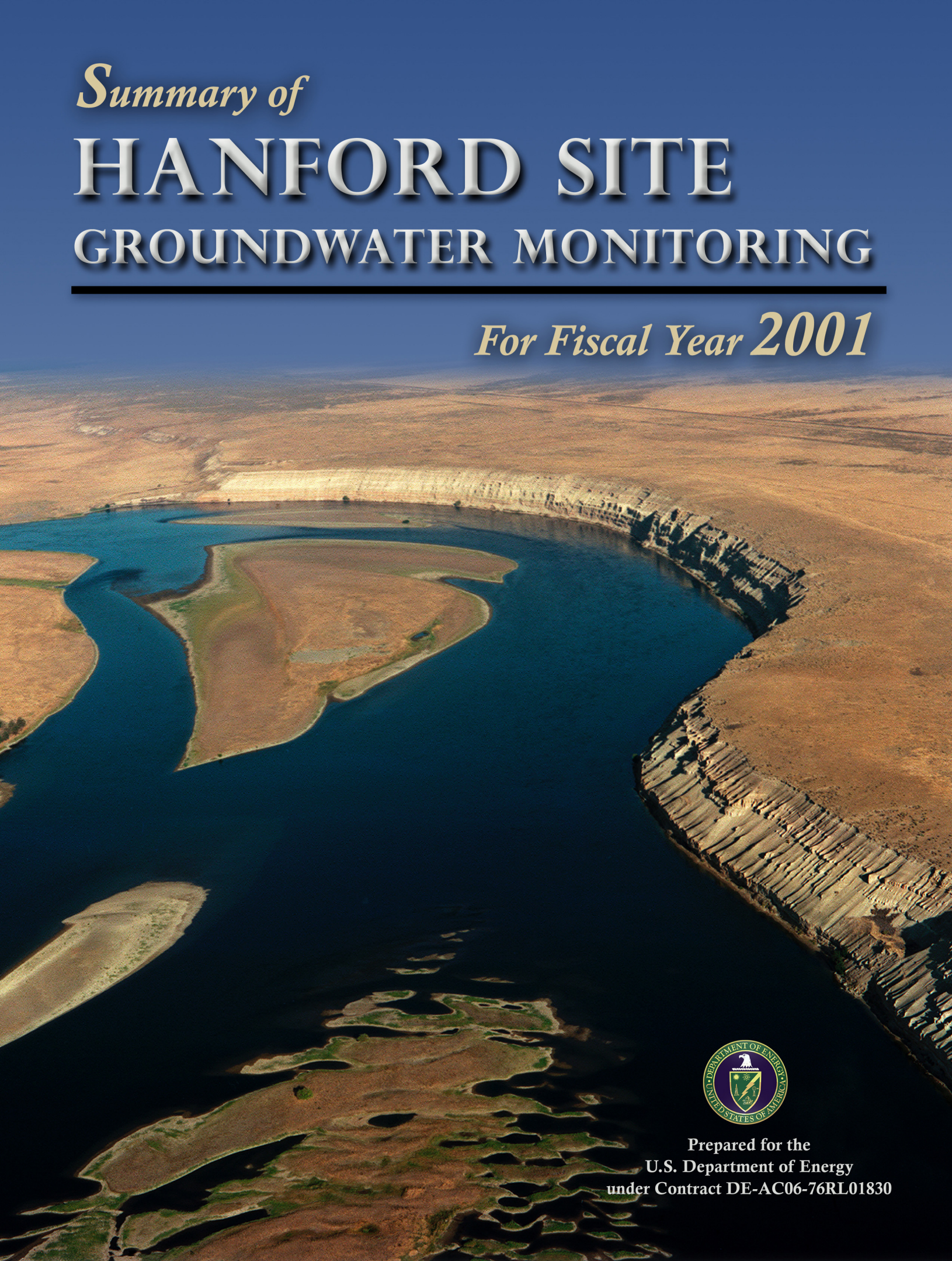
Summary of
HANFORD SITE
GROUNDWATER MONITORING

For Fiscal Year 2001



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Summary of Hanford Site Groundwater Monitoring for Fiscal Year 2001

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Contents

This booklet summarizes a more detailed report, *Hanford Site Groundwater Monitoring for Fiscal Year 2001*. That report is prepared annually to present the results of groundwater and vadose zone monitoring and remediation on the U.S. Department of Energy's Hanford Site in Washington State. The U.S. Department of Energy monitors groundwater at the Hanford Site to fulfill a variety of state and federal regulations. The department manages these activities through the Hanford Groundwater Monitoring Project, which is conducted by Pacific Northwest National Laboratory. The results primarily rely on data from samples collected between October 1, 2000, and September 30, 2001.

This summary booklet is designed to briefly (1) describe the highlights for fiscal year 2001; (2) identify emerging issues in groundwater monitoring; (3) discuss groundwater flow and movement; and (4) provide an overview of current contamination in the Hanford Site groundwater and vadose zone.

For more information about the groundwater project, see http://hanford-site.pnl.gov/groundwater. To obtain copies of this summary booklet, the detailed annual report, or a copy of the reports on CD, contact M. J. Hartman at Pacific Northwest National Laboratory, P.O. Box 999, Richland, Washington 99352 or by electronic mail to mary.hartman@pnl.gov.

Introduction

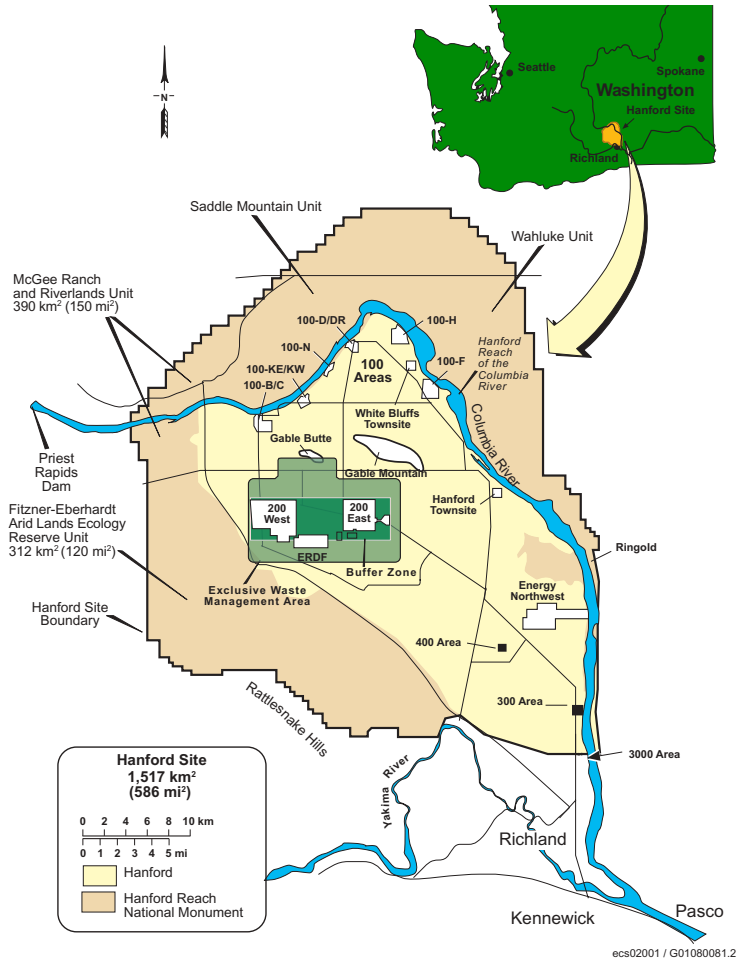
The Hanford Site, a facility in the U.S. Department of Energy (DOE) nuclear weapons complex, encompasses ~1,517 square kilometers northwest of the city of Richland along the Columbia River in southeastern Washington State. The site was acquired by the federal government in 1943, and until the 1980s was dedicated primarily to the production of plutonium for national defense and the management of resulting waste.

In 1995, all unrestricted discharge of radioactive liquid waste to the ground was discontinued. Today, DOE's mission on the Hanford Site is to restore the Columbia River corridor, transition the central portion of the site toward its long-term waste management role, and prepare for the future.

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 vadose zone and groundwater. As regulatory requirements for monitoring increased in the 1980s, there began to be some overlap between various programs. DOE established the Groundwater Monitoring Project in 1996 to ensure protection of the public and the environment while improving the efficiency of monitoring activities. The Groundwater Monitoring Project is designed to address all groundwater monitoring needs at the site, eliminate regulatory program

Groundwater *is the water that fills the pores or cracks between grains in a layer of sediment or rock. An* ***aquifer*** *is a geologic layer that allows water to pass through easily, with all its pores saturated with water. The top of the saturated zone is called the* ***water table****. The* ***vadose zone*** *is the soil or rock between the ground surface and the water table. It usually contains some water, but also contains air.*

Groundwater monitoring *helps determine what contamination exists beneath the Hanford Site. This information will help regulators and DOE make cleanup decisions based on scientific information and technical capabilities.*



The Hanford Site occupies approximately 1,517 square kilometers of arid land in southeastern Washington.

redundancy, and establish a cost-effective hierarchy for groundwater monitoring activities. Specific objectives include

- maintaining and verifying compliance with all applicable groundwater regulations
- characterizing and defining physical and chemical trends in groundwater
- establishing baselines of groundwater quality
- providing continuing, independent assessment of groundwater remediation activities
- identifying and quantifying new or existing groundwater problems.

The Groundwater Monitoring report *is written to meet the requirements in CERCLA, RCRA, the Atomic Energy Act of 1954, and Washington Administrative Code.*

Contamination may reach 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 in Hanford soil and groundwater could have on human health and the environment. DOE works with the regulators, such as the U.S. Environmental Protection Agency (EPA) and the Washington State Department of Ecology, to make cleanup decisions based on sound technical information and the technical capabilities available.

Groundwater Monitoring Highlights for Fiscal Year 2001

Notable achievements of the Groundwater Monitoring Project included the following:

- Workers sampled 706 monitoring wells to determine the distribution and movement of contaminants. Many of these wells were sampled multiple times during the year. Data from these samples were used to identify and characterize existing, potential, and emerging groundwater contamination problems.
- Analytical laboratories analyzed nearly 1,000 Hanford groundwater samples for tritium. Over 400 analyses were run for carbon tetrachloride and technetium-99, and over 300 for hexavalent chromium, iodine-129, strontium-90, and uranium.
- The groundwater project continued to monitor 24 *Resource Conservation and Recovery Act of 1976* (RCRA) sites, 5 other regulated units, and 11 *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) groundwater operable units.
- RCRA monitoring provided no evidence of new contamination from sites in detection programs. Seven sites continued to be monitored under assessment programs, and two under final-status corrective action.
- The groundwater project evaluated the adequacy of RCRA monitoring networks. At single-shell tank Waste Management Areas A-AX and C, groundwater flow directions have been re-interpreted and the monitoring networks may need to be modified. Because the water table is dropping in the 200 Areas, many monitoring wells have gone dry in recent years. Networks contain fewer than the optimal number of wells at 216-S-10 pond, 216-U-12 crib, and Low-Level Waste Management Areas 3 and 4.
- In January 2001, the Washington State Department of Ecology instructed DOE to cease statistical evaluations of RCRA indicator parameters for the Liquid Effluent Retention Facility near the 200 East Area. Most of the monitoring wells have gone dry and cannot be deepened because there is virtually no

saturated sediment above the basalt bedrock. Only one upgradient and one downgradient well can be sampled. DOE continued to collect and analyze samples from those wells.

- EPA performed a 5-year review to determine whether remedial actions specified under records of decision for the Hanford Site protect human health and the environment. The review identified several action items required to address deficiencies.
- Interim remedial actions continued to limit the movement of contamination in the 100-HR-3, 100-KR-4, 100-NR-2, 200-UP-1, and 200-ZP-1 Operable Units, located in the 100 and 200 Areas.
- Monitoring provided no evidence of new leaks from fuel storage basins in the 100 K Area. DOE began to remove fuel canisters from the basin during fiscal year 2001.
- Monitoring results at the following regulated units remained within permit limits: 400 Area Process Ponds, Solid Waste Landfill, State-Approved Land Disposal Site, and Treated Effluent Disposal Facility.
- Characterization and monitoring of the tritium plume at the 618-11 burial ground indicated the plume is localized and has a long travel time to the Columbia River. The study included soil gas monitoring, aquifer characterization, and groundwater sampling.
- Monitoring indicated that the tritium plume that originated in the 200 East Area did not move closer to the city of Richland or its water supply wells.
- Average trichloroethene concentrations in compliance wells in the 1100-EM-1 operable unit (Richland North Area) were below the maximum contaminant level for the first time. This contaminant has been attenuating naturally, as expected.
- Drillers completed 11 new RCRA monitoring wells, 31 injection or monitoring wells at the redox site in 100 D Area, and 6 wells for other projects. Ninety-nine wells, mostly near the Columbia River, were sealed with grout because they were no longer needed and posed a potential environmental or safety hazard.
- The sitewide groundwater model was improved by refining input about historical water levels changes, recharge events, and interaction between the unconfined and confined aquifer systems.
- DOE performed an initial assessment using the System Assessment Capability. This set of computer modules simulates movement of contaminants from waste sites through the vadose zone and groundwater.

Groundwater sampling wells *form a monitoring network across the Hanford Site and along the Columbia River. This network provides a picture of the status of groundwater beneath Hanford that will help protect human health and the environment.*

Vadose Zone Highlights for Fiscal Year 2001

DOE's accomplishments in the vadose zone included the following:

- Scientists monitored helium isotopes in soil gas near the 618-11 burial ground to help define distribution of the tritium plume in groundwater (see groundwater highlights).
- Geophysicists logged 113 boreholes with gamma-ray detection equipment at the single-shell tank farms in fiscal year 2001. Results identified possible contaminant movement in four boreholes at the U tank farm and five boreholes at the T tank farm.

- Scientists installed a new vadose zone monitoring device at the single-shell tank farms, the first of its kind at a Hanford Site tank farm. A borehole at the B tank farm was instrumented with tensiometers, heat and water sensors, and a water flux meter.
- Scientists studied alternative methods of monitoring the vadose zone beneath single-shell tanks by simulating tank leakage with a non-hazardous solution at a clean site.
- DOE constructed earthen berms around 200 West Area single-shell tank farms to prevent natural precipitation from running onto the tank farms and possibly mobilizing existing vadose zone contamination. Leaking water pipes also were capped or repaired.
- Leachate monitoring results at the Environmental Restoration Disposal Facility near the 200 West Area met limits defined in the record of decision.
- Soil gas monitoring continued at the Solid Waste Landfill, with no contaminants of concern exceeding reporting limits for air quality. Some contaminants continued to exceed groundwater quality criteria in the leachate.

***Water-table elevations** are measured across the Hanford Site with an electronic water-level tape once each year. In addition, water levels are measured each time a well is sampled during the year.*

Emerging Issues

As monitoring, remediation, and related work progress, new issues of potential concern arise. Some of the issues that DOE will address in coming years include the following:

- **Waste Inventories** – Recent investigations have refined estimates for radioactive waste inventories (i.e., which type of waste went to which disposal facilities in what quantities). In some instances, the new estimates may require a re-examination of groundwater monitoring strategies.
- **Decreasing Water Table Elevation** – Because wastewater discharge to the ground has been reduced in recent years, the water table in the 200 Areas has dropped. The falling water table has caused 32 wells in the 200 Areas to go dry since fiscal year 1997 and changed groundwater flow directions, leaving gaps in monitoring networks. In some areas, the water table has fallen enough that the unconfined aquifer has disappeared and low-permeability basalt or clay extends above the water table. In these areas, routine groundwater monitoring is not applicable.
- **Monitored Natural Attenuation** – The Environmental Protection Agency has published new criteria to identify and quantify natural attenuation processes. These include a more rigorous determination of the level of contamination. For example, additional parameters to be determined are (a) mass and volume of contaminated groundwater; (b) chemical and biological processes likely to reduce the contaminant level; and (c) rate of contaminant recharge from the overlying vadose zone. These determinations are in addition to more traditional methods of monitoring contaminant concentrations at points of groundwater use or exposure.
- **Uranium Mobility** – Evidence from groundwater monitoring, laboratory studies, and remediation evaluations indicates that uranium may be less mobile in the groundwater than previously considered. New information indicates that uranium moves more slowly than groundwater flow. This is an issue for the pump-and-treat system in the 200 West Area and natural attenuation of uranium in the 300 Area. It also must be considered in evaluating the transport of uranium through the vadose zone.
- **Chromium in 100 D Area** – The concentration of hexavalent chromium in a well in the southwestern 100 D Area increased sharply in fiscal year 2001. In

August, the concentration reached 4,750 μg/L, the highest concentration on the Hanford Site. The reason for the concentration change and related changes in chromium distribution are unknown.

- **Tritium in 100 K Area** – Tritium concentrations in groundwater near the 100-K burial ground have increased in the past two years. Concentrations exceeded the drinking water standard (20,000 pCi/L) by late 2000 and were nearly 100,000 pCi/L in late 2001. It appears unlikely that past leakage from the KE fuel storage basin or continued movement from the KE condensate crib are the source of this tritium. The source has not been positively determined, but the current hypothesis involved a previously unmapped tritium plume located beneath the 100-K burial ground.

Wells in the 200 Areas that were formerly sampled for the Groundwater Project have gone dry as the water table declined. Most of the wells are in the 200 West Area.

Fiscal Year	200 West	200 East	Both
1997	1	1	2
1998	2	1	3
1999	12	1	13
2000	7	1	8
2001	5	1	6
1997 to 2001	27	5	32

*A **groundwater monitoring network** strategically located across the Hanford Site helps determine changes in the direction of groundwater flow as the site returns to pre-Hanford conditions.*

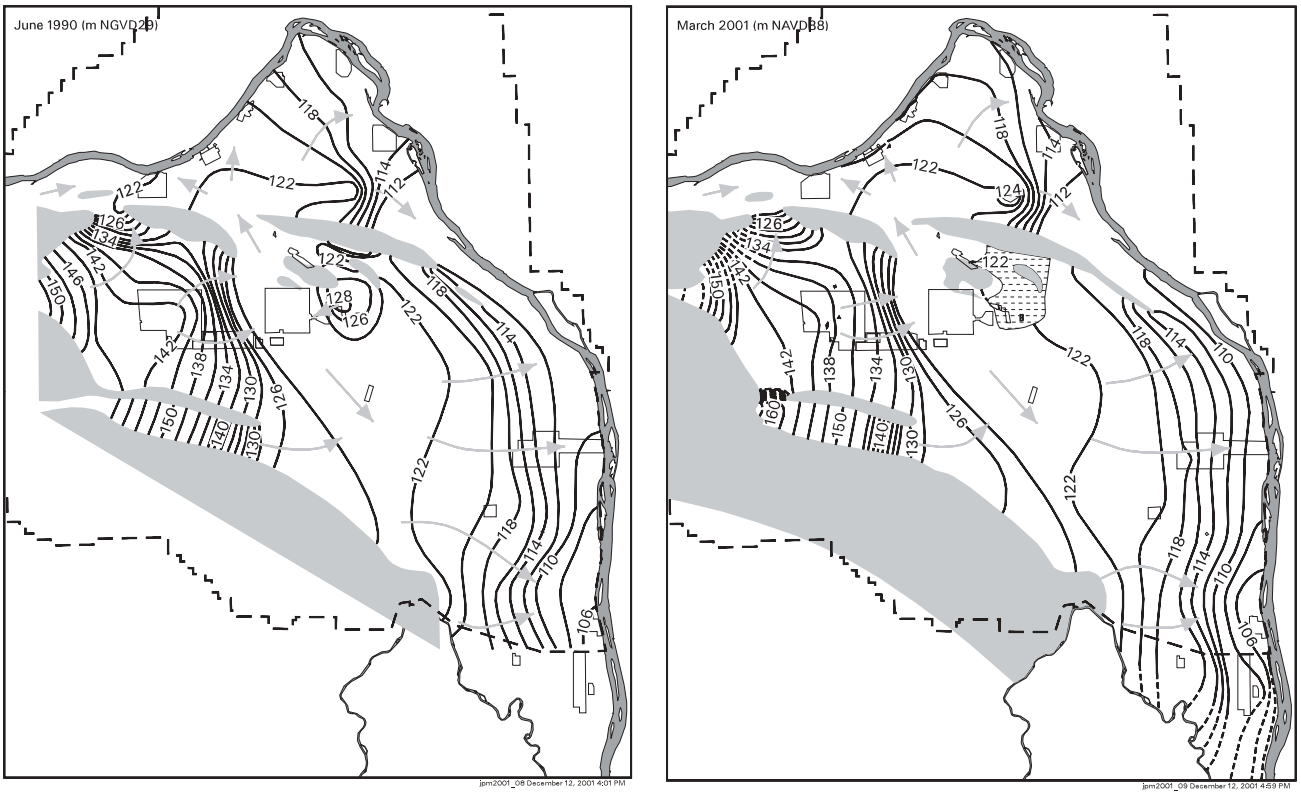
Groundwater Flow and Movement

Groundwater in the unconfined aquifer generally flows from west to east across the Hanford Site to discharge areas along the Columbia River. The direction of groundwater flow is inferred from water-table elevations, barriers to flow (e.g., basalt or mud units at the water table), and the distribution of contaminants.

General directions of groundwater flow are illustrated on the following map (page 6) for March 2001. Beneath the reactor areas groundwater flows generally toward the Columbia River. Groundwater seeps appear along the riverbank when river levels are low. Farther inland, north of Gable Mountain, flow is toward the northeast and east. Groundwater beneath the 200 West Area flows eastward beneath the 200 East Area and then flows to the southeast. Groundwater has moved some contaminants from the northern 200 East Area through the gap between Gable Butte and Gable Mountain. This northward flow appears to be diminishing as discussed below. Groundwater converges on the 300 Area from the northwest, west, and southwest and discharges into the Columbia River to the east. Groundwater in the Richland North Area flows generally eastward to the Columbia River.

*The top of an **unconfined aquifer** is the water table. At Hanford, the unconfined aquifer is in a sequence of sandy, gravelly sediment, and depth to the water table ranges from less than 1 meter near the river to more than 100 meters in the center of the Site. **Confined aquifers** are capped by less permeable layers that cannot transmit much water. Confined aquifers at Hanford occur beneath clay or basalt layers.*

The natural pattern of groundwater flow was altered during the Hanford Site's operating years by the formation of mounds in the water table. The mounds were created by the discharge of large volumes of wastewater to the ground and were present in each reactor area and beneath the 200 Areas. Since effluent disposal has decreased significantly, these mounds are disappearing. The 1990 water-table map shows groundwater mounds beneath the 200 West and 200 East Areas, which created radial flow near the mounds and induced northward flow toward the gap between Gable Mountain and Gable Butte. The 200 East Area mound is gone and



These maps show the water table and inferred flow directions in June 1990 (National Geodetic Vertical Datum of 1929) and March 2001 (North American Vertical Datum of 1988). NGVD29 is ~1 meter lower than NAVD88. The water table declined beneath most of the Hanford Site during that period. Shaded areas in both maps and the area filled with dashed lines in the 2001 map show where the unconfined aquifer is absent.

Water-table maps *are used to help determine the direction of groundwater flow. Groundwater seeps between the sediment grains in the aquifer from areas where the water-table elevation is high to where it is low.*

the 200 West Area mound is much less prominent in the fiscal year 2001 map. Water levels east of the 200 East Area have dropped below the top of a fine-grained confining unit, thus creating a barrier to movement in the surrounding unconfined aquifer. Beneath this confining unit, the uppermost aquifer is a permeable unit in the Ringold Formation. Groundwater flow in this confined aquifer still is influenced by the recharge mound that formerly created an unconfined aquifer above the fine-grained confining unit in the area.

The end of most effluent discharge changed the direction and rate of groundwater movement, especially in the 200 Areas. The water-table decline continued during fiscal year 2001, causing some monitoring wells to go dry. Drillers installed new wells to replace dry ones at locations agreed upon by DOE and the Washington State Department of Ecology.

Groundwater in the upper basalt-confined aquifer generally flows from west to east across the Hanford Site, up through the unconfined aquifer, and into the Columbia River. Vertical gradients between the basalt-confined aquifer and the unconfined aquifer are upward on most of the Hanford Site. Therefore, there is little potential for contaminants to migrate from the unconfined aquifer into the basalt-confined aquifer, where it could move offsite. Downward gradients are measured beneath the western portion of the site and north and east of the Columbia River.

Overview of Contaminants

The distribution of nine principal groundwater contamination plumes is shown on the maps on the following pages. The following paragraphs provide some basic

information about contaminants on the Hanford Site. More specific information is provided in the sections on the geographic regions of the plume sources.

Tritium – Tritium was common in Hanford Site liquid waste discharged to the soil and is the most mobile and most widely distributed radionuclide onsite. It has a relatively short half-life (12.3 years). The drinking water standard, 20,000 pCi/L, is exceeded in parts of the 100, 200, and 600 Areas. The most prominent tritium plume originated from disposal cribs in the 200 East Area near the PUREX Plant and has migrated downgradient to the southeast where it meets the Columbia River.

Iodine-129 – Iodine-129 is a fission product and was present in waste related to fuel processing. The presence of iodine-129 in groundwater is significant because of its relatively low (1 pCi/L) drinking water standard, its long-term releases from nuclear fuel processing facilities, and its long half-life (16 million years). Iodine-129 is very mobile in groundwater. Waste containing iodine-129 was historically disposed of in the 200 Areas, and groundwater plumes are similar in shape and extent to the tritium plumes, though concentrations above the drinking water standard have not reached the Columbia River.

*The **chemical and physical characteristics** of groundwater vary across areas and time. The interpretation of sampling results must, therefore, be carried out with great care.*

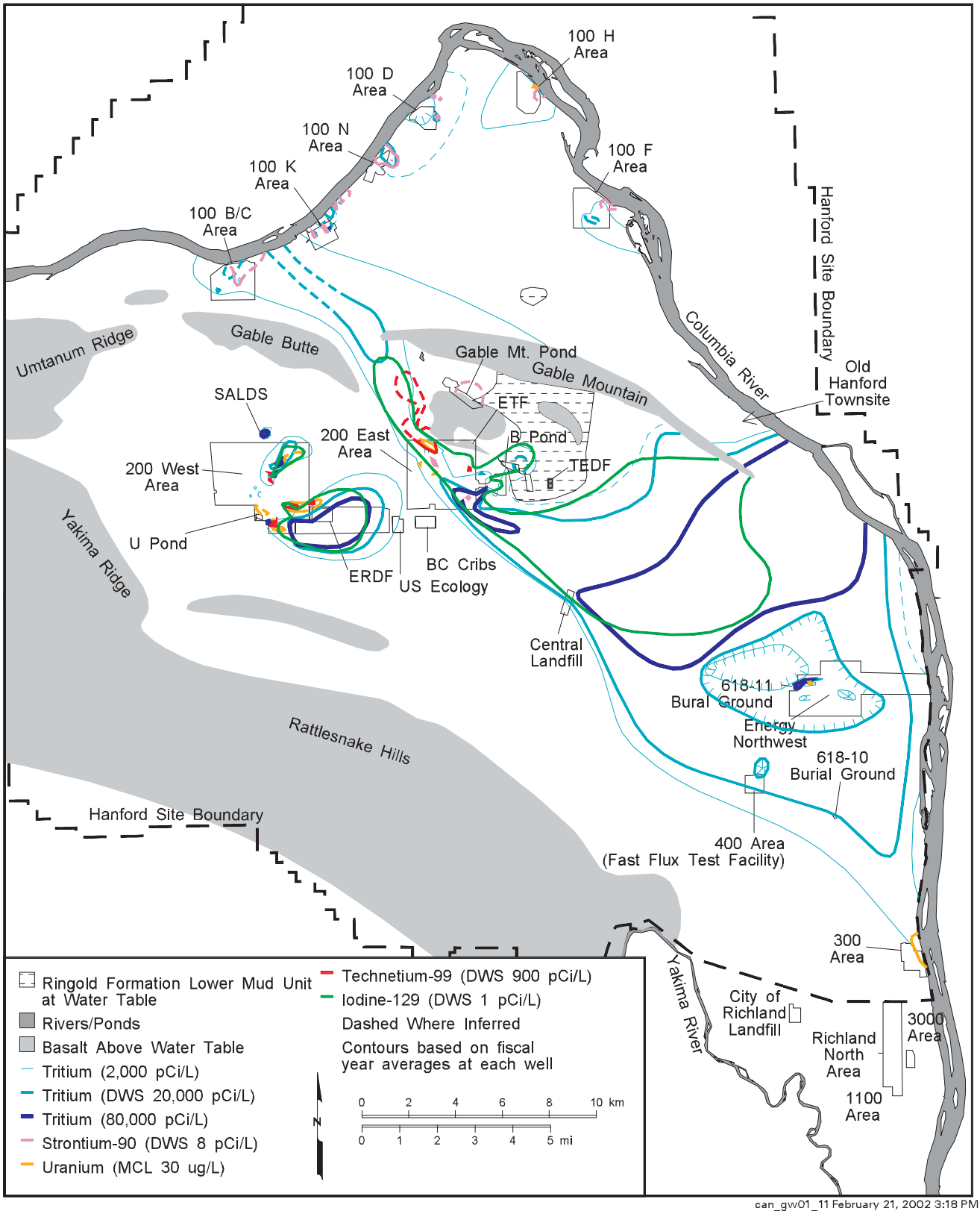
Strontium-90 – Strontium-90 was present in waste associated with fuel processing. It was released also by fuel element failures during reactor operations. Strontium-90 has a half-life of 28.8 years and a drinking water standard of 8 pCi/L. It moves slowly through the vadose zone and in groundwater. A pump-and-treat system in the 100 N Area minimizes its flow into the Columbia River. Strontium-90 also exceeds the drinking water standard beneath the other reactor areas, the 200 Areas, and the former Gable Mountain Pond.

Technetium-99 – Technetium-99 was produced as a high-yield fission product and was present in waste streams associated with fuel processing. It has a half-life of 210,000 years and a drinking water standard of 900 pCi/L. Technetium-99 is very mobile in groundwater and concentrations exceed the drinking water standard beneath portions of the 200 Areas. A technetium-99 plume in the 200 West Area is being contained by a pump-and-treat system. Another plume is located in the northwestern 200 East Area and extends north toward the gap between Gable Butte and Gable Mountain.

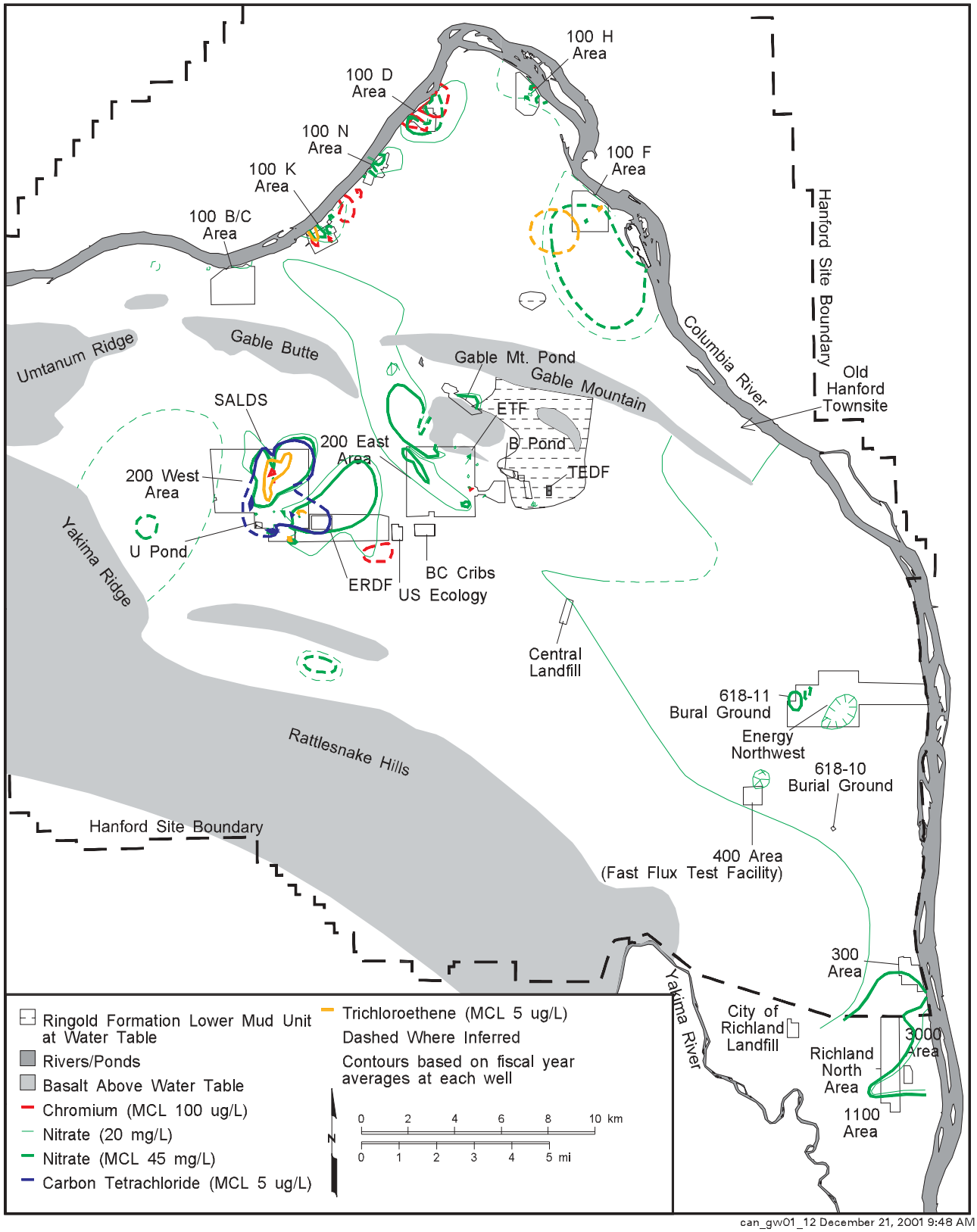
Area of Contaminant Plumes at Levels Above Drinking Water Standards (square kilometers)

Constituent (drinking water standard)	Fiscal Year 1999	Fiscal Year 2000	Fiscal Year 2001
Carbon tetrachloride (5 µg/L)	11.5	9.8	9.8
Chromium (100 µg/L)	2.7	2.8	2.8
Iodine-129 (1 pCi/L)	87.0	89.6	79.5[a]
Nitrate (45 mg/L)	40.5	36.3	38.4
Strontium-90 (8 pCi/L)	2.7	2.8	2.7
Technetium-99 (900 pCi/L)	2.4	2.3	2.4
Trichloroethene (5 µg/L)	4.5	4.2	4.3
Tritium (20,000 pCi/L)	192	152[a]	151
Uranium (20/30 µg/L)	1.9	2.0	1.6
Combined Plumes	249	210[a]	208 (80.3 square miles)
Estimated volume of contaminated groundwater (L)	Not available	1.1 trillion	1 trillion (2.70 billion gallons)

(a) These large changes in estimates of plume area are caused by changing interpretations of the data and changes to the monitoring network. Changes in actual plume size are usually more gradual.



This map shows the distribution of major radionuclides in groundwater at concentrations above maximum contaminant levels or drinking water standards during fiscal year 2001.



This map shows the distribution of major hazardous chemicals in groundwater at concentrations above maximum contaminant levels during fiscal year 2001.

*Because **contaminants** were disposed to the ground or were contained in leaking tanks, groundwater is the major pathway through which contaminants move off the Hanford Site.*

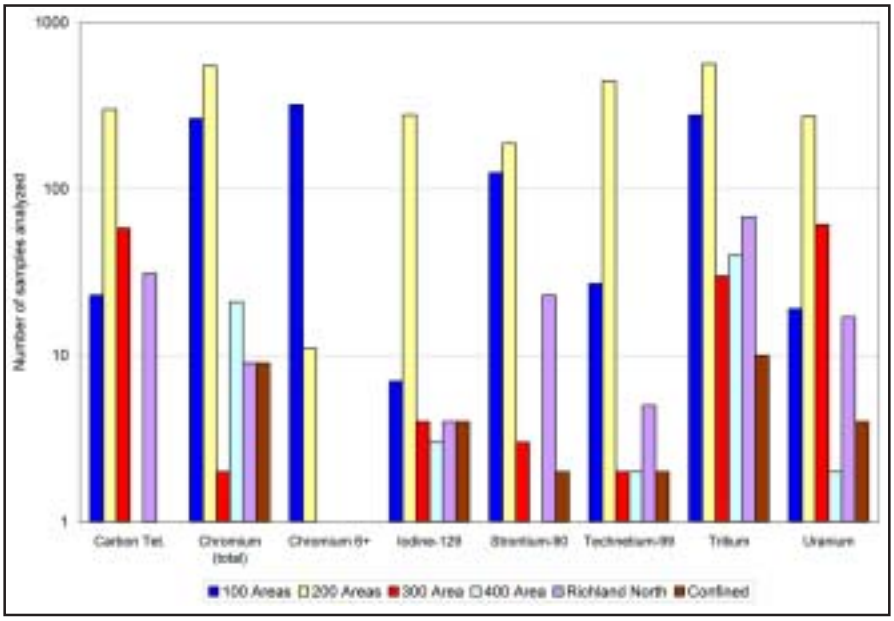
Uranium – Uranium contamination on the Hanford Site had numerous potential sources including fuel fabrication, fuel processing, and uranium recovery from separations activities. Uranium tended to be associated with technetium-99 through the fuel processing cycle, but uranium is less mobile in groundwater on the Hanford Site. The drinking water standard is 30 µg/L. Plumes are detected in the 200 West, 200 East, and 300 Areas.

Chromium – A major source for chromium was the sodium dichromate used as a corrosion inhibitor in cooling water for reactors in the 100 Areas. In the 100 K, 100 D, and 100 H Areas, interim actions are underway to pump and treat groundwater to reduce the amount of chromium reaching the Columbia River. Chromium concentrations continued to exceed the 22 µg/L cleanup goal in all these areas in fiscal year 2001. Another interim action in the 100 D Area is designed to immobilize chromium in the aquifer.

Carbon tetrachloride – Carbon tetrachloride was used in plutonium processing in the 200 West Area, where concentrations in groundwater exceed the 5 µg/L maximum contaminant level. The plume extends beyond the area boundary and forms the most widespread organic contaminant plume on the Hanford Site.

Nitrate – Nitrate contamination in the unconfined aquifer reflects the extensive use of nitric acid in decontamination and chemical processing operations. Like tritium, nitrate was present in many waste streams and is mobile in groundwater. Agricultural sources of nitrate are located off the Hanford Site to the south and west. Nitrate was measured at concentrations greater than the maximum contaminant level (45 mg/L) in wells in all operational areas except 100 B/C.

Trichloroethene – Trichloroethene was used on the Hanford Site in the 1960s and 1970s as a degreasing compound. The drinking water standard is 5 µg/L. The most extensive plume is in the 200 West Area. Trichloroethene also exceeded the standard in the 100 K and 100 F Areas. Annual average concentrations in the 300 and Richland North Areas declined below the standard in all wells in fiscal year 2001.



The groundwater project requests specific laboratory analyses based on the well's location, historical contaminant trends, and regulatory requirements. This graph shows the number of analyses for some of the primary contaminants of concern during fiscal year 2001.

Cyanide – Cyanide was associated with waste discharged to the BY cribs near 200 East Area. In groundwater, it exceeded the 200 µg/L drinking water standard in three wells and concentrations are increasing because of changing flow directions.

Carbon-14 – Carbon-14 exceeded the 2,000 pCi/L drinking water standard in two small plumes near waste disposal facilities adjacent to the KW and KE Reactor buildings where reactor atmosphere gas condensate was discharged to the ground in the past. The half-life is 5,730 years.

Cesium-137 – Cesium-137 is a high-yield fission product with a half-life of 30 years and a drinking water standard of 200 pCi/L. It was present in waste associated with fuel processing and has been released in reactor areas by fuel element failures. Cesium-137 was present in waste that leaked from underground storage tanks in the past. It is present in the vadose zone near the single-shell tanks, but is rarely detected in groundwater.

Plutonium – Plutonium was present in waste associated with fuel processing. It has a low mobility in groundwater and a long half-life (24,000 years for plutonium-239 and 6,500 years for plutonium-240). The only significant detection of plutonium in recent years was associated with the 216-B-5 injection well in the 200 East Area.

Dose Estimates and Risk Estimates

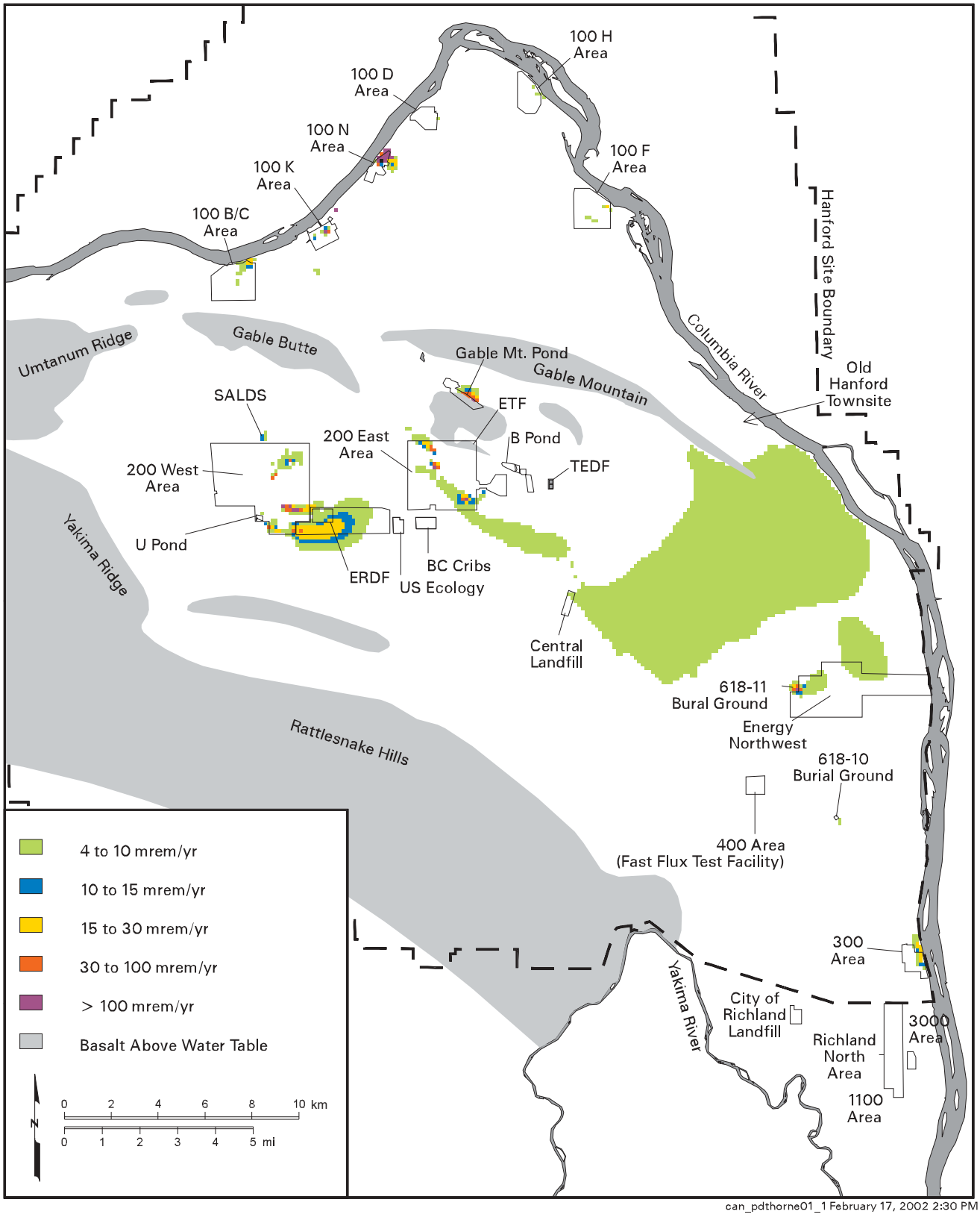
Groundwater is not a primary source of drinking water for most Hanford Site workers. However, comparison to drinking water standards provides perspective for contaminant levels in groundwater. Drinking water standards use the methods set out in 40 CFR 141, 40 CFR 142, and 40 CFR 143 to estimate the concentration in water that could result in a potential radiological dose of 4 millirem per year from consumption of each individual constituent. Similarly, DOE-derived concentration guides provide estimates of radiological concentration that could result in a 100 millirem per year dose as defined in DOE Order 5400.5. DOE estimates the potential dose from ingestion of groundwater by adding the effects of all major radionuclides in Hanford Site groundwater: carbon-14, cesium-137, iodine-129, plutonium, strontium-90, technetium-99, tritium, and uranium.

__Hanford groundwater__ is not a primary source of drinking water, but it flows into the Columbia River, which is a major drinking water source. Therefore, DOE is focusing their remediation efforts on protecting the Columbia River.

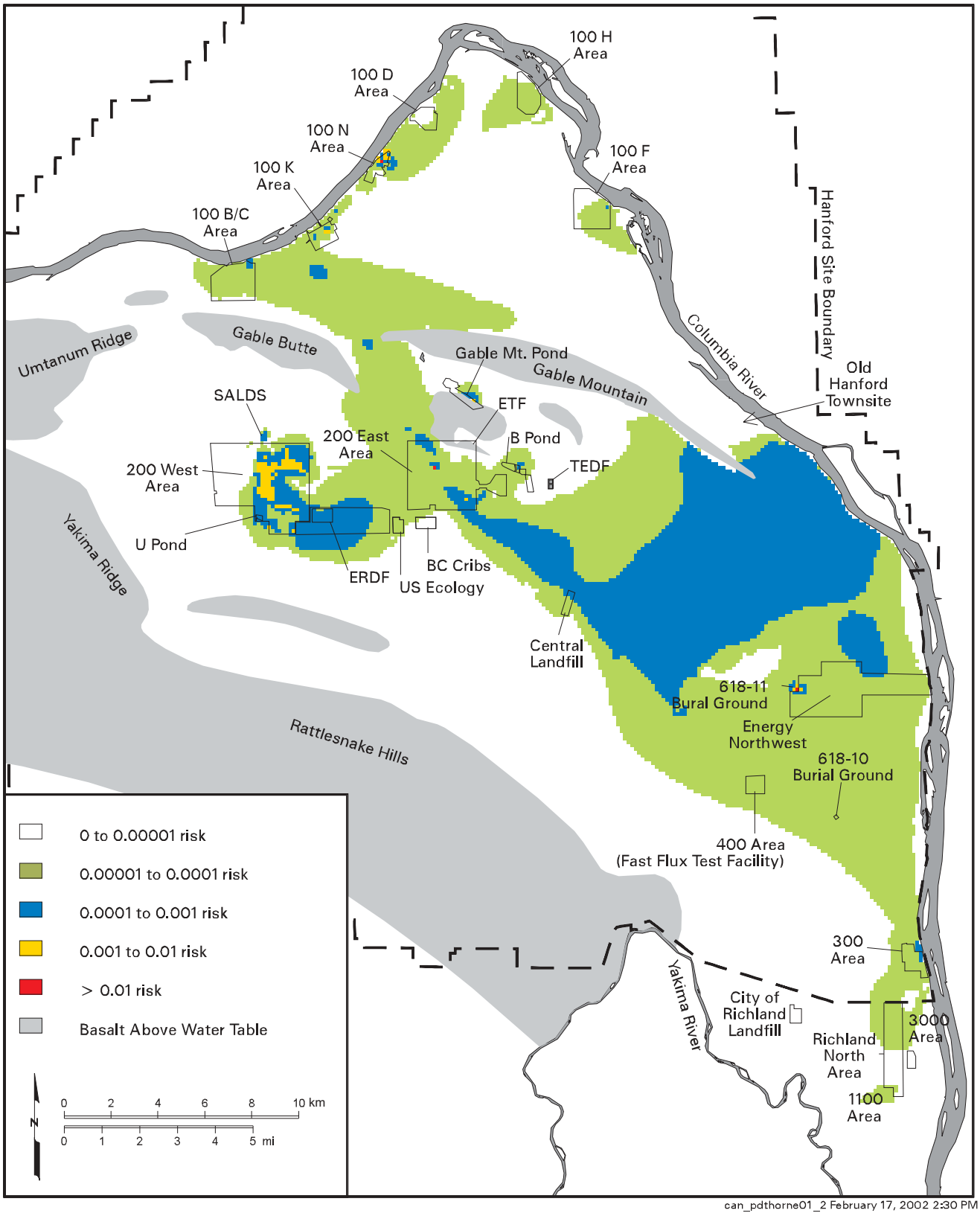
The dose estimates presented on page 12 show that areas above the 100-millirem per year dose standard are restricted to localized parts of the 100 K, 100 N, and 200 Areas and a location around a single well downgradient of the 618-11 burial ground. Portions of the 100, 200, 300, and 600 Areas exceed 4 millirem per year.

DOE estimates the likelihood of a person developing cancer over a lifetime as a result of drinking water contaminated with chemicals and radionuclides at concentrations that have been measured in groundwater across the Hanford Site. Cancer-risk estimates were made by adding concentrations of the radionuclides listed above plus carbon tetrachloride, chloroform, cis-1,2-dichloroethene, hexavalent chromium, nitrate, and trichloroethene. The calculation assumes that a person weighing 70 kilograms consumes 2 liters of groundwater every day for 30 years. Cancer risks exceeding 0.0001 (i.e., 1 in 10,000) are present in portions of the 100, 200, 300, and 600 Areas.

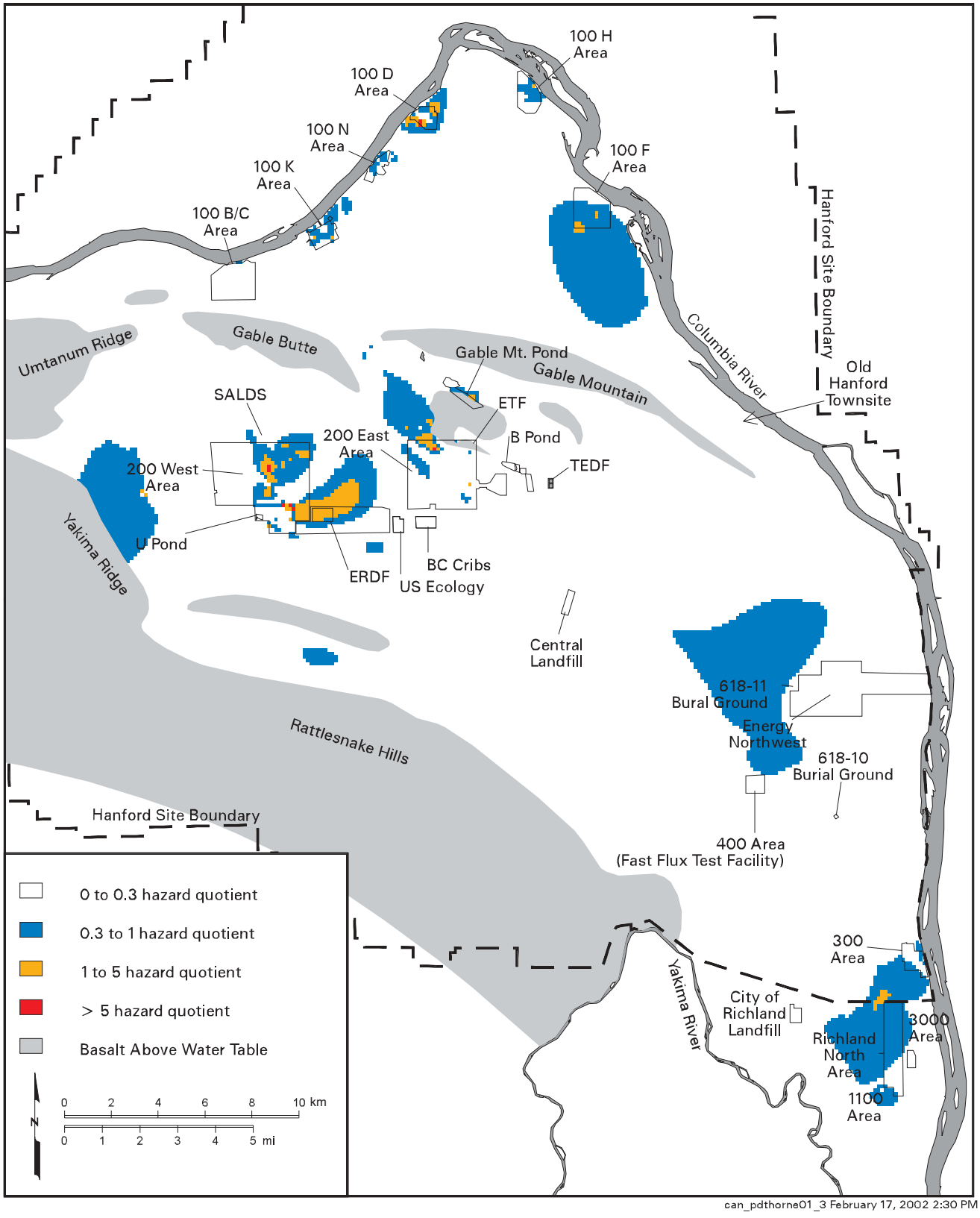
The hazard quotient relates the potential human health hazards associated with exposure to non-carcinogenic substances or carcinogenic substances with systemic toxicity other than cancer (in Hanford Site groundwater, these include hexavalent chromium, nitrate, strontium, and uranium). The calculation assumes that a person weighing 70 kilograms consumes 2 liters of groundwater every day for 30 years. If the hazard quotient is greater than one, there is a possibility of toxic effects.



If people drank contaminated groundwater from the Hanford Site, their dose of radioactivity would equal the combined dose from individual radionuclides. However, Hanford Site groundwater is not a major source of drinking water.



If people drank contaminated groundwater from the Hanford Site for many years, they might increase their risk of cancer. Radiological and chemical contaminants contribute to the total risk.



Health risks caused by non-radiological, non-carcinogenic contaminants are estimated by the "hazard quotient." Consumption of contaminated groundwater would increase these risks.

Hazard quotients between 1 and 5 are present in the 100 and 200 Areas and from offsite contamination in the Richland North Area. The only locations with hazard quotients above 5 are small portions of the 100 D, 200 West, and 200 East Areas.

100 Areas Groundwater Contamination

During 1944 to 1988, fabricated fuel cylinders were shipped by rail from the 300 Area to the reactors in the 100 Areas for irradiation, the second step in the plutonium production process. The nine plutonium production reactors are ~48 kilometers from Richland in the northern portion of the Hanford Site along the south bank of the Columbia River. The reactor areas had to be close to the river because large quantities of water were required for cooling.

Today, the most prominent contaminants in 100 Areas groundwater are tritium, strontium-90, hexavalent chromium, and nitrate. These contaminants originated from disposal cribs, trenches, and leaking retention basins. Because these sites are so close to the Columbia River, all of these contaminants have been detected in springs that discharge to the river.

100 B/C Area. Most of the groundwater contamination in the 100 B/C Area is found in the northern portion of the area, beneath waste trenches and retention basins. Tritium and strontium-90 exceeded drinking water standards in several wells. Nitrate and chromium were somewhat elevated, but were below drinking water standards in fiscal year 2001. Surface waste sites have been excavated and backfilled. There is no active groundwater remediation in the 100 B/C Area.

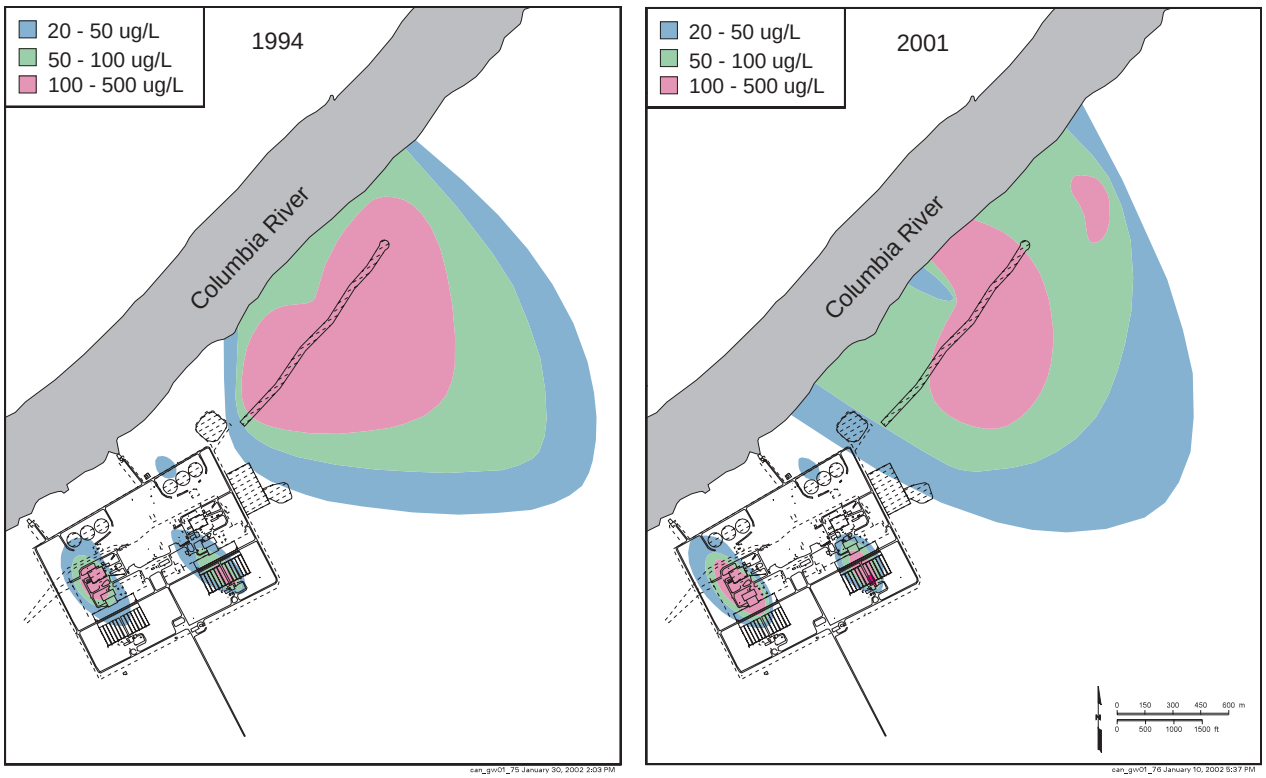
100 K Area. The primary constituents of concern in 100 K Area groundwater are hexavalent chromium and tritium. The major chromium plume is beneath the 116-K-2 trench, located east of 100 K Area near the Columbia River. This plume is the target of a pump-and-treat system that reduces contaminated flow into the river.

Monitoring well networks *are designed specifically for individual areas based on the type of data needed, the hydrogeologic conditions, geologic conditions, groundwater flow directions, and the expected contaminants.*

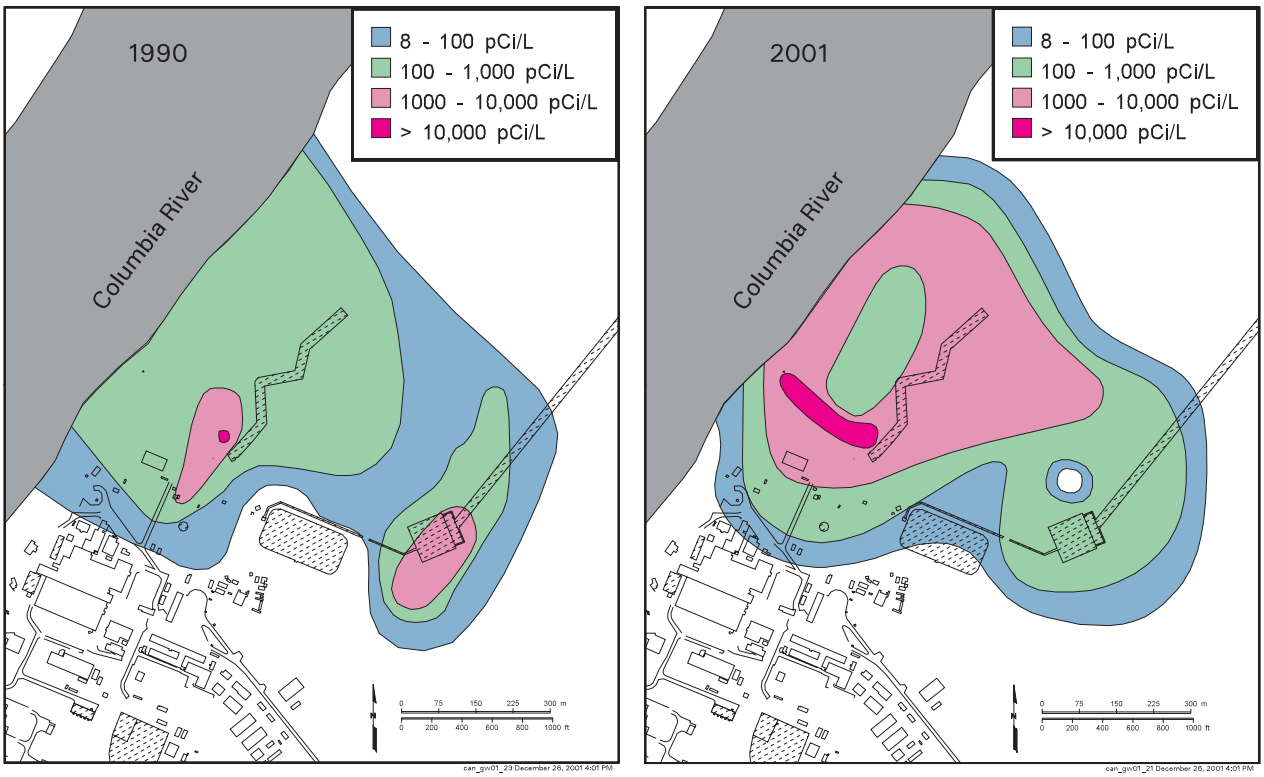
High concentrations of tritium in very small plumes originated from past leaks in fuel storage basins within the KE Reactor building. The highest concentration was 1.75 million pCi/L in fiscal year 2001. No new leaks have been detected since 1993. One monitoring well near the 100-K burial ground detected a sharp rise in tritium concentrations that appears to indicate the presence of a previously unidentified plume. Other groundwater contaminants in the 100 K Area include carbon-14, nitrate, and trichloroethene.

100 N Area. The primary groundwater contaminant in the 100 N Area is strontium-90. This plume originated at the 1301-N crib near the river, and to a lesser extent, the 1325-N crib. The extent of the plume changed very little over the past 10 years but concentrations increased during the 1990s because of changing water levels and the end of effluent discharge. A pump-and-treat system in the 100 N Area operates to reduce the movement of strontium-90 toward the Columbia River. Since strontium-90 binds to sediment grains, pump-and-treat is not an effective way to clean up the aquifer. Tritium also was present in waste discharged to the 100 N 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. One of the major waste disposal facilities was excavated in fiscal year 2001 and will be backfilled in 2002.

100 D Area. Hexavalent chromium is the primary contaminant of concern in the 100 D Area. The source of this contaminant was sodium dichromate added to cooling water to inhibit corrosion. The water was discharged to cribs and ditches, and some spillage of sodium dichromate also occurred. Hexavalent chromium is highly mobile in groundwater. Chromium is distributed in two plumes beneath



A pump-and-treat system in the 100 K Area reduces the amount of chromium entering the Columbia River. The shape of the plume and concentrations within it have remained fairly stable since 1994.



Concentrations of strontium-90 in the 100 N Area increased after 1990, but the shape of the plume remained about the same in 2001. Concentrations near the river decreased because of effects related to a pump-and-treat system.

the 100 D Area. The northern plume is the target of a pump-and-treat system for the 100-HR-3 operable unit, which also includes the 100 H Area. The southwestern chromium plume is being remediated with an in situ system that immobilizes chromium in the aquifer. This plume had the highest chromium concentrations on the Hanford Site in fiscal year 2001: 4,750 μg/L, which was a large increase from fiscal year 2000.

Nitrate also exceeded drinking water standards in the 100 D Area in a fairly widespread plume, while strontium-90 exceeded the standard in one well. Former waste sites in the 100 D Area were excavated and backfilled in 1999 through 2001.

100 H Area. Hexavalent chromium is present in 100 H Area groundwater, but the plume is smaller and concentrations are lower than in the 100 D Area. The plume is intercepted by pumping wells, treated, and the treated water is injected into an upgradient location. Chromium concentrations have decreased in recent years. Nitrate also is elevated, but concentrations have declined from their peaks. Strontium-90 exceeds the drinking water standard beneath former retention basins. Technetium-99 and uranium are elevated in a small area downgradient of the former 183-H evaporation basins, but were below their drinking water standards in most wells. Former waste sites have been excavated and backfilled.

100 F Area. Nitrate exceeds the drinking water standard beneath much of the 100 F Area and the downgradient region. Strontium-90 exceeds the drinking water standard in a small plume beneath former waste sites in the eastern 100 F Area, near the Columbia River. Groundwater in local plumes or single wells exceeded standards for tritium, uranium, and trichloroethene. Excavation of former waste sites began in fiscal year 2001. There is no active groundwater remediation in the 100 F Area.

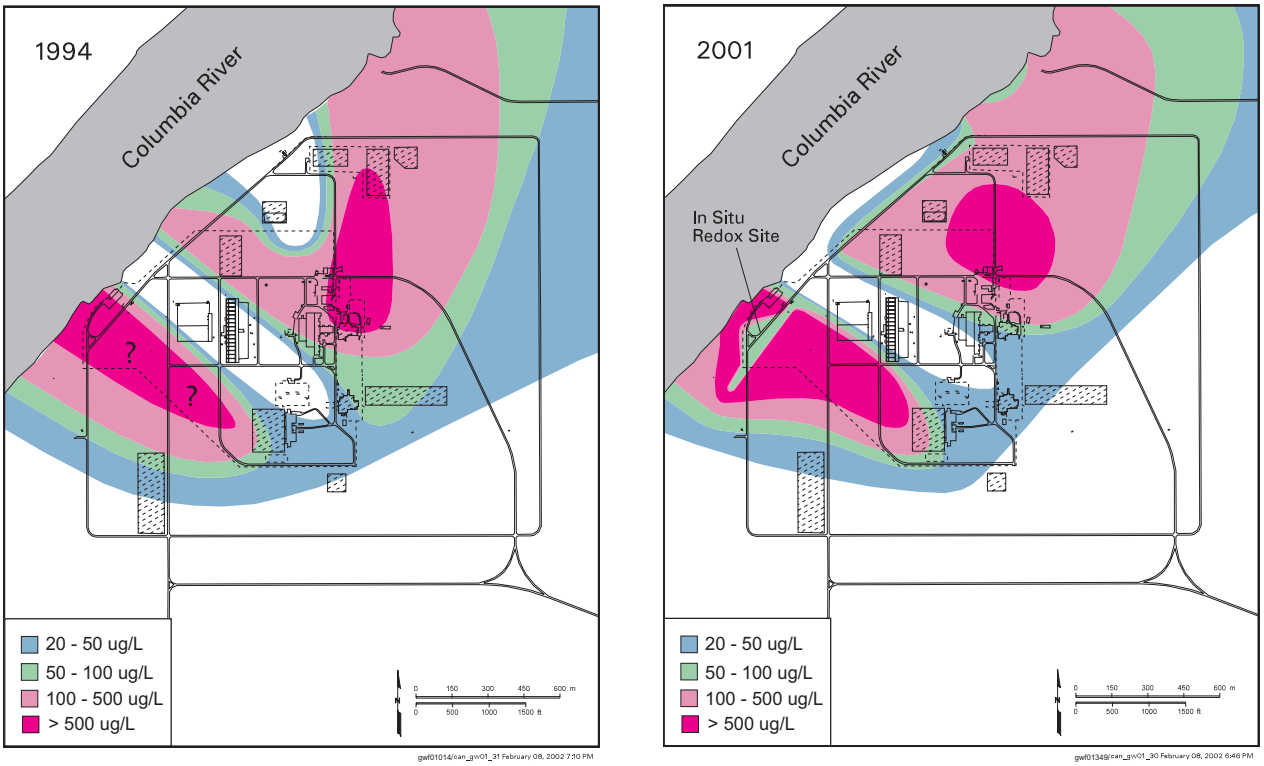
What is pump-and-treat? *Several contaminant plumes in the 100 Areas are of special concern because they are so close to the Columbia River. DOE is pumping contaminated groundwater out of chromium and strontium-90 plumes, treating it to remove the contaminants, and injecting the clean water back into the aquifer. The primary purpose of these pump-and-treat systems is to reduce the amount of contamination entering the river until a final cleanup solution is in place.*

200 Areas Groundwater Contamination

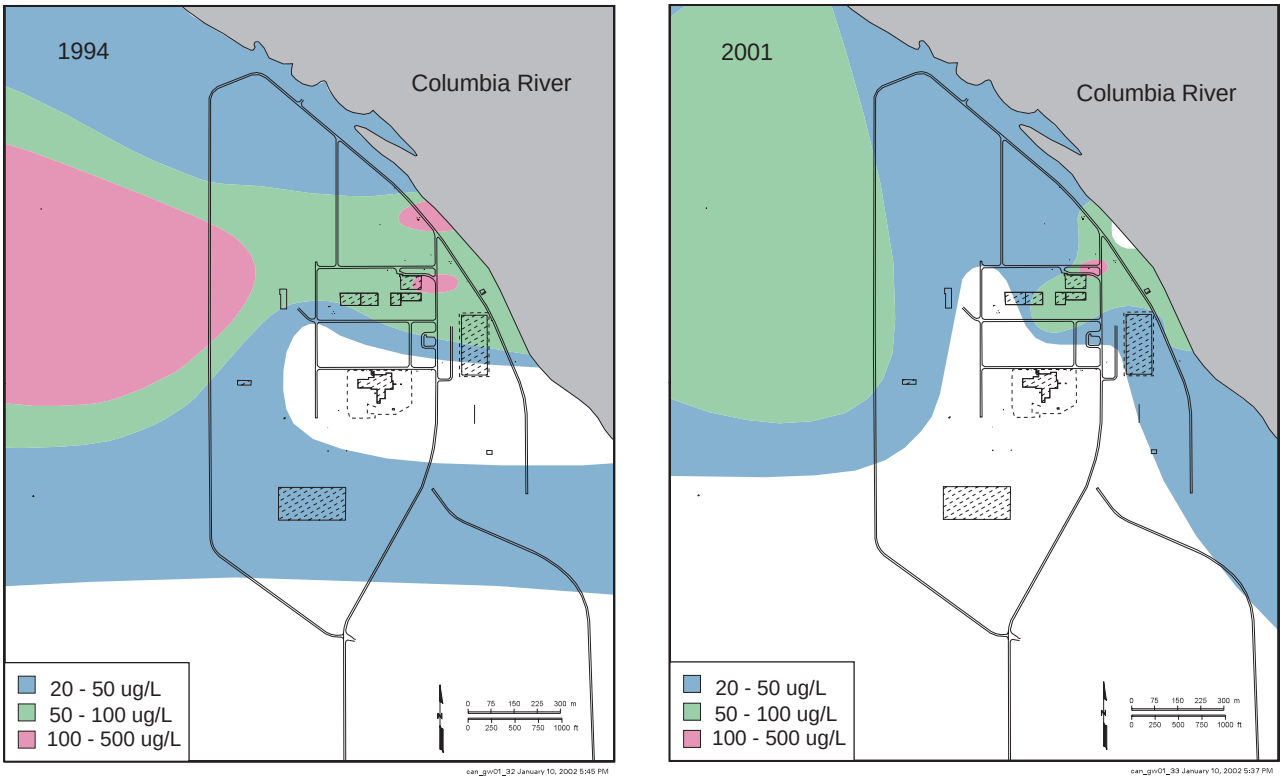
After fuel rods were irradiated in the 100 Areas, they were shipped to the 200 Areas. There, between 1944 and 1987, separations (finishing) plants processed the fuel to extract and purify plutonium. The plutonium extraction first took place at the T and B plants and later at the Reduction-Oxidation (REDOX) and PUREX plants. The Plutonium Finishing Plant was used for plutonium purification. U Plant was used to extract uranium from process waste and T Plant was converted to an equipment decontamination facility. Currently, the 200 Areas are used for waste management and disposal.

The 200 Areas are located ~32 kilometers from Richland on a plateau in the center of the Hanford Site, ~8 kilometers south of the Columbia River. During the finishing process, contaminants such as carbon tetrachloride, chromium, fluoride, iodine-129, nitrate, technetium-99, trichloroethene, tritium, and uranium were disposed to the ground in the 200 Areas. This contamination has moved into the vadose zone and is responsible for groundwater contamination currently detected at these sites.

Radioactive and hazardous chemical waste generated from plutonium production and separation activities historically was stored in single-shell tanks in the 200 Areas. These underground tanks were constructed of reinforced concrete and steel in the 1940s. Although most of the free liquid has been removed, some of these tanks leaked in the past and appear to have contributed to groundwater contamination. The tanks still contain ~87 million liters of highly caustic saltcake and 45 million liters of chemical sludge. The tanks are grouped into farms that are regulated under RCRA and monitored to detect new leaks or to define the extent of contamination.



The shape of the chromium plume in the 100 D Area has changed since 1994, partially as a result of groundwater remediation. The southwestern plume in 1994 had to be estimated because there was only one well monitoring that area.



A pump-and-treat system in the 100 H Area reduces the amount of chromium entering the Columbia River. Between 1994 and 2001, concentrations decreased through most of the plume. Much of the decrease appears to be due to natural processes.

200 West Area. The aquifer beneath the 200 West Area has a lower permeability than beneath the 200 East or 100 Areas, which slows contaminant movement.

The largest plume of chlorinated hydrocarbons on the Hanford Site is beneath the 200 West Area and includes carbon tetrachloride, chloroform, and trichloroethene. The contamination is principally from waste disposal operations associated with the Plutonium Finishing Plant, where organic chemicals were used in plutonium processing. A groundwater pump-and-treat system is operating in this area to prevent the central, high-concentration portion of the carbon tetrachloride plume (>2,000 µg/L) from spreading.

Groundwater from the Hanford Site can reach the Columbia River in days, months, or years depending on the geology and how far it has to travel. During this time, many of the contaminants are decreased by natural decay.

In some areas, concentrations of carbon tetrachloride decrease with depth, but data collected in recent years indicate that in other areas carbon tetrachloride is present at higher concentrations deeper in the Hanford/Ringold sediment than at the water table. Therefore, the extent of the plume at the water table may not reflect the extent in deeper parts of the aquifer system.

The 200 West Area also contains plumes of technetium-99 and uranium from sources near T Plant and U Plant and single-shell tank farms. A groundwater pump-and-treat system is operating near U Plant to contain the technetium-uranium plume there. Contaminant concentrations have declined, and the plumes have shrunk, apparently as a result of remediation and dispersion.

The highest tritium concentrations in the 200 West Area are detected beneath waste facilities associated with T Plant. The maximum concentration detected in fiscal year 2001 was 1.7 million pCi/L, a decrease from the past 2 years. A larger plume (with lower concentrations) originated at sites associated with the REDOX Plant in the southeastern area. It is slowly moving eastward with groundwater flow. Smaller tritium plumes are detected beneath a former waste site in the southwestern area and near an active disposal site north of 200 West Area.

Iodine-129 plumes coincide generally with the tritium plumes associated with the T Plant and REDOX Plant. The maximum concentration in fiscal year 2001 was 64 pCi/L.

The 200 West Area has two main nitrate plumes: one from the vicinity of U Plant extending into the 600 Area, and another near T Plant. Lower concentrations of contamination are found near the Plutonium Finishing and REDOX plants.

Cleaning up *contaminated groundwater often takes longer than expected because groundwater systems are complicated and contamination is invisible to the naked eye. Groundwater monitoring is an essential part of remediation because it helps find contaminants and design systems that can treat or destroy the contamination.*

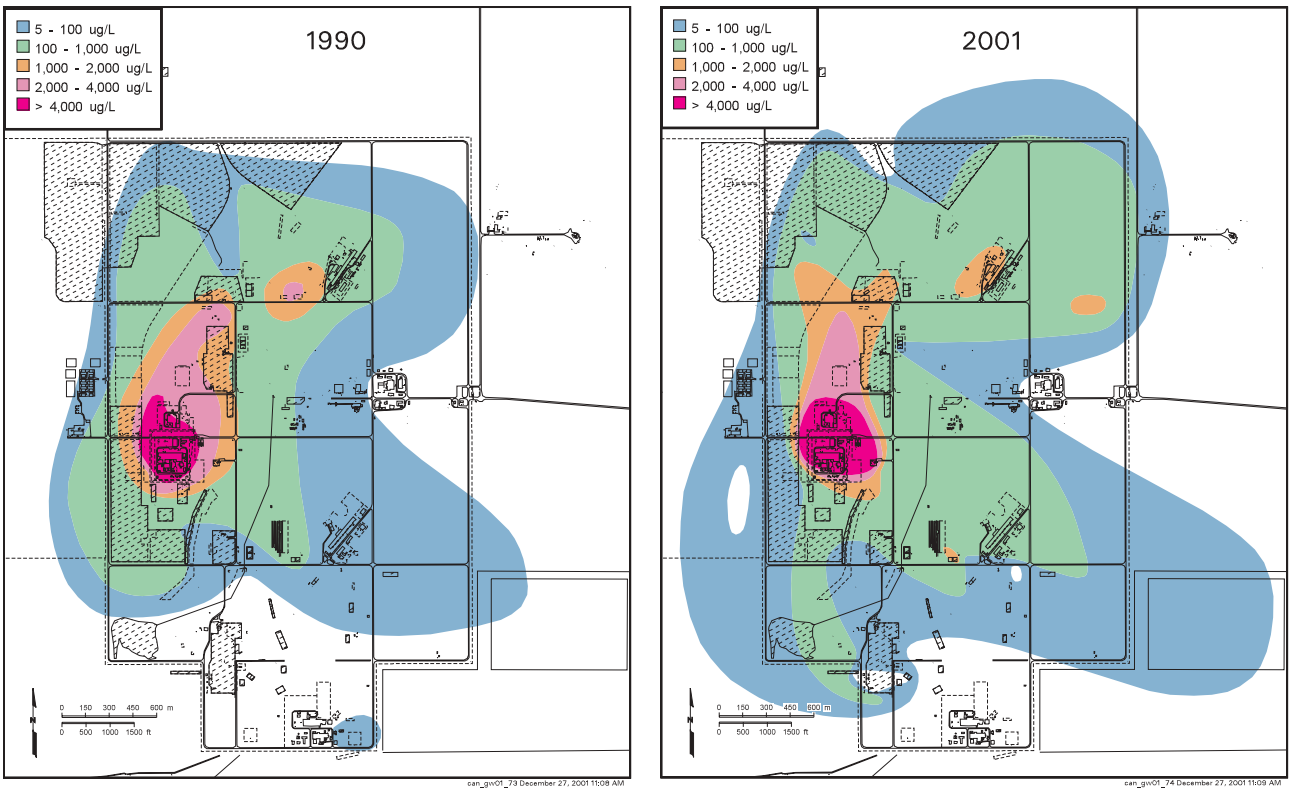
Chromium and fluoride exceeded maximum contaminant levels in several wells near Waste Management Areas T and TX-TY. The plumes are not widespread.

Strontium-90 has been detected in very small areas near facilities that received waste from the REDOX Plant. In fiscal year 2001, only one well had concentrations exceeding the drinking water standard.

200 East Area. Disposal of liquid waste in the 200 Area has contaminated groundwater with tritium, iodine-129, nitrate, and several other contaminants. The most widespread and mobile contaminants have flowed through the permeable aquifer to the Columbia River.

The largest tritium plume originated at waste sites near the PUREX Plant in the southeastern 200 East Area. Concentrations in one well near the former waste sites were up to 4.3 million pCi/L in fiscal year 2001, which is nearly double the highest concentration the previous year.

The movement of the PUREX tritium plume can be traced with historical groundwater data. By 1980, tritium concentrations above 20,000 pCi/L had reached the Columbia River at the Old Hanford Townsite. In the southern portion of the site, the 20,000-pCi/L portion of the plume had apparently flowed around less transmissive sediment beneath the Energy Northwest site. The core of the plume



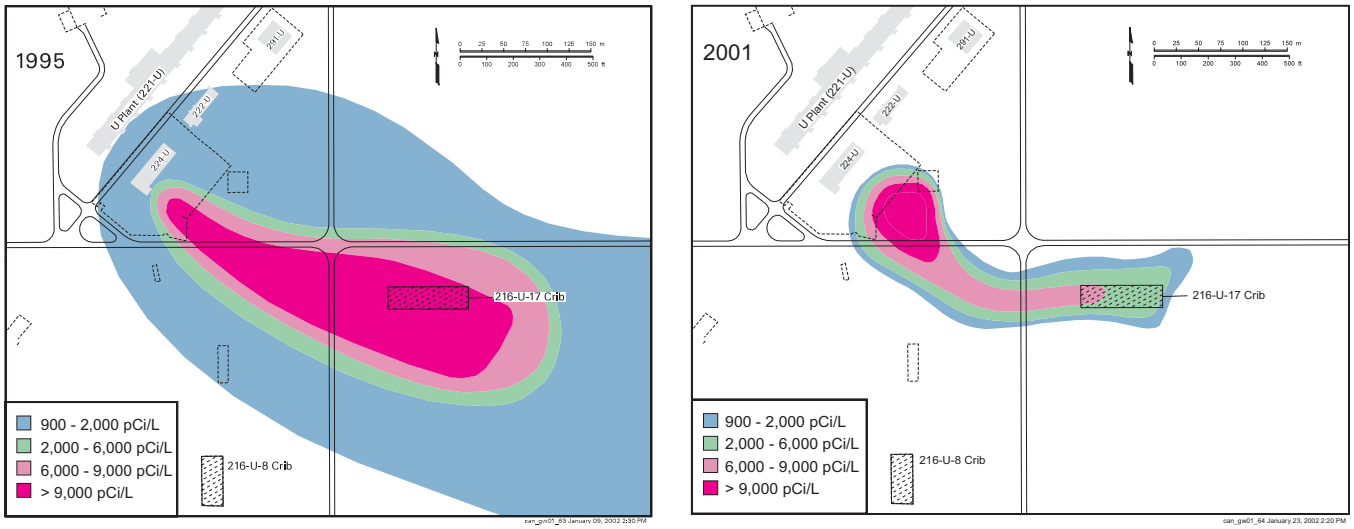
The carbon tetrachloride plume beneath the 200 West Area spread between 1990 and 2001. Since 1996, a pump-and-treat system is helping prevent further spreading of the heart of the plume, shown here in pink and red.

Pump-and-treat systems *are interim actions for groundwater remediation until a final remedy can be identified.*

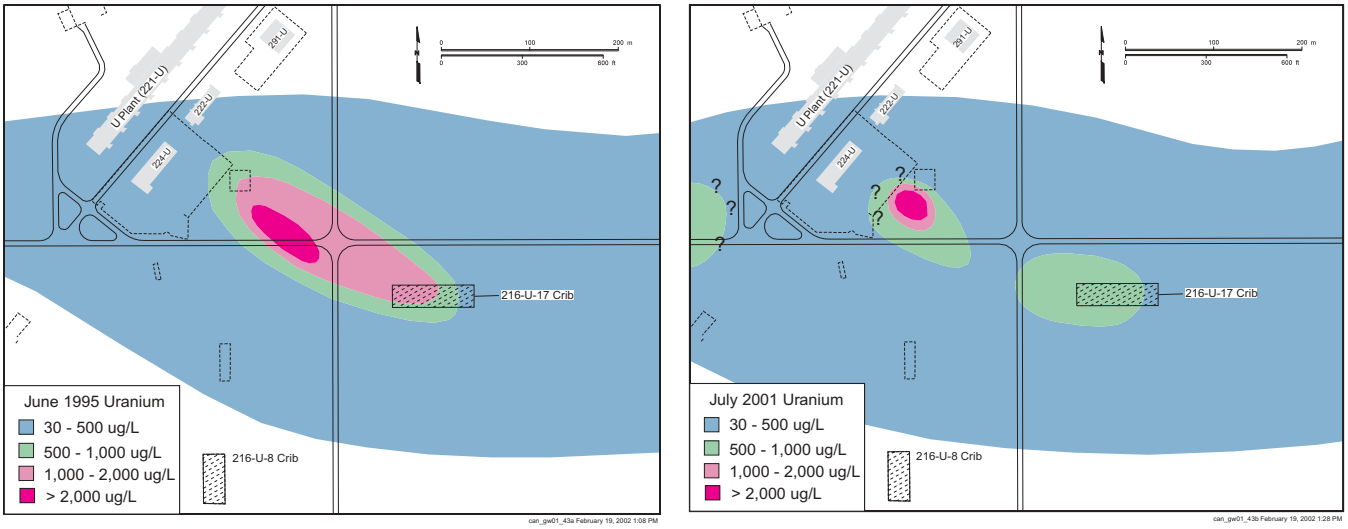
(concentrations >200,000 pCi/L) had broken off from the source in the southeastern 200 East Area. These high concentrations decreased in the past 20 years and are not seen on the map for fiscal year 2001. The southern margin of the plume appears to have ceased its southward migration in ~1995. Concentrations in the southeastern part of the plume are expected to keep declining because of dispersion and radioactive decay. Concentrations also have declined in the past 10 years in the northwestern 200 East Area, but a plume with its origins in that region is now migrating north between Gable Mountain and Gable Butte.

The iodine-129 plume originating in the 200 East Area is similar to the tritium plume, but concentrations greater than the drinking water standard have not reached the Columbia River. The maximum concentration in fiscal year 2001 was 10 pCi/L with a declining trend. The iodine-129 plume from 200 East Area probably migrated at about the same rate as the tritium plume, but iodine-129 data were not commonly collected until the 1980s. By 1990, the portion of the plume exceeding the 1 pCi/L drinking water standard had traveled more than halfway to the Columbia River. It moved an additional 2.5 kilometers between 1990 and 2001. The plume will continue moving toward the river, but concentrations are expected to decline because of dispersion.

Waste sites near the PUREX Plant in the 200 East Area contributed to extensive nitrate plumes that extend to the southeast, but only proportionally small areas contain nitrate at levels above the maximum contaminant level. This plume extends to wells near the Columbia River at the Old Hanford Townsite, where nitrate concentrations are below the maximum contaminant level and are gradually declining. Another nitrate plume originated from sites in the northwestern 200 East Area and spread northward between Gable Butte and Gable Mountain.



A pump-and-treat system at the 200-UP-1 Operable Unit (200 West Area) has decreased the size of the technetium-99 plume. The system began to operate in fall 1995.

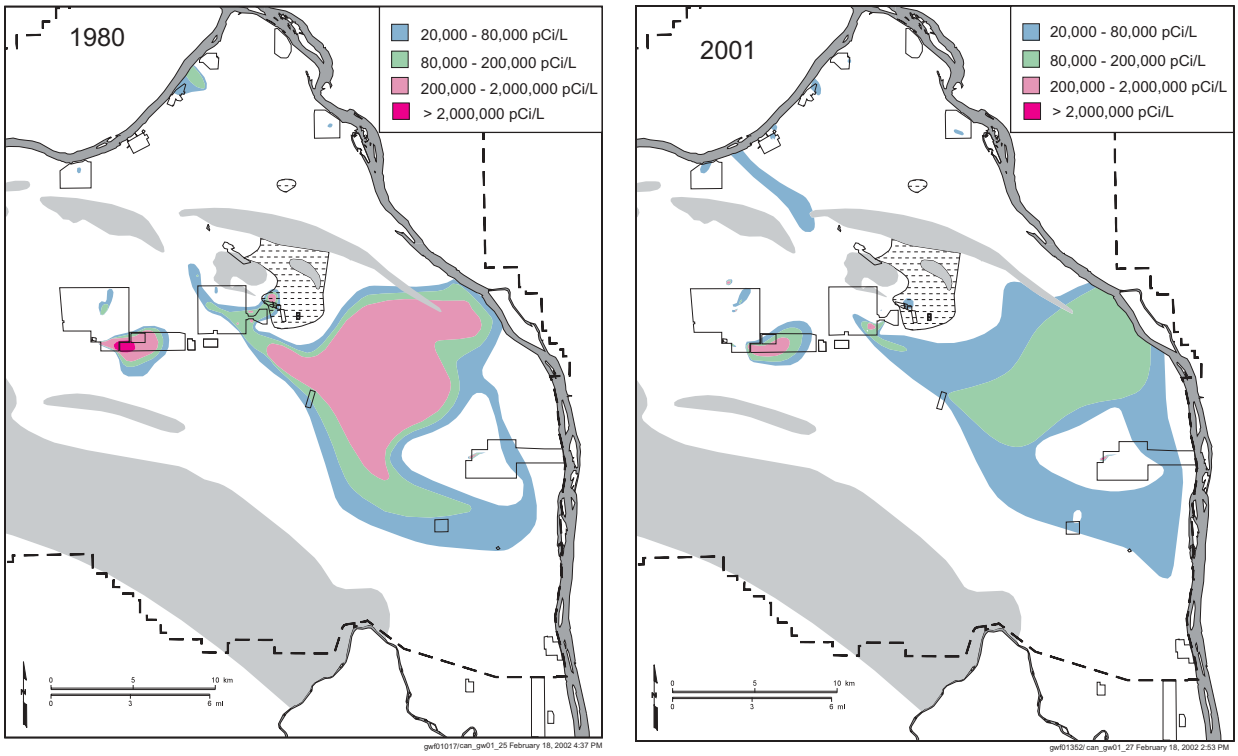


Uranium contamination in the 200-UP-1 Operable Unit is not responding to the pump-and-treat system as quickly as the technetium-99. Also, many monitoring wells in the plume have gone dry, making interpretation of plume size less certain.

Elevated technetium-99 levels are associated with the BY cribs in the northwestern 200 East Area. Past leakage from the B-BX-BY single-shell tank farms also appears to be a source of technetium-99 in this area. The technetium-99 plume is associated with elevated uranium, though the uranium is not as extensive.

The former 216-B-5 injection well in the northwestern 200 East Area contaminated groundwater with radionuclides including cesium-137, plutonium, and strontium-90. The residual contamination is very localized.

Other groundwater contaminants in the 200 East Area include cobalt-60 and cyanide near the BY cribs in the northwestern area, and strontium-90 beneath the former Gable Mountain Pond.



Tritium plumes in 1980 and 2001 are shown in the above maps. Concentrations in the heart of the plume have decreased over the years; in approximately 1995, the southern margin appears to have ceased its southward migration.

***Tritium** is very mobile in groundwater and has migrated from sources in the 200 Areas toward the southeast and the Columbia River.*

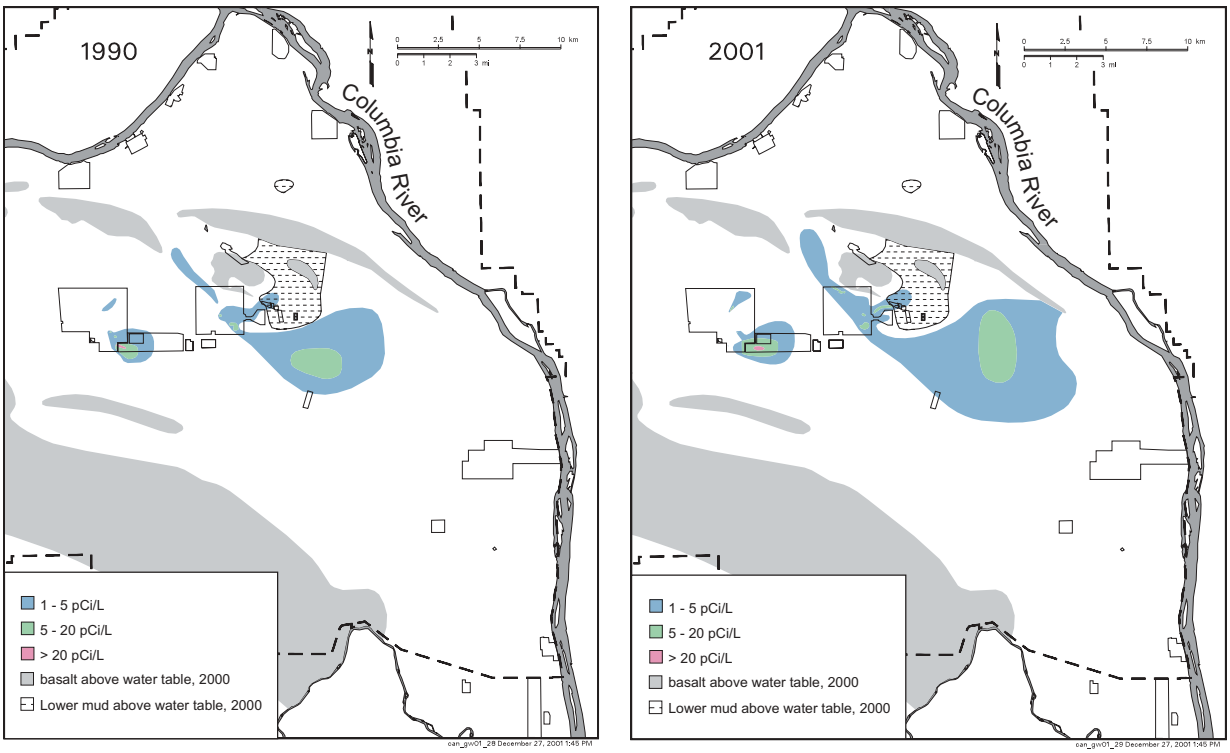
400 Area Groundwater Contamination

The 400 Area is the location of the Fast Flux Test Facility, the largest test reactor on the Hanford Site. DOE has decided that using the facility is impractical and it will be deactivated. The reactor was designed to test fuels and materials for advanced nuclear power plants as well as for the irradiation testing of fuels, core components and target assemblies for liquid metal fast breeder reactors. Nitrate is the only groundwater contaminant attributable to 400 Area operations. The contamination is believed to have come from a sanitary sewage lagoon that is no longer in use. Nitrite also is detected in groundwater but concentrations are below the maximum contaminant level.

300 Area Groundwater Contamination

During years of production, the 300 Area was where uranium fuel was manufactured before it was sent for irradiation in the reactors in the 100 Areas. The 300 Area was also the location of several test reactors during the Manhattan Project and Cold War periods. During the production process, contaminants such as uranium and trichloroethene were discharged to the ground. These elements, along with breakdown products of trichloroethene, are detected in groundwater, but concentrations are decreasing.

An area of elevated uranium concentrations is detected in the 300 Area, downgradient of the 316-5 process trenches and ponds. Uranium contamination is moving from the vicinity of the process trenches toward the southeast, entering the Columbia River. The most heavily contaminated sediment has been removed.



The iodine-129 plume (shown on the above maps) moves similarly to the tritium plume, but it has not moved as far. The plumes have spread between 1990 and 2001.

A plume of trichloroethene in the 300 Area is attenuating naturally, and annual average concentrations remained below the 5 µg/L maximum contaminant level in fiscal year 2001. Bacteria naturally present in the subsurface break down the trichloroethene in this area. This degradation produces cis-1,2-dichloroethene as a byproduct, and this contaminant exceeded the maximum contaminant level in a well that monitors the bottom of the unconfined aquifer in fiscal year 2001.

Tritium from the 200 East Area has migrated into the 300 Area at levels below the drinking water standard. The plume has ceased spreading southward. Strontium-90 concentrations are elevated in one well in the 300 Area but were below the drinking water standard in fiscal year 2001.

The 300-FF-5 groundwater operable unit includes two "satellite areas" north of the 300 Area proper. These include the 618-11 burial ground, located near the Energy Northwest site, where the highest tritium concentrations currently in Hanford Site groundwater have been detected. Concentrations exceeded 8 million pCi/L in fiscal year 2001. Monitoring of nearby wells and soil gas testing indicate that the contamination is very local. The other satellite area includes the 618-10 burial ground and 316-4 crib. Groundwater near these facilities is contaminated with uranium and hydrocarbons.

Iodine-129 *contamination has not reached the Columbia River at concentrations above the drinking water standard.*

Richland North Area Groundwater Contamination

The Richland North Area, located just south of the Hanford Site, contained site support services, such as general stores, shipping, receiving, transportation, maintenance, and general warehouse facilities. In 1998, DOE transferred ownership of portions of the Hanford Site located in the Richland North Area to the Port of Benton.

Groundwater beneath a portion of the Richland North Area is designated the 1100-EM-1 Operable Unit, which contains DOE's inactive Horn Rapids Landfill. A small, narrow plume of trichloroethene, which underlies the landfill and Framatome ANP Richland, Inc. (formerly Siemens Power Corporation), is attenuating naturally. Levels declined below the drinking water standard in fiscal year 2001. Contaminants also flow into the Richland North Area from offsite sources (nitrate from agriculture practices, fluoride, ammonia, and gross alpha from Framatome ANP Richland, Inc.).

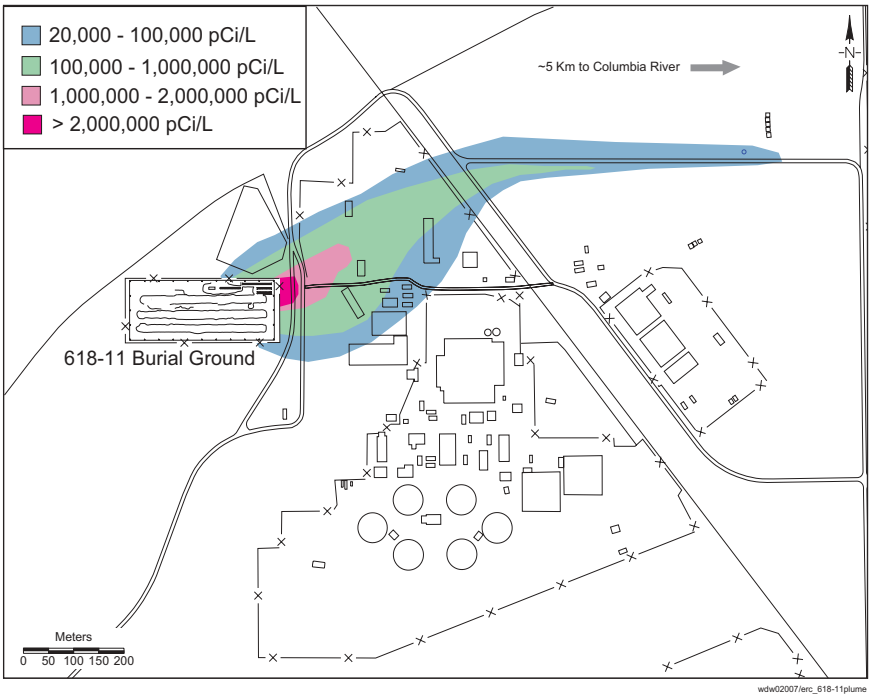
The city of Richland maintains a well field in the Richland North Area. Wells are monitored frequently to detect any changes in Hanford contaminants near these wells. The tritium plume from the 200 East Area has not been detected in these wells. Low levels of tritium, similar to Columbia River water, continue to be detected.

In some areas, DOE and the regulators agree that natural processes will clean up groundwater contamination. For example, dispersion (spreading) and radioactive decay decrease concentrations, while bacteria destroy other types of contaminants. Groundwater is monitored throughout the process to determine if concentrations are falling, as expected. This approach is known as ***monitored natural attenuation*** *and is being applied in the 300 and Richland North Areas.*

Upper Basalt-Confined Aquifer

Although most of Hanford's groundwater contamination is in the unconfined aquifer, DOE monitors wells in the deeper, basalt-confined aquifer because of the potential for downward migration of contamination from the unconfined aquifer and the potential migration of contamination offsite through the confined aquifer.

Most of the confined-aquifer wells are located near and north of the 200 East Area, where researchers believe there is communication between the two aquifer systems. One well in this region contains technetium-99 at levels above the drinking water standard, and co-contaminants nitrate and cyanide at lower levels. This contamination appears to be localized, but no firm conclusions can be drawn because there are very few wells monitoring the confined aquifer nearby. Another well near the former B Pond detects elevated tritium, but levels are far below the



The 618-11 burial ground, ~13 kilometers north of Richland, has created a narrow, concentrated tritium plume. Studies indicate that the high concentrations will decay before the plume reaches the Columbia River.

drinking water standard. Confined aquifer wells located farther from the 200 Area (downgradient; nearer areas of potential discharge) are not contaminated.

RCRA Treatment, Storage, and Disposal Units

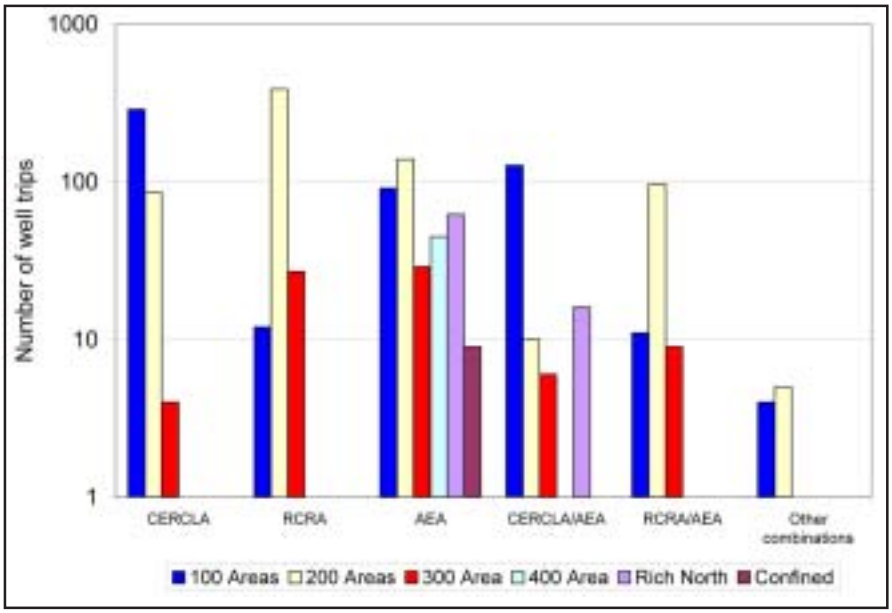
DOE monitors groundwater on the Hanford Site to meet the requirements of the RCRA at 24 waste management areas. Fifteen are monitored under indicator evaluation (or detection) programs and do not appear to affect groundwater with hazardous constituents. The others are monitored under assessment or corrective-action programs. Specific highlights are noted below:

- **183-H solar evaporation basins (100 H Area)** – Corrective-action monitoring continued during operation of the 100-HR-3 chromium pump-and-treat system. Leakage from the 183-H basins in the past contaminated the groundwater with chromium, nitrate, technetium-99, and uranium. The CERCLA program directs corrective action.
- **216-B-3 pond (200 East Area)** – In May 2001, the Washington State Department of Ecology issued a guidance letter regarding alternative statistical methods for indicator evaluation monitoring. DOE submitted a proposal for a new monitoring approach in November 2001.
- **216-S-10 pond and ditch (200 West Area)** – A downgradient well went dry in fiscal year 2001, leaving just one useable, shallow, downgradient well.
- **216-U-12 crib (200 West Area)** – Assessment monitoring continued to indicate that nitrate and technetium-99 plumes are mingled from various sources, including the crib. The monitoring network contains just two useable downgradient wells and no upgradient wells.
- **316-5 process trenches (300 Area)** – Corrective-action monitoring continued in fiscal year 2001. The trenches and other nearby sources contaminated groundwater with cis-1,2-dichloroethene, trichloroethene, and uranium. Corrective action is deferred to CERCLA, and involves natural attenuation of the contaminants. Concentrations of trichloroethene declined below the 5 µg/L maximum contaminant level. A new groundwater monitoring plan was written in fiscal year 2001, implementing the use of alternative statistical methods.
- **Liquid Effluent Retention Facility (200 East Area)** – This site is monitored under an indicator evaluation program. However, a downgradient well went dry in fiscal year 2001, leaving just one useable well. Washington State Department of Ecology instructed DOE to cease statistical evaluations.
- **Single-Shell Tanks Waste Management Areas A-AX and C (200 East Area)** – Indicator evaluation monitoring continued. Directions of groundwater flow were re-interpreted and may require modifications to monitoring networks.
- **Single-Shell Tanks Waste Management Area B-BX-BY (200 East Area)** – These tank farms may have contributed to the technetium-99, nitrate, nitrite, and uranium contamination in the northern 200 East Area. However, the assessment monitoring has not clearly identified a source within the tank farms. This waste management area is located near other major sources of contamination (e.g., the BY Cribs and 216-B-8 crib) that produced the bulk of the contamination. In fiscal year 2001, nitrate continued to migrate across the waste management area, with highest concentrations in the north. Technetium-99 concentrations decreased and uranium concentrations rose sharply in the central part of the waste management area. Assessment studies identified tritium as a new contaminant of interest on the west side of the BX tank farm. Three new monitoring wells were installed in fiscal year 2001.

*The **Resource Conservation and Recovery Act of 1976** (RCRA) regulates facilities used to treat, store, or dispose of hazardous waste. At Hanford, the law applies to sites that contained hazardous or mixed (hazardous and radioactive) waste. RCRA stipulates requirements for monitoring the groundwater beneath these sites.*

*Layers of dense, impermeable **basalt rock** prevent Hanford's groundwater contaminants from entering deep confined aquifers beneath most of the site. However, in some places the top impermeable layer of basalt is absent.*

- **Single-Shell Tanks Waste Management Area S-SX (200 West Area)** – Groundwater studies indicate that sources within the tank farms have contaminated groundwater with chromium, nitrate, and technetium-99. A well in the southwest corner of the area shows the impact of a 1960s tank leak, including high concentrations of technetium-99 and uranium. Monitoring results and solute transport modeling indicate the extent of tank waste in groundwater from that leak is very limited. Technetium-99 in other wells suggests longer-term releases from the waste management area in the past. A notable change in fiscal year 2001 was a sharp rise in chromium, nitrate, and technetium-99. This new contaminant occurrence represents a vadose zone source possibly originating in the S tank farm area. Two new monitoring wells were installed in fiscal year 2001.
- **Single-Shell Tanks Waste Management Area T (200 West Area)** – Results of assessment monitoring indicate that technetium-99, chromium, and nitrate contamination had a source within the tank farm. The tank-related contaminants are largely restricted to a zone of lower permeability in the upper portion of the aquifer. The lateral extent of this low permeability zone and the extent to which contaminants may be migrating into the deeper zone of higher permeability are uncertain. The lateral extent of contamination also is uncertain because of the lack of monitoring wells north and east of the zone of known contamination.
- **Single-Shell Tanks Waste Management Area TX-TY (200 West Area)** – Assessment monitoring in fiscal year 2001 indicated that a nearby pump-and-treat system has affected groundwater flow and may have an impact on the distribution of contaminants around the waste management area. Technetium-99 may be drawn from beneath the area into the pump-and-treat system. One contaminant plume, containing chromium, iodine-129, nitrate, and technetium-99, originated within the waste management area. A second



Wells were sampled to meet the objectives of CERCLA, RCRA, and the Atomic Energy Act in fiscal year 2001. Many wells are sampled for two or three objectives, so well trips and analyses are coordinated to avoid duplication.

plume from sources not in the waste management area is superimposed on the tank waste plume. Seven new wells were installed in fiscal years 2000 and 2001.

- **Single-Shell Tanks Waste Management Area U (200 West Area)** – Assessment monitoring continued in fiscal year 2001. Nitrate and technetium-99 concentrations continued to rise, especially in wells on the west side of the area, but concentrations remained below drinking water standards. Three new monitoring wells were installed in fiscal year 2001.

CERCLA Operable Units

DOE monitors groundwater on the Hanford Site to comply with requirements of CERCLA at 11 groundwater operable units. DOE, EPA, and Washington State Department of Ecology determine methods for remediating contaminated groundwater via formal documents called records of decision.

One operable unit, 1100-EM-1 (Richland North Area), has a final record of decision calling for natural attenuation of volatile organic compounds. Groundwater is monitored to determine the success of this approach. In fiscal year 2001, contaminant concentrations were below their target levels.

At six of the operable units, interim remedial actions are required until final cleanup decisions are made. The environmental restoration contractor monitors groundwater to assess the effectiveness of the interim actions.

- **100-HR-3 (100 D and 100 H Areas) and 100-KR-4 (100 K Area)** – Chromium may pose a threat to aquatic organisms in the Columbia River. Interim records of decision require three interim remedial actions to address chromium contamination. In fiscal year 2001, concentrations remained above cleanup targets.
- **100-NR-2 (100 N Area)** – Strontium-90 concentrations remained much higher than the drinking water standard in wells at the river shore in fiscal year 2001. In 1995, Washington State Department of Ecology instructed DOE to operate a pump-and-treat system for strontium-90 as an expedited response action. The decision was documented in an interim record of decision in 1999.

*The **Comprehensive Environmental Response, Compensation, and Liability Act of 1980** (CERCLA) regulates waste sites that were active before RCRA took effect. It covers sites where radioactive or hazardous waste were disposed or leaked, and also requires groundwater monitoring where appropriate.*

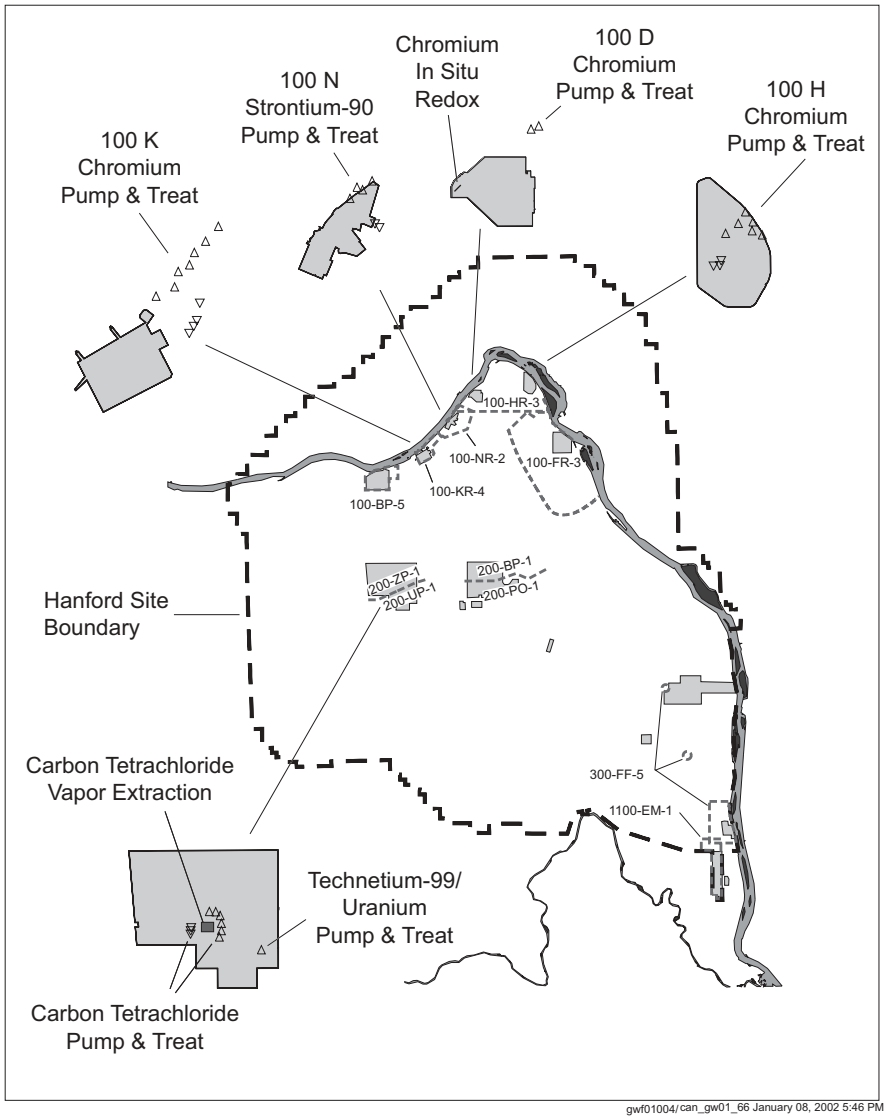
Interim Groundwater Remediation

The goal of groundwater treatment systems on the Hanford Site is to prevent the worst contaminants from spreading. Six pump-and-treat systems removed the following contaminants in fiscal year 2001:

	FY 2001	Total Since Start Including FY 2001
▶ 100 K (chromium):	37 kilograms	141.2 kilograms
▶ 100 N (strontium-90):	0.2 curie	1.07 curies
▶ 100 D and 100 H (chromium):	31.5 kilograms	123.8 kilograms
Note: Also, in the 100 D Area, an in situ remediation system is immobilizing chromium in the aquifer.		
▶ 200 West (carbon tetrachloride):	1,225 kilograms	5,796 kilograms
Note: A soil gas extraction system removed 712 kilograms of carbon tetrachloride from the vadose zone in FY 2001; a total of 77,169 kilograms have been removed since remediation began.		
▶ 200 West (technetium-99):	0.142 curie	1.28 curies
(uranium):	17 kilograms	131.9 kilograms

- **200-UP-1 (200 West Area)** – An interim record of decision required operation of a pump-and-treat system to reduce technetium-99 and uranium contamination. In fiscal year 2001, some concentrations remained above target levels. Many of the wells monitoring this area have gone dry, so the size of the current plumes is uncertain.
- **200-ZP-1 (200 West Area)** – An interim record of decision requires operation of a pump-and-treat system to prevent carbon tetrachloride from spreading. In fiscal year 2001, the system continued to limit migration of the heart of the plume.
- **300-FF-5 (300 Area and satellite areas to the north)** – An interim record of decision calls for natural attenuation of the cis-1,2-dichloroethene, trichloroethene, and uranium plumes. In fiscal year 2001, concentrations of the organic contaminants were low, but uranium remained elevated.

When groundwater is pumped from the subsurface, it is treated to remove contaminants before being discharged. This process is often referred to as a pump-and-treat system. This common form of groundwater remediation is being used at Hanford to remove carbon tetrachloride, chromium, strontium-90, technetium-99, and uranium. However, because these systems often take a long time to meet cleanup goals, their use is reviewed every 5 years.



DOE operates six pump-and-treat systems, one in situ remediation system, and one soil gas extraction system to limit movement of contaminants in groundwater and the vadose zone.

At four operable units, there is no imminent threat to human health or the environment so no interim remedial actions are required. These operable units include 100-BC-5 (100 B/C Area), 100-FR-3 (100 F Area), 200-BP-5, and 200-PO-1 (200 East Area). Waste sites and plumes will continue to be monitored until there are final records of decision.

As required under CERCLA, EPA performed a 5-year review to determine whether remedial actions specified under records of decision for the Hanford Site are protective of human health and the environment. The review was published in fiscal year 2001 and included soil and groundwater remedial actions. EPA identified action items to address deficiencies. Actions related to groundwater monitoring include

- Enhance pump-and-treatment operations at 100 K, 100 D, and 100 H Areas, including new extraction wells at 100 K and 100 D Areas, and a new injection well at 100 K Area.
- Investigate alternative remedial action methods for the 100 N Area strontium-90 plume.
- Investigate detection technologies for dense, non-aqueous phase liquids; investigate enhancements to current carbon tetrachloride pump-and-treat system; install a new monitoring/production well near the Plutonium Finishing Plant.
- Develop new monitoring networks for the 200-BP-5, 200-PO-1, 200-UP-1, and 200-ZP-1 Operable Units.
- Update and expand the operations and maintenance plan for 300-FF-5 Operable Unit.

Liquid waste from past disposal sites, spills, or leaks entered the vadose zone. Not all of this water flowed through to groundwater, so some contaminated sediment or water remains in the vadose zone. This contamination may continue to move downward and into groundwater over time, especially if rain or other sources of water percolate through the contaminated zone.

Well Installation

In fiscal year 2001, 11 new wells were completed for RCRA groundwater monitoring. Thirty-one new wells were installed in the 100 D Area to support groundwater remediation for chromium. Six wells were installed for other projects.

Fifty-eight new wells were drilled on the Hanford Site in fiscal year 2001. Some of them are monitoring wells to replace dry wells or to gather additional information (shown above). Other wells support groundwater remediation.

Ninety-nine wells were decommissioned (sealed with grout) in fiscal year 2001 because they were no longer used, were in poor condition, or were in the way of construction sites. Approximately 400 well maintenance activities were carried out during fiscal year 2001. These activities included well or pump repair, cleaning, and maintenance.

Modeling

*Pacific Northwest National Laboratory completed groundwater modeling to support the **Hanford Carbon Tetrachloride Innovative Treatment Remediation Technology Program** in fiscal year 2001. This work was a first step toward implementing innovative technologies to remediate the carbon tetrachloride plume underlying the 200 West Area.*

Numerical simulations of groundwater flow and contaminant movement are used to predict future conditions and to assess the effects of remediation systems. Pacific Northwest National Laboratory has responsibility for a sitewide, consolidated groundwater flow and transport model.

In fiscal year 2001, Pacific Northwest National Laboratory re-calibrated a base case of the sitewide groundwater model and an alternative case that includes interaction between the unconfined and confined aquifer systems. The re-calibration significantly improved the model's ability to simulate historical trends in water table changes across the Hanford Site, particularly near the 200 West Area. Incorporating groundwater movement between the unconfined aquifer and the underlying confined aquifer into the model provided a small but measurable improvement in overall model performance.

The Groundwater Protection Program has developed the System Assessment Capability as a tool to predict cumulative sitewide effects from all significant Hanford Site contaminants. This tool integrates several linked models, beginning with the waste inventory and simulates release and movement through the vadose zone, groundwater, and Columbia River. In fiscal year 2001, the initial runs were completed. Upgraded hardware and computational efficiencies were implemented in late 2001. Upgrades will continue to be made, and detailed composite analyses will be run in 2003.

Vadose Zone

*The results of **vadose zone characterization** studies improve understanding of the distribution of contamination between the ground surface and the water table.*

Subsurface source characterization, vadose zone monitoring, soil-vapor monitoring, sediment sampling, and several technical demonstrations were conducted in fiscal year 2001.

Vadose zone characterization activities at single-shell tank farms in fiscal year 2001 focused on the B, BX, and BY tank farms in the 200 East Area and the S, SX, T, TX, and TY tank farms in the 200 West Area. Two new boreholes were drilled at Waste Management Area B-BX-BY through subsurface contaminant plumes. A third borehole was drilled immediately outside the tank farms to obtain uncontaminated core for comparison with the contaminated material obtained in the tank farms. Analyses of the samples are ongoing and will be reported in next year's groundwater report.

Steps were taken to minimize the subsurface migration of existing contamination in the single-shell tank farms in 200 West Area. Surface water that could pool around the tank farms was redirected away from the tank farms, and aging water-supply pipelines were capped or tested so they could be repaired.

Characterization of sediment samples from boreholes previously drilled in Waste Management Area SX was reported in fiscal year 2001. Results indicate that cesium, chromium, and pH distributions do not identify the leading edge of contaminant plumes. More mobile indicators, such as electrical conductivity, nitrate, sodium, and technetium identified the leading edges of the contaminant plumes. The bulk of contamination appears to be significantly shallower than the leading edges of the plumes.

Researchers applied mass spectrometry to analyze stable and long-lived isotopes in drill core samples in fiscal year 2001. The purpose of the work was to better understand water and contaminant movement in the vadose zone at the SX tank farm. Results indicated that isotopes of iodine and molybdenum can be used as a tool to fingerprint tank waste leaks. Cesium isotopes were not successful in discerning different leaks. Ratios of several different species also can be used to discern different leaks. Comparison of isotopic and species ratios of contaminants in vadose zone sediment and groundwater can help determine the sources of groundwater contamination.

Other vadose zone studies at the SX tank farm in fiscal year 2001 included a study of water movement inferred from the abundance of stable isotopes of oxygen and hydrogen. These isotopes show where water has undergone significant evaporation, indicating how recently it infiltrated.

Geophysical logging using the spectral gamma technique was performed in 30 boreholes in or near waste sites in the 200 Areas in fiscal year 2001. The method is being used to characterize the vadose zone and to track movement of gamma-emitting radionuclides in the vadose zone. Seven new RCRA wells also were logged.

A comprehensive routine monitoring project using the spectral gamma technique was established in June 2001 in the single-shell tank farms. The goal of the monitoring project is to detect changes occurring since the baseline data were collected. Geophysicists logged 113 boreholes in fiscal year 2001. Possible contaminant movement was identified at the U and T tank farms, so they are being monitored quarterly.

Hanford crews drilled a borehole near tank B-110, one of the first single-shell tanks built in the 1940s. Instruments and sensors were installed to measure soil temperature, soil water pressure, and water content.

Analyses of leachate collected from the Environmental Restoration Disposal Facility showed that the liquid collected so far contains no elevated levels of contaminants of concern. Leachate at the Solid Waste Landfill continued to exceed regulatory standards for some constituents, but soil gas monitoring showed no constituents of concern above reporting limits for air quality.

Soil gas monitoring at the carbon tetrachloride expedited-response-action site continued during fiscal year 2001. The temporary suspension of soil-vapor extraction in fiscal year 2001 appears to have caused minimal transport of carbon tetrachloride through the soil surface to the atmosphere and had no negative impact on groundwater quality. Soil gas monitoring at the 618-11 burial ground also continued to help define the extent of tritium contamination in groundwater and the vadose zone. Results were used to help map the plume and to choose locations for groundwater monitoring wells.

During July and August 2001, a borehole with instruments and sensors for vadose zone monitoring was installed at B tank farm in a well next to tank B-110, one of the first tanks built in the 1940s. The instruments will measure soil temperature, soil water pressure, and water content in the vadose zone. This is the first installation of a vadose zone monitoring system in the sand and gravel at Hanford. Also, the sampling is part of the RCRA corrective action program established in 1998. This sampling will help characterize the contamination that exists underneath the tank farms and determine how the contamination moves through the soil. Results will help regulators determine what corrective measures may be required to slow the movement of contamination to the groundwater.

Air in the vadose zone can become contaminated with gaseous contaminants from landfills or other waste sites. At Hanford, ***soil gas*** *is monitored in the 200 West Area to measure gaseous carbon tetrachloride and to assess how well vadose zone cleanup is working. Soil gas also is monitored beneath two landfills on site.*

Two-dimensional and three-dimensional high-resolution seismic characterization experiments were conducted in May 2001. Information from experiments like these will be used to improve flow and transport models of the vadose zone. The seismic technique did well in identifying hydrologic units. The method achieved vertical imaging from the ground surface to the water table and was used to identify distinct geologic units.

*The purpose of **spectral gamma logging** is to detect and quantify naturally occurring and man-made gamma-emitting radionuclides in the vadose zone near waste disposal sites.*

A 3-year DOE Environmental Management Science Program study of clastic dikes and their influence on movement of subsurface contamination began in fiscal year 2000 and continued in fiscal year 2001. The results indicated that even though the air permeability and saturated hydraulic conductivity within the dikes are very low, clastic dikes may still provide transport paths under unsaturated conditions in the vadose zone.

During July and August 2001, scientists deployed six leak-detection technologies that could be used while removing waste from single-shell tanks at the Hanford Site. The demonstration of these methods was designed to provide data that will lead to the development of a way to detect leaks outside of a single-shell tank during waste retrieval operations.

Preliminary results indicate that all six technologies detected leaks from a mock tank but at different levels of ability. The testing done in fiscal year 2001 will allow the selection of two to three of these technologies for further testing in fiscal year 2002 and beyond. This may eventually result in deployment of one or more of these in an actual tank farm, and possibly produce a reliable leak-detection technology for waste retrieval activities.

Crews installed instruments (left) and completed a GPS survey (right) in preparation for the mock tank demonstration. Scientists tested six leak-detection technologies that could be used to detect leaks outside of a single-shell tank during waste retrieval operations.