defend their territories by singing, they are easier to locate than females. At each of these locations, sagebrush cover, annual grass and forb cover, fire history, and patchiness were determined. Based on the habitat characteristics, each location was assigned to one of the four habitat types and compared to the measured male sage sparrow density. Results showed that sites designated as mature/undisturbed had a mean density of approximately 1 male sage sparrow per hectare, while recovering/disturbed habitats had a mean density of 0.3 male sage sparrow per hectare. Mature/disturbed and recovering/undisturbed had mean densities of 0.5 and 0.8 male sage sparrow per hectare, respectively (Figure 10.11.6).

Results from this study indicate that the current biological resources management plan mitigation thresholds for sage sparrow habitat may need to be revised. Nearly 30% (13 of 44) of the sage sparrow territories measured from 2003 through 2005 had less sagebrush cover than the biological resources management plan mitigation threshold of 10% sagebrush canopy cover. However, these areas all supported sage sparrow territories. In addition, over 40% of the occupied territories also exceeded the maximum threshold of 25% cheatgrass cover in the understory. Results from this study provide information to update the existing mitigation thresholds, and the model provides a method to assess the potential of shrub-steppe habitats on the Hanford Site to support sage sparrows.

## 10.11.3 Ecological Monitoring on Long-Term Plots

J. L. Downs, M. A. Chamness, C. A. Duberstein, K. D. Hand, and J. A. Stegen

Long-term monitoring plots, established as part of the Biological Resources Management Plan (DOE/RL-96-32), are surveyed periodically to determine the status of biological populations and resources on the Hanford Site. Thirty original plots, each with outside dimensions of 1 kilometer (0.62 mile) by 200 meters (219 yards) were surveyed during 1996 to characterize vegetation and bird use. Since 1996, five additional plots have been added to address particular habitats such as riparian areas and abandoned fields. Surveys have also been conducted on selected long-term monitoring plots to provide data to evaluate changes in plant and animal communities after fire and to measure the abundance and

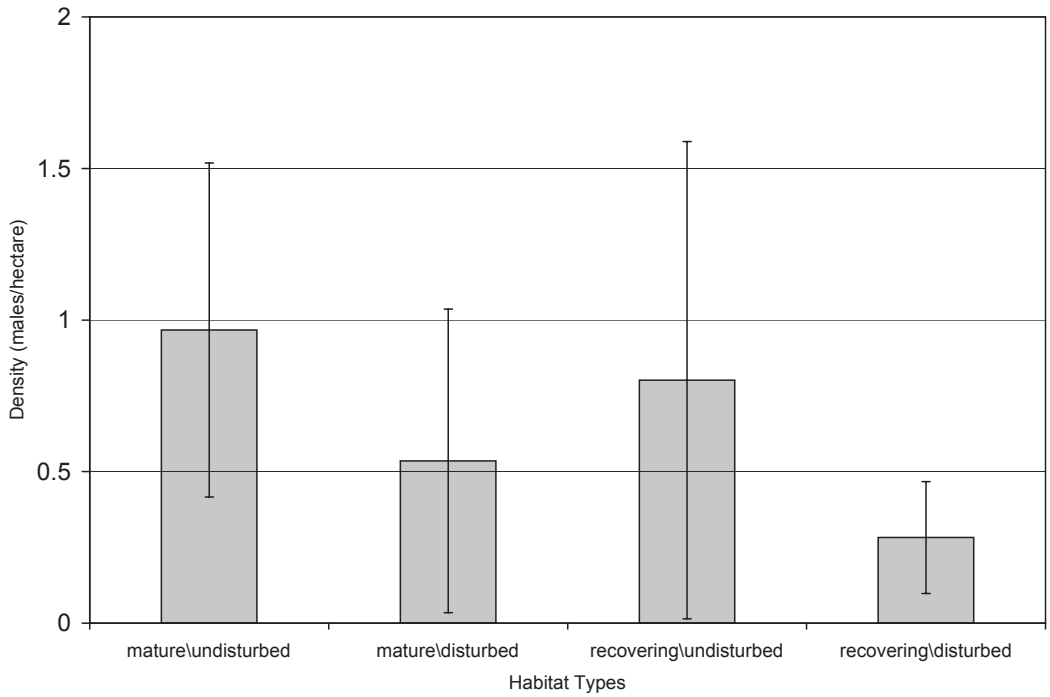



**Figure 10.11.6. Mean Densities of Male Sage Sparrows in Four Habitat Types Identified within the Shrub-Steppe Vegetation Communities of Central Hanford, 2005 (means are plotted with 95% confidence intervals)**

diversity of small mammals in priority habitats. As part of ongoing monitoring efforts, selected plots on the Hanford Central Plateau were sampled during 2005 with four main objectives: (1) evaluate habitat recovery after wildfire, (2) evaluate bird use in burned and unburned habitats, (3) evaluate the small mammal, reptile, and invertebrate communities existing in burned and unburned communities on the Central Plateau, and (4) concurrently measure contaminants of interest in the small mammals, lizards, invertebrates, and soil found in habitats adjacent to the 200 Areas. Data gathered to address the fourth objective provide integrated information on the biological resources and their potential exposure to Hanford-produced contaminants at areas near existing Hanford cleanup operations. These types of information are important supporting data for the ongoing ecological risk assessments at Hanford.

## 10.11.3.1 Vegetation

### J. L. Downs and M. A. Chamness

Vegetation canopy cover has been monitored on selected long-term monitoring plots to evaluate the effects of the 24 Command Wildland Fire (DOE/RL-2000-63) in summer 2000 and assess vegetation recovery. Canopy cover of herbaceous vegetation was measured on all plots in 1996. Five plots that were burned in 2000 have been surveyed periodically since the fire and were revisited in 2005 to evaluate trends in recovery of the vegetation canopy cover. One plot (plot 19) lying outside the burned areas was also revisited in 2005 to evaluate canopy cover. Data were not gathered on all plots during all years, but the canopy cover means for the herbaceous plants on the burned plots are presented here to demonstrate the trends in vegetation recovery compared to the unburned plot. On each of the plots, the canopy cover was measured in 20 quadrants along each of three 100-meter (109-yard) transects spaced systematically across the 20-hectare (50-acre) plot. These data were used to calculate an overall mean value for total herbaceous canopy cover and the canopy cover of cheatgrass, an invasive annual grass. Figure 10.11.7 indicates that the total herbaceous canopy cover was less in 2005 on all the plots – even the unburned plot had less herbaceous cover in 2005 than in 1996. The measured canopy cover of cheatgrass

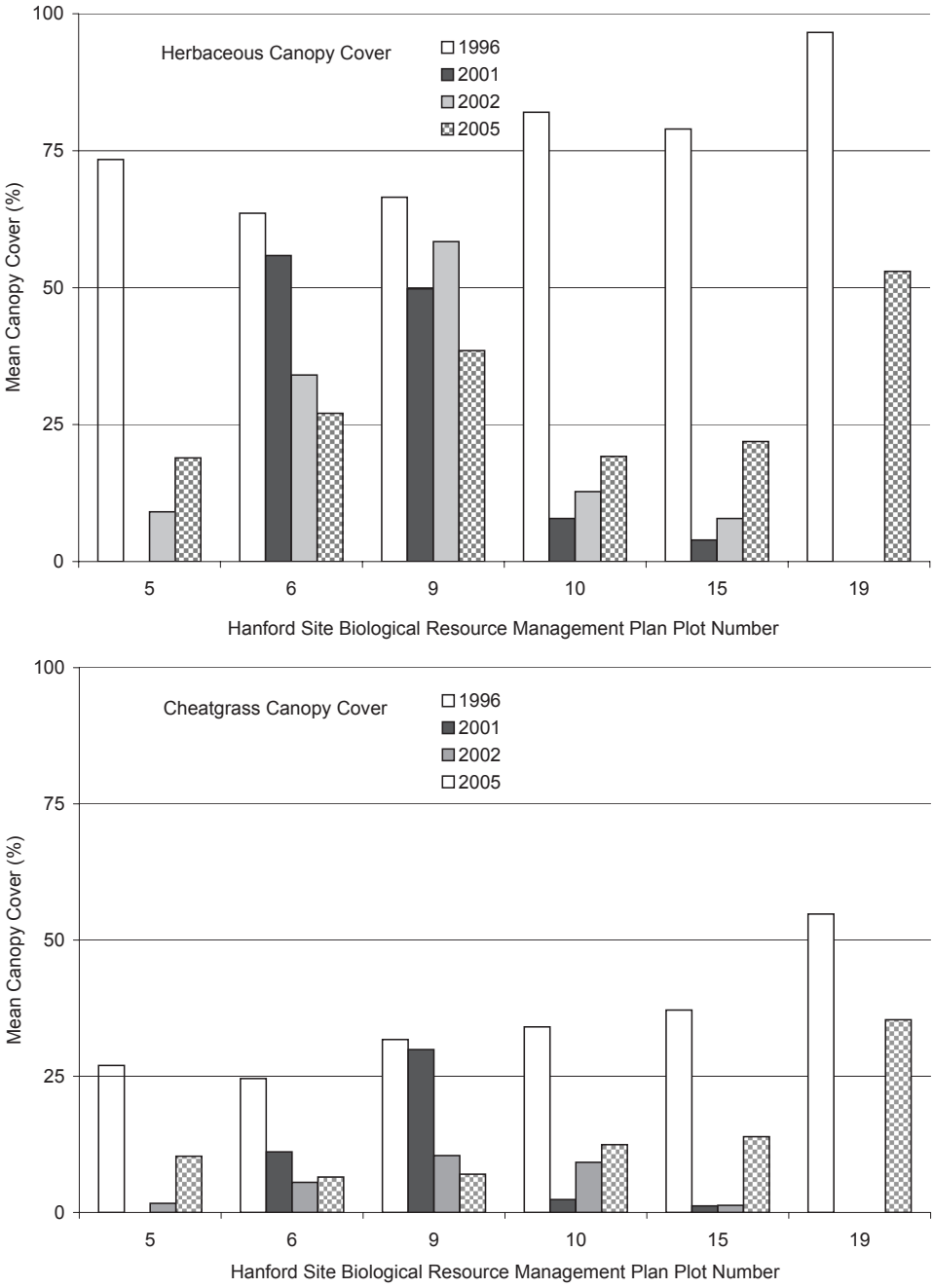



**Figure 10.11.7. Herbaceous and Cheatgrass Canopy Cover on Hanford Site Biological Resources Management Plan Plots, 2005 Compared to Previous Years**

was also found to be lower in 2005 on all plots surveyed. However because the total herbaceous cover is less, cheatgrass actually represents a larger proportion of the herbaceous vegetation in the plots that were burned in 2000. It is important to note that precipitation levels for the winter months of 2004 (PNNL-15160) and 2005 were lower than normal, thus moisture stored in the soil profile was less. These conditions likely contributed to lower vegetation cover measured in the spring of 2005. The data indicate that overall the herbaceous cover on the burned plots has

not recovered to pre-burn levels. Cheatgrass canopy cover is lower, but represents a greater proportion of the total herbaceous vegetation.

## 10.11.3.2 Birds

### C. A. Duberstein and K. B. Larson

Thirteen of the Biological Resources Management Plan (DOE/RL-96-32) plots located within central Hanford were revisited during 2005 to evaluate population trends and provide information that could be used to support ongoing risk assessments. These data are also important in evaluating the response of the bird community after seven of the plots were burned in 2000 during the 24 Command Wildland Fire (Figure 10.11.8). Before the fire, 12 of these plots had a sagebrush overstory and a bunchgrass understory, while the other was dominated by grasses. The burned plots have undergone natural vegetation recovery. The fire eliminated most or all of the shrub overstory, resulting in plant communities dominated by grass and forb species.

At each plot, at least three 10-minute point count surveys were conducted during the spring (Bibby et al. 1992). The total bird count for each plot was divided by the number of surveys to standardize the data for comparisons.

A total of 1,952 individuals of 42 species were recorded. Western meadowlark (*Sturnella neglecta*) was the most abundant and most frequently observed species, being observed

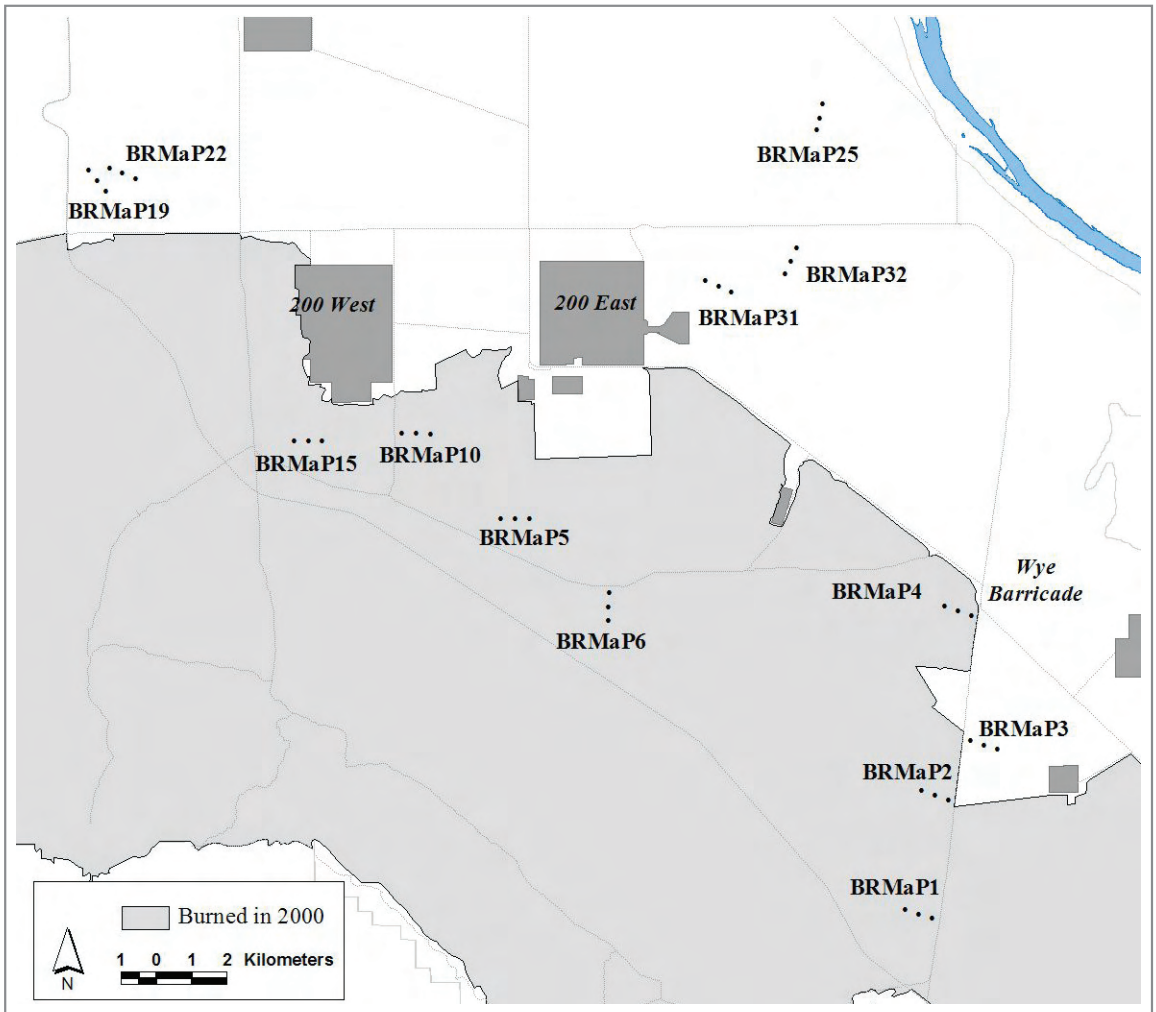



**Figure 10.11.8. Burned and Unburned Hanford Site Biological Resources Management Plan (BRMaP) Plot Locations on Central Hanford that were Surveyed for Breeding Birds in 2005**

in 89% of all surveys. Sage sparrows and horned larks (*Eremophila alpestris*) were also frequently observed, and together these three species accounted for nearly 70% of all birds observed. None of the species observed were listed as threatened or endangered by either the Washington Department of Fish and Wildlife or the federal government. However, the loggerhead shrike (*Lanius ludovicianus*), merlin (*Falco columbarius*), and sage sparrow were observed birds that were classified as Washington State Candidate species by the Washington Department of Fish and Wildlife, and the shrike is also a federal species of concern.

Comparison of the abundances of the 12 most numerous species found in 2005 (post-fire) to abundances recorded prior to the 2000 wildfire showed decreases for only two species: white crowned sparrow (*Zonotrichia leucophrys*) and sage sparrow (Figure 10.11.9). The abundances of two species, loggerhead shrike and horned lark, increased slightly in 2005 compared to pre-fire estimates. For the lark sparrow (*Chondestes grammacus*), long-billed curlew (*Numenius americanus*), brown-headed cowbird (*Molothrus ater*), common raven (*Corvus corax*), savannah sparrow (*Passerculus sandwichensis*), and western meadowlark, there were no changes in abundance. None of the changes in abundance was statistically significant ($\alpha > 0.05$).

Some of the temporal trends in bird abundance detected on the plots were observed elsewhere in the region (cowbird, meadowlark), while others were different than the observed regional trends (horned lark, shrike) (Table 10.11.3). Since most of the birds that breed within Hanford shrub-steppe habitats are migratory and only spend the breeding season in Washington State, it is difficult to determine what factors may be contributing to changes in populations and how much influence any one factor may have.

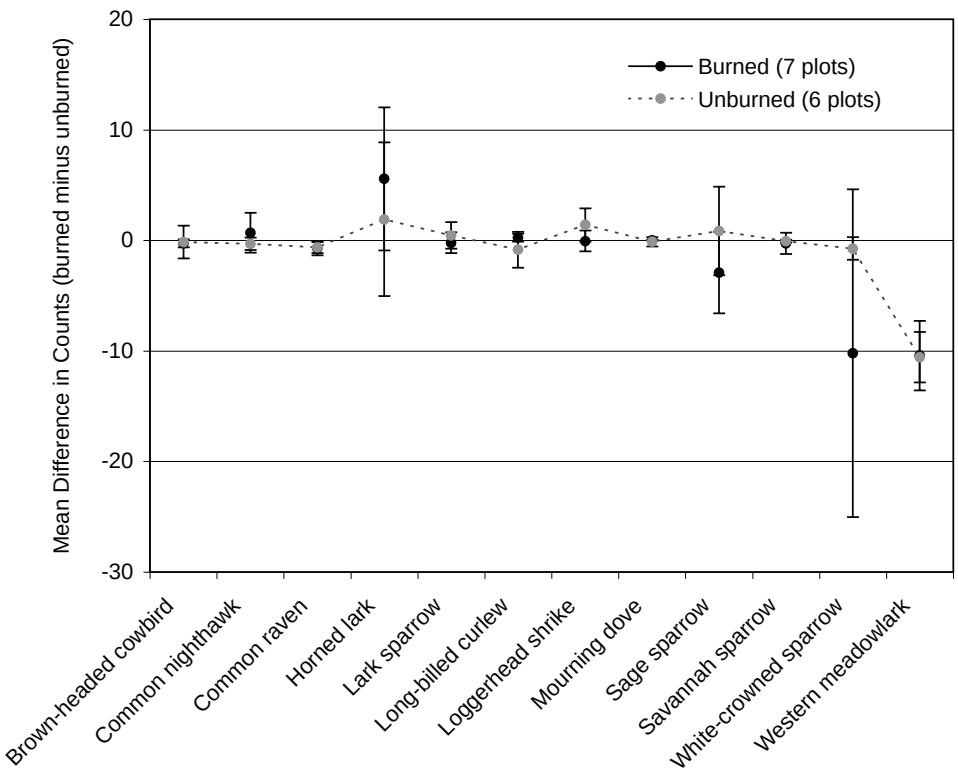



**Figure 10.11.9. Difference in Counts of the Twelve Most Abundant Bird Species on Thirteen Hanford Site Biological Resources Management Plan Plots, 2005 Post-Fire Counts Minus 2000 Pre-Fire Counts (±1 standard deviation)**

**Table 10.11.3. Regional Population Trends of Nine Bird Species Commonly Observed within Central Hanford from 1996 through 2005**

| Common Name | Hanford Site | Washington State[(a)] | Columbia Basin[(a)] | Western U.S.[(a)] |
|---|---|---|---|---|
| brown-headed cowbird | – | – | – | – |
| common raven | – | + | steady | + |
| horned lark | + | – | – | – |
| lark sparrow | steady | + | + | – |
| loggerhead shrike | + | – | – | – |
| long-billed curlew | steady | – | + | + |
| sage sparrow | – | + | variable | – |
| savannah sparrow | – | variable | – | steady |
| western meadowlark | – | – | – | – |

(a) Trends summarized from Sauer et al. 2005.
+ = A population increase.
– = A population decrease.

## 10.11.3.3 Small Mammals, Reptiles, and Invertebrates

### K. D. Hand, J. A. Stegen, and R. E. Durham

Three Biological Resources Management Plan plots (Figure 10.11.8; plots 6, 10, and 19) located on the Hanford Central Plateau were surveyed in May 2005 to estimate small mammal, invertebrate, and lizard species richness and to document the presence/absence of species that are federally or state protected and/or sensitive. Plots 6 and 10 were selected for monitoring based on their location on the 200 Area plateau and because these plots were burned in the 24 Command Wildland Fire in June 2000. Plot 19 is located northwest of the 200-West Area and was not burned in the 2000 fire. The plots within the fire footprint are currently classed as bunchgrass mosaic vegetation cover and have sparse patches of young shrubs scattered through the plots. Vegetation found on monitoring plot 19 is a big sagebrush – spiny hopsage/bunchgrass mosaic.

Live-trapping was used to sample the small mammals, reptiles, and invertebrates on the plots. One hundred and forty-seven Sherman live traps and 36 pitfall traps were placed on each plot and sampled over a 4-night period. The Sherman traps were used to capture small mammals, while pitfall traps captured lizards and invertebrates.

Four small mammal species were captured on all three plots: the northern grasshopper mouse (*Onychomys leucogaster*), white-footed deer mouse (*Peromyscus maniculatus*), Great Basin pocket mouse (*Perognathus parvus*), and Townsend's ground squirrel (*Spermophilus townsendii*). Mammalian species richness was greatest at plot 6 with four species, plot 10 had the next greatest with three, and plot 19 had the lowest species richness with two species found (Table 10.11.4). Reptilian species richness was also greatest at plot 6 (four species), followed by plot 10 (two species) then plot 19 (zero species) (Table 10.11.5). However, the two snakes captured are considered incidental because the trapping methods were not considered suitable for capturing snakes. The invertebrate species' richness (Table 10.11.6) did not follow the trend seen for small mammals and reptiles, plot 19 had the greatest number of species with 26, followed by plot 10 with 18 species, and plot 6 with 17 species.

**Table 10.11.4. Total Number of Individuals and Species Richness for Small Mammals Captured on Hanford Site Biological Resources Management Plan Plots Near the Hanford Site's 200-East and 200-West Areas, 2005**

| Small Mammals | Plot 6 | Plot 10 | Plot 19 |
|---|---|---|---|
| Deer mouse | 18 | 6 | 5 |
| Great Basin pocket mouse | 83 | 89 | 69 |
| Northern grasshopper mouse | 1 | 3 | |
| Townsend's ground squirrel | 1 | | |
| **Total number of individuals** | **103** | **98** | **74** |
| **Number of species** | **4** | **3** | **2** |

**Table 10.11.5. Total Number of Reptiles and Reptile Species Captured on Hanford Site Biological Resources Management Plan Plots Near the Hanford Site's 200-East and 200-West Areas, 2005**

| Reptiles | Plot 6 | Plot 10 | Plot 19 |
|---|---|---|---|
| Western yellow-bellied racer (*Coluber constrictor*) | 1 | | |
| Pygmy short-horned lizard (*Phrynosoma douglasii*) | 2 | | |
| Sagebrush lizard (*Sceloporus graciosus*) | 1 | | |
| Side-blotched lizard (*Uta stansburiana*) | 28 | 17 | |
| Great Basin gopher snake (*Pituophis melanoleucus*) | | 1 | |
| **Total number of individuals**[(a)] | **32** | **18** | **0** |
| **Number of species** | **4** | **2** | **0** |

(a) Individual reptiles were not marked upon release during this study so the resultant total number of individuals may be inflated due to multiple captures of the same individual.

**Table 10.11.6. Total Number of Individuals and Species Richness of Invertebrates Collected on Hanford Site Biological Resources Management Plan Plots Near the Hanford Site's 200-East and 200-West Areas, 2005**

| Common Name | Order | Family | Plot 6 | Plot 10 | Plot 19 |
|---|---|---|---|---|---|
| Spiders | *Araneae* | *Ammotrechidae* | | | 1 |
| (12 species) | | *Araneidae* | 1 | 3 | 8 |
| | | *Gnaphosidae* | | | 18 |
| | | *Lycosidae* | | | 1 |
| | | *Pholcidae* | 2 | 3 | 3 |
| | | *Unknown* | | 1 | 1 |
| Beetles | *Coleoptera* | *Carabidae* | 2 | 2 | 1 |
| (11 species) | | *Curculionidae* | | | 1 |
| | | *Tenebrionidae* | 70 | 121 | 191 |
| True bugs | *Hemiptera* | *Berytidae* | 1 | | |
| (3 species) | | *Lygaeidae* | 9 | 7 | 98 |
| Hoppers (2 species) | *Homoptera* | *Unknown* | 3 | 2 | |
| Ants and wasps | *Hymenoptera* | *Bethylidae* | | 6 | 1 |
| (10 species) | | *Chrysididae* | | | 1 |
| | | *Formicidae* | 10 | 56 | 1 |
| | | *Mutillidae* | | 2 | 1 |
| | | *Sphecidae* | 2 | | 1 |
| Moths and butterflies (2 species) | *Lepidoptera* | *Unknown* | 1 | 1 | |
| Grasshoppers and | *Orthoptera* | *Acrididae* | 1 | | |
| crickets | | *Gryllacrididae* | 18 | 16 | 5 |
| (3 species) | | *Gryllidae* | | | 1 |
| Scorpions (1 species) | *Scorpiones* | *Vaejovidae* | 1 | | 2 |
| Bristletails (1 species) | *Microcoryphia* | *Machilidae* | | | 1 |
| Unknown (1 species) | | | | | 5 |
| **Total number of individuals** | | | **121** | **220** | **342** |
| **Number of species** | **46 (in all plots)** | | **17** | **18** | **26** |

The relative abundance and species richness of small mammals in 2005 were compared to similar data collected on these monitoring plots in 1998 before the 2000 24 Command Wildland Fire. In all three plots, the relative abundance of small mammals was higher in 2005 after the fire than in 1998 (Figures 10.11.10 through 10.11.12). Species richness was also higher on the two burned plots (plots 6 and 10) in 2005 compared to 1998. Two additional species were found in 2005 on the burned plots compared to no change on the unburned plot. Changes in species abundance and composition may be related to differences in the amount of ground litter and the vegetative community after a fire (http://www.npwrc.usgs.gov/resource/habitat/fire/smmammal.htm).

Two Washington State Species of Concern candidate species and one monitor species were encountered during this effort. The Townsend's ground squirrel, a state candidate species as of July 1, 2005, was present on plot 6. The sagebrush lizard, a state candidate species as of July 1, 2005, was present on plot 6. The northern grasshopper mouse, a state monitor species as of July 1, 2005, was present on plots 6 and 10.

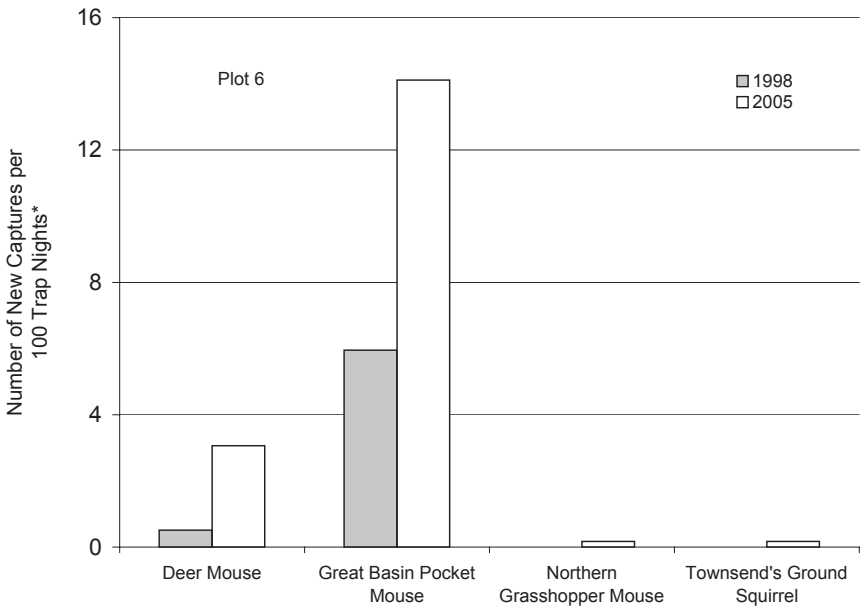
## 10.11.3.4 Contaminant Analysis of Receptors on Long-Term Monitoring

J. A. Stegen

Small mammals, reptiles, and invertebrates surveyed on the three Hanford Site Biological Resources Management Plan monitoring plots (6, 10, and 19) identified in Section 10.11.3.3 were also collected for baseline contaminant analysis (metals and radionuclides) using the same trap layout as described above. In addition, one surface and two rooting zone soil samples were collected from each plot and analyzed for metals. These data can be used to examine future trends in contaminant levels in organisms found on these monitoring plots.

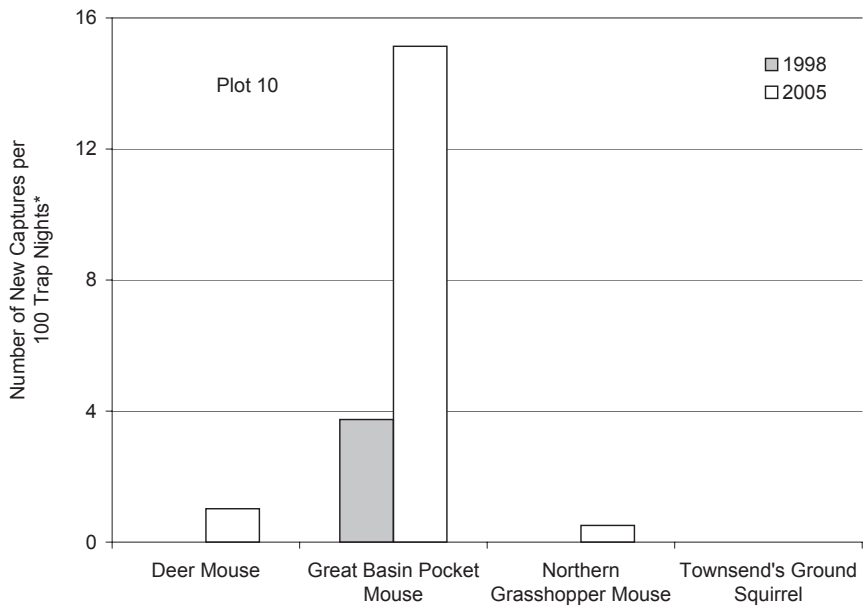
Liver samples were collected from three Great Basin pocket mice on each plot and analyzed for 19 trace metals (Appendix C, Table C.12).

Two sagebrush lizards were collected at plot 10 for analysis. One lizard was submitted whole for analysis while the liver of the other was submitted along with the remaining tissue (offal). These samples (one whole organism, one offal, and



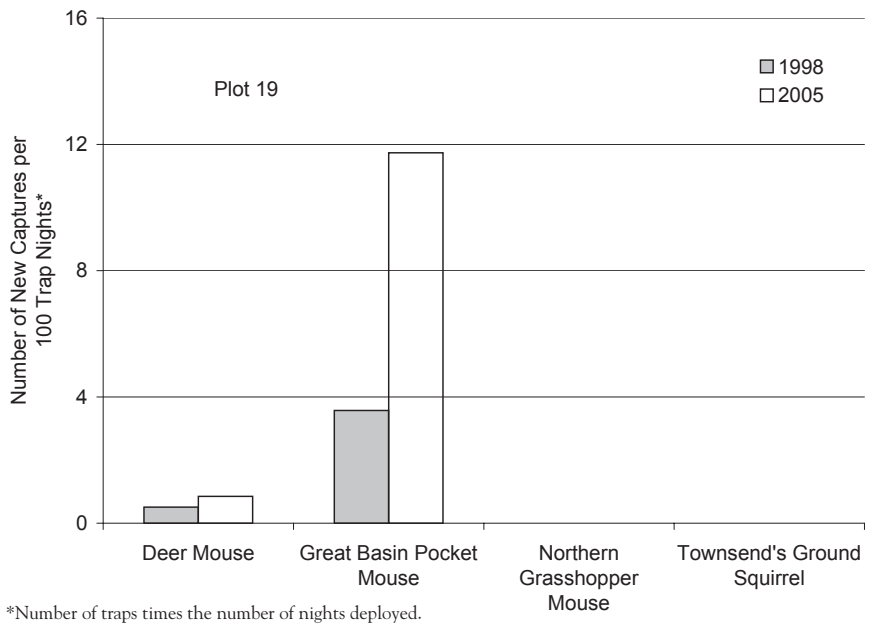

*Number of traps times the number of nights deployed.

**Figure 10.11.10. Relative Abundance of Small Mammals Based on Capture Rates in Sherman Traps on Hanford Site Biological Resources Management Plan Plot 6, 2005 Compared to 1998**




*Number of traps times the number of nights deployed.

**Figure 10.11.11. Relative Abundance of Small Mammals Based on Capture Rates in Sherman Traps on Hanford Site Biological Resources Management Plan Plot 10, 2005 Compared to 1998**




*Number of traps times the number of nights deployed.

**Figure 10.11.12. Relative Abundance of Small Mammals Based on Capture Rates in Sherman Traps on Hanford Site Biological Resources Management Plan Plot 19, 2005 Compared to 1998**

one liver) were analyzed for 19 trace metals (Appendix C, Table C.13). Concentrations for all the metals were similar between the whole organism sample and the carcass sample but in some cases differed from the concentration in the liver sample.

Invertebrate samples were composites of whole organisms collected from each of the three plots. Three samples were submitted from each site and analyzed for 19 trace metals (Appendix C, Table C.14). Levels of most metals were similar between the three sites.

Three soil samples (two rooting zone, one surface) were collected at each of the three plots (6, 10, and 19) and analyzed for 19 trace metals (Appendix C, Table C.15). The concentrations of the majority of the metals were similar between the three sites. One sample from each plot was submitted for gamma analysis and two samples from each plot were submitted for strontium-90 analysis.

Samples of Great Basin pocket mice from the three plots (6, 10, and 19) were analyzed for the presence of various radiological contaminants. Strontium-90 was detected only at plot 10 with a maximum concentration of 0.057 pCi/g wet weight.

Three composite samples of invertebrates from each plot (6, 10, and 19) were analyzed for strontium-90. All results were below analytical detection limits.

## 10.11.4 Monitoring of Fish and Wildlife for Hanford-Produced Contaminants

J. A. Stegen, R. E. Durham, and K. D. Hand

In 2005, several types of wildlife and fish were collected at locations on and around the Hanford Site (Figure 10.11.13) as part of routine monitoring for Hanford-produced contaminants. Samples from these organisms were analyzed for selected radionuclides and metals that are suspected or known to be present on the Hanford Site (Table 10.11.7). Samples were also collected at locations that are distant from the site to obtain reference (background) contaminant measurements.

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

In 2005, 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. Since the 1990s, strontium-90 and cesium-137 have been the most frequently measured radionuclides in fish and wildlife samples. In addition, plutonium-238 and plutonium 239/240 were measured in rabbit livers collected in the 200-East Area and near Prosser, Washington, and in elk livers collected on the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit of the Hanford Reach National Monument.

Strontium-90 is chemically similar to calcium; consequently, it accumulates in hard tissues rich in calcium such as bones, antlers, and eggshells. Strontium-90 has a biological half-life in hard tissue of 14 to 600 days (PNL-9394). Hard-tissue concentrations may profile an organism's lifetime exposure to strontium-90. However, strontium-90 generally does not contribute much to human dose because it does not accumulate in edible portions of fish and wildlife. Strontium-90 is present in the Hanford environs as a result of past operating and waste disposal practices. Currently, contaminated groundwater entering the Columbia River via shoreline springs in the 100-N and 100-H Areas is the primary source of Hanford-produced strontium-90 measurable in the Columbia River; however, the current contaminant contribution relative to historical fallout from atmospheric weapons testing is small (<2%) (PNL-8817).

Cesium-137 is particularly important to the human food chain because it is chemically similar to potassium and is found in the muscle tissues of fish and wildlife. Having a relatively short biological half-life (<200 days in muscle and <20 days in the gastrointestinal tract [PNL-9394]), cesium-137 is an indicator of recent exposure to radioactive materials. Cesium-137 is present in the environment as a result of past Hanford Site operating and waste disposal practices as well as from historical worldwide fallout resulting from nuclear weapons testing.

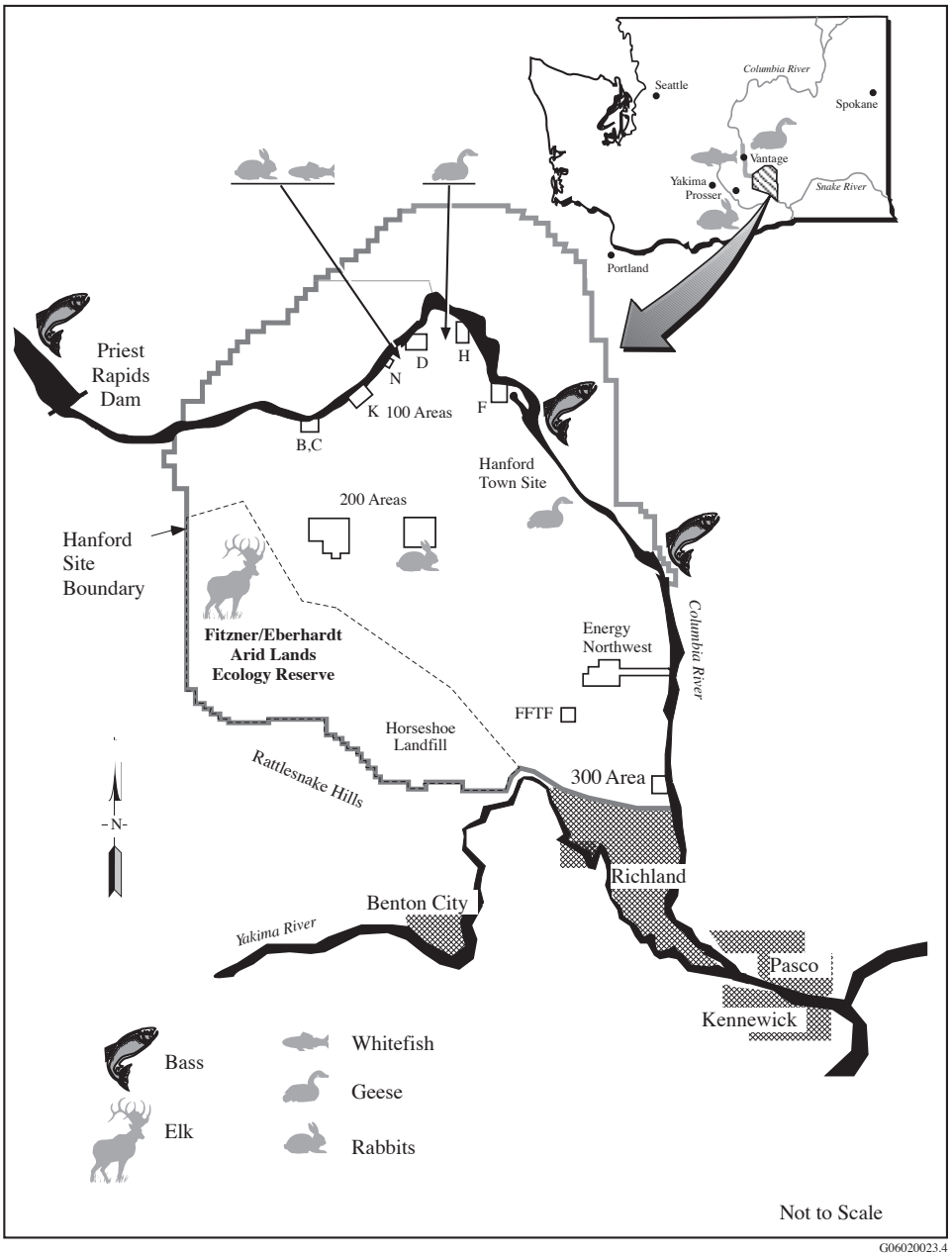



**Figure 10.11.13. Fish and Wildlife Sampling Locations On and Around the Hanford Site, 2005**

Gamma spectrometry results for most radionuclides are not discussed here because concentrations were too low to measure or measured concentrations were considered artifacts of low-background counts. Low-background counts occur at random intervals during sample counting and can produce occasional spurious false-positive results. For many radionuclides, concentrations were below levels that could be detected by the analytical laboratory. Results, propagated analytical uncertainties, and minimum detection amounts for all 2005 wildlife samples may be found in PNNL-15892, APP. 1.

Monitoring various biota for uptake and exposure to radionuclides both near and distant from Hanford Site

**Table 10.11.7. Number of Sampling Locations and Number and Kind of Analyses Performed on Fish and Wildlife Samples Collected On and Around the Hanford Site, 2005**

| | | | Number of Analyses | | | |
|---|---|---|---|---|---|---|
| Biota | Number of Offsite Locations | Number of Onsite Locations | Gamma | Strontium-90 | Trace Metals | Plutonium-238, Plutonium-239/240 |
| Fish (whitefish) | 1[(a)] | 1 | 10 | 10 | 10 | 0 |
| Fish (bass) | 1[(b)] | 3 | 17 | 17 | 17 | 0 |
| Canada geese | 1[(b)] | 2 | 15 | 15 | 15 | 0 |
| Rabbits | 1[(c)] | 2 | 10 | 10 | 8 | 6 |
| Elk | 0 | 1 | 3 | 3 | 0 | 3 |

(a) Samples collected near the Wanapum Dam, Washington.
(b) Samples collected near Desert Aire, Washington.
(c) Samples collected near Prosser, Washington.

operations continues to assure that consumption of fish and wildlife obtained from the Hanford Site environs does not pose a threat to humans. Monitoring also provides long-term contamination trends in selected components of the ecosystem. Wildlife and fish sampled and analyzed during 2005 for radioactive constituents included Canada geese (*Branta canadensis*), cottontail rabbits (*Sylvilagus nuttallii*), whitefish (*Prosopium williamsonii*), smallmouth bass (*Micropterus dolomieu*), and elk (*Cervus elaphus nelsonii*).

A number of trace metals associated with Hanford operations have the potential to accumulate in certain fish and wildlife tissues. These metals are potential contaminants of concern (e.g., chromium, copper, lead, and mercury), particularly along Hanford's Columbia River shoreline where contaminated groundwater flows into the river (PNNL-14295). Historical operations at Hanford resulted in the production of both radiological and non-radiological wastes, including metals, in various forms. Liquid and solid wastes were placed in various disposal sites at Hanford, including trenches, cribs, ditches, ponds, and underground storage tanks (PNNL-13487). Fly ash (ash produced from burning coal) from coal-fired steam/power plants that were associated with each reactor was released to the atmosphere. Fly ash contains trace metals and natural radionuclides that may have deposited on the soil around the reactor areas. In addition to trace metals associated with past Hanford operations, other sources of contamination have impacted the site. Trace metals generated from upriver mining and smelting activities have been transported down the Columbia River (Johnson et al. 1990) and into the Hanford Reach. Also, contaminants associated with past and present agricultural practices have contributed to the metals inventory at the Hanford Site (Yokel and Delistraty 2003). For example, arsenic is likely associated with historical applications of lead arsenate on fruit orchards prior to World War II. Lead arsenate was once the most commonly used insecticide in fruit orchards and studies that examined the extent of arsenic contamination in pre-World War II orchard soil near the 100 Areas showed elevated levels of arsenic compared to levels in soil from background locations (Yokel and Delistraty 2003).

Organisms can accumulate metals through incidental soil ingestion, by drinking contaminated water, and by consuming contaminated foods. The spatial variability of concentrations of metals in the environment is influenced by the contributions of both natural sources and industrial contaminants. Thus, concentrations of metals and organism exposures can vary between locations. This variability can produce some uncertainty in the source of the metals within the sampled organism. To determine the Hanford Site's contribution to levels of metals in biota collected on the Hanford Site or in the Hanford Reach, samples were also collected from the Columbia River upstream of the site and from background areas distant from the site. A comparison of concentrations of metals in upstream and background samples with concentrations in Hanford Reach or Hanford Site samples may provide information on increases in concentrations of metals potentially due to activities on

the Hanford Site. Currently, there is not a large amount of metals data for wildlife and fish from the Hanford Reach, the Hanford Site, or from background locations, and the data show some degree of variability. Additional monitoring data may help to reduce the variability.

Trace metal concentrations were monitored in Canada geese, bass, cottontail rabbits, and whitefish in 2005 and results are summarized in the following discussions. Individual results and their associated uncertainties may be found in PNNL-15892, APP. 1.

### 10.11.4.1 Analytical Results for Fish Samples

Fishing is a popular activity along the Hanford Reach of the Columbia River and fish such as bass and whitefish are harvested for food and could potentially contribute to human exposure. Bass and whitefish are known to migrate seasonally and are likely moving up and down the Hanford Reach and may be exposed to metals and persistent radionuclides in the river environment. Monitoring fish for uptake and exposure to radionuclides and metals at locations both near to and distant from the Hanford Site continues to be important to track the extent and long-term trends of contamination in the Hanford Reach environment. During 2005, 12 smallmouth bass were collected from three locations in the Hanford Reach: 5 from the 100-F Slough, 5 from the Hanford Slough, and 2 from near the 300 Area (Figure 10.11.13). Additionally, five bass were collected at an upstream background location near Desert Aire, Washington. During 2005, five whitefish were collected between the 100-N and 100-D Areas and five were collected near Wanapum Dam, upstream of the Hanford Site. Fillets and the eviscerated remains (carcasses) of whitefish and smallmouth bass were analyzed for a variety of radiological contaminants and liver samples were analyzed for 17 metals.

***Cesium-137***. Cesium-137 results were below the analytical detection limit (0.03 pCi/g [0.001 Bq/g] wet weight) in the 10 whitefish fillet samples and 16 of the 17 bass fillet samples collected during 2005. Cesium-137 was found above the analytical detection limit in one bass sample collected in the Hanford Slough (0.021 pCi/g [0.00078 Bq/g] wet weight). These results are consistent with results reported throughout the past 10 years that indicated a gradual decline in cesium-137 levels in fish found both at background locations and near the Hanford Site.

***Strontium-90***. Strontium-90 was not found above the analytical detection limit (0.05 pCi/g [0.0019 Bq/g] wet weight) in any of the whitefish and bass carcass samples during 2005. These results are similar to results reported from the 100 Areas in preceding years (Figure 10.11.14).

***Trace Metals***. Liver samples from five whitefish collected between the 100-N and 100-D Areas were analyzed for 16 trace metals during 2005. Concentrations in the samples were compared to concentrations in five whitefish samples collected upstream of the site near the Wanapum Dam during 2005. Beryllium and thorium were not detected above method detection limits (0.008 µg/g and 0.01 µg/g dry weight, respectively) in samples from either location (Appendix C, Table C.16; PNNL-15892, APP. 1). Maximum concentrations of aluminum, arsenic, cadmium, chromium, copper, lead, silver, uranium, and zinc were higher in whitefish samples collected near the Wanapum Dam than in whitefish samples collected between the 100-N and 100-D Areas during 2005. The maximum concentrations of selenium, nickel, and thallium in the whitefish samples collected between the 100-N and 100-D Areas were slighted elevated compared to concentrations in samples collected near the Wanapum Dam. However, with the exception of selenium, concentrations were similar to concentrations in liver samples collected from whitefish near the 100-N Area in 2003 (Appendix C, Table C.16; PNNL-15892, APP. 1; PNNL-14687, APP. 1). The maximum concentration of selenium in whitefish collected near the 100-N Area in 2005 was 16 µg/g dry weight compared to 13.6 µg/g dry weight in whitefish collected in 2003.

Liver samples from all 17 bass were analyzed for 17 trace metals during 2005. Beryllium and thorium were not detected above method detection limits in samples collected from the Hanford Reach (Appendix C, Table C.17; PNNL-15892, APP. 1). Concentrations of thallium, uranium, silver, nickel, mercury, chromium, antimony, and aluminum in bass collected in the Hanford Reach were similar to or less than concentrations of these analytes measured in bass collected near Desert Aire in 2005. The maximum arsenic and cadmium concentrations in samples from the Hanford Reach sloughs were elevated relative to the maximum

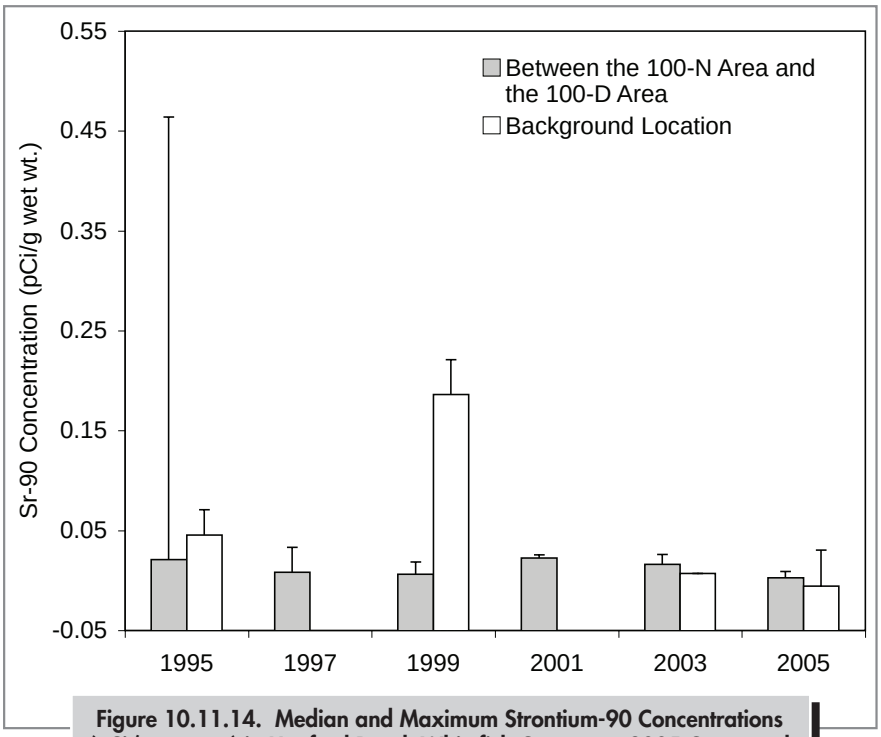



**Figure 10.11.14. Median and Maximum Strontium-90 Concentrations (pCi/g wet wt.) in Hanford Reach Whitefish Carcasses, 2005 Compared to Previous Years. Background Areas: 1995 – Wenatchee River; 1999 – Clearwater River, Idaho; 2003–2005 – Columbia River in the Wanapum Dam Reservoir. Maximum concentrations are represented by the upper bar.**

concentrations of these metals in bass collected near Desert Aire, and from the same sloughs in 2002 (PNNL-14295, APP. 1). The maximum concentration of manganese was somewhat elevated in samples collected from the 100-F Slough (7.5 µg/g dry weight) compared to the maximum concentration reported for bass collected near Desert Aire (5.4 µg/g dry weight). However, concentrations of manganese and cadmium were similar to concentrations found in bass from the 100-F and Hanford Sloughs in 2002 (PNNL-14295, APP. 1). Maximum (16 µg/g dry weight) and median (11 µg/g dry weight) copper concentrations in bass collected from the 100-F Slough in 2005 were slightly elevated when compared to concentrations in samples collected near Desert Aire, Washington (maximum 15 µg/g dry weight and median 6.7 µg/g dry weight) and from the 100-F Slough in 2002 (PNNL-14295, APP. 1).

## 10.11.4.2 Analytical Results for Goose Samples

During the spring of 2005, ten geese were collected along the Hanford Reach of the Columbia River; five between the Hanford town site and the 300 Area and five near the 100 Areas. Five geese were also collected upstream of the Hanford Site near Desert Aire, Washington, in the spring (Figure 10.11.13). All organisms were analyzed for gamma-emitting radionuclides (including cesium-137) in muscle tissue, strontium-90 in bones, and 17 trace metals in the liver.

***Cesium-137***. Manmade gamma-emitting radionuclides, including cesium-137, were not found in any of the muscle samples analyzed in 2005 (minimum detectable activities were 0.0095 to 0.016 pCi/g [0.00035 to 0.00059 Bq/g] wet weight). These results were similar to results reported for goose samples collected along the Hanford Reach from 1995 through 2003. The analytical results suggest that

Canada geese are not accumulating measurable amounts of cesium-137 along the Hanford Reach of the Columbia River.

***Strontium-90***. Strontium-90 concentrations found in goose bones were above the analytical detection limit in two samples collected near the 100 Areas (0.117 pCi/g [0.0043 Bq/g] and 0.272 pCi/g [0.010 Bq/g] wet weight) and in one sample collected between the Hanford town site and the 300 Area (0.161 pCi/g [0.006 Bq/g] wet weight) during 2005. Maximum and median concentrations in Hanford Reach goose samples in 2005 were similar to or less than results reported since 1999 (Figure 10.11.15). Strontium-90 concentrations in Hanford Reach goose samples 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 (Section 10.14).

***Trace Metals***. Liver samples from five geese collected near the 100 Areas, five collected between the Hanford town site and the 300 Area, and five collected near Desert Aire, Washington, were analyzed for 17 trace metals during 2005. Beryllium was not detected above method detection limits in samples collected from the Hanford Reach (Appendix C, Table C.18; PNNL-15892, APP. 1). The maximum and median concentrations of cadmium, copper, lead, selenium, and silver were elevated in geese collected near the 100 Areas and between the Hanford town site and the 300 Area compared to the maximum and median concentrations of these metals found in geese collected near Desert Aire, Washington, in 2005 (Appendix C, Table C.18; PNNL-15892, APP. 1). Concentrations of cadmium in the 2005 Hanford Reach geese were similar to concentrations in geese collected at the same locations in 2003 (PNNL-14687, APP. 1). However, maximum concentrations of selenium and lead were slightly elevated in 2005 samples collected near the 100 Areas and between the Hanford town site and the 300 Area compared to samples collected in 2003 from the same locations (PNNL-14687, APP. 1). Silver was elevated in samples collected in 2005 between the Hanford town site and the 300 Area (0.085 µg/g dry weight) compared to concentrations in samples collected in 2003 (all below the analytical detection limit, 0.044 µg/g dry weight) (PNNL-14687, APP. 1). Goose samples collected during 2003 were not analyzed for copper.

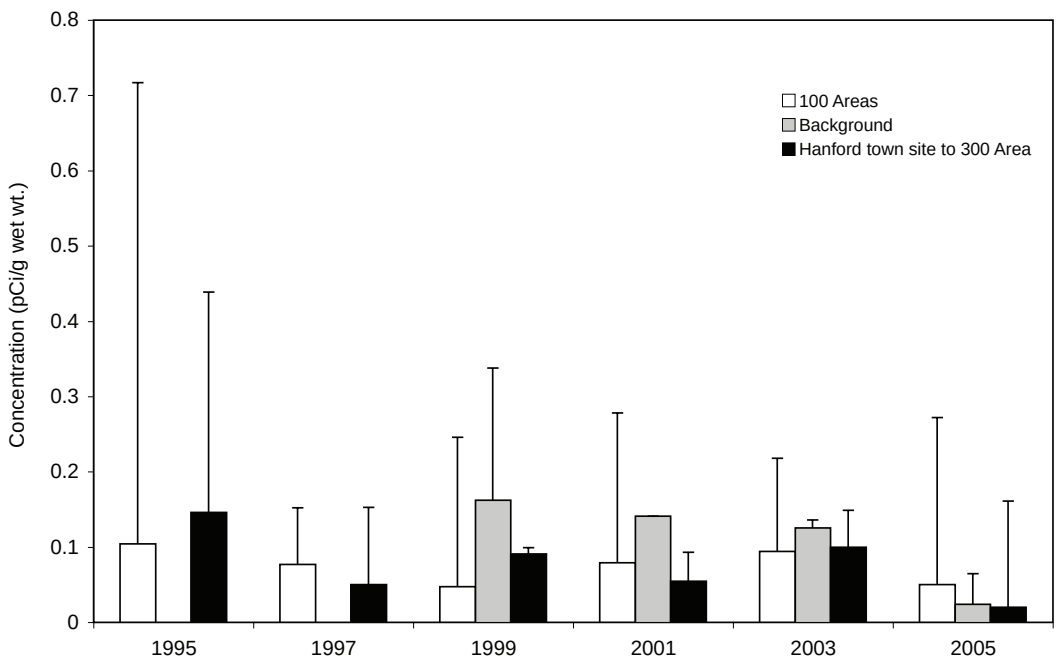



**Figure 10.11.15. Median and Maximum Strontium-90 Concentrations (pCi/g wet wt.) in Hanford Site and Background Canada Goose Bone Samples, 2005 Compared to Previous Years. Maximum concentrations are represented by the upper bar.**

### 10.11.2.3 Analytical Results for Rabbit Samples

Rabbits are useful 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. During 2005, two cottontail rabbits were collected from a background area near Prosser, Washington, four were collected near the 100-N Area, and four were collected near the 200-East Area (Figure 10.11.13). Rabbits were monitored for cesium-137 in muscle tissue, strontium-90 in bones, and 17 trace metals in the liver. Plutonium-238 and plutonium 239/240 were monitored in rabbit livers obtained from animals collected near the 200 Areas and from animals collected near Prosser, Washington.

***Cesium-137***. Cesium-137 concentrations in muscle samples from all of the cottontail rabbits collected on the Hanford Site and at the background location during 2005 were below the analytical detection limit (0.03 pCi/g [0.001 Bq/g] wet weight).

**Strontium-90**. Strontium-90 concentrations in bone tissues from six of the eight rabbits collected onsite during 2005 were above the analytical detection limit with a median concentration of 0.15 pCi/g (0.0056 Bq/g) wet weight (Figure 10.11.16). The maximum concentration measured in rabbits near the 100-N Area during 2005 (0.221 pCi/g [0.0082 Bq/g] wet weight) was similar to the maximum concentration measured in cottontail rabbits collected near the 200-East Area in 2005 (0.249 pCi/g [0.0092 Bq/g] wet weight). The maximum and median concentrations in 2005 samples were generally lower than those reported in rabbits previously collected in the same locations. Results from rabbits collected near the 100-N Area have historically been higher and more variable than results obtained from background areas. Although small sample sizes limit the ability to interpret long-term trends, major changes in strontium-90 levels within rabbit bone tissues have not been apparent over the past decade (Figure 10.11.16).

***Plutonium***. All plutonium-238 and plutonium-239/240 results were below the analytical detection limit (0.003 pCi/g [0.001 Bq/g] to 0.005 pCi/g [0.0018 Bq/g] wet weight) in the four rabbit liver samples obtained during 2005 near the 200-East Area and the two liver samples obtained near Prosser, Washington.

***Trace Metals***. Liver samples from three rabbits collected in the 100-N Area, three collected near the 200-East Area, and two collected near Prosser, Washington, were analyzed for 17 trace metals during 2005. Beryllium, thorium, and uranium were not detected above method detection limits in any rabbits samples collected in 2005 (Appendix C, Table C.19). The maximum concentrations of aluminum, antimony, chromium, copper, lead, manganese, selenium, and zinc were elevated in samples collected from the 100-N Area and near the 200-East Area compared to the maximum concentrations of these metals found in rabbits collected near Prosser in 2005. Maximum concentrations of lead, selenium, manganese, and chromium were elevated in rabbit samples collected from the 100-N Area during 2005 compared to samples collected in the 100-N Area in 2003 (Appendix C, Table C.19 ; PNNL-14687, APP. 1). The maximum (5.5 µg/g dry weight) and median (3.4 µg/g dry weight) concentrations of lead in rabbits collected from the 100-N Area were elevated compared to concentrations in samples collected near the 200-East Area in 2005 (maximum 2.1 µg/g dry weight and median 0.52 µg/g dry weight), near Prosser during 2005 (maximum 0.26 µg/g dry weight), and from the 100 Areas in 2003 (maximum 0.267 µg/g dry weight and median 0.140 µg/g dry weight) (PNNL-14687, APP. 1).

### 10.11.4.4 Analytical Results for Elk Samples

Radionuclide levels in elk collected on the Hanford Reach National Monument Fitzner/Eberhardt Arid Lands Ecology Reserve Unit in 2005 were compared to levels in elk previously collected near the 200 Areas, along roads near the Hanford Site, on the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit, and from a background location in central Idaho. The U.S. Fish and Wildlife Service requested that DOE support the relocation of elk from the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit in 2005 by providing sample collection, preparation, and radiological analyses under the Public Safety and Resource Protection Program. In January 2005, bone, muscle, and liver samples were collected from three elk as part of this effort. Elk samples

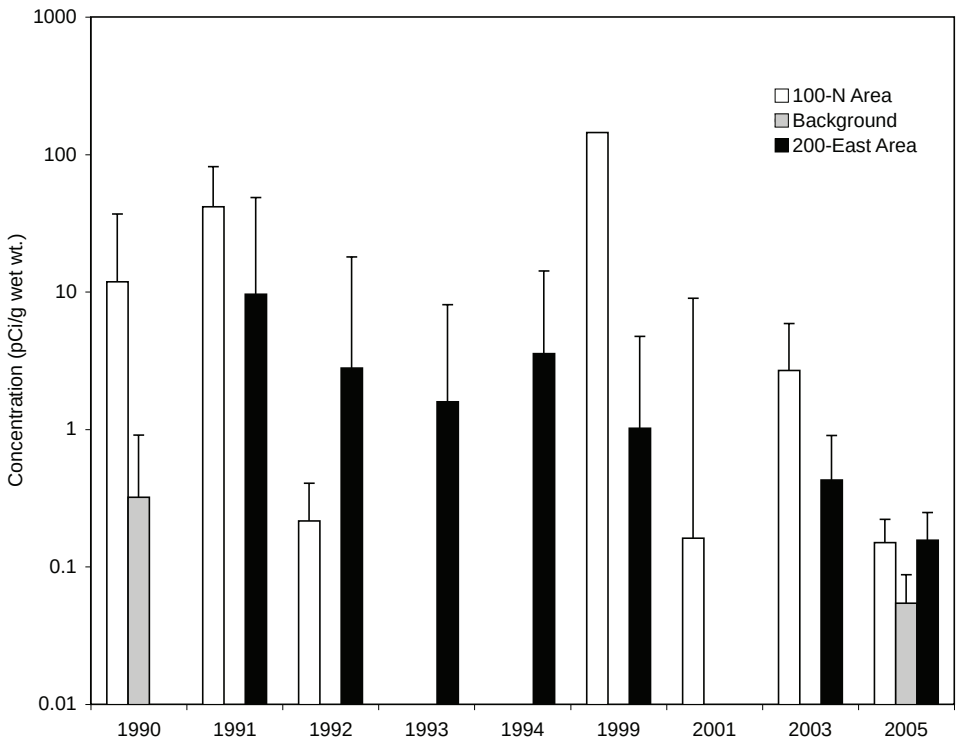



**Figure 10.11.16. Median and Maximum Strontium-90 Concentrations (pCi/g wet wt.) in Hanford Site and Background Rabbit Bone Samples, 2005 Compared to Previous Years. Maximum concentrations are represented by the upper bar.**

were analyzed for gamma emitters in muscle tissue, strontium-90 in bone, and isotopic plutonium in liver tissue.

***Cesium-137***. Cesium-137 was not found above the analytical detection limit in the three elk muscle samples collected in 2005. The muscle samples collected from a central Idaho background location in 1999 have been the only elk muscle samples analyzed at Hanford with cesium-137 concentrations above analytical detection limits. These results were consistent with historical deer sampling results and with concentration trends observed in a Hanford wildlife summary report (PNL-10174). PNL-10174 summarized radionuclide data from wildlife collected on Hanford from 1983 through 1992 and indicated a decline in cesium-137 levels in all wildlife examined. In addition, the levels of cesium-137 found in over 60 Hanford Site deer muscle samples collected during the 1990s were less than the background levels measured in deer samples collected from 1991 through 1995 from Stevens County, Washington, and in 1996, from Vail, Washington (PNNL-12088).

***Strontium-90***. Strontium-90 was detected in elk bone samples analyzed in 2005. The average concentration was consistent with levels previously observed on the Hanford Site and the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit (Figure 10.11.17). Historically, the highest concentrations of strontium-90 in elk bones analyzed at Hanford were measured in background samples collected during 1999 in central Idaho (PNNL-13230).

***Plutonium***. All plutonium-238 and plutonium-239/240 results were below the analytical detection limit (0.00004 pCi/g [0.0000015 Bq/g] wet weight) in the three elk liver samples obtained during 2005. These results were consistent with results reported for elk livers analyzed in 1999. The results were also consistent with results reported for deer sampled on the Hanford Site through the 1990s. Less than 6% (2 of 35) of the deer livers analyzed since 1992 have contained plutonium at concentrations above the analytical detection limit.

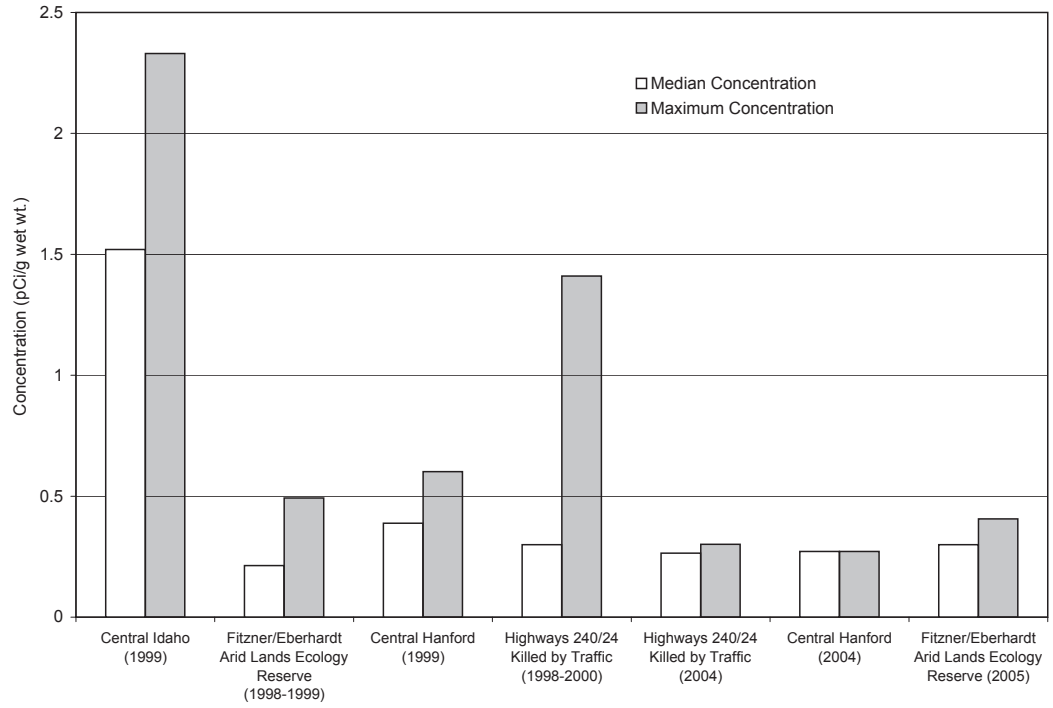



**Figure 10.11.17. Comparison of Median and Maximum Concentrations of Strontium-90 (pCi/g wet wt.) in Hanford Site and Background Elk and Deer Bone Samples, 2005 Compared to Previous Years**

## 10.11.5 Control of Pests and Contaminated Biota

A. R. Johnson, R. C. Roos, J. G. Caudill, J. M. Rodriguez, and R. A. Schieffer

Species of animals such as the domestic pigeon (*Columbia livia*), Northern pocket gopher (*Thomomus talpoides*), house mouse (*Mus musculus*), and deer mouse (*Peromyscus maniculatus*) must be controlled when they become a nuisance, health problem, or contaminated with radioactivity. Biological control personnel responded to approximately 30,000 animal control requests (ranging from requests to remove animals within radioactive waste facilities to insect invasions of work areas) from Hanford employees in 2005. There were approximately 2,300 trap/bait stations used to control populations of animals in and near facilities and offices.

There were 20 contaminated animals or animal-related materials discovered during 2005. This is approximately 60% less than the peak number of 46 in 1999, and is the same as the total for 2004. Flying insects and insect-related materials (e.g., harvester ants and mud-dauber wasp nests) collected during operations on the Hanford Site are monitored for radiological contaminants. Only one of the contaminated animal samples collected in 2005 related to insects, and that was an approximately 2-year-old inactive wasp nest found in a storage container in the 100-H Area near where the wasps were building nests from contaminated mud exposed during the demolition of the 105-H Building in 2003 (PNNL-14687).

There were no incidents of offsite contamination by animals during 2005, and all cases of new contamination reported onsite were cleaned up or scheduled for cleanup.

# 10.12 Threatened and Endangered Species at Hanford

M. R. Sackschewsky

This section discusses federal and state threatened and endangered species, candidate or sensitive plant and animal species, and other species of concern potentially found on the Hanford Site. Endangered species are those that are in danger of extinction within all or a significant portion of their range. Threatened species are those that are likely to become endangered in the foreseeable future. Sensitive species are species that are vulnerable or declining and could become endangered or threatened without active management or removal of threats. The federal list of threatened and endangered species is maintained by the U.S. Fish and Wildlife Service in 50 CFR 17.11 and 50 CFR 17.12, and the state lists are maintained by Washington Natural Heritage Program (WNHP 2006) and the Washington Department of Fish and Wildlife (WDFW 2006).

The purposes of the *Endangered Species Act*, 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) ensure that appropriate steps are taken to achieve the purposes of the treaties and conventions established under 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*. The National Oceanic and Atmospheric Administration Fisheries (NOAA 2006) has the responsibility for the federal listing of anadromous fish (i.e., fish such as the steelhead and spring-run Chinook salmon that require both saltwater and freshwater to complete a life cycle). The U.S. Fish and Wildlife Service has responsibility for all other federally listed species on the Hanford Site. Species of plants and animals listed as threatened, endangered, candidate, or sensitive by either the federal or state governments that occur or potentially occur on the Hanford Site are listed in Table 10.12.1.

One bird species (bald eagle) and two fish species (spring-run Chinook salmon and steelhead) on the federal list of threatened and endangered species are known to regularly occur on the Hanford Site (Table 10.12.1). One additional fish species (bull trout) has been recorded on the Hanford Site but is believed to be transient. 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* (Table 10.12.1). In addition, 12 plant species and 5 bird species have been listed as either threatened or endangered by Washington State. Numerous additional species of animals and plants are listed as sensitive or candidate species by Washington State. There are 28 state-level candidate and sensitive species of insects and animals and 15 sensitive plant species occurring or potentially occurring on the Hanford Site (Table 10.12.1). The U.S. Fish and Wildlife Service also maintains an informal list of species of concern in the Columbia Basin (USFWS 2006), which includes species that are being monitored and may be considered for federal candidate status in the future; there are 14 species that occur on Hanford included on this list.

Washington State maintains additional lower-level lists of species, including a Monitor list for animals (WDFW 2006) and Review and Watch lists for plants (WNHP 2006). Species on the State Monitor, Watch, and Review list are not considered species of concern, but are monitored for status and distribution. They are managed by the state, as needed, to prevent them from becoming endangered, threatened,

**Table 10.12.1. Federal and Washington State Listed Endangered, Threatened, Sensitive, and Candidate Species Occurring or Potentially Occurring on the Hanford Site**

| Common Name | Scientific Name | Federal Status[a] | State Status[a] |
|---|---|---|---|
| **Plants** | | | |
| awned halfchaff sedge | *Lipocarpha (= Hemicarpha) aristulata* | | Threatened |
| beaked spike-rush | *Eleocharis rostellata* | | Sensitive |
| Canadian St. John's wort | *Hypericum majus* | | Sensitive |
| Columbia milkvetch | *Astragalus columbianus* | Species of concern | Sensitive |
| coyote tobacco | *Nicotiana attenuata* | | Sensitive |
| desert dodder | *Cuscuta denticulata* | | Threatened |
| desert evening-primrose | *Oenothera caespitosa* | | Sensitive |
| dwarf evening primrose | *Camissonia (= Oenothera) pygmaea* | | Sensitive |
| fuzzytongue penstemon | *Penstemon eriantherus whitedii* | | Sensitive |
| Geyer's milkvetch | *Astragalus geyeri* | | Threatened |
| grand redstem | *Ammannia robusta* | | Threatened |
| gray cryptantha | *Cryptantha leucophaea* | Species of concern | Sensitive |
| Great Basin gilia | *Gilia leptomeria* | | Threatened |
| Hoover's desert parsley | *Lomatium tuberosum* | Species of concern | Sensitive |
| loeflingia | *Loeflingia squarrosa var. squarrosa* | | Threatened |
| lowland toothcup | *Rotala ramosior* | | Threatened |
| miner's candle | *Cryptantha scoparia* | | Sensitive |
| mousetail | *Myosurus clavicaulis* | | Sensitive |
| persistent sepal yellowcress | *Rorippa columbiae* | Species of concern | Endangered |
| Piper's daisy | *Erigeron piperianus* | | Sensitive |
| rosy pussypaws | *Calyptridium roseum* | | Threatened |
| small-flowered evening-primrose | *Camissonia (= Oenothera) minor* | | Sensitive |
| Snake River cryptantha | *Cryptantha spiculifera (= C. interrupta)* | | Sensitive |
| Suksdorf's monkey flower | *Mimulus suksdorfii* | | Sensitive |
| Umtanum desert buckwheat | *Eriogonum codium* | Candidate | Endangered |
| White Bluffs bladderpod | *Lesquerella tuplashensis* | Candidate | Threatened |
| white eatonella | *Eatonella nivea* | | Threatened |
| **Insects** | | | |
| Columbia River tiger beetle[b] | *Cicindela columbica* | | Candidate |
| silver-bordered fritillary | *Boloria selene atrocostalis* | | Candidate |
| **Fish** | | | |
| bull trout[c] | *Salvelinus confluentus* | Threatened | Candidate |
| leopard dace[c] | *Rhinichthys flacatus* | | Candidate |
| mountain sucker[c] | *Catastomus platyrhynchus* | | Candidate |
| Pacific lamprey | *Lampetra tridentata* | Species of concern | |
| river lamprey[c] | *Lampetra ayresi* | Species of concern | Candidate |
| spring-run Chinook salmon | *Oncorhynchus tshawytscha* | Endangered | Candidate |
| steelhead | *Oncorhynchus mykiss* | Endangered | Candidate |
| **Amphibians and Reptiles** | | | |
| sagebrush lizard | *Sceloporus graciosus* | Species of concern | Candidate |
| striped whipsnake | *Masticophis taeniatus* | | Candidate |
| western toad | *Bufo boreas* | | Candidate |
| **Birds** | | | |
| American white pelican | *Pelecanus erythrorhynchos* | | Endangered |
| bald eagle [d] | *Haliaeetus leucocephalus* | Threatened | Threatened |
| burrowing owl | *Athene cunicularia* | Species of concern | Candidate |
| common loon | *Gavia immer* | | Sensitive |
| ferruginous hawk | *Buteo regalis* | Species of concern | Threatened |

**Table 10.12.1. (contd)**

| Common Name | Scientific Name | Federal Status[a] | State Status[a] |
|---|---|---|---|
| flamulated owl[c] | *Otus flammeolus* | | Candidate |
| golden eagle | *Aquila chrysaetos* | | Candidate |
| Lewis's woodpecker[c] | *Melanerpes lewisi* | | Candidate |
| loggerhead shrike | *Lanius ludovicianus* | Species of concern | Candidate |
| merlin | *Falco columbarius* | | Candidate |
| northern goshawk[c] | *Accipter gentilis* | Species of concern | Candidate |
| olive-sided flycatcher | *Contopus cooperi* | Species of concern | |
| peregrine falcon | *Falco peregrinus* | Species of concern | Sensitive |
| sage sparrow | *Amphispiza belli* | | Candidate |
| sage thrasher | *Oreoscoptes montanus* | | Candidate |
| sandhill crane | *Grus canadensis* | | Endangered |
| western grebe | *Aechmorus occidentalis* | | Candidate |
| western sage grouse | *Centrocercus urophasianus phaios* | Candidate | Threatened |
| **Mammals** | | | |
| black-tailed jackrabbit | *Lepus californicus* | | Candidate |
| Merriam's shrew | *Sorex merriami* | | Candidate |
| Townsend's ground squirrel | *Spermophilus townsendii* | Species of concern | Candidate |
| Washington ground squirrel[c] | *Spermophilus washingtoni* | Candidate | Candidate |
| white-tailed jackrabbit | *Lepus townsendii* | | Candidate |

(a) Endangered = Species in danger of extinction within all or a significant portion of its range.
Threatened = Species likely to become endangered in the foreseeable future.
Candidate = Species that are believed to qualify for threatened or endangered species status, but for which listing proposals have not been prepared.
Sensitive = Taxa that are vulnerable or declining and could become endangered or threatened without active management or removal of threats.
Species of concern = Species that are not currently listed or candidates under the *Endangered Species Act*, but are of conservation concern within specific U.S. Fish and Wildlife Service regions.
(b) Probable, but not observed, on the Hanford Site.
(c) Reported, but seldom observed, on the Hanford Site.
(d) Currently under review for removal from the list of threatened or endangered species.

or sensitive. However, an abundance of these species may be indicative of an ecosystem with relatively high native diversity. There are approximately 50 Washington State Monitor animal and insect species occurring or potentially occurring on the Hanford Site (Table 10.12.2) and 26 Watch or Review list plant species potentially found on the Hanford Site (Table 10.12.3).

**Table 10.12.2. Washington State Monitor Animal Species Occurring or Potentially Occurring on the Hanford Site**

| Common Name | Scientific Name |
|---|---|
| **Mollusks** | |
| Oregon floater | *Anodonta oregonensis* |
| western floater | *Anodonta kennerlyi* |
| western pearlshell | *Margaritifera falcata* |
| **Insects** | |
| Bonneville skipper | *Ochlodes sylvanoides bonnevilla* |
| canyon green hairstreak | *Callophrys sheridanii neoperplexa* |
| coral hairstreak | *Harkenclenus titus immaculosus* |
| juba skipper | *Hesperia juba* |
| Nevada skipper | *Hesperia nevada* |
| northern checkerspot | *Chlosyne palla palla* |
| Pasco pearl | *Phyciodes tharos pascoensis* |
| Persius' duskywing | *Erynnis persius* |
| purplish copper | *Lycaena helloides* |
| ruddy copper | *Lycaena rubida perkinsorum* |
| silver-spotted skipper | *Epargyreus clarus californicus* |
| viceroy | *Limenitis archippus lahontani* |
| **Fish** | |
| piute sculpin | *Cottus beldingi* |
| reticulate sculpin | *Cottus perplexus* |
| sand roller | *Percopsis transmontana* |
| **Amphibians and Reptiles** | |
| night snake | *Hypsiglena torquata* |
| tiger salamander | *Ambystoma tigrinum* |
| Woodhouse's toad | *Bufo woodhousii* |
| **Birds** | |
| Arctic tern[(a)] | *Sterna paradisaea* |
| ash-throated flycatcher[(a)] | *Myiarchus cinerascens* |
| black tern | *Chlidonias niger* |
| black-crowned night-heron | *Nycticorax nycticorax* |
| black-necked stilt | *Himantopus mexicanus* |
| bobolink[(a)] | *Dolichonyx oryzivorus* |
| Caspian tern | *Sterna caspia* |
| Clark's grebe | *Aechmophorus clarkii* |
| Forster's tern | *Sterna forsteri* |
| grasshopper sparrow | *Ammodramus savannarum* |
| gray flycatcher | *Empidonax wrightii* |
| great blue heron | *Ardea herodias* |
| great egret | *Ardea alba* |
| gyrfalcon[(a)] | *Falco rusticolus* |
| horned grebe | *Podiceps auritus* |
| lesser goldfinch | *Carduelis psaltria* |
| long-billed curlew | *Numenius americanus* |
| osprey | *Pandion haliaetus* |
| prairie falcon | *Falco mexicanus* |
| red-necked grebe[(a)] | *Podiceps grisegena* |
| snowy owl | *Nyctea scandiaca* |
| Swainson's hawk | *Buteo swainsoni* |
| turkey vulture[(a)] | *Cathartes aura* |
| western bluebird | *Sialia mexicana* |
| **Mammals** | |
| long-legged myotis | *Myotis volans* |
| northern grasshopper mouse | *Onychomys leucogaster* |
| pallid bat | *Antrozous pallidus* |
| sagebrush vole | *Lagurus curtatus* |
| small-footed myotis | *Myotis leibii* |
| western pipistrelle | *Pipistrellus hesperus* |

(a) Reported, but seldom observed on the Hanford Site.

**Table 10.12.3. Washington State Review and Watch List Plant Species Potentially Found on the Hanford Site**

| Common Name | Scientific Name | State Listing[(a)] |
|---|---|---|
| annual paintbrush | *Castilleja exilis* | Watch List |
| annual sandwort | *Minuartia pusilla var. pusilla* | Review Group 1 |
| basalt milk-vetch | *Astragalus conjunctus var. rickardii* | Watch List |
| bristly combseed | *Pectocarya setosa* | Watch List |
| brittle prickly pear | *Opuntia fragilis* | Review Group 1 |
| chaffweed | *Centunculus minimus* | Review Group 1 |
| Columbia River mugwort | *Artemisia lindleyana* | Watch List |
| crouching milkvetch | *Astragalus succumbens* | Watch List |
| false pimpernel | *Lindernia dubia anagallidea* | Watch List |
| giant helleborine | *Epipactis gigantea* | Watch List |
| hedge hog cactus | *Pediocactus simpsonii var. robustior* | Review Group 1 |
| Kittitas larkspur | *Delphinium multiplex* | Watch List |
| medic milkvetch | *Astragalus speirocarpus* | Watch List |
| pigmy-weed | *Crassula aquatica* | Watch List |
| porcupine sedge | *Carex hystericina* | Watch List |
| Robinson's onion | *Allium robinsonii* | Watch List |
| rosy balsamroot | *Balsamorhiza rosea* | Watch List |
| scilla onion | *Allium scilloides* | Watch List |
| shining flatsedge | *Cyperus bipartitus (rivularis)* | Watch List |
| small-flowered nama | *Nama densum var. parviflorum* | Watch List |
| smooth cliffbrake | *Pellaea glabella simplex* | Watch List |
| southern mudwort | *Limosella acaulis* | Watch List |
| stalked-pod milkvetch | *Astragalus sclerocarpus* | Watch List |
| Thompson's sandwort | *Arenaria franklinii thompsonii* | Review Group 2 |
| vanilla grass | *Hierchloe odorata* | Review Group 1 |
| winged combseed | *Pectocarya penicillata* | Watch List |

(a) Review Group 1 - Taxa for which currently there are insufficient data available to support listing as threatened, endangered, or sensitive.
Review Group 2 - Taxa with unresolved taxonomic questions.
Watch List - Taxa that are more abundant and/or less threatened than previously assumed.

# 10.13 External Radiation Monitoring

E. J. Antonio and C. J. Perkins

External radiation at Hanford is monitored (1) onsite in relative close proximity to known, suspected, or potential radiation sources; (2) onsite at locations away from facilities and operations (site-wide); and (3) offsite in local communities, at locations distant from the site, and on or near the site perimeter. External radiation is defined as radiation originating from a source external to the body. Sources of external radiation at Hanford include waste materials associated with the historical production of plutonium for defense; residual nuclear inventories in former production and processing facilities; radioactive-waste handling, storage, and disposal activities; waste cleanup and remediation actions; atmospheric fallout from historical nuclear weapons testing; and natural sources such as cosmic radiation. During the 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).

The Harshaw thermoluminescent dosimeter (TLD) system is used to measure external radiation at the Hanford Site. This system includes the Harshaw 8800-series dosimeter and the Harshaw 8800 reader. The Harshaw 8800-series environmental dosimeter consists of two TLD-700 chips and two TLD-200 chips and provides both shallow and deep dose measurement capabilities using 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 2005. Thermoluminescent dosimeters were positioned approximately 1 meter (3.3 feet) above the ground and were collected and read quarterly.

Radiation surveys with portable instruments are conducted to monitor and detect contamination and to provide a coarse screening for external radiation fields. The types of areas surveyed in 2005 included underground radioactive materials areas, contamination areas, soil contamination areas, high contamination areas, roads, fence lines, and selected Columbia River shoreline locations.

Gamma radiation levels were monitored with pressurized ionization chambers at four offsite community-operated air-monitoring stations. 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. Results from locations near and downwind of the site are compared to results from a distant location and to thermoluminescent dosimeter measurements obtained at each chamber location.

In the following sections, all 2005 external radiation measurements are compared to results from previous years, and 2005 onsite measurements are compared to measurements obtained at perimeter and distant locations in 2005. For further information about the monitoring and surveillance programs that support these efforts, see Section 10.0 or DOE/RL-91-50.

# 10.13.1 External Radiation Monitoring Onsite Near Facilities and Operations

C. J. Perkins

During 2005, external radiation fields were monitored with thermoluminescent dosimeters at 136 locations near onsite facilities and operations. Thermoluminescent dosimeter results were used individually or averaged to determine dose rates in a given area for a particular sampling period. A comparison of 2005 and 2004 results for thermoluminescent dosimeters located near waste handling facilities on the Hanford Site can be found in Table 10.13.1. Individual thermoluminescent dosimeter results and detailed monitoring-location maps are provided in PNNL-15892, APP. 2.

## 10.13.1.1 External Radiation Measurements Onsite Near Facilities and Operations

***100-B/C Area***. At the former 116-B-11 and 116-C-1 liquid waste disposal facilities (located in the 100-B/C Area), dose rate levels in 2005 were comparable to previous years.

***100-K Area***. Cleanup activities at the 100-K Area basins and adjacent retired reactor buildings continued in 2005, and average dose rates measured in 2005 increased by over 400% relative to 2004 values. The 2005 increase was primarily due to elevated dose rates at monitoring locations situated near radioactive materials transfer and storage areas. Two locations were near the K-East spent nuclear fuel storage basin load-out station and four others were near the K-West spent nuclear fuel storage basin. Dose rates at the K-East and K-West locations steadily increased through the year.

**Table 10.13.1. Thermoluminescent Dosimeter Results (mrem/yr)[a] Near Hanford Site Operations in 2004 and 2005**

| Hanford Site Locations | No. of Dosimeters | 2004 Maximum[b] | 2004 Average[c,d] | 2005 Maximum[b] | 2005 Average[c,d] | % Change[e] |
|---|---|---|---|---|---|---|
| 100-B/C Area | 4 | 88 ± 7 | 86 ± 5 | 94 ± 10 | 88 ± 10 | 3 |
| 100-K Area | 11 | 1,350 ± 3,330 | 229 ± 748 | 5,600 ± 3,600 | 1,270 ± 3,800 | 453 |
| 100-KR-1 | 5 | 104 ± 10 | 97 ± 15 | 159 ± 55 | 113 ± 52 | 17 |
| 100-N Area | 14 | 475 ± 76 | 210 ± 257 | 229 ± 38 | 139 ± 96 | -33 |
| 200-East Area | 42 | 4,000 ± 12,000 | 200 ± 1,202 | 312 ± 151 | 114 ± 95 | -42 |
| 200-West Area | 24 | 3,000 ± 10,000 | 225 ± 1,196 | 182 ± 13 | 105 ± 46 | -52 |
| 200-North Area (212-R) | 1 | 3,000 ± 472 | 3,000 ± 295 | 3,100 ± 487 | 2,700 ± 710 | -5 |
| 300 Area | 8 | 112 ± 12 | 92 ± 25 | 113 ± 8 | 93 ± 23 | 1 |
| 300 TEDF | 6 | 87 ± 5 | 85 ± 4 | 91 ± 10 | 88 ± 4 | 3 |
| 300-FF-2 | 6 | 91 ± 40 | 87 ± 5 | 101 ± 44 | 88 ± 13 | <1 |
| 400 Area | 7 | 85 ± 6 | 83 ± 2 | 87 ± 5 | 84 ± 4 | 1 |
| CVDF | 4 | 258 ± 445 | 177 ± 175 | 1,100 ± 916 | 560 ± 834 | 216 |
| ERDF | 3 | 100 ± 22 | 95 ± 8 | 105 ± 51 | 100 ± 8 | 5 |
| IDF | 1 | NA; new in 2005 | | 90 ± 14 | 89 ± 2 | NA |

(a) To convert to international metric system units, multiply mrem/yr by 0.01 to obtain mSv/yr.
(b) Maximum values are ± analytical uncertainty.
(c) ±2 standard deviation.
(d) Each dosimeter is collected and read quarterly.
(e) Numbers indicate a decrease (-) or increase from the 2004 mean.
CVDF = Cold Vacuum Drying Facility (100-K Area).
ERDF = Environmental Restoration Disposal Facility (200-West Area).
IDF = Integrated Disposal Facility (200-East Area).
NA = Not applicable.
TEDF = 300 Area Treated Effluent Disposal Facility.

Dosimeter monitoring sites around the 100-K Area's Cold Vacuum Drying Facility showed a significant annual dose rate increase of 216% in 2005 compared to 2004. Dose rates at all four monitoring locations began increasing noticeably during mid-year 2004 when radioactive materials associated with cleanup activities in the K Basins began to be stored at the facility.

Dose rate levels measured at the 100-KR-1 (100-K Area) remedial action site in 2005 increased by approximately 17% compared to 2004. This was most likely due to the proximity to the K-West spent nuclear fuel storage basin.

***100-N Area***. The average dose rate measured in the 100-N Area in 2005 was approximately 33% lower than that measured in 2004. Direct radiation levels were, again, highest near facilities that contained or received liquid effluent from the N Reactor. These facilities primarily included the retired 116-N-1 (also known as 1301-N) and 116-N-3 (also known as 1325-N) liquid waste disposal trenches. Annual average dose rates at five monitoring locations near the 116-N-1 trench showed a decrease of approximately 4% compared to levels measured at the same locations in 2004. The 2005 annual average dose rate levels at the three monitoring locations near the 116-N-3 facility showed a decrease of approximately 75% from 2004 levels. This notable reduction in dose rates in 2005 was directly attributable to the continued removal of contaminated materials from the facility. Annual average thermoluminescent dosimeter results for the entire 100-N Area from 1995 through 2005 are presented in Figure 10.13.1.

***100-N Area Shoreline (N Springs)***. Dose rates were measured along the Columbia River shoreline in the 100-N Area (N Springs) to determine potential external radiation doses to onsite workers and to members of the public using the river. Cleanup activities at the retired 116-N-1 and 116-N-3 trenches (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 shoreline and the dose rates there have decreased notably over the past few years (Figure 10.13.1). The 2005 dose rates were similar to the 2004 dose rates.

***200-East and 200-West Areas***. Overall, dose rates measured during 2005 in both the 200-East and 200-West Areas were significantly lower than in 2004. While dose rates were highest near waste handling facilities, they were much lower than the levels measured during peak waste-retrieval activities at the A Tank Farm (200-East Area) and at the S Tank Farm (200-West Area) during the second quarter of 2004. The overall effect was that average dose rates measured in the 200-East and 200-West Areas in 2005 were 42% and 52% lower, respectively, than the 2004 average dose rates (Figure 10.13.1).

Average dose rates measured in 2005 at the Environmental Restoration Disposal Facility (located near the 200-West Area) were similar to 2004 levels, with only a slight increase of approximately 5%.

***200-North Area***. One thermoluminescent dosimeter monitoring site, located in the 200-North Area at the contaminated 212-R Railroad Car Disposition Area, showed a decrease in the annual average dose rate of 5% in 2005 compared to 2004. This thermoluminescent dosimeter location was established in 2000 to monitor expected high radiation levels emitted from contaminated railroad cars staged in the immediate vicinity.

***300 and 400 Areas***. The average dose rates in the 300 Area, at the 300 Area Treated Effluent Disposal Facility, and in the 400 Area in 2005 were virtually unchanged from their 2004 levels (Figure 10.13.1).

Dose rate levels continued to be measured through September 2005 at six locations at the 300-FF-2 remedial action site in the 300 Area. Monitoring was concluded in concert with the completion of the project activities for the year. Dose rates were comparable to typical levels observed at the longer established locations in the 300 and 400 Areas (i.e., approximately 90 mrem/year [0.9 mSv/year]).

### 10.13.1.2 Radiological Surveys at Active and Inactive Waste Disposal Sites

S. M. McKinney and R. M. Mitchell

During 2005, 500 environmental radiological surveys were conducted at active and inactive waste disposal sites and the terrain surrounding them to detect and characterize radioactive surface contamination. Vehicles equipped with radiation detection devices and global positioning systems were used to accurately measure the extent of the contamination.

Figure 10.13.1. Annual Average Thermoluminescent Dosimeter Rates in Selected Areas Near Facilities and Operations on the Hanford Site

Area measurements were entered into the Hanford Geographical Information System, a computer database maintained by Fluor Hanford, Inc. Routine radiological survey locations included 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. These sites were posted as underground radioactive materials areas, contamination areas, and soil contamination areas. It was estimated that the external dose rate at 80% of the outdoor contaminated areas was less than 1 mrem/hr (0.01 mSv/hr), though direct dose rate readings from isolated radioactive specks could have been higher.

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

Contamination areas and 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 or with materials from unplanned releases (e.g., contaminated tumbleweeds and animal feces).

All contaminated areas may be susceptible to contaminant migration and are surveyed at least annually to assess their current radiological status (locations of posted contamination areas are illustrated in PNNL-15892, APP. 2). In addition, onsite paved roadways are surveyed annually and the intersections along the Environmental Restoration Disposal Facility haul routes are surveyed quarterly.

During 2005, the Hanford Site had approximately 3,592 hectares (8,876 acres) of outdoor contaminated areas of all types and approximately 635 hectares (1,569 acres) that contained underground radioactive materials not including active facilities. A list of the contaminated areas, underground radioactive materials areas, interim closed waste sites, their status, and their general locations is provided in Table 10.13.2. No new areas of significant size were discovered during 2005. Waste sites are "interim closed" and released from radiation posting when the remedial actions meet the operable unit's record of decision cleanup requirements. During 2005, approximately 9 hectares (22 acres) of previously posted contamination and/or underground radioactive materials areas underwent remediation action and were interim closed. Table 10.13.3 summarizes the change in status of outdoor contamination areas during 2005.

**Table 10.13.2. Status of Outdoor Contamination Areas at Hanford, 1998 through 2005**

| Area | Contamination Areas,[a] ha | (acres) | Underground Radioactive Materials Areas,[b] ha | (acres) | Interim Closed, ha | (acres) |
|---|---|---|---|---|---|---|
| 100-B/C | 0 | (0) | 37 | (90) | 0 | (0) |
| 100-D/DR | 0 | (0) | 29 | (72) | 0 | (0) |
| 100-F | 0 | (0) | 31 | (77) | 3 | (7) |
| 100-H | 0 | (0) | 10 | (25) | 4 | (10) |
| 100-K | 8 | (20) | 53 | (131) | 9 | (22) |
| 100-N | 2 | (5) | 12 | (30) | 11 | (27) |
| 200-East[c] | 72 | (178) | 141 | (348) | 0 | (0) |
| 200-West[c] | 27 | (67) | 225 | (556) | 0 | (0) |
| 300 | 5 | (12) | 42 | (104) | 15 | (37) |
| 400 | 0 | (0) | 0 | (0) | 0 | (0) |
| 600[d] | 3,478 | (8,594) | 55 | (136) | 0 | (0) |
| **Totals** | **3,592** | **(8,876)** | **635** | **(1,569)** | **42** | **(103)** |

(a) Includes areas posted as contamination/soil contamination or as 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 crib controlled area, Environmental Restoration Disposal Facility, and waste disposal facilities outside the 200-East and 200-West Areas boundaries.

**Table 10.13.3. Change in Status of Outdoor Contamination Areas at Hanford, 2005**

| Areas | Changes | Area, ha (acres) | |
|---|---|---|---|
| 100 | CA/URM to interim closed[(a)] | 7 | (17) |
| 200-East | None to report | 0 | (0) |
| 200-West | None to report | 0 | (0) |
| 300 | CA/URM to interim closed[(a)] | 2 | (5) |
| 400 | None to report | 0 | (0) |
| 600 | None to report | 0 | (0) |

(a) Changes due to remedial action activities.
CA = Contamination/soil contamination area.
URM = Underground radioactive material area.

## 10.13.2 External Radiation Monitoring at Site-Wide and Offsite Locations

E. J. Antonio

During 2005, external radiation levels were measured at 33 site-wide locations on the Hanford Site (Figure 10.13.2), 11 locations around the perimeter of the site, 9 locations in surrounding communities including 2 at distant locations (Figure 10.13.3), and 29 locations along the Columbia River shoreline from the Vernita Bridge to downstream of Bateman Island at the mouth of the Yakima River (Figure 10.13.4). Measurements were made using thermoluminescent dosimeters and pressurized ionization chambers. Annual results for 2005 are compared to results obtained during the previous 5 years in Tables 10.13.4 through 10.13.6. External radiation and surface contamination surveys at specified locations were performed with portable radiation survey instruments.

All community and most of the site-wide and perimeter thermoluminescent dosimeter locations were collocated with air-monitoring stations. The site-wide and perimeter locations were selected based on determinations of the high potential for public exposure to radiation resulting from remediation activities (i.e., access areas and downwind population centers) and 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.

Ground contamination surveys were conducted quarterly at 13 shoreline locations. These surveys were conducted using Geiger-Mueller meters (also called 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 (approximately 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 offsite community-operated air monitoring stations (Section 10.13.2.5). These instruments measured ambient exposure rates near and downwind of the site and at locations distant and upwind of the site. Continuous exposure-rate data were displayed at each station to provide information to the public and to serve as an educational tool for the teachers who manage the stations.

### 10.13.2.1 External Radiation Measurements at Site-Wide Locations

The average dose rates near all operational areas (Table 10.13.4) were higher than average dose rates measured at distant locations (Table 10.13.5). The highest annual average dose rate measured at site-wide locations during 2005 (102 ± 19 mrem [1.02 ± 0.19 mSv]) was detected at the southwest corner of the US Ecology waste burial site (location 28 in Figure 10.13.2). The 5-year maximum annual average site-wide dose rate (107 ± 6 mrem [1.07 ± 0.06 mSv]) was measured during 2002 in the 300 Area.

### 10.13.2.2 External Radiation Measurements at Perimeter and Offsite Locations

The average perimeter dose rate was 92 ± 3 mrem (0.92 ± 0.03 mSv) in 2005; the maximum was 98 ± 5 mrem (0.98 ± 0.05 mSv) (Table 10.13.5). The 5-year (2000 through 2004) perimeter annual average dose rate was 90 ± 2 mrem (0.90 ± 0.02 mSv) and the 5-year maximum annual average dose rate was 106 ± 7 mrem (1.06 ± 0.07 mSv). The location

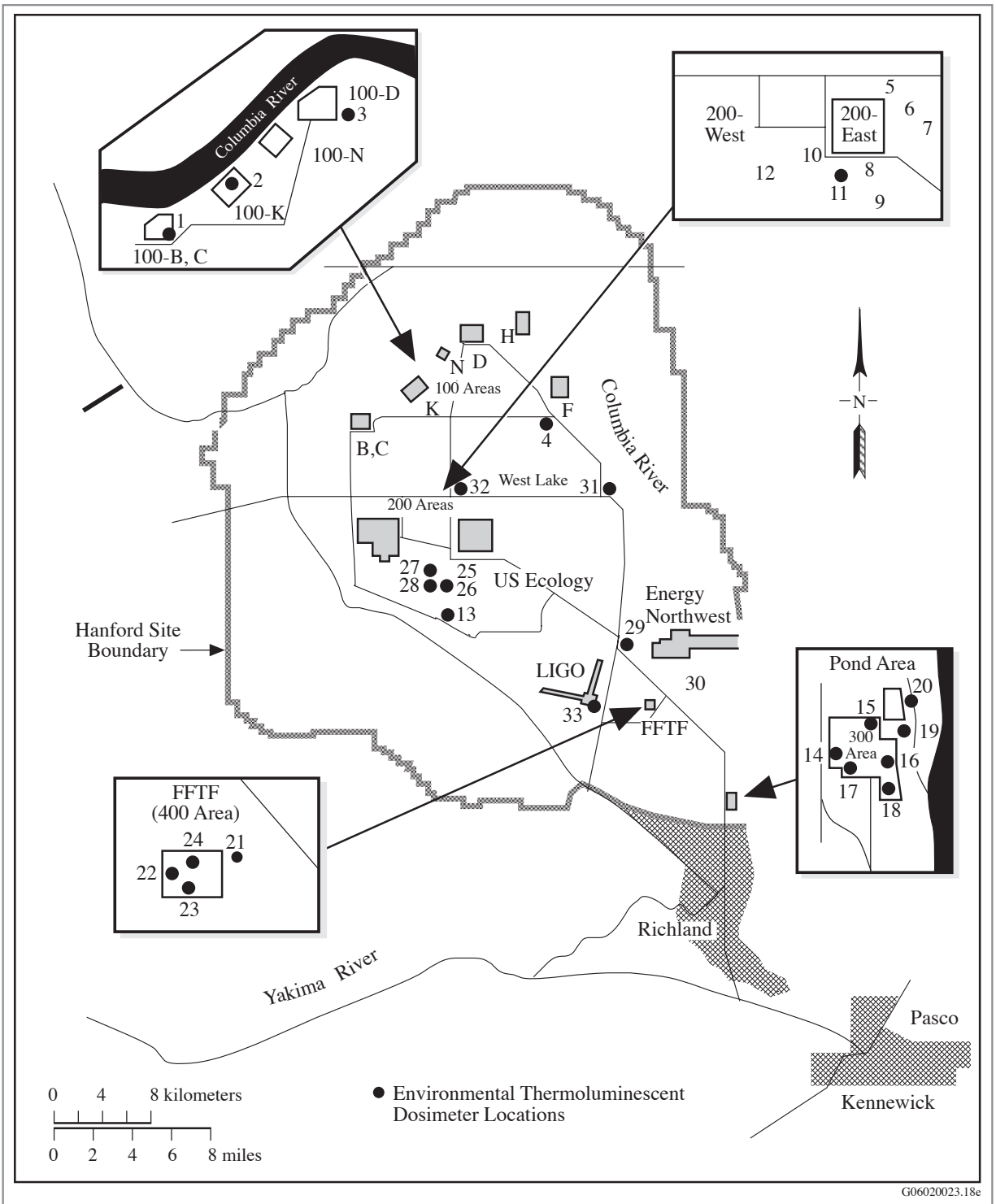



**Figure 10.13.2. Surface Environmental Surveillance Project Thermoluminescent Dosimeter Locations (and station numbers) on the Hanford Site (site-wide), 2005 (see Appendix C, Table C.20 for station names)**

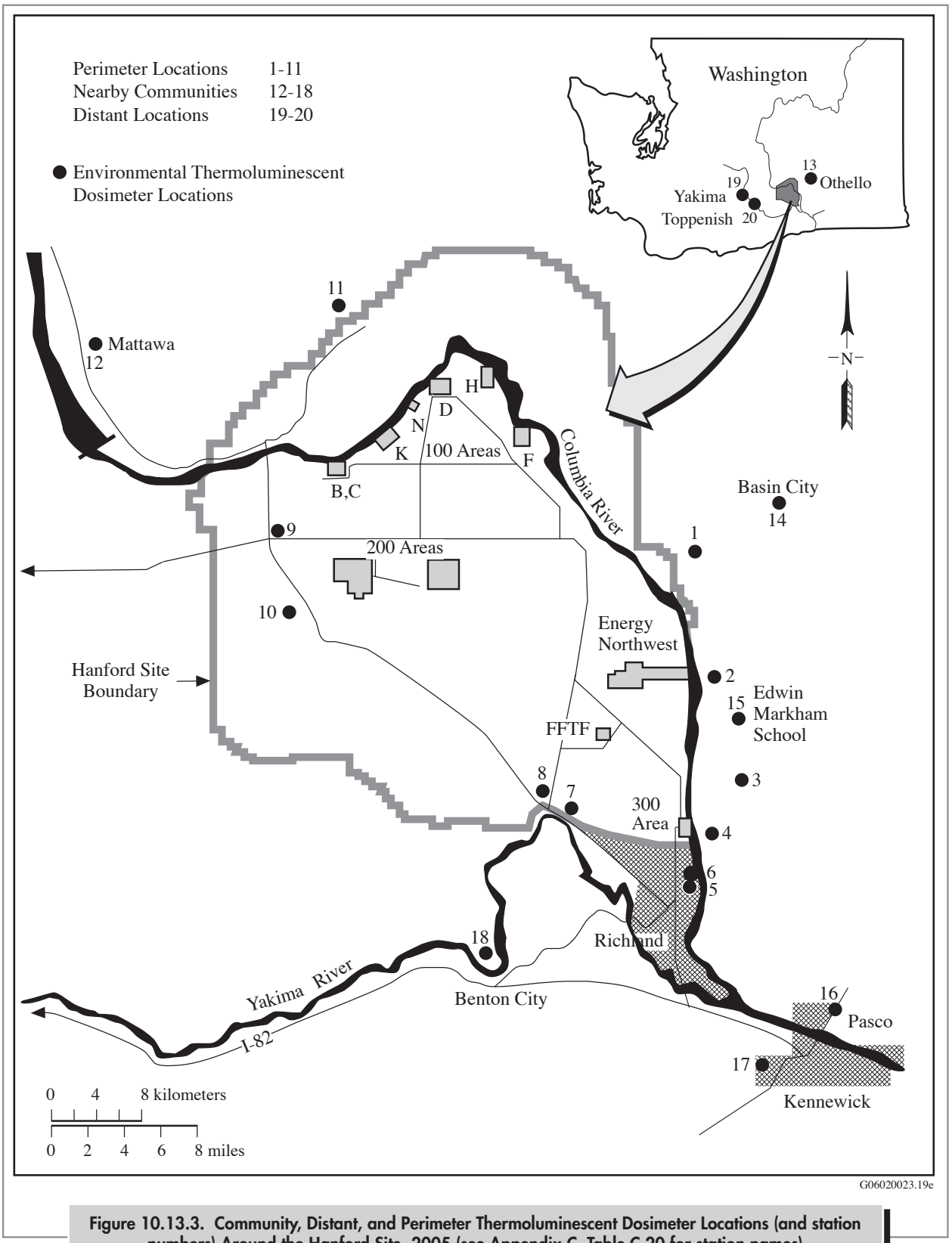



**Figure 10.13.3. Community, Distant, and Perimeter Thermoluminescent Dosimeter Locations (and station numbers) Around the Hanford Site, 2005 (see Appendix C, Table C.20 for station names)**

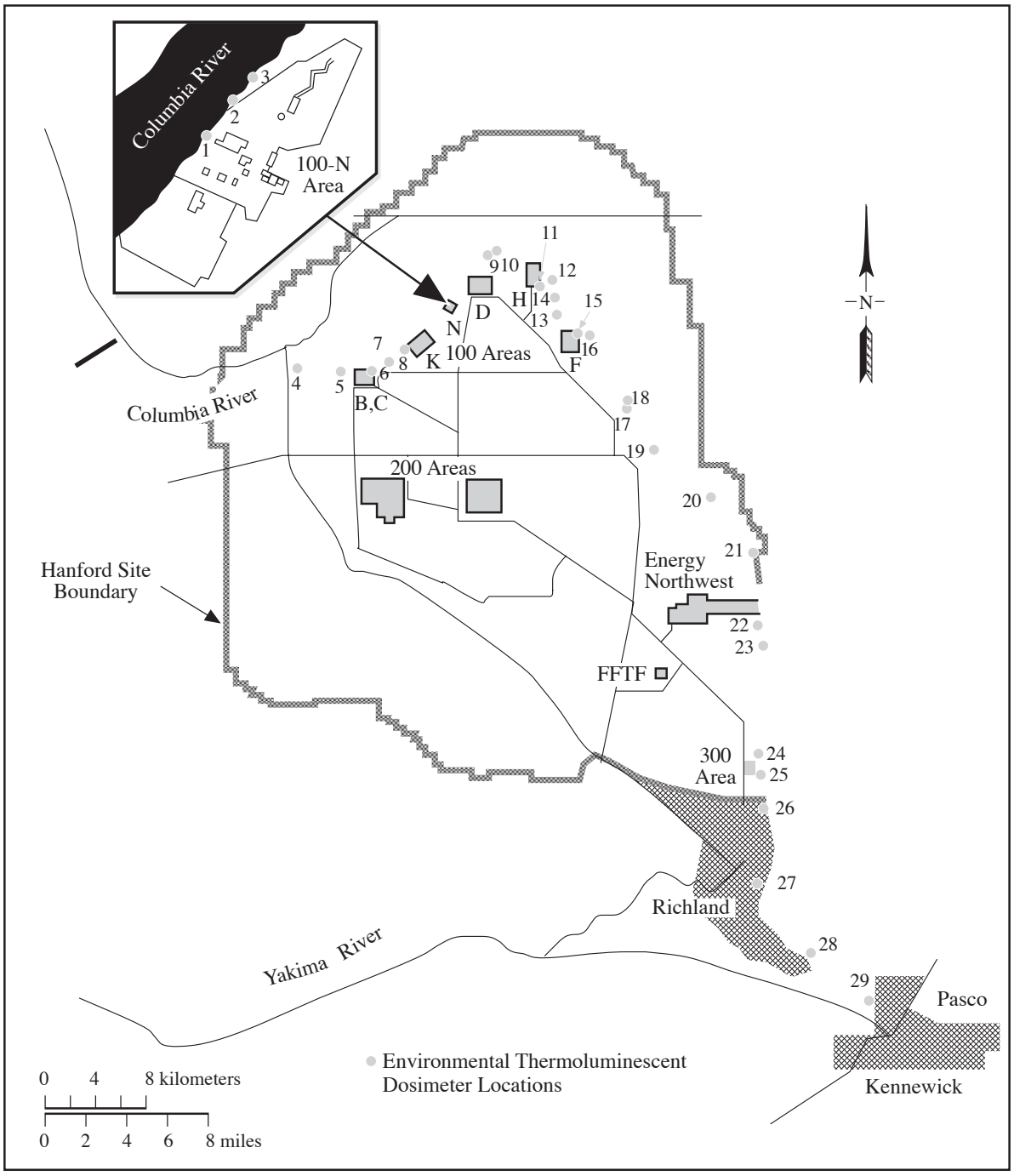



**Figure 10.13.4. Hanford Site Surface Environmental Surveillance Project Thermoluminescent Dosimeter Locations (and station numbers) Along the Columbia River, 2005 (see Appendix C, Table C.20 for station names)**

**Table 10.13.4. Dose Rates (mrem/yr[a]) Measured by Thermoluminescent Dosimeters at Site-Wide Locations on the Hanford Site, 2005 Compared to Previous 5 Years**

| | | 2005 | | 2000-2004 | | |
|---|---|---|---|---|---|---|
| Location | Map Location[b] | Maximum[c] | Average[d] | No. of Samples | Maximum[c] | Average[d] |
| 100 Areas | 1 - 4 | 90 ± 5 | 86 ± 5 | 18 | 88 ± 6 | 81 ± 2 |
| 200 Areas | 5 - 13 | 96 ± 10 | 90 ± 3 | 45 | 96 ± 8 | 87 ± 1 |
| 300 Area | 14 - 20 | 88 ± 18 | 84 ± 2 | 33 | 107 ± 6 | 84 ± 2 |
| 400 Area | 21 - 24 | 89 ± 5 | 85 ± 2 | 20 | 88 ± 5 | 83 ± 1 |
| 600 Area | 25 - 33 | 102 ± 19 | 88 ± 3 | 42 | 101 ± 13 | 87 ± 2 |
| Combined site-wide | 1 - 33 | 102 ± 19 | 87 ± 2 | 158 | 101 ± 13 | 85 ± 1 |

(a) Multiply by 10 to convert to μSv/yr.
(b) All station locations are shown on Figure 10.13.2 and are described in Appendix C, Table C.20.
(c) Maximum annual average dose rate for all locations within a given distance classification (±2 standard deviations).
(d) Computed by averaging annual means for each location within a given distance classification (±2 standard error of the mean).

**Table 10.13.5. Dose Rates (mrem/yr[a]) Measured by Thermoluminescent Dosimeters at Perimeter and Offsite Locations Around the Hanford Site, 2005 Compared to Previous 5 Years**

| | | 2005 | | 2000-2004 | | |
|---|---|---|---|---|---|---|
| Location | Map Location[b] | Maximum[c] | Average[d] | No. of Samples | Maximum[c] | Average[d] |
| Perimeter | 1 - 11 | 98 ± 5 | 92 ± 3 | 56 | 106 ± 7 | 90 ± 2 |
| Community | 12 - 18 | 88 ± 12 | 81 ± 3 | 37 | 88 ± 6 | 79 ± 1 |
| Distant | 19 - 20 | 74 ± 6 | 74 ± 1 | 10 | 73 ± 7 | 71 ± 1 |

(a) Multiply by 10 to convert to μSv/yr.
(b) All station locations are shown on Figure 10.13.3 and are described in Appendix C, Table C.20.
(c) Maximum annual average dose rate for all locations within a given distance classification (±2 standard deviations).
(d) Computed by averaging annual means for each location within a given distance classification (±2 standard error of the mean).

of the 2005 maximum perimeter dose was Byers Landing (location number 4 on Figure 10.13.3). 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 *The Determination of the Penetrating Radiation Dose at Hanford* (PNL-7124).

The average background dose rate (measured in distant communities) in 2005 was 74 ± 1 mrem (0.74 ± 0.01 mSv) per year, which was almost equal to the average for 2004 (PNNL-15222) and the 5-year annual average of 71 ± 1 mrem (0.71 ± 0.01 mSv) (Table 10.13.5). Site-wide and perimeter average dose rates in 2005 were 13 mrem (0.13 mSv) and 18 mrem (0.18 mSv) per year higher, respectively, than average dose rates measured at distant locations (Figure 10.13.5).

**Table 10.13.6. Dose Rates (mrem/yr[a]) Measured by Thermoluminescent Dosimeters Along the Shoreline of the Hanford Reach of the Columbia River, 2005 Compared to Previous 5 Years**

| | | 2005 | | 2000-2004 | | |
|---|---|---|---|---|---|---|
| Location | Map Location[b] | Maximum[c] | Average[d] | No. of Samples | Maximum[c] | Average[d] |
| 100-N Area shoreline | 1 - 3 | 105 ± 11 | 92 ± 11 | 15 | 131 ± 7 | 100 ± 7 |
| Typical shoreline | 4 - 29 | 100 ± 12 | 88 ± 3 | 118 | 101 ± 22 | 86 ± 1 |
| All shoreline | 1 - 29 | 105 ± 11 | 88 ± 3 | 133 | 131 ± 7 | 88 ± 2 |

(a) Multiply by 10 to convert to µSv/yr.
(b) All station locations are shown on Figure 10.13.4 and are described in Appendix C, Table C.20.
(c) Maximum annual average dose rate for all locations within a given distance classification (±2 standard deviations).
(d) Computed by averaging annual means for each location within a given distance classification (±2 standard error of the mean).

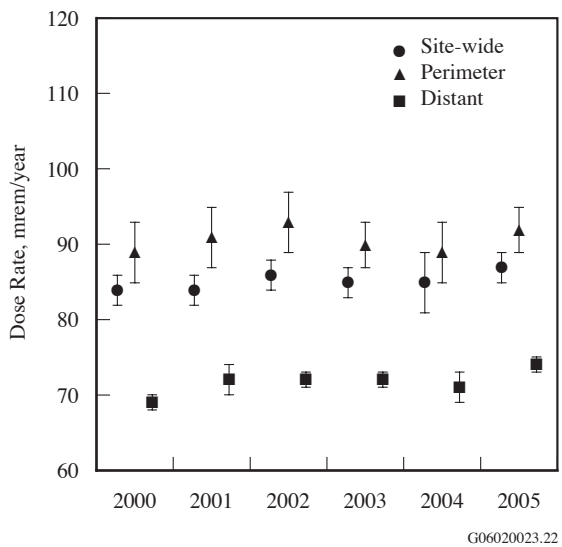



**Figure 10.13.5. Annual Average Dose Rates (±2 standard error of the mean) at Hanford Site-Wide, Perimeter, and Distant Locations, 2000 through 2005**

## 10.13.2.3 External Radiation Measurements at Columbia River Shoreline Locations

During 2005, average dose rates along the Columbia River shoreline near the 100-N Area were approximately 4 mrem (0.04 mSv) per year higher than the average of all other shoreline dose rates (Table 10.13.6). Higher dose rates historically measured along the 100-N Area shoreline were attributed to waste management practices in that area (PNL-3127). The 2005 maximum annual 100-N Area shoreline dose rate of 105 ± 11 mrem (1.05 ± 0.11 mSv) is about the same as the maximum annual dose rate of 103 ± 7 mrem (1.03 ± 0.07 mSv) measured at that location in 2004 (PNNL-15222), but is significantly different (i.e., the 95% confidence intervals associated with the two measurements do not overlap) than the 5-year maximum annual average of 131 ± 7 mrem (1.31 ± 0.07 mSv) measured during 2000. 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 10.13.6). The general public is not permitted 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 Section 10.14 and in *2003 External Radiation Survey Along the Columbia River Shoreline of the Hanford Site's 100 Area* (DOH 320-032).

## 10.13.2.4 Columbia River Shoreline Radiological Survey Results

During 2005, 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 (9 µrem [0.09 µSv] per hour, approximately 78 mrem per year) was measured along the 100-N Area shoreline; the lowest dose

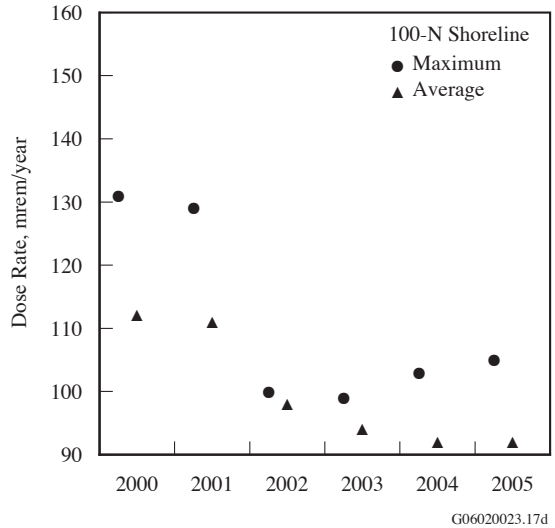



**Figure 10.13.6. Maximum and Average External Dose Rates Measured Along the Columbia River at 100-N Area Shoreline Locations on the Hanford Site, 2000 through 2005**

rate measured with the Bicron® Microrem meter was 4 µrem (0.04 µSv) per hour and was recorded at various locations along the Hanford Reach shoreline. The highest reported count rate measured with a 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 (25 counts per minute) was recorded at several locations throughout the year.

## 10.13.2.5 Pressurized Ionization Chamber Results at Four Offsite Locations

Gamma radiation levels were monitored with pressurized ionization chambers at four community-operated air-monitoring stations during 2005 (Section 10.17). 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 University near Toppenish (locations 36, 40, 35, and 44, respectively, on Figure 10.2.2). Measurements were collected to determine ambient gamma radiation levels near and downwind of the site and upwind and distant from the site, to display near-continuous exposure rate information to the public living near the stations, and for educational information for the teachers who manage the stations.

Data collection systems consisted of computers, data loggers, and radiotelemetry instruments. Data from all stations were transmitted 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://hms.pnl.gov) at 15-minute intervals.

Readings at the Leslie Groves Park and Heritage University 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 Elementary Schools 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.

One µR per hour is approximately equal to 1 microrem per hour. Maximum hourly average exposure rates ranged from 16.0 microroentgen (µR) per hour at Leslie Groves Park during January to 7.9 µR per hour at Edwin Markham Elementary School in July and August (Table 10.13.7). Monthly mean hourly average readings were consistently between 7.4 and 9.2 µR per hour at the stations near Hanford and ranged from 7.7 and 9.0 µR per hour at the distant station (Heritage University). 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 2005 (Table 10.13.8).

**Table 10.13.7. Exposure Rates[a] Measured by Pressurized Ionization Chambers at Four Locations Around the Hanford Site,[b] 2005**

| Month | | Exposure Rate, µR/hr (number of hourly averages) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Leslie Groves Park[c] | | Basin City[d] | | Edwin Markham[d] | | Toppenish[c] | |
| January | Mean | 9.0 | (744) | 8.7 | (727) | 7.6 | (401) | 8.5 | (514) |
| | Maximum | 16.0 | | 14.5 | | 9.5 | | 11.9 | |
| | Minimum | 8.2 | | 7.7 | | 7.0 | | 7.4 | |
| February | Mean | 9.0 | (672) | 8.8 | (670) | 7.6 | (656) | 8.6 | (599) |
| | Maximum | 11.0 | | 10.2 | | 9.3 | | 10.8 | |
| | Minimum | 8.5 | | 8.0 | | 7.0 | | 7.7 | |
| March | Mean | 8.8 | (744) | 8.8 | (747) | 7.6 | (723) | 8.4 | (700) |
| | Maximum | 10.1 | | 11.2 | | 9.6 | | 9.7 | |
| | Minimum | 8.4 | | 8.4 | | 6.8 | | 7.5 | |
| April | Mean | 8.7 | (720) | 8.7 | (720) | 7.5 | (720) | 8.2 | (720) |
| | Maximum | 10.4 | | 10.9 | | 9.1 | | 11.7 | |
| | Minimum | 8.4 | | 8.5 | | 7.2 | | 7.6 | |
| May | Mean | 8.6 | (744) | 8.6 | (744) | 7.5 | (744) | 8.0 | (743) |
| | Maximum | 9.4 | | 11.0 | | 8.5 | | 9.8 | |
| | Minimum | 8.3 | | 8.2 | | 7.1 | | 7.5 | |
| June | Mean | 8.6 | (720) | 8.7 | (720) | 7.4 | (666) | 8.0 | (720) |
| | Maximum | 10.0 | | 10.1 | | 9.5 | | 10.1 | |
| | Minimum | 8.3 | | 7.4 | | 7.1 | | 7.5 | |
| July | Mean | 8.5 | (743) | 8.5 | (744) | 7.4 | (744) | 7.7 | (744) |
| | Maximum | 9.1 | | 9.5 | | 7.9 | | 9.1 | |
| | Minimum | 8.2 | | 8.2 | | 6.5 | | 7.4 | |
| August | Mean | 8.6 | (743) | 8.6 | (744) | 7.4 | (171) | 7.7 | (745) |
| | Maximum | 9.2 | | 9.1 | | 7.9 | | 8.4 | |
| | Minimum | 8.2 | | 8.3 | | 7.2 | | 7.3 | |
| September | Mean | 8.6 | (720) | 8.6 | (720) | ND | | 8.4 | (712) |
| | Maximum | 9.3 | | 9.5 | | ND | | 10.5 | |
| | Minimum | 8.2 | | 8.2 | | ND | | 7.4 | |
| October | Mean | 8.8 | (744) | 8.6 | (744) | ND | | 8.8 | (728) |
| | Maximum | 9.9 | | 9.3 | | ND | | 10.9 | |
| | Minimum | 8.4 | | 8.3 | | ND | | 7.6 | |
| November | Mean | 8.9 | (720) | 8.6 | (720) | ND | | 9.0 | (720) |
| | Maximum | 11.9 | | 10.1 | | ND | | 12.7 | |
| | Minimum | 8.4 | | 8.0 | | ND | | 8.1 | |
| December | Mean | 9.2 | (744) | 8.8 | (742) | ND | | 8.6 | (744) |
| | Maximum | 10.3 | | 10.4 | | ND | | 10.5 | |
| | Minimum | 8.5 | | 8.2 | | ND | | 7.8 | |

(a) Maximum and minimum values are hourly averages. Means are monthly means.
(b) Measurement locations are illustrated in Figure 10.2.2.
(c) Readings are stored every 60 minutes. Each 60-minute reading is an average of measurements collected at 5-second intervals.
(d) 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).
ND = No data collected.

**Table 10.13.8. Quarterly Average Exposure Rates (μR/hr[a]) Measured by Thermoluminescent Dosimeters at Four Locations Around the Hanford Site,[b] 2005**

| Quarter Ending | Leslie Groves Park[c] | Basin City | Edwin Markham | Toppenish |
|---|---|---|---|---|
| March | 9.5 ± 0.1 | 9.2 ± 0.4 | 9.5 ± 0.4 | 8.7 ± 0.1 |
| June | 8.8 ± 0.1 | 9.0 ± 0.1 | 9.0 ± 0.4 | 8.2 ± 0.0 |
| September | 8.7 ± 0.1 | 9.2 ± 0.3 | 8.2 ± 0.1 | 8.7 ± 0.2 |
| December | 8.8 ± 0.2 | 8.7 ± 0.0 | 8.5 ± 0.4 | 8.0 ± 0.0 |

(a) ± counting error.
(b) Sampling locations shown on Figure 10.2.2.
(c) Thermoluminescent dosimeter located ~1 kilometer (0.6 mile) north of Leslie Groves Park at map location 26, Figure 10.13.4.

# 10.14 Potential Radiological Doses from 2005 Hanford Site Operations

E. J. Antonio and K. Rhoads

During 2005, potential radiological doses to the public and biota from Hanford Site operations were evaluated in detail to determine compliance with pertinent regulations and limits. The potential sources of radionuclide contamination included gaseous emissions from stacks and ventilation exhausts, liquid effluent from operating wastewater treatment facilities, contaminated groundwater seeping into the Columbia River, and fugitive emissions from contaminated soil areas and facilities. The methods used to calculate the potential doses are detailed in Appendix E.

The radiological impact of 2005 Hanford Site operations was assessed in terms of the:

- Dose to a hypothetical, maximally exposed individual at an offsite location using a multimedia pathway assessment (DOE Order 5400.5; Section 10.14.1).
- Collective dose to the population residing within 80 kilometers (50 miles) of Hanford Site operating areas (Section 10.14.2).
- Dose for air pathways, using EPA methods, for comparison to the *Clean Air Act* standards in 40 CFR 61, Subpart H, *National Emission Standards for Hazardous Air Pollutants* (Section 10.14.3).
- Maximum dose rate from external radiation at a publicly accessible location at or just within the site boundary (Section 10.14.4.1).
- Dose to a worker consuming drinking water on the site (Section 10.14.4.3).
- Inhalation dose associated with measured radionuclide concentrations in air (Section 10.14.4.4).
- Doses from non-DOE industrial sources on and near Hanford (Section 10.14.5).
- Absorbed dose received by animals exposed to radionuclide releases to the Columbia River and to radionuclides in onsite surface water bodies (Section 10.14.6).

It is generally accepted that radiological dose assessments should be based on direct measurements of radiation dose rates and radionuclide concentrations. However, the amounts of most radioactive materials released during 2005 from Hanford Site sources were, generally, too small to be measured directly once it was dispersed in the offsite environment. For many of the radionuclides present in measurable amounts, it was difficult to separate the contributions from Hanford sources from the contributions from fallout and naturally occurring uranium and its decay products. Therefore, in nearly all instances, offsite doses were estimated using *GENII - The Hanford Environmental Radiation Dosimetry Software System*, Version 1.485 (PNL-6584) and the Hanford Site-specific parameters listed in Appendix E and in PNNL-15892, APP. 1.

Radiological doses from the water pathway were calculated based on the differences in radionuclide concentrations between upstream and downstream sampling points on the Columbia River. During 2005, tritium, strontium-90, technetium-99, iodine-129, and two uranium isotopes were found in the Columbia River downstream of Hanford at greater levels than predicted based on direct discharges from the 100-K Area (Section 10.4 and Appendix C). All other radionuclide concentrations were lower than those predicted from known releases. Shoreline spring water containing radionuclides is known to enter the Columbia River along the portion of the Hanford shoreline extending from the

100-B/C Area downstream to the 300 Area (Sections 10.5 and 10.7). No direct discharge of radioactive materials from the 300 Area to the Columbia River was reported during 2005.

## 10.14.1 Maximally Exposed Individual Dose (Offsite Resident)

The maximally exposed individual is a hypothetical person who lives at a particular location and has a lifestyle that makes it unlikely that any other member of the public would have received a higher radiological dose from Hanford releases during 2005. This individual's exposure pathways were chosen to maximize the combined doses from all reasonable environmental routes of exposure to radionuclides in Hanford Site effluent and emissions using a multimedia pathway assessment (DOE Order 5400.5). In reality, such a combination of maximized parameters is highly unlikely to apply to any single individual.

The location of the hypothetical, maximally exposed individual varies from year to year, depending on the relative contributions of the several sources of radioactive emissions released to the air and liquid effluent released to the Columbia River from Hanford facilities (Figure 10.14.1). During 2005, the dose assessment determined that the maximally exposed individual was located across the Columbia River (east of the Hanford Site) at Sagemoor (Figure 10.14.1). For the calculation, it was assumed that this individual:

- Inhaled and was submersed in airborne radionuclides.
- Received external exposure to radionuclides deposited on the ground.
- Ingested locally grown food products that had been irrigated with water withdrawn from the Columbia River downstream from the Hanford Site.
- Used the Columbia River near the Hanford Site for recreational purposes, resulting in direct exposure from radionuclides in water and radionuclides deposited on the shoreline.
- Ingested locally caught Columbia River fish.

Doses were calculated using Hanford Site air emissions and effluent data (Tables 10.1.1 and 10.3.2) and the calculated quantities of radionuclides assumed to be present in the Columbia River from shoreline spring discharges along the Hanford Site shoreline. The estimated contaminant releases to the river from these sources were derived from the difference between the upstream and downstream radionuclide concentrations in Columbia River water. These radionuclides were assumed to originate from

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, and food) that maximize a hypothetical individual's 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 doses from both methods have historically been significantly lower than health-based exposure criteria.

Recently, 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 food, water, and air pathways and is calculated for the population residing within 80 kilometers (50 miles) of the Hanford Site operating areas. The collective dose is reported in units of person-rem (person-sievert), which is the average estimated individual dose multiplied by the total number of people in the population.

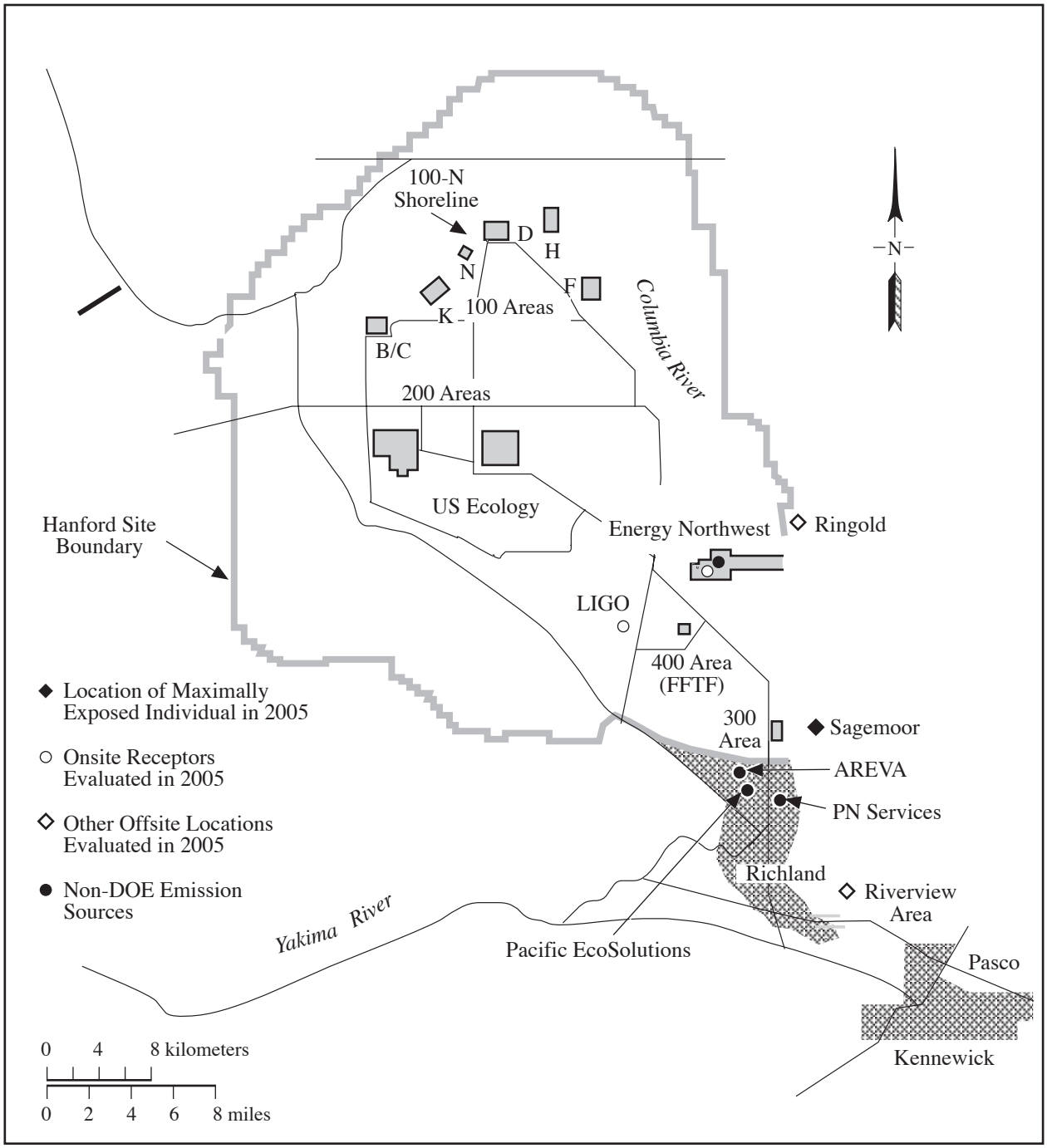



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**Figure 10.14.1. Locations Important to Dose Calculations at the Hanford Site, 2005**

historical releases of contaminants to the ground in the 100 and 200 Areas and to have entered the river through shoreline groundwater springs between the 100-B/C Area and the 300 Area. In 2005, the analytical laboratory analyzing river water samples for tritium had problems analyzing the last four monthly water samples from the Priest Rapids Dam (the upstream reference location) and the Richland Pump House (the downstream reference location). In an effort not to underestimate doses from the water pathway, 2004 tritium data were used in the calculations.

During 2005, the total dose to the maximally exposed individual at Sagemoor (Figure 10.14.1) was calculated to be 0.037 mrem (0.37 µSv) per year (Table 10.14.1). This dose was 0.037% of the DOE limit of 100 mrem (1 mSv) per year specified in DOE Order 5400.5 (Figure 10.14.2.). The primary pathways (Appendix E, Tables E.1, E.2, and E.4) contributing to this dose (and the percentage of all pathways) were:

- The inhalation of air downwind of Hanford (12%) and the consumption of food products grown downwind of Hanford (approximately 43%), resulting in exposure to airborne releases of radon and tritium from the 300 Area.
- The consumption of foods irrigated with Columbia River water withdrawn downstream of Hanford (30%) and the consumption of fish from the Columbia River (12%), resulting in exposure to technetium-99, tritium, and uranium isotopes in the river.

## 10.14.2 Collective Dose

Collective dose is defined as the sum of doses to all individual members of the public within 80 kilometers (50 miles) of the operating areas at Hanford. The regional collective dose from 2005 Hanford Site operations was estimated by calculating the radiological dose to the population residing within an 80-kilometer (50-mile) radius of the onsite operating areas. During 2005, the collective dose calculated for the population was 0.46 person-rem (0.0046 person-Sv) per year (Table 10.14.2; Figure 10.14.3), which is about 50% higher than the 2004 collective dose (0.32 person-rem [0.0032 person-Sv]) per year (Appendix E, Tables E.5 to E.10).

Primary pathways contributing to the 2005 collective dose (and the percentage of all pathways) included:

- Inhalation of radionuclides that were released to the air, principally tritium and radon from the 300 Area and iodine-129 from the 200 Areas (18%), and consumption of food grown downwind of Hanford (approximately 28%).
- The consumption of water withdrawn from the Columbia River downstream of Hanford (48%) and foods irrigated

**Table 10.14.1. Dose to the Hypothetical, Maximally Exposed Individual Residing at Sagemoor from 2005 Hanford Site Operations**

| | | Dose Contributions from Operating Areas, mrem | | | | |
|---|---|---|---|---|---|---|
| **Effluent** | **Pathway** | **100 Areas** | **200 Areas** | **300 Area** | **400 Area** | **Pathway Total** |
| Air | External | $6.3 \times 10^{-10}$ | $3.5 \times 10^{-7}$ | $4.2 \times 10^{-4}$ | $2.8 \times 10^{-8}$ | $4.2 \times 10^{-4}$ |
| | Inhalation | $4.6 \times 10^{-5}$ | $1.4 \times 10^{-4}$ | $4.3 \times 10^{-3}$ | $2.1 \times 10^{-6}$ | $4.5 \times 10^{-3}$ |
| | Foods | $1.4 \times 10^{-6}$ | $2.6 \times 10^{-4}$ | $1.6 \times 10^{-2}$ | $2.1 \times 10^{-7}$ | $1.6 \times 10^{-2}$ |
| | **Subtotal air** | **$4.7 \times 10^{-5}$** | **$4.0 \times 10^{-4}$** | **$2.1 \times 10^{-2}$** | **$2.3 \times 10^{-6}$** | **$2.1 \times 10^{-2}$** |
| Water[(a)] | Recreation | $7.4 \times 10^{-6}$ | $4.5 \times 10^{-5}$ | 0.0 | 0.0 | $5.2 \times 10^{-5}$ |
| | Foods | $1.9 \times 10^{-4}$ | $1.1 \times 10^{-2}$ | 0.0 | 0.0 | $1.1 \times 10^{-2}$ |
| | Fish | $3.1 \times 10^{-4}$ | $4.3 \times 10^{-3}$ | 0.0 | 0.0 | $4.6 \times 10^{-3}$ |
| | **Subtotal water** | **$5.1 \times 10^{-4}$** | **$1.5 \times 10^{-2}$** | **0.0** | **0.0** | **$1.6 \times 10^{-2}$** |
| **Combined total** | | **$5.5 \times 10^{-4}$** | **$1.6 \times 10^{-2}$** | **$2.1 \times 10^{-2}$** | **$2.3 \times 10^{-6}$** | **$3.7 \times 10^{-2}$** |

(a) Tritium data from 2004 were used for the water pathway dose assessment because 2005 data were not available. Zeros indicate no dose contribution to maximally exposed individual through water pathway.

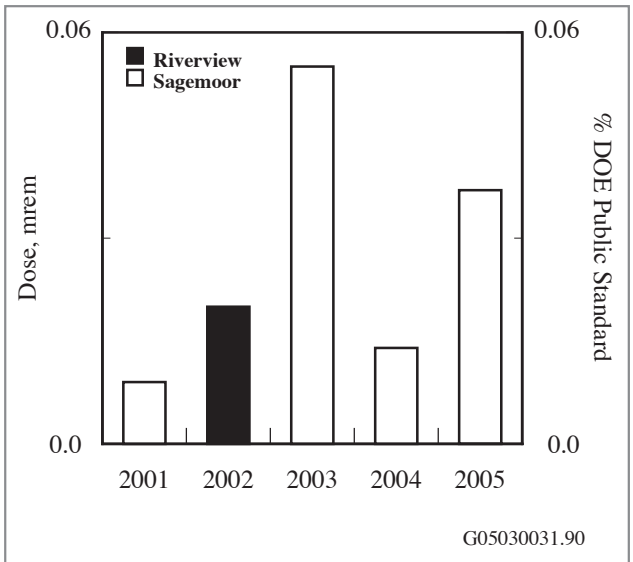


**Figure 10.14.2. Calculated Dose to the Hypothetical, Maximally Exposed Individual Near the Hanford Site, 2001 through 2005**

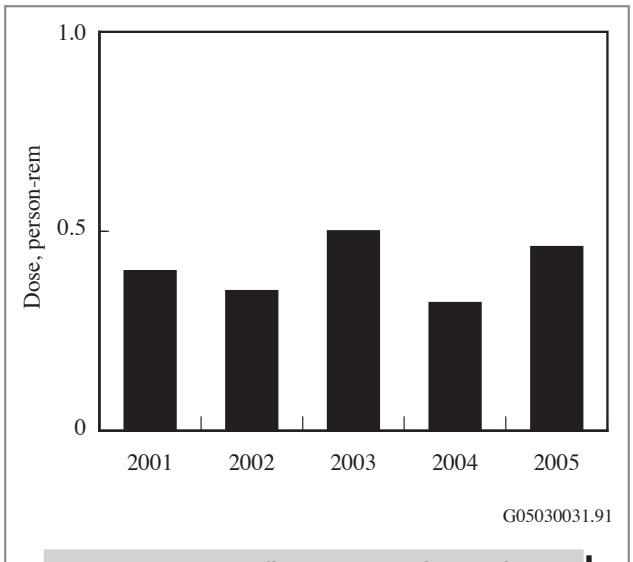


**Figure 10.14.3. Collective Dose to the Population within 80 Kilometers (50 Miles) of the Hanford Site, 2001 through 2005**

with water withdrawn from the Columbia River downstream of Hanford (approximately 2%) containing principally tritium, uranium-234, and uranium-238.

Collective doses reported for 2005 are based on population data from the 2000 census. The collective dose is reported in units of person-rem (person-sievert), which is the average estimated individual dose multiplied by the total number of people in the population. Between 1990 and 2000, the population within 80 kilometers (50 miles) of the major operating areas on the Hanford Site increased by 24% to 29%.

The average individual dose from 2005 Hanford Site operations based on a population of 486,000 within 80 kilometers (50 miles) of the site was 0.001 mrem (0.01 μSv) per year.

**Table 10.14.2. Collective Dose to the Population from 2005 Hanford Site Operations**

| | | Dose Contributions from Operating Areas, person-rem | | | | |
|---|---|---|---|---|---|---|
| **Effluent** | **Pathway** | **100 Areas** | **200 Areas** | **300 Area** | **400 Area** | **Pathway Total** |
| Air | External | $1.2 \times 10^{-7}$ | $3.1 \times 10^{-5}$ | $5.2 \times 10^{-3}$ | $1.4 \times 10^{-6}$ | $5.2 \times 10^{-3}$ |
| | Inhalation | $1.3 \times 10^{-2}$ | $1.9 \times 10^{-2}$ | $5.2 \times 10^{-2}$ | $1.6 \times 10^{-4}$ | $8.4 \times 10^{-2}$ |
| | Foods | $2.0 \times 10^{-4}$ | $2.4 \times 10^{-2}$ | $1.1 \times 10^{-1}$ | $1.2 \times 10^{-5}$ | $1.3 \times 10^{-1}$ |
| | **Subtotal air** | **$1.3 \times 10^{-2}$** | **$4.3 \times 10^{-2}$** | **$1.7 \times 10^{-1}$** | **$1.7 \times 10^{-4}$** | **$2.2 \times 10^{-1}$** |
| Water[(a)] | Recreation | $3.3 \times 10^{-5}$ | $2.7 \times 10^{-4}$ | 0.0 | 0.0 | $3.0 \times 10^{-4}$ |
| | Foods | $2.1 \times 10^{-4}$ | $1.1 \times 10^{-2}$ | 0.0 | 0.0 | $1.1 \times 10^{-2}$ |
| | Fish | $1.1 \times 10^{-4}$ | $1.6 \times 10^{-3}$ | 0.0 | 0.0 | $1.7 \times 10^{-3}$ |
| | Drinking water | $8.8 \times 10^{-4}$ | $2.2 \times 10^{-1}$ | 0.0 | 0.0 | $2.2 \times 10^{-1}$ |
| | **Subtotal water** | **$1.2 \times 10^{-3}$** | **$2.3 \times 10^{-1}$** | **0.0** | **0.0** | **$2.3 \times 10^{-1}$** |
| **Combined total** | | **$1.4 \times 10^{-2}$** | **$2.8 \times 10^{-1}$** | **$1.7 \times 10^{-1}$** | **$1.7 \times 10^{-4}$** | **$4.6 \times 10^{-1}$** |

(a) Tritium data from 2004 were used for the water pathway dose assessment because some 2005 data were not available. Zeros indicate no dose contribution to the population through the water pathway.

To place this estimated dose into perspective, it may be compared with doses received from other routinely encountered sources of radiation such as natural terrestrial and cosmic background radiation, medical treatment and x-rays, natural radionuclides in the body, and inhalation of naturally occurring radon (Figure 10.14.4). The estimated annual average individual dose to members of the public from Hanford Site sources during 2005 was approximately 0.0003% of the estimated annual individual dose received from natural background sources (300 mrem). The calculated radiological doses from Hanford Site operations in 2005 were a small percentage of the federal standards and of doses from natural background sources (Table 10.14.3).

## 10.14.3 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 individual, the EPA requires the use of the CAP-88 computer code (EPA 402-R-00-004) or other EPA-approved computer models to demonstrate compliance with the requirements in 40 CFR 61, Subpart H. The assumptions embodied in the CAP-88 computer code differ slightly from standard assumptions used with the GENII computer 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 10.14.1).

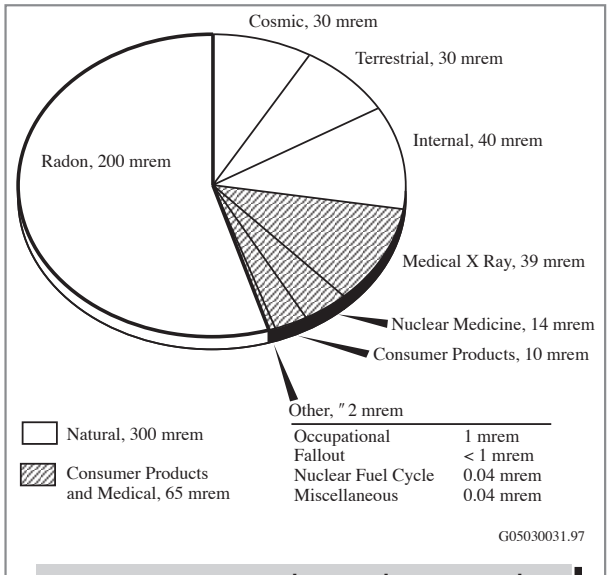


**Figure 10.14.4. Annual National Average Radiological Doses from Various Sources (National Council on Radiation Protection and Measurements 1987)**

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 contributions to offsite dose. For more detailed information about 2005 air emissions on the Hanford Site, refer to the DOE's report to the EPA, *Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2005* (DOE/RL-2006-01).

### 10.14.3.1 Dose to an Offsite Maximally Exposed Individual

Using EPA-specified methods, the maximally exposed offsite individual for air pathways in 2005 was determined to be at a location in the Sagemoor area of Franklin County, approximately 1.4 kilometers (0.8 mile) east of the 300 Area, across the Columbia River (Figure 10.14.1). The potential air pathway dose from stack emissions to a maximally exposed individual at that location calculated using the CAP-88 computer code was determined to be 0.018 mrem (0.00018 mSv) per year, which represented less than 0.2% 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 10.14.1.

### 10.14.3.2 Maximum Dose to Non-DOE Workers on the Site

The DOE Richland Operations Office received guidance from the EPA's Region 10 office and the Washington State Department of Health that, in demonstrating compliance

**Table 10.14.3. Comparison of 2005 Doses to the Public from Hanford Site Effluent and Emissions to Federal Standards and Natural Background Levels**

| Federal Standard | Hanford Dose[a] | Percent of Standard or of Background Dose |
|---|---|---|
| DOE - 100 mrem/yr all pathways MEI[b] | 0.023 mrem/yr | 0.023 |
| EPA - 10 mrem/yr air pathway MEI[c] | 0.018 mrem/yr | 0.18 |
| **Background Dose** | | |
| 300 mrem/yr average U.S. individual[d] | 0.001 mrem/yr | 0.0003 |
| 145,800 person-rem/yr to population within 80 km (50 mi) | 0.47 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) 40 CFR 61.
(d) National Council on Radiation Protection and Measurements (1987).
DOE = U.S. Department of Energy.
EPA = U.S. Environmental Protection Agency.
MEI = Maximally exposed individual.

with the 40 CFR 61 standards, it should evaluate potential doses to non-DOE employees who work on the Hanford Site but who are not under direct DOE control. Accordingly, the doses to members of the public employed at non-DOE facilities that were outside access-controlled areas on the Hanford Site (those requiring DOE access authorization for entry) were evaluated for the 2005 EPA air emissions report (DOE/RL-2006-01). 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 10.14.1). Of those locations, an employee at LIGO received the highest dose for non-DOE employees who worked on the Hanford Site. The dose from stack emissions calculated using the CAP-88 computer code was 0.014 mrem (0.00014 mSv) per year, assuming full-time occupancy.

EPA guidance does not currently allow for adjustment of doses calculated using the CAP-88 computer code to account for less than full-time occupancy at locations within the site boundary. However, if an 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 LIGO. In 2005, the estimated doses to non-DOE onsite workers were lower than the doses to offsite individuals for all locations.

### 10.14.3.3 Dose from Diffuse and Fugitive Radionuclide Emissions

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 (widespread) and fugitive (unintended) emissions as well as emissions from monitored point sources (i.e., stacks). The EPA has not specified or approved standardized methods to estimate diffuse air emissions because of the wide variety of sources at DOE sites. The method developed at Hanford to estimate potential diffuse emissions is based on environmental monitoring measurements of airborne radionuclides at the site perimeter (DOE/RL-2006-01). During 2005, the estimated dose from diffuse emissions to a maximally exposed individual at a location in the Sagemoor area was calculated using the CAP-88 computer code to be 0.021 mrem (0.00021 mSv) per year. This is consistent with results for recent years, where the dose from diffuse emissions has

been somewhat 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 emissions would be similar to, or lower than, the dose at the site perimeter. Therefore, the potential combined dose from stack emissions and diffuse emissions during 2005 was well below the EPA 10-mrem (0.1-mSv) per year standard for either onsite or offsite members of the public.

## 10.14.4 Special Case Dose Estimates

The parameters used to calculate the dose to the maximally exposed individual were selected to provide a scenario yielding a reasonable upper (or bounding) estimate of the dose. However, such a scenario may not have necessarily resulted in the highest conceivable radiological dose. Other low-probability exposure scenarios existed that could have resulted in somewhat higher doses. Four scenarios that could have potentially led to larger doses included (1) an individual who spent time at the site boundary location with the maximum external radiological dose rate, (2) a sportsman who consumed contaminated wildlife that migrated from the site, (3) a person who drank water at the Fast Flux Test Facility in the 400 Area, and (4) individuals at various locations who breathed the measured radionuclide concentrations in air for an entire year. The potential doses resulting from these scenarios are examined in the following sections.

### 10.14.4.1 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 where elevated dose rates might be expected at site-wide locations and at representative locations offsite. 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 measurements during 2005 were made along the 100-N Area shoreline (Figure 10.13.1; Section 10.13). The measurements were consistently above background levels and represented the highest measured boundary dose rates. The Columbia River allows public access to within approximately 100 meters (330 feet) of the N Reactor and supporting facilities at this location.

The highest dose rate along the 100-N Area shoreline during 2005 was about 0.012 mrem (0.12 μSv) per hour, or approximately 20% 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 2005, the external radiological dose received from Hanford operations was approximately 0.002 mrem (0.02 μSv) above the average shoreline dose rate. If an individual had spent 7 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. 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 is very rocky and visitors are not likely to remain on shore for extended periods.

### 10.14.4.2 Sportsman Dose

Wildlife have access to areas of the Hanford Site that are contaminated with radioactive materials. Wildlife have the potential to acquire radioactive contamination and migrate off the site. Wildlife sampling was conducted on the site to estimate the maximum contamination levels that might have existed in animals from Hanford that were hunted off the site. Because this scenario had a relatively low probability of occurrence, this pathway was not considered in the maximally exposed individual calculation.

The only radionuclides detected in routinely collected wildlife samples collected in 2005 were potassium-40, a primordial radioisotope not of Hanford origin; strontium-90, which was only detected in bone samples; cesium-137 in a bass muscle sample collected from the 100-H slough; and uranium-234 was detected in bass muscle samples collected upstream of the Hanford site, near Desert Aire. Because uranium-234 was detected in samples collected upstream of

Hanford, the dose to a sportsman who might consume that bass was not calculated. The dose from consuming 1 kilogram (2.2 pounds) of bass containing 0.0213 pCi/g (0.0008 Bq/g) cesium-137 would be about 1 mrem (10 μSv).

### 10.14.4.3 Onsite Drinking Water

During 2005, groundwater from wells in the 400 Area was used as drinking water by workers in the Fast Flux Test Facility. Columbia River water was used for drinking water in the 100 and 200 Areas. Drinking water was sampled and analyzed throughout the year in accordance with applicable regulations (40 CFR 141). All annual average radionuclide concentrations measured during 2005 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 and radium isotopes were identified in the 100-K Area drinking water (Section 10.6).

Based on the measured concentrations, the potential annual dose to Fast Flux Test Facility workers (an estimate derived by assuming a consumption of 1 liter [0.26 gallon] per day for 240 working days) would be approximately 0.4 mrem (4 μSv). This dose is well below the drinking water dose limit of 4 mrem (40 μSv) per year for public drinking water supplies.

### 10.14.4.4 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. 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 site-wide air monitoring stations during their workday are presented in Table 10.14.4. The average radionuclide concentrations measured at the site-wide air monitoring stations were used in the calculations (Table 10.2.3) and assumed to be constant for the year-long evaluation period. Inhalation doses calculated using this method ranged from 0.00031 mrem (0.0031 μSv) in the 300 Area to 0.039 mrem (0.00039 mSv) at the site perimeter. These were comparable to doses calculated using the CAP-88 computer code and reported for various air pathways (Section 10.14.3).

**Table 10.14.4. Inhalation Doses On and Around the Hanford Site Based on 2005 Average Air Monitoring Data[a]**

| Radionuclide | Group | Dose (mrem/yr)[b,c] |
|---|---|---|
| Tritium | Onsite | $2.1 \times 10^{-4}$ |
| | 300 Area | $3.1 \times 10^{-4}$ |
| | Perimeter | $1.3 \times 10^{-3}$ |
| | Nearby communities | $1.5 \times 10^{-3}$ |
| | Distant communities | $9.9 \times 10^{-4}$ |
| Iodine-129 | Onsite | $7.0 \times 10^{-6}$ |
| | Perimeter | $7.2 \times 10^{-7}$ |
| | Distant communities | $3.5 \times 10^{-8}$ |
| Uranium-238 | Onsite | $5.0 \times 10^{-3}$ |
| | Perimeter | $1.9 \times 10^{-2}$ |
| | Nearby communities | $1.6 \times 10^{-2}$ |
| | Distant communities | $1.7 \times 10^{-2}$ |
| Plutonium-239 | Perimeter | $1.9 \times 10^{-2}$ |
| **Totals** | Onsite | $5.3 \times 10^{-3}$ |
| | 300 Area | $3.1 \times 10^{-4}$ |
| | Perimeter | $3.9 \times 10^{-2}$ |
| | Nearby communities | $1.8 \times 10^{-2}$ |
| | Distant communities | $1.8 \times 10^{-2}$ |

(a) Onsite inhalation dose calculations were based on a 2,000-hour exposure period and a 1.2 $m^3$/hr breathing rate; all offsite inhalation dose calculations were based on an 8,766-hour exposure period and a 0.958 $m^3$/hr 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.

## 10.14.5 Doses from Non-DOE Sources

DOE Order 5400.5, Chapter II, paragraph 7, has a reporting requirement for a combined dose due to the DOE and other manmade sources that exceeds 100 mrem (1 mSv) per year. During 2005, 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; and a commercial decontamination facility operated near the site by PN Services (Figure 10.14.1).

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 2005 individual dose from their combined activities was approximately 0.067 mrem (0.00067 mSv) per year. Therefore, the combined annual dose from Hanford area non-DOE and DOE sources to a member of the public for 2005 was well below any regulatory dose limit.

## 10.14.6 Dose Rates to Animals

Upper estimates have been made of the radiological dose to aquatic organisms in accordance with the DOE Order 5400.5 interim requirement for management and control of liquid discharges. The current dose limit for native aquatic animal organisms is 1 rad (10 mGy) per day. The proposed limit for terrestrial biota is 0.1 rad (1 mGy) per day.

Concentration guides for assessing doses to biota are very different from the DOE derived concentration guides that are used to assess radiological doses to humans. A screening method is used to estimate radiological doses to aquatic and terrestrial biota. This method uses the RESRAD-BIOTA computer code (DOE/EH-0676; DOE/STD-1153-2002) to compare radionuclide concentrations measured by routine monitoring programs to a set of conservative biota concentration guides (e.g., 1 rad [10 mGy] per day for aquatic biota). For samples containing multiple radionuclides, a sum of fractions is calculated to account for the contribution to dose from each radionuclide relative to the dose guideline. If the sum of fractions exceeds 1.0, then the dose guideline has been exceeded. If the initial estimated screening value (Tier 1 [Table 10.14.5]) exceeds the guideline (sum of fractions >1.0), another screening calculation is performed (Tier 2) to more accurately evaluate exposure of the biota to the radionuclides.

**Table 10.14.5. Results of Using the RESRAD-BIOTA[a] Computer Code to Estimate Radiological Doses to Biota On and Around the Hanford Site, Using 2005 Columbia River Water, Shoreline Spring Water, and River Sediment, as Available**

| Location | Tier 1 Screen Sum of Fractions[b] | Pass or Fail |
|---|---|---|
| Priest Rapids Dam | 0.176 | Pass |
| 100-K Area | 0.00983 | Pass |
| 100-N Area | 0.0000212 | Pass |
| 100-D Area | 0.0151 | Pass |
| 100-H Area | 0.0187 | Pass |
| 100-F Area | 0.0562 | Pass |
| White Bluffs Slough | 0.227 | Pass |
| Hanford Slough | 0.0423 | Pass |
| Hanford spring | 0.067 | Pass |
| 300 Area spring | 0.797 | Pass |
| Richland pump house | 0.00737 | Pass |

(a) A screening method to estimate radiological doses to aquatic and terrestrial biota.
(b) A sum of fractions is calculated to account for the contribution to dose from each radionuclide. If the sum of fractions exceeds 1.0, then the dose guideline has been exceeded and further screening (Tier 2) is required.

The process may culminate in a site-specific assessment requiring additional sampling and study of exposure. During 2005, biota dose screening assessments were conducted on and around the site (Table 10.14.5).

Maximum concentrations of radionuclides measured in Columbia River water and sediment and Columbia River shoreline spring water were evaluated using the RESRAD-BIOTA computer code. Shoreline 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 of the screening calculations indicated that the concentrations in all samples passed the Tier 1 screen, indicating that the calculated doses were below the dose limits and guidelines (sum of fractions <1.0) (Table 10.14.5). There were no Tier 2 screening calculations required in 2005.

## 10.14.7 Radiological Dose in Perspective

Scientific studies (National Research Council 1980, 1990; United Nations Science Committee on the Effects of Atomic Radiation 1988) have been performed to estimate the possible risk from exposure to low levels of radiation. These studies provided information to government and scientific organizations and are used to recommend radiological dose limits and standards for public and occupational safety.

Although no increase in the incidence of health effects from low doses of radiation has actually been confirmed by the scientific community, regulatory agencies cautiously assume that the probability of these types of health effects occurring due to exposure to low doses (down to zero dose) is the same per unit dose as the health effects observed after an exposure to much higher doses (e.g., in atomic bomb survivors, individuals receiving medical exposure, or radium-dial painters). This concept is known as the linear no threshold hypothesis. Under these assumptions, even natural background radiation, which is hundreds of times greater than radiation from current Hanford Site releases, increases each person's probability or chance of developing a detrimental health effect.

Scientists do not agree on how to translate the available data on health effects into the numerical probability (risk) of detrimental effects from low radiological doses. Some scientific studies have indicated that low radiological doses result in beneficial effects (Sagan 1987). Because cancer and hereditary diseases in the general population are caused by many sources (e.g., genetic defects, sunlight, chemicals, and background radiation), some scientists doubt that the risk from low-level radiation exposure can ever be proven conclusively. In developing *Clean Air Act* regulations, the EPA used a probability value of approximately 4 per 10 million (0.0004) for the risk of developing a fatal cancer after receiving a dose of 1 mrem (0.01 mSv) (EPA 520/1-89-005). Additional data (National Research Council 1990) support the reduction of even this small risk value, possibly to zero, for certain types of radiation when the dose is spread over an extended time.

Government agencies are trying to determine what level of exposure is safe for members of the public exposed to pollutants from industrial operations (e.g., DOE facilities, nuclear power plants, chemical plants, and 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 are compared to the risks of some activities encountered in everyday life in Table 10.14.6. Some activities are considered approximately equal in risk to that from the dose received by the maximally exposed individual from monitored Hanford effluent and emissions during 2005 (Table 10.14.7).

**Table 10.14.6. 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 | $100 \times 10^{-6}$[b] |
| Taking contraceptive pills (side effects) | $20 \times 10^{-6}$ |
| Drinking 1 can of beer or 0.12 L (4 oz) of wine per day (liver cancer/cirrhosis) | $10 \times 10^{-6}$ |
| Firearms, sporting (accidents) | $10 \times 10^{-6}$[b] |
| Flying as an airline passenger (cross-country roundtrip - accidents) | $8 \times 10^{-6}$[b] |
| Eating ~54 g (4 Tbsp) of peanut butter per day (liver cancer) | $8 \times 10^{-6}$ |
| Pleasure boating (accidents) | $6 \times 10^{-6}$[b] |
| Drinking chlorinated tap water (trace chloroform - cancer) | $3 \times 10^{-6}$ |
| Riding or driving in a passenger vehicle (483 km [300 mi]) | $2 \times 10^{-6}$[b] |
| Eating 41 kg (90 lb) of charcoal-broiled steaks (gastrointestinal tract cancer) | $1 \times 10^{-6}$ |
| Natural background radiological dose (300 mrem [3 mSv]) | 0 to $120 \times 10^{-6}$ |
| Flying as an airline passenger (cross-country roundtrip - radiation) | 0 to $5 \times 10^{-6}$ |
| Dose of 1 mrem (0.01 mSv) for 70 yr | 0 to $4.0 \times 10^{-5}$ |
| Dose to the maximally exposed individual living near Hanford | $2 \times 10^{-8}$ |

(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 10.14.7. Activities Comparable in Risk to the 0.023-mrem (0.0023-mSv) Dose Calculated for the Hanford Site's 2005 Maximally Exposed Individual**

Driving or riding in a car 0.05 km (0.03 mi)
Smoking less than 1/1,000 of a cigarette
Flying ~0.14 km (0.09 mi) on a commercial airliner
Eating ~0.04 Tbsp of peanut butter
Eating one 146-g (~5.2-oz) charcoal-broiled steak
Drinking 0.05 L (~1.8 oz) of chlorinated tap water
Drinking ~0.9 ml (0.03 oz) of wine or 2.7 ml (0.1 oz) of beer

# 10.15 Cultural Resources Monitoring

E. P. Kennedy

Cultural resource management on DOE-managed portions of the Hanford Site is conducted under the auspices of the Richland Operations Office's Hanford Cultural and Historic Resource Program to assure site compliance with federal cultural resource laws and regulations (see Section 5.4.2). Program activities in 2005 included:

- Performing cultural resource reviews for all federal undertakings conducted at Hanford in accordance with Section 106 of the *National Historic Preservation Act*, and the *National Environmental Protection Act*.
- Monitoring cultural resource conditions to assure that important resources were protected.
- Maintaining a database of cultural resource site records, project records, and regional ethnohistory.
- Maintaining archaeological and historical collections.
- Identifying and evaluating new cultural resources so that they could be managed appropriately.
- Consulting with tribes and stakeholders to gather input on the identification, documentation, and management of cultural resources important to them.

The Cultural and Historic Resources Program oversees all cultural resource activities at the Hanford Site. The majority of technical work is performed by Pacific Northwest National Laboratory; Washington Closure Hanford, LLC; and the Columbia River Exhibition of History, Science, and Technology (CREHST) Museum.

## 10.15.1 Cultural Resources Reviews

Pursuant to Section 106 of the *National Historic Preservation Act* and the *National Environmental Policy Act*, DOE conducts cultural resource reviews of all federal undertakings that are the type of activity with potential to cause effects to cultural resources on the Hanford Site. Cultural resource reviews assure that important cultural resources are identified and project impacts to those resources are evaluated so that mitigation can be arranged.

During 2005, 190 Hanford Site cultural resource review requests were received. The Pacific Northwest National Laboratory, which is responsible for performing cultural reviews of site-wide DOE activities, received 121 review requests and Washington Closure Hanford, LLC, the River Corridor Closure contractor, received 69 review requests. Upon initial review, DOE determined that 156 of the 190 undertakings were not the types of activities with the potential to cause effects and, therefore, were exempt from further review. Examples of undertakings that fit the no-effects designation included small excavations, such as routine maintenance activities in previously disturbed areas, especially those located within the fence lines of existing operable units. The majority of these were located in the 200 Areas (Figure 10.15.1).

Six review requests were exempted from full cultural review by the *Programmatic Agreement Among the U.S. Department of Energy, Richland Operations Office, the Advisory Council on Historic Preservation, and the Washington State Historic Preservation Office for the Maintenance, Deactivation, Alteration, and Demolition of the Built Environment on the Hanford Site, Washington* (DOE/RL-96-77). The programmatic agreement exempts undertakings that involve routine maintenance, energy conservation measures, or material replacements when materials are used that match the original materials used in the structure in terms of dimensions, detail, and color. Seven reviews required walk-throughs of historic buildings to assess their contents and identify artifacts that

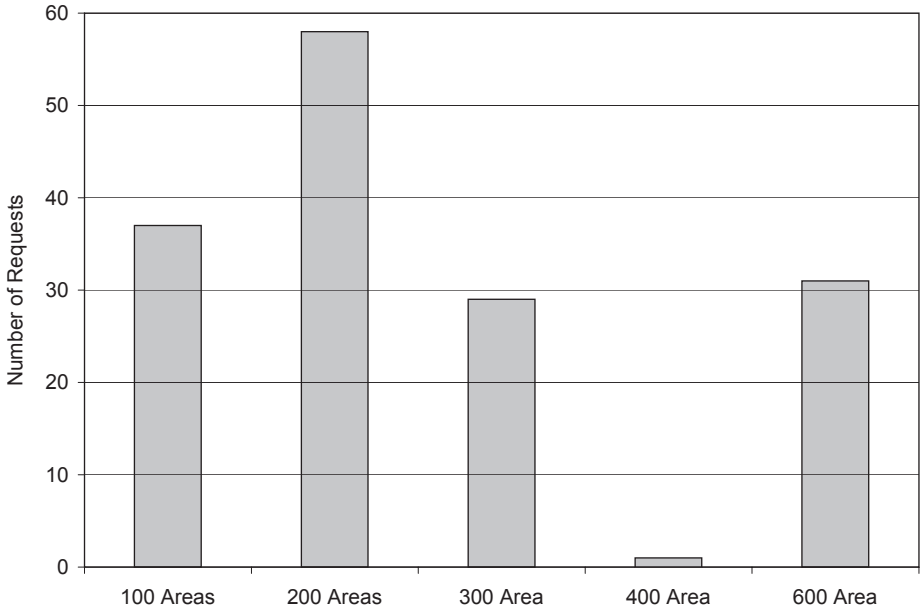


**Figure 10.15.1. Cultural Resources Review Requests* for Hanford Site Operational Areas Received in 2005 (*NPCE requests, e.g., not the type of activity with potential to cause effects to historic properties**

may have potential museum value as interpretive or educational exhibits. Two of the seven had minor excavations associated with them and were, therefore, classified primarily as not the type of activity with potential to cause effects to historic properties and counted as such.

The remaining 23 undertakings required full review, which involved efforts to identify cultural resources that might be affected by the activity, assessment of potential impacts, and development of mitigation measures, if necessary. Some of the full reviews required new areas (approximately 131.5 hectares [325 acres]) to be surveyed for cultural resources.

## 10.15.2 Cultural Resources Protection

Activities to assure protection of cultural resource sites across the Hanford Site are conducted to comply with *National Historic Preservation Act* Section 110, the *Native American Graves Protection and Repatriation Act*, and the *Archaeological Resources Protection Act*. The Hanford Site has had a monitoring program since 1987 to assess the effects of weathering and erosion or unauthorized excavation and collection upon the site's significant cultural resources. Activities include onsite inspections of important sites to monitor site conditions, assess impacts, if any, and respond with protective measures when an impact is significant. In 2005, 28 sites were visited.

Site visits were conducted with tribal cultural resource staff participation. Although there were no major impacts to sites observed, minor impacts due to recreation, natural erosion, and animal activity were recorded in 2005. DOE also continued to visit Locke Island to measure river-caused erosion so that protective measures can be taken if erosion rates begin to increase. In 2005, erosion was still occurring at a measurable rate on the island, and in certain areas, large blocks of bank sediment were toppling into the river. Development of a proactive strategy to mitigate potential loss of cultural resource materials began in 2005.

### 10.15.2.1 Identification and Evaluation Activities

Identification and evaluation activities are performed to comply with *National Historic Preservation Act* Sections 106

and 110. In 2005, eight new archaeological sites were recorded. Six sites were determined ineligible for listing on the National Register of Historic Places, while one site, a prehistoric shell midden designated as 45BN1422, was determined eligible. Three previously recorded archaeological sites (designated as 45BN1344, HT-2003-037, and 45BN1063) were also evaluated for National Register eligibility and determined not eligible.

A major effort was undertaken to visit 17 sites located along the Columbia River and update site records according to current standards. The sites, originally documented in 1968, had only been minimally documented, making management difficult. The site visits revealed that several of the sites contain significant archaeological deposits. In updating the site descriptions, many of the site boundaries were refined.

Pacific Northwest National Laboratory staff also completed a series of four administrative histories, which are scheduled to be published in 2006. Topics included an overview of the long-term site cultural resource monitoring efforts at Hanford, a history of impacts and cultural resources activities within the McGee Ranch-Riverlands Unit of the Hanford Reach National Monument, a description of prehistoric land use on the Hanford Site, and a history of efforts to identify and protect American Indian traditional use areas at Hanford.

### 10.15.2.2 Management of Artifact and Data Collections

Pacific Northwest National Laboratory manages Hanford Site archaeological collections, DOE cultural resource records, a reference library, an electronic database of cultural resource reviews, geographical information system data of cultural sites and surveys, and an assortment of supporting documentations required to facilitate compliance efforts for the DOE Cultural and Historic Resources Program. Files from over 1,400 cultural sites and curated archaeological collections from over 80 sites are stored in an archive room. During 2005, temperature and humidity levels within the archive room remained within limits for storage of numerous types of archived materials. During 2005, the database and geographic information system continued to be used and updated. Pacific Northwest National Laboratory's Total Records Information Management database continues to be used for efficient retrieval of representative site photos, site monitoring photos, historic photos, and archived electronic documents produced by project activities.

The Columbia River Exhibition of History, Science and Technology (CREHST) Museum manages the Hanford Site Manhattan Project and Cold War artifact collection. Efforts to generate new collections are conducted as stipulated in the Programmatic Agreement for the Built Environment (DOE/RL-96-77), which directs DOE to assess the contents of Hanford's historic buildings and structures prior to the commencement of deactivation, decontamination, or decommissioning activities. The purpose of the assessments is to identify and preserve any artifacts (e.g., control panels, signs, scale models, and machinery) that may have value as interpretive or educational exhibits within national, state, or local museums. Walk-throughs were conducted within 10 buildings located in the 300 Area during 2005. Four new artifacts to be collected were identified. Teams of cultural resource specialists, historians, archivists, curators, and facility experts accomplished the assessments.

The Cultural and Historic Resources Program completed a booklet documenting significant Manhattan Project and Cold War Era artifacts that cannot be curated into the Hanford artifact collection because they are too large for long-term storage and/or exhibit purposes or are radiologically contaminated. This booklet is scheduled to be published in 2006.

## 10.15.3 Cultural Resources Consultations and Public Involvement

DOE conducts formal consultations with the Washington State Historic Preservation Office, tribes, and interested parties for cultural resource reviews in order to comply with *National Historic Preservation Act* Section 106 and the *National Environmental Policy Act* (see Section 2.0.2). In 2005, DOE consulted with the Washington State Historic Preservation Office and tribes on the 23 full cultural reviews. No interested parties were consulted in 2005.

The Hanford Cultural and Historic Resources Program also held meetings with tribal cultural resources staff of the

Confederated Tribes of the Umatilla Indian Reservation, the Confederated Tribes and Bands of the Yakama Nation, the Confederated Tribes of the Colville Reservation, the Nez Perce Tribe, and the Wanapum. Discussions focused on cultural resource reviews and issues that concern the protection of cultural resources on the Hanford Site. Meetings in 2005 were held in March, July, October, November, and December. Discussions focused on the 23 full cultural resource reviews initiated in 2005, how the Section 106 review process is implemented on the Hanford Site, proposed revisions to the *Hanford Cultural Resources Management Plan* (DOE/RL-98-10), and approaches to protecting threatened archaeological sites and places with human remains. There were no public meetings with interested parties held in 2005.

# 10.16 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, E.7, E.9, and E.10). Support is provided through weather forecasting and by 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.

Regional temperatures, precipitation, and winds are affected by the presence of mountain barriers. The Cascade Range, beyond Yakima to the west, greatly influences the climate of the Hanford Site because of its rain shadow effect. The Rocky Mountains and ranges in southern British Columbia protect the region 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://hms.pnl.gov. 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. Figure 10.16.1 shows the 2005 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.

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

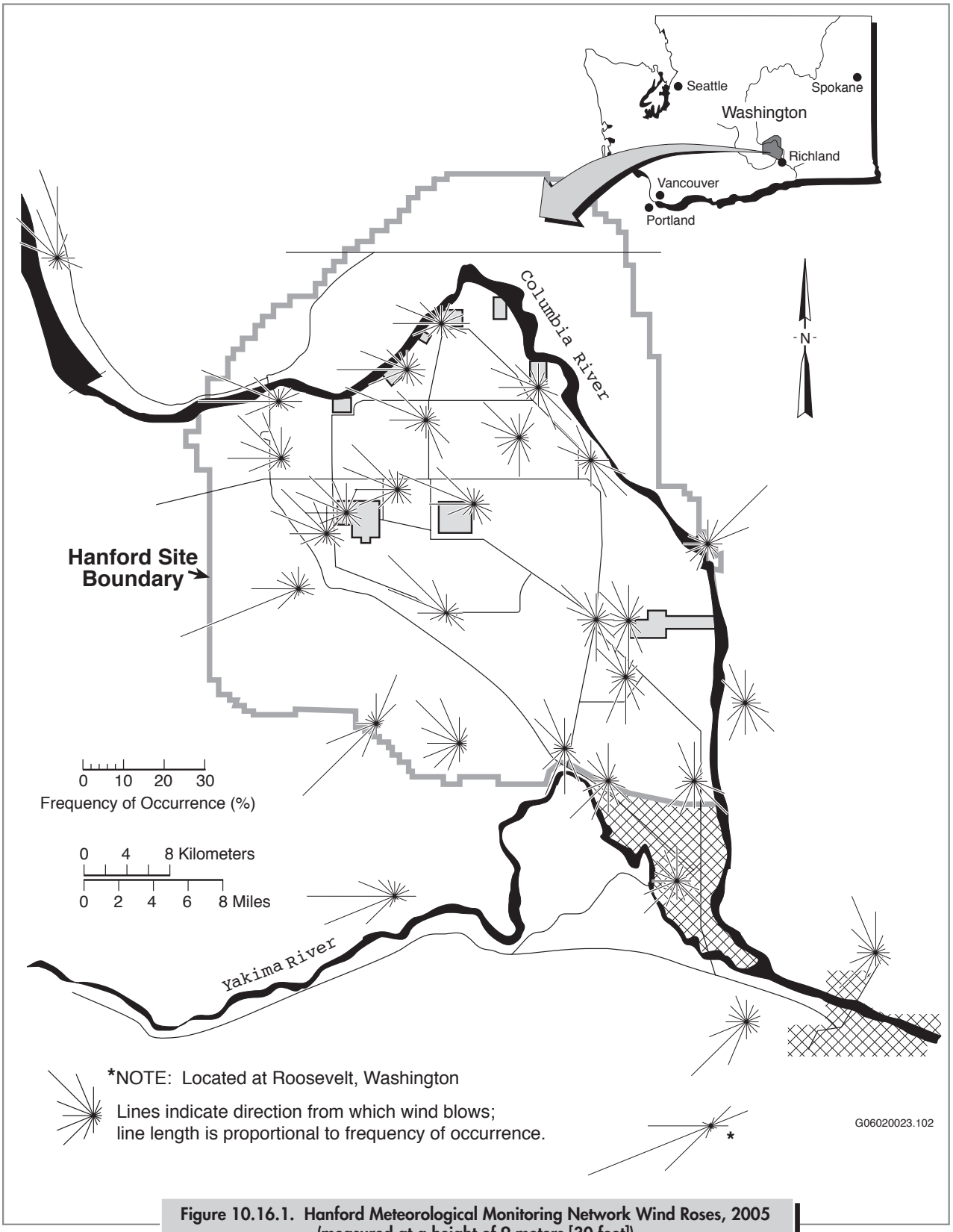


**Figure 10.16.1. Hanford Meteorological Monitoring Network Wind Roses, 2005 (measured at a height of 9 meters [30 feet])**

conditions, primarily during winter, that are associated with stagnant air in stationary high-pressure systems.

## 10.16.1 Historical Climatological Information

Daily and monthly averages and extremes of temperature, dew point temperature, and relative humidity for 1945 through 2004 are reported in PNNL-15160. From 1945 through 2005, the record maximum temperature was 45°C (113.0°F) recorded during August 1961 and July 2002, and the record minimum temperature was -30.6°C (-23.1°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.

## 10.16.2 Results of 2005 Monitoring

The calendar year 2005 average temperature was nearly normal and precipitation was slightly below normal.

The average temperature for 2005 was 11.9°C (53.5°F), which was 0.1°C (0.1°F) below normal (12.0°C [53.6°F]). Five months during 2005 were warmer than normal; five months were cooler than normal, and two were normal. March had the greatest positive departure, 1.6°C (2.8°F); December, at 2.4°C (4.3°F) below normal, had the greatest negative departure.

Precipitation during 2005 totaled 16.2 centimeters (6.39 inches), which is 92% of normal (17.7 centimeters [6.98 inches]). Snowfall for 2005 totaled 30.7 centimeters (12.1 inches), compared to normal snowfall of 39.1 centimeters (15.4 inches).

The average wind speed during 2005 was 3.2 meters per second (7.1 miles per hour), which was 0.2 meter per second (0.5 mile per hour) below normal. The peak gust for the year was 27.3 meters per second (61 miles per hour) on March 16.

Two dust storms were recorded at the Hanford Meteorology Station during 2005. There has been an average of five dust storms per year at the Hanford Meteorology Station during the entire period of record (1945-2005).

Table 10.16.1 provides monthly and annual climatological data collected at the Hanford Meteorology Station during 2005.

**Table 10.16.1. Monthly and Annual Climatological Data for 2005 from the Hanford Meteorology Station**

**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/sec | Departure[b] | Speed, m/sec | Direction | Date |
| J | 2.0 | -4.3 | -1.1 | -1.0 | 14.4 | 19 | -13.9 | 15 | 2.4 | +0.2 | 24.6 | +14.0 | 85.2 | +7.9 | 2.5 | -0.3 | 16.5 | SW | 12 |
| F | 10.9 | -4.4 | 3.2 | 0 | 16.1 | 27 | -8.9 | 19 | 0.1 | -1.6 | 0 | -6.6 | 62.4 | -8.1 | 2.6 | -0.5 | 17.9 | WSW | 4 |
| M | 17.0 | 1.8 | 9.4 | +1.6 | 24.4 | 11 | -2.2 | 31[c] | 0.8 | -0.7 | T[d] | -1.0 | 50.8 | -5.8 | 3.8 | +0.2 | 27.3 | SW | 16 |
| A | 19.5 | 4.5 | 12.0 | 0 | 29.4 | 26 | -2.2 | 15[c] | 0.7 | -0.5 | 0 | -T[d] | 46.6 | -0.7 | 3.5 | -0.4 | 19.2 | WSW | 1 |
| M | 25.3 | 10.6 | 17.9 | +1.4 | 37.2 | 28 | 4.4 | 21 | 2.0 | +0.6 | 0 | 0 | 47.3 | +4.3 | 3.4 | -0.6 | 17.4 | W | 20 |
| J | 28.0 | 12.7 | 20.3 | -0.4 | 37.8 | 21 | 7.8 | 6 | 0.2 | -0.9 | 0 | 0 | 37.4 | -2.2 | 4.1 | 0 | 22.4 | SSW | 21 |
| J | 34.3 | 16.3 | 25.3 | +0.7 | 41.1 | 28 | 11.1 | 3 | 0.2 | -0.5 | 0 | 0 | 30.8 | -2.6 | 4.1 | +0.2 | 19.2 | NW | 2 |
| A | 33.9 | 15.7 | 24.8 | +0.7 | 40.0 | 6[c] | 11.1 | 31[c] | 0.2 | -0.5 | 0 | 0 | 29.1 | -6.5 | 3.5 | 0 | 20.1 | ENE | 12 |
| S | 26.3 | 10.5 | 18.4 | -0.4 | 32.8 | 8 | 4.4 | 26[c] | 1.7 | +0.8 | 0 | 0 | 39.4 | -2.9 | 3.3 | 0 | 19.7 | SW | 29 |
| O | 18.7 | 6.1 | 12.4 | +0.8 | 23.3 | 17 | -0.6 | 30 | 0.7 | -0.5 | 0 | -0.2 | 64.9 | +8.5 | 2.7 | -0.2 | 18.3 | SW | 15 |
| N | 7.7 | -0.6 | 3.5 | -1.0 | 12.2 | 13[c] | -5.0 | 28[c] | 2.3 | -0.2 | T[d] | -5.8 | 78.3 | +4.6 | 2.5 | -0.4 | 17.4 | W | 13 |
| D | 0.7 | -5.8 | -2.6 | -2.4 | 10.0 | 26[c] | -15.6 | 18 | 5.1 | +2.3 | 6.1 | -8.6 | 89.8 | +9.7 | 2.1 | -0.6 | 15.6 | W | 23 |
| Y[e] | 18.7 | 5.2 | 11.9 | -0.1 | 41.1 | Jul 28 | -15.6 | Dec 18 | 16.2 | -1.5 | 30.7 | -8.4 | 55.2 | +0.6 | 3.2 | -0.2 | 27.3 | SW | Mar 16 |

NOTE: See Table A.2, Conversion Table in the section, Helpful Information, for unit conversion information.
(a) Measured on a tower 15 meters (50 feet) above the ground.
(b) Departure columns indicate positive or negative departure of meteorological parameters from 30-year (1971-2000) climatological normals.
(c) Latest of several occurrences.
(d) Trace.
(e) Yearly averages, extremes, and totals.

# 10.17 Community Involvement in Environmental Surveillance

R. W. Hanf

Four teacher-managed radiological air-sampling stations operated near the Hanford Site in 2005. 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 had a large, lighted display that provided real-time weather and background radiation information to the public as well as general information on station equipment, sample types, and analyses (Figure 10.17.1).

Two teachers from nearby schools managed each station. Station equipment included air samplers to collect airborne dust and atmospheric moisture for radiological analyses, a variety of weather monitors, and detectors to monitor ambient radiation levels. The teachers were responsible for collecting samples, preparing 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 served as points of contact for local citizens. The station managers' names and telephone numbers were 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 worked 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 at each station collected and displayed weather and background radiation information. The data were transmitted by radiotelemetry to the Hanford Meteorology Station computer where they were posted on the Internet every 15 minutes (http://hms.pnl.gov/stamap.htm). Analytical results for the radiological air samples collected at these stations during 2005 are discussed in this report in Section 10.2. Results of gamma radiation measurements obtained at the stations during 2005 are discussed in Section 10.13.2.5 of this report.

**Figure 10.17.1. Community Members See Environmental Surveillance in Action at a Community-Operated Environmental Surveillance Station in North Franklin County, Washington**

At the end of September 2005, the Community-Operated Environmental Surveillance Program at Hanford was cancelled – a casualty of reduced Hanford funding. The stations continued to operate and collect data until the end of the calendar year, but the contracts for the teachers managing the stations were terminated in September. The air samplers at the Richland and Basin City stations will continue to operate as part of the Hanford Site environmental surveillance air-sampling network; however, the air samplers at the Toppenish and Edwin Markham Elementary School

locations were removed in early 2006. The other equipment at the stations, including the informational displays, will either be removed or, with the concurrence of the DOE, donated to the schools. This community outreach program, patterned after a similar program at the Nevada Test Site, began operations in 1991 and at one time included nine stations.

# 10.18 Quality Assurance

E. A. Lepel, L. P. Diediker, and D. L. Dyekman

Quality assurance and quality control practices encompass all aspects of Hanford Site environmental monitoring programs. This section discusses specific measures taken in 2005 to ensure quality in project management, sample collection, and analytical results.

Samples were collected and analyzed according to documented standard 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 and quality control for the Hanford Site environmental monitoring programs also included procedures and protocols to:

- Document instrument calibrations.
- Conduct program-specific activities in the field.
- Maintain groundwater wells to ensure representative samples were collected.
- Avoid cross-contamination by using dedicated well sampling pumps.

## 10.18.1 Site-Wide and Offsite Environmental Monitoring and Groundwater Monitoring

During 2005, comprehensive quality assurance programs, including various quality control practices, were maintained to assure the quality of data collected through Pacific Northwest National Laboratory's Surface Environmental Surveillance Project and Groundwater Performance Assessment Project. Quality assurance plans were maintained for all project activities and defined the appropriate controls and documentation required by the EPA and DOE.

### 10.18.1.1 Project Management Quality Assurance

Site environmental monitoring, groundwater monitoring, and related activities such as processing thermoluminescent dosimeters and performing dose calculations were subject to an overall quality assurance program. This program implemented the requirements of DOE Order 414.1B, *Quality Assurance*. Quality assurance plans are maintained by each monitoring project; 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 analyses, 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 projects are approved and awarded.

### 10.18.1.2 Sample Collection Quality Assurance and 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 duplicate samples were collected for air, water, and biota (Table 10.18.1). The water duplicates consisted of three Columbia River water samples and one surface water sample. The biota duplicates included samples of alfalfa and a sample of cow's milk. There were 13 duplicate air samples collected for the analysis of tritium. A field duplicate is used to assess

**Table 10.18.1. Summary of Field Duplicate Sample Results Submitted to Severn Trent Laboratories, Inc., Richland for the Surface Environmental Surveillance Project at Hanford, 2005**

| Media | Radionuclides | Number of Results Reported for Each Radionuclide[(a)] | Number Within Control Limits for Each Radionuclide[(b)] |
|---|---|---|---|
| Air | $^{3}H$ | 9 | 5 |
| Water | $^{3}H$, $^{234}U$, $^{238}U$ | 3 | 3 |
| | Gross beta | 1 | 1 |
| | $^{90}Sr$ | 1 | 0 |
| Biota | $^{3}H$ | 1 | 1 |
| | $^{40}K$ | 3 | 3 |

(a) Number of reported results are those results greater than the minimum detectable activity.
(b) Number of reported results within control limits are those results with the relative percent difference value less than 30%, and the result is greater than the 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

$$RPD \quad \left( \frac{|S \quad D|}{\frac{(S+D)}{2}} \right) \times 100$$

sampling and measurement precision. The analytical results were reviewed against the criterion that the result must be greater than the minimum detectable activity value to be evaluated. To be an acceptable result, the relative percent difference of the two duplicates must be less than 30%. Of the evaluated results, 72% of the 2005 field duplicates were acceptable.

Samples for the Groundwater Performance Assessment Project were collected by trained staff according to approved and documented procedures. Chain-of-custody procedures in *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, SW-846, Third Edition* (EPA 1986) were followed. Samples representing field blanks and field duplicates were obtained during field operations. Summaries of the 2005 groundwater field quality control sample results are provided in Appendix C of PNNL-15670. The percentage of acceptable field blank and duplicate results during fiscal year 2005 was 97% 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. An acceptable result indicates that there was not a contamination problem found with the sample. For a field duplicate, 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.

### 10.18.1.3 Analytical Results Quality Assurance and Quality Control

Routine chemical analyses of water samples were performed under contract primarily by Severn Trent Laboratories, Inc., St. Louis, Missouri, for the environmental surveillance and groundwater monitoring projects. Chemical analysis of split samples and blind standards for the 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 EPA (1986); each program was audited and reviewed internally by Pacific Northwest National Laboratory, which submitted additional quality control double-blind spiked samples to these laboratories for analysis.

Routine inorganic metals analyses were also performed by Pacific Northwest National Laboratory at its Marine Sciences Laboratory in Sequim, Washington. The laboratory participated in the NSI Laboratory Proficiency Testing Program. NSI Solutions, Inc., Raleigh, North Carolina, supplied spiked soil and water samples for analyses. Analytical results

**Double-blind spiked sample** – A sample of known activity and/or concentration prepared to look like a typical sample submitted to the analytical service laboratory.

were provided to NSI Solutions, Inc. and compared to the known concentrations of the spikes. Water sample results from five studies in 2005 were reported. The criteria of being acceptable were met by 95% of the results from the water samples. There were also results reported from two soil studies in 2005; 100% of these results were acceptable. The results are summarized in Table 10.18.2.

Routine radiochemical analyses of samples for the environmental surveillance and groundwater monitoring projects were performed primarily by Severn Trent Laboratories, Inc., Richland, Washington. Severn Trent Laboratories, Inc., Richland, participated in DOE's Mixed Analyte Performance Evaluation Program 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. Additional information on these quality control efforts is provided in the following sections.

### 10.18.1.4 DOE and EPA Comparison Studies

Blind water samples were distributed 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 2005 groundwater samples are provided in PNNL-15670, Appendix C, for the primary laboratory, Severn Trent Laboratories, Inc., St. Louis.

The DOE Mixed Analyte Performance Evaluation Program conducted by the Radiological and Environmental Sciences Laboratory in Idaho Falls, Idaho, and the Environmental Resource Associates Proficiency Testing Program provided standard samples of environmental media (e.g., water, air filters, soil, and vegetation) that contained specific amounts of one or more radionuclides that were unknown by the participating laboratory. After analysis, the results were

**Table 10.18.2. Summary of Battelle's Marine Sciences Laboratory Performance on NSI Laboratory, Inc. Proficiency Testing Program Samples (five studies), 2005**

| Media | Analytes | Number of Results Reported for Each Analyte[(a)] | Number Within Control Limits for Each Analyte[(a)] |
|---|---|---|---|
| Soil | Al, Sb, As, Ba, Be, B, Ca, Cd, Cr, Co, Cu, Fe, Pb, Mg, Mn, Hg, Mo, Na, Ni, K, Se, Ag, Sr, Sn, Tl, Ti, V, Zn | 2 | 2 |
| Water | Hg | 5 | 5 |
| | Mo, Se | 5 | 4 |
| | Total alkalinity ($CaCO_3$) | 5 | 3 |
| | Al, Sb, As, Ba, Be, Cd, Cr, Cu, Pb, Mg Mn, Ni, K, Ag, Na, Tl, V, Zn, pH, specific conductance, total hardness ($CaCO_3$) | 4 | 4 |
| | Ca, Fe | 3 | 3 |
| | Co, Sr | 2 | 2 |
| | Total dissolved solids | 3 | 2 |

(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.

forwarded to the Radiological and Environmental Sciences Laboratory (two studies) or Environmental Resource Associates (three studies) for comparison with known values and results from other laboratories. Both the Radiological and Environmental Sciences Laboratory and Environmental Resource Associates had established criteria for evaluating the accuracy of results (NERL-Ci-0045). The Radiological and Environmental Sciences Laboratory evaluates the DOE Mixed Analyte Performance Evaluation Program radiological and inorganic samples results for accuracy by determining if the result falls within ±30% of a reference value. Summaries of the 2005 results are provided in Tables 10.18.3 and 10.18.4. The DOE Mixed Analyte Performance Evaluation Program provided two sets of performance evaluation

**Table 10.18.3. Summary of Severn Trent Laboratories, Richland, Washington, Performance on Eight Performance Evaluation Samples Provided by the DOE Mixed Analyte Performance Project, 2005**

| Media | Radionuclides | Number of Results Reported for Each Radionuclide | Number of Results Within Acceptable Control Limits for Each Radionuclide[a] |
|---|---|---|---|
| Air filter | Gross alpha, gross beta, $^{54}$Mn, $^{57}$Co, $^{60}$Co, $^{65}$Zn, $^{90}$Sr, $^{134}$Cs, $^{137}$Cs, $^{234}$U, $^{238}$U, $^{238}$Pu, $^{239/240}$Pu, $^{241}$Am | 2 | 2 |
| Soil | $^{40}$K, $^{54}$Mn, $^{57}$Co, $^{60}$Co, $^{63}$Ni, $^{65}$Zn, $^{90}$Sr, $^{134}$Cs, $^{137}$Cs, $^{234}$U, $^{238}$U, $^{241}$Am | 2 | 2 |
| | $^{238}$Pu, $^{239/240}$Pu | 2 | 1 |
| | $^{55}$Fe, $^{99}$Tc | 2 | 0 |
| Vegetation | $^{54}$Mn, $^{57}$Co, $^{60}$Co, $^{65}$Zn, $^{134}$Cs, $^{137}$Cs | 2 | 2 |
| | $^{90}$Sr, $^{234}$U, $^{238}$U, $^{239/240}$Pu | 2 | 1 |
| | $^{238}$Pu, $^{241}$Am | 2 | 0 |
| Water | Gross alpha, gross beta, $^{3}$H, $^{55}$Fe, $^{90}$Sr, $^{99}$Tc, $^{234}$U, $^{238}$Pu, $^{238}$U, $^{239/240}$Pu | 2 | 2 |
| | $^{54}$Mn, $^{57}$Co, $^{60}$Co, $^{63}$Ni, $^{65}$Zn, $^{134}$Cs, $^{137}$Cs | 2 | 1 |

(a) Control limits are from EML-621.

**Table 10.18.4. Summary of Severn Trent Laboratories, Richland, Washington, Performance on Three Performance Evaluation Samples Provided by the Environmental Resource Associates Proficiency Testing Program, 2005**

| Media | Radionuclides | Number of Results Reported for Each Radionuclide | Number Within Control Limits for Each Radionuclide[a] |
|---|---|---|---|
| Water | Gross alpha, gross beta, $^{89}$Sr, $^{90}$Sr, $^{133}$Ba, $^{134}$Cs | 3 | 3 |
| | $^{60}$Co, $^{137}$Cs | 3 | 2 |
| | $^{65}$Zn | 3 | 1 |
| | $^{226}$Ra, $^{228}$Ra, U (natural) | 2 | 2 |
| | $^{3}$H, $^{131}$I | 1 | 1 |

(a) Control limits are from NERL-Ci-0045.

samples that were analyzed by Severn Trent Laboratories, Inc., Richland. Acceptable control limits as defined by the DOE Mixed Analyte Performance Evaluation Program were met by 83% of the DOE performance assessment sample results. The acceptable control limit range as defined by the *National Standards for Water Proficiency Testing Studies, Criteria Document* (NERL-Ci-0045) was met by 89% of the Environmental Resource Associates samples.

### 10.18.1.5 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 2005, 252 blind spiked samples were submitted for analyses for the Groundwater Performance Assessment Project (PNNL-15670, Appendix C). The results of all water sample non-radiochemistry blind spiked determinations are discussed in Appendix C of PNNL-15670 and indicated a good performance by the laboratory.

**Blind spiked sample** – A sample of known activity and/or concentration submitted to the analytical laboratory but not necessarily in the same physical geometry as the typical samples submitted.

Eight blind samples were submitted for analyses for the Surface Environmental Surveillance Project. The samples included air filters, soil, water, and vegetation (Table 10.18.5). For all media, 88% 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 measured by gamma spectroscopy were outside the acceptable range. Two results were for cesium-137 in air filters and the other two were for cobalt-60 in vegetation. In addition, one measurement of uranium-234 and one measurement of uranium-238 in soil were outside the control limit.

### 10.18.1.6 Laboratory Internal Quality Assurance Programs

The analytical laboratories were required to maintain an internal quality assurance and control program. The laboratories are audited at least annually for compliance to the quality assurance and control programs. At Severn Trent

**Table 10.18.5. Summary of Severn Trent Laboratories, Richland, Washington, Performance on Blind Spiked Samples Submitted for the Surface Environmental Surveillance Project, 2005**

| Media | Radionuclides | Number of Results Reported for Each Radionuclide | Number of Results Within Control Limits for Each Radionuclide[a] |
|---|---|---|---|
| Air Filters | $^{60}$Co, $^{90}$Sr, $^{234}$U, $^{238}$Pu, $^{238}$U, $^{239/240}$Pu | 2 | 2 |
| | $^{137}$Cs | 2 | 0 |
| Soil | $^{40}$K, $^{90}$Sr, $^{137}$Cs, $^{238}$Pu, $^{239/240}$Pu | 2 | 2 |
| | $^{234}$U, $^{238}$U | 2 | 1 |
| Vegetation | $^{40}$K, $^{90}$Sr, $^{137}$Cs | 2 | 2 |
| | $^{60}$Co | 2 | 0 |
| | $^{238}$Pu, $^{239/240}$Pu | 1 | 1 |
| Surface Water | $^{3}$H, $^{60}$Co, $^{137}$Cs, $^{234}$U, $^{238}$U, $^{239/240}$Pu | 2 | 2 |
| | $^{134}$Cs, $^{238}$Pu | 1 | 1 |

(a) Control limit of ±30%.

Laboratories, Inc., St. Louis, the quality control program met the quality assurance and control criteria in 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. Detection levels for each analytical method were determined at least annually.

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, the use of matrix and reagent blanks, and maintenance of control charts to indicate analytical deficiencies. Available calibration standards traceable to the National Institute of Standards and Technology were used for radiochemical calibrations. Calculation of minimum detectable concentrations involved the use of factors such as the average counting efficiencies and background for detection instruments, length of time for background and sample counts, sample volumes, radiochemical yields, and a pre-designated uncertainty multiplier (EPA 520/1-80-012).

Periodically, inspections of services were performed and conformance with the contractual requirements of the analytical facility was documented. These inspections provided the framework to identify and resolve potential performance problems. Responses to inspection findings were documented by written communication, and corrective actions were verified by follow-up audits and inspections. In 2005, five audits of the commercial laboratories supporting the Groundwater Performance Assessment Project were performed. Three audits were performed by the DOE Consolidated Assessment Program and two audits were performed by Bechtel Hanford, Inc. The DOE Consolidated Assessment Program audit evaluated Severn Trent Laboratories, Inc, St. Louis, on April 26 to 28, 2005; Lionville Laboratory, Lionville, on May 17 to 19, 2005; and Severn Trent Laboratories, Inc. Richland, on July 11 to 14, 2005. The scope of the DOE 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 Bechtel Hanford, Inc. audits of Severn Trent Laboratories, Inc., Richland, Washington, on June 21 to 23, 2005, and Lionville Laboratory, Lionville, Pennsylvania, on July 19 to 21, 2005, was to evaluate the analytical services supplied to Hanford Site contractors relative to requirements 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 and Lionville Laboratory's quality assurance management plan in accordance with *Hanford Analytical Services Quality Assurance Requirements Document* (DOE/RL-96-68, Volumes 1 and 4), and implementation of corrective actions for deficiencies identified in previous audits.

A total of 24 findings (requiring some corrective action by the laboratory) and 44 observations were noted for the 3 DOE Consolidated Assessment Program audits, 5 findings and 8 observations were identified in the Bechtel Hanford, Inc. audits. Results of these audits are summarized in Appendix C of PNNL-15670. Corrective actions for all the audit findings were accepted and verification of the corrective actions will be performed in future audits. All laboratories have been qualified by the DOE Consolidated Assessment Program to continue to provide analytical services for samples generated at DOE sites.

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 2005 (for the Surface Environmental Surveillance Project) and fiscal year 2005 (for the Groundwater Performance Assessment Project).

## 10.18.1.7 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 via thermoluminescent dosimeters at multiple locations during 2005 as part of its independent oversight monitoring program (see Section 2.0.6). Typical measured external radiation levels are shown in Figure 10.18.1 for the Byers Landing site and, within measurement uncertainty, there is good agreement between the Pacific Northwest National Laboratory and Washington State Department of Health measured values.

Measurements of radioactivity in air samples collected at several collocated sites were also reported. The Washington State Department of Health collected air samples on a weekly basis while Pacific Northwest National Laboratory collected samples on a biweekly basis. Data were compared for sites at the Battelle complex, Prosser Barricade, Wye Barricade, and Yakima Barricade. A typical comparison of gross beta concentrations is shown in Figure 10.18.2. Within measurement uncertainties, there was good agreement between the Washington State Department of Health and Pacific Northwest National Laboratory data.

Additional media that were co-sampled and analyzed for radionuclides included irrigation water, water from 19 locations along and across the Columbia River, water from 4 Columbia River shoreline springs, water from 1 onsite drinking water location, soil from 5 locations on and off the site, and sediment from 7 Columbia River sites from Priest Rapids Dam (upriver from the site) to McNary Dam (downriver from the site). Also co-sampled and analyzed for radionuclides were samples of whitefish, bass, and cottontail rabbit (muscle and bone), as well as upwind and downwind samples of potato tubers, asparagus, alfalfa, leafy vegetables, honey, and red and white wines.

The U.S. Food and Drug Administration also received co-samples from downwind sampling locations and analyzed potato tubers, cherries, alfalfa, and leafy vegetables provided by Pacific Northwest National Laboratory for radionuclides (Table 10.18.6). There were no detectable values determined from these analyses.

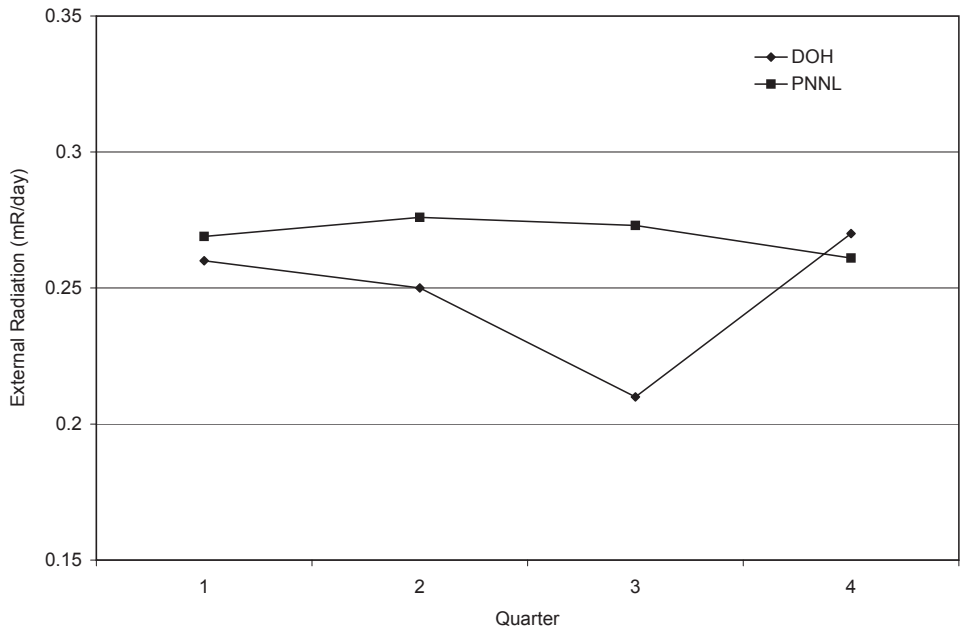


**Figure 10.18.1. A Comparison of External Radiation Levels Measured by the Washington State Department of Health and Pacific Northwest National Laboratory with Thermoluminescent Dosimeters at the Byers Landing Sampling Location Near the Hanford Site, 2005**

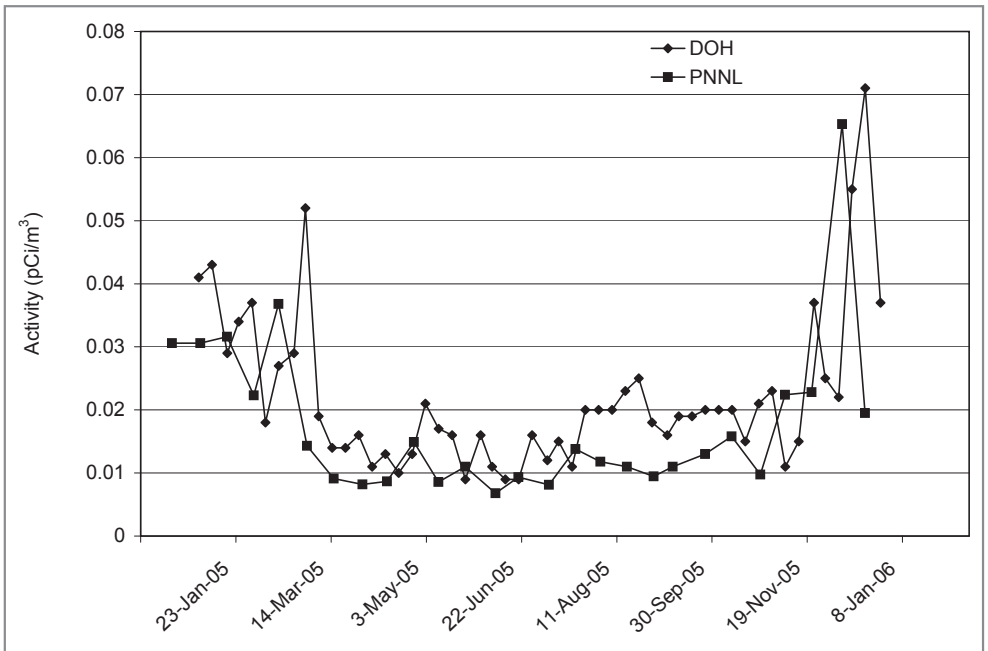


**Figure 10.18.2. Comparison of Gross Beta Levels in Air Measured by the Washington State Department of Health and Pacific Northwest National Laboratory at the Hanford Site's Wye Barricade, 2005**

Quality control for environmental thermoluminescent dosimeters (supplied by Pacific Northwest National Laboratory) included audits by Pacific Northwest National Laboratory that exposed three environmental thermoluminescent dosimeters per quarter to known values of radiation (between 17 and 29 milliroentgen). For the 12 measurements, the lowest ratio of determined/known exposure was 0.94; the highest determined/known exposure ratio was 1.08, with an average and standard deviation of 1.03 ± 0.04 (Table 10.18.7).

## 10.18.2 Effluent Monitoring and Environmental Monitoring Near Facilities and Operations

The Effluent Monitoring and Near-Facility Environmental Monitoring Programs were subject to the quality assurance requirements specified in 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 *Requirements for Quality Assurance Project Plans for Environmental Data Operations* (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.

### 10.18.2.1 Sample Collection Quality Assurance

Samples for the Effluent Monitoring and Near-Facility Environmental Monitoring Programs were collected by staff trained in accordance with approved procedures. Established sampling locations were accurately identified and documented to ensure continuity of data for those sites and are described in DOE/RL-91-50.

**Table 10.18.6. Comparison of Food and Drug Administration and Pacific Northwest National Laboratory Co-Sampling Results for Food and Farm Product Samples Collected Near the Hanford Site, 2005[a]**

| Media | Sampling Area[b] | Organization | Strontium-90, pCi/g[c,d] | Cesium-137, pCi/g[c,d] | Ruthenium-106, pCi/g[c,d] | Iodine-131 pCi/g[c,d] | Tritium pCi/g[c,d] |
|---|---|---|---|---|---|---|---|
| Leafy vegetables (stem-leaf) | Riverview | FDA | <0.002 | <0.03 | <0.1 | <0.03 | <200 |
| | | FDA | <0.002 | <0.03 | <0.1 | <0.03 | <200 |
| | | PNNL | 0.036 ± 0.065 | 0.00020 ± 0.013 | 0.071 ± 0.12 | NA | NA |
| Leafy vegetables (stem-leaf) | Sunnyside | FDA | <0.002 | <0.03 | <0.1 | <0.03 | <200 |
| | | FDA | <0.002 | <0.03 | <0.1 | <0.03 | <200 |
| | | PNNL | 0.036 ± 0.063 | -0.00039 ± 0.014 | 0.031 ± 0.12 | NA | NA |
| Alfalfa | Riverview | FDA | <0.002 | <0.03 | <0.1 | <0.03 | <200 |
| | | FDA | <0.002 | <0.03 | <0.1 | <0.03 | <200 |
| | | PNNL | 0.036 ± 0.025 | 0.0035 ± 0.014 | 0.035 ± 0.12 | NA | NA |
| Alfalfa | Sunnyside | FDA | <0.002 | <0.03 | <0.1 | <0.03 | <200 |
| | | FDA | <0.002 | <0.03 | <0.1 | <0.03 | <200 |
| | | PNNL | 0.098 ± 0.073 | 0.0064 ± 0.013 | -0.016 ± 0.11 | NA | NA |
| Potato tuber | Horn Rapids | FDA | <0.002 | <0.03 | <0.1 | <0.03 | <200 |
| | | FDA | <0.002 | <0.03 | <0.1 | <0.03 | <200 |
| | | PNNL | -0.0011 ± 0.0044 | -0.00018 ± 0.005 | 0.033 ± 0.052 | 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 | 0.0014 ± 0.0048 | -0.0012 ± 0.0039 | 0.011 ± 0.036 | NA | NA |
| Cherries | Sagemoor | FDA | <0.002 | <0.03 | <0.1 | <0.03 | <200 |
| | | FDA | <0.002 | <0.03 | <0.1 | <0.03 | <200 |
| | | PNNL | -0.0018 ± 0.0043 | -0.00069 ± 0.0040 | 0.0060 ± 0.036 | NA | NA |

(a) Sample results are wet weight.
(b) Sampling areas are illustrated in Figure 10.8.1.
(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.
FDA = U.S. Food and Drug Administration.
NA = Not analyzed; not specifically requested by contract unless present.
PNNL = Pacific Northwest National Laboratory.

## 10.18.2.2 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 10.18.8 provides a summary of the Hanford Site's analytical laboratories used for effluent monitoring and near-facility monitoring samples in 2005.

The quality of the analytical data was ensured by several means. For instance, counting room instruments were verified to perform 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 ensured through administrative procedures. Chemical technologists at the laboratories are qualified to perform analyses through formal classroom and on-the-job training.

The participation of the Hanford Site analytical laboratories in EPA and DOE laboratory performance evaluation programs also served to ensure the quality of the data produced. Samples formerly provided by the EPA are now available only from the National Institute of Standards and Technology approved private contractors. The Waste Sampling and Characterization Facility performance was evaluated by

**Table 10.18.7. Comparison of Pacific Northwest National Laboratory Thermoluminescent Dosimeter Results with Known Exposures, 2005**

| Calendar Year Quarter | Exposure Date | Known Exposure,[a] milliroentgen (mR) | Determined Exposure,[b] milliroentgen (mR) | Ratio of Determined/ Known Exposure |
|---|---|---|---|---|
| 1st | February 11, 2005 | 17 ± 0.6 | 17.56 ± 0.15 | 1.03 |
| | | 29 ± 1.1 | 30.95 ± 0.19 | 1.07 |
| | | 24 ± 0.9 | 25.88 ± 1.89 | 1.08 |
| 2nd | May 11, 2005 | 21 ± 0.8 | 21.53 ± 0.51 | 1.03 |
| | | 28 ± 1.0 | 30.09 ± 0.45 | 1.07 |
| | | 23 ± 1.9 | 24.58 ± 0.65 | 1.07 |
| 3rd | August 11, 2005 | 20 ± 0.7 | 19.94 ± 0.35 | 1.00 |
| | | 18 ± 0.7 | 19.16 ± 1.00 | 1.06 |
| | | 27 ± 1.0 | 28.22 ± 0.79 | 1.05 |
| 4th | November 4, 2005 | 26 ± 1.0 | 26.17 ± 0.74 | 1.01 |
| | | 19 ± 0.7 | 17.80 ± 0.87 | 0.94 |
| | | 25 ± 0.9 | 24.34 ± 1.39 | 0.97 |

(a) Variance is 2 standard deviations.
(b) Assumed 2 standard deviation error was 3.72%.

**Table 10.18.8. Hanford Site Laboratories Used by Site Contractors and Types of Effluent Monitoring and Near-Facility Monitoring Samples Analyzed, 2005**

| | Effluent Monitoring Samples | | | | | Near-Facility Environmental Monitoring Samples | | |
|---|---|---|---|---|---|---|---|---|
| | Fluor Hanford, Inc. | | Pacific Northwest National Laboratory | Bechtel Hanford, Inc. and Washington Closure Hanford, LLC | | Fluor Hanford, Inc. | | |
| Analytical Laboratory | 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 Group, Inc.
(c) Operated by Pacific Northwest National Laboratory.

participating in three different laboratory performance studies for 2005. The Waste Sampling and Characterization laboratory received and analyzed samples containing 367 different analytes and compounds during participation in the EPA Water Pollution Studies Nos. 120 and 126 and EPA Soil Studies Nos. 49 and 51. Of the 367 reported results, 366 were acceptable while one was unacceptable for a total acceptable rate of 99.7%. In the DOE Mixed Analyte Performance Evaluation Program studies (MAPEP-05-Study 13 and MAPEP-05-Study 14), samples containing 203 different radionuclides and analytes were submitted to the Waste Sampling and Characterization Facility for analysis. Of the 203 reported results, 191 results were acceptable while 12 were unacceptable for a total acceptable rate of 94%. In the National Institute of Standards and Technology Radiochemistry Intercomparison Program study, samples containing four different radionuclides (strontium-90, plutonium-238, uranium-238, and americium-241) in filters and soils were submitted to the Waste Sampling Characterization Facility for 40 different analyses (i.e., five samplers per matrix). All radionuclide results for both filters and soils were acceptable for a total acceptable rate of 100%.

The 222-S Laboratory participated in EPA Water Pollution intercomparison study number WP-123 when the laboratory was operated by CH2M HILL Hanford Group, Inc. The 222-S Laboratory also participated in EPA Water Pollution intercomparison study number WP-129 when the laboratory was operated by Advanced Technologies and Laboratories International, Inc. The WP-123 study reported two results "non-acceptable" out of a total of 169 results reported for an acceptable rate of 99%. The WP-129 study resulted in three "non-acceptable" results out of a total of 169 results reported, for a total acceptable rate of 98%. In the DOE Quality Assessment Program, samples containing 17 different radionuclides were submitted to the 222-S Analytical Laboratory for analysis. All 17 analytical results were acceptable, for a total acceptable rate of 100%. The 222-S Analytical Laboratory also participated in DOE's Mixed Analyte Performance Evaluation Program (MAPEP). For the MAPEP-04 Study, of the 33 reported results, 32 were found to be acceptable for an acceptable rate of 97%. For the MAPEP Study 12, 32 out of 34 results were acceptable, for an acceptable rate of 94%. For the MAPEP-05 Study13, 31 out of 37 results were acceptable, for an acceptable rate of 84%. For the MAPEP-05 Study 14, 34 out of 39 results were acceptpable, for an acceptable rate of 87%.

Performance evaluation results for DOE Mixed Analyte Performance Evaluation Program and others are presented in Tables 10.18.9 and 10.18.10.

**Table 10.18.9. The Hanford Site's Waste Sampling and Characterization Facility[a] Performance on DOE Mixed Analyte Performance Evaluation Program Samples and National Institute of Standards and Technology Radiochemistry Intercomparison Program Samples, 2005**

| Media | Laboratory | Radionuclide | Number of Results Reported | Number of Results Within Control Limits |
|---|---|---|---|---|
| Air filters | WSCF | $^{54}$Mn, $^{57}$Co, $^{60}$Co, $^{65}$Zn, $^{90}$Sr, $^{134}$Cs, $^{137}$Cs, $^{233/234}$U, $^{238}$Pu, $^{238}$U, $^{239/240}$Pu, $^{241}$Am, gross alpha, gross beta | 28 | 27 ($^{90}$Sr failed once) |
| | NRIP | $^{90}$Sr, $^{238}$Pu, $^{238}$U, $^{239/240}$Pu, $^{241}$Am | 5 | 5 |
| Soil | WSCF | $^{40}$K, $^{54}$Mn, $^{57}$Co, $^{60}$Co, $^{65}$Zn, $^{90}$Sr, $^{134}$Cs, $^{137}$Cs, $^{233/234}$U, $^{238}$Pu, $^{238}$U, $^{239/240}$Pu, $^{241}$Am | 26 | 24 ($^{233/234}$U and $^{239/240}$Pu failed; only naturally occurring uranium was present in the MAPEP soil sample) |
| | NRIP | $^{90}$Sr, $^{233/234}$U, $^{238}$Pu, $^{238}$U, $^{239/240}$Pu, $^{241}$Am | 6 | 6 |
| Vegetation | WSCF | $^{54}$Mn, $^{57}$Co, $^{60}$Co, $^{65}$Zn, $^{90}$Sr, $^{134}$Cs, $^{137}$Cs, $^{233/234}$U, $^{238}$Pu, $^{238}$U, $^{239/240}$Pu, $^{241}$Am | 22 | 19 ($^{54}$Mn, $^{57}$Co, and $^{65}$Zn failed once due to unique matrix/ unmatched geometry) |
| Water | WSCF | $^{3}$H, $^{54}$Mn, $^{57}$Co, $^{60}$Co, $^{65}$Zn, $^{90}$Sr, $^{99}$Tc, $^{134}$Cs, $^{137}$Cs, $^{233/234}$U, $^{238}$Pu, $^{238}$U, $^{239/240}$Pu, $^{241}$Am, gross alpha, gross beta | 32 | 31 ($^{99}$Tc failed once) |

(a) Onsite laboratory operated by Fluor Hanford, Inc.
MAPEP = Mixed Analyte Performance Evaluation Program.
NRIP = National Institute of Standards and Technology Radiochemistry Intercomparison Program.
WSCF = Waste Sampling and Characterization Facility.

**Table 10.18.10. The Hanford Site's 222-S Analytical Laboratory[a] Performance on DOE Quality Assessment Program Samples, 2005**

| Media | Radionuclide | Number of Results Reported | Number of Results Within Acceptable Limits |
|---|---|---|---|
| Air filters | $^{60}$Co, $^{134}$Cs, $^{137}$Cs, gross alpha, gross beta | 5 | 5 |
| Soil | $^{137}$Cs, total uranium | 2 | 2 |
| Vegetation | $^{137}$Cs | 1 | 1 |
| Water | $^{3}$H, $^{60}$Co, $^{90}$Sr, $^{137}$Cs, $^{238}$Pu, $^{239}$Pu, gross alpha, gross beta, total uranium | 9 | 9 |

(a) Onsite high-level radiological laboratory operated by CH2M HILL Hanford Group, Inc. (Note: These samples are low-level environmental activity samples.)

# 10.19 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 measure, 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 $1 \times 10^9$ 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 $2.0 \times 10^3$ (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 $2.0 \times 10^{-5}$ (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.

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

| Symbol | Name |
|---|---|
| **Temperature** | |
| °C | degree Celsius |
| °F | degree Fahrenheit |
| **Time** | |
| d | day |
| hr | hour |
| min | minute |
| ses | second |
| yr | year |
| **Rate** | |
| cfs (or $ft^3$/sec) | cubic feet 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 ($1 \times 10^{-3}$ L) |
| $yd^3$ | cubic yard |
| **Concentration** | |
| ppb | parts per billion |
| ppm | parts per million |
| ppmv | parts per million by volume |
| **Length** | |
| cm | centimeter ($1 \times 10^{-2}$ m) |
| ft | foot |
| in. | inch |
| km | kilometer ($1 \times 10^3$ m) |
| m | meter |
| mi | mile |
| mm | millimeter ($1 \times 10^{-3}$ m) |
| µm | micrometer ($1 \times 10^{-6}$ m) |
| **Area** | |
| ha | hectare ($1 \times 10^4$ $m^2$) |
| $km^2$ | square kilometer |
| $mi^2$ | square mile |
| $ft^2$ | square foot |
| **Mass** | |
| g | gram |
| kg | kilogram ($1 \times 10^3$ g) |
| mg | milligram ($1 \times 10^{-3}$ g) |
| µg | microgram ($1 \times 10^{-6}$ g) |
| lb | pound |

**Table A.2. Conversion Table**

| Multiply | By | To Obtain | Multiply | By | To Obtain |
|---|---|---|---|---|---|
| cm | 0.394 | in. | in. | 2.54 | cm |
| m | 3.28 | ft | ft | 0.305 | m |
| km | 0.621 | mi | mi | 1.61 | km |
| kg | 2.205 | lb | lb | 0.454 | kg |
| L | 0.2642 | gal | gal | 3.785 | L |
| $m^2$ | 10.76 | $ft^2$ | $ft^2$ | 0.093 | $m^2$ |
| ha | 2.47 | acres | acre | 0.405 | ha |
| $km^2$ | 0.386 | $mi^2$ | $mi^2$ | 2.59 | $km^2$ |
| $m^3$ | 35.31 | $ft^3$ | $ft^3$ | 0.0283 | $m^3$ |
| $m^3$ | 1.308 | $yd^3$ | $yd^3$ | 0.7646 | $m^3$ |
| pCi | 1,000 | nCi | nCi | 0.001 | pCi |
| µCi/mL | $10^9$ | pCi/L | pCi/L | $10^{-9}$ | µCi/mL |
| $Ci/m^3$ | $10^{12}$ | $pCi/m^3$ | $pCi/m^3$ | $10^{-12}$ | $Ci/m^3$ |
| $mCi/cm^3$ | $10^{15}$ | $pCi/m^3$ | $pCi/m^3$ | $10^{-15}$ | $mCi/cm^3$ |
| $nCi/m^2$ | 1.0 | $mCi/km^2$ | $mCi/km^2$ | 1.0 | $nCi/m^2$ |
| Ci | $3.7 \times 10^{10}$ | Bq | Bq | $2.7 \times 10^{-11}$ | Ci |
| pCi | 0.037 | Bq | Bq | 27 | pCi |
| rad | 0.01 | Gy | Gy | 100 | rad |
| rem | 0.01 | Sv | Sv | 100 | rem |
| ppm | 1,000 | ppb | ppb | 0.001 | ppm |
| °C | (°C x 9/5) + 32 | °F | °F | (°F -32) ÷ 9/5 | °C |
| oz | 28.349 | g | g | 0.035 | oz |
| ton | 0.9078 | tonne | tonne | 1.1 | ton |

## 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. 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

Radiological dose in this report is usually written in terms of effective dose equivalent and reported numerically in units of millirems (mrem), with the metric units millisieverts (mSv) following in parenthesis or footnoted.

**Table A.3. Names and Symbols for Units of Radioactivity**

| Symbol | Name | Symbol | Name |
|---|---|---|---|
| Ci | curie | Bq | becquerel ($2.7 \times 10^{-11}$ Ci) |
| mCi | millicurie ($1 \times 10^{-3}$ Ci) | kBq | kilobecquerel ($1 \times 10^{3}$ Bq) |
| µCi | microcurie ($1 \times 10^{-6}$ Ci) | MBq | megabecquerel ($1 \times 10^{6}$ Bq) |
| nCi | nanocurie ($1 \times 10^{-9}$ Ci) | mBq | millibecquerel ($1 \times 10^{-3}$ Bq) |
| pCi | picocurie ($1 \times 10^{-12}$ Ci) | GBq | gigabecquerel ($1 \times 10^{9}$ Bq) |
| fCi | femtocurie ($1 \times 10^{-15}$ Ci) | TBq | terabecquerel ($1 \times 10^{12}$ Bq) |
| aCi | attocurie ($1 \times 10^{-18}$ Ci) | | |

| 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 µBq | 37 µBq | 1 mBq | 37 mBq | 1 Bq | 37 Bq | 1 kBq | 37 kBq | 1 MBq | 37 MBq | 1 GBq | 37 GBq | 1 TBq | 37 TBq |

New unit of quantity = Becquerel (Bq) (formerly curie [Ci]) (1 Ci = 3.7 x $10^{10}$ dps).
1 Becquerel = 1 disintegration/sec (dps).

Millirem (millisievert) is a term that relates a given amount of absorbed radiation energy to its biological effectiveness 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 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 µrem | 10 µrem | 100 µrem | 1 mrem | 10 mrem | 100 mrem | 1 rem | 10 rem | 100 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 exposure to electromagnetic radiation (i.e., gamma and x-radiation) 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

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.

**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) |

**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 | $1.3 \times 10^{8}$ 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 | $1.4 \times 10^{10}$ yr |
| $^{59}Ni$ | nickel-59 | 75,000 yr | U or uranium | natural uranium | $\sim 4.5 \times 10^{9}$[b] |
| $^{60}Co$ | cobalt-60 | 5.3 yr | $^{233}U$ | uranium-233 | $1.59 \times 10^{5}$ yr |
| $^{63}Ni$ | nickel-63 | 100.1 yr | $^{234}U$ | uranium-234 | $2.4 \times 10^{5}$ yr |
| $^{65}Zn$ | zinc-65 | 243.9 d | $^{235}U$ | uranium-235 | $7 \times 10^{8}$ yr |
| $^{85}Kr$ | krypton-85 | 10.7 yr | $^{237}Np$ | neptunium-237 | $2.14 \times 10^{6}$ yr |
| $^{90}Sr$ | strontium-90 | 29.1 yr | $^{238}U$ | uranium-238 | $4.5 \times 10^{9}$ 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 | $2.4 \times 10^{4}$ yr |
| $^{99}Tc$ | technetium-99 | $2.1 \times 10^{5}$ yr | $^{240}Pu$ | plutonium-240 | $6.5 \times 10^{3}$ 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 | $3.76 \times 10^{5}$ 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 | $1.6 \times 10^{7}$ 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 $\sim 4.5 \times 10^{9}$ years.

## 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.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, or 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 (e.g., chemical or water quality measurements) 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, 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 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).

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

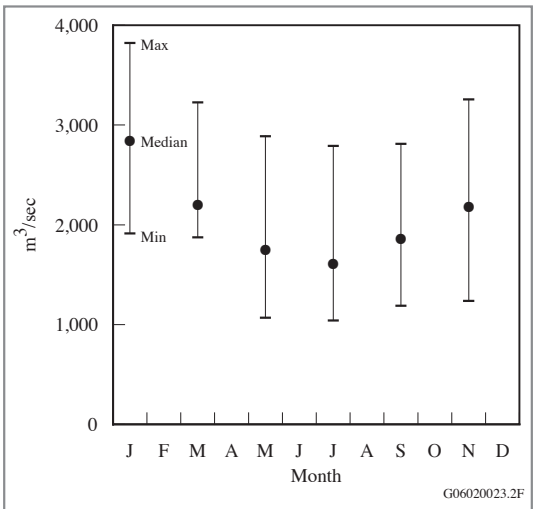


**Figure A.1. A Graphical Representation of Maximum, Median (or sometimes average), and Minimum Values**

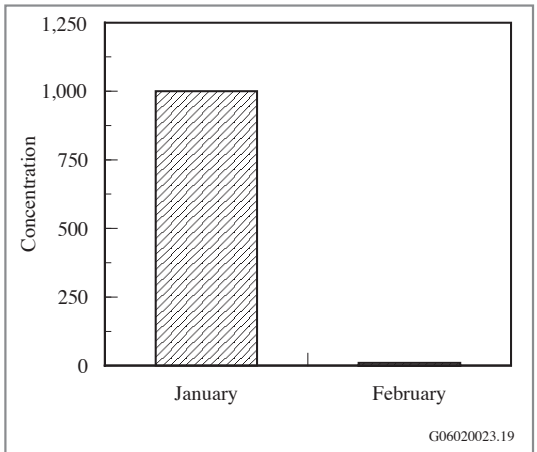


**Figure A.2. Data Plotted Using a Linear Scale**

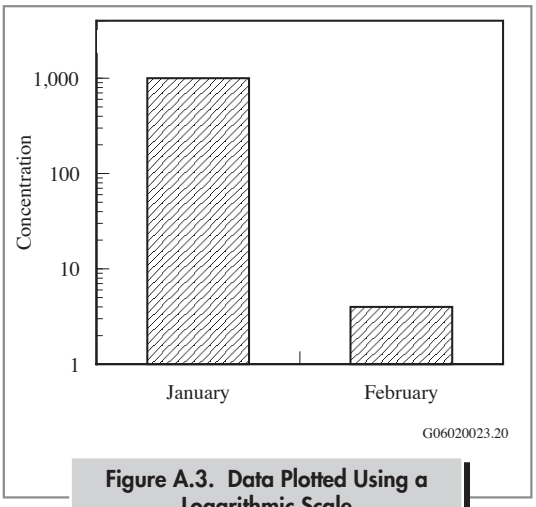


**Figure A.3. Data Plotted Using a Logarithmic Scale**

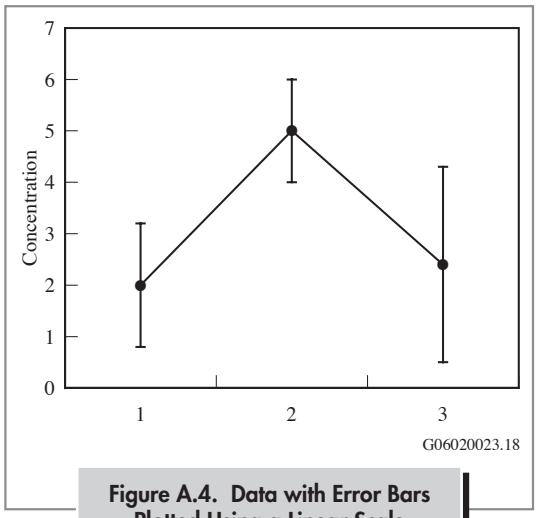


**Figure A.4. Data with Error Bars Plotted Using a Linear Scale**

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.

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 (≤ or ≥) 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 in 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 composed 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. It also includes *radiation* from global *fallout* from historical atmospheric nuclear weapons testing. 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 per second). Another unit of *radioactivity*, the *curie*, is related to the becquerel: 1 Ci = $3.7 \times 10^{10}$ Bq.

**beta particle** - A 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* to various tissues in the body, each multiplied by the appropriate weighting factor.

**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 sampling 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 ($3.7 \times 10^{10}$) 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* or *emissions* are spread or mixed when they are 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/hr).

**dosimeter** - Portable device for measuring the accumulated *exposure* or *absorbed dose* from specific types or energies of 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 material released from a facility.

**effluent monitoring** - Sampling or measuring specific liquid *effluent* streams for the presence of pollutants.

**emission** - Gaseous stream 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.

**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, and soil) that is grabbed from the collection site.

**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 the absorption of 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-activity waste** - See *high-level waste*.

**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-activity waste** - See *low-level waste*.

**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:

$$\text{mean} = \frac{\sum x}{n}$$

where n is the number of measurements and $\sum x$ 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.

**monitoring** - As defined in DOE Order 5400.5, the collection and analysis of samples or measurements of liquid *effluent* and gaseous *emissions* for purposes of characterizing and quantifying contaminants, assessing *radiation exposure* to the public, and demonstrating compliance with regulatory standards.

**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 composed 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 a 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 (e.g., *alpha* and *beta 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* emitting *radiation* (such as *alpha* or *beta particles*, or high-energy *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 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 (or cleanup) 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 variants in the International System of Units (SI). The common unit for *dose equivalent* and its variants, 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*.

**surveillance** - As defined in DOE Order 5400.5, the collection and analysis of samples of air, water, soil, foodstuffs, biota, and other media, and the measurement of *external radiation* for purposes of demonstrating compliance with applicable standards, assessing *exposures* to the public, and assessing effects, if any, on the local environment.

**tank farm** - A group of underground waste storage tanks.

**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*) per gram of alpha-emitting transuranic isotopes (*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 the intake of radioactive material and *dose equivalent* from exposure to *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 ground 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. "Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions." U.S. Environmental Protection Agency, *Code of Federal Regulations*.

40 CFR 761.61(c). "PCB Remediation Waste." U.S. Environmental Protection Agency, *Code of Federal Regulations*.

DOE Order 5400.5. 1990. "Radiation Protection of the Public and the Environment." U.S. Department of Energy, Washington, D.C.

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. Accessed on June 12, 2006, at http://www.epa.gov/region5/defs/html/rcra.htm.

*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 2005

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This appendix contains additional information on 2005 monitoring results, supplementing the data summarized in the main body of the report. More detailed information is available in *Hanford Site Environmental Surveillance Data Report for Calendar Year 2005* (PNNL-15892, APP. 1).

**Table C.1. Concentrations of Selected Radionuclides (pCi/m³)[a] in Near-Facility Air Samples, 2005 Compared to Previous Years**

| | | 2005 | | | | | 2000-2004 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Number of | | | | Sampler | Number of | | | | |
| Radionuclide | Site | Samples | Detections[b] | Average[c] | Maximum[d] | Number | Samples | Detections[b] | Average[c] | Maximum[d] | DCG |
| Gross alpha | 100-B/C RA | 135 | 123 | 1.2E-03 ± 1.3E-03 | 3.7E-03 ± 9.5E-04 | N497 | 381 | 331 | 1.2E-03 ± 1.4E-03 | 4.1E-03 ± 1.0E-03 | 2.0E-02 |
| | 100-F RA | 73 | 60 | 1.2E-03 ± 1.5E-03 | 3.9E-03 ± 1.3E-03 | N553 | 332 | 290 | 1.3E-03 ± 1.6E-03 | 4.7E-03 ± 1.1E-03 | |
| | 100 Area ISS | 68 | 60 | 1.2E-03 ± 1.5E-03 | 3.9E-03 ± 1.1E-03 | N525 | 497 | 378 | 1.5E-03 ± 3.9E-03 | 2.3E-02 ± 1.2E-01 | |
| | 100-K D&D | 81 | 67 | 1.0E-03 ± 1.4E-03 | 4.1E-03 ± 1.2E-03 | N476 | 287 | 249 | 1.2E-03 ± 1.5E-03 | 5.8E-03 ± 1.2E-03 | |
| | 100-KR-1 RA | 78 | 74 | 1.3E-03 ± 1.5E-03 | 4.8E-03 ± 1.3E-03 | N529 | 170 | 150 | 1.2E-03 ± 1.7E-03 | 6.4E-03 ± 1.4E-03 | |
| | 118-K-1 RA | 39 | 37 | 1.6E-03 ± 3.0E-03 | 7.5E-03 ± 1.6E-03 | N535 | 132 | 115 | 1.2E-03 ± 1.5E-03 | 5.4E-03 ± 1.2E-03 | |
| | 100-K SNF | 215 | 193 | 1.3E-03 ± 2.3E-03 | 1.4E-02 ± 1.6E-02 | N478 | 1,044 | 912 | 1.2E-03 ± 1.5E-03 | 7.7E-03 ± 2.2E-03 | |
| | 100-N | 107 | 100 | 1.3E-03 ± 1.4E-03 | 3.9E-03 ± 1.1E-03 | N102 | 489 | 431 | 1.3E-03 ± 1.5E-03 | 5.7E-03 ± 1.5E-03 | |
| | 200-East | 540 | 500 | 1.2E-03 ± 1.4E-03 | 4.6E-03 ± 1.3E-03 | N158 | 2486 | 2,217 | 1.2E-03 ± 1.6E-03 | 9.5E-03 ± 3.1E-03 | |
| | 200-West | 666 | 618 | 1.3E-03 ± 1.6E-03 | 1.1E-02 ± 1.6E-02 | N994 | 2,876 | 2,544 | 1.2E-03 ± 1.6E-03 | 7.7E-03 ± 1.3E-03 | |
| | 300 Area D&D | 23 | 20 | 1.4E-03 ± 2.8E-03 | 7.3E-03 ± 1.7E-03 | N557 | 0 | 0 | | | |
| | 300-FF-2 RA | 68 | 59 | 1.4E-03 ± 1.9E-03 | 4.8E-03 ± 1.3E-03 | N130 | 377 | 334 | 1.2E-03 ± 1.4E-03 | 6.3E-03 ± 7.8E-03 | |
| | ERDF | 108 | 91 | 1.1E-03 ± 1.3E-03 | 3.4E-03 ± 1.0E-03 | N482 | 496 | 429 | 1.1E-03 ± 1.3E-03 | 5.4E-03 ± 1.5E-03 | |
| Gross beta | 100-B/C RA | 135 | 135 | 1.8E-02 ± 2.4E-02 | 5.3E-02 ± 4.9E-03 | N466 | 381 | 381 | 1.7E-02 ± 2.3E-02 | 6.7E-02 ± 5.8E-03 | 9.0E+00 |
| | 100-F RA | 73 | 73 | 1.9E-02 ± 2.7E-02 | 7.1E-02 ± 7.6E-03 | N553 | 332 | 332 | 1.8E-02 ± 2.5E-02 | 7.6E-02 ± 6.4E-03 | |
| | 100 Area ISS | 68 | 68 | 2.2E-02 ± 3.0E-02 | 6.7E-02 ± 6.0E-03 | N524 | 497 | 492 | 2.0E-02 ± 4.6E-02 | 3.6E-01 ± 1.7E-01 | |
| | 100-K D&D | 81 | 81 | 1.9E-02 ± 2.8E-02 | 7.1E-02 ± 6.5E-03 | N476 | 287 | 287 | 1.8E-02 ± 2.3E-02 | 6.5E-02 ± 5.7E-03 | |
| | 100-KR-1 RA | 78 | 78 | 1.9E-02 ± 2.7E-02 | 6.7E-02 ± 6.1E-03 | N529 | 170 | 170 | 1.8E-02 ± 2.5E-02 | 7.3E-02 ± 6.2E-03 | |
| | 118-K-1 RA | 39 | 39 | 2.3E-02 ± 3.4E-02 | 7.8E-02 ± 7.9E-03 | N534 | 132 | 132 | 1.8E-02 ± 2.4E-02 | 6.7E-02 ± 5.9E-03 | |
| | 100-K SNF | 215 | 215 | 2.0E-02 ± 2.8E-02 | 7.1E-02 ± 6.5E-03 | N476 | 1,044 | 1,044 | 1.8E-02 ± 2.4E-02 | 1.2E-01 ± 1.1E-02 | |
| | 100-N | 107 | 107 | 2.0E-02 ± 2.6E-02 | 6.8E-02 ± 6.1E-03 | N103 | 489 | 489 | 1.8E-02 ± 2.4E-02 | 8.2E-02 ± 7.0E-03 | |
| | 200-East | 540 | 540 | 1.8E-02 ± 2.5E-02 | 7.9E-02 ± 7.7E-03 | N481 | 2,486 | 2,484 | 1.7E-02 ± 2.1E-02 | 9.6E-02 ± 4.1E-03 | |
| | 200-West | 666 | 665 | 1.8E-02 ± 2.3E-02 | 6.8E-02 ± 6.4E-03 | N200 | 2,876 | 2,876 | 1.6E-02 ± 2.1E-02 | 7.1E-02 ± 6.8E-03 | |
| | 300 Area D&D | 23 | 23 | 1.7E-02 ± 2.7E-02 | 6.4E-02 ± 6.8E-03 | N557 | 0 | 0 | | | |
| | 300-FF-2 RA | 68 | 68 | 2 .1E-02 ± 3.5E-02 | 8.1E-02 ± 1.0E-02 | N546 | 377 | 376 | 1.6E-02 ± 2.2E-02 | 7.5E-02 ± 6.4E-03 | |
| | ERDF | 108 | 108 | 1.7E-02 ± 2.4E-02 | 6.6E-02 ± 5.9E-03 | N518 | 496 | 495 | 1.6E-02 ± 2.2E-02 | 7.1E-02 ± 6.8E-03 | |
| $^{60}$Co | 100-B/C RA | 10 | 0 | -2.6E-06 ± 6.7E-05 | 7.1E-05 ± 8.4E-05 | N466 | 32 | 0 | 3.5E-06 ± 8.9E-05 | 8.1E-05 ± 9.0E-05 | 8.0E+01 |
| | 100-F RA | 7 | 1 | 1.3E-04 ± 5.2E-04 | 7.5E-04 ± 5.4E-04 | N558 | 28 | 0 | -4.5E-06 ± 6.8E-05 | 6.3E-05 ± 1.1E-04 | |
| | 100 Area ISS | 10 | 0 | 1.8E-05 ± 1.1E-04 | 9.1E-05 ± 1.6E-04 | N524 | 76 | 1 | -1.7E-05 ± 8.0E-04 | 1.0E-03 ± 1.7E-03 | |
| | 100-K D&D | 4 | 0 | -1.8E-05 ± 8.4E-05 | 3.4E-05 ± 7.6E-05 | N476 | 20 | 0 | 1.2E-05 ± 5.2E-05 | 5.9E-05 ± 9.4E-05 | |
| | 100-KR-1 RA | 6 | 0 | -1.8E-05 ± 9.8E-05 | 6.7E-05 ± 1.1E-04 | N529 | 15 | 1 | 2.9E-05 ± 2.2E-04 | 3.9E-04 ± 2.3E-04 | |
| | 118-K-1 RA | 6 | 0 | 1.3E-04 ± 4.7E-04 | 5.5E-04 ± 5.7E-04 | N534 | 10 | 0 | -7.2E-07 ± 1.1E-04 | 8.1E-05 ± 9.3E-05 | |
| | 100-K SNF | 16 | 0 | -1.4E-06 ± 9.9E-05 | 8.9E-05 ± 8.1E-05 | N479 | 80 | 0 | 1.0E-05 ± 9.5E-05 | 1.2E-04 ± 8.5E-05 | |
| | 100-N | 8 | 6 | 2.0E-04 ± 2.8E-04 | 4.4E-04 ± 1.6E-04 | N526 | 37 | 9 | 1.5E-04 ± 3.8E-04 | 1.0E-03 ± 3.2E-04 | |
| | 200-East | 40 | 1 | 9.3E-06 ± 1.0E-04 | 1.4E-04 ± 6.7E-05 | N984 | 190 | 1 | 4.3E-06 ± 8.3E-05 | 1.1E-04 ± 7.8E-05 | |
| | 200-West | 51 | 0 | -4.6E-06 ± 7.8E-05 | 9.0E-05 ± 8.4E-05 | N956 | 222 | 0 | 5.2E-06 ± 8.8E-05 | 1.6E-04 ± 9.0E-05 | |
| | 300 Area D&D | 4 | 0 | -4.6E-05 ± 3.8E-04 | 8.2E-05 ± 1.6E-04 | N557 | 0 | 0 | | | |
| | 300-FF-2 RA | 10 | 0 | -6.5E-05 ± 8.9E-04 | 1.1E-03 ± 1.3E-03 | N549 | 38 | 0 | -3.2E-05 ± 2.7E-04 | 3.0E-04 ± 1.3E-04 | |
| | ERDF | 8 | 0 | 7.8E-06 ± 1.4E-04 | 1.5E-04 ± 1.2E-04 | N517 | 38 | 3 | 3.3E-05 ± 1.7E-04 | 3.0E-04 ± 1.4E-04 | |

**Table C.1. (contd)**

| Radionuclide | Site | 2005 Number of Samples | 2005 Number of Detections[b] | 2005 Average[c] | 2005 Maximum[d] | Sampler Number | 2000-2004 Number of Samples | 2000-2004 Number of Detections[b] | 2000-2004 Average[c] | 2000-2004 Maximum[d] | DCG |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $^{90}$Sr | 100-B/C RA | 10 | 3 | 4.8E-05 ± 1.8E-04 | 2.1E-04 ± 1.1E-04 | N497 | 32 | 4 | -1.2E-05 ± 2.7E-04 | 2.7E-04 ± 1.1E-04 | 9.0E+00 |
| | 100-F RA | 7 | 0 | -1.0E-04 ± 2.5E-04 | 2.4E-05 ± 1.1E-04 | N520 | 28 | 13 | 9.7E-05 ± 2.9E-04 | 5.3E-04 ± 2.0E-04 | |
| | 100 Area ISS | 10 | 2 | -5.6E-05 ± 5.4E-04 | 4.8E-04 ± 4.6E-04 | N524 | 76 | 29 | 6.2E-04 ± 5.9E-03 | 2.4E-02 ± 4.7E-03 | |
| | 100-K D&D | 4 | 1 | 8.6E-05 ± 1.8E-04 | 2.2E-04 ± 1.6E-04 | N476 | 20 | 9 | 5.3E-05 ± 2.4E-04 | 2.7E-04 ± 9.5E-05 | |
| | 100-KR-1 RA | 6 | 1 | 1.5E-04 ± 6.6E-04 | 8.5E-04 ± 2.9E-04 | N528 | 15 | 3 | 6.4E-05 ± 6.3E-04 | 1.1E-03 ± 3.6E-04 | |
| | 118-K-1 RA | 6 | 3 | 1.5E-04 ± 1.1E-03 | 9.5E-04 ± 4.3E-04 | N534 | 10 | 5 | 8.2E-05 ± 1.8E-04 | 2.7E-04 ± 1.2E-04 | |
| | 100-K SNF | 16 | 3 | 4.7E-05 ± 1.7E-04 | 2.2E-04 ± 1.6E-04 | N476 | 80 | 30 | 5.8E-05 ± 2.3E-04 | 2.7E-04 ± 9.5E-05 | |
| | 100-N | 8 | 2 | 3.5E-05 ± 2.2E-04 | 2.0E-04 ± 1.2E-04 | N102 | 37 | 10 | 5.2E-05 ± 2.6E-04 | 4.5E-04 ± 1.8E-04 | |
| | 200-East | 40 | 6 | 3.6E-05 ± 2.5E-04 | 5.0E-04 ± 1.8E-04 | N985 | 190 | 75 | 9.5E-05 ± 5.4E-04 | 3.2E-03 ± 6.4E-04 | |
| | 200-West | 51 | 5 | 3.0E-05 ± 2.6E-04 | 6.6E-04 ± 2.6E-04 | N551 | 222 | 63 | 3.6E-05 ± 2.2E-04 | 4.4E-04 ± 1.6E-04 | |
| | 300 Area D&D | 4 | 0 | -5.6E-06 ± 4.5E-04 | 3.8E-04 ± 4.7E-04 | N557 | 0 | 0 | | | |
| | 300-FF-2 RA | 2 | 0 | -1.5E-05 ± 3.9E-05 | 4.6E-06 ± 4.6E-05 | N130 | 11 | 2 | 1.9E-05 ± 2.1E-04 | 1.4E-04 ± 8.7E-05 | |
| | ERDF | 8 | 1 | 5.7E-05 ± 1.7E-04 | 2.3E-04 ± 1.1E-04 | N482 | 38 | 8 | 3.9E-05 ± 2.0E-04 | 2.8E-04 ± 1.2E-04 | |
| $^{137}$Cs | 100-B/C RA | 10 | 0 | 3.4E-05 ± 8.0E-05 | 9.5E-05 ± 7.1E-05 | N497 | 32 | 0 | 1.3E-05 ± 9.0E-05 | 1.5E-04 ± 2.0E-04 | 4.0E+02 |
| | 100-F RA | 7 | 1 | -2.1E-05 ± 1.9E-04 | 1.2E-04 ± 1.0E-04 | N519 | 28 | 2 | 4.0E-05 ± 1.5E-04 | 3.3E-04 ± 1.5E-04 | |
| | 100 Area ISS | 10 | 1 | 1.9E-05 ± 2.1E-04 | 3.1E-04 ± 2.6E-04 | N524 | 76 | 3 | 1.7E-04 ± 1.2E-03 | 4.4E-03 ± 3.6E-03 | |
| | 100-K D&D | 4 | 0 | 3.7E-05 ± 6.5E-06 | 4.1E-05 ± 7.3E-05 | N476 | 20 | 1 | 1.8E-05 ± 9.3E-05 | 1.6E-04 ± 1.5E-04 | |
| | 100-KR-1 RA | 6 | 0 | 3.4E-05 ± 5.2E-05 | 7.9E-05 ± 7.2E-05 | N528 | 15 | 1 | 1.0E-05 ± 1.8E-04 | 2.3E-04 ± 1.7E-04 | |
| | 118-K-1 RA | 6 | 1 | 2.0E-05 ± 2.2E-04 | 1.3E-04 ± 9.7E-05 | N403 | 10 | 1 | 8.1E-05 ± 8.9E-05 | 1.6E-04 ± 1.0E-04 | |
| | 100-K SNF | 16 | 1 | 4.4E-05 ± 7.9E-05 | 1.3E-04 ± 9.7E-05 | N403 | 80 | 3 | 3.4E-05 ± 1.0E-04 | 1.6E-04 ± 1.0E-04 | |
| | 100-N | 8 | 3 | 2.2E-04 ± 5.7E-04 | 8.0E-04 ± 3.2E-04 | N526 | 37 | 10 | 2.6E-04 ± 1.1E-03 | 2.5E-03 ± 7.9E-04 | |
| | 200-East | 40 | 4 | 8.1E-05 ± 4.2E-04 | 9.9E-04 ± 3.9E-04 | N158 | 190 | 31 | 7.5E-05 ± 3.7E-04 | 2.3E-03 ± 7.6E-04 | |
| | 200-West | 51 | 4 | 4.8E-05 ± 1.6E-04 | 4.0E-04 ± 2.1E-04 | N551 | 222 | 30 | 8.5E-05 ± 3.0E-04 | 1.3E-03 ± 5.1E-04 | |
| | 300 Area D&D | 4 | 0 | 8.5E-06 ± 1.4E-04 | 1.2E-04 ± 3.1E-04 | N557 | 0 | 0 | | | |
| | 300-FF-2 RA | 10 | 0 | -2.6E-05 ± 4.1E-04 | 2.0E-04 ± 5.0E-04 | N548 | 38 | 0 | 3.6E-05 ± 1.9E-04 | 4.6E-04 ± 7.8E-04 | |
| | ERDF | 8 | 1 | 9.3E-05 ± 1.4E-04 | 2.6E-04 ± 1.5E-04 | N517 | 38 | 4 | 6.4E-05 ± 1.0E-04 | 2.6E-04 ± 1.6E-04 | |
| $^{234}$U | 100-B/C RA | 10 | 10 | 8.4E-06 ± 5.1E-06 | 1.3E-05 ± 8.1E-06 | N464 | 32 | 29 | 1.3E-05 ± 1.8E-05 | 5.1E-05 ± 2.1E-05 | 9.0E-02 |
| | 100-F RA | 7 | 6 | 1.7E-05 ± 1.5E-05 | 2.9E-05 ± 2.0E-05 | N520 | 28 | 24 | 1.5E-05 ± 1.4E-05 | 3.8E-05 ± 1.4E-05 | |
| | 100 Area ISS | 10 | 7 | 1.7E-05 ± 2.2E-05 | 4.6E-05 ± 2.4E-05 | N525 | 76 | 54 | 2.5E-05 ± 4.1E-05 | 1.6E-04 ± 8.0E-05 | |
| | 100-K D&D | 4 | 4 | 1.1E-05 ± 6.5E-06 | 1.5E-05 ± 9.1E-06 | N476 | 20 | 20 | 1.4E-05 ± 2.0E-05 | 4.7E-05 ± 1.3E-05 | |
| | 100-KR-1 RA | 6 | 6 | 9.1E-06 ± 3.3E-06 | 1.1E-05 ± 7.3E-06 | N529 | 15 | 11 | 1.5E-05 ± 1.7E-05 | 4.1E-05 ± 2.4E-05 | |
| | 118-K-1 RA | 6 | 4 | 3.2E-05 ± 5.4E-05 | 8.4E-05 ± 4.3E-05 | N535 | 10 | 10 | 1.5E-05 ± 1.2E-05 | 2.6E-05 ± 1.2E-05 | |
| | 100-K SNF | 16 | 14 | 1.2E-05 ± 9.8E-06 | 2.2E-05 ± 1.2E-05 | N401 | 80 | 73 | 1.2E-05 ± 1.3E-05 | 4.7E-05 ± 1.3E-05 | |
| | 100-N | 8 | 7 | 1.0E-05 ± 5.4E-06 | 1.5E-05 ± 8.5E-06 | N102 | 37 | 35 | 1.4E-05 ± 1.1E-05 | 3.3E-05 ± 1.1E-05 | |
| | 200-East | 40 | 36 | 1.2E-05 ± 1.2E-05 | 3.3E-05 ± 1.6E-05 | N978 | 190 | 173 | 1.4E-05 ± 1.2E-05 | 3.9E-05 ± 1.8E-05 | |
| | 200-West | 51 | 45 | 1.4E-05 ± 2.0E-05 | 6.3E-05 ± 2.8E-05 | N551 | 222 | 205 | 1.4E-05 ± 1.1E-05 | 5.0E-05 ± 2.1E-05 | |
| | 300 Area D&D | 4 | 4 | 5.1E-05 ± 7.0E-05 | 1.1E-04 ± 5.3E-05 | N557 | 0 | 0 | | | |
| | 300-FF-2 RA | 10 | 6 | 5.6E-05 ± 1.1E-04 | 1.7E-04 ± 1.2E-04 | N548 | 38 | 38 | 4.9E-05 ± 9.0E-05 | 1.9E-04 ± 9.7E-05 | |
| | ERDF | 8 | 8 | 1.6E-05 ± 1.2E-05 | 2.9E-05 ± 1.5E-05 | N517 | 38 | 35 | 1.6E-05 ± 1.6E-05 | 4.8E-05 ± 2.2E-05 | |

**Table C.1. (contd)**

| | | 2005 | | | | | 2000-2004 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Number of | | | | Sampler | Number of | | | | |
| Radionuclide | Site | Samples | Detections[b] | Average[c] | Maximum[d] | Number | Samples | Detections[b] | Average[c] | Maximum[d] | DCG |
| $^{235}U$ | 100-B/C RA | 10 | 3 | 3.5E-06 ± 3.2E-06 | 7.2E-06 ± 5.3E-06 | N464 | 32 | 9 | 4.2E-06 ± 8.3E-06 | 2.1E-05 ± 1.6E-05 | 1.0E-01 |
| | 100-F RA | 7 | 3 | 4.9E-06 ± 9.6E-06 | 1.4E-05 ± 1.4E-05 | N520 | 28 | 10 | 4.6E-06 ± 8.1E-06 | 2.2E-05 ± 1.1E-05 | |
| | 100 Area ISS | 10 | 2 | 6.3E-06 ± 8.6E-06 | 1.7E-05 ± 1.3E-05 | N524 | 76 | 17 | 9.9E-06 ± 2.9E-05 | 8.8E-05 ± 1.8E-04 | |
| | 100-K D&D | 4 | 1 | 3.3E-06 ± 3.3E-06 | 5.3E-06 ± 5.4E-06 | N476 | 20 | 3 | 4.3E-06 ± 1.5E-05 | 3.2E-05 ± 9.9E-06 | |
| | 100-KR-1 RA | 6 | 2 | 3.0E-06 ± 2.4E-06 | 5.2E-06 ± 4.1E-06 | N530 | 15 | 1 | 2.2E-06 ± 2.3E-06 | 4.2E-06 ± 4.1E-06 | |
| | 118-K-1 RA | 6 | 1 | 9.8E-06 ± 1.5E-05 | 2.3E-05 ± 2.3E-05 | N534 | 10 | 2 | 2.8E-06 ± 2.5E-06 | 5.2E-06 ± 5.3E-06 | |
| | 100-K SNF | 16 | 4 | 3.3E-06 ± 5.6E-06 | 1.2E-05 ± 7.9E-06 | N479 | 80 | 13 | 3.2E-06 ± 8.9E-06 | 3.2E-05 ± 9.9E-06 | |
| | 100-N | 8 | 1 | 2.2E-06 ± 2.8E-06 | 4.7E-06 ± 4.2E-06 | N103 | 37 | 12 | 4.3E-06 ± 1.2E-05 | 2.7E-05 ± 1.0E-05 | |
| | 200-East | 40 | 13 | 3.3E-06 ± 4.0E-06 | 1.0E-05 ± 6.8E-06 | N978 | 190 | 48 | 3.2E-06 ± 4.7E-06 | 1.3E-05 ± 6.2E-06 | |
| | 200-West | 51 | 12 | 3.1E-06 ± 6.3E-06 | 1.9E-05 ± 1.2E-05 | N987 | 222 | 74 | 3.4E-06 ± 5.9E-06 | 2.4E-05 ± 9.1E-06 | |
| | 300 Area D&D | 4 | 0 | 3.2E-06 ± 5.9E-06 | 6.0E-06 ± 7.2E-06 | N557 | 0 | 0 | | | |
| | 300-FF-2 RA | 10 | 3 | 2.8E-05 ± 7.3E-05 | 1.3E-04 ± 8.9E-05 | N548 | 38 | 12 | 8.8E-06 ± 2.1E-05 | 4.7E-05 ± 4.6E-05 | |
| | ERDF | 8 | 2 | 3.3E-06 ± 4.5E-06 | 7.8E-06 ± 5.7E-06 | N518 | 38 | 6 | 2.7E-06 ± 4.3E-06 | 1.1E-05 ± 6.7E-06 | |
| $^{238}Pu$ | 100-B/C RA | 10 | 2 | 2.4E-06 ± 6.2E-06 | 8.8E-06 ± 6.1E-06 | N497 | 32 | 4 | 3.0E-06 ± 1.1E-05 | 2.6E-05 ± 1.2E-05 | 2.0E-02 |
| | 100-F RA | 7 | 0 | 1.4E-06 ± 2.7E-06 | 3.5E-06 ± 3.6E-05 | N558 | 28 | 9 | 7.7E-06 ± 2.9E-05 | 5.4E-05 ± 2.7E-05 | |
| | 100 Area ISS | 10 | 2 | 1.2E-05 ± 4.3E-05 | 7.6E-05 ± 3.5E-05 | N525 | 76 | 25 | 2.6E-05 ± 1.3E-04 | 4.2E-04 ± 3.2E-04 | |
| | 100-K D&D | 4 | 1 | 4.9E-06 ± 8.0E-06 | 1.1E-05 ± 9.7E-06 | N477 | 20 | 5 | 5.7E-06 ± 1.5E-05 | 2.4E-05 ± 1.4E-05 | |
| | 100-KR-1 RA | 6 | 3 | 6.1E-06 ± 9.4E-06 | 1.4E-05 ± 9.5E-06 | N529 | 15 | 1 | 3.8E-06 ± 6.5E-06 | 9.9E-06 ± 8.6E-06 | |
| | 118-K-1 RA | 6 | 2 | 1.0E-05 ± 4.3E-05 | 5.4E-05 ± 3.3E-05 | N534 | 10 | 5 | 1.4E-05 ± 2.9E-05 | 4.8E-05 ± 2.4E-05 | |
| | 100-K SNF | 16 | 7 | 8.6E-06 ± 1.3E-05 | 2.6E-05 ± 1.8E-05 | N401 | 80 | 18 | 8.5E-06 ± 2.3E-05 | 5.8E-05 ± 2.7E-05 | |
| | 100-N | 8 | 4 | 8.1E-06 ± 7.0E-06 | 1.6E-05 ± 8.6E-06 | N526 | 37 | 17 | 7.2E-06 ± 1.2E-05 | 2.7E-05 ± 1.4E-05 | |
| | 200-East | 40 | 7 | 6.7E-06 ± 3.2E-05 | 7.2E-05 ± 3.2E-05 | N984 | 190 | 49 | 5.2E-06 ± 1.9E-05 | 8.8E-05 ± 2.2E-05 | |
| | 200-West | 51 | 16 | 2.4E-05 ± 1.6E-04 | 4.4E-04 ± 1.7E-04 | N165 | 222 | 135 | 2.6E-05 ± 1.5E-04 | 5.4E-04 ± 2.1E-04 | |
| | 300 Area D&D | 4 | 1 | 1.1E-05 ± 3.2E-05 | 3.9E-05 ± 2.8E-05 | N557 | 0 | 0 | | | |
| | 300-FF-2 RA | 8 | 1 | 8.2E-05 ± 4.0E-04 | 6.2E-04 ± 2.5E-04 | N548 | 13 | 3 | 7.1E-06 ± 2.4E-05 | 3.7E-05 ± 1.3E-05 | |
| | ERDF | 8 | 3 | 4.6E-06 ± 6.3E-06 | 1.1E-05 ± 7.4E-06 | N517 | 38 | 19 | 2.3E-05 ± 1.4E-04 | 4.3E-04 ± 1.3E-04 | |
| $^{238}U$ | 100-B/C RA | 10 | 9 | 7.6E-06 ± 3.8E-06 | 1.2E-05 ± 7.2E-06 | N464 | 32 | 25 | 1.0E-05 ± 9.5E-06 | 2.8E-05 ± 1.3E-05 | 1.0E-01 |
| | 100-F RA | 7 | 3 | 1.1E-05 ± 1.1E-05 | 2.0E-05 ± 1.8E-05 | N520 | 28 | 24 | 1.1E-05 ± 1.1E-05 | 2.6E-05 ± 1.2E-05 | |
| | 100 Area ISS | 10 | 7 | 1.2E-05 ± 1.2E-05 | 2.1E-05 ± 1.4E-05 | N525 | 76 | 45 | 2.0E-05 ± 4.6E-05 | 1.6E-04 ± 1.9E-04 | |
| | 100-K D&D | 4 | 4 | 9.8E-06 ± 4.3E-06 | 1.2E-05 ± 7.9E-06 | N476 | 20 | 17 | 1.1E-05 ± 1.4E-05 | 3.6E-05 ± 1.1E-05 | |
| | 100-KR-1 RA | 6 | 5 | 7.7E-06 ± 3.0E-06 | 1.1E-05 ± 6.9E-06 | N530 | 15 | 12 | 1.1E-05 ± 9.3E-06 | 2.4E-05 ± 1.7E-05 | |
| | 118-K-1 RA | 6 | 4 | 2.1E-05 ± 2.5E-05 | 3.9E-05 ± 2.6E-05 | N535 | 10 | 10 | 1.4E-05 ± 1.1E-05 | 2.6E-05 ± 1.2E-05 | |
| | 100-K SNF | 16 | 15 | 8.3E-06 ± 5.6E-06 | 1.3E-05 ± 7.5E-06 | N401 | 80 | 70 | 9.8E-06 ± 1.1E-05 | 3.6E-05 ± 1.1E-05 | |
| | 100-N | 8 | 6 | 6.9E-06 ± 4.1E-06 | 9.4E-06 ± 6.3E-06 | N102 | 37 | 33 | 1.1E-05 ± 1.0E-05 | 3.0E-05 ± 1.1E-05 | |
| | 200-East | 40 | 36 | 1.1E-05 ± 1.1E-05 | 2.9E-05 ± 1.4E-05 | N978 | 190 | 171 | 1.2E-05 ± 1.0E-05 | 4.0E-05 ± 1.9E-05 | |
| | 200-West | 51 | 43 | 1.2E-05 ± 1.6E-05 | 4.6E-05 ± 2.2E-05 | N551 | 222 | 206 | 1.2E-05 ± 1.1E-05 | 3.5E-05 ± 1.6E-05 | |
| | 300 Area D&D | 4 | 2 | 1.5E-05 ± 1.9E-05 | 2.7E-05 ± 1.5E-05 | N557 | 0 | 0 | | | |
| | 300-FF-2 RA | 10 | 8 | 4.6E-05 ± 9.4E-05 | 1.5E-04 ± 1.0E-04 | N548 | 38 | 36 | 3.8E-05 ± 6.8E-05 | 1.3E-04 ± 7.9E-05 | |
| | ERDF | 8 | 8 | 1.3E-05 ± 1.6E-05 | 3.2E-05 ± 1.6E-05 | N517 | 38 | 36 | 1.4E-05 ± 1.7E-05 | 4.9E-05 ± 2.2E-05 | |

**Table C.1. (contd)**

| | | 2005 | | | | 2000-2004 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Radionuclide | Site | Number of Samples | Number of Detections[b] | Average[c] | Maximum[d] | Sampler Number | Number of Samples | Number of Detections[b] | Average[c] | Maximum[d] | DCG |
| $^{239/240}Pu$ | 100-B/C RA | 10 | 2 | 2.4E-06 ± 6.2E-06 | 8.8E-06 ± 6.1E-06 | N497 | 32 | 4 | 3.0E-06 ± 1.1E-05 | 2.6E-05 ± 1.2E-05 | 2.0E-02 |
| | 100-F RA | 7 | 0 | 1.4E-06 ± 2.7E-06 | 3.5E-06 ± 3.6E-05 | N558 | 28 | 9 | 7.7E-06 ± 2.9E-05 | 5.4E-05 ± 2.7E-05 | |
| | 100 Area ISS | 10 | 2 | 1.2E-05 ± 4.3E-05 | 7.6E-05 ± 3.5E-05 | N525 | 76 | 25 | 2.6E-05 ± 1.3E-04 | 4.2E-04 ± 3.2E-04 | |
| | 100-K D&D | 4 | 1 | 4.9E-06 ± 8.0E-06 | 1.1E-05 ± 9.7E-06 | N477 | 20 | 5 | 5.7E-06 ± 1.5E-05 | 2.4E-05 ± 1.4E-05 | |
| | 100-KR-1 RA | 6 | 3 | 6.1E-06 ± 9.4E-06 | 1.4E-05 ± 9.5E-06 | N529 | 15 | 1 | 3.8E-06 ± 6.5E-06 | 9.9E-06 ± 8.6E-06 | |
| | 118-K-1 RA | 6 | 2 | 1.0E-05 ± 4.3E-05 | 5.4E-05 ± 3.3E-05 | N534 | 10 | 5 | 1.4E-05 ± 2.9E-05 | 4.8E-05 ± 2.4E-05 | |
| | 100-K SNF | 16 | 7 | 8.6E-06 ± 1.3E-05 | 2.6E-05 ± 1.8E-05 | N401 | 80 | 18 | 8.5E-06 ± 2.3E-05 | 5.8E-05 ± 2.7E-05 | |
| | 100-N | 8 | 4 | 8.1E-06 ± 7.0E-06 | 1.6E-05 ± 8.6E-06 | N526 | 37 | 17 | 7.2E-06 ± 1.2E-05 | 2.7E-05 ± 1.4E-05 | |
| | 200-East | 40 | 7 | 6.7E-06 ± 3.2E-05 | 7.2E-05 ± 3.2E-05 | N984 | 190 | 49 | 5.2E-06 ± 1.9E-05 | 8.8E-05 ± 2.2E-05 | |
| | 200-West | 51 | 16 | 2.4E-05 ± 1.6E-04 | 4.4E-04 ± 1.7E-04 | N165 | 222 | 135 | 2.6E-05 ± 1.5E-04 | 5.4E-04 ± 2.1E-04 | |
| | 300 Area D&D | 4 | 1 | 1.1E-05 ± 3.2E-05 | 3.9E-05 ± 2.8E-05 | N557 | 0 | 0 | | | |
| | 300-FF-2 RA | 8 | 1 | 8.2E-05 ± 4.0E-04 | 6.2E-04 ± 2.5E-04 | N548 | 13 | 3 | 7.1E-06 ± 2.4E-05 | 3.7E-05 ± 1.3E-05 | |
| | ERDF | 8 | 3 | 4.6E-06 ± 6.3E-06 | 1.1E-05 ± 7.4E-06 | N517 | 38 | 19 | 2.3E-05 ± 1.4E-04 | 4.3E-04 ± 1.3E-04 | |
| $^{241}Am$ | 100-K D&D | 4 | 1 | 9.2E-06 ± 5.4E-06 | 1.3E-05 ± 7.3E-06 | N477 | 20 | 5 | 8.0E-06 ± 1.8E-05 | 3.6E-05 ± 1.7E-05 | 2.0E-02 |
| | 118-K-1 RA | 2 | 1 | 2.7E-05 ± 2.1E-05 | 3.8E-05 ± 2.3E-05 | N403 | 10 | 2 | 9.8E-06 ± 2.0E-05 | 2.9E-05 ± 2.0E-05 | |
| | 100-K SNF | 16 | 4 | 1.1E-05 ± 1.9E-05 | 3.8E-05 ± 2.3E-05 | N403 | 80 | 13 | 8.1E-06 ± 1.8E-05 | 3.6E-05 ± 1.7E-05 | |
| | 200-East | 4 | 0 | 5.1E-06 ± 8.9E-06 | 1.3E-05 ± 1.6E-05 | N481 | 20 | 2 | 6.5E-06 ± 1.7E-05 | 3.3E-05 ± 1.7E-05 | |

(a) 1 pCi = 0.037 Bq.
(b) Number of samples with measurable concentrations of contaminant.
(c) Average ± two standard deviations of all samples analyzed.
(d) Maximum ± analytical uncertainty.
D&D = Decontamination and decommissioning.
DCG = DOE derived concentration guide.
ERDF = Environmental Restoration Disposal Facility.
ISS = Interim safe storage projects at 105-D/DR/H.
RA = Remedial action project.
SNF = Spent nuclear fuel.

**Table C.2. Selected U.S. Geological Survey Columbia River Water Quality Data for Vernita and Richland, Washington,[a] 2005**

| | | Vernita Bridge (upstream) | | | | Richland (downstream) | | | | Washington Ambient Surface Water Quality Standard[b] |
|---|---|---|---|---|---|---|---|---|---|---|
| Analysis | Units | No. of Samples | Median | Maximum | Minimum | No. of Samples | Median | Maximum | Minimum | |
| Temperature | °C | 3 | 11 | 14 | 4.4 | 3 | 11 | 14 | 4.7 | 20 (maximum) |
| Dissolved oxygen | mg/L | 3 | 12.5 | 13.2 | 10.3 | 3 | 11.0 | 13.6 | 10.4 | 8 (minimum) |
| Turbidity | NTU | 3 | <2 | <2 | <2 | 3 | <2 | <2 | <2 | 5 + background |
| pH | pH units | 3 | 7.9 | 8.0 | 7.8 | 3 | 7.7 | 7.7 | 7.7 | 6.5 - 8.5 |
| Sulfate, dissolved | mg/L | 3 | 9.5 | 10 | 7.8 | 3 | 9.6 | 10 | 7.6 | --[c] |
| Dissolved solids, 180°C (356°F) | mg/L | 3 | 83 | 85 | 79 | 3 | 81 | 82 | 79 | -- |
| Specific conductance | µS/cm | 3 | 136 | 138 | 126 | 3 | 137 | 137 | 126 | -- |
| Total hardness, as $CaCO_3$ | mg/L | 3 | 62 | 69 | 57 | 3 | 62 | 69 | 57 | -- |
| Alkalinity | mg/L | 3 | 53 | 59 | 51 | 3 | 56 | 59 | 50 | |
| Phosphorus, total | mg/L | 3 | <0.04 | <0.04 | <0.04 | 3 | <0.04 | <0.04 | <0.04 | -- |
| Chromium, dissolved | µg/L | 3 | <0.8 | <0.8 | 0.08 | 3 | <0.8 | 1.1 | 0.06 | -- |
| Dissolved organic carbon | mg/L | 3 | 1.1 | 1.7 | 1.0 | 3 | 1.1 | 1.7 | 1.0 | -- |
| Iron, dissolved | µg/L | 3 | 7 | 15 | <6 | 3 | 5[d] | <6 | 3[d] | -- |
| Ammonia, dissolved, as N | mg/L | 3 | <0.04 | 0.04 | <0.04 | 3 | <0.04 | <0.04 | <0.04 | -- |
| Nitrite + nitrate, dissolved, as N | mg/L | 3 | 0.10 | 0.15 | 0.07 | 3 | 0.11 | 0.11 | 0.07 | -- |

(a) Provisional data from U.S. Geological Survey National Stream Quality Accounting Network (NASQAN), subject to revision.
(b) From WAC 173-201A.
(c) Dashes indicate no standard available.
(d) Estimated value.
NTU = Nephelometric turbidity units.

## Table C.3. Radionuclide Concentrations in Columbia River Water Samples Collected at Priest Rapids Dam, Washington, 2005 Compared to Previous 5 Years

| Radionuclide[a] | | 2005 No. of Samples | 2005 Concentration,[b] pCi/L Maximum | 2005 Concentration,[b] pCi/L Average | 2000-2004 No. of Samples | 2000-2004 Concentration,[b] pCi/L Maximum | 2000-2004 Concentration,[b] pCi/L Average | Ambient Surface Water Quality Standard, pCi/L |
|---|---|---|---|---|---|---|---|---|
| **Composite System** | | | | | | | | |
| Tritium[c] | | 8 | 24 ± 7.6 | 19 ± 7.0 | 60 | 80 ± 9.0 | 35 ± 27 | 20,000[d] |
| Alpha (gross) | | 12 | 1.2 ± 1.0[e] | 0.48 ± 0.66[e] | 60 | 1.7 ± 1.1 | 0.50 ± 0.75 | 15[f,g] |
| Beta (gross) | | 12 | 2.0 ± 1.3[e] | 0.89 ± 1.6[e] | 60 | 3.5 ± 1.7 | 0.73 ± 1.9 | 50[f,g] |
| Strontium-90 | | 12 | 0.24 ± 0.085 | 0.064 ± 0.12 | 60 | 0.15 ± 0.047 | 0.073 ± 0.040 | 8[f,g] |
| Technetium-99 | | 12 | 0.40 ± 0.33[e] | 0.14 ± 0.46[e] | 60 | 0.53 ± 0.55[e] | 0.036 ± 0.39[e] | 900[d] |
| Iodine-129 | | 4 | 0.0000041 ± 0.00000043 | 0.0000034 ± 0.00000094 | 20 | 0.000021 ± 0.0000028 | 0.0000082 ± 0.000012 | 1[d] |
| Uranium-234 | | 12 | 0.27 ± 0.11 | 0.22 ± 0.048 | 60 | 0.28 ± 0.064 | 0.22 ± 0.051 | --[h] |
| Uranium-235 | | 12 | 0.013 ± 0.015[e] | 0.0086 ± 0.0077[e] | 60 | 0.014 ± 0.014[e] | 0.0046 ± 0.0083 | -- |
| Uranium-238 | | 12 | 0.21 ± 0.10 | 0.16 ± 0.036 | 60 | 0.25 ± 0.058 | 0.18 ± 0.056 | -- |
| Uranium (total) | | 12 | 0.45 ± 0.15 | 0.40 ± 0.058 | 60 | 0.54 ± 0.087 | 0.40 ± 0.094 | -- |
| **Continuous System** | | | | | | | | |
| Cesium-137 | P | 12 | 0.00079 ± 0.00098[e] | 0.00018 ± 0.00065[e] | 60 | 0.0032 ± 0.0013 | 0.00045 ± 0.0012 | 200[d] |
| | D | 12 | 0.0018 ± 0.0020[e] | 0.00057 ± 0.0017[e] | 60 | 0.0034 ± 0.0021[e] | 0.0010 ± 0.0021[e] | |
| Europium-155 | P | 12 | 0.0040 ± 0.0051[e] | 0.00032 ± 0.0029[e] | 60 | 0.0030 ± 0.0026[e] | 0.00031 ± 0.0020[e] | 600[d] |
| | D | 12 | 0.0079 ± 0.0059[e] | 0.0026 ± 0.0055[e] | 60 | 0.0091 ± 0.0046[e] | 0.0019 ± 0.0048[e] | |
| Plutonium-239/240 | P | 4 | 0.00012 ± 0.000049 | 0.000046 ± 0.00010 | 19 | 0.00018 ± 0.000069 | 0.000030 ± 0.000078 | -- |
| | D | 4 | 0.000042 ± 0.000050[e] | 0.000028 ± 0.000023[e] | 20 | 0.000055 ± 0.000072[e] | 0.000025 ± 0.000034 | |

(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 10.4).
(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) Data only available from January 1, 2005 through August 31, 2005. Tritium values are preliminary and subject to change.
(d) WAC 173-201A-50 and EPA-570/9-76-003.
(e) Less than the laboratory-reported detection limit.
(f) WAC 246-290.
(g) 40 CFR 141.
(h) Dashes indicate no concentration guides available.

**Table C.4. Radionuclide Concentrations in Columbia River Water Samples Collected at Richland, Washington, 2005 Compared to Previous 5 Years**

| Radionuclide[a] | | 2005 No. of Samples | 2005 Concentration,[b] pCi/L Maximum | 2005 Concentration,[b] pCi/L Average | 2000-2004 No. of Samples | 2000-2004 Concentration,[b] pCi/L Maximum | 2000-2004 Concentration,[b] pCi/L Average | Ambient Surface Water Quality Standard, pCi/L |
|---|---|---|---|---|---|---|---|---|
| **Composite System** | | | | | | | | |
| Tritium[c] | | 8 | 54 ± 12 | 41 ± 19 | 60 | 140 ± 14 | 67 ± 53 | 20,000[d] |
| Alpha (gross) | | 12 | 0.86 ± 0.87[e] | 0.36 ± 0.84[e] | 60 | 1.6 ± 1.1 | 0.55 ± 0.78 | 15[f,g] |
| Beta (gross) | | 12 | 2.0 ± 2.0[e] | 1.1 ± 1.4[e] | 60 | 2.8 ± 2.1[e] | 0.71 ± 1.4[e] | 50[f,g] |
| Strontium-90 | | 12 | 0.26 ± 0.059 | 0.066 ± 0.13 | 60 | 0.14 ± 0.035 | 0.070 ± 0.046 | 8[f,g] |
| Technetium-99 | | 12 | 0.91 ± 0.52 | 0.31 ± 0.50 | 60 | 1.2 ± 0.57 | 0.079 ± 0.50 | 900[d] |
| Iodine-129 | | 4 | 0.000056 ± 0.0000046 | 0.000049 ± 0.000014 | 20 | 0.00019 ± 0.000022 | 0.000084 ± 0.000070 | 1[d] |
| Uranium-234 | | 12 | 0.32 ± 0.11 | 0.26 ± 0.067 | 60 | 0.33 ± 0.078 | 0.26 ± 0.070 | --[h] |
| Uranium-235 | | 12 | 0.014 ± 0.014[e] | 0.0065 ± 0.0076[e] | 60 | 0.018 ± 0.018[e] | 0.0072 ± 0.0090 | -- |
| Uranium-238 | | 12 | 0.22 ± 0.10 | 0.19 ± 0.035 | 60 | 0.31 ± 0.066 | 0.21 ± 0.070 | -- |
| Uranium (total) | | 12 | 0.54 ± 0.15 | 0.45 ± 0.090 | 60 | 0.63 ± 0.095 | 0.48 ± 0.13 | -- |
| **Continuous System** | | | | | | | | |
| Cesium-137 | P | 12 | 0.0012 ± 0.0012[e] | 0.000059 ± 0.0011[e] | 60 | 0.0016 ± 0.0010[e] | 0.00050 ± 0.00086[e] | 200[g] |
| | D | 12 | 0.0015 ± 0.0020[e] | 0.00072 ± 0.0018[e] | 60 | 0.0026 ± 0.0016[e] | 0.00076 ± 0.0019[e] | |
| Europium-155 | P | 12 | 0.0032 ± 0.0087[e] | 0.00062 ± 0.0022[e] | 60 | 0.0026 ± 0.0028[e] | 0.00031 ± 0.0019[e] | 600[g] |
| | D | 12 | 0.0074 ± 0.0077[e] | 0.0026 ± 0.0044[e] | 60 | 0.0070 ± 0.0049[e] | 0.0014 ± 0.0053[e] | |
| Plutonium-239/240 | P | 4 | 0.000043 ± 0.000028 | 0.000024 ± 0.000034 | 19 | 0.000089 ± 0.000046 | 0.000023 ± 0.000046 | -- |
| | D | 4 | 0.000059 ± 0.000060[e] | 0.0000060 ± 0.00012[e] | 20 | 0.00015 ± 0.000070 | 0.000027 ± 0.000074 | |

(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 10.4).
(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) Data only available from January 1, 2005 through August 31, 2005. Tritium values are preliminary and subject to change.
(d) WAC 173-201A-50 and EPA-570/9-76-003.
(e) Less than the laboratory-reported detection limit.
(f) WAC 246-290.
(g) 40 CFR 141.
(h) Dashes indicate no concentration guides available.

**Table C.5. Radionuclide Concentrations Measured in Columbia River Water Samples Collected Along Transects of the Hanford Reach, 2005**

| Transect/Radionuclide | No. of Samples | Concentration,[a] pCi/L Maximum | Concentration,[a] pCi/L Minimum |
|---|---|---|---|
| **Vernita Bridge (HRM 0.3)** | | | |
| Tritium[b] | 12 | 28 ± 7.2 | 14 ± 4.9 |
| Strontium-90 | 16 | 0.19 ± 0.052 | -0.048 ± 0.11[c] |
| Uranium (total) | 16 | 0.48 ± 0.14 | 0.31 ± 0.14 |
| **100-N Area (HRM 9.5)** | | | |
| Tritium[b] | 6 | 62 ± 13 | 23 ± 6.5 |
| Strontium-90 | 7 | 0.075 ± 0.041 | 0.048 ± 0.039 |
| Uranium (total) | 7 | 0.58 ± 0.15 | 0.38 ± 0.13 |
| **100-F Area (HRM 19)** | | | |
| Tritium[b] | 0 | | |
| Strontium-90 | 6 | 0.056 ± 0.040 | 0.036 ± 0.040[c] |
| Uranium (total) | 6 | 0.38 ± 0.14 | 0.33 ± 0.14 |
| **Hanford Town Site (HRM 28.7)** | | | |
| Tritium[b] | 0 | | |
| Strontium-90 | 6 | 0.052 ± 0.042 | 0.022 ± 0.040[c] |
| Uranium (total) | 6 | 0.41 ± 0.14 | 0.30 ± 0.13 |
| **300 Area (HRM 43.1)** | | | |
| Tritium[b] | 0 | | |
| Strontium-90 | 6 | 0.060 ± 0.041 | 0.026 ± 0.039[c] |
| Uranium (total) | 6 | 1.0 ± 0.19 | 0.33 ± 0.14 |
| **Richland (HRM 46.4)** | | | |
| Tritium[b] | 12 | 95 ± 9.5 | 16 ± 5.2 |
| Strontium-90 | 25 | 0.10 ± 0.044 | -0.0038 ± 0.034[c] |
| Uranium (total) | 25 | 0.99 ± 0.18 | 0.35 ± 0.14 |

(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.
(b) Not all 2005 transect results for tritium were available at time of printing. Reported values are preliminary and are subject to change.
(c) Less than the laboratory-reported detection limit.
HRM = Hanford river marker.

**Table C.6. Radionuclide Concentrations Measured in Columbia River Water Samples Collected at Near-Shore Locations in the Hanford Reach, 2005**

| Near-Shore/Radionuclide | No. of Samples | Concentration,[a] pCi/L Maximum | Concentration,[a] pCi/L Minimum |
|---|---|---|---|
| **Vernita Bridge (HRM 0.3)** | | | |
| Tritium[b] | 3 | 23 ± 6.5 | 16 ± 5.2 |
| Strontium-90 | 4 | 0.052 ± 0.041 | 0.040 ± 0.039 |
| Uranium (total) | 4 | 0.42 ± 0.14 | 0.36 ± 0.14 |
| **100-N Area (HRM 8.4 to 9.8)** | | | |
| Tritium | 5 | 62 ± 13 | 22 ± 6.2 |
| Strontium-90 | 6 | 0.12 ± 0.043 | 0.046 ± 0.037 |
| Uranium (total) | 6 | 0.42 ± 0.14 | 0.34 ± 0.13 |
| **100-F Area (HRM 18 to 23)** | | | |
| Tritium[b] | 0 | | |
| Strontium-90 | 4 | 0.041 ± 0.040 | 0.033 ± 0.038[c] |
| Uranium (total) | 4 | 0.42 ± 0.14 | 0.33 ± 0.14 |
| **Hanford Town Site (HRM 26 to 30)** | | | |
| Tritium[b] | 0 | | |
| Strontium-90 | 5 | 0.052 ± 0.041 | 0.018 ± 0.038[c] |
| Uranium (total) | 5 | 0.43 ± 0.14 | 0.36 ± 0.14 |
| **300 Area (HRM 41.5 to 43.1)** | | | |
| Tritium[b] | 0 | | |
| Strontium-90 | 5 | 0.093 ± 0.052 | 0.0040 ± 0.041[c] |
| Uranium (total) | 5 | 0.50 ± 0.15 | 0.33 ± 0.14 |
| **Richland (HRM 43.5 to 46.4)** | | | |
| Tritium | 6 | 88 ± 17 | 64 ± 13 |
| Strontium-90 | 18 | 0.10 ± 0.044 | -0.0038 ± 0.034[c] |
| Uranium (total) | 18 | 1.5 ± 0.23 | 0.35 ± 0.14 |

(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.
(b) Not all 2005 transect results for tritium were available at time of printing. Reported values are preliminary and are subject to change.
(c) Less than the laboratory-reported detection limit.
HRM = Hanford river marker.

**Table C.7. Concentrations (µg/L) of Dissolved Metals in Columbia River Transect and Near-Shore Water Samples Collected Near the Hanford Site, 2005**

| Location | Metal | No. of Samples | Maximum | Minimum | Average | ±2SD |
|---|---|---|---|---|---|---|
| Vernita Bridge | Antimony | 4 | 0.18 | 0.13 | 0.15 | 0.049 |
| | Arsenic | 4 | 0.50 | 0.50 | 0.50 | 0.0082 |
| | Beryllium | 4 | 0.010 | 0.010 | 0.010 | 0[(a)] |
| | Cadmium | 4 | 0.012 | 0.0081 | 0.0096 | 0.0035 |
| | Chromium | 4 | 0.12 | 0.039 | 0.065 | 0.070 |
| | Copper | 4 | 0.61 | 0.56 | 0.58 | 0.045 |
| | Lead | 4 | 0.12 | 0.099 | 0.11 | 0.022 |
| | Nickel | 4 | 0.78 | 0.66 | 0.71 | 0.10 |
| | Selenium | 4 | 0.21 | 0.20 | 0.20 | 0.0091 |
| | Silver | 4 | 0.0017 | 0.0017 | 0.0017 | 0[(a)] |
| | Thallium | 4 | 0.012 | 0.010 | 0.012 | 0.0016 |
| | Zinc | 4 | 1.0 | 0.71 | 0.88 | 0.31 |
| 100-N Area | Antimony | 10 | 0.15 | 0.13 | 0.14 | 0.010 |
| | Arsenic | 10 | 0.58 | 0.49 | 0.50 | 0.050 |
| | Beryllium | 10 | 0.010 | 0.010 | 0.010 | 0[(a)] |
| | Cadmium | 10 | 0.011 | 0.0080 | 0.0097 | 0.0021 |
| | Chromium | 10 | 0.13 | 0.039 | 0.049 | 0.057 |
| | Copper | 10 | 0.70 | 0.54 | 0.59 | 0.095 |
| | Lead | 10 | 0.28 | 0.077 | 0.11 | 0.12 |
| | Nickel | 10 | 0.72 | 0.65 | 0.68 | 0.052 |
| | Selenium | 10 | 0.22 | 0.16 | 0.18 | 0.038 |
| | Silver | 10 | 0.0017 | 0.0017 | 0.0017 | 0[(a)] |
| | Thallium | 10 | 0.013 | 0.011 | 0.012 | 0.0012 |
| | Zinc | 10 | 1.2 | 0.60 | 0.80 | 0.35 |
| 100-F Area | Antimony | 9 | 0.16 | 0.10 | 0.14 | 0.034 |
| | Arsenic | 9 | 0.61 | 0.34 | 0.56 | 0.17 |
| | Beryllium | 9 | 0.010 | 0.010 | 0.010 | 0[(a)] |
| | Cadmium | 9 | 0.026 | 0.0045 | 0.010 | 0.012 |
| | Chromium | 9 | 0.19 | 0.039 | 0.080 | 0.12 |
| | Copper | 9 | 0.70 | 0.54 | 0.59 | 0.10 |
| | Lead | 9 | 0.14 | 0.059 | 0.091 | 0.064 |
| | Nickel | 9 | 1.1 | 0.69 | 0.80 | 0.27 |
| | Selenium | 9 | 0.43 | 0.13 | 0.24 | 0.19 |
| | Silver | 9 | 0.0025 | 0.0017 | 0.0018 | 0.00058 |
| | Thallium | 9 | 0.017 | 0.012 | 0.014 | 0.0027 |
| | Zinc | 9 | 1.3 | 0.56 | 0.79 | 0.49 |
| Hanford Town Site | Antimony | 10 | 0.16 | 0.13 | 0.14 | 0.020 |
| | Arsenic | 10 | 0.67 | 0.57 | 0.60 | 0.062 |
| | Beryllium | 10 | 0.010 | 0.010 | 0.010 | 0[(a)] |
| | Cadmium | 10 | 0.011 | 0.0041 | 0.0069 | 0.0039 |
| | Chromium | 10 | 0.074 | 0.039 | 0.043 | 0.022 |
| | Copper | 10 | 0.85 | 0.53 | 0.64 | 0.22 |
| | Lead | 10 | 0.15 | 0.056 | 0.089 | 0.060 |
| | Nickel | 10 | 0.86 | 0.67 | 0.72 | 0.11 |
| | Selenium | 10 | 0.33 | 0.16 | 0.21 | 0.096 |
| | Silver | 10 | 0.017 | 0.017 | 0.017 | 0[(a)] |
| | Thallium | 10 | 0.015 | 0.013 | 0.014 | 0.0017 |
| | Zinc | 10 | 1.1 | 0.57 | 0.79 | 0.35 |

**Table C.7. (contd)**

| Location | Metal | No. of Samples | Maximum | Minimum | Average | ±2SD |
|---|---|---|---|---|---|---|
| 300 Area | Antimony | 10 | 0.18 | 0.13 | 0.15 | 0.031 |
| | Arsenic | 10 | 1.0 | 0.59 | 0.67 | 0.24 |
| | Beryllium | 10 | 0.010 | 0.010 | 0.010 | 0[(a)] |
| | Cadmium | 10 | 0.12 | 0.0082 | 0.047 | 0.078 |
| | Chromium | 10 | 0.065 | 0.039 | 0.048 | 0.010 |
| | Copper | 10 | 0.75 | 0.58 | 0.63 | 0.12 |
| | Lead | 10 | 0.26 | 0.069 | 0.13 | 0.11 |
| | Nickel | 10 | 0.78 | 0.67 | 0.72 | 0.080 |
| | Selenium | 10 | 0.60 | 0.22 | 0.30 | 0.22 |
| | Silver | 10 | 0.0017 | 0.0017 | 0.0017 | 0[(a)] |
| | Thallium | 10 | 0.015 | 0.012 | 0.013 | 0.0016 |
| | Zinc | 10 | 1.4 | 0.56 | 0.85 | 0.48 |
| Richland | Antimony | 10 | 0.24 | 0.13 | 0.20 | 0.090 |
| | Arsenic | 10 | 1.0 | 0.59 | 0.68 | 0.26 |
| | Beryllium | 10 | 0.010 | 0.010 | 0.010 | 0[(a)] |
| | Cadmium | 10 | 0.013 | 0.0040 | 0.0077 | 0.0055 |
| | Chromium | 10 | 0.094 | 0.039 | 0.058 | 0.052 |
| | Copper | 10 | 0.96 | 0.62 | 0.72 | 0.20 |
| | Lead | 10 | 0.14 | 0.071 | 0.11 | 0.047 |
| | Nickel | 10 | 0.83 | 0.69 | 0.74 | 0.082 |
| | Selenium | 10 | 0.33 | 0.15 | 0.24 | 0.11 |
| | Silver | 10 | 0.0020 | 0.0017 | 0.0018 | 0.00027 |
| | Thallium | 10 | 0.015 | 0.013 | 0.014 | 0.00088 |
| | Zinc | 10 | 2.6 | 0.84 | 1.2 | 1.0 |

(a) All values were below the limit of detection (shown).
SD = Standard deviation.

**Table C.8. Radionuclide and Total Organic Carbon Concentrations in Sediment from the Columbia River Near the Hanford Site, 2005 Compared to Previous 5 Years**

| Location and TOC Concentrations (2005 TOC Value) | Radionuclide | 2005 No. of Samples | 2005 Concentration, pCi/g[a] Median[b] | 2005 Concentration, pCi/g[a] Maximum[c] | 2000-2004 No. of Samples | 2000-2004 Concentration, pCi/g[a] Median[b] | 2000-2004 Concentration, pCi/g[a] Maximum[c] |
|---|---|---|---|---|---|---|---|
| Priest Rapids Dam (11,700 - 21,600 mg/kg) | Cobalt-60 | 2 | -0.0028[d] | 0.0035 ± 0.01[d] | 11 | 0.0034[d] | 0.0082 ± 0.016[d] |
| | Cesium-137 | 2 | 0.26 | 0.26 ± 0.039 | 11 | 0.37 | 0.65 ± 0.086 |
| | Europium-155 | 2 | 0.055[d] | 0.056 ± 0.028[d] | 11 | 0.047[d] | 0.089 ± 0.043[d] |
| | Plutonium-239/240 | 2 | 0.0098 | 0.010 ± 0.0043 | 13 | 0.0096 | 0.015 ± 0.0024 |
| | Strontium-90 | 2 | 0.026[d] | 0.031 ± 0.029[d] | 11 | 0.0027 | 0.028 ± 0.028[d] |
| | Uranium-234 | 2 | 0.79 | 0.95 ± 0.16 | 11 | 0.72 | 0.87 ± 0.16 |
| | Uranium-235 | 2 | 0.028 | 0.030 ± 0.011 | 11 | 0.021 | 0.038 ± 0.017 |
| | Uranium-238 | 2 | 0.66 | 0.74 ± 0.13 | 11 | 0.60 | 0.71 ± 0.13 |
| White Bluffs Slough (7,380 mg/kg) | Cobalt-60 | 1 | | 0.012 ± 0.010[d] | 5 | 0.051 | 0.061 ± 0.023 |
| | Cesium-137 | 1 | | 2.8 ± 0.33 | 5 | 0.58 | 1.5 ± 0.18 |
| | Europium-155 | 1 | | 0.056 ± 0.031[d] | 5 | 0.045[d] | 0.053 ± 0.075[d] |
| | Plutonium-239/240 | 1 | | 0.0054 ± 0.0024 | 5 | 0.0069 | 0.010 ± 0.0019 |
| | Strontium-90 | 1 | | 0.016 ± 0.015[d] | 5 | -0.0017[d] | 0.0028 ± 0.029[d] |
| | Uranium-234 | 1 | | 0.51 ± 0.090 | 5 | 0.47 | 1.6 ± 0.30 |
| | Uranium-235 | 1 | | 0.027 ± 0.0098 | 5 | 0.020 | 0.053 ± 0.016 |
| | Uranium-238 | 1 | | 0.46 ± 0.081 | 5 | 0.43 | 1.3 ± 0.24 |
| 100-F Slough (2,630 mg/kg) | Cobalt-60 | 1 | | 0.012 ± 0.010[d] | 5 | 0.0068[d] | 0.016 ± 0.011[d] |
| | Cesium-137 | 1 | | 0.22 ± 0.032 | 5 | 0.30 | 0.39 ± 0.055 |
| | Europium-155 | 1 | | 0.064 ± 0.028[d] | 5 | 0.030[d] | 0.069 ± 0.062[d] |
| | Plutonium-239/240 | 1 | | 0.00053 ± 0.0011[d] | 4 | 0.0020 | 0.0023 ± 0.00054 |
| | Strontium-90 | 1 | | -0.0054 ± 0.021[d] | 5 | 0.00018[d] | 0.0079 ± 0.017[d] |
| | Uranium-234 | 1 | | 0.18 ± 0.037 | 5 | 0.15 | 0.31 ± 0.062 |
| | Uranium-235 | 1 | | 0.0089 ± 0.0056 | 5 | 0.0023 | 0.011 ± 0.0068 |
| | Uranium-238 | 1 | | 0.18 ± 0.037 | 5 | 0.17 | 0.29 ± 0.058 |
| Hanford Slough (4,940 mg/kg) | Cobalt-60 | 1 | | -0.0060 ± 0.0096[d] | 5 | 0.0099 | 0.055 ± 0.020 |
| | Cesium-137 | 1 | | 0.023 ± 0.012 | 5 | 0.027 | 0.32 ± 0.046 |
| | Europium-155 | 1 | | 0.040 ± 0.027[d] | 5 | 0.054[d] | 0.059 ± 0.064[d] |
| | Plutonium-239/240 | 1 | | 0.00064 ± 0.00042 | 5 | 0.00078 | 0.0053 ± 0.0026 |
| | Strontium-90 | 1 | | 0.0034 ± 0.015[d] | 5 | 0.0021 | 0.0059 ± 0.019[d] |
| | Uranium-234 | 1 | | 0.33 ± 0.060 | 5 | 0.36 | 0.53 ± 0.10 |
| | Uranium-235 | 1 | | 0.011 ± 0.0058 | 5 | 0.012 | 0.021 ± 0.016 |
| | Uranium-238 | 1 | | 0.30 ± 0.056 | 5 | 0.32 | 0.47 ± 0.092 |

**Table C.8. (contd)**

| Location | Radionuclide | 2005 No. of Samples | 2005 Concentration, pCi/g[a] Median[b] | 2005 Concentration, pCi/g[a] Maximum[c] | 2000-2004 No. of Samples | 2000-2004 Concentration, pCi/g[a] Median[b] | 2000-2004 Concentration, pCi/g[a] Maximum[c] |
|---|---|---|---|---|---|---|---|
| Richland (3,150 mg/kg) | Cobalt-60 | 1 | | 0.0092 ± 0.011[d] | 5 | 0.0013[d] | 0.032 ± 0.023[d] |
| | Cesium-137 | 1 | | 0.11 ± 0.020 | 5 | 0.19 | 0.24 ± 0.049 |
| | Europium-155 | 1 | | 0.080 ± 0.031[d] | 5 | 0.047[d] | 0.10 ± 0.053[d] |
| | Plutonium-239/240 | 1 | | 0.0015 ± 0.0013 | 4 | 0.0015 | 0.0016 ± 0.00049 |
| | Strontium-90 | 1 | | 0.015 ± 0.020[d] | 5 | -0.0073[d] | 0.00065 ± 0.020[d] |
| | Uranium-234 | 1 | | 0.29 ± 0.054 | 5 | 0.22 | 0.25 ± 0.053 |
| | Uranium-235 | 1 | | 0.0037 ± 0.0061[d] | 5 | 0.0093 | 0.011 ± 0.0094 |
| | Uranium-238 | 1 | | 0.26 ± 0.051 | 5 | 0.21 | 0.24 ± 0.053 |
| McNary Dam (No 2005 TOC Results) | Cobalt-60 | 2 | 0.020[d] | 0.029 ± 0.011[d] | 17 | 0.024[d] | 0.12 ± 0.042[d] |
| | Cesium-137 | 2 | 0.23 | 0.24 ± 0.036 | 17 | 0.31 | 1.1 ± 0.15 |
| | Europium-155 | 2 | 0.070[d] | 0.082 ± 0.055[d] | 17 | 0.079[d] | 0.13 ± 0.066[d] |
| | Plutonium-239/240 | 2 | 0.0086 | 0.0099 ± 0.0032 | 20 | 0.0079 | 0.032 ± 0.0048 |
| | Strontium-90 | 2 | 0.032[d] | 0.034 ± 0.047[d] | 20 | 0.012 | 0.043 ± 0.028 |
| | Uranium-234 | 2 | 1.1 | 1.4 ± 0.24 | 17 | 0.82 | 1.0 ± 0.18 |
| | Uranium-235 | 2 | 0.043 | 0.052 ± 0.015 | 17 | 0.022 | 0.032 ± 0.012 |
| | Uranium-238 | 2 | 0.87 | 1.0 ± 0.19 | 17 | 0.65 | 0.80 ± 0.14 |

(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) Below detection limit.
TOC = Total organic content.

**Table C.9. Median Metal Concentrations (mg/kg dry wt.) in Sediment Samples Collected from the Columbia River Near the Hanford Site, 2005**

| Metal | (n=2) Priest Rapids Dam | (n=4) Hanford Reach[a] | (n=2) McNary Dam | (n=6) Shoreline Springs[b] |
|---|---|---|---|---|
| Antimony | 1.1 | 0.83 | 0.83 | 0.68 |
| Arsenic | 9.1 | 5.4 | 8.6 | 7.1 |
| Beryllium | 1.4 | 1.6 | 1.5 | 1.4 |
| Cadmium | 6.2 | 0.62 | 1.4 | 0.63 |
| Chromium | 76 | 48 | 52 | 68 |
| Copper | 51 | 24 | 33 | 18 |
| Lead | 45 | 34 | 25 | 24 |
| Mercury | 0.17 | 0.029 | 0.12 | 0.018 |
| Nickel | 45 | 21 | 30 | 20 |
| Selenium | 0.45 | 0.085 | 0.28 | 0.17 |
| Silver | 0.15 | 0.053 | 0.10 | 0.062 |
| Thallium | 1.1 | 0.55 | 0.64 | 0.51 |
| Zinc | 540 | 280 | 260 | 160 |

(a) White Bluffs Slough, 100-F Slough, Hanford Slough, and Richland.
(b) 100-F Area (n=1), 100-H Area (n=1), Hanford town site (n=2), and 300 Area (n=2).
n = Number of samples.

**Table C.10. Radionuclide Concentrations Measured in Columbia River Water Samples Collected from Shoreline Springs Along the Hanford Site, 2005 Compared to Previous 5 Years**

| Location/Radionuclide | 2005 No. of Samples | 2005 Concentration,[a] pCi/L Maximum | 2005 Concentration,[a] pCi/L Average | 2000-2004 No. of Samples | 2000-2004 Concentration,[a] pCi/L Maximum | 2000-2004 Concentration,[a] pCi/L Average | Washington State Ambient Surface Water Quality Standard,[b] pCi/L |
|---|---|---|---|---|---|---|---|
| **100-B Area** | | | | | | | |
| Alpha (gross) | 1 | 0.40 ± 0.35[d] | | 8 | 9.4 ± 3.8 | 2.6 ± 5.8 | 15 |
| Beta (gross) | 1 | 4.4 ± 1.4 | | 8 | 24 ± 4.5 | 9.4 ± 14 | 50 |
| Strontium-90 | 0 | | | 8 | 4.0 ± 0.59 | 0.90 ± 3.3 | 8 |
| Technetium-99 | 0 | | | 8 | 12 ± 0.95 | 5.5 ± 8.0 | 900[c] |
| Tritium | 1 | 1,600 ± 220 | | 8 | 7,600 ± 420 | 5,700 ± 2,000 | 20,000 |
| **100-K Area** | | | | | | | |
| Alpha (gross) | 5 | 2.6 ± 1.2 | 0.93 ± 2.2 | 10 | 3.2 ± 1.9 | 1.2 ± 1.9 | 15 |
| Beta (gross) | 5 | 34 ± 7.3 | 12 ± 26 | 10 | 7.2 ± 2.3 | 4.9 ± 2.5 | 50 |
| Strontium-90 | 1 | 2.7 ± 0.41 | | 10 | 3.2 ± 0.72 | 1.3 ± 2.7 | 8 |
| Technetium-99 | 1 | 12 ± 8.8 | | 6 | 2.3 ± 0.28 | 0.62 ± 1.9 | 900[c] |
| Tritium | 5 | 7,200 ± 460 | 2,300 ± 5,900 | 10 | 6,100 ± 530 | 1,600 ± 4,600 | 20,000 |
| **100-N Area** | | | | | | | |
| Alpha (gross) | 1 | 0.11 ± 0.43[d] | | 6 | 4.9 ± 2.7 | 2.3 ± 2.6 | 15 |
| Beta (gross) | 1 | 1.2 ± 2.1[d] | | 6 | 9.3 ± 2.4 | 5.4 ± 4.2 | 50 |
| Strontium-90 | 1 | 0.010 ± 0.038[d] | | 8 | 0.043 ± 0.020 | 0.020 ± 0.044 | 8 |
| Technetium-99 | 1 | 0.30 ± 0.35[d] | | 2 | 0.64 ± 0.40 | 0.61 ± 0.089 | 900[c] |
| Tritium | 1 | 5,600 ± 310 | | 8 | 18,000 ± 800 | 11,000 ± 8,200 | 20,000 |
| **100-D Area** | | | | | | | |
| Alpha (gross) | 6 | 11 ± 4.3 | 4.7 ± 7.6 | 8 | 14 ± 4.9 | 2.7 ± 9.0 | 15 |
| Beta (gross) | 6 | 9.5 ± 1.9 | 5.2 ± 7.6 | 8 | 41 ± 7.9 | 8.7 ± 27 | 50 |
| Strontium-90 | 2 | 0.19 ± 0.056 | 0.11 ± 0.23 | 7 | 1.4 ± 0.36 | 0.41 ± 0.92 | 8 |
| Tritium | 6 | 10,000 ± 2,300 | 2,900 ± 17,000 | 8 | 5,200 ± 450 | 1,100 ± 3,500 | 20,000 |
| Uranium (total) | 2 | 3.2 ± 0.43 | 1.9 ± 3.8 | 4 | 1.2 ± 0.84 | 0.67 ± 0.85 | --[e] |
| **100-H Area** | | | | | | | |
| Alpha (gross) | 5 | 2.3 ± 0.93 | 1.5 ± 1.4 | 11 | 3.9 ± 2.2 | 1.6 ± 2.3 | 15 |
| Beta (gross) | 5 | 13 ± 2.3 | 5.8 ± 8.4 | 11 | 27 ± 4.7 | 11 ± 17 | 50 |
| Strontium-90 | 1 | 0.065 ± 0.047 | | 10 | 14 ± 3.2 | 4.7 ± 11 | 8 |
| Technetium-99 | 1 | 0.33 ± 0.49[d] | | 11 | 8.0 ± 0.97 | 1.2 ± 5.2 | 900[c] |
| Tritium | 5 | 4,300 ± 340 | 2,700 ± 3,400 | 11 | 5,500 ± 470 | 1,300 ± 3,200 | 20,000 |
| Uranium (total) | 1 | 4.1 ± 0.60 | | 11 | 2.7 ± 1.9 | 1.2 ± 1.6 | --[e] |

**Table C.10. (contd)**

| Location/Radionuclide | 2005 No. of Samples | 2005 Concentration,[a] pCi/L Maximum | 2005 Concentration,[a] pCi/L Average | 2000-2004 No. of Samples | 2000-2004 Concentration,[a] pCi/L Maximum | 2000-2004 Concentration,[a] pCi/L Average | Washington State Ambient Surface Water Quality Standard,[b] pCi/L |
|---|---|---|---|---|---|---|---|
| **100-F Area** | | | | | | | |
| Alpha (gross) | 1 | 14 ± 6.1 | | 6 | 10 ± 4.5 | 5.1 ± 5.1 | 15 |
| Beta (gross) | 1 | 15 ± 4.3 | | 6 | 13 ± 3.5 | 8.8 ± 5.0 | 50 |
| Strontium-90 | 1 | -0.015 ± 0.038[d] | | 6 | 0.058 ± 0.023 | 0.012 ± 0.065 | 8 |
| Tritium | 2 | 1,000 ± 130 | 1,000 ± 28 | 6 | 1,400 ± 120 | 910 ± 940 | 20,000 |
| Uranium (total) | 1 | 5.4 ± 0.67 | | 6 | 5.2 ± 3.6 | 3.3 ± 3.0 | --[e] |
| **Hanford Town Site** | | | | | | | |
| Alpha (gross) | 3 | 1.8 ± 1.2 | 1.1 ± 1.4 | 12 | 5.0 ± 2.5 | 2.3 ± 2.3 | 15 |
| Beta (gross) | 3 | 25 ± 4.5 | 16 ± 15 | 12 | 36 ± 5.8 | 22 ± 19 | 50 |
| Iodine-129[f] | 3 | | | 12 | 0.27 ± 0.029 | 0.16 ± 0.13 | 1 |
| Technetium-99 | 3 | 40 ± 2.4 | 26 ± 27 | 12 | 110 ± 7.5 | 58 ± 66 | 900[c] |
| Tritium | 3 | 39,000 ± 2,800 | ± | 12 | 110,000 ± 4,100 | 55,000 ± 64,000 | 20,000 |
| Uranium (total) | 3 | 1.6 ± 0.24 | 1.4 ± 0.47 | 12 | 3.9 ± 2.7 | 2.2 ± 2.3 | --[e] |
| **300 Area** | | | | | | | |
| Alpha (gross) | 4 | 95 ± 21 | 43 ± 75 | 12 | 140 ± 36 | 76 ± 75 | 15 |
| Beta (gross) | 4 | 23 ± 4.5 | 15 ± 12 | 12 | 55 ± 10 | 26 ± 25 | 50 |
| Iodine-129[f] | 2 | | | 12 | 0.0068 ± 0.0084 | 0.0045 ± 0.0025 | 1 |
| Technetium-99 | 0 | | | 4 | 16 ± 2 | 12 ± 5.0 | 900[c] |
| Tritium | 4 | 12,000 ± 920 | 8,100 ± 9,300 | 15 | 12,000 ± 580 | 8,100 ± 4,600 | 20,000 |
| Uranium (total) | 4 | 100 ± 11 | 54 ± 79 | 15 | 140 ± 96 | 68 ± 81 | --[e] |

(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.4.
(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.
(f) 2005 results were not available at time of printing.

**Table C.11. Radionuclide and Total Organic Carbon Concentrations in Columbia River Shoreline Sediment for 2005 Compared to Previous 5 Years**

| Location and TOC Concentrations (2005 TOC Value) | Radionuclide | 2005 No. of Samples | 2005 Concentration, pCi/g[a] Median[b] | 2005 Concentration, pCi/g[a] Maximum[c] | 2000-2004 No. of Samples | 2000-2004 Concentration, pCi/g[a] Median[b] | 2000-2004 Concentration, pCi/g[a] Maximum[c] |
|---|---|---|---|---|---|---|---|
| 100-B Spring | Cobalt-60 | 0 | | | 5 | 0.0045[d] | 0.022 ± 0.013[d] |
| | Cesium-137 | 0 | | | 5 | 0.063 | 0.075 ± 0.019 |
| | Europium-155 | 0 | | | 5 | 0.078 | 0.095 ± 0.037[d] |
| | Strontium-90 | 0 | | | 5 | 0.0020[d] | 0.0068 ± 0.016[d] |
| | Uranium-234 | 0 | | | 5 | 0.24 | 0.48 ± 0.097 |
| | Uranium-235 | 0 | | | 5 | 0.0098 | 0.014 ± 0.0080 |
| | Uranium-238 | 0 | | | 5 | 0.21 | 0.41 ± 0.085 |
| 100-K Spring | Cobalt-60 | 0 | | | 2 | 0.0049[d] | 0.0053 ± 0.013[d] |
| | Cesium-137 | 0 | | | 2 | 0.11 | 0.11 ± 0.024 |
| | Europium-155 | 0 | | | 2 | 0.038[d] | 0.57 ± 0.041[d] |
| | Strontium-90 | 0 | | | 2 | 0.016[d] | 0.017 ± 0.019[d] |
| | Uranium-234 | 0 | | | 2 | 0.28 | 0.30 ± 0.065 |
| | Uranium-235 | 0 | | | 2 | 0.0088 | 0.0091 ± 0.0064 |
| | Uranium-238 | 0 | | | 2 | 0.26 | 0.28 ± 0.060 |
| 100-F Spring | Cobalt-60 | 1 | | 0.0085 ± 0.014[d] | 5 | 0.0071[d] | 0.021 ± 0.032[d] |
| | Cesium-137 | 1 | | 0.10 ± 0.025 | 5 | 0.092 | 0.26 ± 0.051 |
| | Europium-155 | 1 | | 0.050 ± 0.034[d] | 5 | 0.058[d] | 0.073 ± 0.033[d] |
| | Strontium-90 | 1 | | -0.0018 ± 0.024[d] | 5 | -0.0016[d] | 0.013 ± 0.032[d] |
| | Uranium-234 | 1 | | 0.26 ± 0.091 | 5 | 0.52 | 0.70 ± 0.14 |
| | Uranium-235 | 1 | | 0.015 ± 0.0092 | 5 | 0.023 | 0.060 ± 0.019 |
| | Uranium-238 | 1 | | 0.23 ± 0.11 | 5 | 0.45 | 0.65 ± 0.13 |
| Hanford Spring | Cobalt-60 | 2 | 0.016[d] | 0.025 ± 0.013[d] | 4 | 0.036[d] | 0.062 ± 0.017 |
| | Cesium-137 | 2 | 0.15 | 0.20 ± 0.033 | 4 | 0.19 | 0.26 ± 0.041 |
| | Europium-155 | 2 | 0.075[d] | 0.076 ± 0.037[d] | 4 | 0.090 | 0.10 ± 0.035[d] |
| | Uranium-234 | 2 | 0.48 | 0.49 ± 0.11 | 4 | 0.59 | 0.63 ± 0.12 |
| | Uranium-235 | 2 | 0.014 | 0.015 ± 0.014 | 4 | 0.014 | 0.018 ± 0.0082 |
| | Uranium-238 | 2 | 0.39 | 0.41 ± 0.13 | 4 | 0.45 | 0.47 ± 0.089 |

**Table C.11. (contd)**

| Location and TOC Concentrations | Radionuclide | 2005 No. of Samples | 2005 Concentration, pCi/g[a] Median[b] | 2005 Concentration, pCi/g[a] Maximum[c] | 2000-2004 No. of Samples | 2000-2004 Concentration, pCi/g[a] Median[b] | 2000-2004 Concentration, pCi/g[a] Maximum[c] |
|---|---|---|---|---|---|---|---|
| 300 Area Spring | Cobalt-60 | 4 | 0.0044[d] | 0.0073 ± 0.0096[d] | 10 | 0.0067[d] | 0.014 ± 0.011[d] |
| | Cesium-137 | 4 | 0.066 | 0.19 ± 0.033 | 10 | 0.056 | 0.27 ± 0.035 |
| | Europium-155 | 4 | 0.051[d] | 0.072 ± 0.031[d] | 10 | 0.065[d] | 0.085 ± 0.037[d] |
| | Strontium-90 | 2 | 0.022[d] | 0.027 ± 0.021[d] | 9 | 0.0065[d] | 0.020 ± 0.031[d] |
| | Uranium-234 | 4 | 2.2 | 3.3 ± 0.53 | 10 | 2.2 | 11 ± 2.0 |
| | Uranium-235 | 4 | 0.099 | 0.21 ± 0.042 | 10 | 0.085 | 0.38 ± 0.075 |
| | Uranium-238 | 4 | 2.0 | 2.9 ± 0.48 | 10 | 2.1 | 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) Below detection limit.
TOC = Total organic content.

**Table C.12. Concentrations (µg/g dry weight) of Metals in Livers from Great Basin Pocket Mice Collected from Hanford Site Biological Resources Management Plan Plots 6, 10, and 19, 2005[a]**

| | Plot 6 (n=3) | | | Plot 10 (n=3) | | | Plot 19 (n=3) | | |
|---|---|---|---|---|---|---|---|---|---|
| Metal | Maximum | Minimum | Median | Maximum | Minimum | Median | Maximum | Minimum | Median |
| Aluminum | 36 | 2.0[b] | 4.3[b] | 2.0[b] | 1.5[c] | 1.5[c] | 3.5[b] | 1.5[c] | 1.5[c] |
| Antimony | 0.0093[b,d] | 0.0054[b,d] | 0.0066[b,d] | 0.014[d] | 0.0071[b,d] | 0.0074[b,d] | 0.0058[b,d] | 0.005[c] | 0.005[c] |
| Arsenic | 0.1[c] | 0.1[c] | 0.1[c] | 0.1[c] | 0.1[c] | 0.1[c] | 0.35 | 0.1[c] | 0.1[c] |
| Barium | 0.4[c] | 0.4[c] | 0.4[c] | 0.4[c] | 0.4[c] | 0.4[c] | 0.4[c] | 0.4[c] | 0.4[c] |
| Beryllium | 0.01[c] | 0.01[c] | 0.01[c] | 0.01[c] | 0.01[c] | 0.01[c] | 0.01[c] | 0.01[c] | 0.01[c] |
| Cadmium | 0.29 | 0.094 | 0.18 | 0.21 | 0.094 | 0.21 | 0.23 | 0.060 | 0.16 |
| Chromium | 0.31 | 0.21 | 0.28 | 0.30 | 0.18 | 0.20 | 1.7 | 0.17 | 0.25 |
| Copper | 20 | 12 | 13 | 18 | 14 | 16 | 16 | 13 | 14 |
| Lead | 0.5[c] | 0.057 | 0.13 | 0.5[c] | 0.44 | 0.5[c] | 0.5[c] | 0.067 | 0.14 |
| Manganese | 18 | 13 | 14 | 15 | 7.3 | 7.7 | 12 | 7.8 | 9.3 |
| Mercury | 0.022[b,d] | 0.011[b,d] | 0.016[b,d] | 0.011[b,d] | 0.0075[b,d] | 0.0094[b,d] | 0.017[b,d] | 0.011[b,d] | 0.014[b,d] |
| Nickel | 0.12 | 0.082 | 0.089 | 0.094 | 0.052 | 0.067 | 0.31 | 0.057 | 0.062 |
| Selenium | 1.6 | 0.96 | 0.96 | 1.1 | 1.0 | 1.1 | 1.3 | 1.2 | 1.2 |
| Silver | 0.0030[b,d] | 0.003[c] | 0.003[c] | 0.003[c] | 0.003[c] | 0.003[c] | 0.003[c] | 0.003[c] | 0.003[c] |
| Thallium | 0.017 | 0.0095[b] | 0.013 | 0.0063[b] | 0.004[c] | 0.0042[b] | 0.0055[b] | 0.0041[b] | 0.0044[b] |
| Thorium | 0.011 | 0.01[c] | 0.01[c] | 0.015 | 0.01[c] | 0.01[c] | 0.01[c] | 0.01[c] | 0.01[c] |
| Uranium | 0.001[c] | 0.001[c] | 0.001[c] | 0.001[c] | 0.001[c] | 0.001[c] | 0.0012[b] | 0.001[c] | 0.001[c] |
| Vanadium | 0.045 | 0.03[c] | 0.03[c] | 0.054 | 0.03[c] | 0.036[d] | 0.11 | 0.03[c] | 0.03[c] |
| Zinc | 95 | 64 | 75 | 82 | 67 | 80 | 110 | 65 | 73 |

(a) Data are not blank corrected.
(b) Concentration > method (analytical) detection limit and < reporting detection limit.
(c) Below analytical detection limit.
(d) Detected in both sample and associated quality control blank, sample concentration <=5 times blank concentration.
n = Number of samples.

**Table C.13. Concentration (µg/g dry weight) of Metals in Sagebrush Lizards Collected from Hanford Site Biological Resources Management Plan Plot 10 on the Hanford Central Plateau, 2005[a]**

| | Plot 10 | | |
|---|---|---|---|
| **Metal** | **Offal** | **Whole Organism** | **Liver** |
| Aluminum | 870 | 750 | 13 |
| Antimony | 0.011[b] | 0.012[b] | 0.18 |
| Arsenic | 0.1[c] | 0.18 | 0.1[c] |
| Barium | 10 | 11 | 0.4[c] |
| Beryllium | 0.015 | 0.019 | 0.01[c] |
| Cadmium | 0.041 | 0.059 | 0.57 |
| Chromium | 1.1 | 0.87 | 0.94 |
| Copper | 4.8 | 4.7 | 23 |
| Lead | 0.28 | 0.31 | 0.067 |
| Manganese | 33 | 21 | 13 |
| Mercury | 0.025[c,d] | 0.044[c,d] | 0.46 |
| Nickel | 1.4 | 1.2 | 0.51 |
| Selenium | 0.55[b] | 0.68[b] | 3.9 |
| Silver | 0.0055[c,d] | 0.0050[c,d] | 0.0035[c,d] |
| Thallium | 0.0086[b] | 0.0093[b] | 0.017 |
| Thorium | 0.16 | 0.10 | 0.01[c] |
| Uranium | 0.033 | 0.024 | 0.001[c] |
| Vanadium | 5.7 | 2.3 | 0.23 |
| Zinc | 160 | 160 | 180 |

(a) Data are not blank corrected.
(b) Detected in both sample and associated quality control blank, sample concentration <=5 times blank concentration.
(c) Below analytical detection limit.
(d) Concentration > method (analytical) detection limit and < reporting detection limit.

**Table C.14. Concentrations (µg/g dry weight) of Metals in Whole Organism Composite Samples of Invertebrates Collected from Hanford Site Biological Resources Management Plan Plots 6, 10, and 19, 2005[a]**

| | Plot 6 (n=3) | | | Plot 10 (n=3) | | | Plot 19 (n=3) | | |
|---|---|---|---|---|---|---|---|---|---|
| Metal | Maximum | Minimum | Median | Maximum | Minimum | Median | Maximum | Minimum | Median |
| Aluminum | 1,400 | 270 | 610 | 1,200 | 290 | 300 | 1,600 | 240 | 700 |
| Antimony | 0.022[b] | 0.0064[b,c] | 0.015[b] | 0.024 | 0.012 | 0.012 | 0.038[b] | 0.011[b] | 0.025[b] |
| Arsenic | 1.5 | 0.62 | 1.1 | 1.6 | 0.82 | 1.4 | 2.0 | 1.2 | 1.4 |
| Barium | 17 | 3.3 | 8.7 | 14 | 4 | 11 | 14 | 3.9 | 8.4 |
| Beryllium | 0.032 | 0.01[d] | 0.018 | 0.030 | 0.01[d] | 0.01[d] | 0.037 | 0.01[d] | 0.018 |
| Cadmium | 0.28 | 0.11 | 0.15 | 0.076 | 0.067 | 0.073 | 0.33 | 0.036 | 0.043 |
| Chromium | 2.2 | 0.39 | 0.79 | 1.1 | 0.35 | 0.37 | 1.3 | 0.29 | 0.79 |
| Copper | 18 | 14 | 17 | 16 | 13 | 15 | 36 | 10 | 13 |
| Lead | 0.41 | 0.17 | 0.22 | 0.41 | 0.083 | 0.12 | 0.5 | 0.11 | 0.30 |
| Manganese | 40 | 19 | 25 | 51 | 15 | 21 | 50 | 13 | 23 |
| Mercury | 0.031[b,c] | 0.024[b,c] | 0.027[b,c] | 0.024[b,c] | 0.015[b,c] | 0.023[b,c] | 0.024[b,c] | 0.012[b,c] | 0.014[b,c] |
| Nickel | 1.6 | 0.53 | 0.65 | 1.1 | 0.36 | 0.46 | 0.96 | 0.27 | 0.62 |
| Selenium | 0.22[b] | 0.10[b,c] | 0.11[b,c] | 0.20[b,c] | 0.1[d] | 0.12[b,c] | 0.56[b] | 0.20[b,c] | 0.26[b] |
| Silver | 0.011[b] | 0.0042[b] | 0.0086[b,c] | 0.011[b] | 0.0038[b,c] | 0.0041[b,c] | 0.034[b] | 0.0051[b,c] | 0.0080[b,c] |
| Thallium | 0.014 | 0.0044[c] | 0.0077[c] | 0.013 | 0.004[d] | 0.004[d] | 0.015 | 0.0052[c] | 0.0089[c] |
| Thorium | 0.20 | 0.031 | 0.10 | 0.24 | 0.036 | 0.16 | 0.31 | 0.050 | 0.23 |
| Uranium | 0.050 | 0.0063[c] | 0.018 | 0.044 | 0.0097[c] | 0.014 | 0.050 | 0.0073[c] | 0.045 |
| Vanadium | 4.5 | 0.52 | 2.2 | 4.8 | 1.0 | 1.5 | 5.3 | 0.73 | 2.5 |
| Zinc | 98 | 73 | 84 | 79 | 64 | 78 | 130 | 50 | 53 |

(a) Data are not blank corrected.
(b) Detected in both sample and associated quality control blank, sample concentration <=5 times blank concentration.
(c) Concentration > method (analytical) detection limit and < reporting detection limit.
(d) Below analytical detection limit.
n = Number of samples.

**Table C.15. Concentrations (µg/g dry weight) of Metals in Soil Samples Collected from Hanford Site Biological Resources Management Plan Plots 6, 10, and 19, 2005[a]**

| | Plot 6 (n=1) | | | Plot 10 (n=1) | | | Plot 19 (n=1) | | |
|---|---|---|---|---|---|---|---|---|---|
| Metal | Root Zone | Root Zone | Surface | Root Zone | Root Zone | Surface | Root Zone | Root Zone | Surface |
| Aluminum | 7,600 | 8,200 | 7,100 | 7,900 | 8,700 | 8,400 | 9,100 | 12,000 | 13,000 |
| Antimony | 0.078[b] | 0.078[b] | 0.092[b] | 0.087[b] | 0.082[b] | 0.087[b] | 0.11[b] | 0.088[b] | 0.083[b] |
| Arsenic | 2.4 | 2.2 | 2.4 | 3.0 | 2.9 | 2.9 | 4.0 | 3.6 | 3.4 |
| Barium | 88 | 74 | 62 | 110 | 110 | 100 | 110 | 130 | 120 |
| Beryllium | 0.24 | 0.28 | 0.24 | 0.32 | 0.36 | 0.31 | 0.38 | 0.42 | 0.47 |
| Cadmium | 0.11 | 0.092 | 0.087 | 0.12 | 0.13 | 0.11 | 0.14 | 0.13 | 0.13 |
| Chromium | 12 | 14 | 13 | 9 | 10 | 10 | 11 | 14 | 14 |
| Copper | 11 | 9.7 | 8.6 | 13 | 16 | 14 | 15 | 18 | 18 |
| Lead | 4.6 | 4.7 | 4.8 | 5.5 | 5.9 | 5.9 | 7.0 | 8.0 | 8.0 |
| Manganese | 280 | 310 | 270 | 440 | 480 | 430 | 420 | 470 | 470 |
| Mercury | 0.006[b,c] | 0.006[b,c] | 0.006[b,c] | 0.006[b,c] | 0.0067[b,d] | 0.006[b,c] | 0.006[b,c] | 0.007[b,d] | 0.006[b,c] |
| Nickel | 11 | 12 | 11 | 10 | 11 | 10 | 11 | 13 | 13 |
| Selenium | 0.2[c] | 0.2[c] | 0.2[c] | 0.2[c] | 0.2[c] | 0.2[c] | 0.2[c] | 0.2[c] | 0.2[c] |
| Silver | 0.029 | 0.023 | 0.020 | 0.035 | 0.043 | 0.033 | 0.05 | 0.046 | 0.040 |
| Thallium | 0.086 | 0.089 | 0.066 | 0.096 | 0.099 | 0.096 | 0.11 | 0.13 | 0.13 |
| Thorium | 3.7 | 4.2 | 3.0 | 3.4 | 4.0 | 4.4 | 4.5 | 5.3 | 6.0 |
| Uranium | 0.44 | 0.47 | 0.41 | 0.47 | 0.52 | 0.66 | 0.61 | 0.63 | 0.74 |
| Vanadium | 34 | 37 | 34 | 73 | 83 | 78 | 56 | 66 | 66 |
| Zinc | 39 | 41 | 39 | 55 | 60 | 58 | 50 | 58 | 58 |

(a) Data are not blank corrected.
(b) Estimate, inappropriate digestion method, samples biased low.
(c) Below analytical detection limit.
(d) Concentration > method (analytical) detection limit and < reporting detection limit.
n = Number of samples.

**Table C.16. Concentrations (µg/g dry wt.) of Metals in Livers from Whitefish Collected from the Hanford Reach of the Columbia River and at a Columbia River Background Location Above Wanapum Dam in 2005[a]**

| | 100-N to 100-D Areas (n=5) | | | Upriver, Wanapum Dam (n=5) | | |
|---|---|---|---|---|---|---|
| **Metal** | **Maximum** | **Minimum** | **Median** | **Maximum** | **Minimum** | **Median** |
| Aluminum | 2[b] | 2[b] | 2[b] | 6.2 | 2[b] | 3[c] |
| Antimony | 0.016 | 0.01[b] | 0.01[b] | 0.017 | 0.01[b] | 0.01[b] |
| Arsenic | 0.76 | 0.40 | 0.42 | 0.83 | 0.43 | 0.57 |
| Beryllium | 0.008[b] | 0.008[b] | 0.008[b] | 0.008[b] | 0.008[b] | 0.008[b] |
| Cadmium | 1.6 | 0.52 | 0.96 | 3.0 | 0.60 | 1.5 |
| Chromium | 0.14 | 0.1[b] | 0.1[b] | 0.56 | 0.29 | 0.37 |
| Copper | 14 | 8.4 | 9.3 | 77 | 6.0 | 8.1 |
| Lead | 0.095 | 0.03[b] | 0.038 | 0.93 | 0.03[b] | 0.03[b] |
| Manganese | 11 | 5.6 | 8.0 | 11 | 4.3 | 5.2 |
| Mercury | NA | NA | NA | 3.6 | 0.29 | 0.73 |
| Nickel | 0.11 | 0.05[b] | 0.070 | 0.086 | 0.05[b] | 0.068 |
| Selenium | 16 | 5.0 | 6.2 | 12 | 4.8 | 8.3 |
| Silver | 0.077 | 0.031 | 0.036 | 2.8 | 0.0072[c] | 0.035 |
| Thallium | 0.85 | 0.25 | 0.52 | 0.68 | 0.50 | 0.60 |
| Thorium | 0.01[b] | 0.01[b] | 0.01[b] | 0.01[b] | 0.01[b] | 0.01[b] |
| Uranium | 0.025 | 0.0081[c] | 0.014 | 0.067 | 0.015 | 0.020 |
| Zinc | 76 | 70 | 70 | 99 | 88 | 94 |

(a) Data are not blank corrected.
(b) Analyte not detected above the method detection limit.
(c) Value less than reporting detection limit and greater than method detection limit.
n = Number of samples.
NA = Not analyzed.

**Table C.17. Concentrations (µg/g dry wt.) of Metals in Livers from Bass Collected from the Hanford Reach of the Columbia River and at a Columbia River Background Location Near Desert Aire, Washington, in 2005[a]**

| | 100-F Slough (n=5) | | | Hanford Slough (n=5) | | | 300 Area (n=2) | | Desert Aire, Washington (n=5) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Contaminant | Maximum | Minimum | Median | Maximum | Minimum | Median | Maximum | Minimum | Maximum | Minimum | Median |
| Aluminum | 1.5[b] | 0.64[b] | 1.1[b] | 2[c] | 0.87[b] | 2[c] | 2[c] | 2[c] | 2.1[b] | 1.5[c] | 1.5[c] |
| Antimony | 0.01[c] | 0.01[c] | 0.01[c] | 0.011[d] | 0.009[c] | 0.009[c] | 0.01[c] | 0.01[c] | 0.012[d] | 0.0057[b,d] | 0.0075[b,d] |
| Arsenic | 1.9 | 1.1 | 1.1 | 1.6 | 0.51 | 0.70 | 0.47 | 0.27 | 0.79 | 0.64 | 0.73 |
| Beryllium | 0.02[c] | 0.02[c] | 0.02[c] | 0.02[c] | 0.007[c] | 0.007[c] | 0.008[c] | 0.008[c] | 0.01[c] | 0.01[c] | 0.01[c] |
| Cadmium | 1.7 | 0.60 | 0.91 | 4.2 | 0.64 | 0.98 | 0.086 | 0.069 | 0.90 | 0.51 | 0.83 |
| Chromium | 0.35 | 0.19 | 0.21 | 0.36 | 0.085[b,d] | 0.092[b,d] | 0.16 | 0.1[c] | 0.33 | 0.24 | 0.29 |
| Copper | 16 | 5.2 | 11 | 13 | 5.7 | 8.2 | 3.0 | 2.8 | 15 | 4.3 | 6.7 |
| Lead | 0.024[b] | 0.02[c] | 0.02[c] | 0.048 | 0.02[c] | 0.03[c] | 0.01[c] | 0.01[c] | 0.5[c] | 0.5[c] | 0.5[c] |
| Manganese | 7.5 | 2.4 | 3.1 | 4.7 | 3.0 | 3.5 | 2.2 | 2.2 | 5.4 | 2.3 | 3.4 |
| Mercury | 0.26 | 0.080 | 0.20 | 0.29 | 0.14 | 0.26 | 0.15 | 0.081 | 1.1 | 0.21 | 0.23 |
| Nickel | 0.067 | 0.046 | 0.053 | 0.069 | 0.05[c] | 0.051 | 0.05[c] | 0.05[c] | 0.092 | 0.056 | 0.079 |
| Selenium | 8.0 | 6.2 | 6.4 | 8.1 | 5.2 | 6.3 | 4.5 | 4.3 | 7.8 | 4.7 | 6.2 |
| Silver | 0.0091[b] | 0.009[c] | 0.009[c] | 0.016 | 0.0040[b] | 0.010 | 0.003[c] | 0.003[c] | 0.017[d] | 0.003[c] | 0.0053[b] |
| Thallium | 0.21 | 0.071 | 0.082 | 0.26 | 0.20 | 0.24 | 0.056 | 0.013 | 0.26 | 0.17 | 0.21 |
| Thorium | 0.02[c] | 0.02[c] | 0.02[c] | 0.02[c] | 0.01[c] | 0.01[c] | 0.01[c] | 0.01[c] | 0.011 | 0.01[c] | 0.01[c] |
| Uranium | 0.009[c] | 0.009[c] | 0.009[c] | 0.009[c] | 0.0011[b] | 0.0070[b] | 0.001[c] | 0.001[c] | 0.0026[b] | 0.001[c] | 0.0018[b] |
| Zinc | 89 | 66 | 76 | 91 | 65 | 68 | 50 | 48 | 97 | 70 | 92 |

(a) Data are not blank corrected.
(b) Value less than reporting detection limit and greater than method detection limit.
(c) Analyte not detected above the method detection limit.
(d) Analyte detected in both the sample and associated quality control blank, and the sample concentration was <=5 times the blank concentration.
n = Number of samples.

**Table C.18. Concentrations (µg/g dry wt.) of Metals in Livers from Canada Geese Collected from the Hanford Reach of the Columbia River and at a Columbia River Background Location Near Desert Aire, Washington, in 2005[a]**

| | 100 Areas (n=5) | | | Hanford Town Site to 300 Area (n=5) | | | Desert Aire, Washington (n=5) | | |
|---|---|---|---|---|---|---|---|---|---|
| **Metal** | **Maximum** | **Minimum** | **Median** | **Maximum** | **Minimum** | **Median** | **Maximum** | **Minimum** | **Median** |
| Aluminum | 3.5[b] | 1.3[b] | 2.3[b] | 3.2[b] | 1.9[b] | 2.6[b] | 14 | 1.9[b] | 3.8[b] |
| Antimony | 0.01[c] | 0.01[c] | 0.01[c] | 0.011[d] | 0.01[c] | 0.01[c] | 0.015[d] | 0.01[c] | 0.012[d] |
| Arsenic | 0.19 | 0.13 | 0.17 | 0.29 | 0.07[c] | 0.15 | 0.21 | 0.07[c] | 0.14 |
| Beryllium | 0.007[c] | 0.007[c] | 0.007[c] | 0.007[c] | 0.007[c] | 0.007[c] | 0.011[b] | 0.007[c] | 0.007[c] |
| Cadmium | 8.2 | 0.22 | 4.8 | 6.5 | 0.90 | 1.0 | 6.1 | 0.68 | 0.91 |
| Chromium | 0.22 | 0.18 | 0.2 | 0.30 | 0.16 | 0.23 | 0.19 | 0.17 | 0.18 |
| Copper | 65 | 26 | 59 | 86 | 26 | 58 | 27 | 13 | 19 |
| Lead | 0.74 | 0.041 | 0.13 | 0.33 | 0.050 | 0.069 | 0.21 | 0.03[c] | 0.065 |
| Manganese | 13 | 6.3 | 9.9 | 17 | 7.2 | 9.7 | 11 | 8.0 | 8.3 |
| Mercury | 0.10 | 0.027[b,d] | 0.032[b,d] | 0.082 | 0.040[b] | 0.061 | 0.025[b,d] | 0.019[b,d] | 0.021[b,d] |
| Nickel | 0.05[c] | 0.05[c] | 0.05[c] | 0.066 | 0.05[c] | 0.05[c] | 0.05[c] | 0.05[c] | 0.05[c] |
| Selenium | 4.2 | 2.8 | 3.6 | 7.5 | 3.4 | 4.0 | 2.8 | 1.6 | 2.2 |
| Silver | 0.042 | 0.0043[b] | 0.031 | 0.085 | 0.0054[b] | 0.040 | 0.023 | 0.0043[b] | 0.012 |
| Thallium | 0.099 | 0.032 | 0.040 | 0.054 | 0.033 | 0.050 | 0.0084[b] | 0.004[c] | 0.004[c] |
| Thorium | 0.011 | 0.01[c] | 0.01[c] | 0.01[c] | 0.01[c] | 0.01[c] | 0.096 | 0.047[d] | 0.077[d] |
| Uranium | 0.0024[b] | 0.0015[b] | 0.0019[b] | 0.0043[b] | 0.0022[b] | 0.0030[b] | 0.0057[b] | 0.00098[b] | 0.0043[b] |
| Zinc | 180 | 130 | 150 | 180 | 110 | 150 | 160 | 120 | 140 |

(a) Data are not blank corrected.
(b) Value less than reporting detection limit and greater than method detection limit.
(c) Analyte not detected above the method detection limit.
(d) Analyte detected in both the sample and associated quality control blank, and the sample concentration was <=5 times the blank concentration.
n = Number of samples.

**Table C.19. Concentrations (µg/g dry wt.) of Metals in Livers from Cottontail Rabbits Collected on the Hanford Site in the 100-N Area, Near the 200-East Area, and at a Background Location Near Prosser, Washington, in 2005[a]**

| | 100-N Area (n=3) | | | 200-East Area (n=3) | | | Prosser, Washington (n=2) | |
|---|---|---|---|---|---|---|---|---|
| **Metal** | **Maximum** | **Minimum** | **Median** | **Maximum** | **Minimum** | **Median** | **Maximum** | **Minimum** |
| Aluminum | 20 | 3.4[b] | 6.6 | 18 | 4.0[b] | 5.3 | 8.0 | 7.7 |
| Antimony | 1.7 | 0.033 | 0.21 | 0.14 | 0.024 | 0.066 | 0.026[c] | 0.014[c] |
| Arsenic | 0.66 | 0.19 | 0.24 | 0.32 | 0.27 | 0.27 | 1.4 | 0.95 |
| Beryllium | 0.008[d] | 0.007[d] | 0.008[d] | 0.008[d] | 0.008[d] | 0.008[d] | 0.007[d] | 0.007[d] |
| Cadmium | 1.1 | 0.62 | 0.82 | 1.6 | 0.45 | 1.1 | 2.0 | 0.28 |
| Chromium | 0.48 | 0.22 | 0.24 | 0.23 | 0.10 | 0.10 | 0.32 | 0.31 |
| Copper | 27 | 16 | 27 | 21 | 9.9 | 14 | 21 | 14 |
| Lead | 5.5 | 0.21 | 3.4 | 2.1 | 0.21 | 0.52 | 0.26 | 0.23 |
| Manganese | 14 | 11 | 14 | 14 | 11 | 11 | 10 | 6.9 |
| Mercury | NA | NA | | NA | NA | | 0.017[b] | 0.015[b] |
| Nickel | 0.14 | 0.075 | 0.12 | 0.085 | 0.05[d] | 0.054 | 0.093 | 0.057 |
| Selenium | 5.4 | 3.2 | 4.3 | 4.4 | 3.4 | 4.4 | 0.37 | 0.37 |
| Silver | 0.0091[b] | 0.003[d] | 0.0060[b] | 0.0051[b] | 0.003[d] | 0.003[d] | 0.0037[b] | 0.003[d] |
| Thallium | 0.015 | 0.0087[b] | 0.01[d] | 0.013 | 0.01[d] | 0.012 | 0.004[d] | 0.004[d] |
| Thorium | 0.01[d] | 0.01[d] | 0.01[d] | 0.01[d] | 0.01[d] | 0.01[d] | 0.01[d] | 0.01[d] |
| Uranium | 0.001[d] | 0.001[d] | 0.001[d] | 0.001[d] | 0.001[d] | 0.001[d] | 0.002[d] | 0.002[d] |
| Zinc | 530 | 200 | 250 | 260 | 98 | 170 | 210 | 150 |

(a) Data are not blank corrected.
(b) Analyte not detected above the method detection limit.
(c) Analyte detected in both the sample and associated quality control blank, and the sample concentration was <=5 times the blank concentration.
(d) Value less than reporting detection limit and greater than method detection limit.
n = Number of samples.
NA = Not analyzed.

**Table C.20. Annual Average Dose Rates Measured at Site-Wide and Offsite Locations in 2005**

| Location | Location Number | Annual Average (mrem/yr)[a] |
|---|---|---|
| **Site-wide**[b] | | |
| 100 B Reactor Museum | 1 | 89 ± 9 |
| 100 K Area | 2 | 77 ± 8 |
| 100 D Area | 3 | 90 ± 5 |
| 100 F Met Tower | 4 | 87 ± 10 |
| N of 200 E | 5 | 94 ± 9 |
| B Pond | 6 | 84 ± 9 |
| E of 200 E | 7 | 90 ± 8 |
| 200 ESE | 8 | 90 ± 5 |
| S of 200 E | 9 | 96 ± 10 |
| 200 Tel. Exchange | 10 | 85 ± 12 |
| SW of B/C Cribs | 11 | 88 ± 7 |
| 200 W SE | 12 | 86 ± 4 |
| Army Loop Camp | 13 | 91 ± 10 |
| 3705 Bldg. 300 Area | 14 | 84 ± 7 |
| 313 Bldg. | 15 | 88 ± 18 |
| 300 Water Intake | 16 | 80 ± 10 |
| 300 Southwest Gate | 17 | 83 ± 5 |
| 300 South Gate | 18 | 83 ± 9 |
| 300 Trench | 19 | 87 ± 12 |
| 300 NE | 20 | 84 ± 6 |
| 400 E | 21 | 83 ± 4 |
| 400 W | 22 | 89 ± 5 |
| 400 S | 23 | 85 ± 5 |
| 400 N | 24 | 84 ± 8 |
| US Ecology NE Corner | 25 | 90 ± 7 |
| US Ecology SE Corner | 26 | 90 ± 3 |
| US Ecology NW Corner | 27 | 87 ± 6 |
| US Ecology SW Corner | 28 | 102 ± 19 |
| Wye Barricade | 29 | 87 ± 5 |
| WPPSS 1; S of WNP 2 | 30 | 90 ± 3 |
| Hanford Town site | 31 | 83 ± 1 |
| West Lake | 32 | 91 ± 5 |
| LIGO | 33 | 78 ± 8 |
| **Perimeter**[c] | | |
| Ringold Met Tower | 1 | 94 ± 3 |
| W End of Fir Road | 2 | 98 ± 9 |
| Dogwood Met Tower | 3 | 93 ± 8 |
| Byers Landing | 4 | 98 ± 5 |
| Battelle Complex | 5 | 83 ± 4 |
| WPPSS 4; WPS Warehse | 6 | 81 ± 6 |
| Horn Rapids Substation | 7 | 86 ± 8 |
| Prosser Barricade | 8 | 93 ± 16 |
| Yakima Barricade | 9 | 97 ± 4 |
| Rattlesnake Springs | 10 | 95 ± 6 |
| Wahluke Slope | 11 | 96 ± 5 |
| **Community**[c] | | |
| Mattawa | 12 | 83 ± 8 |
| Othello | 13 | 77 ± 4 |
| Basin City School | 14 | 79 ± 3 |
| Edwin Markham School | 15 | 77 ± 10 |
| Pasco | 16 | 88 ± 12 |
| Kennewick - Ely Street | 17 | 79 ± 7 |
| Benton City | 18 | 84 ± 3 |
| **Distant**[c] | | |
| Yakima | 19 | 74 ± 6 |
| Toppenish | 20 | 74 ± 6 |
| **Columbia River Shoreline**[e] | | |
| Below 100N Outfall | 1 | 85 ± 4 |
| Above Tip 100N Berm | 2 | 86 ± 9 |
| 100 N Trench Spring | 3 | 105 ± 11 |
| S End Vernita Bridge | 4 | 81 ± 9 |
| Above 100 B Area | 5 | 87 ± 2 |
| Below 100B Retention Basin | 6 | 100 ± 12 |
| Coyote Rapids[d] | 7 | 85 ± 27 |
| Above 1K Boat Ramp | 8 | 95 ± 6 |
| Below 100 D Area | 9 | 74 ± 5 |
| 100-D Island | 10 | 80 ± 6 |
| 100 H Area | 11 | 86 ± 9 |
| Lower End Locke Island | 12 | 89 ± 8 |
| White Bluffs Ferry Landing | 13 | 85 ± 7 |
| White Bluffs Slough | 14 | 94 ± 8 |
| Below 100 F | 15 | 83 ± 4 |
| 100 F Flood Plain | 16 | 86 ± 5 |
| Hanford Slough | 17 | 97 ± 6 |
| Hanford Powerline Crossing | 18 | 96 ± 7 |
| Hanford Railroad Track | 19 | 95 ± 14 |
| Savage Island Slough | 20 | 84 ± 14 |
| Ringold Island | 21 | 86 ± 8 |
| Powerline Crossing | 22 | 85 ± 12 |
| S End Wooded Island | 23 | 97 ± 5 |
| Island Above 300 Area | 24 | 95 ± 6 |
| Island Near 300 Area | 25 | 91 ± 8 |
| Port of Benton-River | 26 | 85 ± 8 |
| N. Richland | 27 | 78 ± 7 |
| Riverview | 28 | 77 ± 8 |
| Island Downstream Bateman Island[d] | 29 | 96 ± 10 |

(a) Average for four quarterly measurements ±2 standard deviations of the dose rate.
(b) All locations are shown on Figure 10.13.2.
(c) All locations are shown on Figure 10.13.3.
(d) Measurements for two calendar quarters only.
(e) All locations are shown on Figure 10.13.4.

# References

40 CFR 141. "National Primary Drinking Water Regulations; Radionuclides; Proposed Rule." U.S. Environmental Protection Agency. *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-15892, APP. 1. 2005. *Hanford Site Environmental Surveillance Data Report for Calendar Year 2005*. LE 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. "Public Water Supplies." *Washington Administrative Code*, Olympia, Washington.

# Appendix D
# Standards and Permits

R. W. Hanf

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.1.

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.2 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 DOE, *Clean Air Act*, or drinking water dose standards.

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 2005 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, *Water Quality Standards for Surface Waters of the State of Washington*. 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. In 2003, the Washington State Department of Ecology revised the surface-water quality standards and submitted them to the U.S. Environmental Protection Agency (EPA) for approval. As the new standards are approved, the Class A (Excellent) designation uses are being replaced by other use designations. Four use designations have been identified for water bodies in the state: (1) Aquatic Life Uses, (2) Recreational Uses, (3) Water Supply Uses, and (4) Miscellaneous Uses. Within each designation are categories that apply to specific bodies of water. For the Hanford Reach of the Columbia River, the category for Aquatic Life Uses is noncore salmon and trout; for the protection of spawning, noncore rearing, and migration of salmon and trout, and other associated aquatic life. The category for Recreational Uses is primary contact recreation, which refers to the allowable amount of fecal coliform organisms. Designated water supply uses and miscellaneous uses include domestic water, industrial water, agricultural water, stock water, wildlife habitat, harvesting, commerce and navigation, boating, and aesthetics. Some of the new use designations and their criteria have been approved and some have not. For those not yet approved, the old criteria are still in effect. A summary of currently applicable Hanford Reach water criteria is provided in Table D.3. Table D.4 summarizes drinking water standards from EPA in Title 40, *Code of Federal Regulations*, Part 141 (40 CFR 141) and WAC 246-290, *Public Water Systems*. Select surface freshwater quality criteria for toxic pollutants are included in Table D.5.

**Table D.1. 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. This permit expired August 1, 2005, and is scheduled to be reissued in August 2006. The old permit will remain in effect until the new permit is issued.

Permit ST 4501 allows for the discharge of cooling water and other primarily uncontaminated wastewater from 400 Area facilities to two ponds located north-northeast of the 400 Area perimeter fence. Expired July 31, 2001. A renewal application has been submitted. 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. This permit expired in May 2005 and is scheduled to be reissued in August 2006. The old permit will remain in effect until the new permit is issued.

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. Still operating on an extension of the old permit, which will be in effect until a new permit is issued.

Permit ST 4511 is a consolidation of permits ST 4508, ST 4509, and ST 4510. This Categorical State Waste Discharge Permit authorizes the discharge of wastewater from maintenance, construction, and hydrotesting activities and allows for cooling water, condensate, and industrial stormwater discharges at the Hanford Site. Issued February 16, 2005; expires February 16, 2010.

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 05-020, issued by Washington Department of Fish and Wildlife to Pacific Northwest National Laboratory for 2005; covered the collection of food fish, shellfish, and wildlife, including game fish, for research 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<br>Department of Ecology<br>P.O. Box 47600<br>Olympia, WA 92504-7600 | U.S. Environmental Protection Agency<br>Region 10<br>1200 Sixth Avenue<br>Seattle, WA 98101 | U.S. Department of Energy<br>Richland Operations Office<br>825 Jadwin Avenue<br>Richland, WA 99352 |

**Table D.2. 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.

Environmental radiation protection standards are published in U.S. Department of Energy (DOE) Order 5400.5, *Radiation Protection of the Public and the Environment*. The Order establishes limits for public radiation dose and gives guidance to keep radiation exposure to members of the public as low as reasonably achievable. These standards are based on guidelines recommended by authoritative organizations such as the International Commission on Radiological Protection and the National Council on Radiation Protection and Measurements. DOE initiated a policy to create and implement public radiation protection standards that are generally consistent with the standards used by the U.S. Nuclear Regulatory Commission to regulate and license non-DOE nuclear facilities, such as nuclear power plants. Table D.6 shows the radiation standards from DOE Order 5400.5, *National Emission Standards for Hazardous Air Pollutants* (40 CFR 61), and *National Primary Drinking Water Regulations* (40 CFR 141). These standards govern allowable public exposure to ionizing radiation from DOE operations.

**Table D.3. Washington State Water Quality Criteria 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)<br>(2) Not more than or equal to 10% of samples may exceed the geometric mean value of 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<br>(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)<br>(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<br>(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 |
| 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 EPA-570/9-76-003 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.
EPA = U.S. Environmental Protection Agency.
WAC = *Washington Administrative Code*.

**Table D.4. Selected Drinking Water Standards**

| Radiological Constituent | Primary Maximum Contaminant Level | Interim Drinking Water Standard | Agency | Status |
|---|---|---|---|---|
| Gross alpha[a] | 15 pCi/L (0.56 Bq/L) | | DOH,[b] EPA[c] | Final |
| Beta particle and photon activity | 4 mrem/yr (40 µSv/yr)[d] | | DOH,[b] EPA[c] | Final |
| Tritium | 20,000[e] pCi/L (740 Bq/L) | | DOH,[b] EPA[c] | Final |
| Beryllium-7 | | 6,000[e] pCi/L (222 Bq/L) | EPA[f] | Interim |
| Cobalt-60 | | 100[e] pCi/L (3.7 Bq/L) | EPA[f] | Interim |
| Strontium-90 | 8[e] pCi/L (0.296 Bq/L) | | DOH,[b] EPA[c] | Final |
| Technetium-99 | | 900[e] pCi/L (33.3 Bq/L) | EPA[f] | Interim |
| Ruthenium-106 | | 30[e] pCi/L (1.11 Bq/L) | EPA[f] | Interim |
| Antimony-125 | | 300[e] pCi/L (11.1 Bq/L) | EPA[f] | Interim |
| Iodine-129 | | 1[e] pCi/L (0.037 Bq/L) | EPA[f] | Interim |
| Iodine-131 | | 3[e] pCi/L (0.111 Bq/L) | EPA[f] | Interim |
| Cesium-134 | | 20,000[e] pCi/L (740 Bq/L) | EPA[f] | Interim |
| Cesium-137 | | 200[e] pCi/L (7.4 Bq/L) | EPA[f] | Interim |
| Europium-154 | | 200[e] pCi/L (7.4 Bq/L) | EPA[f] | Interim |
| Europium-155 | | 600[e] pCi/L (22.2 Bq/L) | EPA[f] | Interim |
| Uranium | 30 µg/L (0.03 ppm)[g] | | EPA[e] | Final[h] |
| Radium-226 | 20 pCi/L (0.74 Bq/L)[c] | 3 pCi/L (0.111 Bq/L)[b] | DOH, EPA | Final |
| Radium-226 and -228 | 5 pCi/L (0.185 Bq/L) | | EPA | Final |
| Fluoride | 4 mg/L (4 ppm) | | DOH,[b] EPA[c,i] | Final/under review |
| Nitrate, as $NO_3^-$ | 45 mg/L (45 ppm) | | DOH,[b] EPA[c,i] | Final |
| Chromium | 100 µg/L (0.1 ppm) | | DOH,[b] EPA[c,i] | Final |
| Cyanide | 200 µg/L (0.2 ppm) | | EPA[b,c,i] | Final |
| Trichloroethene | 5 µg/L (0.005 ppm) | | DOH,[b] EPA[c,i] | Final |
| Tetrachloroethene | 5 µg/L (0.005 ppm) | | DOH,[b] EPA[c,i] | Final |
| Carbon tetrachloride | 5 µg/L (0.005 ppm) | | DOH,[b] EPA[c,i] | Final |
| Chloroform (THM)[j] | 100 µg/L (0.1 ppm) | | DOH,[b] EPA[i] | Final |
| cis-1,2-Dichloroethene | 0.07 mg/L (0.07 ppm) | | EPA[i] | Final |

(a) Excluding radon and uranium but including radium-226.
(b) WAC 246-290.
(c) 40 CFR 141.
(d) Beta and photon radioactivity from manmade radionuclides. Annual average activity shall not exceed an effective dose equivalent of 4 mrem per year.
(e) Activity assumed to yield an annual dose of 4 mrem per year.
(f) EPA-570/9-76-003.
(g) Equivalent to 27 pCi/L (assuming typical uranium natural abundance in rock).
(h) 40 CFR Parts 9, 141, and 142. Final rule promulgated December 7, 2000 (65 FR 76708).
(i) EPA 822-R-96-001.
(j) Standard is for total trihalomethanes (THM).
DOH = Washington State Department of Health.
EPA = U.S. Environmental Protection Agency.

**Table D.5. 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 the 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.6. 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.

# References

40 CFR 61. "National Emission Standards for Hazardous Air Pollutants." U.S. Environmental Protection Agency, *Code of Federal Regulations*.

40 CFR 131.36. "Toxics Criteria for Those States not Complying with the Clean Water Act Section 303(c)(2)(B)." U.S. Environmental Protection Agency, *Code of Federal Regulations*.

40 CFR 141. "National Primary Drinking Water Regulations." U.S. Environmental Protection Agency, *Code of Federal Regulations*.

40 CFR Parts 9, 141, and 142. "National Primary Drinking Water Regulations; Radionuclides; Final Rule." U.S. Environmental Protection Agency, *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. 1990. "Radiation Protection of the Public and the Environment." U.S. Department of Energy, Washington, D.C.

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. "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, which 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 commonly used 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), measured in units of roentgen (R). The exposure is multiplied by a factor of 0.98 to convert to a dose (D), in rad, to soft tissue (Shleien 1992). This conversion factor relating R to rad is, however, assumed to be unity (1) throughout this report for consistency with past reports. This dose is further modified by a quality factor, Q = 1, for beta and gamma radiation and the product of all other modifying factors (N). N is assumed to be unity to obtain dose equivalence (H) measured in rem. The international unit, the sievert (Sv), is equivalent to 100 rem.

$$D\ (\text{rad}) = X\ (R) * 1.0$$

$$H\ (\text{rem}) = D * N * Q$$

## Calculations

The radiological dose that the public could have received in 2005 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 expressed in units of 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 contribute following 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

(a) 1 rem (0.01 Sv) = 1,000 mrem (10 mSv).

to the 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 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 using 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 in the following paragraphs.

The RESRAD-BIOTA computer code was used to screen the 2005 radionuclide concentrations in environmental media (water and sediment) to see if they exceeded 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 1, no further analysis is required. However, if the sum of fractions does exceed 1, 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 2005 air emissions report (DOE/RL-2006-01).

## 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 must be used in estimating public doses.
- That calculations of doses to the public from exposures resulting from both routine and unplanned activities must be performed using EPA or DOE dose conversion factors or analytical models prescribed in regulations applicable to DOE operations.
- Doses to the public must 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/hr 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 Hanford Reach of the Columbia River.
- Recreation along the Hanford Reach of 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 emissions released to the air and effluent released to the Columbia River from Hanford facilities. Based on experience since 1990, three separate locations (Figure 10.13.1) 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 the Riverview area to Hanford facilities that historically released airborne emissions, 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 in the Ringold area. In 1991, 1992, 2000, and again in 2002, the maximally exposed individual resided in the Riverview area. However, from 1993 through 1999, 2001, 2003, 2004, and again in 2005, the hypothetical, maximally exposed individual was located across the Columbia River from the 300 Area in the Sagemoor area (Figure 10.13.1).

***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 contaminated groundwater originating from the 100 and 200-East Areas enters the 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 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 effluent from Hanford facilities. For the calculation, it was assumed that the Riverview area 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 potentially contaminated irrigated food products and potential 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 in the Sagemoor area, 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 area 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 area 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 area of Pasco in Franklin County. Enough food is grown in this area 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.
- ***Columbia 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-15892, 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.

## 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

The DOE established the Hanford Dose Overview Panel to promote consistency and defensibility of environmental dose calculations at Hanford. The panel was 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. This panel is no longer functional. 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 a former panel member. Summaries of dose calculation technical details for this report are shown in Tables E.5 through E.10 and in PNNL-15892, APP. 1.

**Table E.1. Food Pathway Parameters Used in Hanford Site Dose Calculations, 2005**

| | Holdup (days)[a] | | | | | | |
|---|---|---|---|---|---|---|---|
| Medium | Maximally Exposed Individual | Average Individual | Growing Period (days) | 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[c] | 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.
(c) Drinking water holdup in calculations is 1.5 days for 100 Area releases and 1.0 day for 200 Area releases.

**Table E.2. Dietary Parameters Used in Hanford Site Dose Calculations, 2005**

| 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/yr (33,075 lb/yr).

**Table E.3. Residency Parameters Used in Hanford Site Dose Calculations, 2005**

| Parameter | Exposure (hr/yr): Maximally Exposed Individual | Exposure (hr/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 $cm^3$/sec (16.5 $in.^3$/sec).

**Table E.4. Columbia River Recreational Parameters Used in Hanford Site Dose Calculations, 2005**

| Parameter | Exposure (hr/yr)[a]: Maximally Exposed Individual | Exposure (hr/yr)[a]: Average Individual |
|---|---|---|
| Shoreline | 500 | 17 |
| Boating | 100 | 5 |
| Swimming | 100 | 10 |

(a) Transit times for water to irrigation and recreation sites vary by release and receptor locations.

## 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 2005 are given in Table E.11.

## Ambient-Air 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-K Area of the Hanford Site, 2005**

| | |
|---|---|
| Facility name | 100-K Area |
| Releases (Ci [Bq]) | $^{90}$Sr (2.8 x $10^{-5}$ [1.0 x $10^{6}$]), $^{238}$Pu (1.6 x $10^{-6}$ [5.9 x $10^{4}$]), $^{239}$Pu (1.2 x $10^{-5}$ [4.4 x $10^{5}$]), $^{241}$Pu (1.3 x $10^{-4}$ [4.8 x $10^{6}$]), $^{241}$Am (1.4 x $10^{-5}$ [5.2 x $10^{5}$]) |
| Meteorological conditions | 2005 annual average, calculated using the GENII Joint Frequency Data (GENJFD) computer code from data collected at the 100-K Area and the Hanford Meteorology Station from January through December 2005 |
| $\overline{X}$/Q' dispersion factors | Maximally exposed individual, 1.6 x $10^{-8}$ sec/m$^3$ at 41 km (25 mi) SE; 80-km (50-mi) population, 4.5 x $10^{-3}$ person-sec/m$^3$ |
| Release height | 10-m (33-ft) effective stack height |
| Population distribution | ~482,000 (PNNL-14428) |
| 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 contaminant plume and atmospheric contaminants deposited on the ground<br>Inhalation<br>Ingestion of foods produced locally at Riverview |
| Files addressed | Radionuclide Library, Rev. 7-1-92<br>Food Transfer Library, Rev. 8-29-88<br>External Dose Factor Library, Rev. 5-9-88<br>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, 2005**

| | |
|---|---|
| Facility name | 100-N Area |
| Releases (Ci [Bq]) | $^{3}$H (7.5 x $10^{-3}$ [2.8 x $10^{8}$]), $^{90}$Sr (5.0 x $10^{-2}$ [1.9 x $10^{9}$]), $^{125}$Sb (4.7 x $10^{-3}$ [1.7 x $10^{8}$]), $^{137}$Cs (4.1 x $10^{-3}$ [1.5 x $10^{8}$]), $^{152}$Eu (8.5 x $10^{-3}$ [3.1 x $10^{8}$]), $^{154}$Eu (3.5 x $10^{-3}$ [1.3 x $10^{8}$]), $^{238}$Pu (5.3 x $10^{-6}$ [2.0 x $10^{5}$]), $^{239}$Pu (2.7 x $10^{-6}$ [1.0 x $10^{5}$]) |
| Mean river flow | 2,966 $m^3$/sec (104,737 $ft^3$/sec) |
| Shore width factor | 0.2 |
| Population distribution | 130,000 for drinking water pathway<br>125,000 for aquatic recreation pathway<br>2,000 for consumption of irrigated foodstuffs pathway |
| 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, river water, and shoreline sediments<br>Ingestion of aquatic foods, assuming a 15,000 kg/yr (33,075 lb/yr) total harvest of Columbia River fish, and irrigated farm products |
| Files addressed | Radionuclide Library, Rev. 7-1-92<br>Food Transfer Library, Rev. 8-29-88<br>External Dose Factor Library, Rev. 5-9-88<br>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, 2005**

| | |
|---|---|
| Facility name | 200 Areas |
| Releases (Ci [Bq]) | 200-East Area<br><br>$^{90}$Sr (3.3 x $10^{-5}$ [1.2 x $10^{6}$]), $^{129}$I (1.3 x $10^{-3}$ [4.8 x $10^{7}$]), $^{137}$Cs (3.4 x $10^{-5}$ [1.3 x $10^{6}$]), $^{238}$Pu (5.4 x $10^{-8}$ [2.0 x $10^{3}$]), $^{239}$Pu (2.6 x $10^{-6}$ [9.6 x $10^{4}$]), $^{241}$Am (3.7 x $10^{-6}$ [1.4 x $10^{5}$])<br><br>200-West Area<br><br>$^{90}$Sr (2.2 x $10^{-5}$ [8.1 x $10^{5}$]), $^{137}$Cs (1.4 x $10^{-6}$ [5.2 x $10^{4}$]), $^{155}$Eu (3.9 x $10^{-8}$ [1.4 x $10^{3}$]), $^{238}$Pu (1.5 x $10^{-6}$ [5.6 x $10^{4}$]), $^{239}$Pu (6.6 x $10^{-5}$ [2.4 x $10^{6}$]), $^{241}$Pu (6.0 x $10^{-5}$ [2.2 x $10^{6}$]), $^{241}$Am (1.1 x $10^{-5}$ [4.1 x $10^{5}$]) |
| Meteorological conditions | 2005 annual average, calculated using the GENII Joint Frequency Data (GENJFD) computer code from data collected at the Hanford Meteorology Station from January through December 2005 |
| $\overline{X}$/Q' dispersion factors | Maximally exposed individual, 1.8 x $10^{-8}$ sec/m$^3$ at 28 km (17 mi) SE; 80-km (50-mi) population, 2.4 x $10^{-3}$ person-sec/m$^3$ |
| Release height | 89-m (292-ft) effective stack height |
| Population distribution | ~486,000 (PNNL-14428) |
| 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 contaminant plume and atmospheric contaminants deposited on the ground<br>Inhalation<br>Ingestion of foods produced locally at Riverview |
| Files addressed | Radionuclide Library, Rev. 7-1-92<br>Food Transfer Library, Rev. 8-29-88<br>External Dose Factor Library, Rev. 5-9-88<br>Internal Dose Factor Library, Rev. 12-3-90 |

**Table E.8. Technical Details of Liquid Release Dose Calculations for the 200 Areas of the Hanford Site Calculated as Difference in Upstream and Downstream Concentrations, 2005**

| | |
|---|---|
| Facility name | 200 Areas |
| Releases (Ci [Bq])[(a)] | $^{3}H$ ($3.5 \times 10^{3}$ [$1.3 \times 10^{14}$]), $^{90}Sr$ ($1.9 \times 10^{-1}$ [$7.0 \times 10^{9}$]), $^{99}Tc$ ($1.6 \times 10^{1}$ [$5.9 \times 10^{11}$]), $^{129}I$ ($4.3 \times 10^{-3}$ [$1.6 \times 10^{8}$]), $^{234}U$ ($3.7 \times 10^{0}$ [$1.4 \times 10^{11}$]), $^{238}U$ ($2.8 \times 10^{0}$ [$1.0 \times 10^{11}$]) |
| Mean river flow | 2,966 $m^3$/sec (104,737 $ft^3$/sec) |
| Shore width factor | 0.2 |
| Population distribution | 130,000 for drinking water pathway<br>125,000 for aquatic recreation pathway<br>2,000 for consumption of irrigated foodstuffs pathway |
| 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, river water, and shoreline sediments<br>Ingestion of aquatic foods, assuming 15,000 kg/yr (33,075 lb/yr) total harvest of Columbia River fish, and irrigated farm products |
| Files addressed | Radionuclide Library, Rev. 7-1-92<br>Food Transfer Library, Rev. 8-29-88<br>External Dose Factor Library, Rev. 5-9-88<br>Internal Dose Factor Library, Rev. 12-3-90 |

(a) Concentration of $^{3}H$ based on 2004 data because 2005 data were not available.

**Table E.9. Technical Details of Airborne Release Dose Calculations for the 300 Area of the Hanford Site, 2004**

| | |
|---|---|
| Facility name | 300 Area |
| Releases (Ci [Bq]) | $^{3}$H (as HT)[(a)] (1.3 x $10^{1}$ [4.8 x $10^{11}$]), $^{3}$H (as HTO)[(a)] (7.6 x $10^{1}$ [2.8 x $10^{12}$]), $^{90}$Sr (1.1 x $10^{-6}$ [4.1 x $10^{4}$]), $^{131m}$Xe (1.0 x $10^{-6}$ [3.7 x $10^{4}$]), $^{131}$Xe (1.3 x $10^{-7}$ [4.8 x $10^{3}$]), $^{135}$Xe (7.0 x $10^{-8}$ [2.6 x $10^{3}$]), $^{137}$Cs (8.2 x $10^{-6}$ [3.0 x $10^{5}$]), $^{220}$Rn (4.3 x $10^{1}$ [1.6 x $10^{12}$]), $^{222}$Rn (1.2 x $10^{0}$ [4.4 x $10^{10}$]), $^{239}$Pu (6.9 x $10^{-8}$ [2.6 x $10^{3}$]), $^{241}$Am (4.9 x $10^{-7}$ [1.8 x $10^{4}$]) |
| Meteorological conditions | 2005 annual average, calculated using the GENII Joint Frequency Data (GENJFD) computer code from data collected at the 300 Area and the Hanford Meteorology Station from January through December 2005 |
| $\overline{X}$/Q' dispersion factors | Maximally exposed individual at residence, 8.8 x $10^{-7}$ sec/m$^{3}$ at 1.4 km (0.87 mi) E; 80-km (50-mi) population, 1.1 x $10^{-2}$ person-sec/m$^{3}$ |
| Release height | 10-m (33-ft) effective stack height |
| Population distribution | ~349,000 (PNNL-14428) |
| 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 contaminant plume and atmospheric contaminants deposited on the ground<br>Inhalation<br>Ingestion of foods produced locally at Riverview |
| Files addressed | Radionuclide Library, Rev 7-1-92<br>Food Transfer Library, Rev. 8-29-88<br>External Dose Factor Library, Rev. 5-9-88<br>Internal Dose Factor Library, Rev. 12-3-90 |

(a) HT = Elemental tritium; HTO = Tritiated water vapor.

| | |
|---|---|
| Facility name | 400 Area |
| Releases (Ci [Bq]) | $^{137}Cs$ ($8.9 \times 10^{-6}$ [$3.3 \times 10^{5}$]), $^{239}Pu$ ($3.0 \times 10^{-7}$ [$1.1 \times 10^{4}$]) |
| Meteorological conditions | 2005 annual average, calculated using the GENII Joint Frequency Data (GENJFD) computer code from data collected at the 400 Area and the Hanford Meteorology Station from January through December 2005 |
| $\overline{X}$/Q' dispersion factors | Maximally exposed individual at residence, $8.7 \times 10^{-8}$ sec/m$^3$ at 11 km (7 mi) SE; 80-km (50-mi) population, $6.5 \times 10^{-3}$ person-sec/m$^3$ |
| Release height | 10-m (33-ft) effective stack height |
| Population distribution | ~354,000 (PNNL-14428) |
| 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 |
| Files addressed | Radionuclide Library, Rev. 7-1-92<br>Food Transfer Library, Rev. 8-29-88<br>External Dose Factor Library, Rev. 5-9-88<br>Internal Dose Factor Library, Rev. 12-3-90 |

**Table E.11. Annual Dose to Workers in the 100-K Area of the Hanford Site from Ingestion of Drinking Water Obtained from the Columbia River and to Workers in the 400 Area from Ingestion of Drinking Water Obtained from Groundwater Wells, 2005**

| Radionuclide | Average Drinking Water Activity (pCi/L) | Intake (pCi/yr) | Ingestion Dose Factor (rem/pCi) | Ingestion Dose (rem/yr) |
|---|---|---|---|---|
| **100-K Area** | | | | |
| $^{226}Ra$ | 0.1109 | 26.6 | $1.1 \times 10^{-6}$ | $2.9 \times 10^{-5}$ |
| $^{228}Ra$ | 0.831 | 199 | $1.2 \times 10^{-6}$ | $2.4 \times 10^{-4}$ |
| **Total** | | | | **$2.6 \times 10^{-4}$** |
| **400 Area** | | | | |
| Gross beta | 6.37 | 1,530 | $5.0 \times 10^{-8}$ | $7.6 \times 10^{-5}$ |
| $^{226}Ra$ | 0.158 | 37.9 | $1.1 \times 10^{-6}$ | $4.2 \times 10^{-5}$ |
| $^{228}Ra$ | 0.886 | 208 | $1.2 \times 10^{-6}$ | $2.5 \times 10^{-4}$ |
| Tritium | 3,098 | 743,000 | $6.3 \times 10^{-11}$ | $4.7 \times 10^{-5}$ |
| **Total** | | | | **$4.1 \times 10^{-4}$** |

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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 monitoring samples.

# Appendix G
# Errata for Environmental Report 2004

The following errors were found in the *Hanford Site Environmental Report for Calendar Year 2004* (PNNL-15222) and supplemental documents:

1. Error in the *Hanford Site Environmental Report for Calendar Year 2004* (PNNL-15222). On page 8.104, Sections 8.83 through 8.86, concentration values should be pCi/g rather than pCi/L.
2. Error in the *Hanford Site Environmental Surveillance Data Report for Calendar Year 2004* (PNNL-15222, APP. 1). Data were inadvertently mislabeled in Tables D.6 through D.9 of the report, located on pages 258 through 261. The tables, which contain atmospheric dispersion factors ($\overline{X}/Q'$), were not used for the population or individual dose calculations reported in the main report, *Hanford Site Environmental Report for Calendar Year 2004* (PNNL-15222). The values in these tables were calculated independent of the dose estimates and are included in the report for information only. As such, they do not affect the dose calculations or compliance status for 2004 as reported in the site environmental report (PNNL-15222). Corrected tables can be found in an electronic version of the document (PNNL-15222, APP. 1) on the web at http://hanford-site.pnl.gov/envreport.

This same error appears in the electronic version of the *Hanford Site Environmental Surveillance Data Report for Calendar Year 2004* (PNNL-15222, APP. 1) included on the CD with the main report, *Hanford Site Environmental Report for Calendar Year 2004* (PNNL-15222).

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| DOE Public Reading Room (2P/2CD/2S) | H2-53 |
| Hanford Site Administrative Record (2P/2CD/2S) | H6-08 |
| Hanford Technical Library (2P/2CD/2S) | P8-55 |
| Historical File—R. W. Hanf (P/CD/S) | K6-75 |
| LMSI Central Files (P/CD/S) | B1-07 |