6.2 Groundwater Monitoring Results

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The following sections summarize the distribution of radioactive and chemical contaminants detected in Hanford Site groundwater during 2001. 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 PNNL-13788. However, because PNNL-13788 (the annual groundwater report) covers the fiscal year (October 2000 through September 2001), it does not include results from the last 3 months of 2001. This report includes a summary of results for January through December 2001.

One way to assess the potential impact of radionuclides and chemicals in 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; see 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 of 4 mrem/yr (0.04 millisievert/yr). 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/yr (0.04 millisievert/yr) to the affected organ. The guides are based on an effective dose equivalent of 100 mrem/yr (1 millisievert/yr) (see Appendix D, Tables D.2 and D.5). In addition, the standards use older factors to calculate the concentrations that would produce a 4-mrem/yr (0.04 millisievert/yr) dose than are used to calculate the guides. Thus, the standards used in this section do not always agree with the guides, which are available only for radionuclides. 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 ~208 square kilometers (80 square miles) in 2001. This area, which is a decrease of ~1% compared to 2000,[(a)] occupies ~14% 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). The total volume of contaminant plumes at levels above drinking water standards during 2001 was estimated to be 1.03 trillion liters (272 billion gallons). Contaminant plumes with concentrations exceeding DOE derived concentration guides occur in isolated areas. The only contaminants at levels above DOE derived concentration guides in 2001 were tritium, uranium, and strontium-90.

Summaries of maximum concentrations for the most widespread contaminants are presented by geographic area in Table 6.2.2 and by monitoring purpose in Table 6.2.3. As expected, most of the maximum

(a) The total area of contaminated plumes in 2000 was changed from ~231 to ~210 square kilometers (~89 to ~81 square miles) because of a re-interpretation of the data and changes to the monitoring network.

Table 6.2.1. Area of Contaminant Plumes at Levels above Drinking Water Standards (adapted from PNNL-13788)

Constituent	Drinking Water Standard	Area (km^2)
Tritium	20,000 pCi/L	151
Iodine-129	1 pCi/L	79.5
Nitrate	45 mg/L	38.4
Carbon tetrachloride	5 µg/L	9.8
Trichloroethene	5 µg/L	4.3
Filtered chromium	100 µg/L	2.8
Strontium-90	8 pCi/L	2.7
Technetium-99	900 pCi/L	2.4
Total uranium	30 µg/L	1.6
Combined plumes	--	208

1 pCi/L = 0.037 Bq/L.

concentrations were detected in the 100 and 200 Areas because these areas contain the largest number of waste sites that have affected groundwater quality (see Table 6.2.2). Some contaminants were not detected or not analyzed for in some of the areas. Strontium-90 is not a contaminant of concern in the 400 Area; therefore, samples from this area were not analyzed for strontium-90 during 2001. 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 the radionuclides listed in 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). In 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 shows the 2001 distribution of tritium in the unconfined aquifer. Tritium is one of the most widespread contaminants in groundwater across the Hanford Site and exceeded the 20,000-pCi/L (740-Bq/L) drinking water standard in portions of the 100, 200, 400, and 600 Areas. Of these areas, tritium levels exceeded the 2 million-pCi/L (74,000-Bq/L) DOE derived concentration guide in portions of the 200 and 600 Areas. The highest tritium concentration measured at the Hanford Site in 2001 was 5.29 million pCi/L (196,000 Bq/L) near the 618-11 burial ground. Tritium levels are expected to decrease because of dispersion and radioactive decay (half-life is 12.35 years).

In 2001, the only liquid effluent containing tritium was discharged to the soil column at the State-Approved Land Disposal Site, which began operating in 1995 and

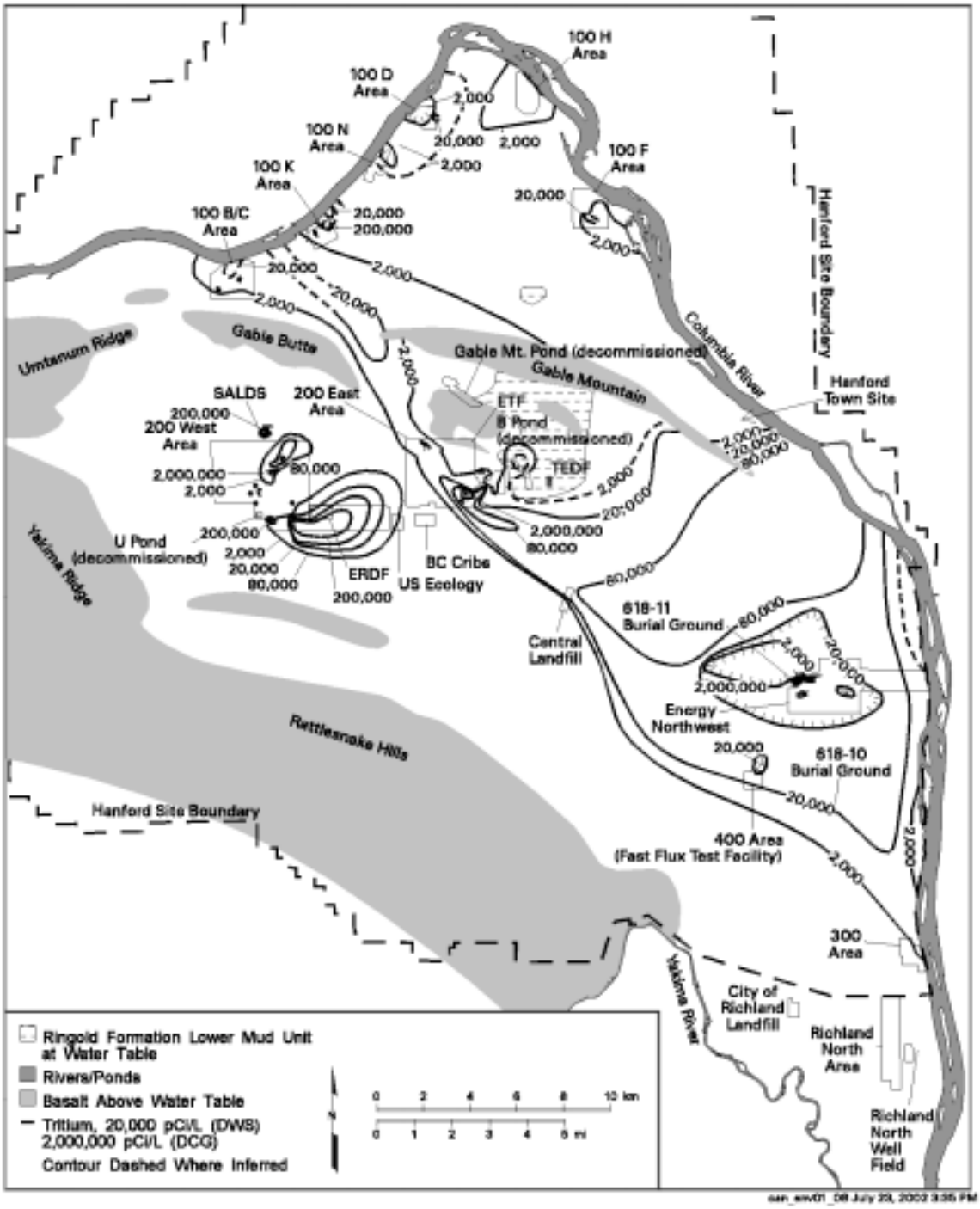

Figure 6.2.1. Average Tritium Concentrations in the Unconfined Aquifer, 2001

Table 6.2.2. Summary of Maximum Concentrations by Geographic Area, Calendar Year 2001

Constituent	Hanford Site	100 Areas	200 Areas	300 Area	400 Area	600 Area[a]
Tritium (pCi/L)	5,290,000	1,140,000	4,300,000	8,870	27,700	5,290,000
Iodine-129 (pCi/L)	26	Not detected	22.4	Not detected	Not detected	26
Nitrate (mg/L)	1,300	125	1,300	89	29.2	162
Carbon tetrachloride (µg/L)	7,400	Not detected	7,400	0.41	Not detected	7.1
Trichloroethene (µg/L)	21	19	21	3.3	Not detected	15
Filtered chromium (µg/L)	5,660	5,660	1,640	4.4	Not detected	106
Strontium-90 (pCi/L)	12,000	9,690	12,000	3.64	Not analyzed	3.9
Technetium-99 (pCi/L)	81,500	243	81,500	Not detected	Not detected	168
Total uranium (µg/L)	3,110	43.7	3,110	198	0.2	22.7

(a) Includes the former 1100 and 3000 Areas.
1 pCi/L = 0.037 Bq/L.

Table 6.2.3. Summary of Maximum Concentrations by Monitoring Purpose, Calendar Year 2001

Constituent	Restoration	Waste Management	Surveillance
Tritium (pCi/L)	5,290,000	4,300,000	5,290,000
Iodine-129 (pCi/L)	16.7	22.4	26
Nitrate (mg/L)	553	1,300	1,300
Carbon tetrachloride (µg/L)	7,400	4,600	6,200
Trichloroethene (µg/L)	21	14	19
Filtered chromium (µg/L)	5,660	1,640	2,370
Strontium-90 (pCi/L)	9,690	1,500	12,000
Technetium-99 (pCi/L)	22,900	81,500	12,600
Total uranium (µg/L)	3,110	678	1,040

(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.

is located just north of the 200-West Area. The total radionuclides received by this facility in 2001 was 0.08 curies (2.96 billion becquerels) of tritium.

Tritium in the 100 Areas. In 2001, 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-F, 100-K, and 100-N 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 the 100-B/C Area declined during 2001. However, tritium concentrations continued to exceed the drinking water standard in several 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 2001, the maximum tritium concentration was 40,700 pCi/L (1,510 Bq/L) in the southwestern part of the 100-B/C Area.

One well in the 100-F Area contained tritium at concentrations greater than the drinking water standard. A maximum of 38,600 pCi/L (1,430 Bq/L) occurred near the 118-F-1 burial ground in 2001. Tritium levels in this well have remained relatively stable the last few years. The burial ground received only solid waste, and the source of the tritium contamination is not known.

A tritium plume near the KE Reactor in the 100-K Area continued to contain the highest tritium concentrations within the 100 Areas. The maximum concentration was 1.14 million pCi/L (42,200 Bq/L) immediately downgradient of the 116-KE-1 crib (Figure 6.2.2). The tritium concentrations at this location (well 199-K-30) are most likely the result of downward migration of tritium in moisture from the vadose zone. This tritium is associated with the 116-KE-1 crib. Carbon-14 is a co-contaminant with tritium in the groundwater. The tritium trend for well 199-K-30 is shown in Figure 6.2.3. A second source of this plume is past leakage of the KE Fuel Storage Basin, with the latest leakage occurring in 1993. Tritium concentrations in the plume farther downgradient of the 116-KE-1 crib continued to rise in 2001 and most likely indicate the arrival of the plume originating from leakage of the KE Fuel Storage Basin in 1993. In the northwestern corner of the 100-K burial ground, tritium concentrations increased rapidly to levels above the drinking water standard from late 2000 through 2001. The maximum concentration was 98,100 pCi/L (3,630 Bq/L) in 2001. 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. Near the KW Reactor Building, tritium concentrations exceeded the drinking water standard in one well in 2001. Tritium levels greater than the drinking water standard, but much less than the DOE derived concentration guide, continued to occur during 2001 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 1301-N and 1325-N Liquid Waste Disposal Facilities. The size of the tritium plume at levels above the drinking water standard continued to decrease in 2001 because of dispersion and radioactive decay. The maximum tritium level reported in the 100-N Area in 2001 was 36,900 pCi/L (1,370 Bq/L) near the Columbia River.

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 4.3 million pCi/L (159,000 Bq/L) in 2001, which is greater than the maximum detected in this well in 2000. Tritium concentrations continued to exceed the drinking water standard in many wells monitoring the cribs near the Plutonium-Uranium Extraction Plant.

In the plume that extends from the southeastern portion of the 200-East Area, tritium concentrations above 200,000 pCi/L (7,400 Bq/L) occurred in a small area downgradient of the Plutonium-Uranium Extraction Plant and did not extend beyond the 200-East Area boundary. The plume area at levels above 200,000 pCi/L (7,400 Bq/L) has 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 (see 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 the low permeability Ringold Formation lower mud 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 discharging to the river occurred near the Hanford town site, where concentrations in groundwater wells ranged from ~90,000 to 106,000 pCi/L (~3,300 to 3,900 Bq/L) during 2001.

Separate tritium pulses associated with the two episodes of Plutonium-Uranium Extraction Plant operations can be distinguished in the plume. A trend plot (Figure 6.2.4) of the tritium concentrations in well 699-40-1 east of the 200-East Area near the shore of 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 began in 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 in early 1987 (Figure 6.2.5). Tritium concentrations from the earlier pulse shown in Figure 6.2.4 were at least three times the maximum concentrations in the later pulse. The effects of the 1983 to 1988 operational period have not been detected near the Columbia River.

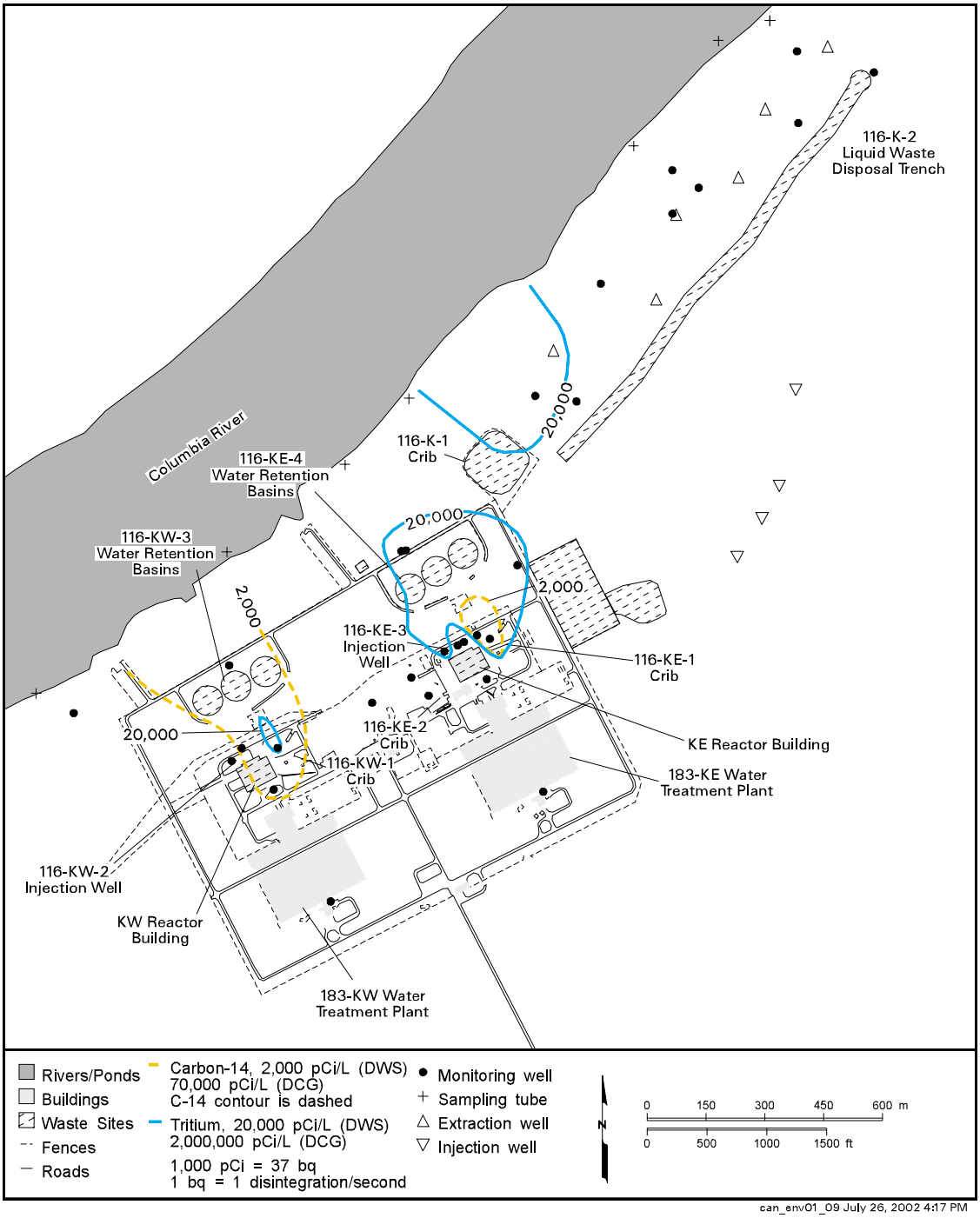

Figure 6.2.2. Average Tritium and Carbon-14 Concentrations in the 100-K Area, 2001

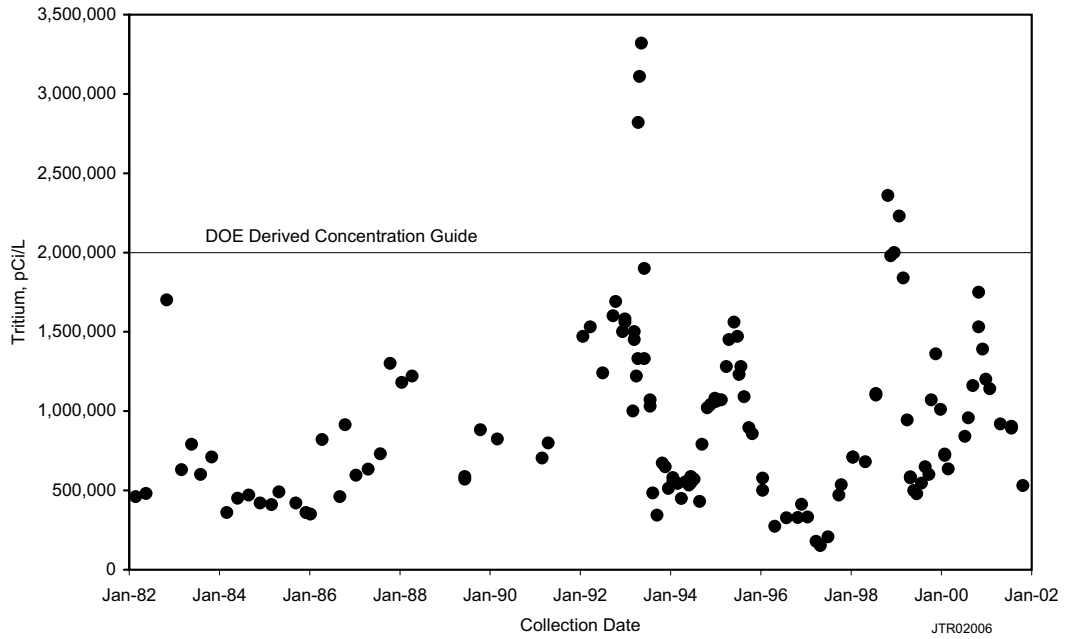

Figure 6.2.3. Tritium Concentrations in Well 199-K-30, 1982 through 2001

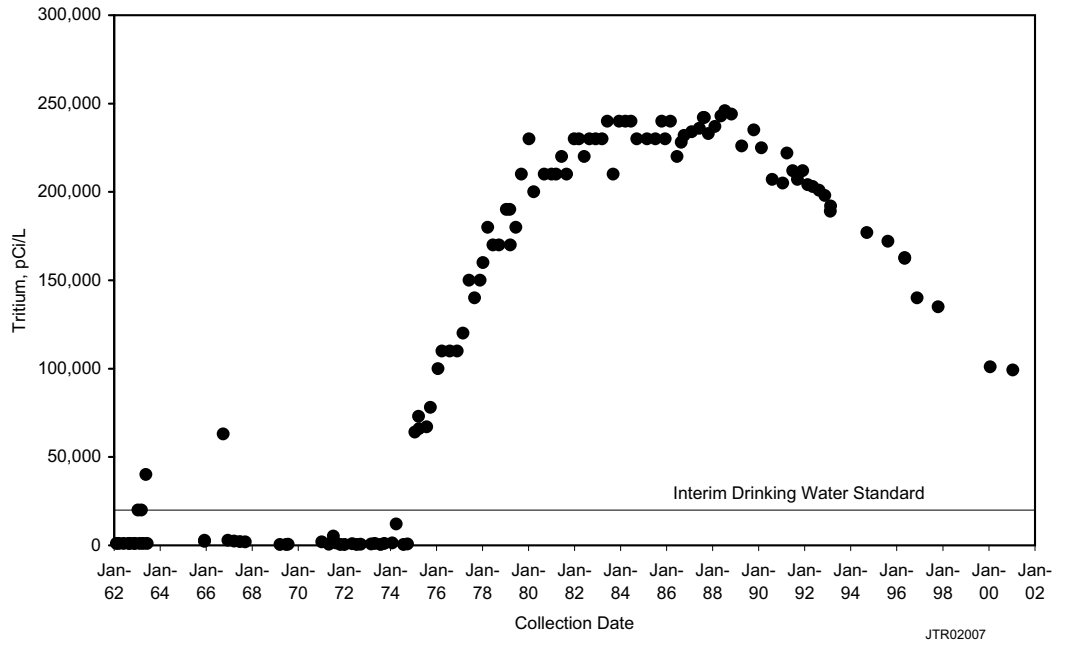

Figure 6.2.4. Tritium Concentrations in Well 699-40-1, 1962 through 2001

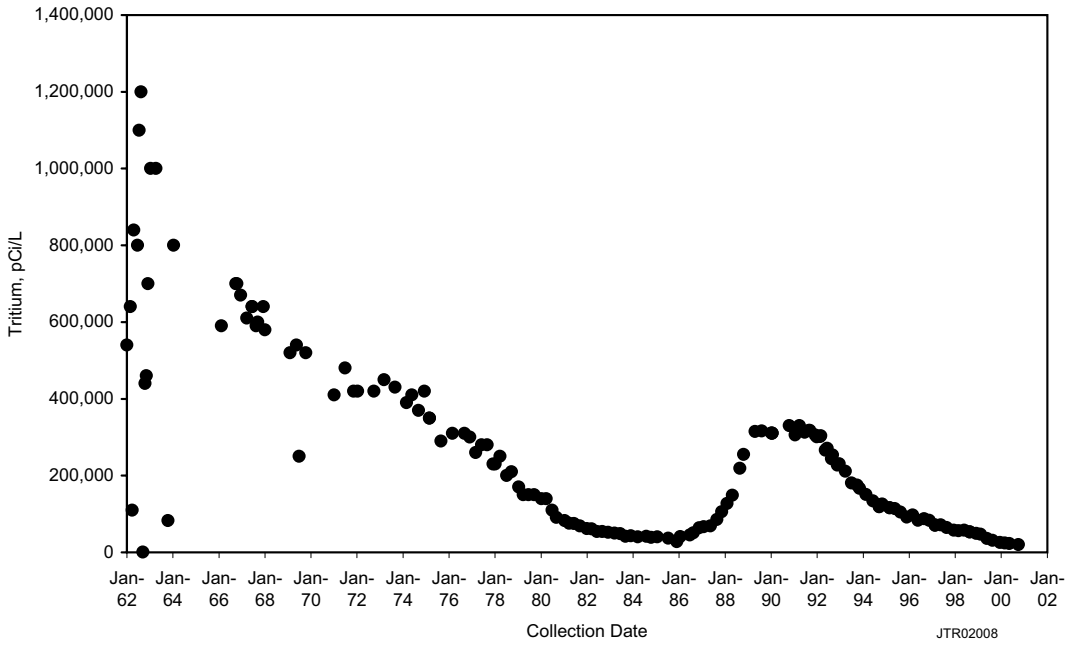

Figure 6.2.5. Tritium Concentrations in Well 699-24-33, 1962 through 2001

The tritium plume, which has been monitored since the 1960s, provides information on the extent of groundwater contamination over time. Figure 6.2.6 shows the distribution of tritium in selected years from 1964 through 2001. This figure was created from maps in BNWL-90, BNWL-1970, PNL-5041, PNL-6825 (Section 5.0), PNNL-11141, and PNNL-13404. The contours in the original references were recalculated and interpreted to provide uniform contour intervals. Figure 6.2.6 shows that tritium at levels greater than the drinking water standard reached the Columbia River near the Hanford town site in approximately the mid-1970s. 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 2001.

Tritium also is found at levels above the drinking water standard in the northwestern part of the 200-East Area (see 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. In one well near the Columbia River between the 100-B/C and 100-K Areas, tritium levels exceeded the drinking water standard for the first time in 2001. This indicates that the leading edge of the tritium pulse extending to the northwest through the gap reached the Columbia River during 2001. Sources of tritium in these areas include waste sites in the vicinity of B Plant. The tritium distribution to 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 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 (see Figure 6.2.1). This plume has generally stopped spreading and has begun to decrease in size in some areas of the plume 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 highest tritium concentrations in the plume are declining, and the maximum concentration detected in this plume east of the Reduction-Oxidation Plant in 2001 was 859,000 pCi/L (31,800 Bq/L). Tritium concentrations exceeded the drinking water standard in much of the plume, including a small area near the former

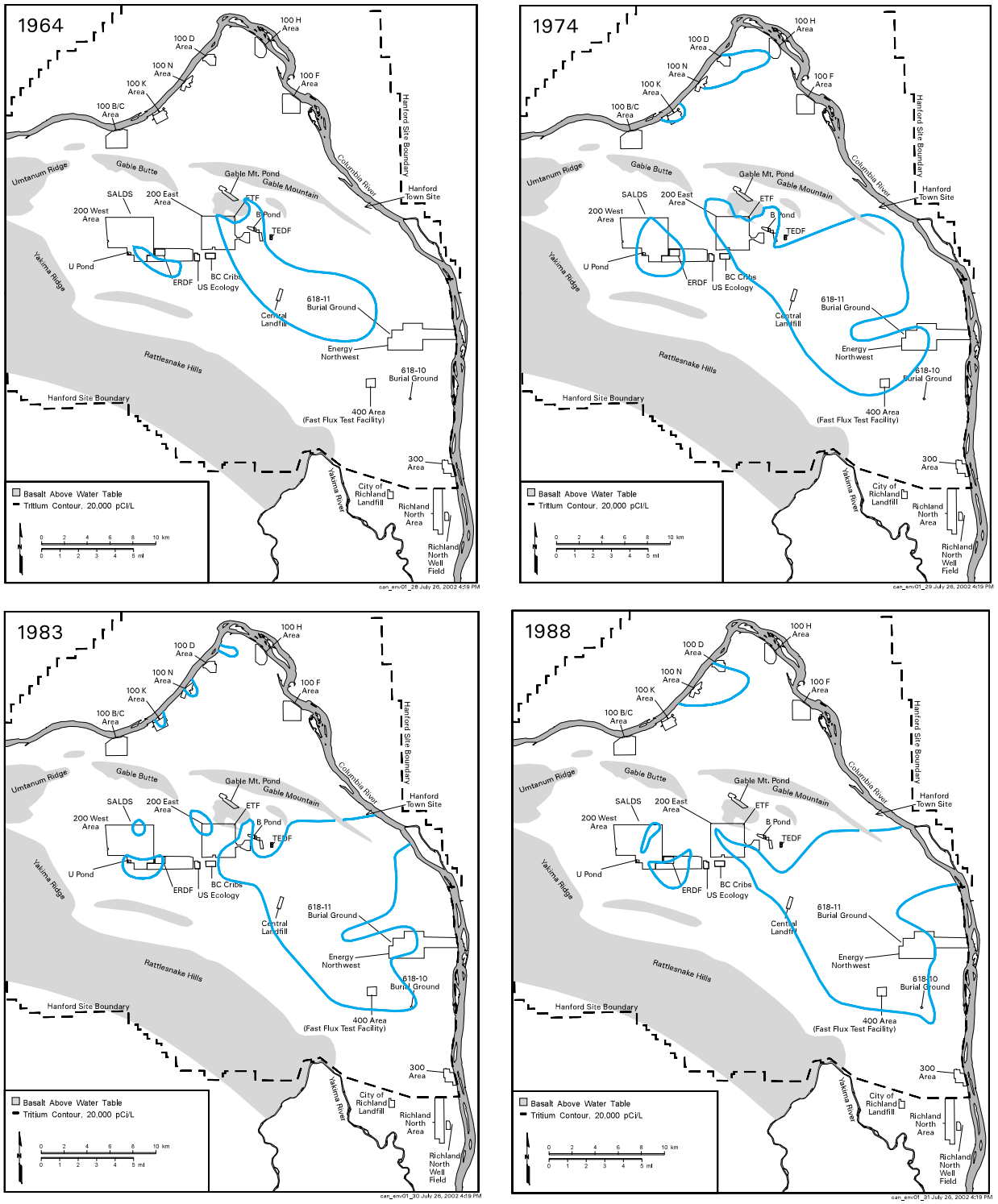

Figure 6.2.6. Historical Tritium Concentrations on the Hanford Site

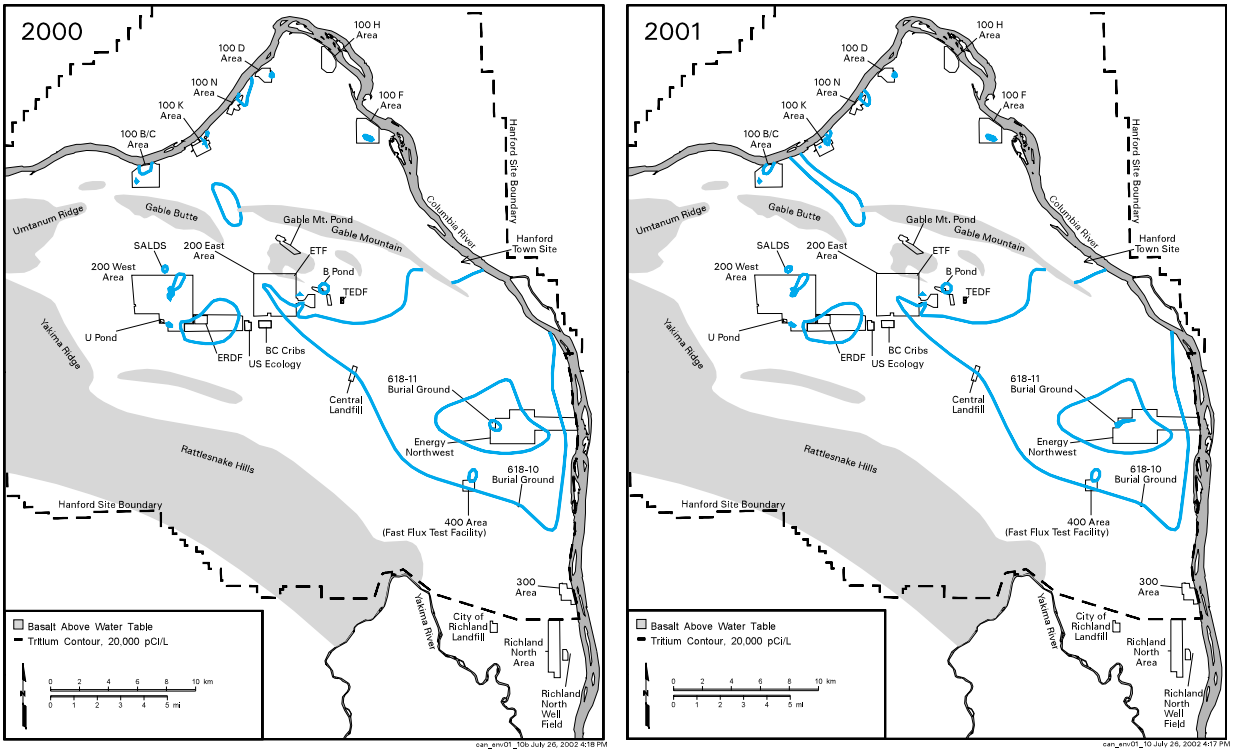

Figure 6.2.6. (contd)

216-S-25 crib and S-SX tank farm upgradient of the Reduction-Oxidation Plant. The maximum tritium concentration in these areas in 2001 was 155,000 pCi/L (5,740 Bq/L) adjacent to the former 216-S-25 crib. Tritium concentrations near this facility decreased during 2000 and 2001 after several years of increasing concentrations.

A smaller tritium plume covers much of the northern part of the 200-West Area and extends to the northeast (see Figure 6.2.1). This plume is associated with former T Plant waste sites, including 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 1.69 million pCi/L (63,000 Bq/L) just east of the TX and TY tank farms near the 216-T-26 crib. Tritium concentrations at this location, which exceeded the DOE derived concentration guide in 2001, increased sharply in 1999, decreased in 2000 and early 2001, and then began to increase again in mid-2001. 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 generally declined in 2001 at wells monitoring the State-Approved Land Disposal Site just north of the 200-West Area. At one of the wells monitoring this facility, tritium concentrations increased sharply to a maximum of 670,000 pCi/L (24,800 Bq/L) in early 2001 and then decreased sharply to levels less than the 20,000-pCi/L (740-Bq/L) drinking water standard during the latter part of 2001. The reason for this spike is that increased levels of tritium were discharged to the State-Approved Land Disposal Site during late 2000. In the deeper portion of the unconfined aquifer, tritium concentrations rose to a maximum of 980,000 pCi/L (36,300 Bq/L) by early 2001 and then decreased to 750,000 pCi/L (27,800 Bq/L) by late 2001. This rise and fall in the tritium concentrations is from the effluent from an earlier discharge containing tritium (prior to April 1999). Approximately 0.08 curies (2.96 billion becquerels) of tritium were discharged to this facility during 2001. By the end of December 2001, ~325 curies (~12.025 trillion becquerels) of tritium and over 424 million liters (112 million gallons) of treated effluent containing tritium had been discharged to this facility since operations began in 1995.

Tritium in the 300 Area and 618-11 Burial Ground. The eastern portion of the tritium plume that emanates from the 200-East Area continues to move to the east-southeast and discharge into the Columbia River (see Figure 6.2.1). The southern edge of the tritium plume extends into the 300 Area, as shown in Figure 6.2.7.

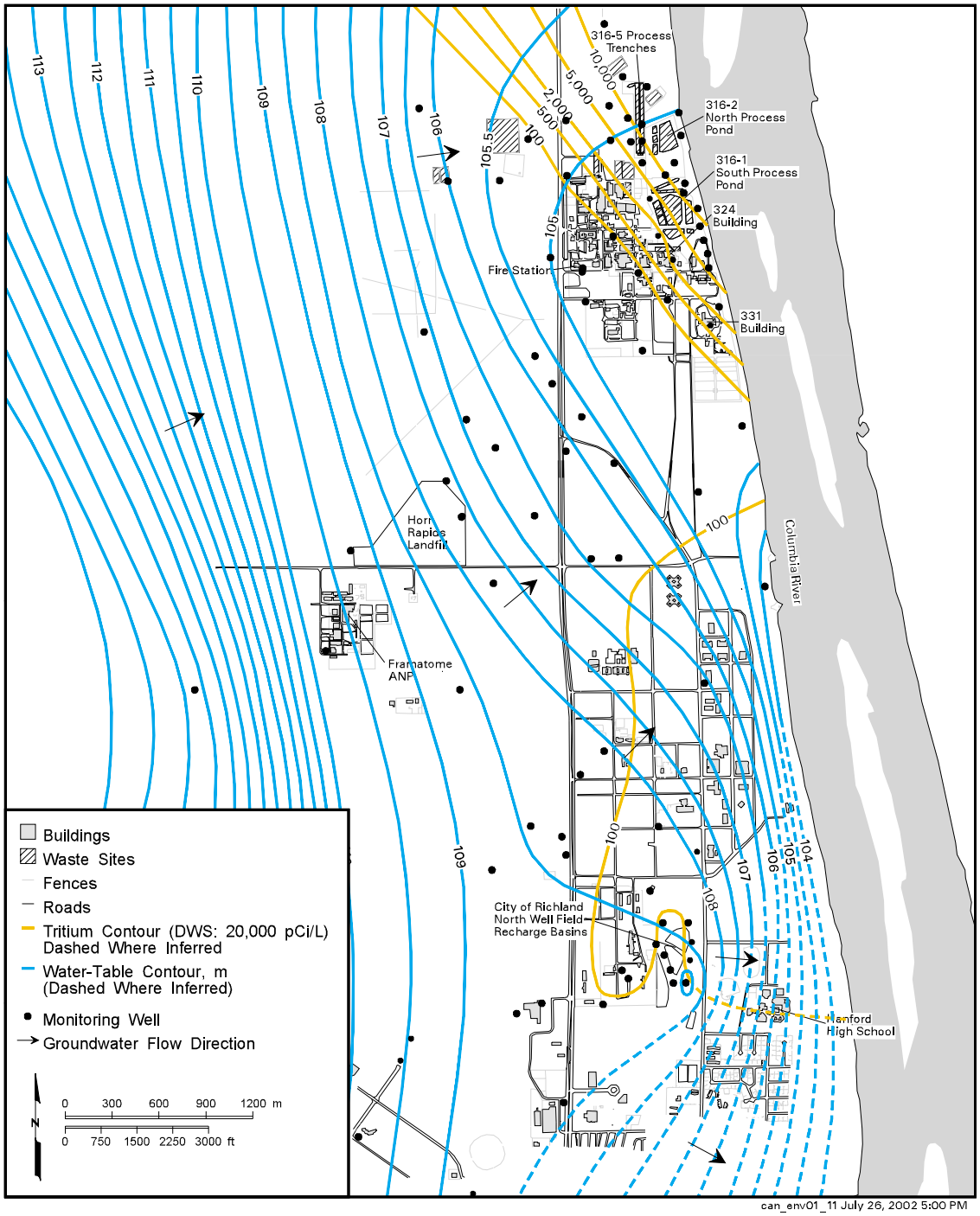

Figure 6.2.7. Average Tritium Concentrations and Groundwater Flow near the 300 Area, 2001

Figure 6.2.7 shows that 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. The tritium contours shifted slightly to the northeast, indicating that the tritium plume in the 300 Area decreased in size between 2000 and 2001. Although tritium in the 300 Area is at levels (a maximum of 8,870 pCi/L [329 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 (see Figure 6.2.7). The highest tritium level detected south of the 300 Area was 551 pCi/L (20 Bq/L) near 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 (see Figure 6.2.7). 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 (see Figure 6.2.7), minimizing the southward movement of the regional tritium plume from the Hanford Site. Recharge from agricultural irrigation occurs south of the Hanford Site boundary and contributes to eastward flow. The recharge ponds are supplied with Columbia River water, which infiltrates to the groundwater. The amount of recharge water exceeded the amount pumped at the well field by a factor of at least 2:1 in 2001, 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.

The highest tritium concentrations measured in Hanford Site groundwater in 2001 were in one well (699-13-3A) immediately downgradient of the 618-11 burial ground. The maximum tritium concentration at this well was 5.29 million pCi/L (196,000 Bq/L) in 2001. The 618-11 burial ground is located west of the Energy Northwest reactor complex in the eastern 600 Area (Figure 6.2.8). 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 in 2000 determined that the burial ground was the source of the tritium contamination (PNNL-13228). However, potential tritium source materials and locations within the burial ground have not been identified.

The investigation continued in 2001 to define the lateral and vertical extent of contamination. The 2001 study defined a tritium plume that is narrow and extends

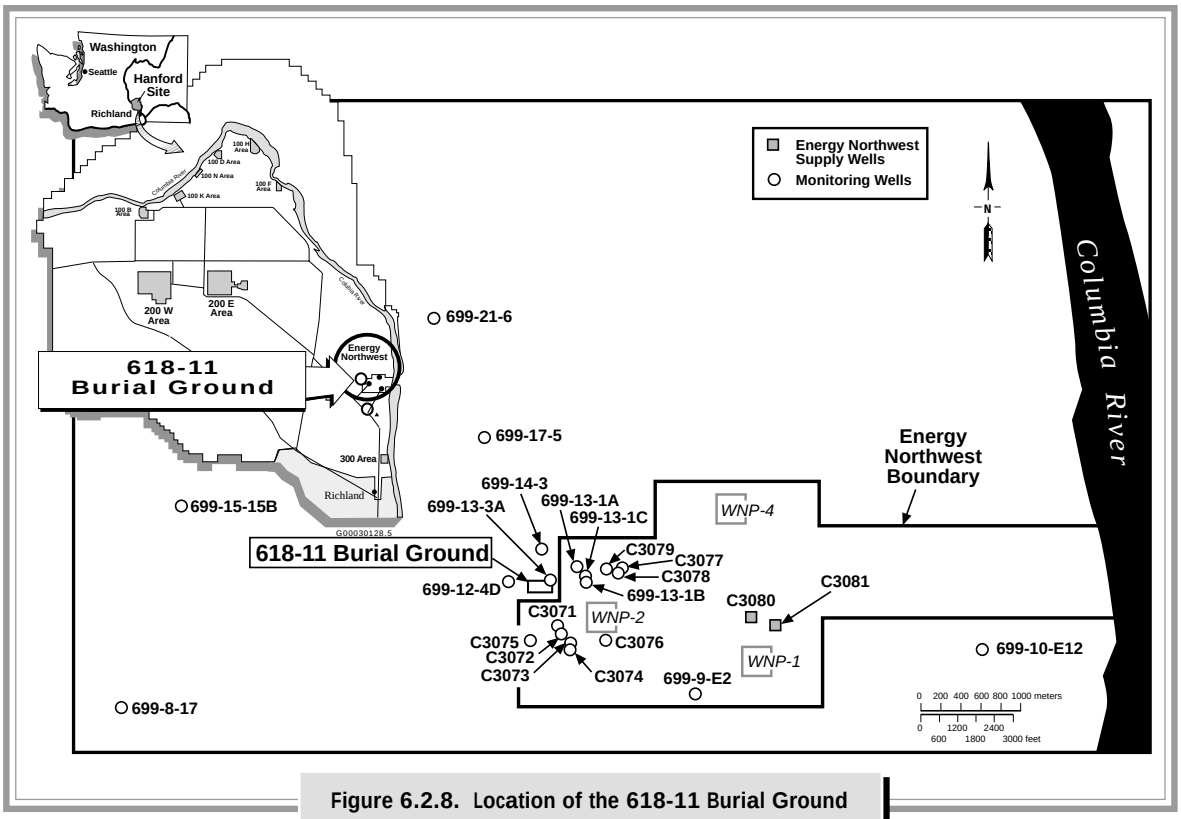

Figure 6.2.8. Location of the 618-11 Burial Ground

~900 meters (~984 yards) east-northeast of the burial ground (Figure 6.2.9). The vertical extent of the plume was throughout the unconfined aquifer above a silt layer that is 13 meters (43 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. The estimated travel time for the tritium plume to reach the Columbia River is between 43 and 166 years. Therefore, 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. The maximum concentration detected in this area during 2001 was 27,700 pCi/L (1,030 Bq/L) in the northern part of the 400 Area. The water supply wells also 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) in 2001. However, tritium levels in one of these wells (499-S0-7) did exceed the drinking water standard in one monthly sample (20,700 pCi/L [767 Bq/L]) in early 2001. 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). The 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 in 2001. 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 2001 on the Hanford Site was 26 pCi/L (0.96 Bq/L) in the 600 Area east of the Reduction-Oxidation Plant in the 200-West Area.

Iodine-129 in the 200-East Area. The highest iodine-129 concentrations in the 200-East Area are in the southeast near the Plutonium-Uranium Extraction Plant and in the northwest in the vicinity of B Plant (Figure 6.2.10). The maximum level of iodine-129 detected in 2001 in the 200-East Area was 9.8 pCi/L (0.36 Bq/L) south of the Plutonium-Uranium Extraction Plant near the 216-A-36B crib. Iodine-129 concentrations near this area are declining slowly or are stable. The iodine-129 plume extends from the Plutonium-Uranium Extraction Plant area southeast into the 600 Area and appears coincident with the tritium plumes (see Figure 6.2.10). 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. The iodine-129 contamination can be detected as far to the east as the Columbia River but at levels less than the drinking water standard. Data indicate that the portion of the iodine-129 plume at levels above the drinking water standard moved 2.5 kilometers (1.6 miles) toward the Columbia River between 1990 and 2001. The leading edge of the iodine-129 plume at levels equal to the 1 pCi/L (0.037 Bq/L) drinking water standard was 3 to 4 kilometers (1.9 to 2.5 miles) from the river in 2001. 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 6.2.10. The highest level detected in the 200-West Area in 2001 was 22.4 pCi/L (0.83 Bq/L) near the TX and TY tank farms. This level occurs in a plume that extends northeast toward T Plant. The 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 located between the TX and TY tank farms. A much larger iodine-129 plume occurs in the southeastern part of the 200-West Area, which originates near the Reduction-Oxidation Plant, and extends east into the 600 Area. This plume is essentially coincident with the tritium plume, though there appears to be a contribution from cribs to the north near U Plant. In 2001, the maximum concentration detected in this plume was 26 pCi/L (0.96 Bq/L) in 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

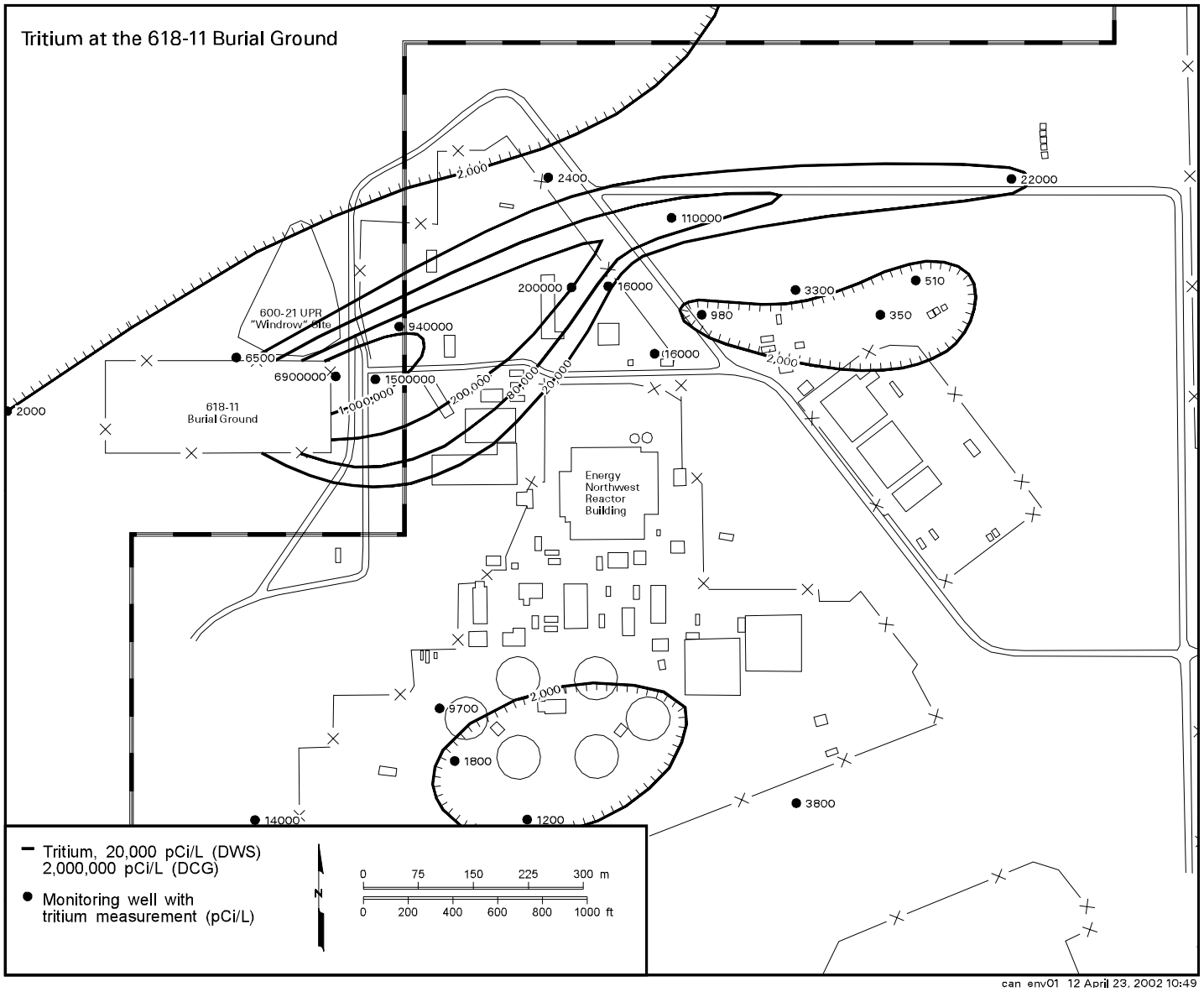

Figure 6.2.9. Average Tritium Concentrations in the Unconfined Aquifer at 618-11 Burial Ground, 2001

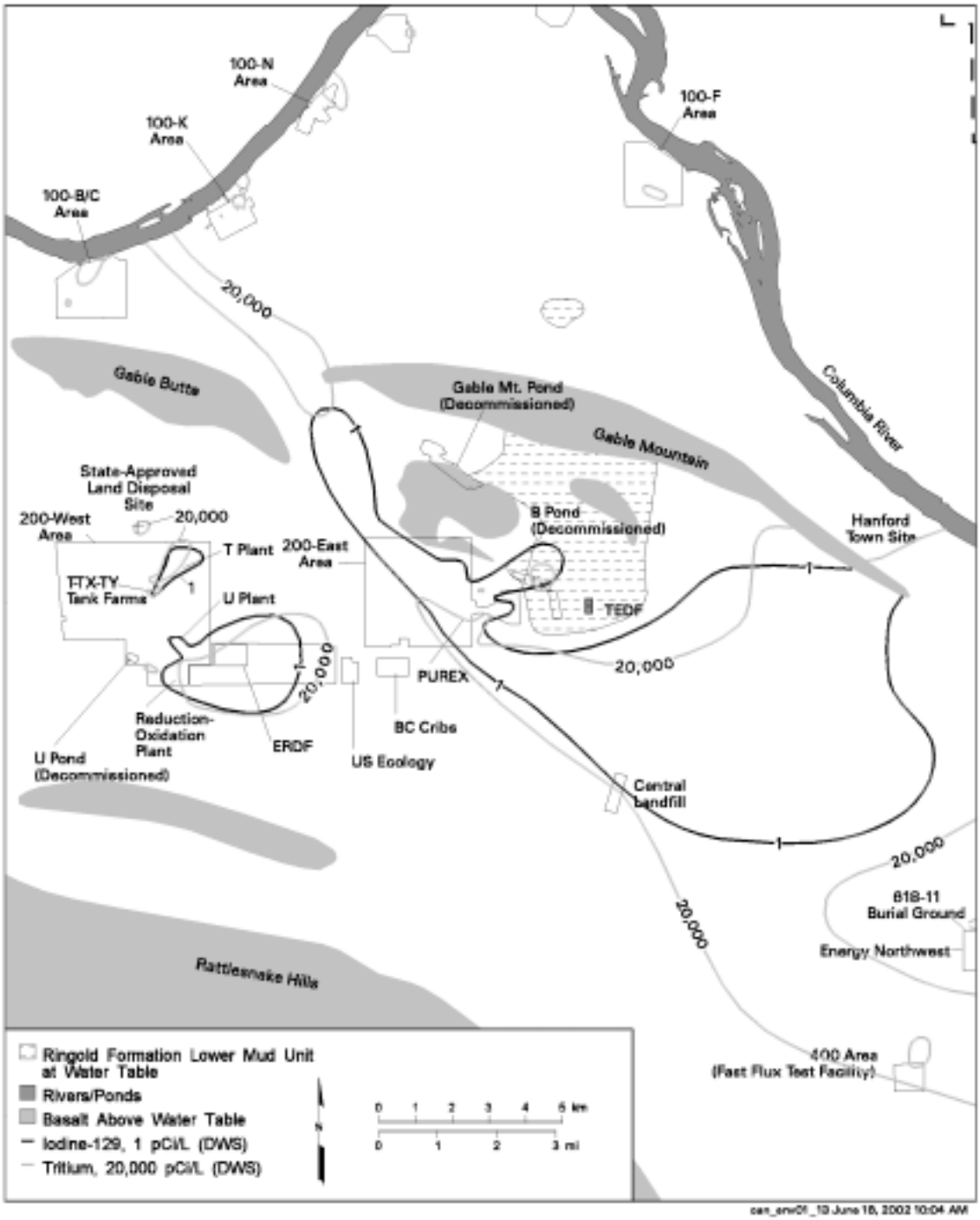

Figure 6.2.10. Average Iodine-129 and Tritium Concentrations in the Unconfined Aquifer, 2001

solution as anions that sorb poorly to sediments. Therefore, technetium-99 is very mobile in site groundwater.

The DOE derived concentration guide is 100,000 pCi/L (3,700 Bq/L) and the interim drinking water standard is 900 pCi/L (33 Bq/L) for technetium-99. Technetium-99 was found at concentrations greater than the 900-pCi/L interim drinking water standard in the 200-East and 200-West Areas. The highest level measured on the Hanford Site in 2001 was 81,500 pCi/L (3,020 Bq/L) 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 6.2.11). The source of the technetium contamination was apparently the BY cribs (Section 2.9.1 in PNNL-13116). However, some of this contamination is believed to originate from tank farms B, BX, and BY (PNNL-11826). Technetium-99 concentrations began to decrease in several wells monitoring tank farms B, BX, and BY in 2001 after reaching a maximum concentration in late 2000 to early 2001 (Figure 6.2.12). The maximum concentration in the 200-East Area in 2001 occurred at the BY cribs at a level of 12,600 pCi/L (467 Bq/L). Technetium-99 concentrations in the plume north of the 200-East Area have exceeded the drinking water standard (maximum of 3,200 pCi/L [118 Bq/L] in 2000). The sampling frequency for wells in this area was changed from annual to triennial; thus, the wells were not sampled in 2001. The wells in this area will be sampled in 2002 and 2003. 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 southeast.

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 in 2001 (see Section 2.3.11). Technetium-99 concentrations have generally declined in the central part of the plume since pump-and-treat operations began in 1997. The maximum level in this plume was detected at a concentration of 22,900 pCi/L (848 Bq/L).

Several wells that monitor tank farms T, TX, and TY consistently showed technetium-99 concentrations above the interim drinking water standard in recent years (see Figure 6.2.13). In 2001, the highest was 5,670 pCi/L (210 Bq/L) east of the TX and TY tank farms. The 200-ZP-1 pump-and-treat operation immediately to the south 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 contaminants beneath the tank farms toward the pump-and-treat system.

In the northeastern corner of T tank farm, technetium-99 levels were above the interim drinking water standard. The maximum in this area was 5,010 pCi/L (186 Bq/L) in 2001. Technetium-99 concentrations have generally declined in the northeastern corner of T tank farm after reaching maximum concentrations in the late 1990s. The sources of the technetium-99 contamination include tank farms T, TX, and TY (PNNL-11809).

Technetium-99 contamination in small areas in the southern part of the 200-West Area originates near tank farms S and SX and the 216-S-13 crib. Multiple sources of technetium-99 contribute to groundwater contamination in this area (PNNL-11810; PNNL-13441). The maximum level detected was 81,500 pCi/L (3,020 Bq/L) in the southwestern corner of tank farm SX. This was the highest technetium-99 concentration detected on the Hanford Site in 2001.

Total Uranium. There were numerous possible sources of uranium released to the groundwater at the Hanford Site in the past, including fuel fabrication, fuel reprocessing, and uranium recovery operations. Uranium may exist in several states, including elemental uranium or uranium oxide as well as tetravalent and hexavalent cations. Only the hexavalent form has significant mobility in groundwater, largely by forming dissolved carbonate species. Uranium mobility is, thus, dependent on oxidation state, pH, and the presence of carbonate. Uranium is observed to migrate in site groundwater but is retarded relative to more mobile species such as technetium-99 and tritium. The EPA's drinking water standard for uranium[(b)] is 30 μg/L, which is protective of both chemical toxicity and cancer risk.

(b) 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).

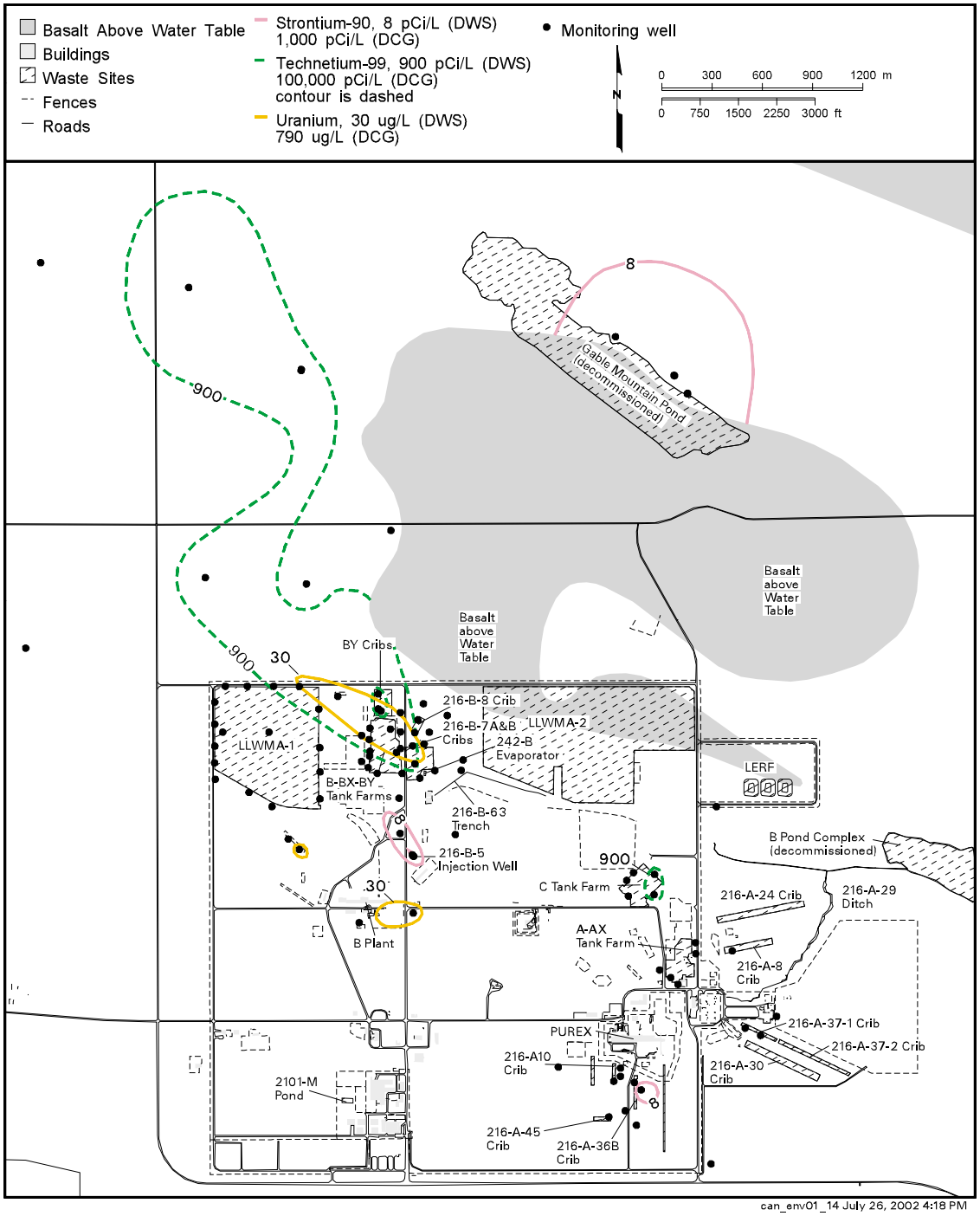

Figure 6.2.11. Average Technetium-99, Total Uranium, and Strontium-90 Concentrations in the Unconfined Aquifer near the 200-East Area, 2001

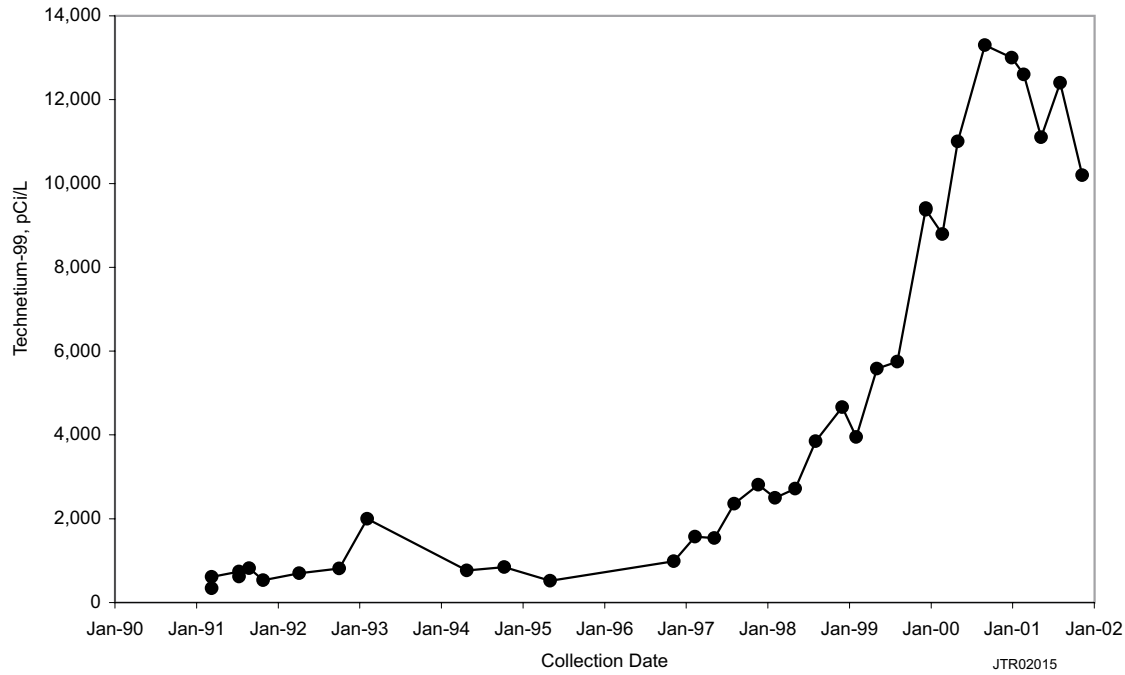

Figure 6.2.12. Technetium-99 Concentrations in Well 299-E33-38 near the B, BX, and BY Tank Farms, 1991 through 2001

The DOE derived concentration guide that represents an annual effective dose equivalent of 100 mrem/yr (1 millisievert/yr) is 790 µg/L for uranium.

Total uranium has been detected 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 in 2001 were in the 200-West Area near U Plant, where uranium levels were 3,110 µg/L and exceeded the DOE derived concentration guide.

Total Uranium in the 100 Areas. Uranium was detected at levels exceeding the 30-µg/L drinking water standard in a small area in the 100-H Area. The maximum level detected in 2001 was 43.7 µg/L between the 183-H solar 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 183-H solar 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 (see Figure 6.2.11). The uranium distribution in 2001 indicates the highest concentrations were in the vicinity of the B, BX, and BY tank farms; BY cribs; and 216-B-5 injection well that has been inactive since 1947. The highest concentration detected was 678 µg/L at the BY tank farm (south of the BY cribs). The uranium plume, which is associated with technetium-99 at the BY tank farm area, has a narrow northwest-southeast shape. Though unclear, a likely source of the uranium contamination is from the tank farm area.

Total Uranium in the 200-West Area. The highest uranium concentrations in Hanford Site groundwater occurred near U Plant (see Figure 6.2.13). The 216-U-1 and 216-U-2 cribs are the major sources of the uranium. The maximum detected in this area and on the Hanford Site in 2001 was 3,110 µg/L in a former pump-and-treat well adjacent to U Plant (Figure 6.2.14). 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 is similar to past years. The high concentrations exceeded the DOE

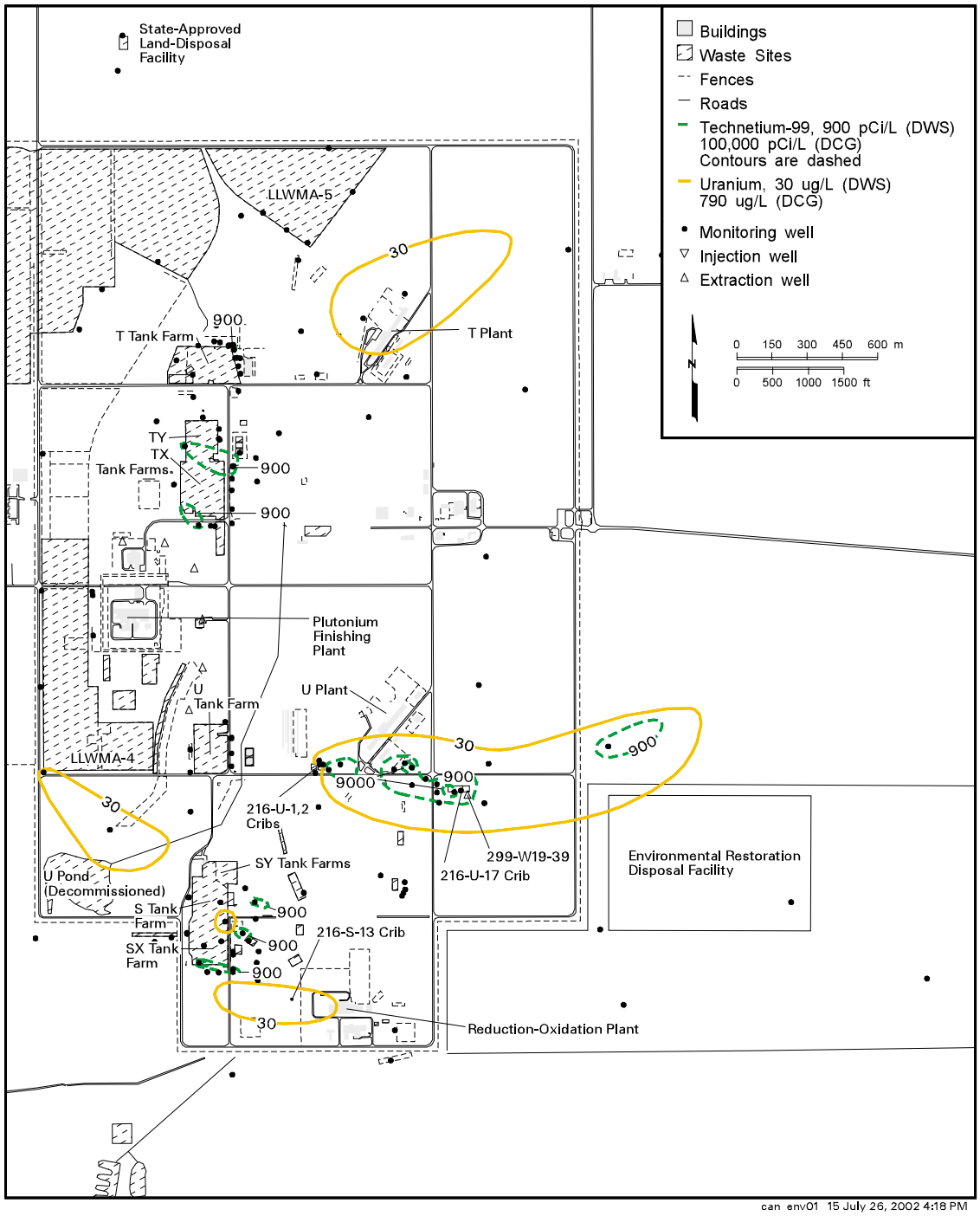

Figure 6.2.13. Average Technetium-99 and Total Uranium Concentrations in the Unconfined Aquifer in the 200-West Area, 2001

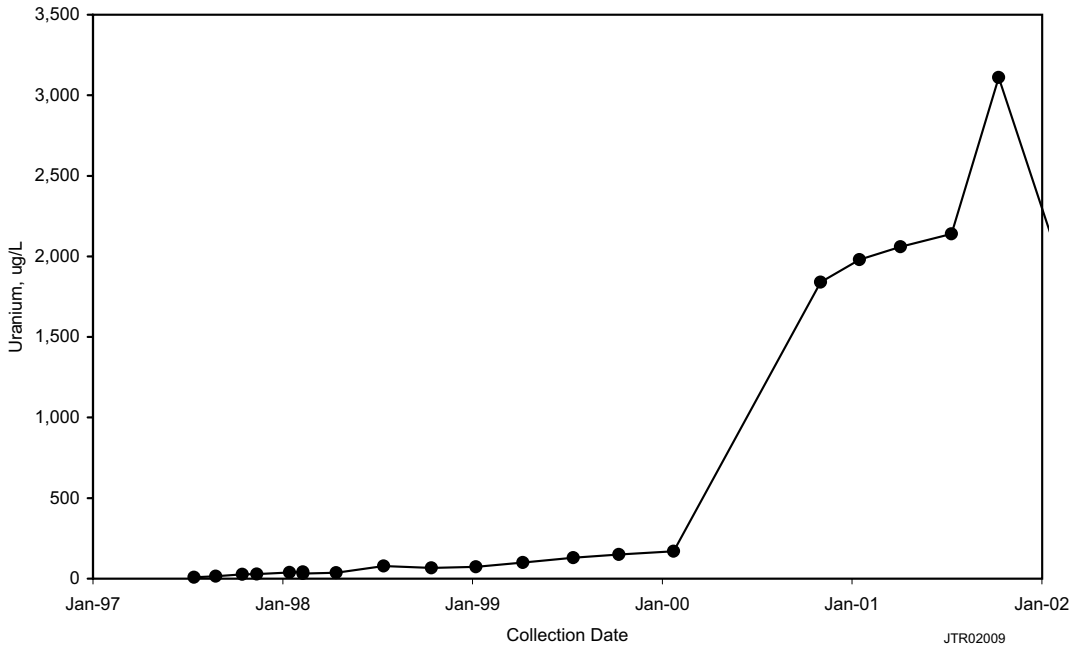

Figure 6.2.14. Uranium Concentrations in Well 299-W19-36, a Former Pump-and-Treat Well Adjacent to U Plant, 1997 through 2001

derived concentration guide for uranium. A pump-and-treat system continued to operate in 2001 to remove uranium from groundwater (see Section 2.3.11).

In the northern part of the 200-West Area, a localized area of uranium contamination occurs near T Plant, where concentrations were above the drinking water standard at a maximum level of 433 µg/L.

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 in 2001 was 198 µg/L southeast of the South Process Pond near the Columbia River. Because wastewater is no longer discharged to the 316-5 process trenches, elevated concentrations at the south end of the process trenches indicate that the soil column contributes uranium contamination to the groundwater. Uranium levels in the 300 Area fluctuate annually but show an overall decline. The annual fluctuation in uranium levels is caused by river stage changes, which results in mobilization of more uranium during high river stages in spring and less uranium during low river stages in fall and early winter.

A localized area of elevated levels of uranium between the 324 Building and the Columbia River moved downgradient with groundwater flow to a position adjacent to the Columbia River in recent years. The source of this localized uranium is suspected to be the former 307 trenches. In 2001, the elevated uranium concentrations adjacent to the river declined to a maximum level (110 µg/L) that is no longer distinguishable from concentrations in the process trenches uranium plume.

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.

In 2001, strontium-90 concentrations greater than the 8-pCi/L (0.3-Bq/L) drinking water standard were

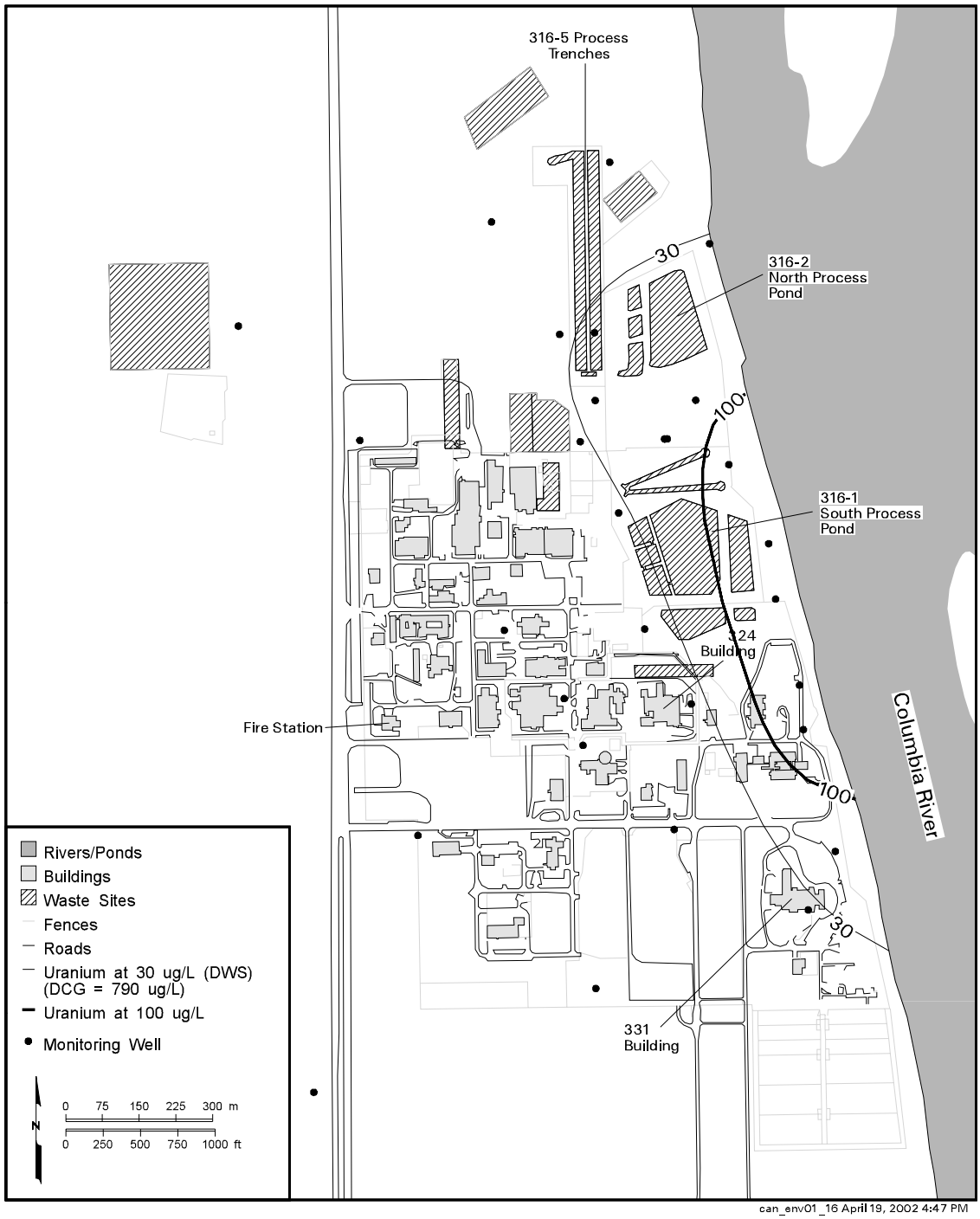

Figure 6.2.15. Average Total Uranium Concentrations in the Unconfined Aquifer in the 300 Area, 2001

found in one or more wells in each of the 100 and 200 Areas. Levels of strontium-90 were greater than the 1,000-pCi/L (37-Bq/L) DOE derived concentration guide in the 100-K, 100-N, and 200-East Areas. The 100-N Area had the widest distribution detected at the Hanford Site during 2001. The maximum concentration detected at the Hanford Site was 12,000 pCi/L (444 Bq/L) in the 200-East Area.

Strontium-90 in the 100 Areas. Strontium-90 concentrations 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. The maximum concentration increased to 135 pCi/L (5.0 Bq/L) during 2001. The 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).

Strontium-90 is not widely distributed in the 100-D Area. Strontium-90 levels were consistently greater than the drinking water standard in one well near the inactive D Reactor fuel storage basin in the past. However, this well was decommissioned in late 1999, and strontium-90 levels in nearby wells were less than the drinking water standard in 2001. Strontium-90 was detected at levels just above the drinking water standard near the former 116-D-7 retention basin in the northern part of the 100-D Area. The maximum concentration in this area was 13.1 pCi/L (0.49 Bq/L) in 2001. Strontium-90 levels near the former 116-D-7 retention basin have not changed significantly in recent years.

Strontium-90 exceeded the drinking water standard 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 in 2001 was 37.6 pCi/L (1.4 Bq/L). Strontium-90 levels 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 an area adjacent to the Columbia River near the 107-H retention basin. The maximum detected in the 100-H Area in 2001 was 38.1 pCi/L (1.4 Bq/L) between the retention basin and the Columbia River. The source of the contamination is past disposal of reactor coolant containing strontium-90 to the 107-H retention basin, the 107-H liquid waste disposal trench, and the 107-H 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 are generally stable in the 100-H Area.

Strontium-90 at levels greater than the drinking water standard continues to occur in isolated areas in 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 in 2001 was 5,210 pCi/L (193 Bq/L) at well 199-K-109A, the only well in the 100-K Area where levels were above the DOE derived concentration guide. 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 undergoing treatment by 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 are less than the drinking water standard. The maximum strontium-90 concentration near the disposal trench in 2001 was 38.9 pCi/L (1.4 Bq/L), the same as in 2000. Near the KW Reactor, strontium-90 is elevated above the drinking water standard. The maximum strontium-90 concentration near the KW Reactor was 41.9 pCi/L (1.6 Bq/L) in 2001.

The distribution of strontium-90 in the 100-N Area is shown in Figure 6.2.16. Strontium-90 was detected at concentrations greater than the DOE derived concentration guide in several wells located between the 1301-N Liquid Waste Disposal Facility, a source of the strontium-90, and the Columbia River. The 1325-N Liquid Waste Disposal Facility is also a source of strontium-90 in groundwater. The maximum level detected in the 100-N Area has been near the head end of the 1301-N facility (well 199-N-67), where concentrations have ranged between 18,000 and 24,000 pCi/L (670 and 890 Bq/L) in recent years. However, this well could not be sampled in 2001 because of a low water table. The distribution of strontium-90 near this facility has not changed significantly in the past 20 years.

In the 100-N Area, strontium-90 discharges to the Columbia River through springs along the shoreline. Sections 3.2 and 4.2 give the results of spring water sampling. Because of high concentrations in wells near the river, it was expected that strontium-90 exceeded the drinking water standard at the interface between the groundwater and the river (DOE/RL-96-102). The highest strontium-90 concentration in a near-river well in 2001 was 9,690 pCi/L (359 Bq/L). This was the highest strontium-90 concentration detected in 100-N Area groundwater during 2001. Strong, positive correlations between high groundwater-level elevations and high

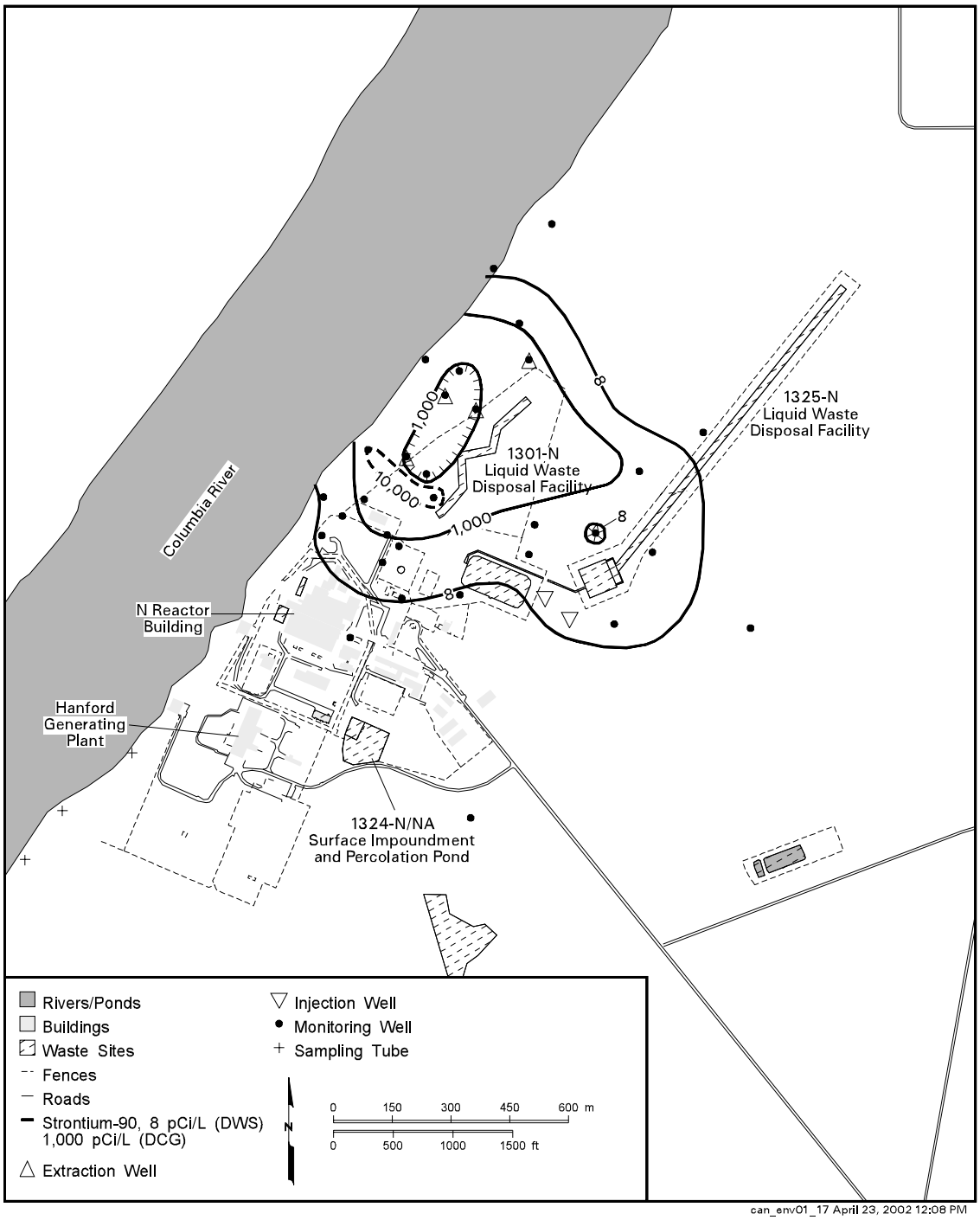

Figure 6.2.16. Average Strontium-90 Concentrations in the Unconfined Aquifer in the 100-N Area, 2001

strontium-90 concentrations in wells indicate that strontium-90 is remobilized during periods of high water levels. A pump-and-treat system continued to operate in 2001 to reduce the discharge of strontium-90 to the Columbia River (see Section 2.3.11).

Strontium-90 in the 200 and 600 Areas. Strontium-90 distribution in the 200-East Area is shown in Figure 6.2.11. Strontium-90 concentrations in the 200-East Area were above the DOE derived concentration guide in two wells near the inactive 216-B-5 injection well. The maximum strontium-90 concentration detected near the injection well in 2001 was 12,000 pCi/L (444 Bq/L), which was the highest strontium-90 concentration detected on the Hanford Site in 2001. The former injection well received 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. Strontium-90 levels increased in this well to 21 pCi/L (0.78 Bq/L) in 2001.

In the 200-West Area, strontium-90 was detected at a level exceeding the 8-pCi/L (0.3-Bq/L) drinking water standard in one well near the Reduction-Oxidation Plant cribs. The maximum concentration near the cribs was 76.2 pCi/L (2.8 Bq/L) in 2001. Strontium-90 levels have been increasing in this well in recent years.

In the 600 Area, the highest strontium-90 concentrations have been measured in the past near the former Gable Mountain Pond area (see Figure 6.2.11). The level of strontium-90 rose above the DOE derived concentration guide in 2000. Strontium-90 contamination in this area resulted from the discharge of radioactive liquid waste to the former Gable Mountain Pond during its early use. Wells near this former pond were not sampled during 2001 because of waste management issues associated with sample disposal. Many wells completed above the basalt in this area are becoming difficult to sample because of declining groundwater levels.

Carbon-14. Carbon-14 concentrations occur in the 100-K Area and exceed the 2,000-pCi/L (74-Bq/L) interim drinking water standard in two small plumes near the KE and KW Reactors (see Figure 6.2.2). The sources of the carbon-14 were the 116-KE-1 and 116-KW-1 condensate cribs, respectively. However, waste disposal to these cribs ended in 1971. Carbon-14 was included with tritium in the condensate wastewater disposed to the 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). The maximum concentration in 2001 was 12,900 pCi/L (478 Bq/L) near the 116-KW-1 crib. Carbon-14 levels have remained stable in most of the 100-K Area wells. The DOE derived concentration guide for carbon-14 is 70,000 pCi/L (2,590 Bq/L). Carbon-14 has a long half-life of 5,730 years, which suggests that some of the carbon-14 will reach the Columbia River before it decays. 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).

Cesium-137 was detected in three wells located near the inactive 216-B-5 injection well in the 200-East Area. The injection well received waste containing cesium-137 from 1945 to 1947. The maximum cesium-137 concentration in 2001 was 1,910 pCi/L (70.7 Bq/L), which is greater than the interim drinking water standard. 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 in 2001 were less than the 100-pCi/L (3.7-Bq/L) interim drinking water standard. The DOE derived concentration guide for cobalt-60 is 5,000 pCi/L (185 Bq/L).

Cobalt-60 was detected 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 concentration measured in 2001 was 71 pCi/L (2.6 Bq/L) at the BY cribs. Cobalt-60 levels near the BY cribs generally decreased in 2001 along with associated cyanide and technetium-99 after reaching maximum concentrations in 2000. 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-millirem (1-millisievert) dose standard is converted to the 4-millirem (40-microsieverts) 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 in groundwater on the Hanford Site was near the inactive 216-B-5 injection well in the 200-East Area. The maximum plutonium-239/240 concentration near this injection well during 2001 was 63 pCi/L (2.3 Bq/L), which exceeds the 30-pCi/L (1.1-Bq/L) DOE derived concentration guide. Plutonium levels near the injection well have changed significantly since monitoring for plutonium began in the 1980s. Because plutonium is strongly adsorbed to sediments 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 by 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, and fluoride.

A number of parameters such as pH, specific conductance, total carbon, total organic carbon, and total organic halides are used as indicators of contamination. These are mainly discussed in Section 6.4. Other chemical parameters listed in 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 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, arsenic, 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; see Appendix D).

Nitrate. Many groundwater samples collected in 2001 were analyzed for nitrate. The distribution of nitrate on the Hanford Site is shown in Figure 6.2.17; this distribution 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 at concentrations greater than the drinking water standard (45 mg/L 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 1,300 mg/L 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

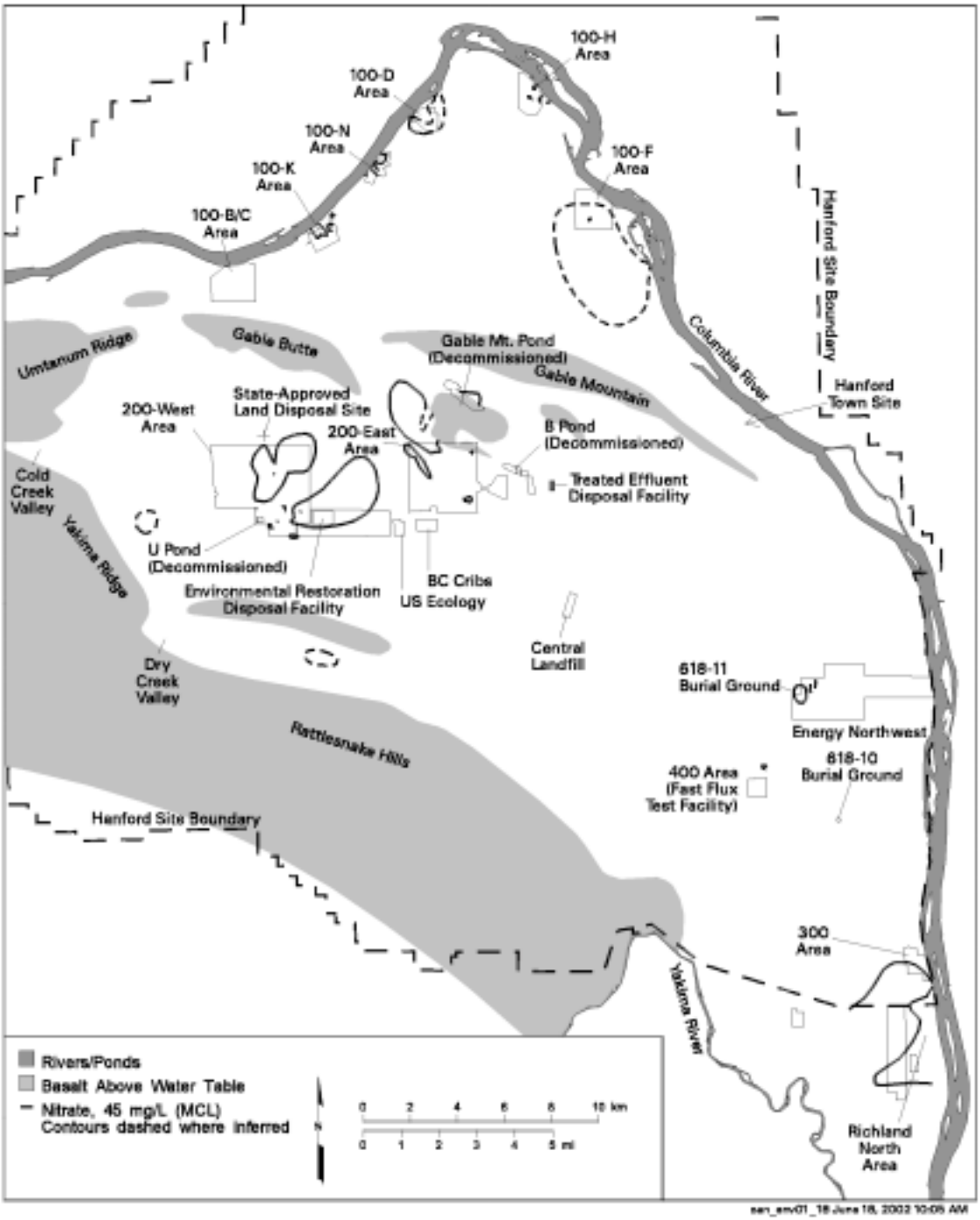

Figure 6.2.17. Average Nitrate Concentrations in the Unconfined Aquifer, 2001

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

Nitrate is found at levels greater than the drinking water standard in much of the 100-D Area. The highest nitrate level found in the 100-D Area in 2001 was 89.7 mg/L near the 120-D-1 ponds. Nitrate concentrations near the 120-D-1 ponds continued to show an increasing trend in 2001.

Nitrate continues to be widely distributed in the 100-F Area and the adjacent 600 Area to the south. The central and southern portions of the 100-F Area and the adjacent 600 Area contain nitrate at levels greater than the drinking water standard. Trends showed increasing or stable nitrate levels in many of the 100-F Area wells in 2001. The 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 was to the southeast. The maximum nitrate detected in the 100-F Area in 2001 was 116 mg/L near F Reactor.

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 183-H solar evaporation basins. The maximum nitrate detected in 2001 was 94.3 mg/L 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 2001. In the 100-K Area, nitrate levels decreased in a number of wells between 1999 and 2000. The maximum concentration detected in the 100-K Area in 2001 was 119 mg/L in a well adjacent to the KE Reactor.

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 in the 100-N Area was 125 mg/L in a well located between the 1301-N 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 exceeds 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 north and 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. A 2001 nitrate plume map of the northern part of the 200-East Area and the adjacent 600 Area is presented in Figure 2.9-9 of PNNL-13788.

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 be associated with past releases from the B-BX-BY tank farms. In 2001, the highest 200-East Area concentrations were reported in several wells near the BY and 216-B-8 cribs, where nitrate concentrations continued to increase. The maximum concentration was 748 mg/L in a well west of 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 tended to decrease in the past few years but remained greater than the drinking water standard, though these cribs were removed from service in 1987. An exception to these decreases is an increase to a maximum of 233 mg/L in one well adjacent to the 216-A-36B crib.

Nitrate has been 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 in 2001 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 the multiple sources in the 200-West Area. Nitrate plume maps of the 200-West and adjacent 600 Areas are presented in Figure 2.8-10 of PNNL-13788.

Near U Plant, widespread nitrate contamination 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 in 2001 was 553 mg/L near the inactive 216-U-17 crib. Nitrate concentrations decreased near this crib in 2001. A pump-and-treat system continued to operate in this area (see Section 2.3.11). However, nitrate is not the primary target of the pump-and-treat system. The primary target of the pump-and-treat system is uranium and technetium-99.

Nitrate concentrations continued to be elevated above the drinking water standard near other inactive cribs to the south 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 reported in these areas in 2001 was 54 mg/L at a crib near 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 concentration was 646 mg/L. Nitrate concentrations in this small plume 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 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] of nitrate to the 216-T-7 crib). Maximum concentrations in these wells in 2001 ranged up to 1,300 mg/L just south of the T tank farm. These are the highest nitrate concentrations measured on the Hanford Site during 2001. Nitrate concentrations have increased in many of the wells near T tank farm in the past several years.

A smaller area of elevated nitrate concentrations 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 the elevated 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. The highest reported concentration in 2001 at the Plutonium Finishing Plant was 299 mg/L in a pump-and-treat extraction well adjacent to the trench, which is located east of the Plutonium Finishing Plant.

Nitrate in the 300, 600, and Former 1100 Areas. Nitrate contamination 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 from off the site, south of the Hanford Site, to the 300 Area to the northeast. Nitrate concentrations generally continued to increase in the southern part of the Hanford Site and the adjacent area south of the Hanford Site in 2001. The maximum nitrate concentration in 2001 was 282 mg/L off the Hanford Site just south of the Hanford Site boundary (EMF-1865, Addendum 27). This nitrate is likely the result of agriculture to the west and southwest. A 2001 plume map showing detail of the nitrate distribution is presented in Figure 2.12-9 in PNNL-13788.

Although most nitrate detected on the site is the result of Hanford Site operations, elevated nitrate concentrations in the western part of the site appear to be the result of increasing agricultural activity in offsite areas (e.g., Cold Creek Valley). There is no known source of nitrate in these areas associated with site operations, and groundwater flow is from the west toward the Hanford Site facilities to the east. Nitrate levels have fluctuated considerably in wells upgradient of the 200 Areas over the past 30 years. In Cold Creek Valley, nitrate levels have been near or greater than the drinking water standard in one well since 1985. A maximum nitrate concentration of 59.3 mg/L was found in a well located just north of the Rattlesnake Hills.

Nitrate was detected at levels exceeding the drinking water standard in a well downgradient of the 400 Area process ponds. These levels, which have remained steady, were attributed to a former sanitary sewage lagoon west and upgradient of the process ponds. The maximum concentration observed was 82.8 mg/L in 2001.

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.

Both filtered and unfiltered samples were collected from several of the wells onsite 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 above the drinking water standard in 2001 in the 100-D, 100-H, 100-K, and 100-N Areas. The maximum detected concentration was 5,660 µg/L in the 100-D Area. Groundwater pump-and-treat systems continued to operate in 2001 to reduce the amount of hexavalent chromium entering the Columbia River at the 100-D, 100-H, and 100-K Areas (see Section 2.3.11). 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, which is the EPA's standard for protection of freshwater aquatic life (EPA 822-Z-99-001).

The chromium distribution in the 100-D Area is shown in Figure 6.2.18. Chromium contamination at levels greater than the drinking water standard is defined by two plumes that appear to be merging. 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 the chromium plume in the southwestern part of the 100-D Area 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. In 2001, the maximum chromium concentration from filtered samples was 5,660 µg/L in the southwestern plume near the Columbia River, where concentrations increased significantly in 2001 (Figure 6.2.19). The southwestern plume contains the highest concentrations of hexavalent chromium on the Hanford Site. 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 chromium concentration in the northern plume was 830 µg/L in 2001. 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.

A small chromium plume in the northeastern part of the 100-H Area contains chromium levels greater than the drinking water standard (see Figure 6.2.18). In 2001, the maximum chromium concentration from filtered samples collected from the shallow parts of the unconfined aquifer was 101 µg/L between the former 183-H solar evaporation basins and the Columbia River. Chromium levels have fluctuated in response to changing water-table conditions. Potential sources include past disposal of sodium dichromate near H Reactor, disposal to the inactive 107-H liquid waste disposal trench, and chromium in acid waste stored in the former 183-H basins (Peterson and Connelly 1992). Upgradient sources include waste sites in the 100-D Area. Chromium was also found at levels above the drinking water standard in one well monitoring the deeper part of the unconfined aquifer. Filtered samples from this well, located near the former 183-H basins, contained 140 µg/L of chromium in 2001. Chromium levels in this well have been decreasing in recent years. Chromium concentrations exceeded the drinking water standard in two 600-Area wells west of the 100-H Area. The maximum chromium concentration in these wells in 2001 was 106 µg/L.

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 near the KW Reactor in 2001 was 564 µg/L. Chromium concentrations in the plume near the KW Reactor increased in 2001. One potential source of the chromium plume near the KW Reactor is 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 in this plume in 2001 was

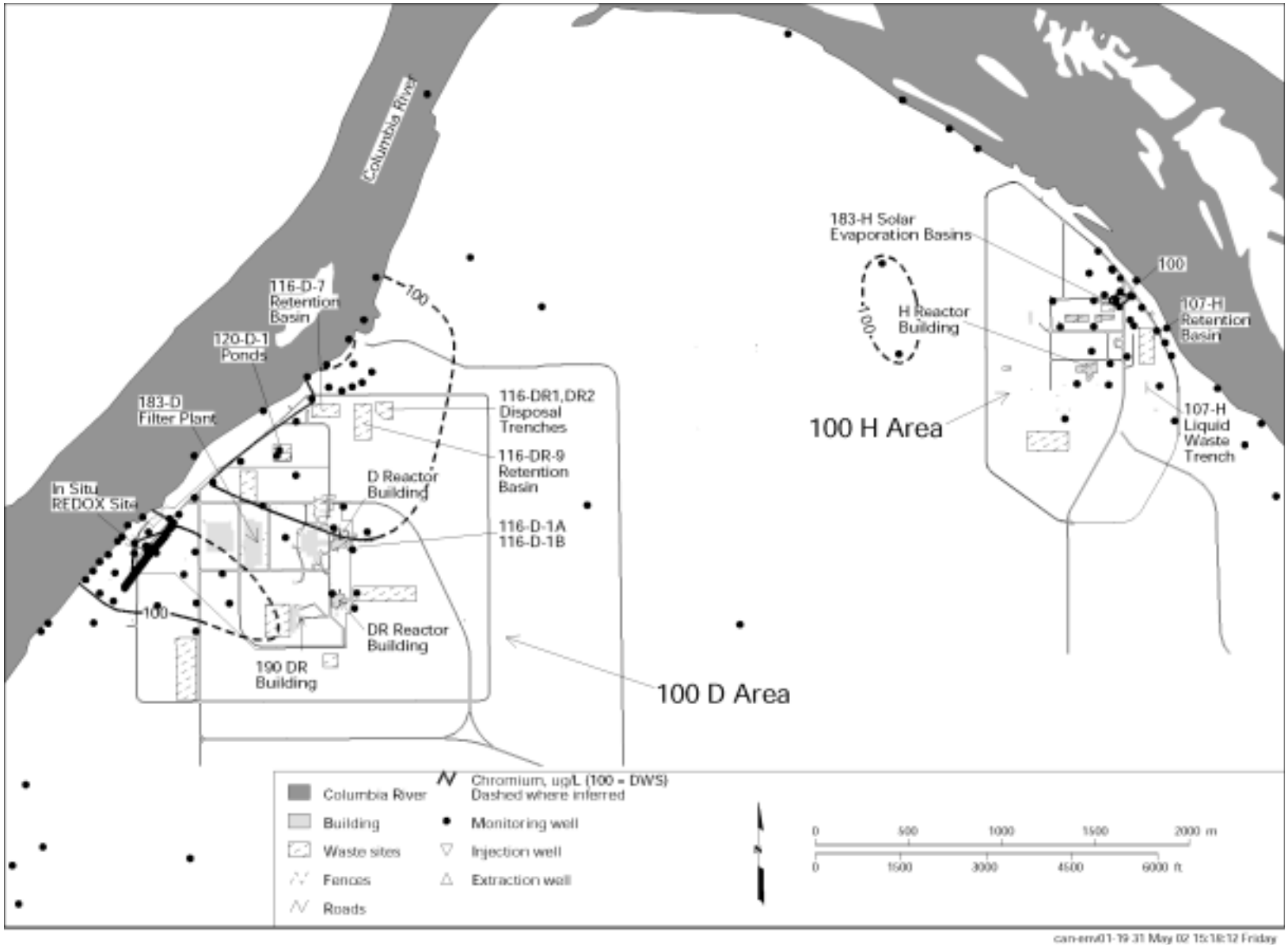

Figure 6.2.18. Average Filtered Chromium Concentrations in the 100-D and 100-H Areas, 2001

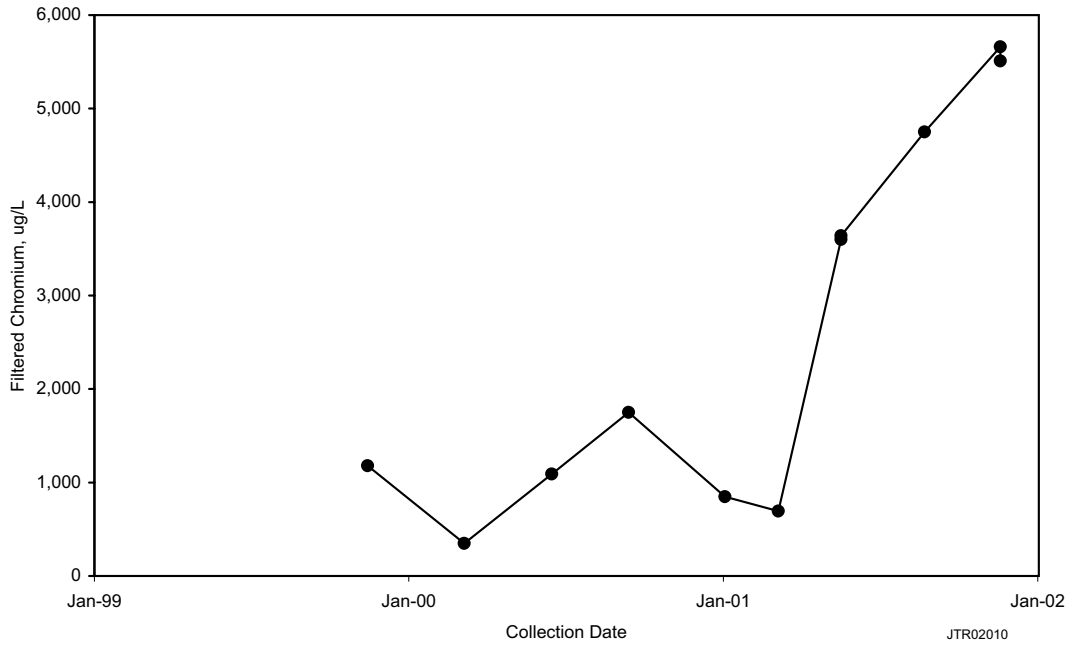

Figure 6.2.19. Filtered Chromium Concentrations in Well 199-D5-39 in the Southwestern 100-D Area, 1999 through 2001

1,332 μg/L adjacent to the treatment basins. Chromium concentrations in this plume have generally been rising.

A much wider area of chromium contamination is found in vicinity of the former 116-K-2 liquid waste disposal trench to the northeast. The maximum concentration in this area was 155 μg/L in 2001.

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 1301-N Liquid Waste Disposal Facility. The maximum chromium concentration in 2001 was 173 μg/L. Chromium was disposed to the 1301-N 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 one well on the southern boundary of A and AX tank farms. The maximum concentration detected in samples collected from this well in 2001 was 1,640 μg/L. Elevated metal (chromium, nickel, and manganese) concentrations historically found at this well are related to corrosion of the well screen (PNNL-13404).

Chromium contamination has been found in small areas in the 200-West Area. Areas where concentrations exceeded the drinking water standard in 2001 include the T, TX, TY, and S-SX tank farms and near the Reduction Oxidation Plant. Filtered samples from a well east of TX and TY tank farms showed a maximum concentration of 287 μg/L, the highest filtered chromium concentration in the 200-West Area. Chromium concentrations have generally been increasing near the TX and TY tank farms. A small chromium plume in the vicinity of T tank farm showed a maximum chromium concentration of 225 μg/L in 2001. The 216-T-36 crib and pipes leading to the crib are suspected of being a source of the chromium contamination at T tank farm. Filtered chromium concentrations were detected at levels above the drinking water standard for the first time at the southern end of the S-SX tank farm in December 2000. The maximum chromium concentration was 138 μg/L in January 2001. However, chromium concentrations at S-SX tank farm fell to levels less than the drinking water standard by late 2001. Near the Reduction Oxidation Plant, chromium concentrations have shown an increasing trend since 1997 and increased to a level (161 μg/L) above the drinking water standard in 2001.

Chromium in Other Areas. Filtered chromium concentrations have consistently exceeded the drinking water standard south of the 200-East Area. This area was not sampled for filtered chromium in 2001 because the sampling frequency was changed from annual to every 3 years. The maximum concentration detected in

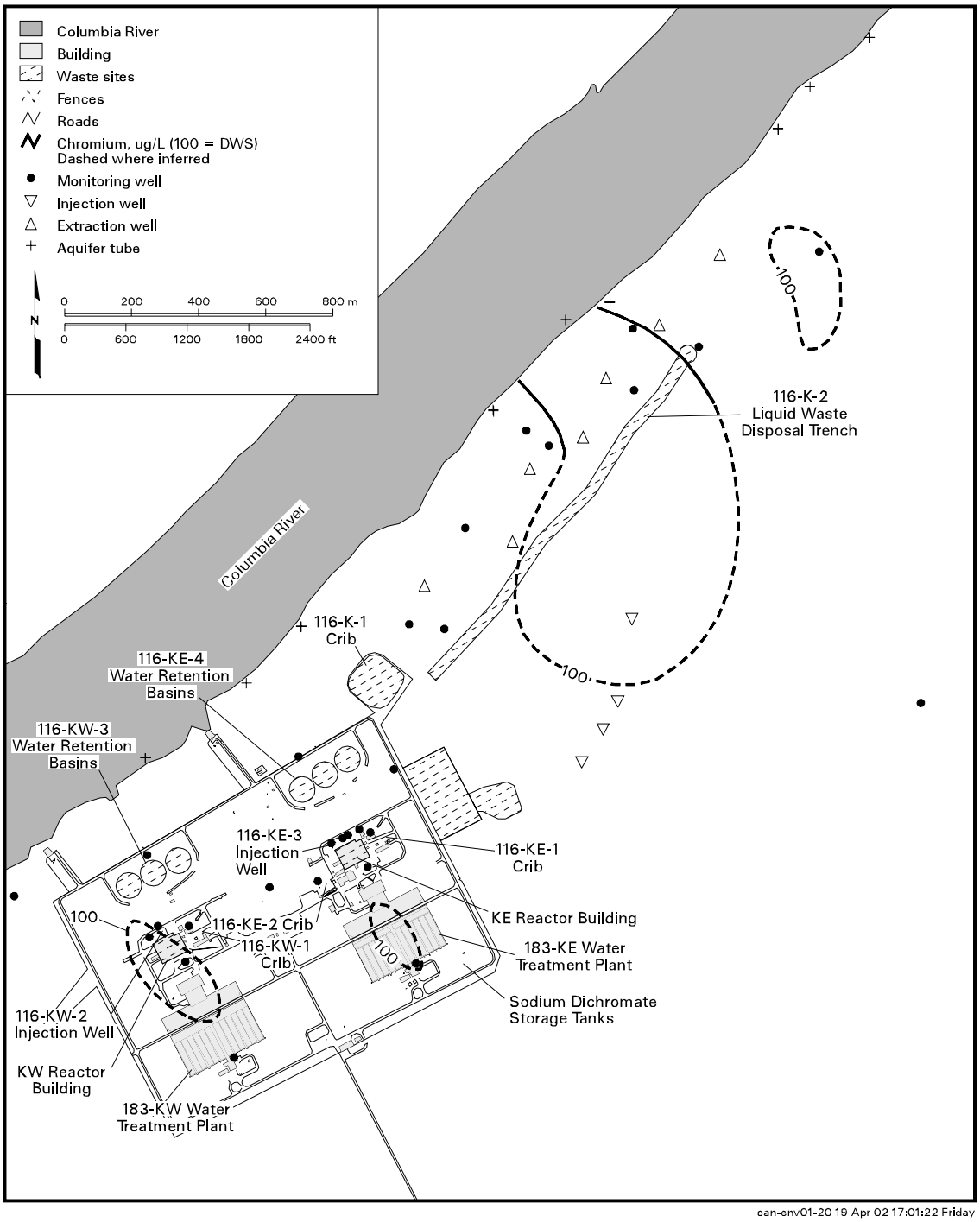

Figure 6.2.20. Average Filtered Chromium Concentrations in the 100-K Area, 2001

filtered samples in this area in 2000 was 201 μg/L. Filtered chromium will be sampled 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 the 5-μg/L drinking water standard 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 that is more than 11 square kilometers (4 square miles), extends past the 200-West Area boundary into the 600 Area. The maximum detected concentration in 2001 was 7,400 μg/L north of the Plutonium Finishing Plant in the 200-West Area.

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 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. Sources 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, with levels exceeding the drinking water standard by more than two orders of magnitude. The maximum concentration was 7,400 μg/L near the northern pump-and-treat extraction wells just north of the plant. Pump-and-treat operations, which began in 1994, have influenced the distribution of carbon tetrachloride. 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, which extends to the north reaching the TX-TY tank farms (see Section 2.3.11). In recent years, the center of the plume area within the 4,000-μg/L contour increased in size because of the effects of pumping from the extraction wells downgradient of this area. The plume center moved to the north and east toward the extraction wells in recent years, as evidenced by increased concentrations in several extraction and monitoring wells (BHI-01311). The extraction wells are located north and east of the Plutonium Finishing Plant. However, in 2001 carbon tetrachloride concentrations generally decreased in the center of the plume, as illustrated in Figure 6.2.22. This indicates that the center of the plume at high concentrations is beginning to decrease in size. Carbon tetrachloride concentrations were below the minimum detection limit in the vicinity of the injection wells southwest of the plant during 2001. Concentrations have declined because of injection of the treated water.

The carbon tetrachloride plume is divided into two major lobes, one in the northern half and one in the southern half of the 200-West Area. In the northern lobe, an area of increasing carbon tetrachloride concentrations has moved slowly beyond the northeastern 200-West Area boundary since 1997. This area is the greatest concern for transport of carbon tetrachloride from the 200-West Area. The highest concentration detected in this northern lobe in 2001 was 1,200 μg/L near the eastern boundary of the 200-West Area. In the southern lobe, carbon tetrachloride concentrations continue to increase near the S-SX tank farm to a maximum level of 190 μg/L during 2001.

Geostatistical models of the carbon tetrachloride concentrations for 2000 and 2001 were used to compare overall changes in the distribution of the plume. The model was developed in 2000 to increase the efficiency in the monitoring program by optimizing the number of samples. Comparison of the 2000 and 2001 models shows a decrease of ~500 to 1,500 μg/L in the center of the plume near the Plutonium Finishing Plant. The model comparison shows an increase of a few hundred to ~1,500 μg/L north of the Plutonium Finishing Plant. A large area of small increases (ranging up to ~500 μg/L) occurred in the eastern part of the 200-West Area and adjacent 600 Area and in the northwestern and southwestern part of the plume. These large areas of small increases indicate that the carbon tetrachloride plume continued to expand laterally between 2000 and 2001. An area of small decreases (ranging up to ~500 μg/L) in carbon tetrachloride concentrations is north of the 200-West Area near the State-Approved Land Disposal Site, where treated effluent that does not contain carbon tetrachloride is discharged to the ground and recharges the unconfined aquifer.

The extent of carbon tetrachloride contamination in deeper parts of the aquifer is uncertain because of the limited concentration data from depths below the water table. The limited amount of data indicates that the concentrations are highest at the top of the aquifer and decline with depth at most locations within the plume. Carbon tetrachloride contamination has been detected to depths greater than 60 meters (197 feet) below the water table. In recent years, carbon tetrachloride was detected at levels of 1,600 μg/L (1998) at 33 meters

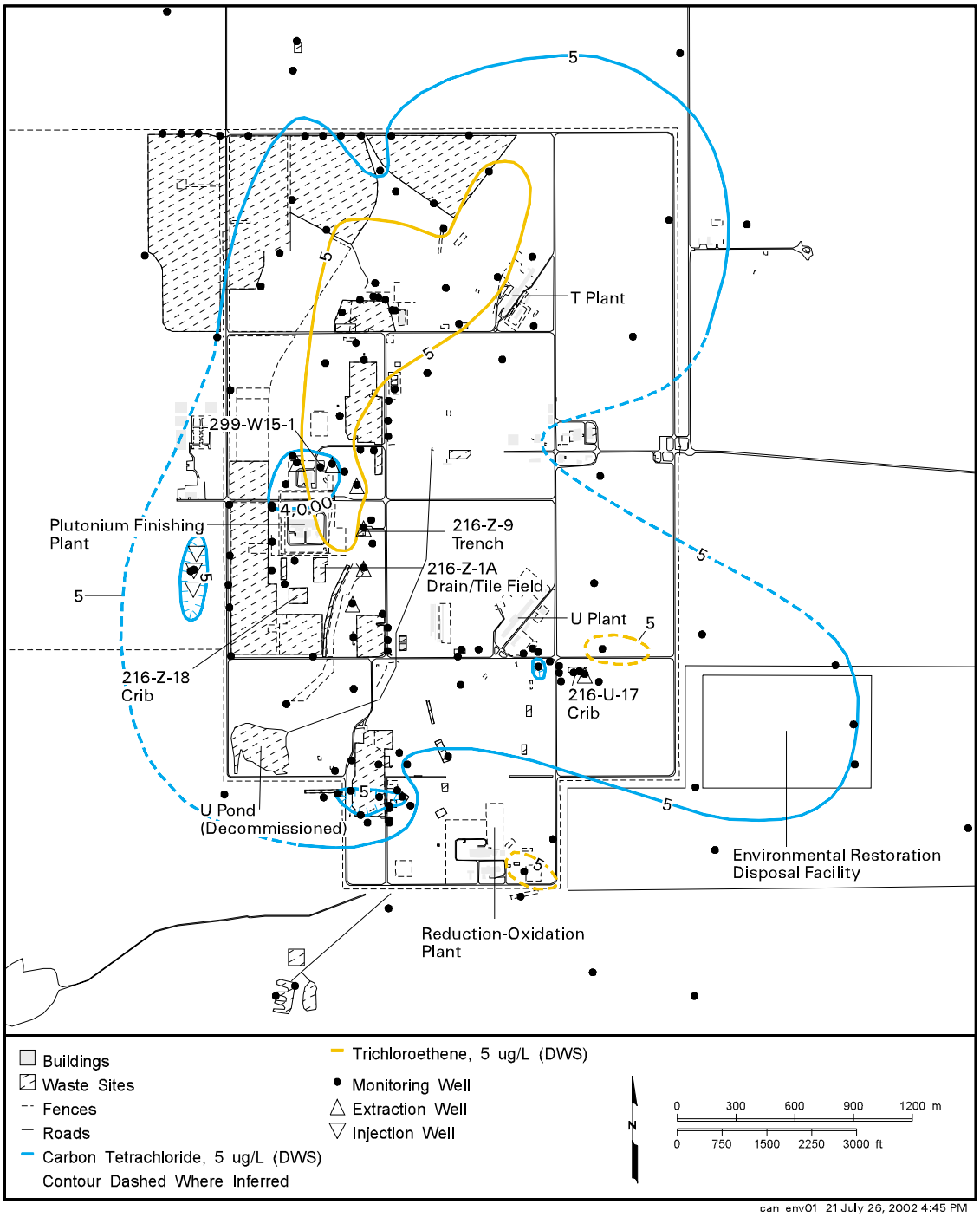

Figure 6.2.21. Average Chlorinated Hydrocarbon Concentrations in the Unconfined Aquifer in the 200-West Area, 2001

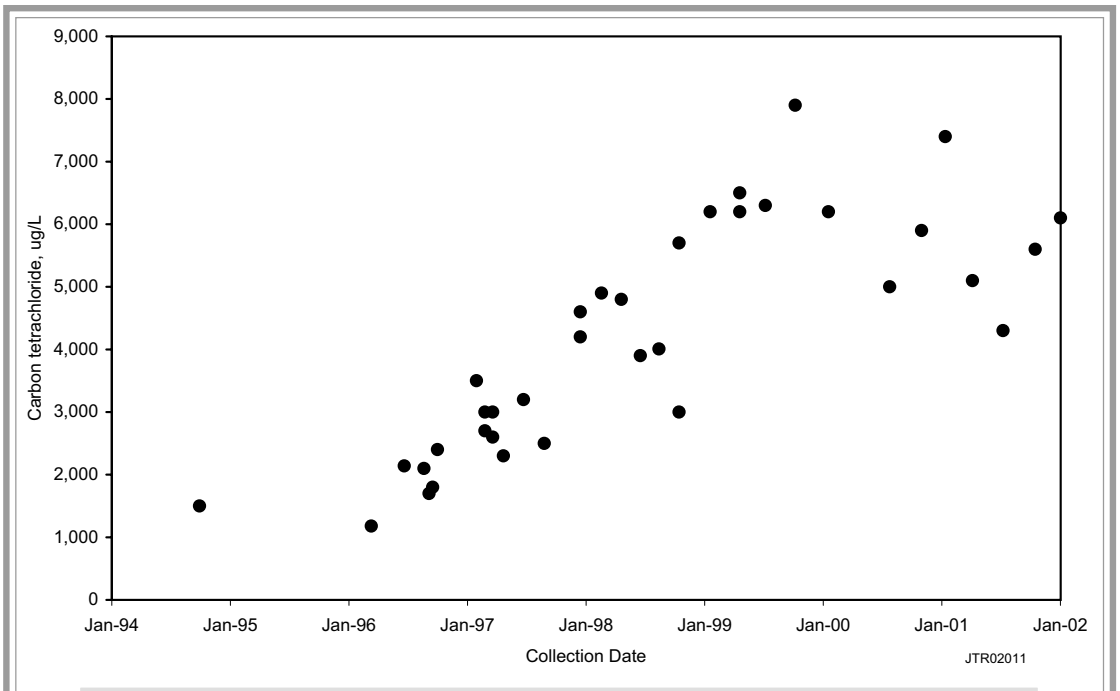

Figure 6.2.22. Carbon Tetrachloride Concentrations in Well 299-W15-1 near the Northern Extraction Wells in the 200-West Area, 1994 through 2001

(108 feet) below the water table near T tank farm, 590 µg/L (1998) at 68 meters (223 feet) below the water table near TX-TY tank farm, and 5.6 µg/L (1999) at 53 meters (174 feet) below the water table near S-SX tank farm.

Changes in groundwater flow since decommissioning U Pond may have influenced the plume configuration and the concentrations at particular locations. Another potential influence is the continued spreading of carbon tetrachloride above the water table, in either the liquid or the vapor phase. Free-phase, liquid, carbon tetrachloride above and possibly below the water table may provide a continuing source of contamination, in which case, lateral expansion of the carbon tetrachloride plume would 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 the vicinity of the Plutonium Finishing Plant, where the maximum level was 160 µg/L in early 2001. However, chloroform concentrations at this location dropped to levels less than the drinking water standard by late 2001. The drinking water standard for chloroform is 100 µg/L (total trihalomethanes), which is 20 times higher than that for carbon tetrachloride. The origin of chloroform is suspected to be a biodegradation product of carbon tetrachloride or an anaerobic degradation product associated with septic drain fields.

Trichloroethene. A commonly used organic solvent, trichloroethene has a drinking water standard of 5 µg/L. In 2001, trichloroethene was detected at levels greater than the drinking water standard in several wells in the 100, 200, and 600 Areas. The most widespread area of contamination occurred in the 200-West Area.

Trichloroethene in the 100 and 600 Areas. Trichloroethene was detected at levels greater than the drinking water standard in the southwestern corner of the 100-F Area and in the adjacent 600 Area. Trichloroethene concentrations in this area showed increases in the 100-F Area and a slowly declining trend in the adjacent 600 Area. The maximum concentration detected in the 100-F Area was 18 µg/L. 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 19 µg/L. Trichloroethene concentrations appear to be constant with time.

In 2001, trichloroethene concentrations decreased to levels less than the 5-µg/L drinking water standard near the DOE's inactive Horn Rapids Landfill in the southern part of the Hanford Site. This contamination degrades naturally and has an origin off the Hanford Site.

Trichloroethene in the 200 Areas. Trichloroethene was detected at levels greater than the drinking water standard in several parts of the 200-West Area (see Figure 6.2.21). The most significant area extends from the Plutonium Finishing Plant northeast to an area west of T Plant. The source of the contamination is presumably past disposal in these plant areas. The highest concentration was 21 µg/L northeast of the Plutonium Finishing Plant near the northern extraction wells for the carbon tetrachloride 200-ZP-1 pump-and-treat system. A smaller, isolated area of contamination occurs downgradient of the U Plant cribs, where the maximum concentration was 11 µg/L. 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 in 2001 was 9.4 µg/L.

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 the 70-µg/L drinking water standard. In 2001, a maximum concentration of 190 µg/L was measured in this well. The source of the cis-1,2-dichloroethene is the inactive 316-5 process trenches.

Cyanide. Waste fractionation activities 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, thus, normally 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.

The highest cyanide levels 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 showed concentrations above the drinking water standard in 2001. The maximum concentration near the cribs was 423 µg/L. Cyanide levels near the cribs generally decreased in 2001 along with associated technetium-99 and cobalt-60 after reaching maximum concentrations in 2000. 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.

Fluoride. At this time, fluoride has a primary drinking water standard of 4 mg/L and a secondary standard of 2 mg/L. Secondary standards are based primarily on aesthetic rather than health considerations. Fluoride was detected above the primary drinking water standard in two wells monitoring T tank farm in the 200-West Area in 2001. The maximum fluoride concentration was 4.9 mg/L 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.

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 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. 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 that are sampled annually to triennially. Most of these wells are located near the 200 Areas in the central part of the Hanford Site (see Figure 6.1.2). During 2001, eleven upper basalt-confined aquifer wells were sampled for chemical and radiological constituents. During 2001, most of the wells that represent the upper basalt-confined aquifer were sampled for tritium, iodine-129, and nitrate. These constituents are the most widespread in the overlying unconfined aquifer, are most mobile in groundwater, and provide an early warning of potential contamination in the upper basalt-confined aquifer. Groundwater samples from the upper basalt-confined aquifer were also analyzed for other anions besides nitrate, cations, gross alpha, gross beta,

gamma-emitters, strontium-90, and technetium-99. The distribution of sample results for selected constituents is shown in Figure 6.2.23.

The only constituent that showed levels exceeding the drinking water standard was technetium-99 in one well in the northern part of the 200-East Area. Technetium-99 was at a level of 1,120 pCi/L (41 Bq/L) during 2001. Technetium-99 levels in this well have decreased very slowly. Contamination in this well is attributed to migration of high-salt waste down the borehole during construction when it was open to both the unconfined and confined aquifers (RHO-RE-ST-12 P). Tritium and nitrate were at levels less than their respective drinking water standards in 2001 and iodine-129 was not detected in samples from the upper basalt-confined aquifer. The distribution of contaminants in the upper basalt-confined aquifer is discussed more thoroughly in the fiscal year 2001 annual groundwater report (PNNL-13788).

Aquifers confined below the uppermost basalt layers are affected much less from Hanford Site contamination than the unconfined aquifer system within the overlying sediment. The contamination found in the basalt-confined aquifers may be attributed to several factors. These factors include areas where the confining layers of basalt have been eroded away, areas where past disposal of large amounts of water resulted in downward gradients, and areas where wells penetrating to the confined aquifers provided pathways for contaminant migration. These factors produced intercommunication between the aquifers, meaning they permitted the flow of groundwater from the unconfined aquifer to the underlying confined aquifer, thereby increasing the potential to spread contamination.

Intercommunication between the unconfined and basalt-confined aquifers in vicinity of the northern part of the 200-East Area has been identified previously in RHO-BWI-ST-5 and RHO-RE-ST-12 P. Several confined aquifer wells north and east of the 200-East Area that show evidence of intercommunication with the overlying unconfined aquifer were identified in PNL-10817. Intercommunication between the unconfined and confined aquifers in this area has been attributed to erosion of the upper Saddle Mountains Basalt and a downward vertical gradient that resulted from groundwater mounding associated with past waste disposal. Since the groundwater mound diminished, the downward vertical gradient has decreased in recent years and was negligible in 2001.

Groundwater data indicate that a downward hydraulic gradient from the unconfined to the confined aquifers also occurs in the western portion of the Hanford Site and in regions north and east of the Columbia River. However, groundwater chemical and radiological data from most confined aquifer wells in these other areas do not exhibit evidence of contamination.

6.2.4 Groundwater Flow

The water-table elevation contours shown in Figure 6.2.24 indicate the direction of groundwater flow and the magnitude of the hydraulic gradient in the unconfined aquifer. 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 transmissivity 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. Figure 6.2.25 shows the generalized distribution of transmissivity as determined from aquifer pumping tests and groundwater flow model calibration. 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 per year (4 inches per year) in areas where soil is coarse textured and bare of vegetation.

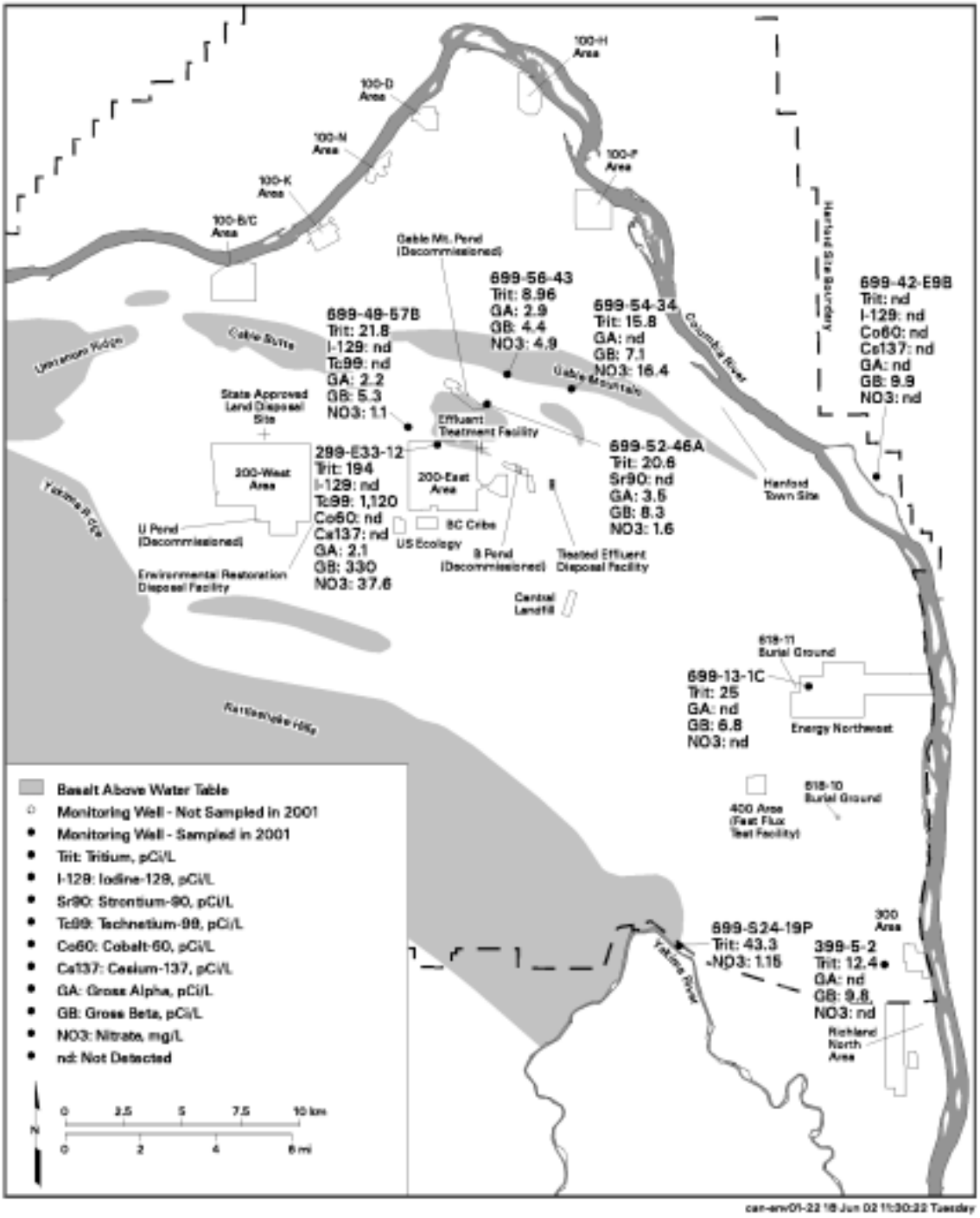

Figure 6.2.23. Results of Tritium and Other Constituents Sampled in Confined Aquifer Wells, 2001

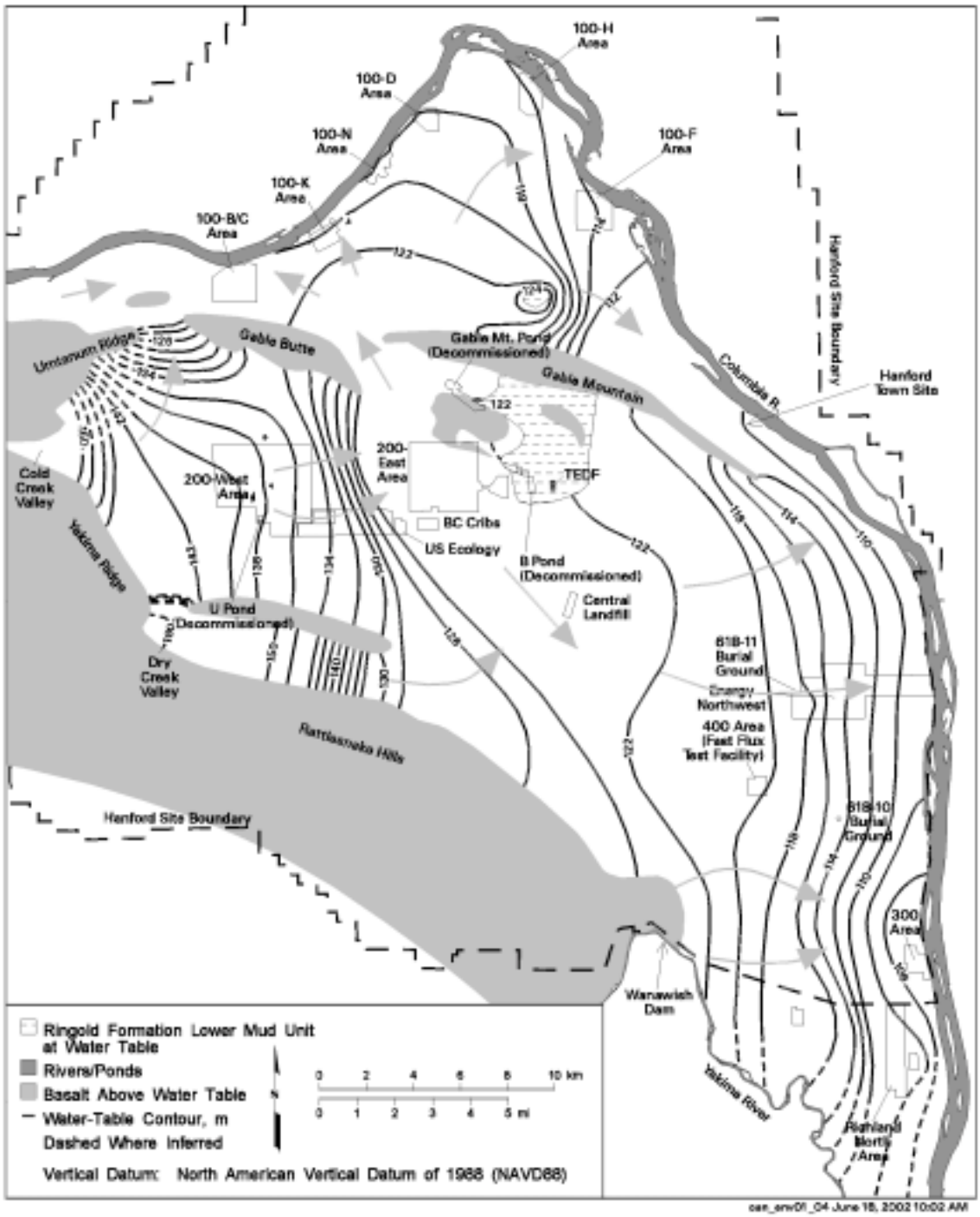

Figure 6.2.24. Water-Table Elevations for the Unconfined Aquifer at the Hanford Site, March 2001

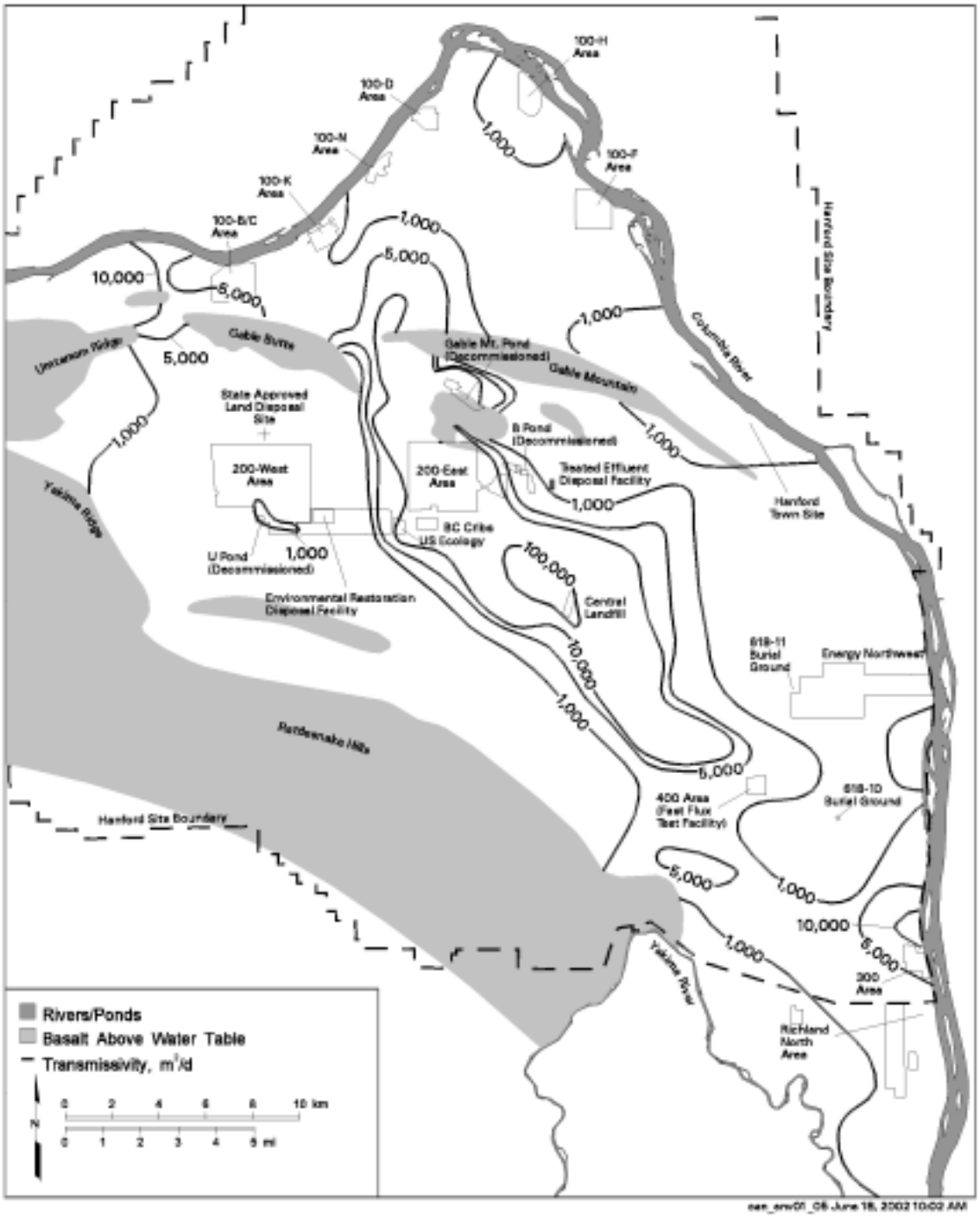

Figure 6.2.25. Transmissivity Distribution in the Unconfined Aquifer

Large-scale, artificial recharge to the unconfined aquifer occurred because of past liquid waste disposal in the operating areas and offsite agricultural irrigation to the west and south. 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 has been significantly reduced and, in response, the water table subsequently declined over most of the site. The water table continues to decline, as illustrated by Figure 6.2.26. The water table declined up to 0.25 meter (0.8 foot) over most of the site between 2000 and 2001. The largest decline in the water table was 1 meter (3.28 feet) near a pump-and-treat system in the 100-K Area. A result of the declining water table is that 32 wells have gone dry in the 200 Areas since 1997.

The decline in the water table has altered the flow pattern of the unconfined aquifer, 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 (see 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 216-U-10 pond (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 (see Figure 6.2.26). 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. The water-table elevation near B Pond increased to a maximum before 1990 and decreased because of reduced discharge. 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.

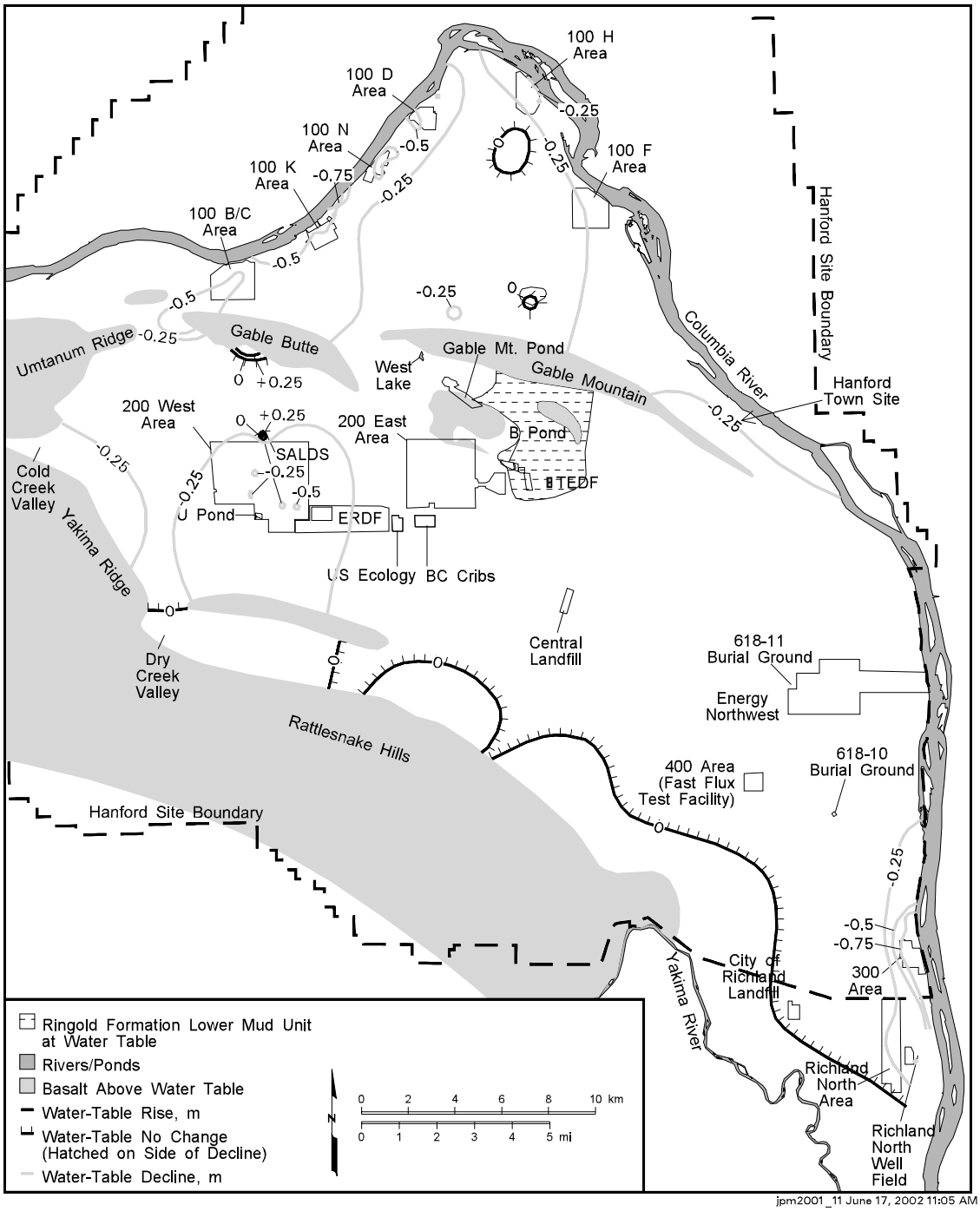

Figure 6.2.26. Change in Water-Table Elevations between 2000 and 2001