



## 6.2 GROUNDWATER MONITORING RESULTS

*D. R. Newcomer*

The following sections summarize the distribution of radioactive and chemical contaminants detected in Hanford Site groundwater during 2002. These discussions are followed by a summary of groundwater monitoring results for RCRA sites (Section 6.4). Detailed information on groundwater monitoring, including listings of analysis results for each monitoring well in electronic format, is available in the Hanford Site annual groundwater report, PNNL-14187. The Hanford Site annual groundwater report covers the fiscal year (October 2001 through September 2002) and does not include results from the last 3 months of 2002. This report includes a summary of results for January through December 2002.

One way to assess the potential impact of radionuclides and chemicals to groundwater is to compare their concentrations to EPA's drinking water standards and DOE's derived concentration guides (40 CFR 141 and DOE Order 5400.5; Appendix D, Tables D.2 and D.5). The drinking water standards were established to protect public drinking water supplies. The DOE derived concentration guides were established to protect the public from radionuclides resulting from DOE operations. Specific drinking water standards have been defined for only a few radiological constituents. Drinking water standards have been calculated for other radionuclides, using an annual dose limit of 4 mrem (0.04 mSv). Calculations of these standards consider their half-life, the energy and nature of the radioactive decay, and the physiological factors such as its buildup in particular organs. Drinking water standards are more restrictive than derived concentration guides because the standards are based on an annual dose of 4 mrem (0.04 mSv) to the affected organ. The guides are based on an effective dose equivalent of 100 mrem (1 mSv) per year (Appendix D, Tables D.2 and D.5). Primary and secondary drinking water standards are given for some chemical

constituents; secondary standards are based on aesthetic (e.g., odor, taste) rather than health considerations.

The total area of contaminant plumes with concentrations exceeding drinking water standards was estimated to be ~196 square kilometers (76 square miles) during 2002. This area occupies ~13% of the total area of the Hanford Site. The most widespread contaminants within these plumes were tritium, iodine-129, nitrate, carbon tetrachloride, trichloroethene, chromium, strontium-90, technetium-99, and uranium. The area of contaminant plumes for these constituents at levels above drinking water standards are summarized in Table 6.2.1. Most of the contaminant plume area, represented by tritium, lies southeast of the 200-East Area extending to the Columbia River (Figure 6.2.1). Contaminant plumes with concentrations exceeding DOE derived concentration guides

**Table 6.2.1. Areas of Contaminant Plumes on the Hanford Site at Levels Above Drinking Water Standards, 2002 (adapted from PNNL-14187)**

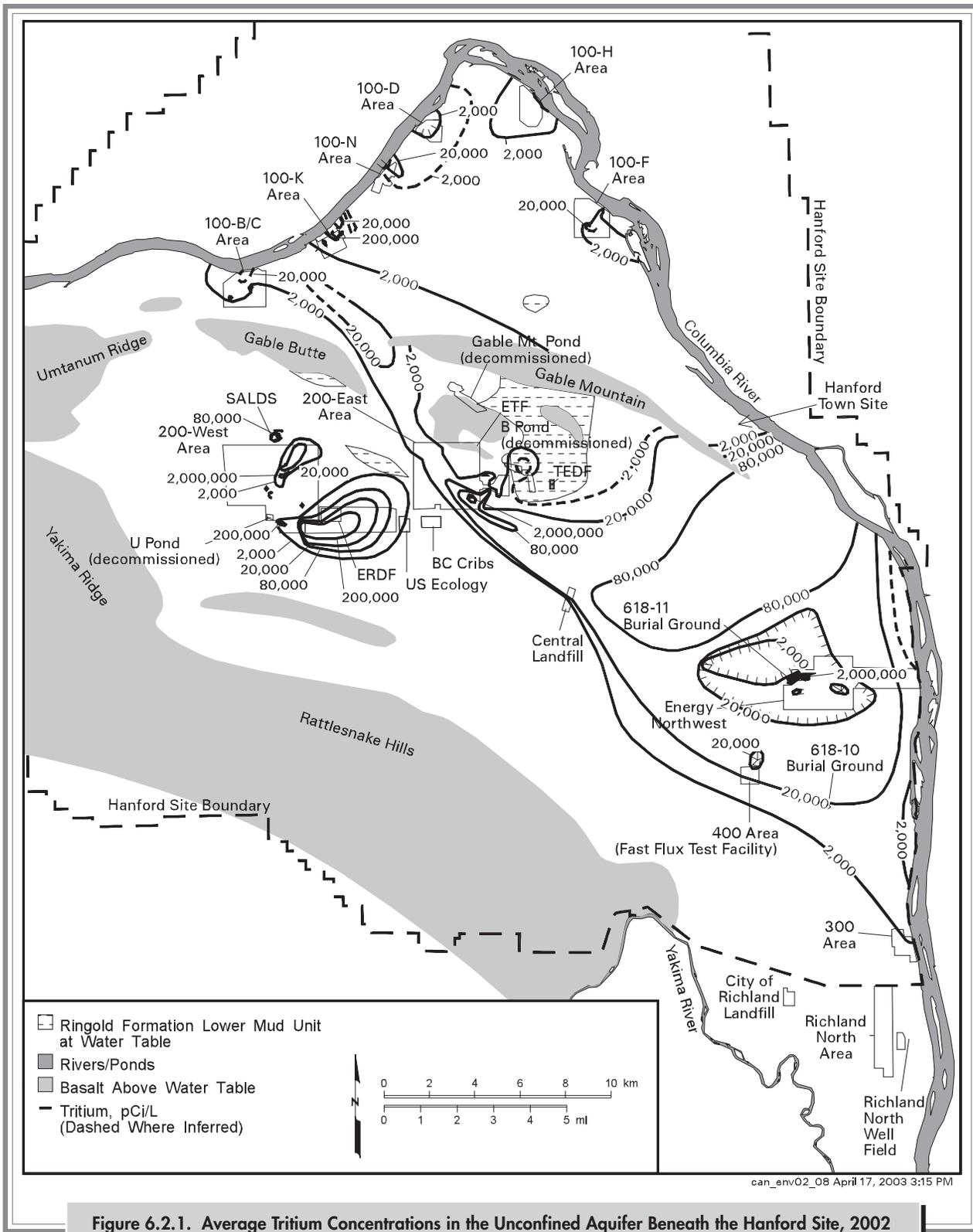
<u>Constituent</u>	<u>Drinking Water Standard</u>	<u>Area (km<sup>2</sup>)</u>
Tritium	20,000 pCi/L	142
Iodine-129	1 pCi/L	79.4
Nitrate	45 mg/L	35.7
Carbon tetrachloride	5 µg/L	9.9
Trichloroethene	5 µg/L	3.4
Filtered chromium	100 µg/L	2.6
Strontium-90	8 pCi/L	2.7
Technetium-99	900 pCi/L	2.3
Total uranium	30 µg/L	1.5
Combined plumes	--	196 <sup>(a)</sup>

(a) Total reflects some overlap of contaminant plumes.

1 pCi/L = 0.037 Bq/L.

1 µg/L = 0.001 ppm.

1 mg/L = 1 ppm.



**Figure 6.2.1. Average Tritium Concentrations in the Unconfined Aquifer Beneath the Hanford Site, 2002**

occur in isolated areas. The only contaminants at levels above DOE derived concentration guides during 2002 were strontium-90, tritium, and uranium.

Summaries of maximum concentrations for the most widespread contaminants are presented in Table 6.2.2 and by monitoring purpose in Table 6.2.3. As expected, most of the maximum concentrations were detected in the 100 and 200 Areas because these areas contain the largest number of waste sites that have affected groundwater quality (Table 6.2.2). Some contaminants were not detected or not analyzed for in some of the areas. For each monitoring purpose, the maximum concentrations detected were greater than the drinking water standards for all of the most widespread contaminants listed in Table 6.2.3. A list of drinking water standards for these contaminants is provided in Table D.2 in Appendix D.

## 6.2.1 RADIOLOGICAL MONITORING RESULTS FOR THE UNCONFINED AQUIFER

Hanford Site groundwater was analyzed for several radionuclides (Table 6.1.4). The distribution of tritium, iodine-129, technetium-99, uranium, strontium-90, carbon-14, cesium-137, cobalt-60, and plutonium are

discussed in the following sections. Tritium and iodine-129 are the most widespread radiological contaminants associated with past site operations. Technetium-99 and uranium plumes are extensive in the 200 Areas and adjacent 600 Area. Strontium-90 plumes exhibit high concentrations in the 100 Areas but are of relatively smaller extent. Strontium-90 also occurs in the 200 Areas and near the former Gable Mountain Pond in the 600 Area. Carbon-14 is present in two small plumes in the 100-K Area. Cesium-137, cobalt-60, and plutonium contamination occurs in isolated areas in the 200 Areas. Gross alpha and gross beta results are used as indicators of radionuclide distribution and are not discussed in detail because the specific radionuclides contributing to these measurements are discussed individually. Several other radionuclides, including ruthenium-106, antimony-125, and americium-241, are associated with waste from Hanford Site operations. Because of their low concentrations in groundwater, they are not discussed in this section. Half-lives of the radionuclides are presented in Appendix A, Table A.7.

**Tritium.** Tritium, which is present in irradiated nuclear fuel, was released in process condensates associated with decladding and dissolution of the fuel. Tritium also was manufactured as part of the Hanford mission by irradiating targets containing lithium in several reactors from 1949 to 1952 (DOE/EIS-0119F; WHC-SD-EN-RPT-004).

**Table 6.2.2. Summary of Maximum Contaminant Concentrations in Hanford Site Groundwater, 2002**

Constituent	Hanford Site	100 Areas	200 Areas	300 Area	400 Area	600 Area <sup>(a)</sup>
Tritium (pCi/L)	5,570,000	588,000	5,570,000	8,910	13,000	4,230,000
Iodine-129 (pCi/L)	31.6	Not detected	31.6	Not detected	Not detected	29.9
Nitrate (mg/L)	2,090	474	2,090	89.9	3.4	188
Carbon tetrachloride (µg/L)	6,900	Not detected	6,900	Not detected	Not detected	35
Trichloroethene (µg/L)	16	11	16	4.3 J	Not detected	3.5 J
Filtered chromium (µg/L)	6,250	5,300	6,250	4.6 B	Not detected	112
Strontium-90 (pCi/L)	18,500	18,500	53.6	3.4	Not detected	2.7
Technetium-99 (pCi/L)	99,700 <sup>(b)</sup>	986	99,700	Not analyzed	Not detected	164
Total uranium (µg/L)	2,100	119	2,100	235 B	0.025	16.3

(a) Includes the former 1100 and 3000 Areas.

B = Detected at a value less than the contract required detection limit.

J = Reported value is an estimate.

1 pCi/L = 0.037 Bq/L.

1 µg/L = 0.001 ppm.

1 mg/L = 1 ppm.

**Table 6.2.3. Summary of Maximum Contaminant Concentrations in Hanford Site Groundwater by Monitoring Purpose, 2002**

<b>Constituent</b>	<b>Restoration</b>	<b>Waste</b>	
		<b>Management</b>	<b>Surveillance</b>
Tritium (pCi/L)	4,230,000	5,570,000	4,230,000
Iodine-129 (pCi/L)	29.9	31.6	5.8
Nitrate (mg/L)	2,090	2,090	735
Carbon tetrachloride (µg/L)	6,900	3,400	3,300
Trichloroethene (µg/L)	16	16	13
Filtered chromium (µg/L)	5,300	6,250	5,300
Strontium-90 (pCi/L)	18,500	1,240	18,500
Technetium-99 (pCi/L)	22,400	99,700	10,600
Total uranium (µg/L)	2,100	391	329

(a) Maximum concentrations may be the same between monitoring purposes because of co-sampling between groundwater monitoring programs.

1 pCi/L = 0.037 Bq/L.

1 µg/L = 0.001 ppm.

During the late 1960s, tritium production took place in N Reactor (WHC-MR-0388).

Tritium was present in many historical waste streams at the Hanford Site and is highly mobile, essentially moving at the same velocity as the groundwater. Consequently, the extent of groundwater contamination from site operations is generally reflected by tritium distribution. For this reason, tritium is the most frequently monitored radionuclide at the Hanford Site (Figure 6.2.1). Tritium is one of the most widespread contaminants in groundwater across the Hanford Site and exceeded the drinking water standard (20,000 pCi/L [740 Bq/L]) in portions of the 100, 200, and 600 Areas. Of these areas, tritium levels exceeded the DOE derived concentration guide (2 million pCi/L [74,000 Bq/L]) in portions of the 200 and 600 Areas. The highest tritium concentration measured at the Hanford Site in 2002 was 5.57 million pCi/L (206,300 Bq/L) near the Plutonium-Uranium Extraction Plant in the 200-East Area. Tritium levels are expected to decrease because of dispersion and radioactive decay (half-life is 12.35 years).

During 2002, the State-Approved Land Disposal Site was the only site at Hanford where liquid effluent containing a radionuclide was discharged to the soil column. The State-Approved Land Disposal Site received a total of 8.6 curies (319 billion becquerels) of tritium during 2002. This facility, which began operating in 1995, is located just north of the 200-West Area.

**Tritium in the 100 Areas.** During 2002, there was no waste containing tritium discharged in the 100 Areas. All the tritium detected here comes from past activities at Hanford. Tritium concentrations greater than the drinking water standard were detected in groundwater beneath portions of the 100-B/C, 100-K, 100-N, and 100-D Areas. The largest tritium plume in the 100 Areas, with concentrations above the drinking water standard, occurs along the Columbia River in the northeast part of the 100-N Area.

Tritium concentrations in groundwater beneath most of the 100-B/C Area declined during 2002. However, tritium concentrations continued to exceed the drinking water standard in two wells in

the northern and southwestern parts of the 100-B/C Area. Most of the tritium contamination is associated with past liquid disposal practices at 100-B/C retention basins and trenches near the Columbia River. In 2002, the maximum tritium concentration measured was 30,600 pCi/L (1,133 Bq/L) in a sample from the northern part of the 100-B/C Area.

In the 100-K Area, tritium contamination in groundwater is associated with the KE and KW Reactor complexes and the 116-K-2 liquid waste disposal trench. Sources of tritium contamination at the KE and KW Reactor complexes are the 116-KE-1 and 116-KW-1 cribs where condensate from earlier discharges continues to migrate downward through the soil column. Carbon-14 is a co-contaminant with tritium in the effluent disposed to these cribs and in the groundwater. Potential sources of tritium contamination beneath the 116-K-2 liquid waste disposal trench include vadose zone moisture beneath the trench, and leakage from the KE Fuel Storage Basin, the 116-KE-1 crib, and the 118-K-1 burial ground.

The tritium plume near the KE Reactor continued to contain the highest tritium concentrations within the 100 Areas. The maximum concentration measured was 588,000 pCi/L (21,800 Bq/L) in a well located immediately downgradient of the 116-KE-1 crib (Figure 6.2.2). Tritium concentrations in groundwater at this location (well 199-K-30) are most likely the result of downward

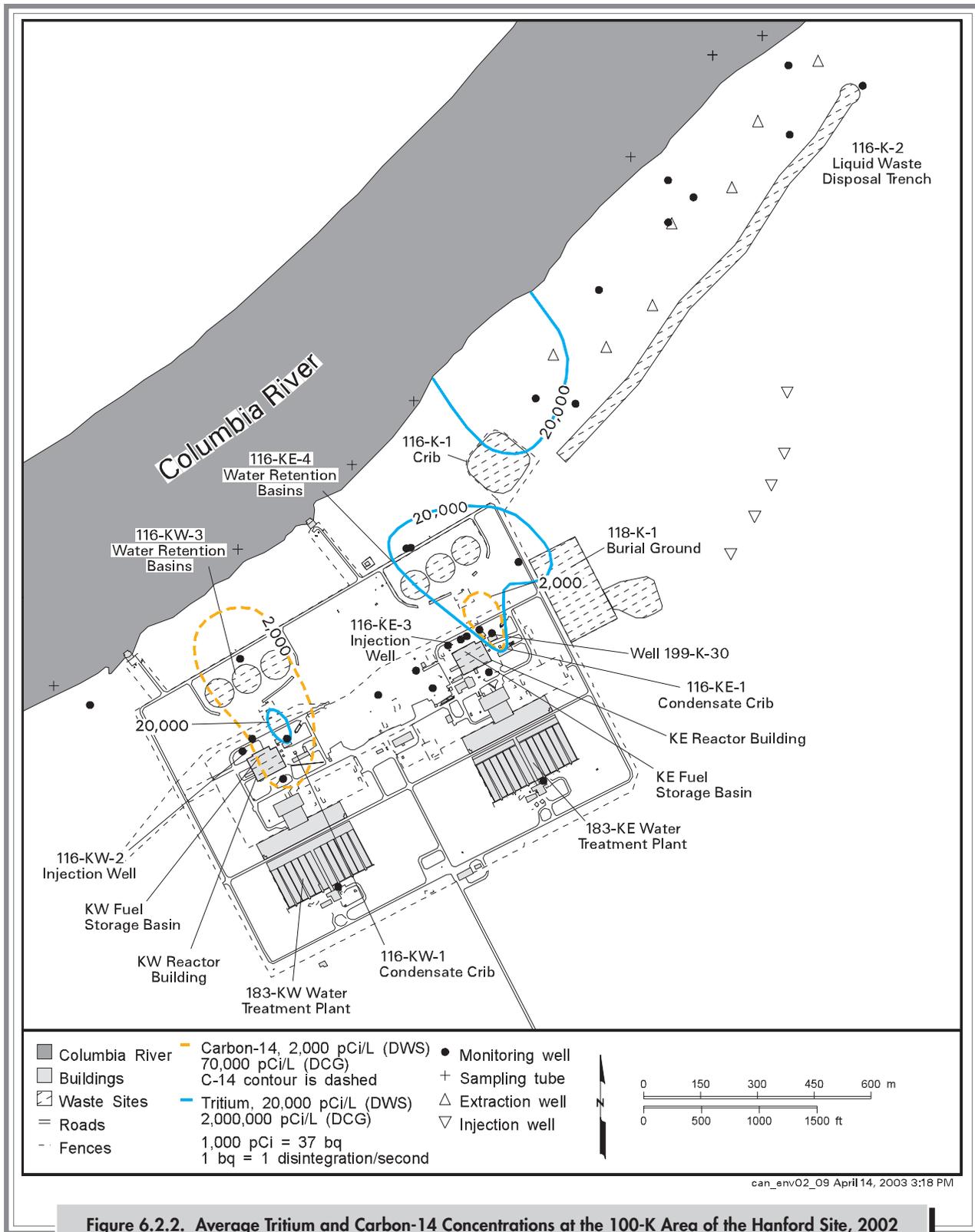


Figure 6.2.2. Average Tritium and Carbon-14 Concentrations at the 100-K Area of the Hanford Site, 2002

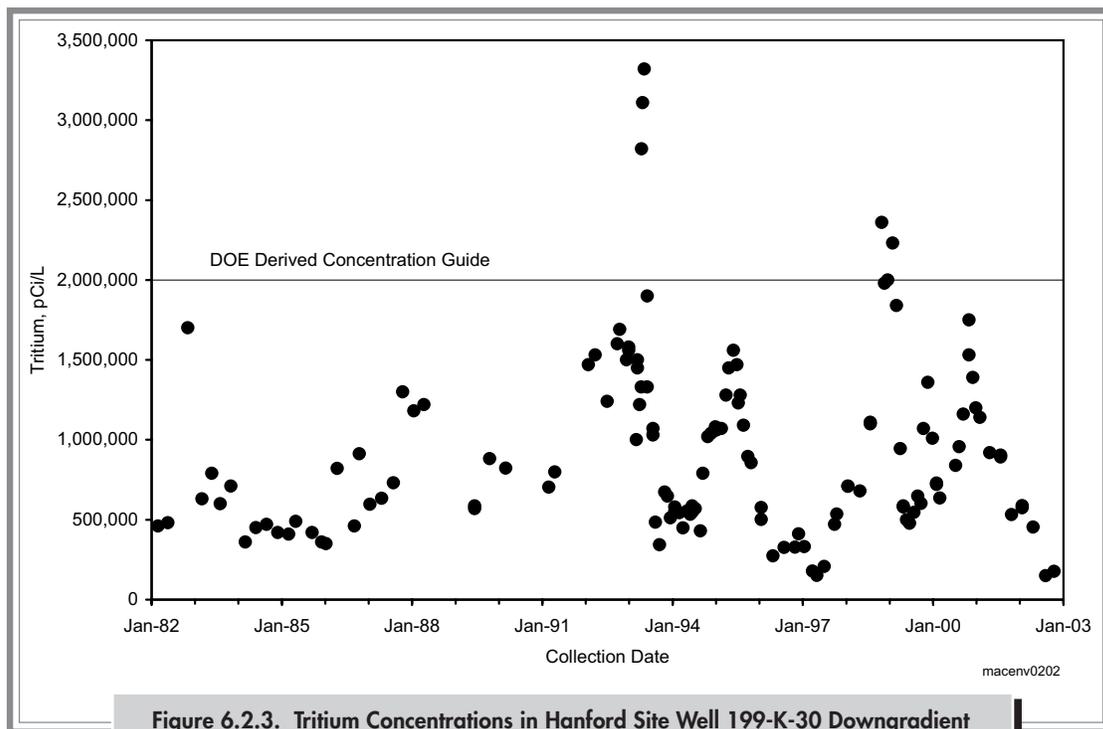
movement of vadose zone moisture containing tritium (Figure 6.2.3). A second source of this plume is past leakage from the KE Fuel Storage Basin, with the latest leakage occurring in 1993. Tritium concentrations in a plume farther downgradient of the 116-KE-1 crib rose during 2001 and then began to decline during 2002. This rise and fall most likely indicates the arrival of a plume originating from leakage of the KE Fuel Storage Basin in 1993 (Figure 6.2.4). In the northwestern corner of the 118-K-1 burial ground, tritium concentrations increased rapidly to levels above the drinking water standard from late 2000 through 2001 and then began to decline in 2002. The maximum concentration measured during 2001 was 98,100 pCi/L (3,630 Bq/L). By the end of 2002, the maximum level had declined to 62,400 pCi/L (2,310 Bq/L). The elevated tritium in this area is from a previously unidentified plume to the east or southeast and circumstantial evidence suggests the burial ground is the source. Various investigations to identify the source of tritium in the northwestern corner of the 118-K-1 burial ground are currently underway (PNNL-14031).

Near the KW Reactor Building, tritium concentrations exceeding the drinking water standard were measured in one well in 2002. Tritium levels in this well increased to a

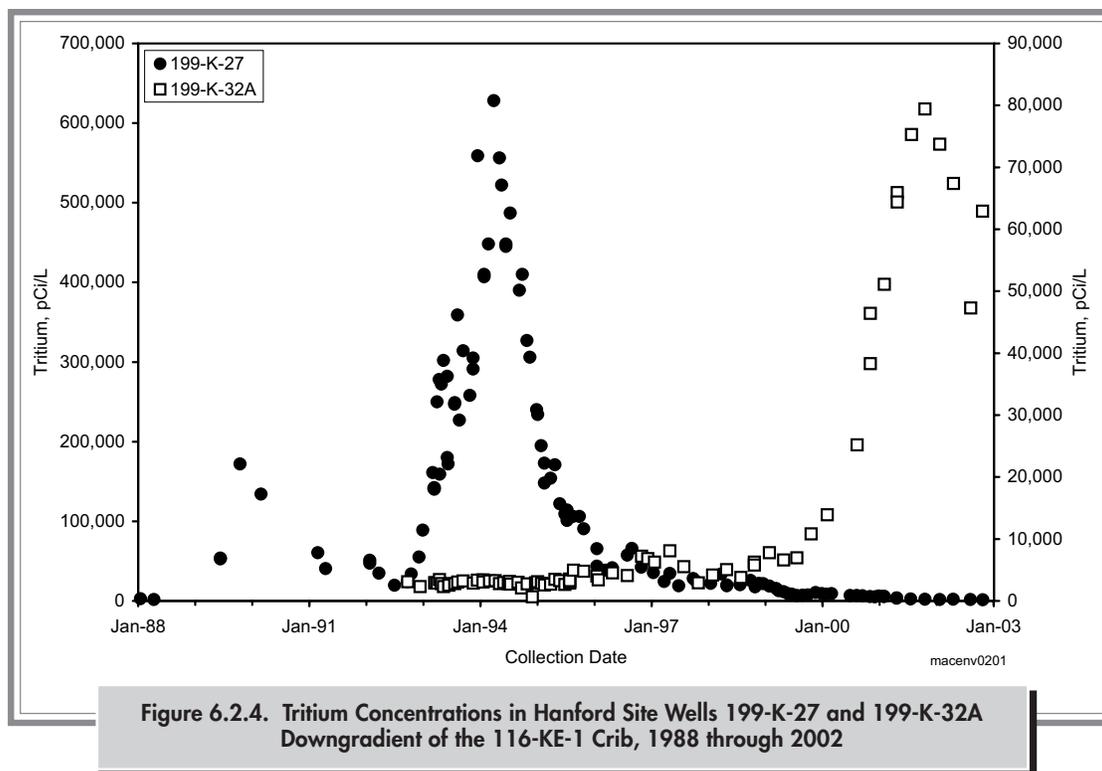
maximum of 280,000 pCi/L (10,370 Bq/L) in early 2002 and then began to decline during the middle to latter part of 2002. Tritium levels greater than the drinking water standard, but much less than the DOE derived concentration guide, continued to occur during 2002 in a small area near a pump-and-treat extraction well between the 116-K-1 liquid waste disposal trench and the Columbia River.

A tritium plume at levels exceeding the drinking water standard occurs in the northern part of the 100-N Area. This plume, which generally occurs in the same area as the strontium-90 plume, is associated with past liquid disposal to the 116-N-1 and 116-N-3 liquid waste disposal facilities. The size of the tritium plume at levels above the drinking water standard continued to decrease during 2002 because of dispersion and radioactive decay. The portion of the tritium plume containing the highest concentrations, formerly beneath the 116-N-3 facility, migrated to the northwest toward the Columbia River. The maximum tritium level measured in the 100-N Area during 2002 was 39,300 pCi/L (1,456 Bq/L) in a well near the Columbia River.

Tritium concentrations rose above the drinking water standard in one well in the western part of the 100-D Area.



**Figure 6.2.3. Tritium Concentrations in Hanford Site Well 199-K-30 Downgradient of the 116-KE-1 Crib, 1982 through 2002**



Tritium reached a maximum level of 23,700 pCi/L (878 Bq/L) during 2002 and most likely migrated from the 100-N Area.

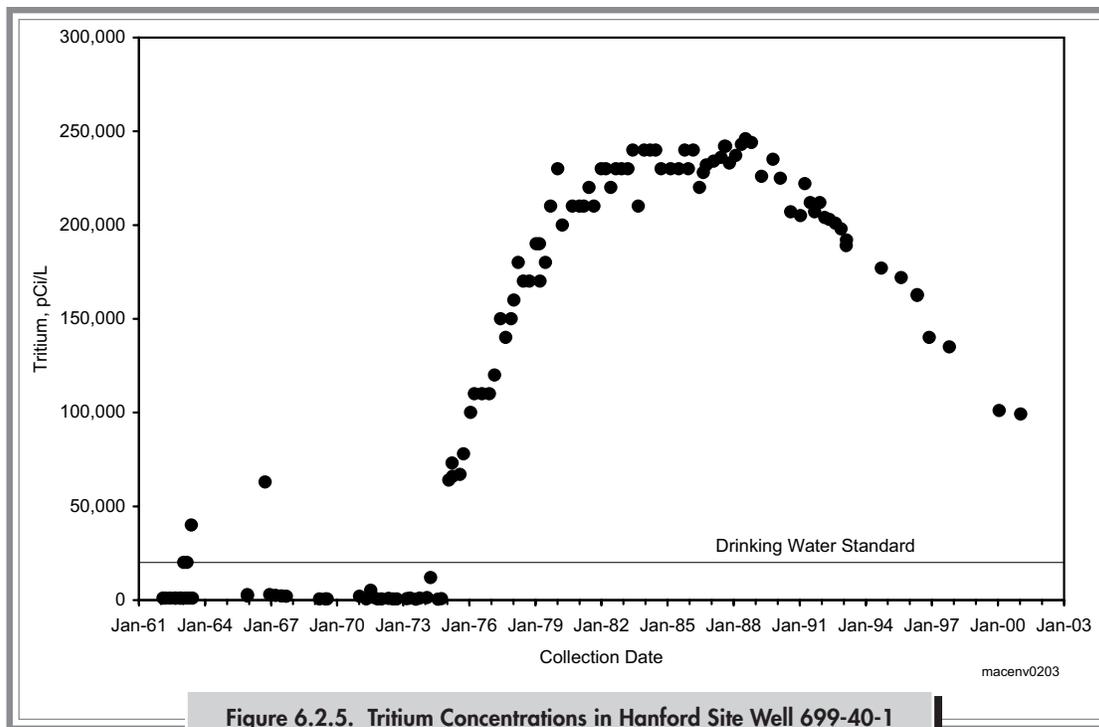
***Tritium in the 200-East and 600 Areas.*** The highest tritium concentrations in the 200-East Area continued to be measured in wells near cribs that received effluent from the Plutonium-Uranium Extraction Plant. Tritium levels are decreasing slowly in most wells in this area because of dispersion and radioactive decay. However, levels greater than the DOE derived concentration guide were detected in one well (299-E17-9) near the 216-A-36B crib in the southeastern part of the 200-East Area. The maximum tritium level detected in this well was 5.57 million pCi/L (206,000 Bq/L) in 2002, which is greater than the maximum detected in this well in 2001. Tritium concentrations continued to exceed the drinking water standard in many wells monitoring the cribs near the Plutonium-Uranium Extraction Plant.

In a plume that extends from the southeastern portion of the 200-East Area, tritium concentrations above 200,000 pCi/L (7,400 Bq/L) were measured in a small area downgradient of the Plutonium-Uranium Extraction Plant and were not found beyond the 200-East Area boundary.

The plume area at levels above 200,000 pCi/L (7,400 Bq/L) had extended at least as far southeast as the Central Landfill in the past (PNL-8073).

A widespread tritium plume extends from the southeastern portion of the 200-East Area to the Columbia River (Figure 6.2.1). In the western part of this tritium plume, a control in the movement of the plume to the southeast is the presence of a low permeability Ringold Formation unit at the water table east of the 200-East Area (PNNL-12261). Flow to the southeast also appears to be controlled by a zone of highly permeable sediment, stretching from the 200-East Area toward the 400 Area (PNL-7144). Near Energy Northwest, an area of lower tritium concentration is a result of a higher degree of cemented Ringold Formation sediment in the unconfined aquifer. The shape of the tritium plume indicates that tritium discharges to the Columbia River between the Hanford town site and the 300 Area. The highest tritium concentrations in groundwater discharging to the river occurred near the Hanford town site (Figure 6.2.1).

Separate tritium pulses associated with the two episodes of Plutonium-Uranium Extraction Plant operations can be distinguished in the plume. A trend plot (Figure 6.2.5) of



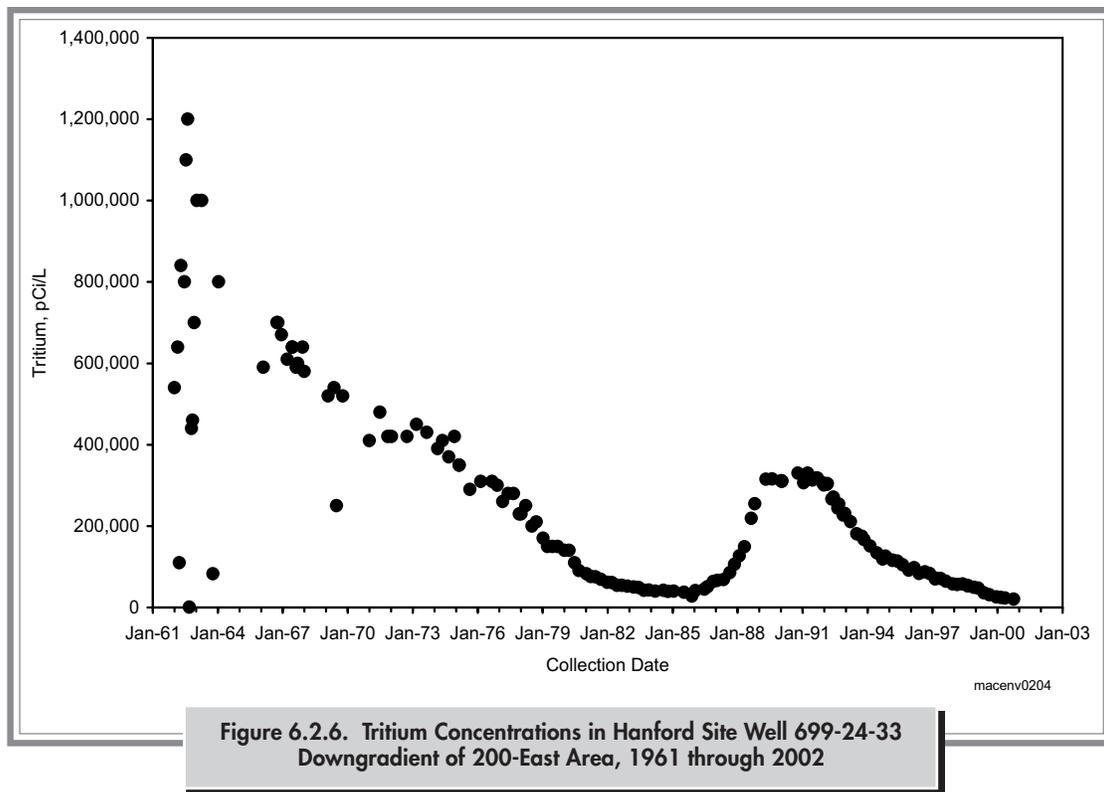
**Figure 6.2.5. Tritium Concentrations in Hanford Site Well 699-40-1 Near the Columbia River, 1961 through 2002**

the tritium concentrations in well 699-40-1 near the Hanford town site near the Columbia River clearly shows the arrival of a pulse in the mid-1970s. High tritium concentrations near the Columbia River result from discharges to the ground during the operation of the Plutonium-Uranium Extraction Plant from 1956 to 1972. Following an 11-year shutdown, plant operation resumed during 1983 and ceased in December 1988. This resulted in elevated tritium levels measured in several wells downgradient from the 200-East Area. Movement of the leading edge of this later pulse shows arrival near the Central Landfill during early 1987 (Figure 6.2.6). Tritium concentrations from the earlier pulse (Figure 6.2.5) were higher than the maximum concentrations in the later pulse. The effects of the 1983 to 1988 operational period have not been detected near the Columbia River.

The tritium plume, which has been monitored since the 1960s, provides information on the extent of groundwater contamination over time. Figure 6.2.7 shows the distribution of tritium in selected years from 1964 through 2002. This figure was created from maps in BNWL-90, BNWL-1970, PNL-5041, PNL-6825 (Section 5.0), PNNL-11141, and PNNL-14187. The contours in the

original references were re-calculated and interpreted to provide uniform contour intervals. Tritium at levels greater than the drinking water standard reached the Columbia River near the Hanford town site in approximately the mid-1970s (Figure 6.2.7). By the late 1980s, tritium at these levels was discharging to the Columbia River several kilometers south of the Hanford town site. The tritium plume continued to expand in the southeastern part of the Hanford Site. By 1995, tritium at concentrations exceeding 20,000 pCi/L (740 Bq/L) was entering or very near the Columbia River along greater portions of the shoreline extending between the Hanford town site and the 300 Area. Tritium levels did not change significantly between 1995 and 2002.

Tritium in groundwater also is found at levels above the drinking water standard in the northwestern part of the 200-East Area (Figure 6.2.1). This plume appears to extend to the northwest through the gap between Gable Mountain and Gable Butte where a pulse of tritium also occurs at levels above the drinking water standard. Waste sites in the vicinity of B Plant in the 200-East Area are the sources of tritium contamination in groundwater in the Gable Mountain/Gable Butte area. The tritium distribution to



**Figure 6.2.6. Tritium Concentrations in Hanford Site Well 699-24-33 Downgradient of 200-East Area, 1961 through 2002**

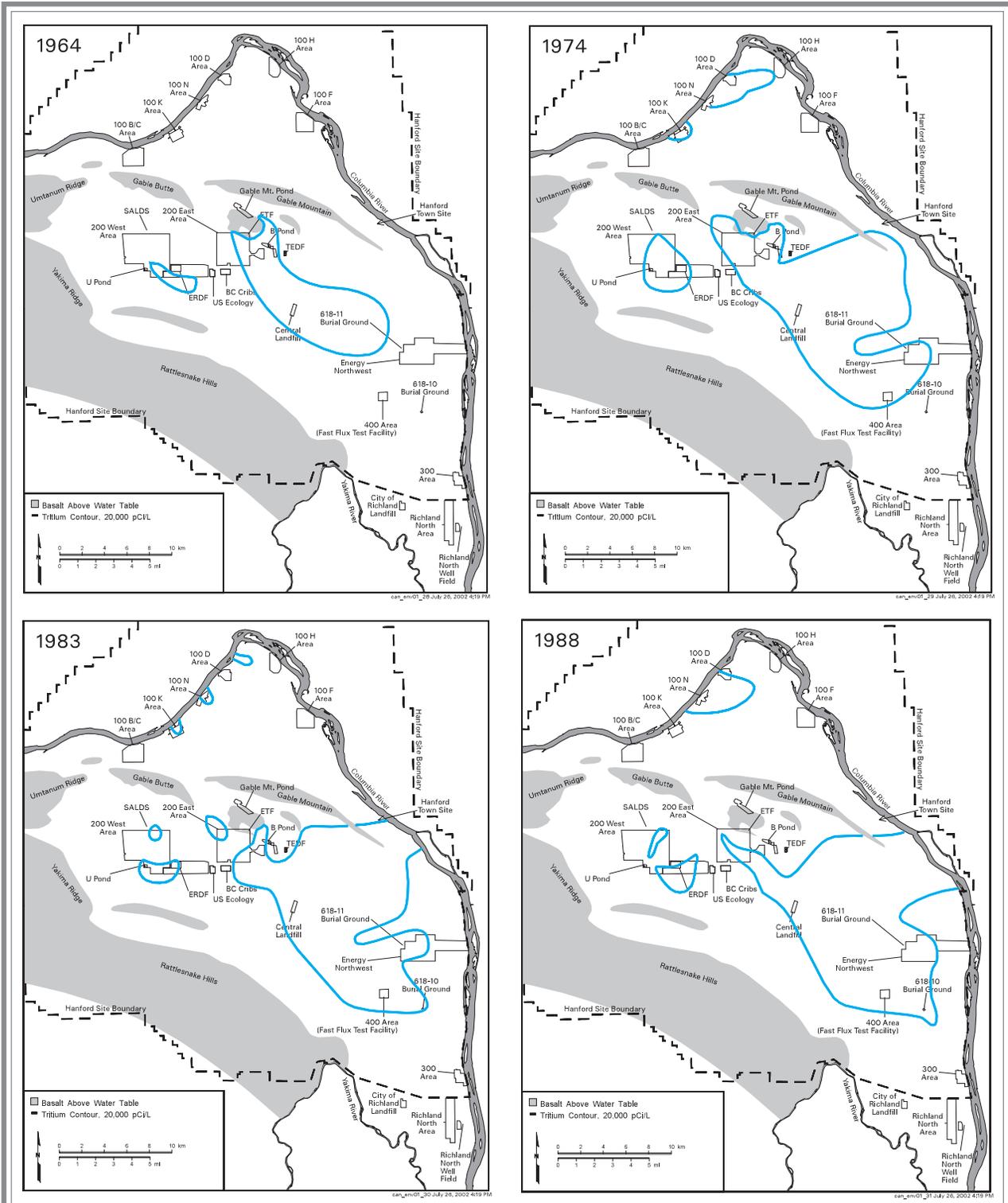
the northwest and southeast of the 200-East Area indicates a divide in groundwater flow direction across the 200-East Area.

**Tritium in the 200-West Area.** Tritium from sources near the Reduction-Oxidation Plant forms the most extensive tritium groundwater plume associated with the 200-West Area. The Reduction-Oxidation Plant is located in the southeastern part of the 200-West Area and operated from 1951 through 1967. This plume extends into the 600 Area east of the 200-West Area to US Ecology's facility, and the eastern part of the plume curves to the north (Figure 6.2.1). This plume continues to decrease in size because of radioactive decay. The movement of plumes in the 200-West Area is expected to be slow because the Ringold Formation sediment that underlies the area has low permeability and restricts flow. Movement of the plumes in the 200-West Area also is slowing further because of declining hydraulic gradients. The maximum concentration detected in this plume during 2002 was 914,000 pCi/L (33,850 Bq/L) east of the Reduction-Oxidation Plant. Tritium concentrations exceeded the drinking water standard in much of the plume, including a small area near the former 216-S-25 crib and the S and SX Tank Farms upgradient of the Reduction-Oxidation

Plant. The maximum tritium concentration measured near these facilities during 2002 was 300,000 pCi/L (11,110 Bq/L) in a well adjacent to the former 216-S-25 crib.

A smaller tritium plume occurs in the northern part of the 200-West Area and extends to the northeast (Figure 6.2.1). This plume is associated with former T Plant waste sites, including the TY Tank Farm, the 242-T evaporator, T Pond, and inactive disposal cribs and trenches. The highest tritium concentration detected in the 200-West Area was 1.77 million pCi/L (65,560 Bq/L) just east of the TX and TY Tank Farms near the 216-T-26 crib. The area where the drinking water standard was exceeded extends northeast past the northern boundary of the 200-West Area.

Tritium concentrations in the top of the unconfined aquifer near the State-Approved Land Disposal Site (an active tritium discharge site) just north of the 200-West Area exceeded the drinking water standard during 2002. The maximum tritium concentration detected in the top of the unconfined aquifer was 240,000 pCi/L (8,890 Bq/L). In the deeper portion of the unconfined aquifer, tritium concentrations continued to decrease during 2002 after reaching a peak of 980,000 pCi/L (36,300 Bq/L) in 2001. Tritium



**Figure 6.2.7. Current and Historical Tritium Concentrations in Hanford Site Groundwater**

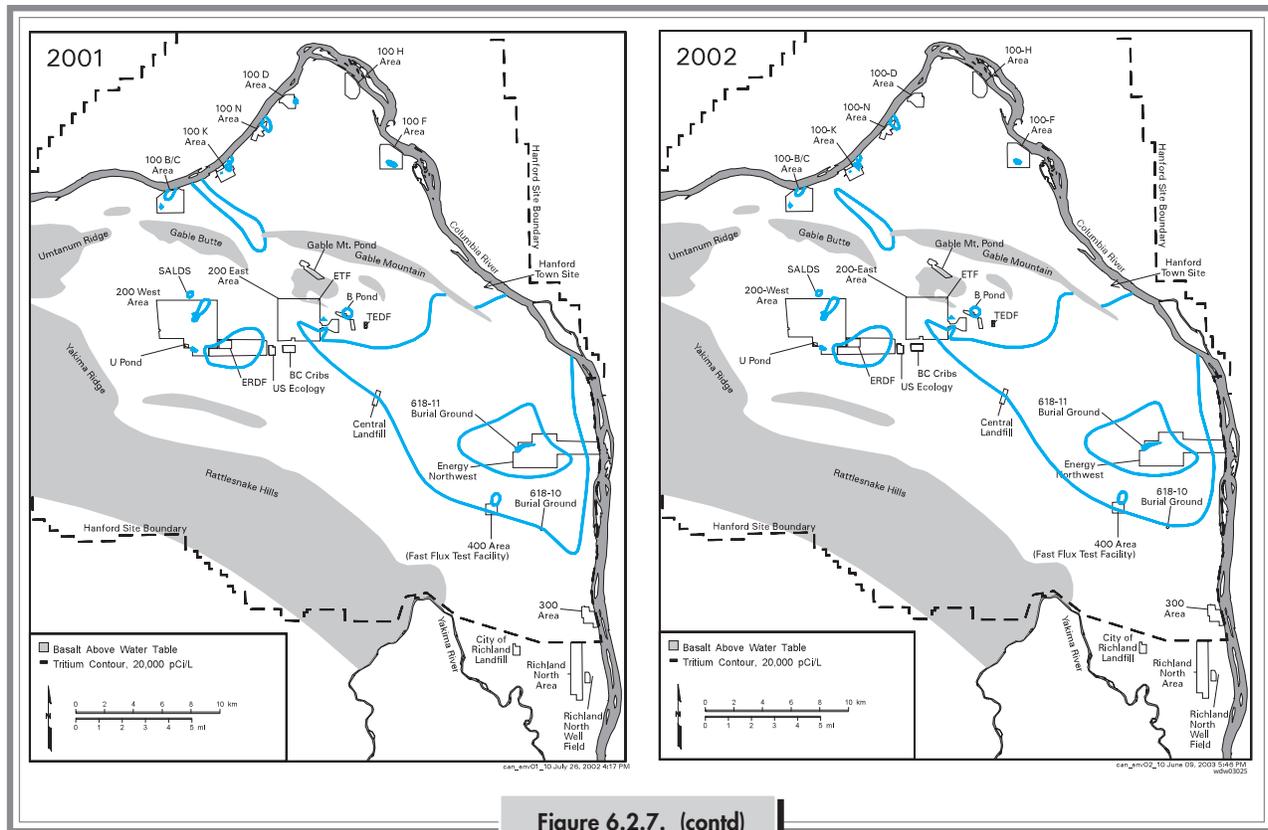


Figure 6.2.7. (contd)

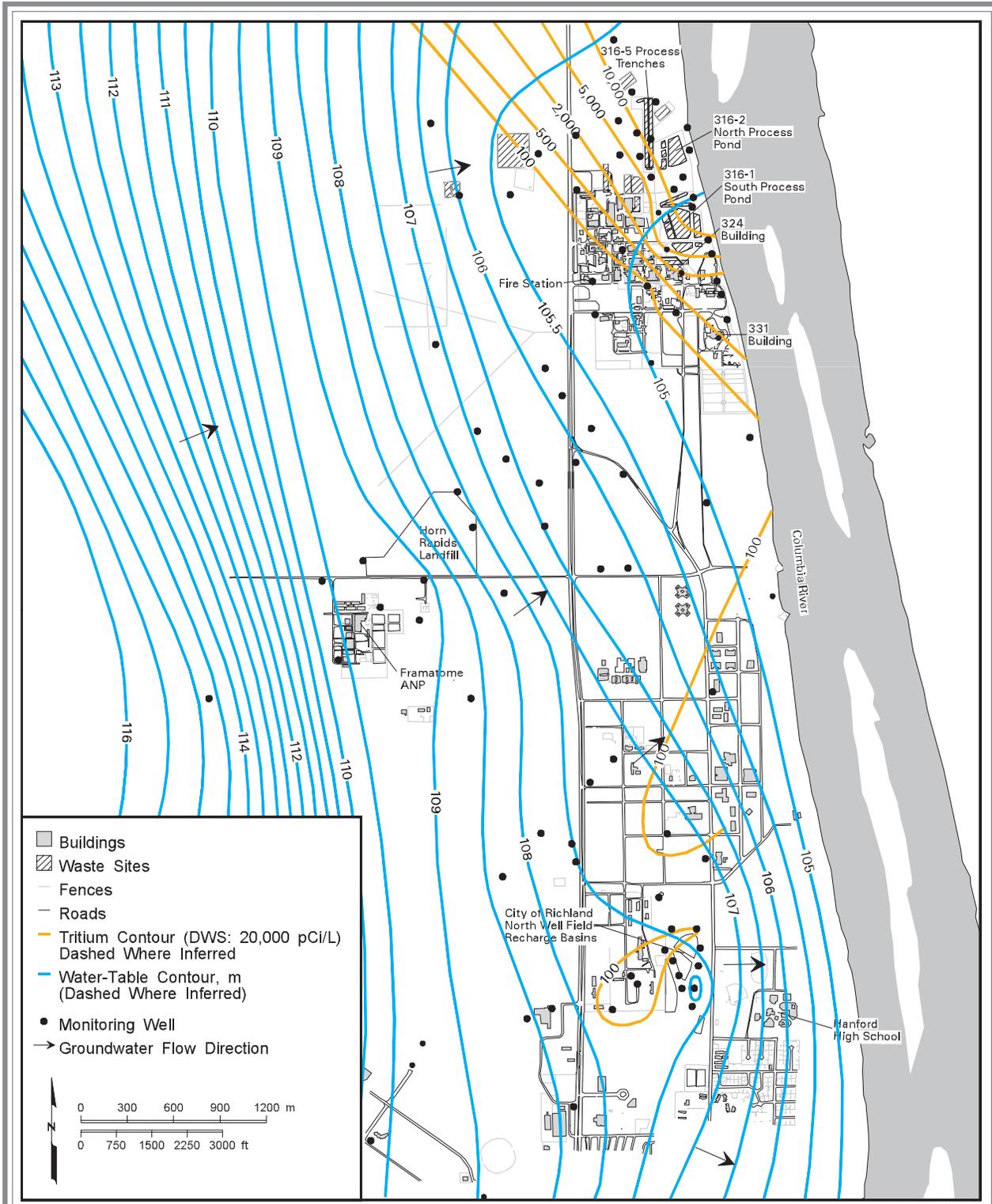
concentrations in the deeper portion of the unconfined aquifer decreased to 490,000 pCi/L (18,150 Bq/L) by July 2002. This rise and fall in the tritium concentrations is related to effluent from earlier discharges containing tritium prior to April 1999. Approximately 8.6 curies (~319 billion becquerels) of tritium were discharged to this facility during 2002. By the end of December 2002, ~333 curies (~12.33 trillion becquerels) of tritium and ~556 million liters (~147 million gallons) of treated effluent containing tritium had been discharged to this facility since operations began during 1995.

#### ***Tritium in the 300 Area and 618-11 Burial Ground.***

The eastern portion of the groundwater tritium plume that emanates from the 200-East Area continues to move to the east-southeast and discharge into the Columbia River (Figure 6.2.1). The southern edge of the tritium plume extends into the 300 Area (Figure 6.2.8). Tritium concentrations decrease from >10,000 pCi/L (>370 Bq/L) in the northeastern part of the 300 Area to <100 pCi/L (<3.7 Bq/L) in the southwestern part of the 300 Area (Figure 6.2.8). The tritium contours shifted slightly to the northeast, indicating that the tritium plume in the 300 Area

decreased in size between 2001 and 2002. Although tritium in the 300 Area is at levels (a maximum of 8,910 pCi/L [330 Bq/L]) less than the drinking water standard, a concern has been the potential migration of tritium to a municipal water supply to the south. The municipal water supply consists of the city of Richland's well field and recharge ponds (Figure 6.2.8). The highest tritium level detected south of the 300 Area was 727 pCi/L (27 Bq/L) ~300 meters (~980 feet) from the well field. Monitoring data indicate that the Hanford Site tritium plume has not reached the municipal water supply.

The tritium plume is not expected to affect the well field because of the influence of groundwater flow from the Yakima River, recharge from agricultural irrigation, and recharge from infiltration ponds at the well field (Figure 6.2.8). The Yakima River is at a higher elevation than the water table and recharges the groundwater in this area. Groundwater flows from west to east (Figure 6.2.8), minimizing the southward movement of the regional tritium plume from the Hanford Site. Recharge from agricultural irrigation occurs south of the Hanford Site boundary and contributes to eastward flow. The recharge ponds are



**Figure 6.2.8. Average Tritium Concentrations and Groundwater Flow Near the Hanford Site's 300 Area, 2002**

supplied with Columbia River water, which infiltrates to the groundwater. The amount of recharge water exceeded the amount pumped at the well field by a factor of at least 2:1 during 2002, resulting in groundwater flow away from the well field. Recharge creates a mound that further assures that tritium-contaminated groundwater will not reach the well field.

Some of the highest tritium concentrations measured in Hanford Site groundwater in 2002 were in one well (699-13-3A) immediately downgradient of the 618-11 burial ground. The maximum tritium concentration at this well was 4.23 million pCi/L (156,670 Bq/L) in 2002. The 618-11 burial ground is located west of the Energy Northwest reactor complex in the eastern portion of the 600 Area (Figure 6.2.9). The burial ground was active from 1962 to 1967 before the Energy Northwest reactor complex was constructed and received a variety of low- and high-level waste from the 300 Area. A special investigation during 2000 determined that the burial ground was the likely source of the tritium contamination after an unexpected discovery of high tritium concentrations up to several million picocuries per liter in early 1999 (PNNL-13228).

However, potential tritium source materials and locations within the burial ground have not been identified.

The investigation continued during 2001 to define the lateral and vertical extent of contamination. The 2001 study defined a tritium plume that is narrow and extends ~900 meters (~2,950 feet) east-northeast of the burial ground (Figure 6.2.10). The vertical extent of the plume was throughout the unconfined aquifer above a silt layer that is ~14 meters (46 feet) below the water table. Based on this extent, the plume is estimated to contain between 190 and 235 curies (7.03 and 8.70 trillion becquerels) of tritium. In 2001, the travel time for the tritium plume to reach the Columbia River was estimated to be between 43 and 166 years. During 2002, additional methods using alternative assumptions provided a range of 43 to 129 years for the travel time to reach the Columbia River (PNNL-14187). These calculations indicate that the tritium in this plume will most likely decay to levels less than the drinking water standard before it reaches the river.

**Tritium in the 400 Area.** The tritium plume that originated in the 200-East Area extends under the 400 Area.

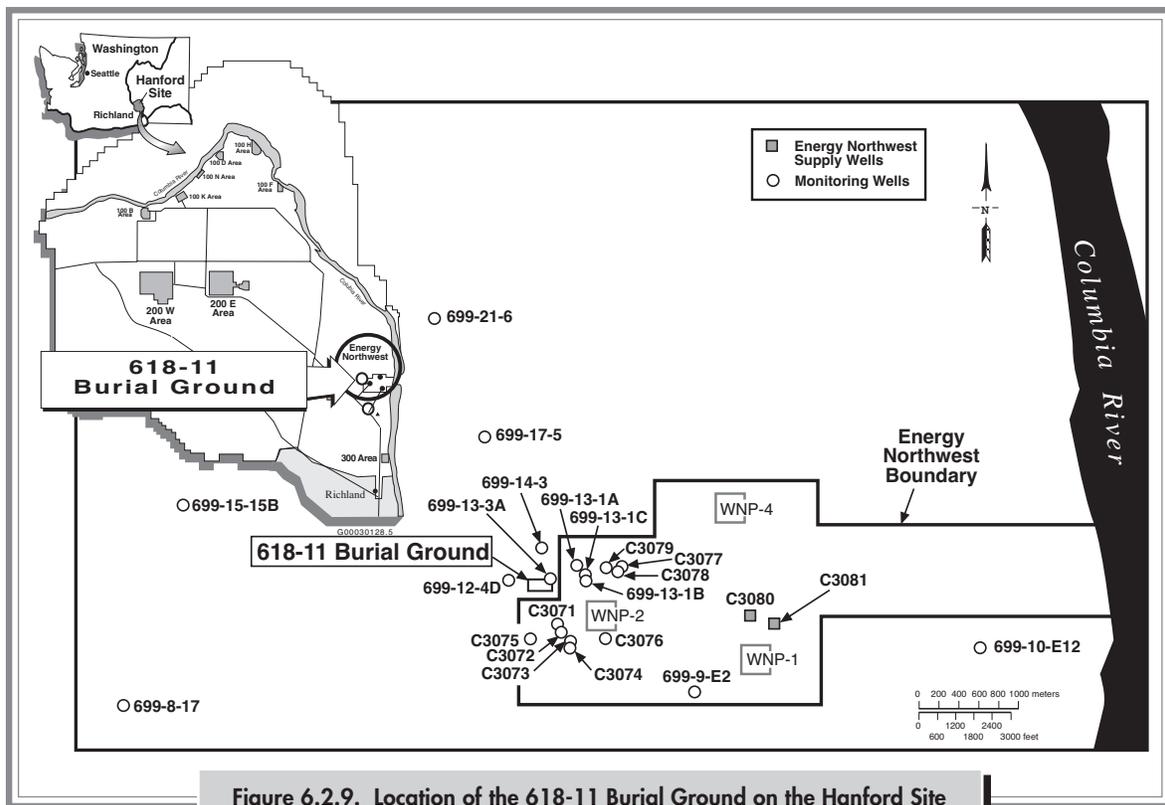
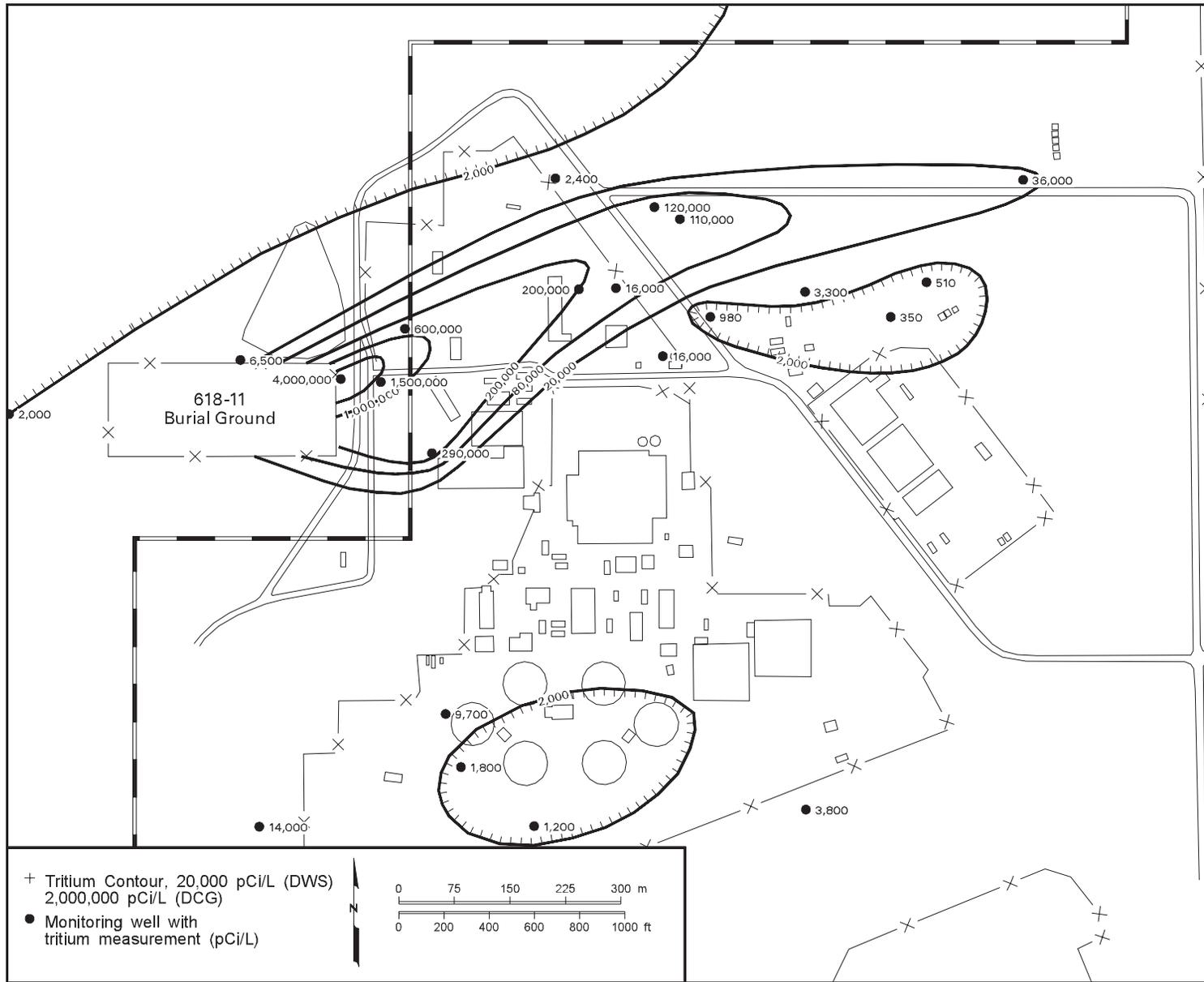


Figure 6.2.9. Location of the 618-11 Burial Ground on the Hanford Site



can\_env02\_12 June 09, 2003 5:47

**Figure 6.2.10. Average Tritium Concentrations in the Unconfined Aquifer at the Hanford Site's 618-11 Burial Ground, 2002**

The maximum concentration detected in this area during 2002 was 19,900 pCi/L (737 Bq/L) near the 4608 B/C process ponds. The water supply wells are located in the northern part of the 400 Area. Tritium levels in the primary (499-S1-8J) and backup (499-S0-7 and 499-S0-8) water supply wells did not exceed the annual average drinking water standard of 20,000 pCi/L (740 Bq/L) during 2002. Tritium levels in the 400 Area are slowly declining because of dispersion and radioactive decay. Additional information on the 400 Area water supplies is provided in Section 4.3.

**Iodine-129.** Iodine-129 has a relatively low drinking water standard (1 pCi/L [0.037 Bq/L]), has the potential to accumulate in the environment as a result of long-term releases from nuclear fuel reprocessing facilities (Soldat 1976), and has a long half-life (16 million years). An iodine-129 plume at levels exceeding the drinking water standard is extensive in the 200 and 600 Areas. No groundwater samples showed iodine-129 concentrations above the 500-pCi/L (18.5-Bq/L) DOE derived concentration guide during 2002. Iodine-129 may be released as a vapor during fuel dissolution and during other elevated temperature processes and, thus, may be associated with process condensate waste. At the Hanford Site, the main contributor of iodine-129 to groundwater is past-practice liquid discharges to cribs in the 200 Areas. Iodine-129 has essentially the same high mobility in groundwater as tritium. The highest level of iodine-129 detected in groundwater during 2002 on the Hanford Site was 31.6 pCi/L (1.2 Bq/L) in a well sample collected near the TX and TY Tank Farms in the 200-West Area.

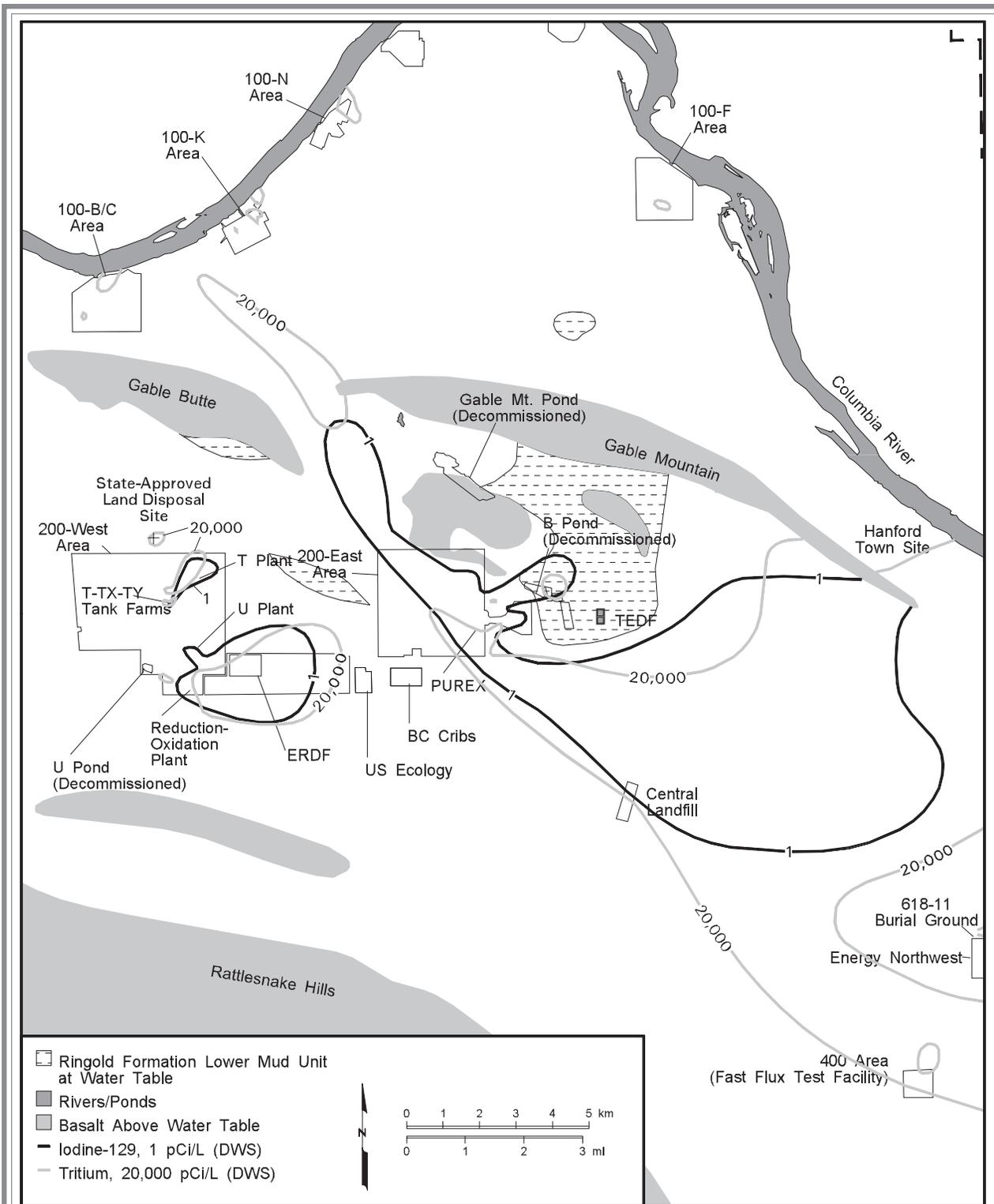
**Iodine-129 in the 200-East Area.** The highest iodine-129 concentrations in groundwater in the 200-East Area are near the Plutonium-Uranium Extraction Plant and in the vicinity of B Plant (Figure 6.2.11). The maximum level of iodine-129 detected during 2002 in the 200-East Area was 11.2 pCi/L (0.41 Bq/L) in a well located south of the Plutonium-Uranium Extraction Plant near the 216-A-36B crib. Iodine-129 concentrations near this crib are declining slowly or are stable. This iodine-129 plume extends from the Plutonium-Uranium Extraction Plant area southeast into the 600 Area and appears coincident with the tritium plumes (Figure 6.2.11). The iodine-129 plume likely had the same sources as the tritium plume. The iodine-129 plume appears smaller than

the tritium plume because of the lower initial concentration of iodine-129. Iodine-129 also is present in groundwater at levels above the drinking water standard in the northwestern portion of the 200-East Area and extends northwest into the gap between Gable Mountain and Gable Butte.

**Iodine-129 in the 200-West Area.** The distribution of iodine-129 in Hanford Site groundwater is shown in Figure 6.2.11. The highest level detected in groundwater in the 200-West Area during 2002 was 31.6 pCi/L (1.2 Bq/L) in a well near the TX and TY Tank Farms. This level occurs in a plume that extends northeast toward T Plant. This iodine-129 plume, which is generally coincident with the technetium-99 and tritium plumes in this area, most likely originates from the 242-T evaporator facility located between the TX and TY Tank Farms. A much larger iodine-129 plume occurs in the southeastern part of the 200-West Area. This plume originates near the Reduction-Oxidation Plant, with a possible contribution from cribs to the north near U Plant, and extends east into the 600 Area. This plume is essentially coincident with the tritium plume in that area. During 2002, the maximum concentration detected in this plume was 29.9 pCi/L (1.1 Bq/L) measured in a well at the 600 Area east of the Reduction-Oxidation Plant. Iodine-129 levels in this plume have not changed significantly in the last several years.

**Technetium-99.** Technetium-99, which has a half-life of 210,000 years, was produced as a high-yield fission byproduct and was present in waste streams associated with fuel reprocessing. Past reactor operations also may have resulted in the release of some technetium-99 associated with fuel element breaches. Technetium-99 is typically associated with uranium through the fuel processing cycle, but uranium is less mobile in groundwater. Under the chemical conditions that exist in Hanford Site groundwater, technetium-99 is normally present in solution as anions that sorb poorly to sediments. Therefore, technetium-99 is very mobile in site groundwater.

The DOE derived concentration guide for technetium-99 is 100,000 pCi/L (3,700 Bq/L) and the interim drinking water standard is 900 pCi/L (33 Bq/L). Technetium-99 was found at concentrations greater than the interim drinking water standard (900 pCi/L [33 Bq/L]) in the 200-East, 200-West, and 100-H Areas. The highest level



can\_env02\_13 April 08, 2003 2:49 PM

**Figure 6.2.11. Average Iodine-129 and Tritium Concentrations in the Unconfined Aquifer at the Hanford Site, 2002**

measured on the Hanford Site during 2002 was 99,700 pCi/L (3,690 Bq/L) in a well near the SX Tank Farm in the 200-West Area.

**Technetium-99 in the 200-East Area.** Groundwater in the northwestern part of the 200-East Area and a part of the 600 Area north of the 200-East Area contains technetium-99 at concentrations above the interim drinking water standard (Figure 6.2.12). The primary source of the technetium contamination was apparently the BY cribs (Section 2.9.1 in PNNL-13116). However, some of this contamination is also believed to originate from B, BX, and BY Tank Farms (PNNL-11826). The maximum concentration (10,600 pCi/L [393 Bq/L]) in groundwater in the 200-East Area during 2002 was measured in a well at the BY cribs. During 2002, technetium-99 concentrations near B, BX, and BY Tank Farms generally decreased from 2001 technetium-99 levels. Technetium-99 levels near the tank farms reached maximum concentrations in late 2000 and early 2001. The extent of technetium-99 contamination in groundwater north of the 200-East Area is uncertain. This larger portion of the plume to the north appears to be moving north through the gap between Gable Mountain and Gable Butte. Increasing technetium-99 concentrations southeast of the BX and BY Tank Farms in recent years indicate that part of the technetium-99 plume is moving to the south.

**Technetium-99 in the 200-West Area.** The largest technetium-99 plume in the 200-West Area originates from cribs that received effluent from U Plant and extends into the 600 Area to the east (Figure 6.2.13). The technetium plume is approximately in the same location as the uranium plume because technetium-99 and uranium, which are typically associated with the same fuel reprocessing cycle, were disposed to the same 216-U-1, 216-U-2, and 216-U-17 cribs. A pump-and-treat system reduced technetium-99 concentrations in the central part of the plume during 2001 (Section 2.3.13). Technetium-99 concentrations have generally declined in the central part of the plume since pump-and-treat operations began in 1997. The maximum technetium-99 level detected in this plume during 2002 was 22,400 pCi/L (829 Bq/L).

Several wells that monitor T, TX, and TY Tank Farms consistently showed technetium-99 concentrations above the interim drinking water standard in recent years (Figure 6.2.13). In 2002, the highest measured concentration

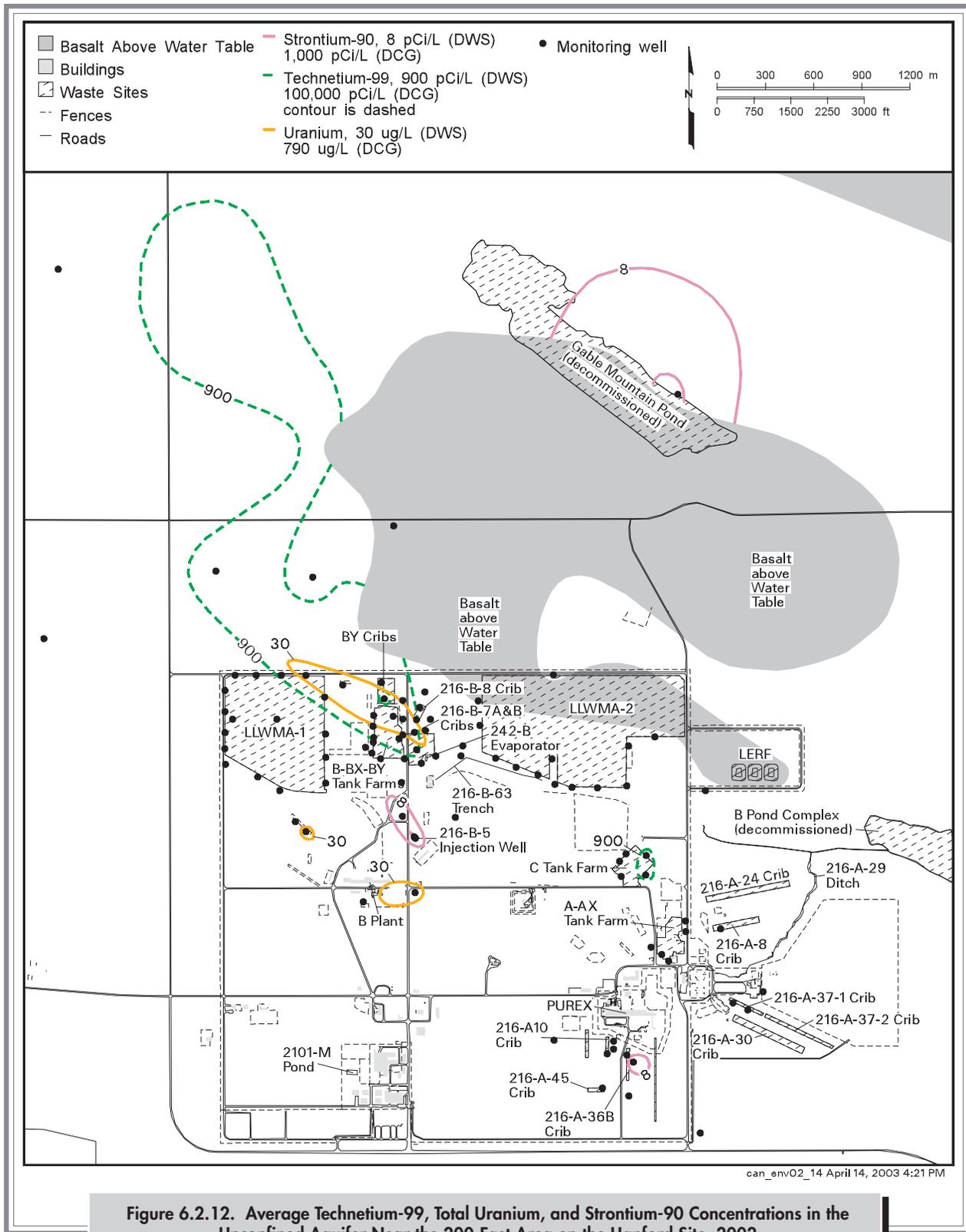
was 6,510 pCi/L (241 Bq/L) in a well east of T Tank Farm. The 200-ZP-1 pump-and-treat operation immediately to the south of the TX and TY Tank Farms is having a significant influence on the distribution of contaminants beneath the TX and TY Tank Farms. A large cone of depression in the water table is resulting in the movement of groundwater contaminants from beneath the tank farms toward the pump-and-treat system.

Technetium-99 levels in groundwater were above the interim drinking water standard near the T Tank Farm. The maximum technetium-99 concentration in this area during 2002 was 6,790 pCi/L (251 Bq/L). Technetium-99 concentrations generally increased near T Tank Farm during 2002. The sources of the technetium-99 contamination include T, TX, and TY Tank Farms (PNNL-11809).

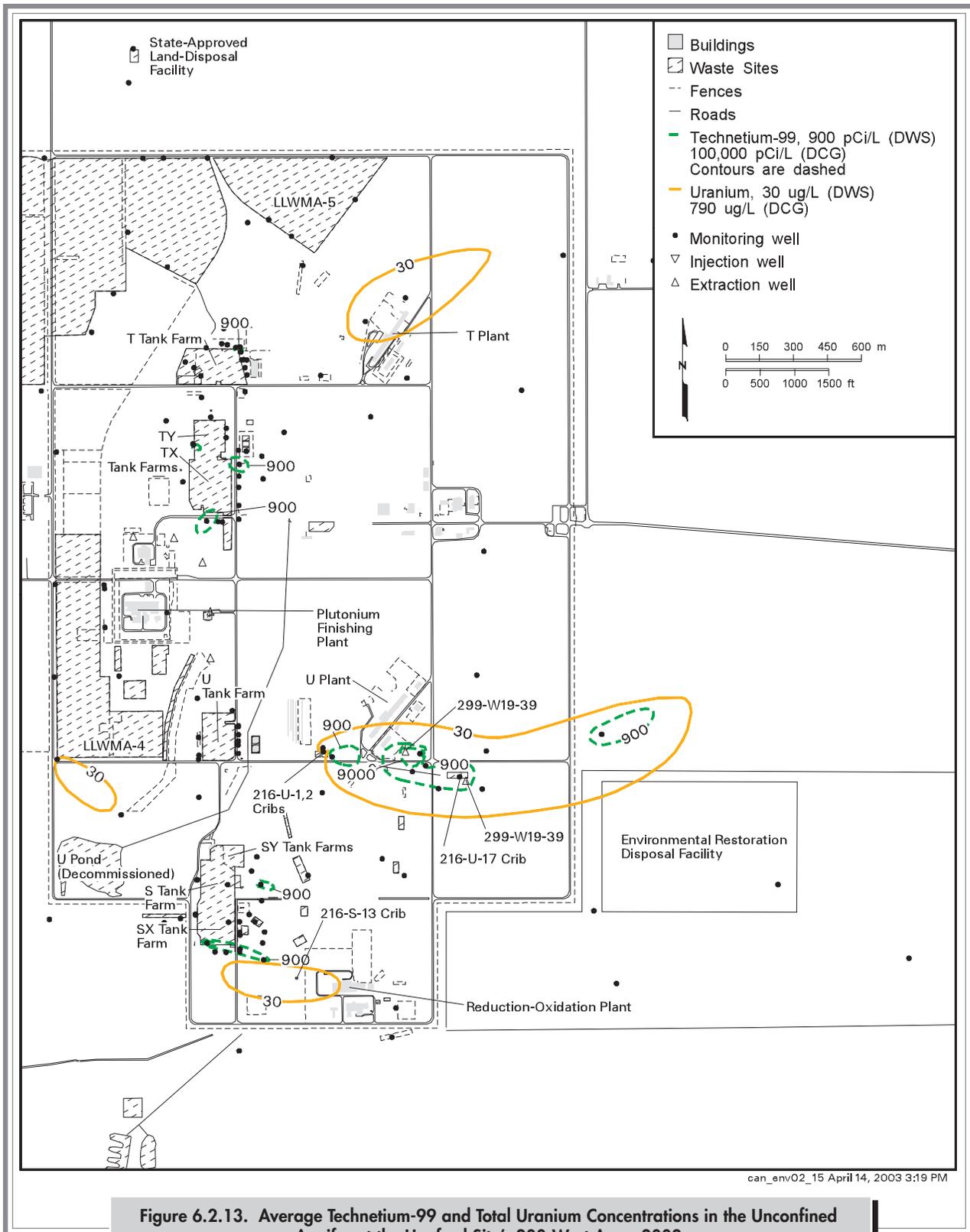
Technetium-99 contamination in two small areas in the southern part of the 200-West Area originates near S and SX Tank Farms and the 216-S-13 crib. Multiple sources of technetium-99 contribute to groundwater contamination in this area (PNNL-13441; PNNL-13801). One plume containing technetium-99 has migrated east of the S Tank Farm, where the maximum technetium-99 concentration was 4,670 pCi/L (173 Bq/L) in 2002. A second small, but narrow plume containing technetium-99 located south of the SX Tank Farm changed significantly on the downgradient margin during 2002. The downgradient margin of the plume moved through and beyond the farthest downgradient well southeast of the SX Tank Farm. The maximum level detected in this plume was 99,700 pCi/L (3,690 Bq/L) in the southwestern corner of SX Tank Farm. This was the highest technetium-99 concentration detected on the Hanford Site during 2002.

**Technetium-99 in the 100-H Area.** Technetium-99 exceeded the interim drinking water standard in one well near the 116-H-6 evaporation basins in 2002 for the first time. The technetium-99 concentration was 986 pCi/L (36.5 Bq/L) in this well.

**Total Uranium.** There were numerous possible contributors of uranium released to the groundwater at the Hanford Site in the past, including fuel fabrication, fuel reprocessing, and uranium recovery operations. Uranium may exist in several states, including elemental uranium or uranium oxide as well as tetravalent and hexavalent cations. Only the hexavalent form has significant mobility in groundwater,



**Figure 6.2.12. Average Technetium-99, Total Uranium, and Strontium-90 Concentrations in the Unconfined Aquifer Near the 200-East Area on the Hanford Site, 2002**



can\_env02\_15 April 14, 2003 3:19 PM

largely by forming dissolved carbonate species. Uranium mobility is, thus, dependent on oxidation state, pH, and the presence of carbonate. Uranium is observed to migrate in site groundwater but is retarded relative to more mobile species such as technetium-99 and tritium. The EPA's drinking water standard for uranium<sup>(a)</sup> is 30 µg/L (0.03 ppm), which protects against both chemical toxicity and cancer risk. The DOE derived concentration guide, which represents an annual effective dose equivalent of 100 mrem (1 mSv), is 790 µg/L (0.79 ppm) for uranium. Total uranium has been detected in groundwater at concentrations greater than the drinking water standard in portions of the 100, 200, and 300 Areas. The highest levels detected at the Hanford Site during 2002 were in the 200-West Area near U Plant, where uranium levels were 2,100 µg/L (2.1 ppm) and exceeded the DOE derived concentration guide.

**Total Uranium in the 100 Areas.** Uranium was detected at levels exceeding the 30-µg/L (0.03 ppm) drinking water standard in a small area in the 100-H Area. The maximum level detected during 2002 was 119 µg/L (0.119 ppm) between the 116-H-6 evaporation basins and the Columbia River. Concentrations of uranium (and associated technetium-99) in the 100-H Area have generally fluctuated in response to changes in groundwater levels in the past several years. Near the river, low groundwater levels are usually associated with higher concentrations. Past leakage from the 116-H-6 evaporation basins is the source of the 100-H Area uranium contamination.

**Total Uranium in the 200-East Area.** In the 200-East Area, uranium contamination at levels greater than the drinking water standard is limited to isolated areas associated with B Plant (Figure 6.2.12). The uranium distribution during 2002 indicates the highest concentrations were in the vicinity of B, BX, and BY Tank Farms; the BY cribs; and the 216-B-5 injection well, which has been inactive since 1947. The highest concentration detected was 391 µg/L (0.391 ppm) at the BY Tank Farm (south of the BY cribs). The uranium plume, which is associated with technetium-99 at the BY Tank Farm, has a narrow northwest-southeast shape. Though unclear, a likely source of the uranium contamination is the tank farm.

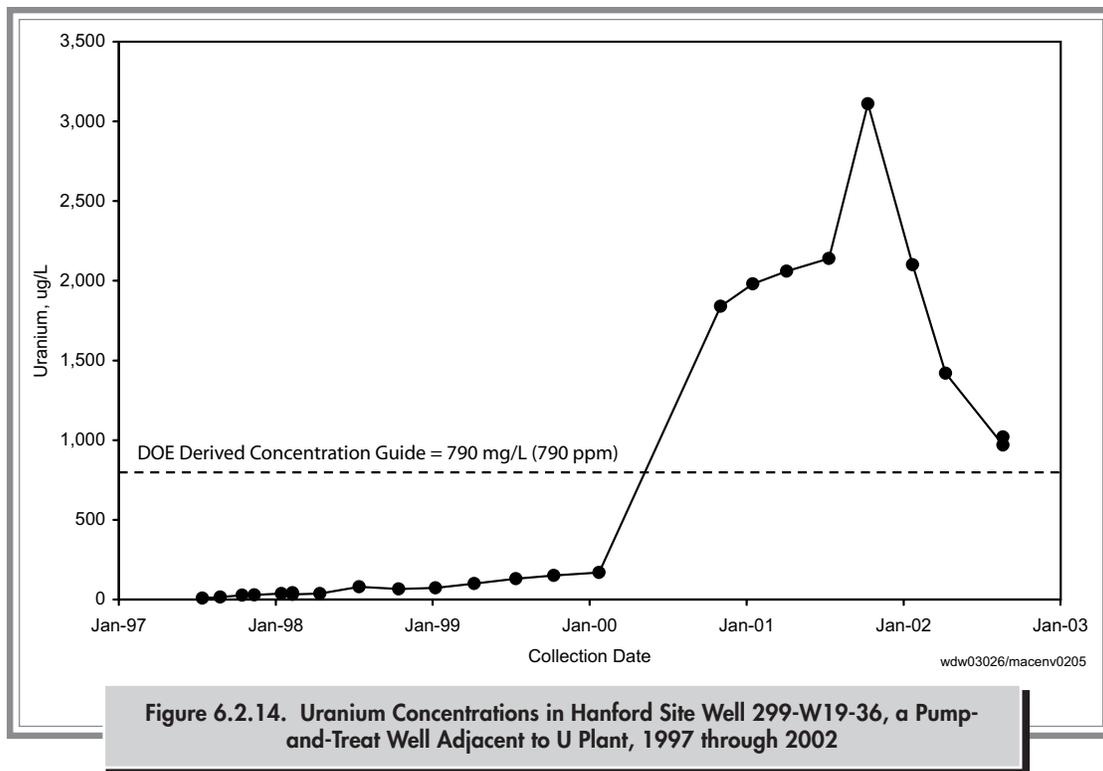
**Total Uranium in the 200-West Area.** The highest uranium concentrations in Hanford Site groundwater occurred near U Plant (Figure 6.2.13). The 216-U-1 and 216-U-2 cribs are the major sources of the uranium. The maximum concentration detected in this area and on the Hanford Site during 2002 was 2,100 µg/L (2.1 ppm) in a well (299-W19-36) adjacent to U Plant (Figure 6.2.14). This former pump-and-treat well was converted to an extraction well in early 2002. Uranium concentrations in this well declined during most of 2002 after uranium levels in this well peaked in late 2001, just prior to the start of extraction. The uranium plume, which extends into the 600 Area to the east, is approximately in the same location as the technetium-99 plume discussed above. Uranium and technetium-99 were typically associated with the same fuel reprocessing cycle and were disposed to the same cribs. However, uranium is less mobile than technetium-99 because of its stronger sorption to the sediment. A greater proportion of the uranium contamination remains at or near the source area. The general configuration of the uranium plume during 2002 was similar to past years. The high concentrations exceeded the DOE derived concentration guide for uranium. A pump-and-treat system continued to operate in the 200-West Area in 2002 to remove uranium from groundwater (Section 2.3.13).

In the northern part of the 200-West Area, a localized area of uranium contamination in groundwater occurs near T Plant, where concentrations were above the drinking water standard at a maximum level of 411 µg/L (0.411 ppm).

**Total Uranium in the 300 Area.** A plume of uranium contamination exists near former uranium fuel fabrication facilities and inactive waste sites known to have received uranium waste. The plume extends downgradient from inactive liquid waste disposal facilities to the Columbia River (Figure 6.2.15). The major source of the contamination is the inactive 316-5 process trenches, as indicated by the distribution of the uranium concentrations downgradient from these trenches. The maximum concentration detected at this area during 2002 was 235 µg/L (0.235 ppm) northeast of the North Process Pond near the Columbia River. Because wastewater is no longer discharged to the 316-5 process trenches, elevated concentrations at the

---

(a) The final rule for the uranium drinking water standard was promulgated on December 7, 2000, and becomes effective on December 8, 2003 (40 CFR Parts 9, 141, and 142).



south end of the process trenches indicate that the soil column contributes uranium contamination to the groundwater. Uranium levels in 300 Area groundwater fluctuate annually but show an overall decline in recent years. The annual fluctuations in uranium levels are caused by river stage changes, which mobilize more uranium during high river stages in spring months and less uranium during low river stages in fall and early winter months. This is consistent with the results of a recent study of uranium leaching and adsorption in the 300 Area (PNNL-14022).

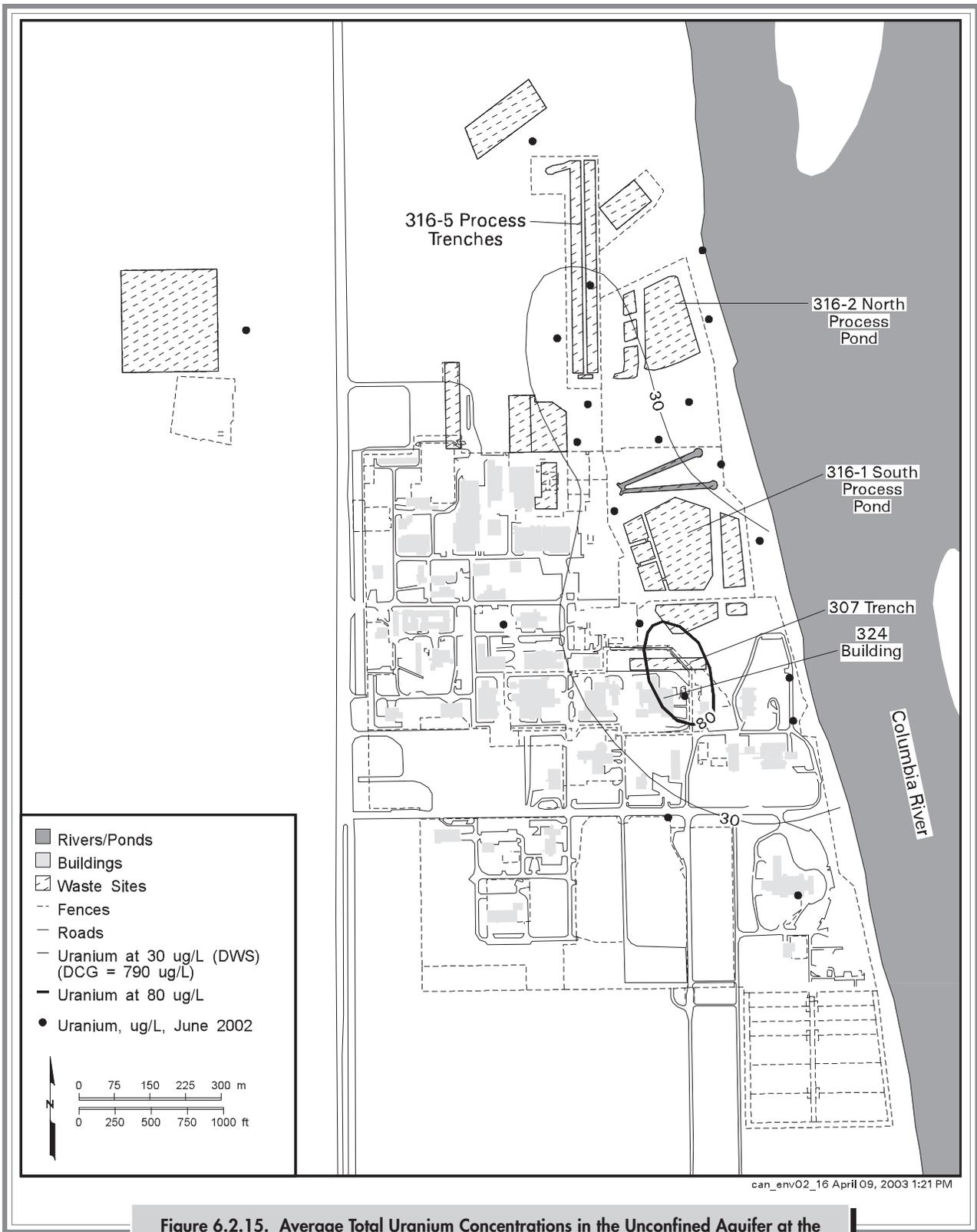
**Strontium-90.** Strontium-90 was produced as a high-yield fission product and was present in waste streams associated with past fuel reprocessing. Reactor operations also resulted in the release of some strontium-90 associated with fuel element breaches. Strontium-90 mobility in Hanford Site groundwater is reduced by adsorption onto sediment particles. However, strontium-90 is moderately mobile in groundwater because its adsorption is much weaker than for other radionuclides such as cesium-137 and plutonium. Because of sorption, a large proportion of the strontium-90 in the subsurface is not present in solution. The half-life of strontium-90 is 29.1 years.

During 2002, strontium-90 concentrations greater than the 8-pCi/L (0.3-Bq/L) drinking water standard were found

in one or more wells in each of the 100 and 200 Areas. Levels of strontium-90 were greater than the DOE derived concentration guide (1,000 pCi/L [37 Bq/L]) in the 100-K and 100-N Areas. The 100-N Area had the widest distribution detected at the Hanford Site during 2002. The maximum concentration detected in groundwater at the Hanford Site during 2002 was 18,500 pCi/L (685 Bq/L) in the 100-N Area.

**Strontium-90 in the 100 Areas.** Strontium-90 concentrations in groundwater at levels greater than the drinking water standard extend from the B Reactor to the Columbia River in the northeastern part of the 100-B/C Area. The highest concentration was found near the inactive 116-C-1 trench at a level of 39.3 pCi/L (1.5 Bq/L) during 2002. Strontium-90 concentrations in 100-B/C Area groundwater are generally declining. Sources for the strontium-90 appear to be inactive liquid waste disposal sites near B Reactor and inactive liquid overflow trenches near the Columbia River (DOE/EIS-0119F).

A small plume of strontium-90 with levels exceeding the drinking water standard occurs near the 116-F-14 retention basins and 116-F-2 and 116-F-9 trenches in the eastern part of the 100-F Area. The maximum concentration detected during 2002 was 27.8 pCi/L (1.0 Bq/L) between the



**Figure 6.2.15. Average Total Uranium Concentrations in the Unconfined Aquifer at the Hanford Site's 300 Area, 2002**

116-F-2 trench and the Columbia River. Strontium-90 levels in groundwater fluctuate with changing river levels in the 100-F Area.

In the 100-H Area, strontium-90 contamination levels greater than the drinking water standard were present in wells in an area adjacent to the Columbia River near the 116-H-7 retention basin. The maximum concentration detected during 2002 was 23.2 pCi/L (0.86 Bq/L) in a pump-and-treat well adjacent to the retention basin. The source of the contamination is past disposal of reactor coolant containing strontium-90 to the 116-H-7 retention basin, the 116-H-1 liquid waste trench, and the 116-H-5 sludge burial trench in the 100-H Area. Contaminated soil was excavated from the upper portion of the vadose zone at these facilities and disposed of to the Environmental Restoration Disposal Facility during 1999 and 2000. Strontium-90 levels in groundwater are generally stable in the 100-H Area.

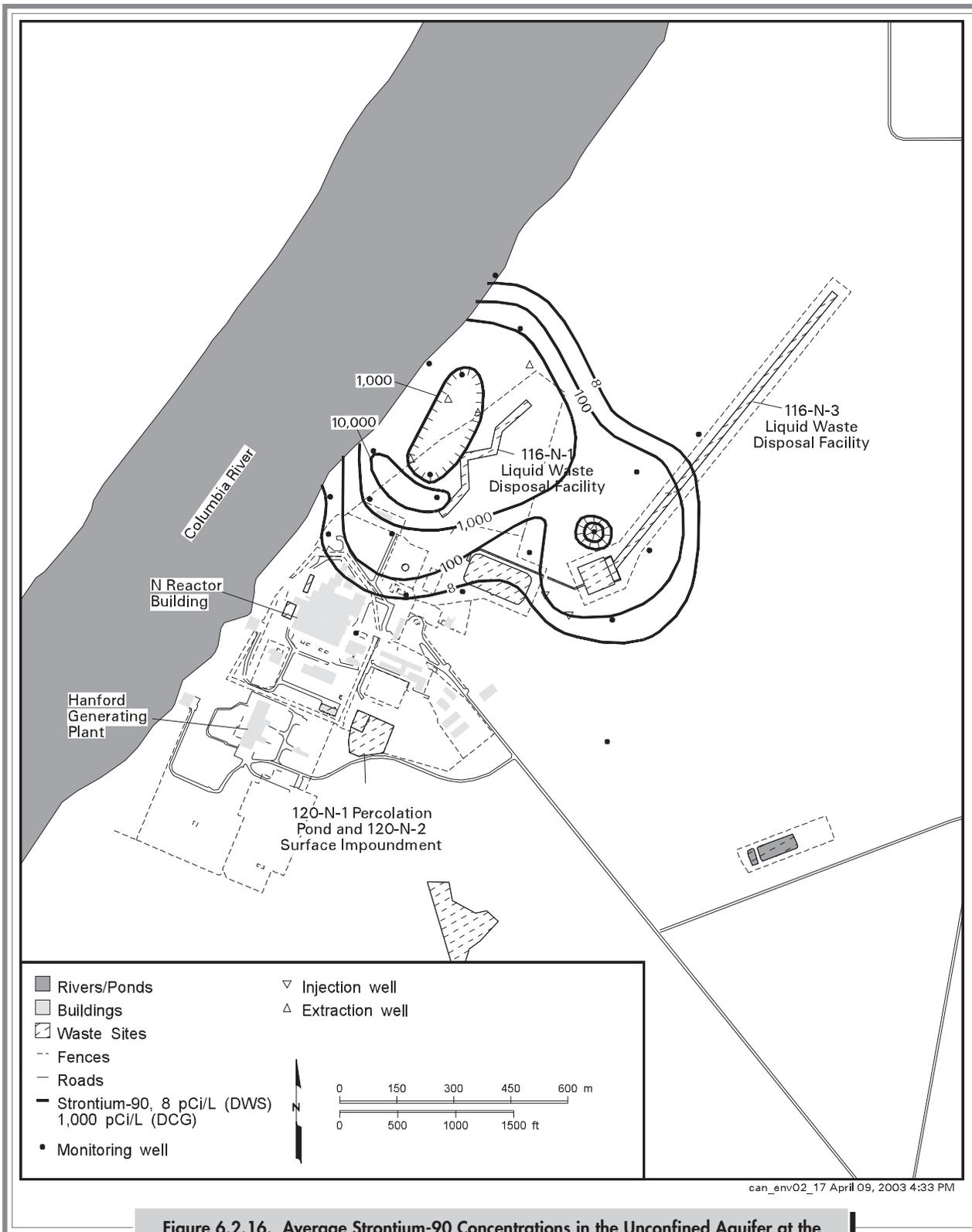
Strontium-90 at levels greater than the drinking water standard continues to be found in wells in isolated areas of the 100-K Area. These areas include fuel storage basin drain fields/injection wells associated with the KE and KW Reactors and the area between the inactive 116-K-2 liquid waste disposal trench and the Columbia River. The maximum concentration detected during 2002 was 2,440 pCi/L (90 Bq/L) at well 199-K-109A, the only well in the 100-K Area where strontium-90 levels were above the DOE derived concentration guide. Strontium-90 concentrations in this well decreased to a level below the DOE derived concentration guide by mid-2002, but increased above the DOE derived concentration guide by late 2002. The original source of the strontium-90 in this well was identified as past-practice disposal to the 116-KE-3 drain field/injection well near KE Reactor (PNNL-12023). Strontium-90 is a co-contaminant with chromium in the groundwater, which is being treated with a pump-and-treat system. However, strontium-90 is not removed by the treatment system that removes chromium from the extracted groundwater. Therefore, strontium-90 is returned to the aquifer via the pump-and-treat injection wells. Strontium-90 concentrations measured in the returned groundwater have been less than the drinking water standard since the pump-and-treat system began operating in 1997. The maximum strontium-90 concentration measured in groundwater near the inactive 116-K-2 liquid waste disposal trench during 2002 was

39.5 pCi/L (1.5 Bq/L). Near the KW Reactor, strontium-90 is elevated above the drinking water standard. The maximum strontium-90 concentration measured in groundwater near the KW Reactor during 2002 was 35.6 pCi/L (1.3 Bq/L).

The general distribution of strontium-90 in the 100-N Area has not changed significantly in the past 10 years or more (Figure 6.2.16). Strontium-90 was detected at concentrations greater than the DOE derived concentration guide in several wells located between the 116-N-1 liquid waste disposal facility, a source of the strontium-90, and the Columbia River. A pump-and-treat system is operating in this area to remove strontium-90 from groundwater. The 116-N-3 liquid waste disposal facility is also a source of strontium-90 in groundwater. The maximum level detected in the 100-N Area during 2002 was near the head end of the 116-N-1 liquid waste facility (well 199-N-67), where concentrations ranged between 4,490 and 18,500 pCi/L (166 and 685 Bq/L). The concentration 18,500 pCi/L (685 Bq/L) was the highest strontium-90 concentration detected in Hanford Site groundwater during 2002.

In the 100-N Area, strontium-90 enters the Columbia River via springs along the shoreline (Sections 3.2 and 4.2). Because of high strontium-90 concentrations in wells near the river, it was expected that strontium-90 concentrations would exceed the drinking water standard at the interface between the groundwater and the river (DOE/RL-96-102). The highest strontium-90 concentration measured in a near-river well during 2002 was 4,810 pCi/L (178 Bq/L). Strong, positive correlations between increases in groundwater levels and high strontium-90 concentrations in wells near the shoreline indicate that strontium-90 is remobilized during periods of high water levels. A pump-and-treat system continued to operate in the 100-N Area during 2002 to reduce the amount of strontium-90 to the Columbia River in that area (Section 2.3.13).

**Strontium-90 in the 200-East Area.** Strontium-90 distribution in the 200-East Area is shown in Figure 6.2.12. In the past, strontium-90 concentrations in the 200-East Area have been detected above the DOE derived concentration guide in two wells near the inactive 216-B-5 injection well. However, monitoring wells near the injection well were not sampled during 2002 because waste management documentation in support of CERCLA sampling needed to be developed. The former injection well received



**Figure 6.2.16. Average Strontium-90 Concentrations in the Unconfined Aquifer at the Hanford Site's 100-N Area, 2002**

an estimated 27.9 curies (1.03 trillion becquerels) of strontium-90 during 1945 and 1946 (PNL-6456). Elsewhere in the 200-East Area, strontium-90 was detected above the drinking water standard in one well near the Plutonium-Uranium Extraction Plant cribs. The maximum strontium-90 level measured in this well during 2002 was 21.4 pCi/L (0.79 Bq/L).

**Carbon-14.** Carbon-14 contamination occurs in the 100-K Area and groundwater concentrations exceeded the interim drinking water standard (2,000 pCi/L [74 Bq/L]) in two small plumes near the KE and KW Reactors (Figure 6.2.2). The sources of the carbon-14 were the 116-KE-1 and 116-KW-1 cribs. Waste disposal to these cribs ended during 1971. Carbon-14 was included with tritium in the condensate wastewater disposed to these cribs. However, the distribution of carbon-14 in groundwater is not the same as for tritium because carbon-14 sorbs onto sediment and is less mobile than tritium (PNNL-12023). Carbon-14 concentrations in 100-K Area groundwater were lower in 2002 than in previous years. The maximum concentration measured during 2002 was 20,900 pCi/L (774 Bq/L) in a well near the 116-KW-1 crib. The DOE derived concentration guide for carbon-14 is 70,000 pCi/L (2,590 Bq/L). Carbon-14 has a relatively long half-life of 5,730 years, which suggests that some of the carbon-14 will reach the Columbia River before the carbon-14 decays away. A portion of the carbon-14 will likely remain fixed on soil particles.

**Cesium-137.** Cesium-137, which has a half-life of 30 years, was produced as a high-yield fission product and was present in historical waste streams associated with fuel processing. Former reactor operations also may have resulted in the release of some cesium-137 associated with fuel element breaches. Normally, cesium-137 is strongly sorbed on soil and, thus, is not very mobile in Hanford Site groundwater. The interim drinking water standard for cesium-137 is 200 pCi/L (7.4 Bq/L); the DOE derived concentration guide is 3,000 pCi/L (110 Bq/L).

In the past, cesium-137 has been detected at levels above the 200-pCi/L (7.4-Bq/L) interim drinking water standard near the inactive 216-B-5 injection well in the 200-East Area. However, monitoring wells near the injection well were not sampled in 2002 because waste management documentation in support of CERCLA sampling needed to

be developed. The injection well received waste containing cesium-137 from 1945 to 1947. It is estimated that this well received 81 curies (2,997 gigabecquerels) of cesium-137 (RHO-CD-673). Cesium-137 appears to be restricted to the immediate vicinity of the former injection well.

**Cobalt-60.** Cobalt-60 in groundwater is typically associated with waste generated by reactor effluent disposed to the ground in the past. Cobalt-60 is normally present as a divalent transition metal cation and, as such, tends to be immobile in groundwater. However, complexing agents may mobilize it. All cobalt-60 levels in groundwater samples analyzed during 2002 were less than the interim drinking water standard (100 pCi/L [3.7 Bq/L]). The DOE derived concentration guide for cobalt-60 is 5,000 pCi/L (185 Bq/L).

Cobalt-60 was detected in groundwater in the northwestern part of the 200-East Area. This is the same area where the technetium-99 contamination associated with the BY cribs is found. Apparently, cobalt in this plume is mobilized by reaction with cyanide or ferrocyanide in the waste stream, forming a dissolved cobalt species. The maximum cobalt-60 concentration measured in groundwater during 2002 was 48.4 pCi/L (1.8 Bq/L) at the BY cribs. Because of its relatively short half-life (5.3 years), much of the cobalt-60 in groundwater in this area has decayed to low concentrations.

**Plutonium.** Plutonium was released to the soil column in the past at several locations in both the 200-West and 200-East Areas. Plutonium is generally considered to sorb strongly to sediment, which limits its mobility in the aquifer. The DOE derived concentration guide for both plutonium-239 and plutonium-240 is 30 pCi/L (1.1 Bq/L). Radiological analysis is incapable of distinguishing between plutonium-239 and plutonium-240; therefore, the results are expressed as a concentration of plutonium-239/240. There is no explicit drinking water standard for plutonium-239/240; however, the gross alpha drinking water standard of 15 pCi/L (0.56 Bq/L) would be applicable at a minimum. However, if the DOE derived concentration guide based on a 100-mrem (1-mSv) dose standard is converted to the 4-mrem (40-mSv) dose equivalent used for the drinking water standard, 1.2 pCi/L (0.04 Bq/L) would be the relevant guideline. The half-lives of plutonium-239 and plutonium-240 are 24,000 and 6,500 years, respectively.

The only location where plutonium isotopes were detected at levels above the 30-pCi/L (1.1-Bq/L) DOE derived concentration guide in groundwater on the Hanford Site in the past was near the inactive 216-B-5 injection well in the 200-East Area. This well was not sampled during 2002 because waste management documentation in support of CERCLA sampling needed to be developed. Plutonium levels near the injection well have not changed significantly since monitoring for plutonium began during the 1980s. Because plutonium is strongly adsorbed to sediment and may have been injected into the aquifer as suspended particles, it is likely that the values measured result in part from solid rather than dissolved material. The injection well received an estimated 244 curies (9.03 trillion becquerels) of plutonium-239/240 during its operation from 1945 to 1947 (PNL-6456).

## 6.2.2 CHEMICAL MONITORING RESULTS FOR THE UNCONFINED AQUIFER

Chemical analyses performed for various monitoring programs at the Hanford Site have identified several hazardous chemicals in groundwater at concentrations greater than their respective drinking water standards. Nitrate, chromium, and carbon tetrachloride are the most widely distributed of these hazardous chemicals and have the highest concentrations in groundwater at the Hanford Site. Hazardous chemicals that are less widely distributed and have lower concentrations in groundwater include chloroform, trichloroethene, tetrachloroethene, cis-1,2-dichloroethene, cyanide, fluoride, and arsenic.

A number of parameters such as pH, specific conductance, total carbon, total organic carbon, and total organic halides are used as indicators of contamination (Section 6.4). Other chemical parameters (Table 6.1.4) are indicators of the natural chemical composition of groundwater and are usually not considered contaminants from operations at the Hanford Site. These include alkalinity, aluminum, calcium, iron, magnesium, manganese, potassium, silica, and sodium. Chloride and sulfate occur naturally in groundwater. However, these constituents also have been introduced as contaminants from site operations. There are no primary drinking water standards for chloride or sulfate. The secondary standard for each is 250 mg/L (250 ppm) and is based on aesthetic rather than health

considerations; therefore, they will not be discussed in detail. The analytical technique used to determine the concentration of metals in groundwater provides results for a number of constituents. These trace metal constituents, rarely observed at greater than background concentrations, include antimony, barium, beryllium, boron, cadmium, copper, nickel, silver, vanadium, and zinc.

The following presents a summary of the chemical constituents in groundwater at concentrations greater than existing or proposed drinking water standards (40 CFR 141 and EPA 822-R-96-001; Appendix D).

**Nitrate.** Many groundwater samples collected during 2002 were analyzed for nitrate (Figure 6.2.17). The distribution of nitrate on the Hanford Site is similar to previous evaluations. Nitrate is the most widespread chemical contaminant in Hanford Site groundwater because of its mobility in groundwater and the large volumes of liquid waste containing nitrate discharged to the ground. However, the areas affected by levels greater than the drinking water standard are small. Nitrate was measured in groundwater at concentrations greater than the drinking water standard (45 mg/L [45 ppm] as nitrate ion) in portions of the 100, 200, 300, 600, and former 1100 Areas. The maximum nitrate concentration measured on the Hanford Site was 2,090 mg/L (2,090 ppm) in a well in the 200-West Area. Nitrate contamination in the unconfined aquifer reflects the extensive use of nitric acid in decontamination and chemical reprocessing operations. Nitrate is associated primarily with process condensate liquid waste, though other liquids discharged to the ground also contained nitrate. However, additional sources of nitrate, primarily associated with agriculture, occur off the site to the south, west, and southwest.

**Nitrate in the 100 Areas.** Nitrate in groundwater was measured at concentrations exceeding the drinking water standard in all of the 100 Areas except the 100-B/C Area. Nitrate concentrations have generally been rising in many 100 Areas wells.

Nitrate in groundwater is found at levels greater than the drinking water standard in two separate plumes in the 100-D Area. These two nitrate plumes generally coincide with the chromium plumes. The highest nitrate level found during 2002 was 107 mg/L (107 ppm) in a well in the southwestern part of the 100-D Area. Levels of nitrate in groundwater are generally declining in the 100-D Area.

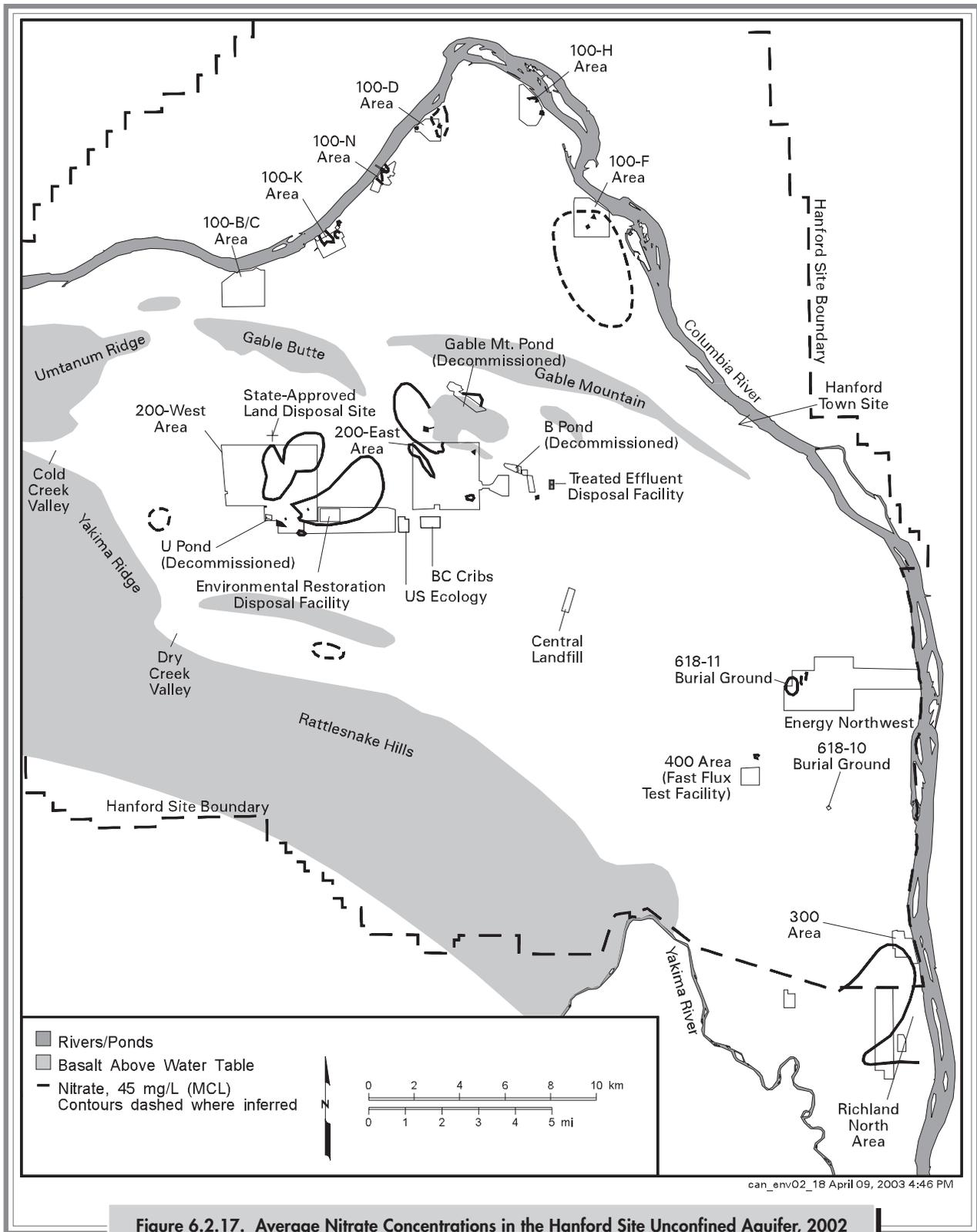


Figure 6.2.17. Average Nitrate Concentrations in the Hanford Site Unconfined Aquifer, 2002

Nitrate continues to be widely distributed in groundwater in the 100-F Area and the adjacent 600 Area to the south. Groundwater in the central and southern portions of the 100-F Area and the adjacent 600 Area contains nitrate at levels greater than the drinking water standard. A nitrate plume extends to the south and southeast into the 600 Area from upgradient sources near F Reactor. In the southern part of the 100-F Area, groundwater flow is to the southeast. The maximum nitrate concentration detected in the 100-F Area during 2002 was 177 mg/L (177 ppm) in a well in the southwestern part of the 100-F Area, where nitrate concentrations are increasing. The wide distribution of nitrate in the 100-F Area suggests multiple sources of nitrate in the 100-F Area or the adjacent 600 Area.

A nitrate plume with concentrations above the drinking water standard lies in the eastern portion of the 100-H Area adjacent to the Columbia River. The highest concentrations are restricted to a small area downgradient of the former 116-H-6 evaporation basins. The maximum nitrate concentration detected in 2002 was 474 mg/L (474 ppm) in a well located between the basins and the river.

Nitrate is widely distributed in the 100-K Area and has multiple sources, including septic system drain fields and past-practice disposal to the soil column. The drinking water standard for nitrate was exceeded in a number of 100-K Area wells during 2002. Nitrate concentration trends vary in the 100-K Area. The maximum nitrate concentration detected in 100-K Area groundwater during 2002 was 94.3 mg/L (94.3 ppm) in a well near the southwestern end of the 116-K-2 liquid waste disposal trench.

Although detected over most of the 100-N Area, nitrate contamination above the drinking water standard occurs at isolated locations in the 100-N Area. The maximum concentration measured in the 100-N Area during 2002 was 60 mg/L (60 ppm) in a well located between the 116-N-1 liquid waste disposal facility and the Columbia River.

**Nitrate in the 200-East Area.** The nitrate plume in the 200-East Area covers a nearly identical area to that of the tritium plume. However, the area with nitrate exceeding the drinking water standard is smaller than the area with tritium exceeding its drinking water standard. Nitrate concentrations exceed the drinking water standard in the northern part of the 200-East Area and adjacent 600 Area

to the northwest and near the Plutonium-Uranium Extraction Plant in the southeastern part of the 200-East Area. In the northern part of the 200-East Area, the plume has two parts, a western plume that extends from B Plant to the northwest and an eastern portion that extends from the BY and surrounding cribs to the south and to the northwest. The two portions of the plume join northwest of the 200-East Area and extend through the gap between Gable Butte and Gable Mountain (see Figure 2.9-9 of PNNL-14187.)

Past disposal practices related to the BY cribs is a major contributor to the high nitrate concentrations in the northern part of the 200-East Area and adjacent 600 Area. Some nitrate may also be associated with past releases from the B, BX, and BY Tank Farms. During 2002, the highest 200-East Area nitrate concentrations were measured in several wells near the BY and 216-B-8 cribs, where nitrate concentrations continue to increase. The maximum concentration measured during 2002 was 735 mg/L (735 ppm) in a well located at the BY cribs. Nitrate originating from the BY cribs is a co-contaminant with cobalt-60, cyanide, and technetium-99.

High nitrate concentrations continued to be found near liquid waste disposal facilities that received effluent from Plutonium-Uranium Extraction Plant operations. Nitrate concentrations in wells near the inactive 216-A-10 and 216-A-36B cribs have decreased in the past few years but remained greater than the drinking water standard, though these cribs were removed from service during 1987. The maximum nitrate concentration detected near the Plutonium-Uranium Extraction Plant during 2002 was 170 mg/L (170 ppm) in a well adjacent to the 216-A-36B crib.

Nitrate is known to be elevated above the drinking water standard in a few wells near the former Gable Mountain Pond, north of the 200-East Area. However, these wells were not sampled during 2002 because they are sampled on a triennial schedule.

**Nitrate in the 200-West Area.** Nitrate concentrations greater than the drinking water standard were widespread in groundwater beneath the 200-West Area and adjacent parts of the 600 Area. The major nitrate plumes were found in wells east of U Plant and wells in the north-central part of the 200-West Area. The widespread distribution of

nitrate reflects multiple sources in the 200-West Area (see Figures 2.8-8 and 2.8-39 of PNNL-14187).

Near U Plant, widespread nitrate contamination in groundwater is associated with the tritium and iodine-129 plumes. The nitrate contamination in this area is attributed to multiple sources, including the 216-U-1 and 216-U-2 cribs southwest of U Plant, and the 216-U-17 crib southeast of U Plant. The 216-U-1 and 216-U-2 cribs received more than 1 million kilograms (2.2 million pounds) of chemicals containing nitrate during their operation from 1951 to 1967 (PNL-6456). The highest nitrate concentration measured in the plume east of U Plant during 2002 was 236 mg/L (236 ppm) in a well located near the inactive 216-U-17 crib. Nitrate concentrations continued to decrease near this crib during 2002. A pump-and-treat system continued to operate in this area during 2002 (Section 2.3.13). However, nitrate is not the primary target of the pump-and-treat system. The primary targets of the pump-and-treat system are uranium and technetium-99.

Nitrate concentrations in groundwater continued to be elevated above the drinking water standard near other inactive cribs to the south of U Plant that are associated with the U Plant and Reduction-Oxidation Plant. These elevated levels represent nitrate plumes that merge with the plume from the U Plant area. The maximum nitrate concentration measured in this merged area of the groundwater plume during 2002 was 72.6 mg/L (72.6 ppm) near the 216-S-20 crib southeast of the Reduction-Oxidation Plant.

A small, isolated plume of elevated nitrate occurs west of the Reduction-Oxidation Plant near the inactive 216-S-25 crib and S and SX Tank Farms, where the maximum measured concentration was 1,000 mg/L (1,000 ppm) during 2002. Nitrate concentrations, which increased in this plume during 2002, appear to be associated with technetium-99.

A large area, encompassing much of the northern half of the 200-West Area, contains nitrate in groundwater at concentrations much greater than the drinking water standard. Wells showing the highest concentrations are located near several inactive liquid waste disposal facilities (cribs) that received waste from early T Plant operations. A large amount of nitrate was disposed to these cribs (e.g., ~2.3 million kilograms [~5.1 million pounds]) to the

216-T-7 crib). Maximum concentrations in these wells in 2002 ranged up to 2,090 mg/L (2,090 ppm) in wells located just south of the T Tank Farm. These are the highest nitrate concentrations measured on the Hanford Site during 2002 and concentrations continued to increase during the year.

A smaller area of elevated nitrate concentrations in groundwater above the drinking water standard is located in vicinity of the Plutonium Finishing Plant, which is in the central part of the 200-West Area. One source of this nitrate is the 216-Z-9 trench, which received ~1.3 million kilograms (~2.9 million pounds) of chemicals containing nitrate from 1955 to 1962. Waste sites near the Plutonium Finishing Plant have contributed to the large nitrate plume in the northern half of the 200-West Area. The highest measured concentration during 2002 at the Plutonium Finishing Plant was 333 mg/L (333 ppm) in a pump-and-treat extraction well adjacent to the 216-Z-9 trench, which is located east of the Plutonium Finishing Plant.

#### ***Nitrate in the 300, 600, and Former 1100 Areas.***

Nitrate contamination in groundwater occurs near the city of Richland in the former 1100 Area, Richland North Area, and adjacent parts of the 600 Area along the southern boundary of the Hanford Site. This contamination is apparently affected by nitrate sources off the Hanford Site. These sources may include agriculture, food processing, and nuclear fuel manufacturing at offsite commercial facilities. The part of this plume with nitrate concentrations greater than the drinking water standard extends south of the Hanford Site and northeast to the 300 Area. Nitrate concentrations generally continued to increase in the southern part of the Hanford Site and the adjacent area south of the Hanford Site during 2002. The maximum nitrate concentration measured in groundwater wells just south of the Hanford Site boundary during 2002 was 280 mg/L (280 ppm) (EMF-1865, Addendum 30). This nitrate contamination is likely the result of agricultural activities to the west and southwest. The maximum nitrate concentration measured in 300 Area groundwater during 2002 was 89.9 mg/L (89.9 ppm) (see Figure 2.12-13 in PNNL-14187).

Nitrate was detected at levels exceeding the drinking water standard in a well downgradient of the 4608 B/C process ponds. These levels, which declined during 2002, were attributed to a former sanitary sewage lagoon west and upgradient of the process ponds and later to a drainfield

associated with septic tanks southwest of the ponds. The maximum concentration measured in this well during 2002 was 71.3 mg/L (71.3 ppm).

**Chromium.** Use of chromium on the Hanford Site has been extensive. In the 100 Areas, sodium dichromate was added to cooling water as a corrosion inhibitor, and some residual chromium in soil and groundwater remains from that use. Chromium was used for decontamination in the 100, 200, and 300 Areas and for oxidation state control in the Reduction-Oxidation Plant process. In the hexavalent form, chromium is present in a soluble anionic state. Thus, hexavalent chromium is freely mobile in the groundwater. The drinking water standard for chromium is 100 µg/L (0.1 ppm).

Both filtered and unfiltered samples were collected from several onsite wells for analyses of chromium and other metals. Unfiltered samples may contain metals present as particulate matter, whereas filtered samples are representative of the more mobile, dissolved metals. Filtered samples also may contain some colloidal particles that are fine enough to pass through the filter. In general, filtered samples provide the best indication of groundwater contamination levels for chromium because unfiltered samples are subject to greater variability introduced by the sampling process. Chromium concentrations in filtered samples, which are considered representative of dissolved hexavalent chromium, will be used to describe the level of contamination in the discussion below.

**Chromium in the 100 Areas.** Chromium was detected in groundwater above the drinking water standard during 2002 in 100-D, 100-H, 100-K, and 100-N Area wells. The maximum detected concentration was 5,300 µg/L (5.3 ppm) in the 100-D Area. Groundwater pump-and-treat systems continued to operate during 2002 to reduce the amount of hexavalent chromium entering the Columbia River at the 100-D, 100-H, and 100-K Areas (Section 2.3.13). The purpose of the pump-and-treat systems is to prevent discharge of hexavalent chromium into the Columbia River at concentrations exceeding 11 µg/L (0.011 ppm), which is the EPA's standard for protection of freshwater aquatic life (EPA 822-Z-99-001).

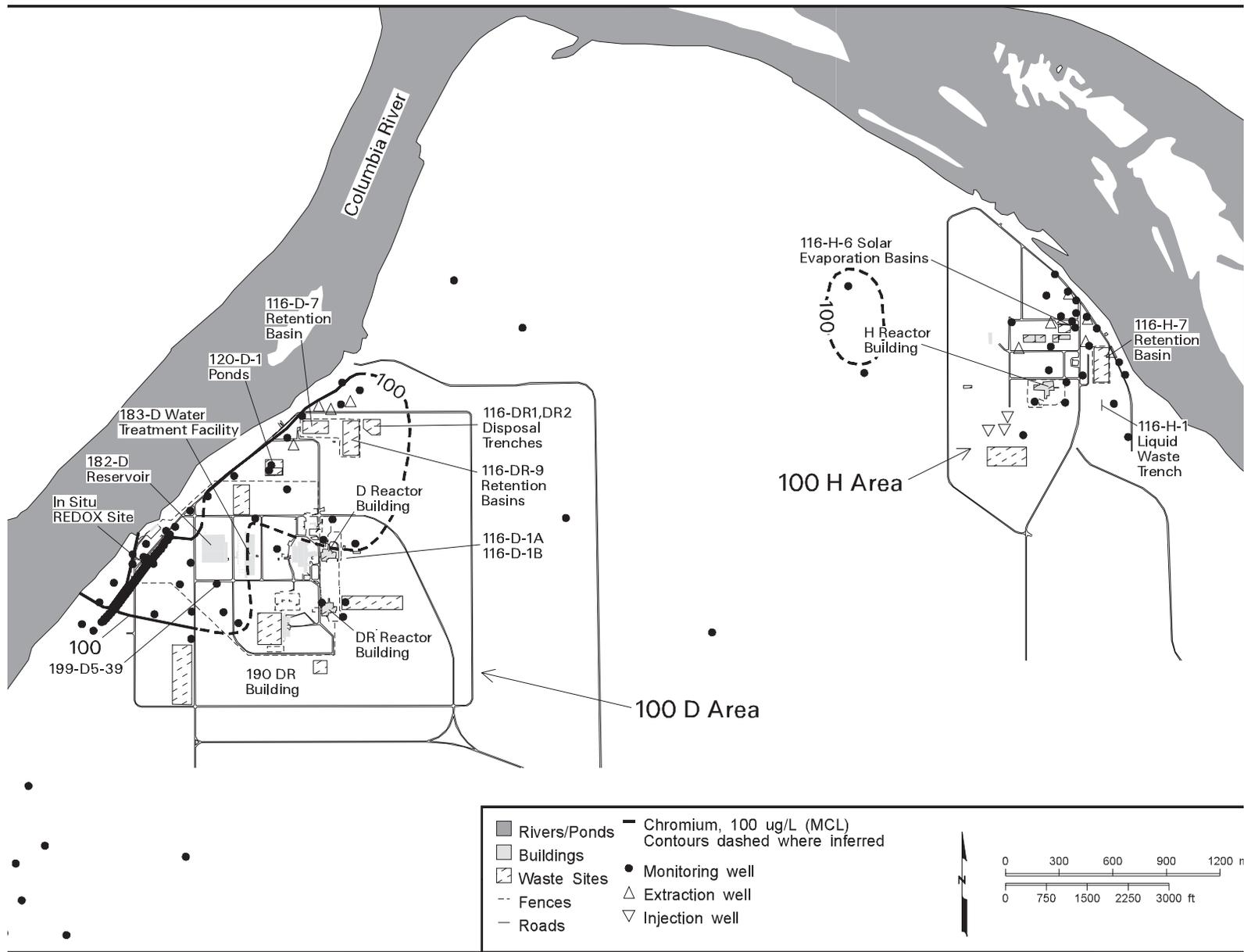
Chromium contamination in 100-D Area groundwater at levels greater than the drinking water standard is defined by two plumes that appear to be merging (Figure 6.2.18).

The chromium plume in the southwestern part of the 100-D Area has expanded in size to the north, where chromium concentrations have been increasing in recent years. The source of this chromium plume has not been identified with certainty, but is suspected to be past use of sodium dichromate at the 183-DR water treatment facility or at a transfer station. Vadose zone studies in these areas failed to locate source areas of high chromium contamination in the vadose zone (PNNL-13486; PNNL-13107). The maximum measured chromium concentration from filtered samples collected in 2002 was 5,300 µg/L (5.3 ppm) in the southwestern plume near the Columbia River, where concentrations continued to increase during 2002 (Figure 6.2.19). The southwestern plume contained the highest concentrations of hexavalent chromium on the Hanford Site during 2002.

The source of the chromium plume in the northern part of the 100-D Area is sodium dichromate released to the ground at former facilities near D Reactor. Leakage from inactive retention basins and liquid waste disposal trenches north of D Reactor may also have contributed to this chromium plume. The maximum measured chromium concentration in the northern plume was 792 µg/L (0.792 ppm) during 2002. The area of low chromium concentrations between the plumes is suspected to be a result of past leakage of clean water from the 182-D reservoir. Leakage of clean water from the reservoir is suspected to mix with chromium contaminated groundwater, thereby lowering the chromium concentrations.

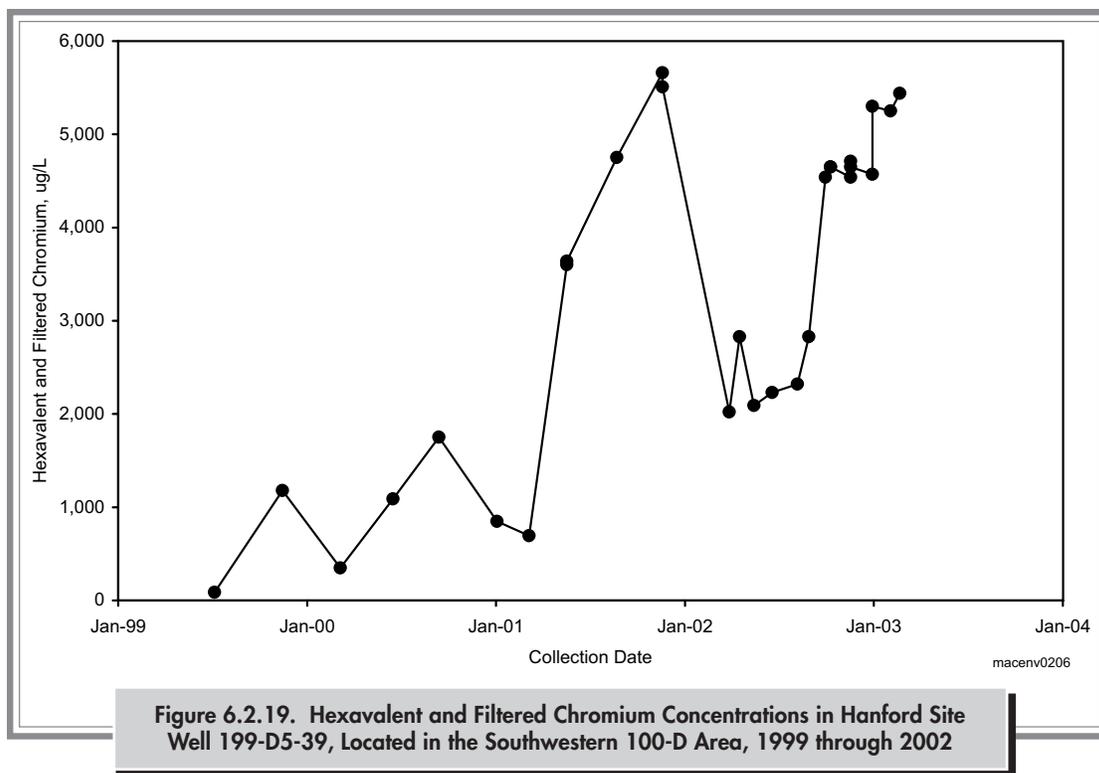
A small chromium plume in the northeastern part of the 100-H Area contains chromium levels greater than the drinking water standard (Figure 6.2.18). During 2002, the maximum chromium concentration from filtered samples collected from the shallow parts of the unconfined aquifer was 81 µg/L (0.081 ppm) between the former 116-H-6 evaporation basins and the Columbia River. Chromium levels at this location are known to fluctuate in response to changing water-table conditions. Potential chromium sources include past disposal of sodium dichromate near H Reactor, disposal to the inactive 116-H-1 liquid waste disposal trench, and chromium in acid waste stored in the former 116-H-6 evaporation basins (Peterson and Connelly 1992). Upgradient sources also include waste sites in the 100-D Area. Chromium was also found at levels above the drinking water standard in one well monitoring a deeper

◆ 6.43 ◆



can\_env02\_19 April 10, 2003 4:3

**Figure 6.2.18. Average Filtered Chromium Concentrations at the Hanford Site's 100-D and 100-H Areas, 2002**



part of the unconfined aquifer. Filtered samples from this well, located near the former 116-H-6 evaporation basins, contained 154  $\mu\text{g/L}$  (0.154 ppm) of chromium during 2002. Chromium levels in this well have been decreasing in recent years, but increased during 2002. Chromium concentrations exceeded the drinking water standard in one 600 Area well west of the 100-H Area. The maximum chromium concentration in this well in 2002 was 112  $\mu\text{g/L}$  (0.112 ppm).

Chromium in the 100-K Area occurs in groundwater at levels greater than the drinking water standard in three areas (Figure 6.2.20). Two localized areas of chromium contamination occur near the KW Reactor and the water treatment basins southeast of the KE Reactor. The maximum concentration measured near the KW Reactor during 2002 was 707  $\mu\text{g/L}$  (0.707 ppm). Chromium concentrations in the plume near the KW Reactor were stable or decreased during 2002. Potential sources of the chromium plume near the KW Reactor are the railcar transfer station and storage tanks southeast of the 183-KW water treatment plant.

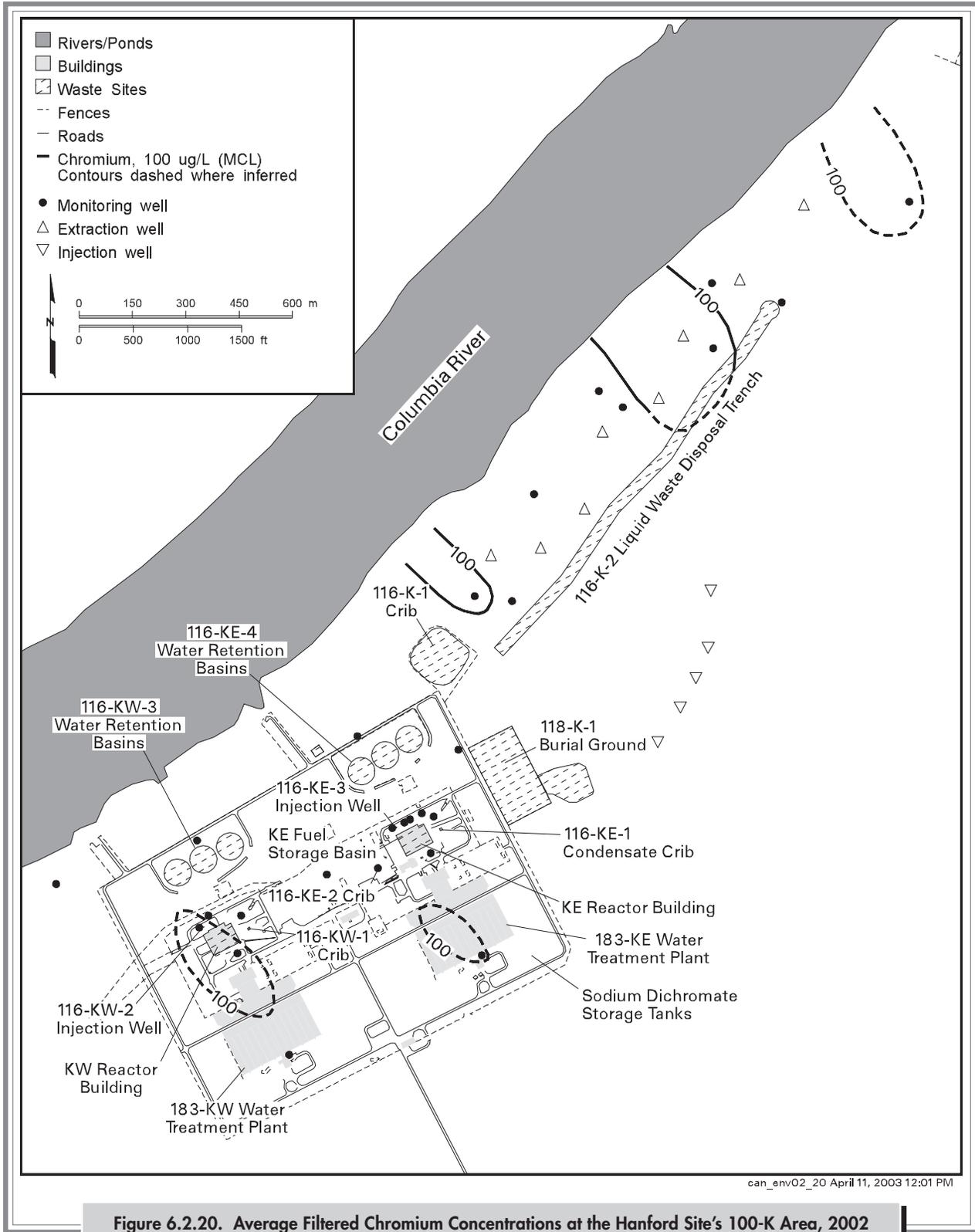
The other small chromium plume occurs near the 183-KE water treatment basins. The most likely sources of this chromium are sodium dichromate storage tanks or the railcar transfer station near the area. The maximum chromium

concentration measured in this plume during 2002 was 735  $\mu\text{g/L}$  (0.735 ppm) in a well adjacent to the treatment basins. Chromium concentrations in this plume decreased during 2002 after rising during 2001.

A much wider area of chromium contamination is found in vicinity of the former 116-K-2 liquid waste disposal trench to the northeast of the reactor areas. The maximum concentration in this area in 2002 was 149  $\mu\text{g/L}$  (0.149 ppm).

In the 100-N Area, chromium contamination is not widespread in groundwater. However, filtered samples in one well that monitors a locally confined unit within the Ringold Formation have consistently shown concentrations at steady levels greater than the drinking water standard. This well is northwest of the 116-N-1 liquid waste disposal facility. The maximum chromium concentration measured at this location during 2002 was 168  $\mu\text{g/L}$  (0.168 ppm). Chromium was disposed to the 116-N-1 liquid waste disposal facility until the early 1970s (DOE/RL-96-39).

**Chromium in the 200 Areas.** Chromium at concentrations greater than the drinking water standard in the 200-East Area was found in two wells on the southern



**Figure 6.2.20. Average Filtered Chromium Concentrations at the Hanford Site's 100-K Area, 2002**

boundary of A and AX Tank Farms. The maximum concentration detected in samples collected from one of these wells during 2002 was 6,250 µg/L (6.25 ppm).

Chromium contamination in groundwater has been found in small areas in the 200-West Area. Areas where concentrations exceeded the drinking water standard during 2002 include the T, TX, and TY Tank Farms, the former 216-S-10 pond, and near the Reduction-Oxidation Plant. Filtered samples from a well east of TX and TY Tank Farms showed a maximum concentration of 427 µg/L (0.427 ppm), which is the highest filtered chromium concentration measured in the 200-West Area during 2002. Chromium concentrations have generally been increasing near TX and TY Tank Farms. In 2002, a small chromium plume in the vicinity of T Tank Farm showed a maximum chromium concentration of 307 µg/L (0.307 ppm). Chromium concentrations generally increased near T Tank Farm during 2002. The 216-T-36 crib and pipes leading to the crib are suspected of being sources of the chromium contamination at T Tank Farm. Chromium concentrations near the former 216-S-10 pond increased to levels above the drinking water standard during 2002. Chromium concentrations near this facility reached a maximum of 204 µg/L (0.204 ppm). Near the Reduction-Oxidation Plant, chromium concentrations have shown an increasing trend since 1997 and increased to 381 µg/L (0.381 ppm) during 2002.

**Chromium in Other Areas.** Filtered chromium concentrations have consistently exceeded the drinking water standard in groundwater just southwest of the 200-East Area. This area was not sampled for filtered chromium during 2001 and 2002 because the sampling frequencies for these wells were changed from annual to every 3 years. The maximum concentration detected in filtered samples in this area during 2000 was 201 µg/L (0.201 ppm). Filtered chromium will be sampled again in this area in 2003. The extent of chromium contamination in this area is poorly defined, and the source has not been determined.

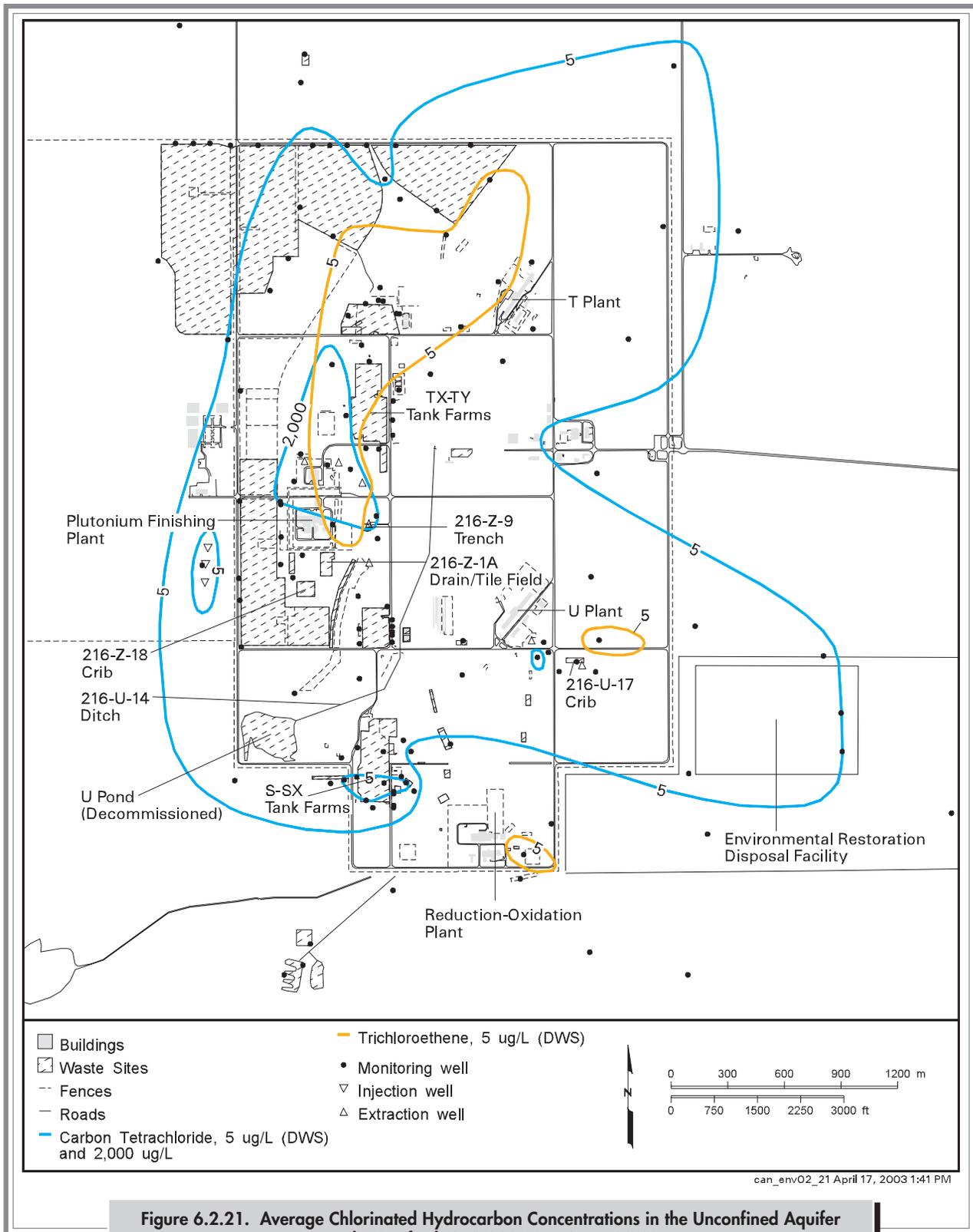
**Carbon Tetrachloride.** Carbon tetrachloride occurs at levels exceeding its drinking water standard (5 µg/L [0.005 ppm]) in much of the 200-West Area and represents one of the most significant contaminant plumes at the Hanford Site (Figure 6.2.21). The plume, which covers an area of more than 11 square kilometers (4 square miles), extends past the 200-West Area boundary into the 600 Area. The maximum detected concentration in this plume during

2002 was 6,900 µg/L (6.9 ppm) in a pump-and-treat well north of the Plutonium Finishing Plant.

The bulk of the contamination is believed to be from pre-1973 waste disposal operations associated with the Plutonium Finishing Plant in the west-central part of the 200-West Area. Major sources identified in this area include the 216-Z-9 trench, the 216-Z-1A drain/tile field, and the 216-Z-18 crib. Carbon tetrachloride was used as the carrier solvent for tributyl phosphate in the final purification of plutonium. Carbon tetrachloride was also used in the same facility as a non-flammable thinning agent while machining plutonium. A minor source of carbon tetrachloride is a former waste disposal crib near T Plant. Carbon tetrachloride is immiscible in water but exhibits a relatively high solubility (805,000 µg/L [804 ppm] at 20°C [68°F]). Carbon tetrachloride has been found to have a relatively high degree of mobility in groundwater. Mobilization above the water table can also occur through vapor transport. Monitoring and soil-gas extraction of carbon tetrachloride in the vadose zone are discussed in Section 7.2.

Wells in vicinity of the Plutonium Finishing Plant showed the highest concentrations in the plume. The maximum concentration measured during 2002 was 6,900 µg/L (6.9 ppm) in a pump-and-treat extraction well just north of the plant. Pump-and-treat operations, which began during 1994, have influenced the distribution of carbon tetrachloride in the vicinity of the operations. The purpose of the pump-and-treat system is to contain the portion of the carbon tetrachloride plume where concentrations are >2,000 µg/L (>2 ppm), which extends to the north reaching an area west of TX and TY Tank Farms (Section 2.3.13). The extraction wells are located north and east of the Plutonium Finishing Plant. Carbon tetrachloride concentrations generally were stable in the center part of the plume during 2002. Carbon tetrachloride concentrations continued to be below the minimum detection limit in the pump-and-treat injection wells southwest of the plant during 2002. Concentrations in these injection wells have declined because of injections of the treated water.

The carbon tetrachloride plume is divided into two major lobes, one in the northern half and one in the southern half of the 200-West Area. In the northern lobe, an area of increasing carbon tetrachloride concentrations has moved



can\_env02\_21 April 17, 2003 1:41 PM

slowly beyond the northeastern 200-West Area boundary since 1997. This area is the greatest concern for transport of carbon tetrachloride from the 200-West Area. The highest concentration detected in this northern lobe during 2002 was 1,500 µg/L (1.5 ppm) near T Plant in the 200-West Area. In the southern lobe of the carbon tetrachloride plume, carbon tetrachloride concentrations increased in wells near S and SX Tank Farms from levels less than the drinking water standard during 1995 to a maximum of 290 µg/L (0.29 ppm) during 2002.

The extent of carbon tetrachloride contamination in deeper parts of the aquifer is uncertain because of the limited amount of concentration data collected from depths below the water table. The available data indicate that concentrations are highest at the top of the aquifer and decline with depth at most locations within the plume. During 2002, carbon tetrachloride concentrations ranging between 130 and 180 µg/L (0.13 and 0.18 ppm) were detected at depths of greater than 19 meters (62 feet) below the water table near U Plant. These concentrations indicate that carbon tetrachloride contamination has moved into deeper parts of the unconfined aquifer at locations considerably distant from and downgradient of the source area.

Changes in groundwater flow since 216-U-10 pond (U Pond) was decommissioned in 1984 may have influenced the plume configuration and the concentrations at particular locations. Another potential influence is the continued spreading of carbon tetrachloride in the vadose zone above the water table, in either a liquid or a vapor phase. Carbon tetrachloride in the liquid phase above and possibly below the water table may provide a continuing source of groundwater contamination, in which case, lateral expansion of the carbon tetrachloride plume will continue.

**Chloroform.** A chloroform plume appears to be associated with, but not exactly coincident with, the carbon tetrachloride plume in the 200-West Area. The highest chloroform concentrations were measured in a new well near the Plutonium Finishing Plant, where the maximum level measured during 2002 (January) was 680 µg/L (0.68 ppm). However, chloroform concentrations at this well decreased to levels less than the drinking water standard one month later. The drinking water standard for chloroform was reduced from 100 µg/L (0.1 ppm) (total trihalomethanes) to

80 µg/L (0.08 ppm) during January 2002 (EPA 822-F-02-013). The origins of the chloroform are suspected to be the chlorination of organic matter during purification of potable water or the biodegradation of carbon tetrachloride.

**Trichloroethene.** A commonly used organic solvent, trichloroethene has a drinking water standard of 5 µg/L (0.005 ppm). In 2002, trichloroethene was detected at levels greater than the drinking water standard in several wells in the 100 and 200 Areas. The most widespread area of groundwater contamination occurred in the 200-West Area.

**Trichloroethene in the 100 Areas.** Trichloroethene was detected in groundwater at levels greater than the drinking water standard in the southwestern corner of the 100-F Area. Trichloroethene concentrations in this area showed increases during 2002. The maximum concentration detected in the 100-F Area during 2002 was 9.8 µg/L (0.0098 ppm). No specific sources of this contamination have been identified.

In the 100-K Area, a localized area of trichloroethene contamination occurs near the KW Reactor complex. This area of contamination resulted from the past disposal/spillage of organic solvents. One well downgradient of the KW Reactor showed a maximum trichloroethene concentration above the drinking water standard at a level of 11 µg/L (0.011 ppm). Trichloroethene concentrations in groundwater near the KW Reactor complex are gradually declining with time.

**Trichloroethene in the 200 Areas.** Trichloroethene was detected at levels greater than the drinking water standard in wells in several parts of the 200-West Area (Figure 6.2.21). The most significant area extends from the Plutonium Finishing Plant northeast to an area west of T Plant. Sources of the contamination are presumably disposal facilities near the plant. The highest concentration measured during 2002 was 16 µg/L (0.016 ppm) in a well west of TX and TY Tank Farms. A smaller, isolated area of trichloroethene contamination occurs downgradient of the U Plant cribs, where the maximum concentration measured during 2002 was 8.8 µg/L (0.0088 ppm). Another localized area of trichloroethene contamination occurs east of the Reduction-Oxidation Plant in the southern part of the 200-West Area. The maximum concentration in this area during 2002 was 15 µg/L (0.015 ppm).

**cis-1,2-Dichloroethene.** Concentrations of cis-1,2-dichloroethene remain elevated in one well near the former process trenches and ponds in the 300 Area. This well is completed in the bottom of the unconfined aquifer and is the only well on the site where this constituent is found at levels above its drinking water standard (70 µg/L [0.07 ppm]). During 2002, a maximum concentration of 160 µg/L (0.16 ppm) was measured in this well. The source of the cis-1,2-dichloroethene is the inactive 316-5 process trenches.

**Cyanide.** Waste fractionation performed in the late 1950s used large quantities of sodium and nickel ferrocyanide to recover cesium-137. Large volumes of aqueous supernatant waste containing excess ferrocyanide were disposed to the ground in both the northern and southern portions of the 200-East Area. Smaller quantities were also disposed to former cribs in the 200-West Area. Procedures used to analyze for cyanide do not distinguish between ferrocyanide and free cyanide. Cyanide results reported here are assumed to be residual ferrocyanide associated with the discharges from the waste fractionation activities performed more than 30 years ago. A chemical speciation study performed in 1988 indicated that approximately one-third of the cyanide in groundwater is present as free cyanide and the rest may be present as ferrocyanide (Section 4.1 in PNL-6886 and Section 3.2.2 in PNL-7120). The drinking water standard for cyanide is 200 µg/L (0.2 ppm).

The highest cyanide levels measured in groundwater during 2002 were detected in samples collected from wells in the northwestern part of the 200-East Area. Samples collected from two wells near the inactive BY cribs in 2002 showed concentrations above the drinking water standard. The maximum concentration near the cribs was 299 µg/L (0.299 ppm). Cyanide levels near the cribs generally remained stable during 2002. Although cobalt-60 is normally immobile in the subsurface, it appears to be chemically complexed by cyanide or ferrocyanide. The complexed chemical species is more soluble and more mobile in groundwater (Peterson et al. 2002).

**Fluoride.** At this time, fluoride has a primary drinking water standard of 4 mg/L (4 ppm) and a secondary standard of 2 mg/L (2 ppm). Secondary standards are based primarily on aesthetic rather than health considerations. Fluoride

was detected above the primary drinking water standard near T Tank Farm in the 200-West Area during 2002. The maximum fluoride concentration measured in 2002 was 4.4 mg/L (4.4 ppm) in a well located on the east side of T Tank Farm. A few other wells near T Tank Farm showed concentrations above the secondary standard. Aluminum fluoride nitrate, used in past 200-West Area processes, is the probable source of the fluoride contamination.

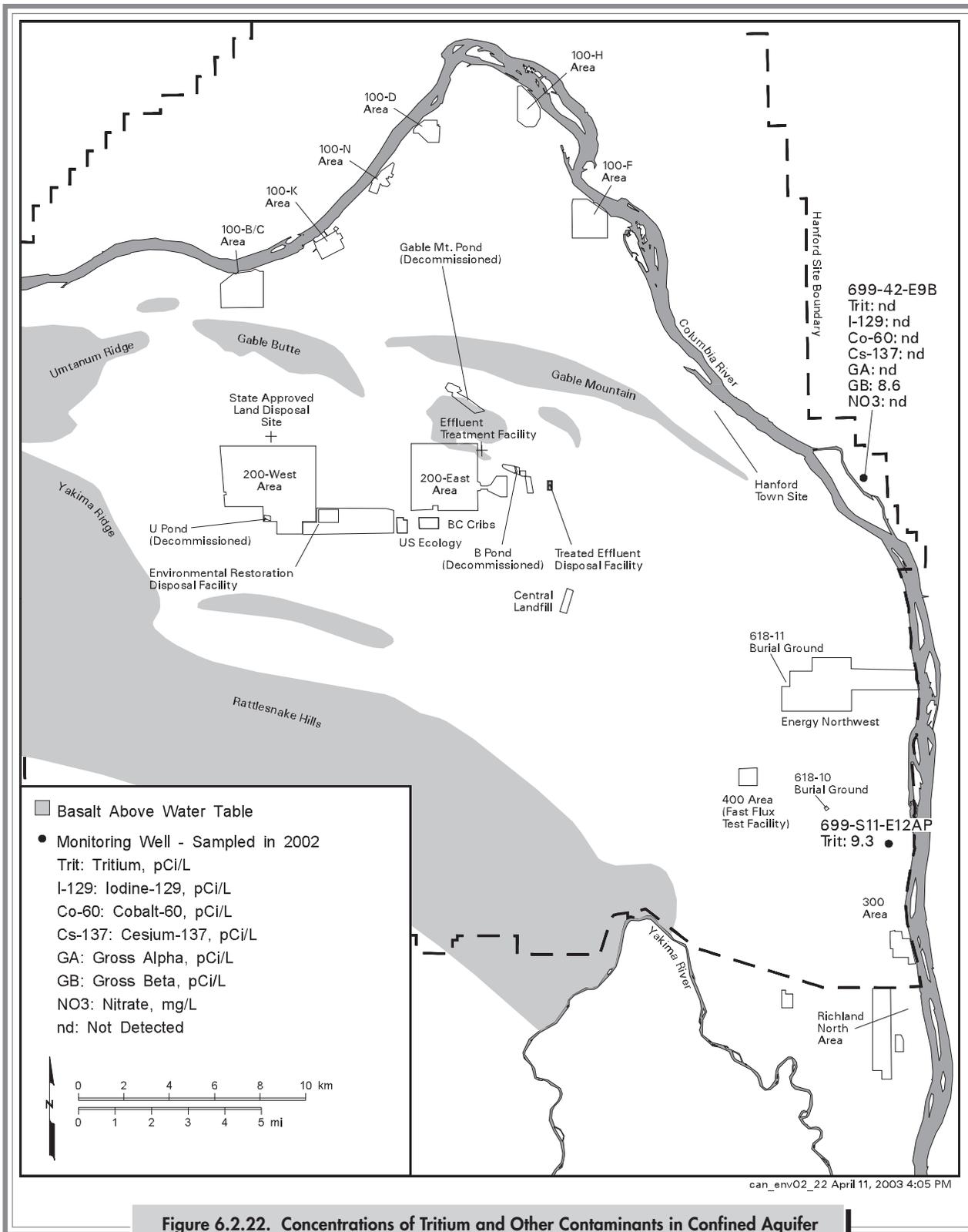
**Arsenic.** During 2002, arsenic exceeded the 10-µg/L (0.01-ppm)<sup>(b)</sup> final drinking water standard in three unfiltered groundwater samples from wells within the in situ redox manipulation zone in the 100-D Area. The reducing environment of the treatment zone increases the solubility of arsenic, which occurs naturally in the aquifer sediments.

### 6.2.3 RADIOLOGICAL AND CHEMICAL MONITORING RESULTS FOR THE UPPER BASALT-CONFINED AQUIFER

Monitoring the upper basalt-confined aquifer is important because of the potential for the downward migration of contaminants from the overlying unconfined aquifer. Contaminants that reach the upper basalt-confined aquifer have the potential to migrate off the Hanford Site through the upper basalt-confined aquifer. The upper basalt-confined aquifer is also monitored to assess the potential migration of contaminants onto the Hanford Site from offsite sources.

The upper basalt-confined aquifer is monitored by ~20 wells of which most are sampled on a triennial schedule. Most of these wells are located near the 200 Areas in the central part of the Hanford Site (Figure 6.1.2). During 2002, two upper basalt-confined aquifer wells were sampled for tritium, iodine-129, nitrate and other anions, cations, gross alpha, gross beta, and gamma-emitters. Tritium, iodine-129, and nitrate are the most widespread contaminants in the overlying unconfined aquifer, are the most mobile in groundwater, and provide an early warning of potential contamination in the upper basalt-confined aquifer (Figure 6.2.22).

(b) The drinking water standard for arsenic was changed from 50 to 10 µg/L (0.05 to 0.01 ppm) on January 22, 2001 (40 CFR Parts 9, 141, and 142).



**Figure 6.2.22. Concentrations of Tritium and Other Contaminants in Confined Aquifer Wells on the Hanford Site, 2002**

## 6.2.4 GROUNDWATER FLOW

The water-table elevation contours for the Hanford Site unconfined aquifer indicate the direction of groundwater flow and the magnitude of the hydraulic gradient (Figure 6.2.23). Groundwater flow is generally perpendicular to the water-table contours from areas of higher elevation to areas of lower elevation. Areas where the contours are closer together are high-gradient areas, where the driving force for groundwater flow is greater. However, because sediment with low permeability inhibits groundwater flow, producing steeper gradients, a high gradient does not necessarily mean high groundwater velocity. Lower permeability and steeper gradients are often associated with areas where the water table is below the bottom of the Hanford formation and the aquifer is entirely within the less permeable Ringold sediment. Additional information on aquifer hydraulic properties at Hanford is presented in DOE/RW-0164 (Vol. 2) and PNL-8337.

Recharge of water within the unconfined aquifer (RHO-ST-42) comes from several sources. Natural recharge occurs from infiltration of precipitation along the mountain fronts, run-off from intermittent streams such as Cold and Dry Creeks on the western margin of the site, and limited infiltration of precipitation on the site. The Yakima River, where it flows along the southern boundary of the site, also recharges the unconfined aquifer. The Columbia River is the primary discharge area for the unconfined aquifer. However, the Columbia River also recharges the unconfined aquifer for short periods during high-river stage, when river water is transferred into the aquifer along the riverbank. Recharge from infiltration of precipitation is highly variable on the Hanford Site both spatially and temporally. The rate of natural recharge depends primarily on soil texture, vegetation, and climate (Gee et al. 1992; PNL-10285). Natural recharge rates range from near zero, where fine-grained soil and deep-rooted vegetation are present, to greater than 10 centimeters (4 inches) per year in areas where soil is coarse textured and bare of vegetation.

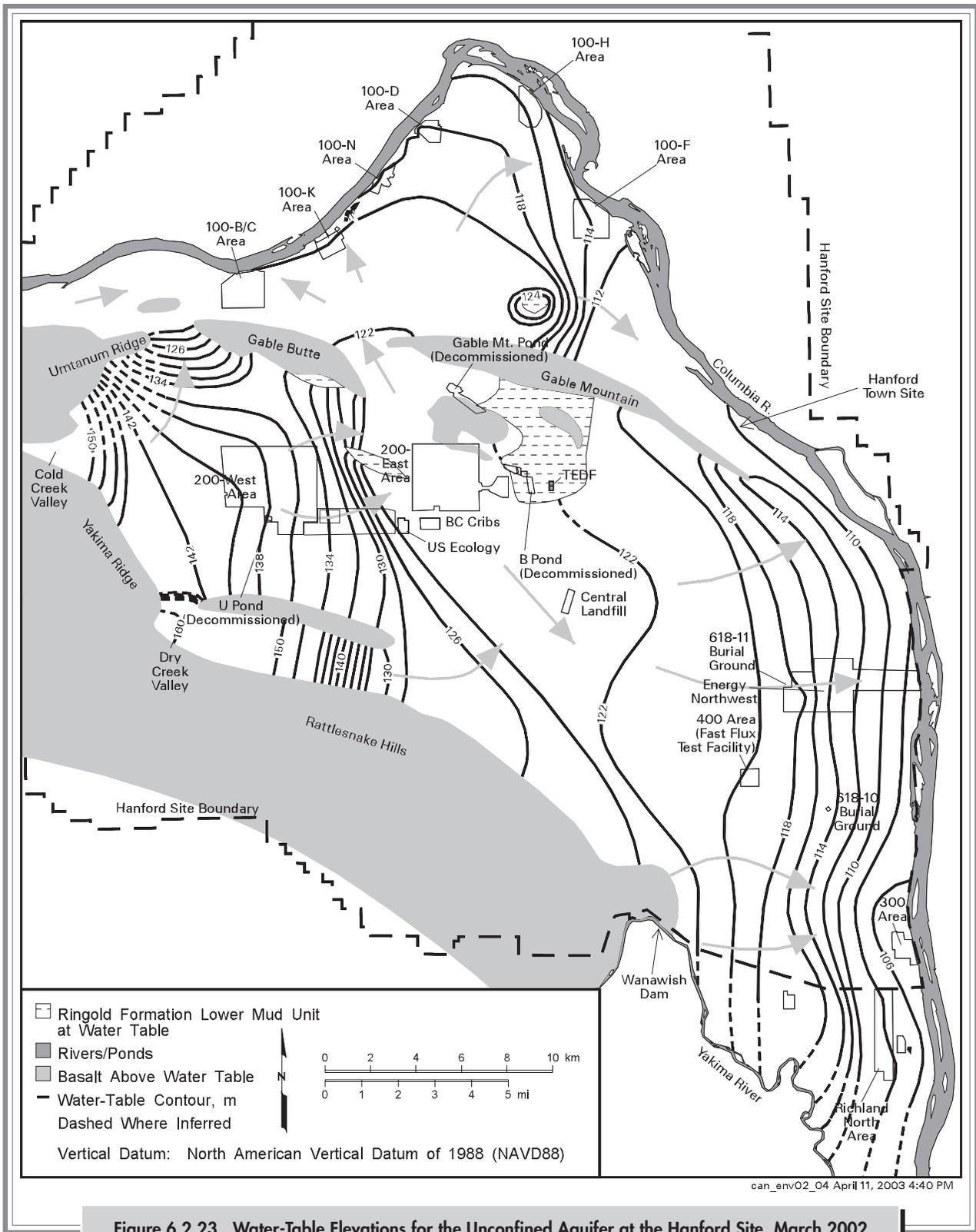
Large-scale, artificial recharge to the Hanford Site unconfined aquifer occurred because of past liquid waste disposal

in the operating areas and offsite agricultural irrigation to the west and south of the site. Discharge of wastewater caused the water table to rise over most of the Hanford Site. Since the peak discharge in 1984, discharge of wastewater to the ground at Hanford has been significantly reduced and, in response, the water table subsequently declined over most of the site. The water-table elevation declined up to 0.25 meter (0.8 foot) over most of the site between 2001 and 2002. The water-table elevation declined by an average of 0.19 meter (0.6 foot) in the 200-East Area and 0.36 meter (1.2 feet) in the 200-West Area. A result of the declining water table is that 52 wells have gone dry at the Hanford Site, including 45 in the 200 Areas, since 1997.

A large decline in the water table between 2001 and 2002 was 1.19 meter (3.9 feet) near the Richland North Well Field and Recharge Basins south of the Hanford Site. This decline is a response to a change in the net volume of recharge at the recharge basins.

The decline in the water table has altered the flow pattern of the unconfined aquifer on the site, which is generally from the recharge areas in the west to the discharge areas (primarily the Columbia River) in the east and north. Water levels in the unconfined aquifer have continually changed as a result of variations in the volume and location of wastewater discharge. Consequently, the movement of groundwater and its associated constituents has also changed with time (Sections 6.2.1 and 6.2.2).

In the past, two major groundwater mounds formed near the 200-East and 200-West Areas in response to wastewater discharges. The first of these mounds was created by disposal at the U Pond in the 200-West Area. After U Pond was decommissioned in 1984, the mound slowly dissipated. The water table continues to decline in this area. The second major mound was created by discharge to the decommissioned, or former, 216-B-3 pond (B Pond), east of the 200-East Area. After discharge to B Pond ceased in August 1997, the decline in the water-table elevation accelerated. Groundwater mounding related to wastewater discharges also occurred in the 100 and 300 Areas in the past. However, groundwater mounding in these areas was not as great as in the 200 Areas primarily because of lower discharge volumes.



**Figure 6.2.23. Water-Table Elevations for the Unconfined Aquifer at the Hanford Site, March 2002**