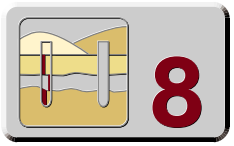


Groundwater Investigation and Remediation

Richard G. Blake
Michael J. Taffet

Introduction

During 2002, groundwater investigations and remediations under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) continued at both the Livermore site and Site 300. LLNL regularly samples and analyzes groundwater from areas of known or suspected contamination. Portions of the two sites that contain soil or groundwater with concentrations of chemicals of concern are actively investigated to determine the magnitude of the contamination and its source. Remediation strategies are developed and evaluated in preparation for a CERCLA removal action or through the feasibility study process. An approved remedy for each study area is developed in consultation with the regulatory agencies and the community.

This chapter reviews the distribution of contaminants in groundwater and the progress LLNL has made in removing contaminants from groundwater and from the unsaturated zone (soil vapor) at the Livermore site and Site 300. The sites are similar in that the contamination is, for the most part, confined to the site. The sites differ in that Site 300, with an area of 30.3 km^2 (11.8 mi^2), is much larger than the Livermore site and has been divided into eight operable units based on the nature and extent of contamination, and topographic and hydrologic considerations. The Livermore site at 3.08 km^2 (1.3 m^2) is effectively one operable unit.

Livermore Site Ground Water Project

Physiographic Setting

The general topography of the Livermore site is described in Chapter 1. The Livermore Valley groundwater system is a sequence of semiconfined aquifers in which groundwater moves downslope from the valley uplands toward the east-west axis of the valley. It then flows generally westward toward the southwest portion of the basin. From there, groundwater has historically flowed south into the Sunol Valley Groundwater Basin.

The largest quantities of groundwater are pumped from the central and western portions of the Livermore Valley, where the valley fill sediment is thickest. These sediments make up two aquifers: the Livermore Formation and its overlying alluvium.

The Livermore Formation averages about 1000 m in thickness and occupies an area of approximately 250 km^2. The alluvium, which is about 100 m thick, is the principal water-producing formation within the valley.

Hydrogeology of the Livermore Site

Sediment types at the Livermore site are grouped into four categories—clay, silt, sand, and gravel—based on the dominant particle type. Groundwater flow beneath the site is primarily in alluvial sand bodies, gravel lenses, and channels, bounded by the less permeable clay and silt.

The alluvial sediments have been mapped into nine hydrostratigraphic units (HSUs) beneath the Livermore site, using data collected over the years. HSUs can be defined as sedimentary sequences whose permeable layers show evidence of hydraulic connection. The HSUs of concern beneath the Livermore site are the Quaternary alluvial deposits of the upper member of the Livermore Formation (see **Figure 8-1**). HSUs 1B, 2, 3A, 3B, 4, and 5 contain contaminants that are primarily solvents (Blake et al. 1995; Hoffman et al. 1998).

Background

Initial releases of hazardous materials occurred at the Livermore site in the mid-to-late 1940s when the site was the Livermore Naval Air Station (Thorpe et al. 1990). There is also evidence that localized spills, leaking tanks and impoundments, and landfills contributed volatile organic compounds (VOCs), fuel hydrocarbons (FHCs), lead, chromium, and tritium to the groundwater and unsaturated sediment in the post-Navy era. The Livermore site was placed on the U.S. Environmental Protection Agency (EPA) National Priorities List in 1987.

A screening of all environmental media showed that groundwater and unsaturated sediment are the only media that require remediation (Thorpe et al. 1990). The identified compounds that currently exist in groundwater at various locations beneath the site at concentrations above drinking water standards, or maximum contaminant levels (MCLs), are trichloroethylene (TCE), perchloroethylene (PCE), 1,1-dichloroethylene (1,1-DCE), chloroform, 1, 2-dichloroethylene (1,2-DCE), 1,1-dichloroethane (1,1-DCA), 1,2-dichloroethane (1,2-DCA), trichlorotrifluoroethane (Freon 113), trichlorofluoromethane (Freon 11), and carbon tetrachloride.

Remedial Activities

In 2002, the Livermore site Ground Water Project (GWP) treated more than 939 million liters of groundwater and removed approximately 146 kg of VOCs (**Table 8-1**). The GWP also brought new treatment facilities on line, installed wells, conducted hydraulic tests, developed groundwater models, published required documents, and maintained close contact with regulatory agencies and the community.

LLNL removes contaminants from groundwater and from the unsaturated zone (soil vapor) at the Livermore site through a system of 28 treatment facilities located throughout the 6 HSUs containing contaminants of concern. Extraction wells are used to extract groundwater for each facility, which is then treated to remove VOCs.

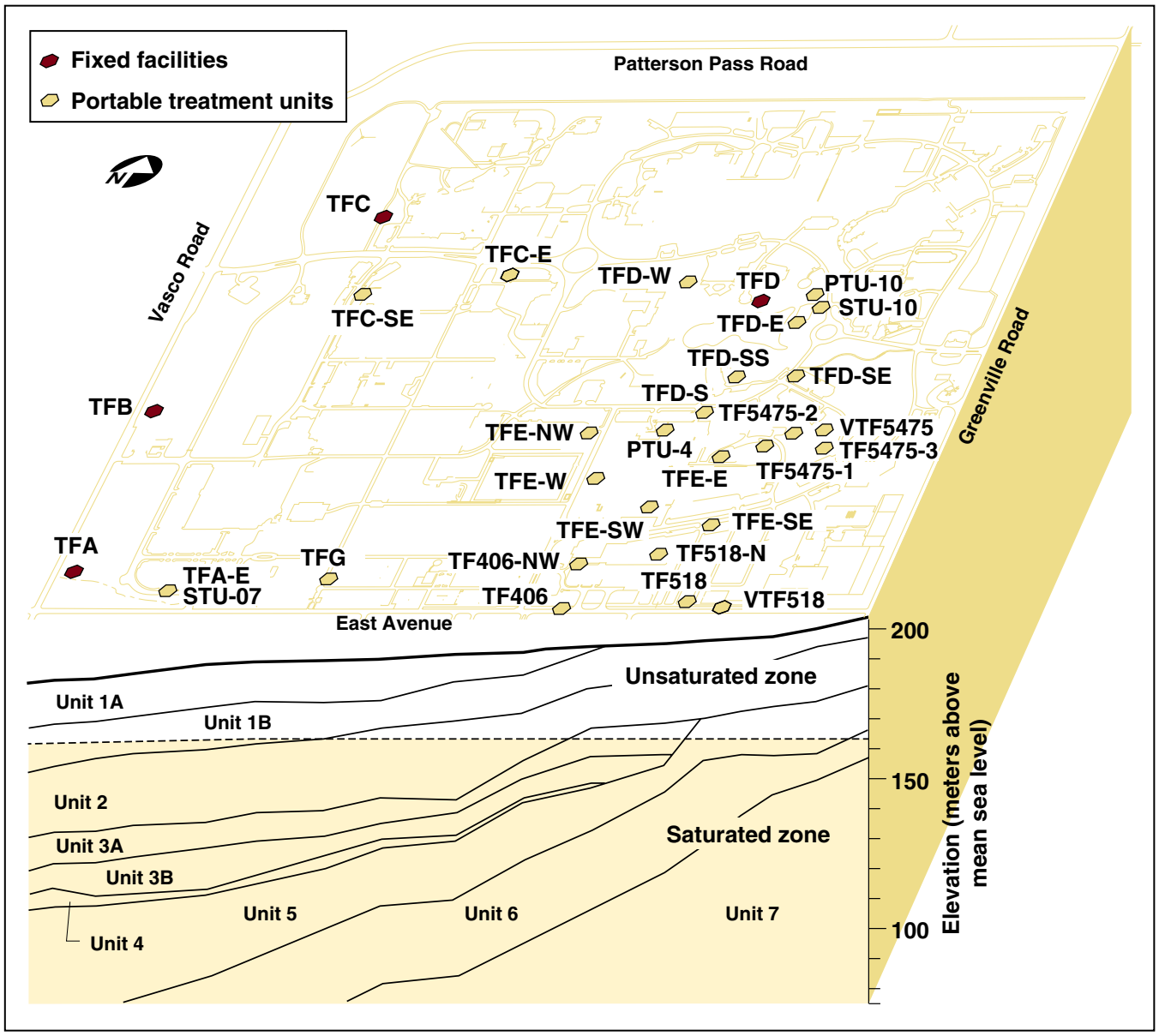


Figure 8-1. Map and cross section of the Livermore site showing hydrostratigraphic units and the locations of the treatment facilities

Treatment usually consists of removing VOCs with an air-stripping system, after which any VOCs present in the stripper's effluent air are removed with granular activated carbon filters. Treatment methods are noted in the following discussion of treatment facilities. Table 8-2 lists the extraction wells by treatment facility, according to the HSU in which they are screened, and the total flow rate for each treatment area.

Table 8-1. Volatile organic compounds removed from groundwater and soil at the Livermore site

Treatment facility[a]	Startup date	2002		Cumulative total	
		Water treated (ML)[b]	VOCs removed (kg)	Water treated (ML)	VOCs removed (kg)
TFA	9/89	251.4	5.7	3658	154
TFB	10/90	130.2	6.1	787	54.2
TFC	10/93	107.9	7.1	595	53.9
TFD	9/94	281.3	68.4	1505	500
TFE	11/96	110.5	17.5	544	139
TFG	4/96	12.1	0.7	70.4	3.7
TF406	8/96	40.5	1.0	211	7.7
TF518	1/98	4.9	0.6	37.1	4.3
TF5475	9/98	0.72	0.7	2.3	4.8
Total[c]		939	108	7410	921
		Soil vapor treated ($10^3 m^3$)	VOCs removed (kg)	Soil vapor treated ($10^3 m^3$)	VOCs removed (kg)
VTF518[d]	9/95	0	0	425	153
VTF5475[d]	1/99	143.5	37.7	659	306
Total[c]		144	38	1084	459

a Includes fixed and portable units

b ML = million liters

c Totals rounded to nearest whole number

d Vapor treatment facility

Of the 28 treatment facilities in operation in 2002, 27 are groundwater treatment facilities and 1 is a vapor treatment facility (VTF). A total of 82 groundwater extraction wells operated at 27 separate locations at an average flow rate of 1787 liters per minute (L/min). One vapor extraction well operated at an average flow rate of 0.27 m^3/min.

Since operations began in 1989, approximately 7410 million liters of groundwater and approximately 1.1 million m^3 of vapor have been treated, and more than 1380 kg of VOCs have been removed. **Table 8-1** shows both the 2002 totals and the cumulative totals of groundwater and soil vapor treated at the facilities and the estimated VOCs removed from the subsurface. A graph of VOC mass removal at the Livermore site since 1989 is presented in **Figure 8-2**. Concentrations of total VOCs in the third quarter 2002 are depicted as isoconcentration maps in the six HSUs in **Figures 8-3** through **8-8.** The VOC plumes in HSUs 1B, 2, 3A, 3B, 4, and 5 continue to be hydraulically controlled based on trends in groundwater chemistry, capture zone analysis, and the total VOC isoconcentration maps for each HSU (**Figures 8-3** through **8-8**).

The new wells installed in 2002 are shown in **Table 8-3** by treatment facility area. Well construction details, well closure data, and results of hydraulic tests are provided in the *LLNL Ground Water Project 2002 Annual Report* (Dibley et al. 2003).

Table 8-2. 2002 summary of treatment facilities, associated extraction locations and wells, and extraction rates

Treatment facility area	Hydrostratigraphic Unit	Extraction wells	Average extraction rate (L/min) [a]
TFA	HSU 1B	W-262, W-254, W-408, W-520, W-601, W-602, W-1001, W-1004	478.2
	HSU 1B/2	W-415	
	HSU 2	W-109, W-457, W-518, W-522, W-603, W-605, W-609, W-614, W-714, W-903, W-904, W-1009	
	HSU 3A	W-712	
TFB	HSU 1B	W-610, W-620, W-704	247.8
	HSU 2	W-357, W-621, W-655, W-1423	
TFC	HSU 1B	W-368, W-701, W-1015, W-1102, W-1103, W-1104, W-1116, W-1213	205.3
	HSU 2	W-413	
TFD	HSU 2	W-1215, W-1216, W-1303, W-1306, W-1308, W-1510, W-1602	535.1
	HSU 2/3A	W-906	
	HSU 3A/3B	W-1208, W-1301, W-1504, W-1550, W-1551, W-1552, W-1601, W-1603, W-1651, W-1654	
	HSU 4	W-314, W-351, W-1206, W-1307, W-1503, W-1523	
	HSU 5	W-907	
TFE	HSU 2	W-305, W-1109, W-1409, W-1518	210.3
	HSU 3A/3B	W-292, W-1422, W-1522	
	HSU 4	W-1211, W-1418, W-1520	
	HSU 5	W-359, W-566	
TF406	HSU 3A	W-1801	77.1
	HSU 5	W-1310	
TFG	HSU 1B/2	W-1111	23.0
TF518	HSU 4	W-1410	9.4
TF5475	HSU 2	W-1415	0.72
	HSU 3A	W-1302, W-1606, W-1608	
	HSU 5	W-1610	
VTF5475		SVI-ETS-504, W-1608	0.27 (scmm)[b]

a L/min= Liters per minute

b scmm = Standard cubic meters per minute

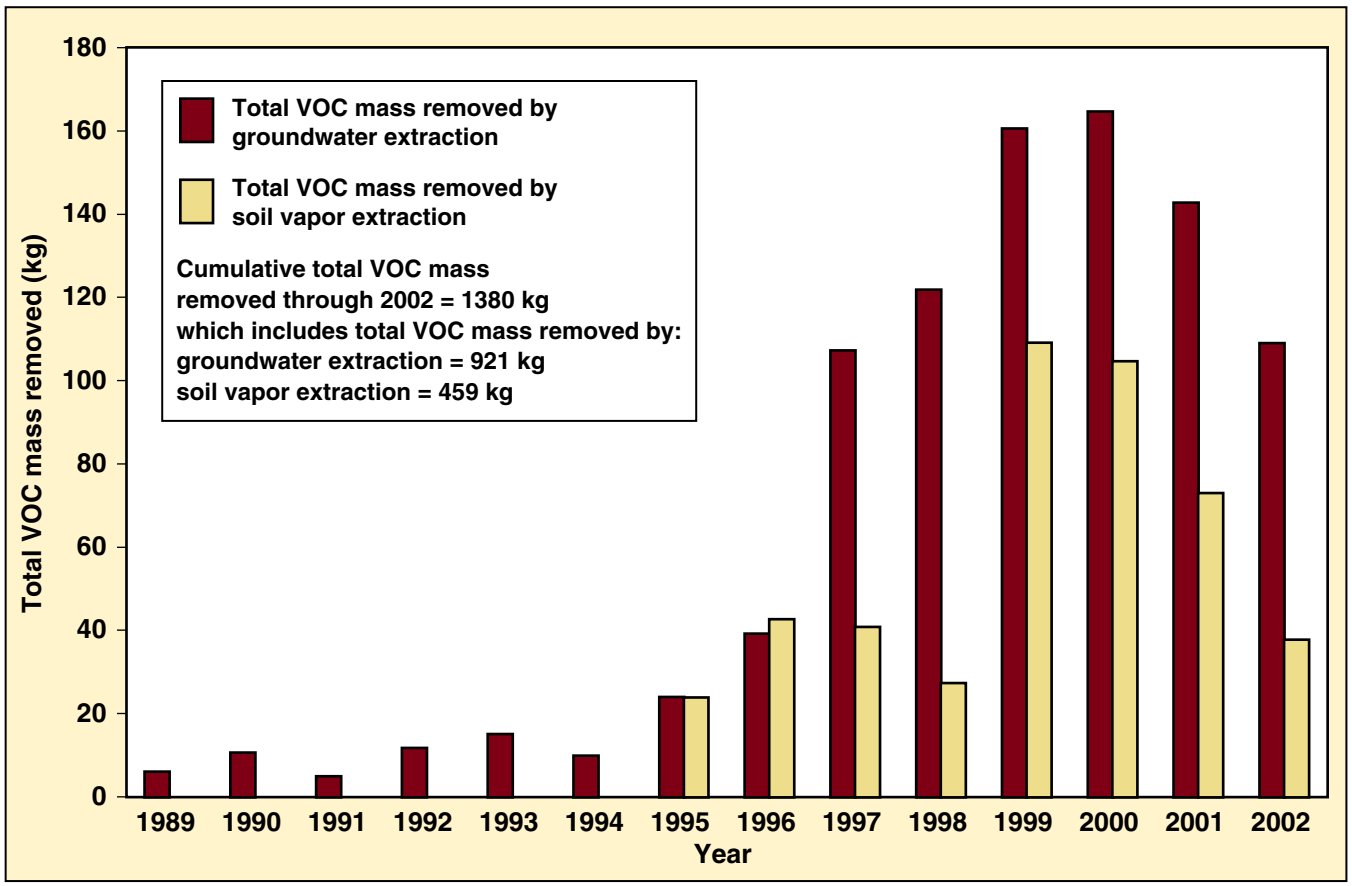


Figure 8-2. Total VOC mass removed from the subsurface of the Livermore site, 1989–2002

Treatment Facility A

Treatment Facility A (TFA) is a fixed facility located in the southwestern quadrant of the Livermore site near Vasco Road and East Avenue (**Figure 8-1**). Groundwater from HSUs 1B, 2, and 3A is treated using the large-capacity air-stripping system installed in June 1997. VOCs are stripped from the groundwater, and the effluent air from the stripper is passed through granular activated carbon filters to remove VOCs. The treated effluent air is then vented to the atmosphere. Treated groundwater from TFA is discharged to the Recharge Basin, located about 600 m southeast of TFA on Department of Energy (DOE) property administered by Sandia National Laboratories/California (Sandia/California). TFA has not exceeded the 5 parts per billion (ppb) total VOC discharge limit since the large capacity air-stripping system was installed in 1997. Solar treatment unit TFA East (TFA-E) is located east of TFA and removes VOCs in groundwater using granular activated carbon. TFA facilities were in compliance through 2002.

In 2002, wells at TFA and TFA-E pumped at a combined flow rate of about 478 L/min and the facilities treated 251 million liters of groundwater containing an estimated 5.7 kg of VOCs.

One new monitoring well (W-1805) was installed in the TFA area in 2002 (**Table 8-3**).

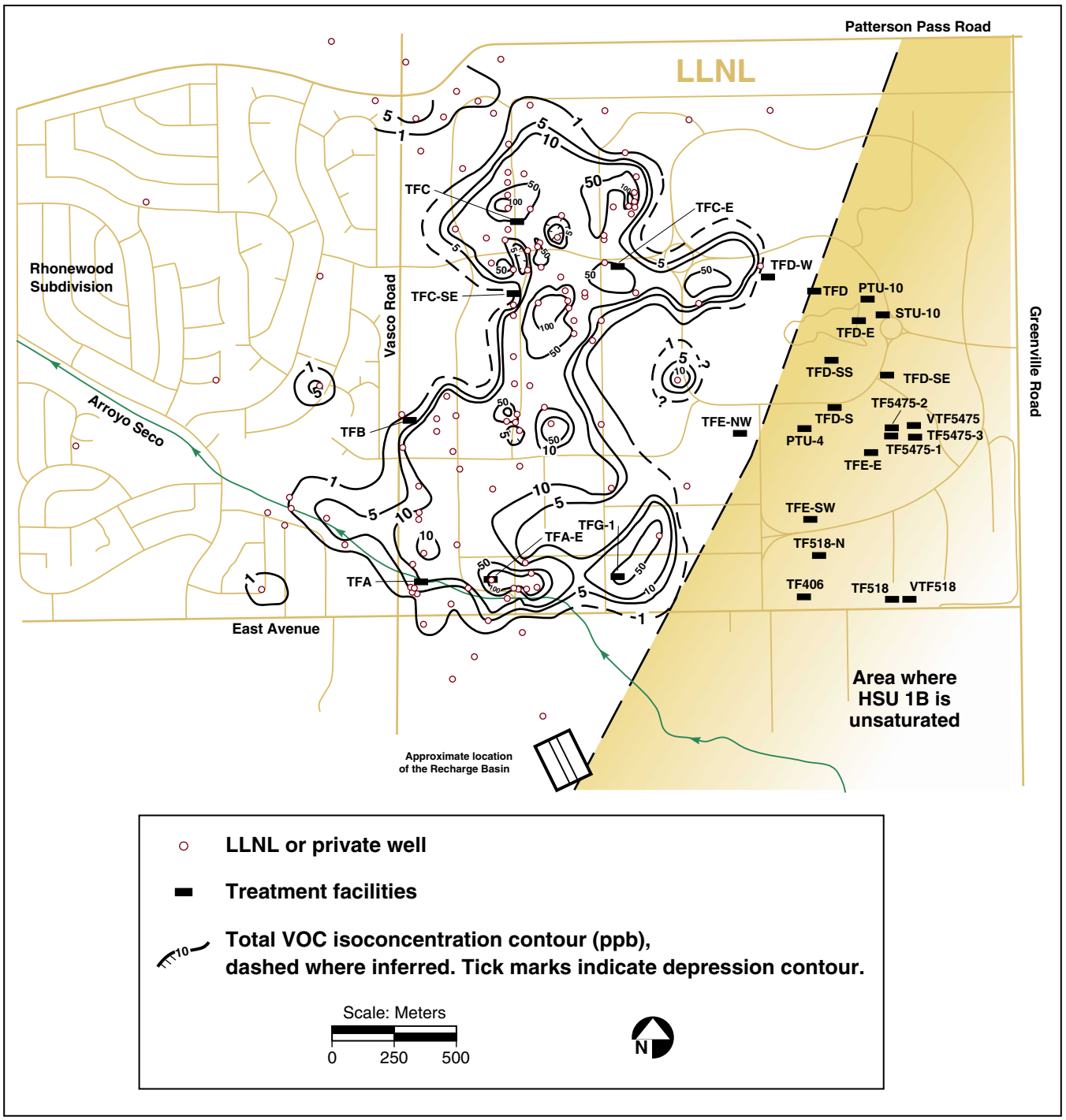


Figure 8-3. Isoconcentration contour map of total VOCs within HSU 1B (3rd quarter, 2002)

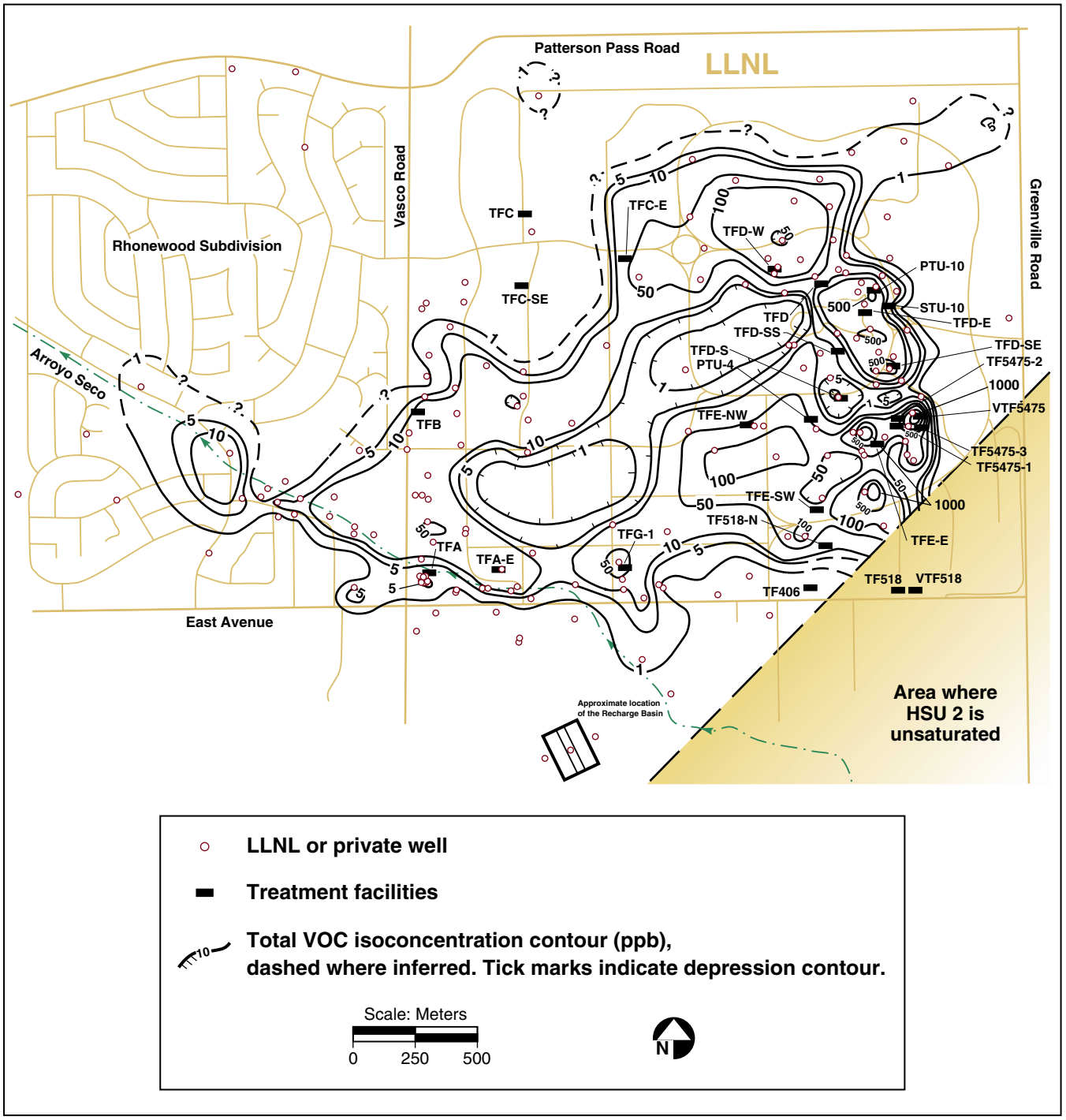


Figure 8-4. Isoconcentration contour map of total VOCs within HSU 2 (3rd quarter, 2002)

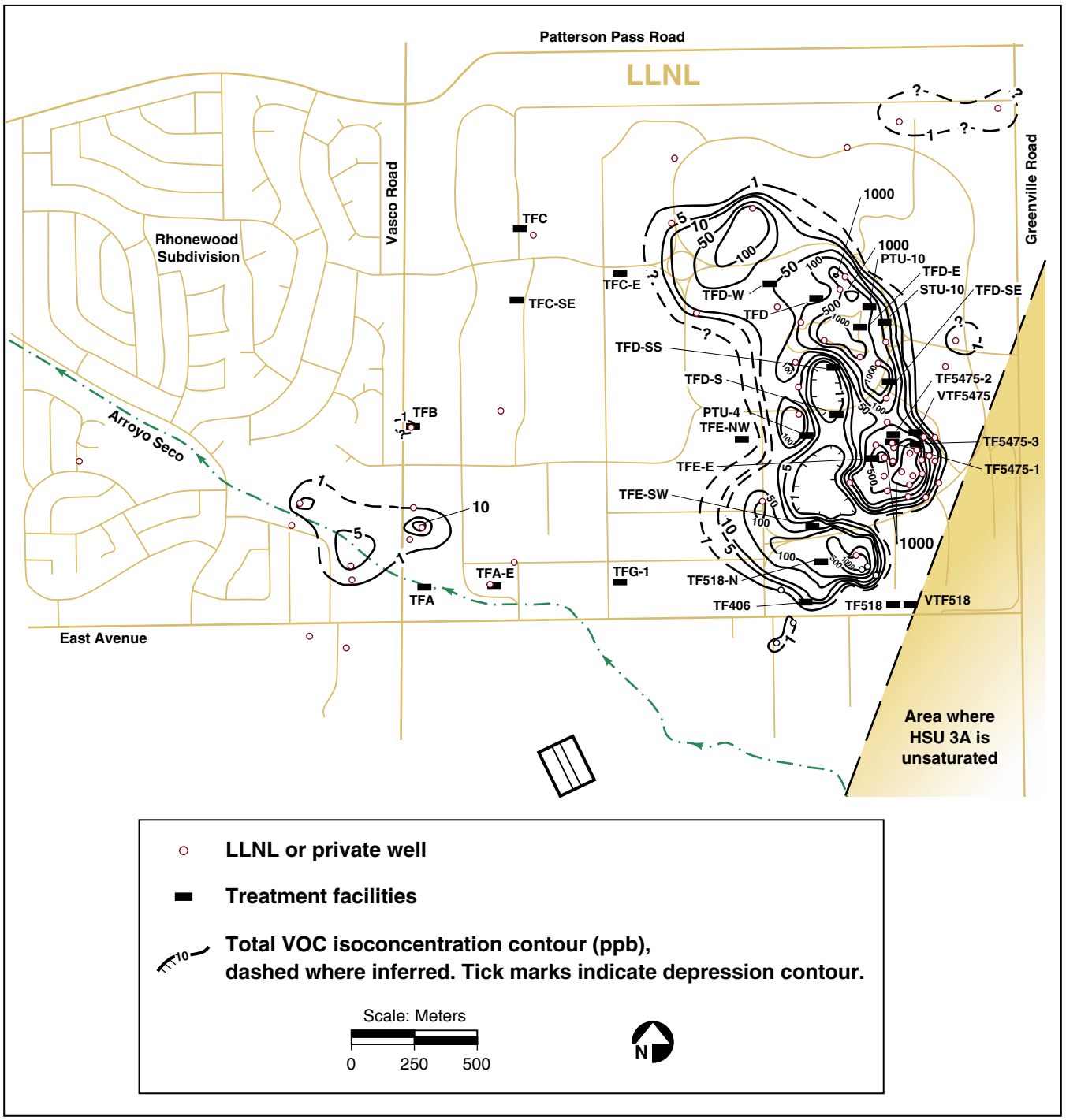


Figure 8-5. Isoconcentration contour map of total VOCs within HSU 3A (3rd quarter, 2002)

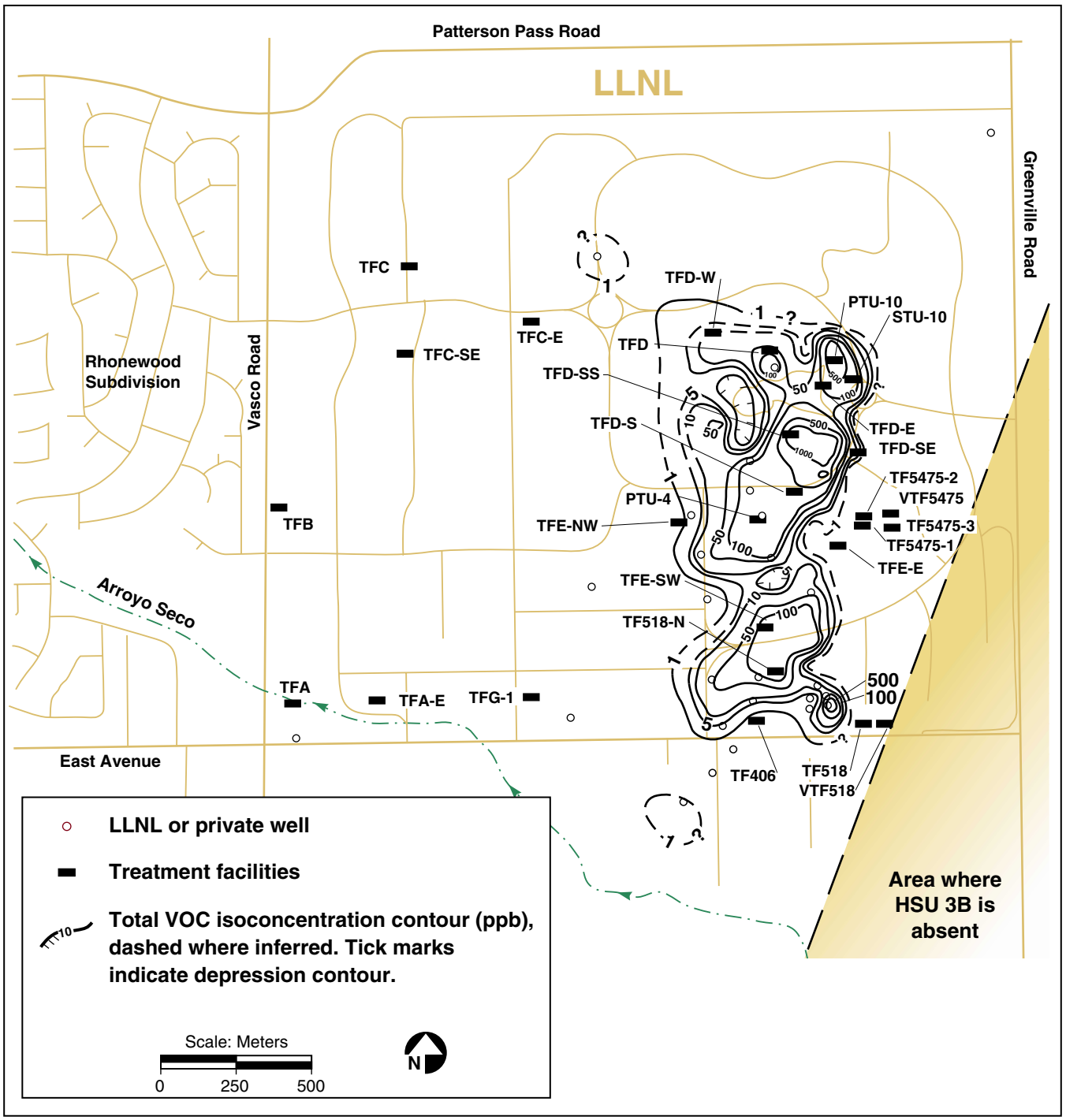


Figure 8-6. Isoconcentration contour map of total VOCs within HSU 3B (3rd quarter, 2002)

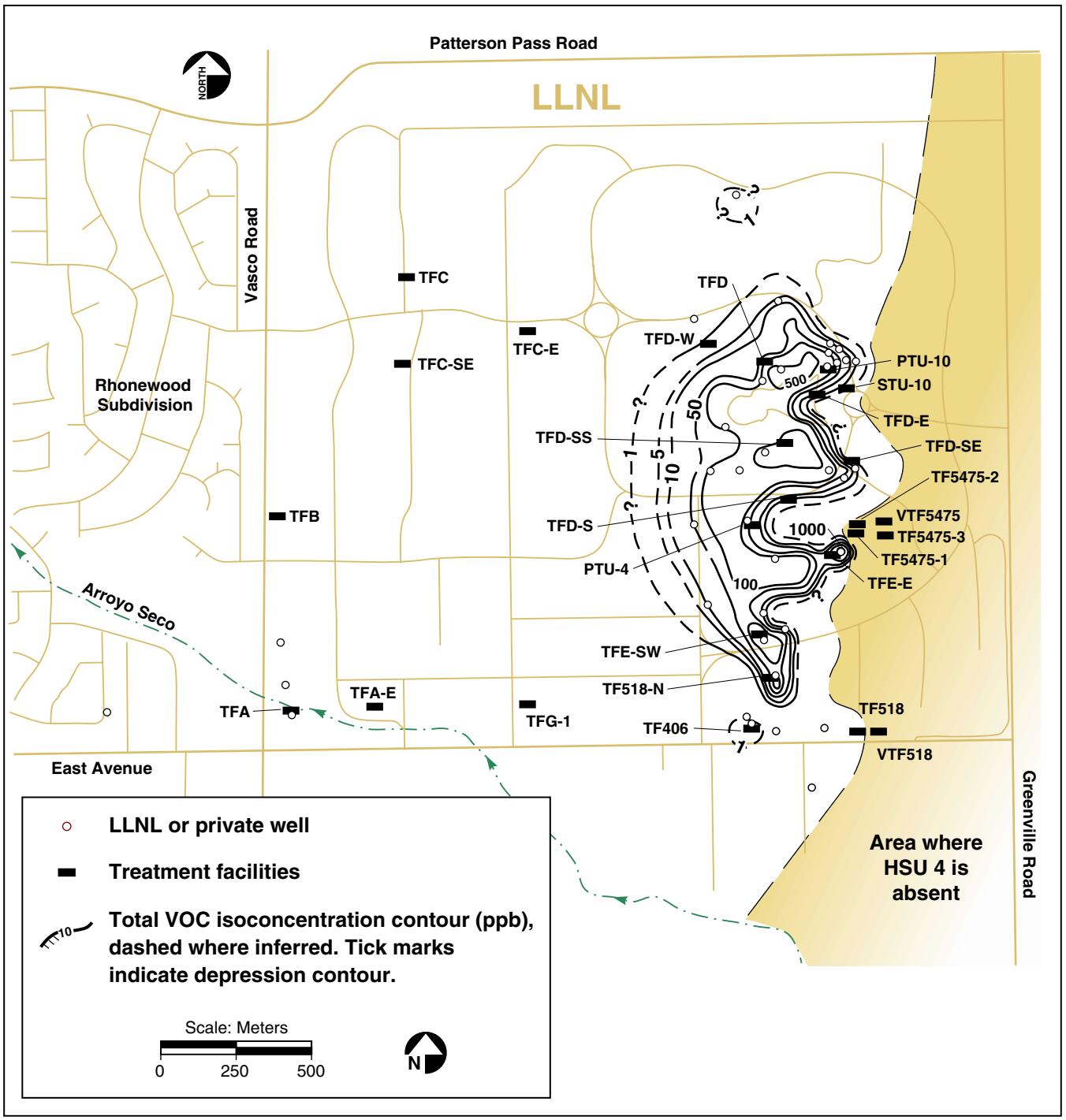


Figure 8-7. Isoconcentration contour map of total VOCs within HSU 4 (3rd quarter, 2002)

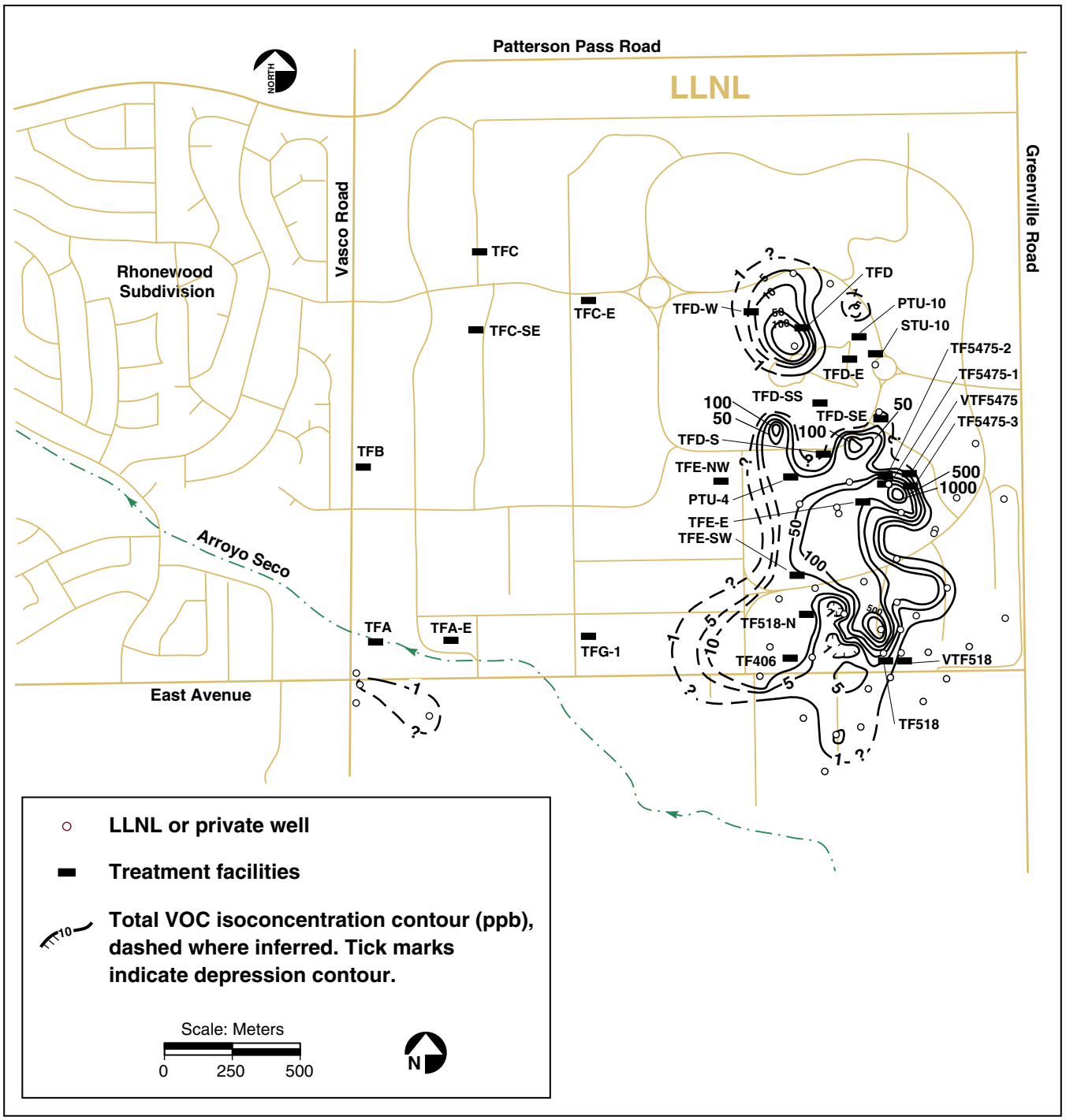


Figure 8-8. Isoconcentration contour map of total VOCs within HSU 5 (3rd quarter, 2002)

Table 8-3. Wells installed in 2002

Treatment facility area	Hydrostratigraphic unit	Monitoring/extraction well
TFA	HSU 1B	W-1805
TFB		None
TFC		None
TFD	HSU 2, 3A, 4	W-1802, W-1803, W-1804, W-1902
TFE	HSU 2	W-1903
TF406	HSU 3A	W-1801
TFG	HSU 1B, 2	W-1806, W-1807, W-1901
TF518		None
TF5475		None

Treatment Facility B

Treatment Facility B (TFB) is located in the west-central portion of the Livermore site (**Figure 8-1**). Groundwater from HSUs 1B and 2 is treated using the large-capacity air-stripping system installed in October 1998. This unit replaced an ultraviolet/hydrogen peroxide (UV/H_2O_2) system that had been in use since 1990. Groundwater is also treated for hexavalent chromium (chromium(VI)) in an ion-exchange unit, during December through March, based on the current San Francisco Bay Regional Water Quality Control Board (SFBRWQCB) discharge substantive requirements. Treated groundwater from TFB is discharged into the north-flowing drainage ditch parallel to Vasco Road that empties into Arroyo Las Positas to the north.

The seven extraction wells at TFB pumped at a combined flow rate of about 248 L/min, and TFB treated about 130 million liters of groundwater containing an estimated 6.1 kg of VOCs in 2002.

In 2002, TFB was in compliance, and no new wells were installed.

Treatment Facility C

Treatment Facility C (TFC) is located in the northwest quadrant of the Livermore site (**Figure 8-1**). Portable treatment unit (PTU) location TFC Southeast (TFC-SE) is located near the intersection of Avenue A and Sixth Street in the northwest quadrant of the Livermore site. A new treatment facility, TFC East (TFC-E), was constructed in 2002 and is located just west of the West Traffic Circle on the Livermore site.

TFC, TFC-E, and TFC-SE process VOCs in groundwater using air stripping. The effluent air from the stripper is treated with granular activated carbon prior to discharge to the atmosphere. Groundwater is treated for chromium(VI) in an ion-exchange unit during the wet season, December through March, in order to meet the current SFBRWQCB discharge substantive requirements. Treated groundwater from TFC is discharged into Arroyo Las Positas; from TFC-E and TFC-SE, groundwater is discharged into north-flowing drainage ditches that empty into Arroyo Las Positas to the north. The TFC effluent chromium(VI) concentration was below the wet season discharge limit of 22 ppb during 2002. All TFC treatment facilities were in compliance throughout 2002 (Dibley et al. 2003).

Wells in the TFC area pumped at a combined flow rate of about 205 L/min and the facilities treated about 108 million liters of groundwater containing an estimated 7.1 kg of VOCs. Since system start up in 1993, the combined TFC area facilities have treated more than 595 million liters of groundwater and removed about 54 kg of VOC mass from the subsurface.

No new wells were installed in the TFC area during 2002.

Treatment Facility D

The Treatment Facility D (TFD) area is located in the northeast quadrant of the Livermore site (see **Figure 8-1**). During 2002, eight treatment facilities operated in the TFD area. The TFD area extraction wells hydraulically control VOCs in HSUs 2, 3A, 3B, 4, and 5.

Fixed and portable facilities operating in the TFD area process VOCs in groundwater using air stripping, although STU10 uses granular activated carbon. The effluent air from the air strippers is treated with granular activated carbon prior to discharge to the atmosphere. Treated groundwater from TFD, TFD-Southshore (TFD-SS), and TFD-East (TFD-E) is discharged either into the Drainage Retention Basin (DRB), or into an underground pipeline downstream of the DRB weir, flowing northward to Arroyo Las Positas. Treated groundwater from TFD-West (TFD-W) is discharged into a nearby storm sewer that also empties into Arroyo Las Positas. Treated groundwater from TFD-South (TFD-S) and TFD-Southeast (TFD-SE) is discharged into drainage ditches, each flowing north into the DRB. PTU10 and STU10 are temporary facilities that are included in the TFD totals on **Table 8-1**. STU10 ceased operation in the TFD area in 2002.

Electroosmosis was tested from September 2000 to February 2001 to evaluate its ability to help remove VOCs from fine-grained sediments in a source area near the Helipad in the TFD area. Although no new electroosmosis tests were conducted in the TFD area in 2002, PTU10, located northeast of the DRB (**Figure 8-1**), continued to operate in 2002 by treating groundwater from wells W-1551, W-1552, W-1651, and W-1654 (all in HSU 3A/3B) to expedite VOC mass removal and source area cleanup.

The combined TFD facilities operated at an average flow rate of 535 L/min in 2002. During 2002, these units treated about 281 million liters of groundwater containing an estimated 68 kg of VOCs. Distal VOC plumes in the western TFD area should be hydraulically controlled now that TFC-E is operating.

Seven monitoring wells and two piezometers were sealed and abandoned in the TFD area in 2002. Monitor wells W-010A, W-211, W-360, W-414, W-1218, W-1220, and W-1221 were sealed due to construction of the Terascale Simulation Facility. Piezometers SIP-HPA-102 and SIP-HPA-103, located north of the DRB, were sealed due to the planned construction of a new cafeteria.

All TFD facilities were in compliance through 2002. Four new wells (W-1802, W-1803, W-1804, and W-1902) were installed in the TFD area during 2002 (**Table 8-3**) and a one-hour drawdown test was conducted on well W-1802 (Dibley et al. 2003).

Treatment Facility E

The Treatment Facility E (TFE) area is located in the southeastern quadrant of the Livermore site (**Figure 8-1**). Six treatment facilities, TFE East (TFE-E), TFE Northwest (TFE-NW), TFE Southwest (TFE-SW), TFE Southeast (TFE-SE), TFE West (TFE-W), and PTU4 operated in 2002 in the

TFE area (**Figure 8-1**). PTU4 is a portable hydraulic test unit that operates in the TFE area when not being used elsewhere for testing. PTU4 data are included in the TFE totals on **Table 8-1**. In 2002, TFE-E continued treating groundwater using a PTU. TFE-E is located in the east-central portion of the Livermore site and provides hydraulic containment of some portions of VOC plumes in HSUs 2, 4, and 5. TFE-NW treats groundwater from extraction wells in HSU 2 and HSU 4 and is located south of the Inner Loop Road, immediately west of Southgate Drive.

All TFE area treatment units treat VOCs using an air stripper. Before the effluent air is vented to the atmosphere, it is treated using granular activated carbon to remove VOCs. Treated groundwater from the facilities is discharged into a drainage ditch that flows north into the DRB or into a storm drain that flows north into Arroyo Las Positas.

In 2002, TFE wells pumped at a combined flow rate of about 210 L/min and TFE area facilities treated about 110 million liters of groundwater containing an estimated 17.5 kg of VOCs. Since system startup in 1996, the combined TFE facilities have treated more than 544 million liters of groundwater and removed about 139 kg of VOC mass from the subsurface.

All TFE treatment facilities were in compliance in 2002. One new well (W-1903) was installed in the TFE area during 2002 to extract both water and soil vapor.

Treatment Facility G

Treatment Facility G (TFG) is located in the south-central portion of the Livermore site (**Figure 8-1**) and treats groundwater from one well. Groundwater is treated with a granular activated carbon unit and is discharged to a storm drain located about 15 m north of TFG. The storm drain empties into Arroyo Seco.

During 2002, TFG operated at an average flow rate of 23 L/min, treating 12.1 million liters of groundwater containing an estimated 0.7 kg of VOCs (**Table 8-1**). Since system startup in 1996, TFG has treated over 70 million liters of groundwater and removed about 3.7 kg of VOC mass from the subsurface.

All TFG treatment facilities were in compliance in 2002. Two new extraction wells (W-1806 and W-1807) and one new monitoring well (W-1901) were installed in the TFG area in 2002.

Treatment Facility 406

TF406 is located in the south-central portion of the Livermore site, east of Southgate Drive near East Avenue (**Figure 8-1**). TF406 uses PTU5 equipped with an air stripper to treat VOCs in groundwater. Granular activated carbon removes VOCs from effluent air prior to discharge to the atmosphere. One new treatment facility, TF406-Northwest (TF406-NW), was added to the TF406 area in 2002. TF406-NW is a granular activated carbon treatment unit located east of Southgate Drive and south of South Outer Loop Road. Treated groundwater from TF406 facilities is discharged into the storm drain that flows north to Arroyo Las Positas.

Passive bioremediation continued in the TF406 area during 2002 to remediate FHCs in HSUs 3A and 3B. Active groundwater extraction and treatment for residual dissolved FHCs at former Treatment Facility F (TFF) was discontinued in 1996 with regulatory agency concurrence (SFBRWQCB 1996).

During 2002, TF406 operated at an average flow rate of 77 L/min, treating more than 40 million liters of groundwater containing an estimated 1.0 kg of VOCs (see **Table 8-1**). Since system startup in 1996, TF406 has treated about

211 million liters of groundwater and removed about 7.7 kg of VOC mass from the subsurface (see **Table 8-1**).

All TF406 facilities were in compliance through 2002. One new extraction well (W-1801) was installed in 2002.

Groundwater Treatment Facility 518

One groundwater treatment facility, TF518 North (TF518-N), operated in the TF518 area in 2002. TF518-N is located south of South Outer Loop Road, north of Building 411 (**Figure 8-1**). TF518-N employs a series of aqueous-phase granular activated carbon canisters to treat VOCs in groundwater. Treated groundwater from TF518-N is discharged into an underground storm drain that flows north and ultimately empties into Arroyo Las Positas.

During 2002, TF518-N operated at an average flow rate of 9.4 L/min, treating 4.9 million liters of groundwater containing an estimated 0.6 kg of VOCs. Since system startup in January 1998, TF518 has processed approximately 37 million liters of groundwater containing an estimated 4.3 kg of VOCs (**Table 8-1**). No new wells were installed and no hydraulic tests were conducted in the TF518 area in 2002. All TF518 facilities were in compliance in 2002.

Vapor Treatment Facility 518

Vapor treatment facility 518 (VTF518) is located north of East Avenue in the southeast portion of the Livermore site (**Figure 8-1**). VTF518 did not operate during 2002 due to a blower malfunction that was not repairable. The very low soil vapor flow rates (<0.028 m^3/min) yielded by VTF518 vapor extraction wells in 2001 were interpreted to be due to the high moisture content of shallow sediments at this location. The entire area around VTF518 was paved during 2002 to help reduce infiltration of surface water that may be contributing to the high moisture conditions. This area will be addressed by July 30, 2004 when both groundwater and soil vapor extraction and treatment are scheduled to be implemented.

Groundwater Treatment Facility 5475

Three groundwater treatment facilities (TF5475-1, TF5475-2, TF5475-3) operated in 2002 in the Treatment Facility 5475 (TF5475) area, located in the east-central portion of the Livermore site (**Figure 8-1**). TF5475-1 and TF5475-3 use catalytic reductive dehalogenation (CRD) to remediate the VOCs. Dual phase soil vapor and groundwater extraction capacity was added to the HSU 3A extraction wells at TF5475-2 in 2002.

During 2002, the TF5475 area facilities operated at an average flow rate of 0.72 L/min to treat about 0.72 million liters of groundwater containing an estimated 0.7 kg of VOCs. Since system start up in 1998, the combined TF5475 facilities have treated about 2.3 million liters of groundwater and removed about 4.8 kg of VOC mass from the subsurface (**Table 8-1**).

All TF5475 facilities were in compliance in 2002. No new boreholes or wells were drilled and no hydraulic tests were conducted in the TF5475 area during 2002.

Vapor Treatment Facility 5475

Vapor treatment facility 5475 (VTF5475) is located north of TF5475-3 in the east-central portion of the Livermore site, and treats soil vapor from vadose zone well SVI-ETS-504 (**Figure 8-1**). Soil vapor is extracted from the vadose zone and treated at VTF5475 using granular activated carbon. Due to elevated tritium concentrations in the vadose zone, VTF5475 is a closed-loop system to prevent aboveground tritium releases. The vapor stream is heated to reduce the humidity of the triti-

ated vapor prior to entering the granular activated carbon. This minimizes the absorption of tritium-containing water on the granular activated carbon.

Following removal of VOCs from the air-stream, tritiated vapor is re-injected into the subsurface at soil vapor inlet well SVI-ETS-505. Tritium absorbed by the granular activated carbon during VOC treatment is handled as mixed waste. Because no effluent vapor from VTF5475 is released to the atmosphere, the Bay Area Air Quality Management District has granted the facility an exemption from air discharge requirements.

During 2002, VTF5475 operated at an average flow rate of 0.27 m^3/min and treated 144 m^3 of vapor containing an estimated 38 kg of VOCs. Since system start up in 1999, VTF5475 has treated about 659,000 m^3 of vapor containing an estimated 306 kg of VOCs (**Table 8-1**).

Two instrumented membrane system (IMS) sampling/monitor wells, SEA-ETS-506 and SEA-ETS-507, continued to monitor vadose zone remediation in the VTF5475 area. The IMS system is used to collect vapor pressure, soil temperature, soil moisture, and soil vapor concentration data from various discrete depths. In 2002, VTF5475 was expanded to treat vapor from HSU3A dual phase extraction wells at TF5475-2.

Groundwater Flow and Transport Modeling

Groundwater flow and contaminant transport models are used at the Livermore site to optimize remediation system design and operation; to support ongoing subsurface characterization activities; and to improve LLNL's ability to forecast, monitor, and interpret the progress of the groundwater remediation program. In 2002, LLNL continued to improve its three-dimensional (3-D) and two-dimensional (2-D) groundwater models for the Livermore site, and began incorporating capabilities to evaluate regional scale dewatering issues. Continued use of the existing models and development of new models in 2002 are described below.

Three-Dimensional Models

In 2002, LLNL continued to use the 3-D groundwater flow and transport model developed for HSUs 1B and 2 (HSU 1B/2 model) to evaluate PCE and TCE transport throughout the Livermore site. The model was used to optimize extraction well flow rates, evaluate potential capture zones of proposed extraction wells, and evaluate plume migration and hydraulic interference patterns under increased pumping conditions. The HSU 1B/2 model was also used to evaluate the role of the Recharge Basin in the overall remediation of the TFA area. The model was revised to include recent well pumping histories, changing boundary conditions, and refined flow and transport parameters to evaluate the effect of varying the quantity of TFA effluent discharged to the Recharge Basin. LLNL 3-D simulations indicate that potential decreases in effluent discharge to the Recharge Basin would not adversely affect groundwater elevations or capture zones, and therefore should not prolong the overall remediation of the TFA area (Dibley et al. 2003).

In addition to the HSU 1B/2 model, preliminary work began to develop a new 3-D model that incorporates all identified HSUs beneath the Livermore site. The objectives of this 3-D model are to provide decision support for well field management that incorporates the limited vertical communication between HSUs, help understand the recharge characteristics of the deeper HSUs, and help evaluate regional-scale dewatering issues. The new 3-D model should be functional in fiscal year 2004.

Two-Dimensional Models

In 2002, LLNL continued to develop and improve 2-D models for deeper HSUs 3A, 3B, 4, and 5. The primary purpose of the individual 2-D models was to understand the flow and transport characteristics of each HSU separately before incorporating them into the larger, all HSU, 3-D model for the entire Livermore site. The 2-D models proved very useful in identifying the recharge and discharge boundary conditions of these HSUs, as well as areas of vertical communication. The 2-D model for HSU-2 was further refined to evaluate the effects of a potential injection well near the edge of saturation in the TFD area, and to help select the location for newly installed injection well W-1904. Alternative scenarios for the optimal location of an injection well and for different injection rates were simulated to evaluate the impact of injection in relation to plume migration, source area remediation, and dewatering issues.

Site 300 CERCLA Project

Environmental investigations and cleanup activities at Site 300 began in 1981. Site 300 became a CERCLA site in 1990, when it was placed on the National Priorities List. The CERCLA environmental restoration operable units (OUs) are shown in **Figure 8-9**. All contaminant release sites have been assigned to one of eight OUs based on the nature and extent of contamination, and topographic and hydrologic considerations. The major contaminants of concern are listed in **Table 8-4**. CERCLA work at Site 300 is conducted under a Federal Facility Agreement (FFA) and other requirements. Key milestone and deliverable due dates for 2002 are listed in **Table 8-5**.

Geology of Site 300

Site 300 is located in the sparsely populated Altamont Hills, which are part of the Coast Ranges Physiographic Province and separate the Livermore Valley to the west from the San Joaquin Valley to the east. Site 300 stratigraphy is shown in **Figure 8-10**. Rocks exposed in the region are classified into three groups:

- Late Tertiary-Quaternary (0–5 million years ago)—alluvium and semilithified sediments, mainly of continental origin.
- Early to late Tertiary (5–65 million years ago)—shallow marine and continental sedimentary and volcaniclastic rocks.
- Jurassic-Cretaceous (65–180 million years ago)—Great Valley sequence (marine sedimetary rocks and ophiolites) and Franciscan Complex (sheared and variably metamorphosed sedimentary and igneous rocks).

Distinctive blue-gray to brown weathering volcaniclastic sandstone and sandy siltstone, interbedded with light gray weathering tuffaceous claystone and conglomerate, are exposed extensively within Site 300. These rocks are mapped as the late Miocene Neroly Formation (Huey 1948; Dibblee 1980). The Neroly Formation is also present in the subsurface beneath Site 300.

The Neroly Formation is the principal hydrologic unit within Site 300 and has been the focus of the detailed geologic and hydrogeologic studies conducted during recent years (summarized in the *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300*, [Webster-Scholten 1994]). The complete section of the Neroly Formation is about 150 m thick beneath Site 300.

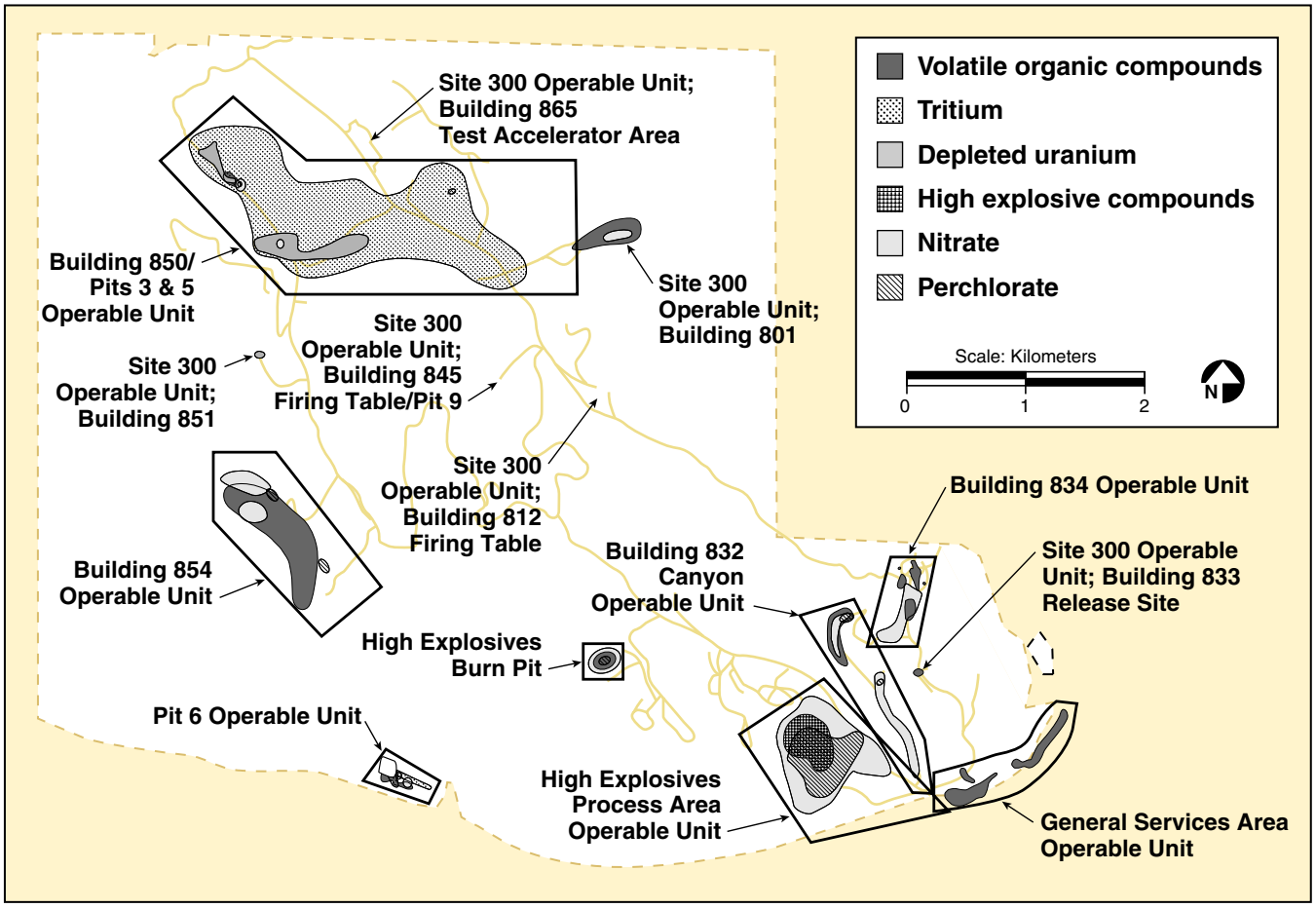


Figure 8-9. Contaminants of concern at environmental restoration operable units at Site 300

Table 8-4. Major contaminants of concern found in soil, rock, and groundwater at Site 300

Operable Unit (OU)	Contaminant of concern[a]
General Services Area (GSA) (OU1)	VOCs (primarily TCE)
Building 834 Complex (OU2)	VOCs (primarily TCE), organosilicate oil, nitrate
Pit 6 (OU3)	VOCs (primarily TCE), tritium, nitrate, perchlorate
High Explosives Process Area (OU4)	VOCs (primarily TCE), HE (primarily RDX), nitrate, perchlorate
Building 850/Pits 3 & 5 (OU5)	Tritium, depleted uranium, VOCs (primarily TCE), nitrate, perchlorate
Building 854 (OU6)	VOCs (primarily TCE), nitrate, perchlorate
Building 832 Canyon (OU7)	VOCs (primarily TCE), nitrate, perchlorate
Site 300 (OU8)	VOCs (primarily TCE and Freon 113), nitrate, perchlorate, depleted uranium, tritium, metals, RDX

a See Acronyms and Abbreviations for list of acronyms

Table 8-5. Deliverable and milestone dates for Site 300 environmental restoration activities outlined in the FFA and other agreements, 2002

Deliverable/Milestone[a]	Due Date
Building 834 Draft Final 5-Year Review report	January 7, 2002
Building 834 Final Remedial Design report	January 28, 2002
Building 834 Final 5-Year Review report	February 7, 2002
High Explosives Process Area Draft Interim Remedial Design Report	February 18, 2002
Draft Site-Wide Compliance Monitoring Plan and Contingency Plan for Interim Remedies	March 29, 2002
Public Workshop for the Draft Site-Wide Compliance Monitoring Plan and Contingency Plan for Interim Remedies	April 16, 2002
Building 854 Characterization Summary report	May 3, 2002
High Explosives Process Area Draft Interim Remedial Design report	July 1, 2002
High Explosives Process Area Draft Final Interim Remedial Design report	August 1, 2002
Draft Final Site-Wide Compliance Monitoring Plan and Contingency Plan for Interim Remedies	August 13, 2002
High Explosives Process Area Final Interim Remedial Design report	August 15, 2002
Final Site-Wide Compliance Monitoring Plan and Contingency Plan for Interim Remedies	September 13, 2002
Construct B815-PRX groundwater extraction and treatment facility in the High Explosives Process Area OU	September 30, 2002
Initiate build-out and upgrade of the B834-SRC groundwater and soil vapor treatment facility in the Building 834 OU	December 2, 2002

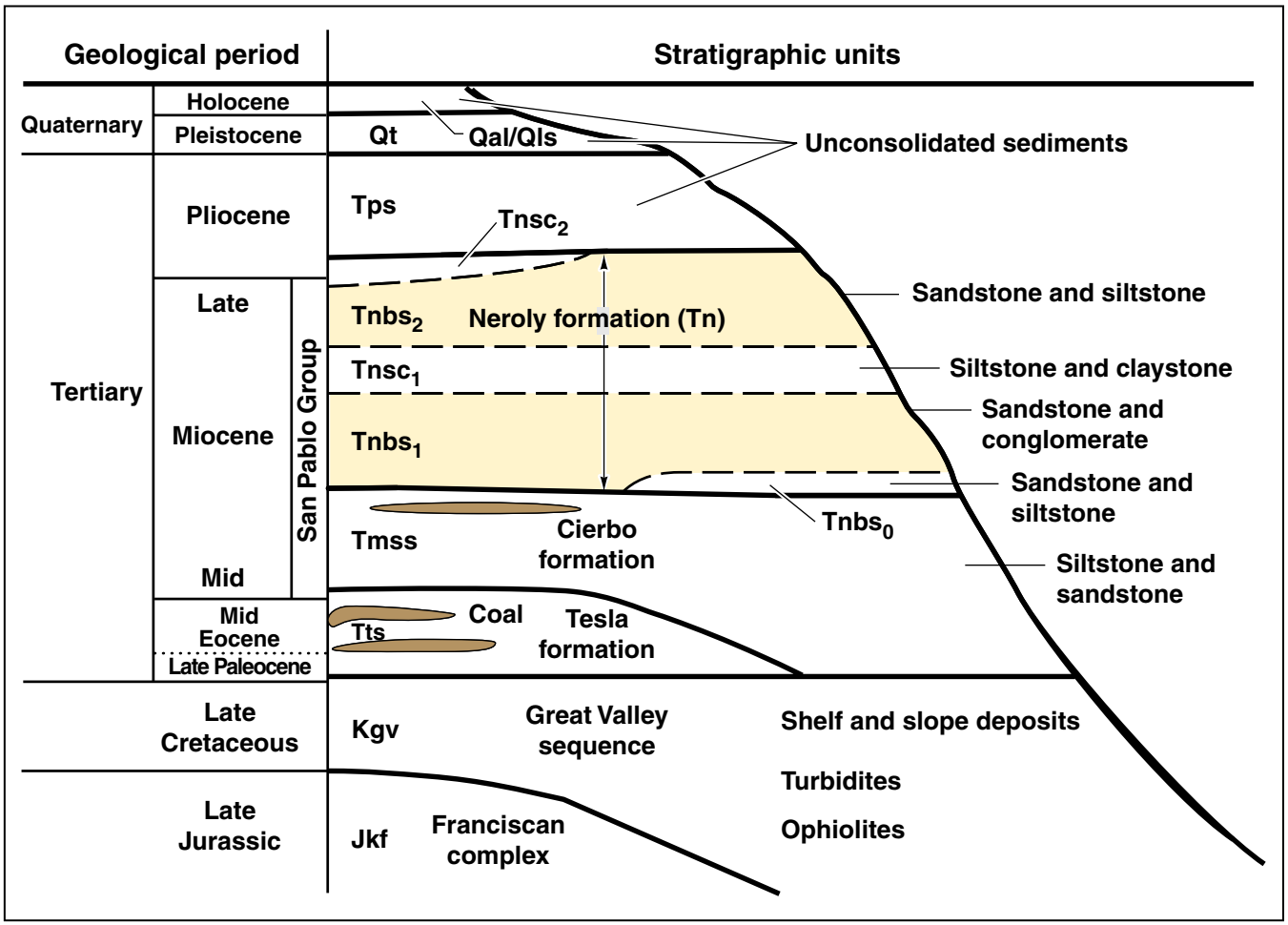
a See Acronyms and Abbreviations for list of acronyms

The floodplain of Corral Hollow Creek lies along the southern boundary of Site 300 and borders portions of the General Services Area (GSA), the High Explosives Process Area, and the area of closed landfill Pit 6. Floodplain alluvium consists dominantly of coarse cobble and boulder-bearing terrace gravel derived from sources to the south, with lenses and local cappings of sandy silt and silty clay.

The bedrock sequence within Site 300 has been slightly deformed into several gentle, low-amplitude folds. The locations and characteristics of these folds, in combination with the regional fault and fracture patterns, locally influence groundwater flow within the site and have therefore been studied in great detail as part of the CERCLA investigations.

Hydrogeology of Site 300

Site 300 is semiarid, with an average annual rainfall of 27 cm. The site is underlain by gently dipping sedimentary bedrock dissected by steep ravines. The bedrock consists of interbedded conglomerates, sandstones, siltstones, and claystones (see **Figure 8-10**).



Source: Webster-Scholten 1994

Figure 8-10. Site 300 stratigraphy

Groundwater primarily occurs in the Neroly Formation upper and lower blue sandstone units ($Tnbs_2$ and $Tnbs_1$) and in the underlying Cierbo Formation (Tmss). Saturated conditions also exist in two units that occur at the base of the Neroly Formation in the Building 854 and Pits 3 and 5 areas, respectively ($Tnsc_0$ and $Tnbs_0$). Groundwater can also be present in permeable Quaternary alluvium valley fill (Qal) during the winter rainy season.

Some groundwater is present as perched water-bearing zones beneath hilltops. The perched water-bearing zones primarily occur in the unconsolidated sediments of the Miocene-age nonmarine unit (Tps) in the Building 833 and 834 areas and in the High Explosives Process Area. An extensive perched water-bearing zone also occurs in $Tnbs_1$ sandstones in the northwestern portion of the East and West Firing Area. Fine-grained siltstone and claystone interbeds in $Tnbs_1$ and Tmss act as aquitards, confining layers, or perching horizons. Portions of the bedrock section at Site 300 are abundantly fractured, and thus much of the groundwater flow occurs in fractures as well as in pores. Bedrock-hosted groundwater is typically present under confined conditions in the southern half of the site but is often unconfined elsewhere. **Figure 8-11** is a map of the potentiometric surface for the first continuous water-bearing zone at

Site 300, which principally occurs in the Neroly lower blue sandstone aquifer ($Tnbs_1$).

Recharge occurs where saturated alluvial valley fill is in contact with underlying permeable bedrock, and where bedrock strata crop out. Local recharge occurs on hilltops, creating the perched water-bearing zones in the Building 832, 834, 854, and 829/High Explosives Burn Pit areas. Low rainfall, high evapotranspiration rates, steep topography, and intervening aquitards generally preclude direct vertical recharge to the deeper bedrock aquifers.

Groundwater flow in the bedrock follows the inclination, or dip, of the layers. The tectonic forces that uplifted the Altamont Hills faulted, gently folded, and tilted the once-horizontal sedimentary strata. A major structure, the east-west trending Patterson anticline, occupies a central location within the site. North of the anticline, bedrock generally dips east-northeast. South of the anticline, bedrock dips south-southeast.

The Cierbo Formation (Tmss) is saturated beneath Doall Ravine, the Building 851 and 854 areas, and the southern part of the East Firing Area. The Tmss unit is unsaturated or does not otherwise yield water to wells in other parts of the East and West Firing Areas. The thickness of the Cierbo Formation is not well known because most boreholes are not deep enough to completely penetrate this formation. Some of the deeper wells in the GSA penetrate the uppermost Tmss. The continuity of saturation in the Tmss between the northwest and southeast areas of Site 300 is undetermined. Groundwater in the Tmss occurs under unconfined to artesian conditions.

The Tps unit is the youngest bedrock unit identified at Site 300 and is generally present only on hilltops. Where present, groundwater is typically perched, discontinuous, and ephemeral. The exception to this condition exists in the High Explosives Process Area, where the extent of saturation in Tps sediments is significant. Groundwater in the Tps unit is generally unconfined, although water under confined conditions does occur locally.

Quaternary alluvium (Qal) is present as valley fill in ravines throughout Site 300 but is perennially saturated only in the Corral Hollow Creek stream channel, in Doall Ravine, and in southern Elk Ravine in the vicinity of Building 812. Qal in the Pits 3 and 5 area is only saturated during rainy seasons and for extended periods of higher than normal rainfall. Saturated Quaternary terrace alluvium deposits (Qt) are present at Pit 6, in the GSA, and in the Building 832 Canyon area; some of these groundwater occurrences are ephemeral. Small quantities of groundwater are present in some local landslide (Qls) deposits.

All groundwater contaminant plumes at Site 300 occur in Neroly Formation (Tn) rocks, unnamed Pliocene nonmarine sediments (Tps), or unconsolidated Quaternary sediments (Qal, Qls, or Qt) stratigraphic units. The extent of groundwater contamination at Site 300 is shown on **Figure 8-12**.

Remediation Activities at Site 300

Background information for LLNL environmental characterization and restoration activities at Site 300 can be found in the *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300* (Webster-Scholten 1994). LLNL submitted all required documentation to oversight agencies on time in 2002. (See Chapter 2.)

Dedicated groundwater and soil vapor extraction and treatment facilities operate at the eastern GSA, central GSA, and Building 834 areas. Eight portable treatment facilities also are operating. Thus, in all, 11 treatment facilities that remove and treat VOCs operated throughout 2002. Twenty-

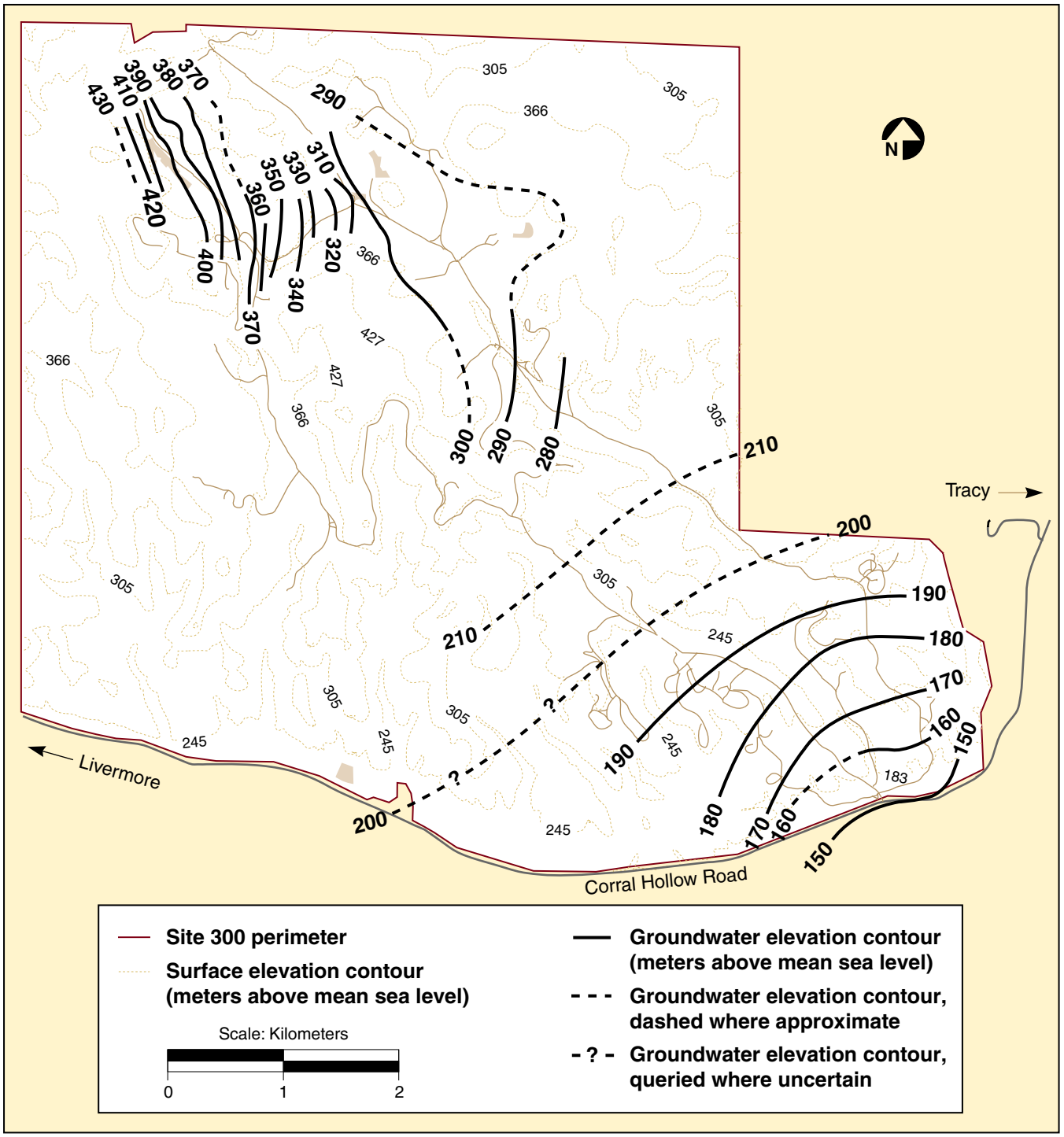


Figure 8-11. Approximate groundwater elevations in the principal continuous water-bearing zone at Site 300

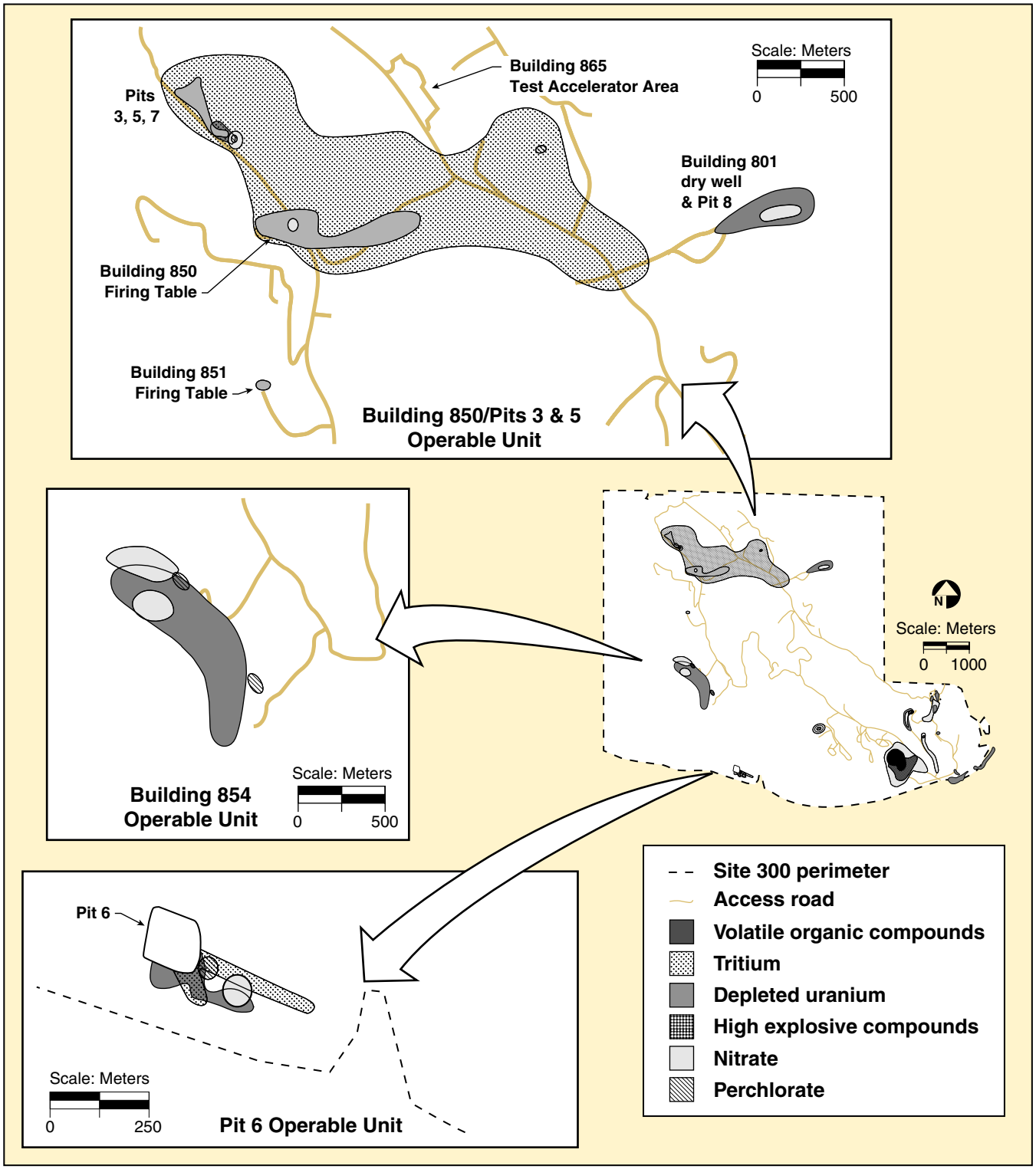
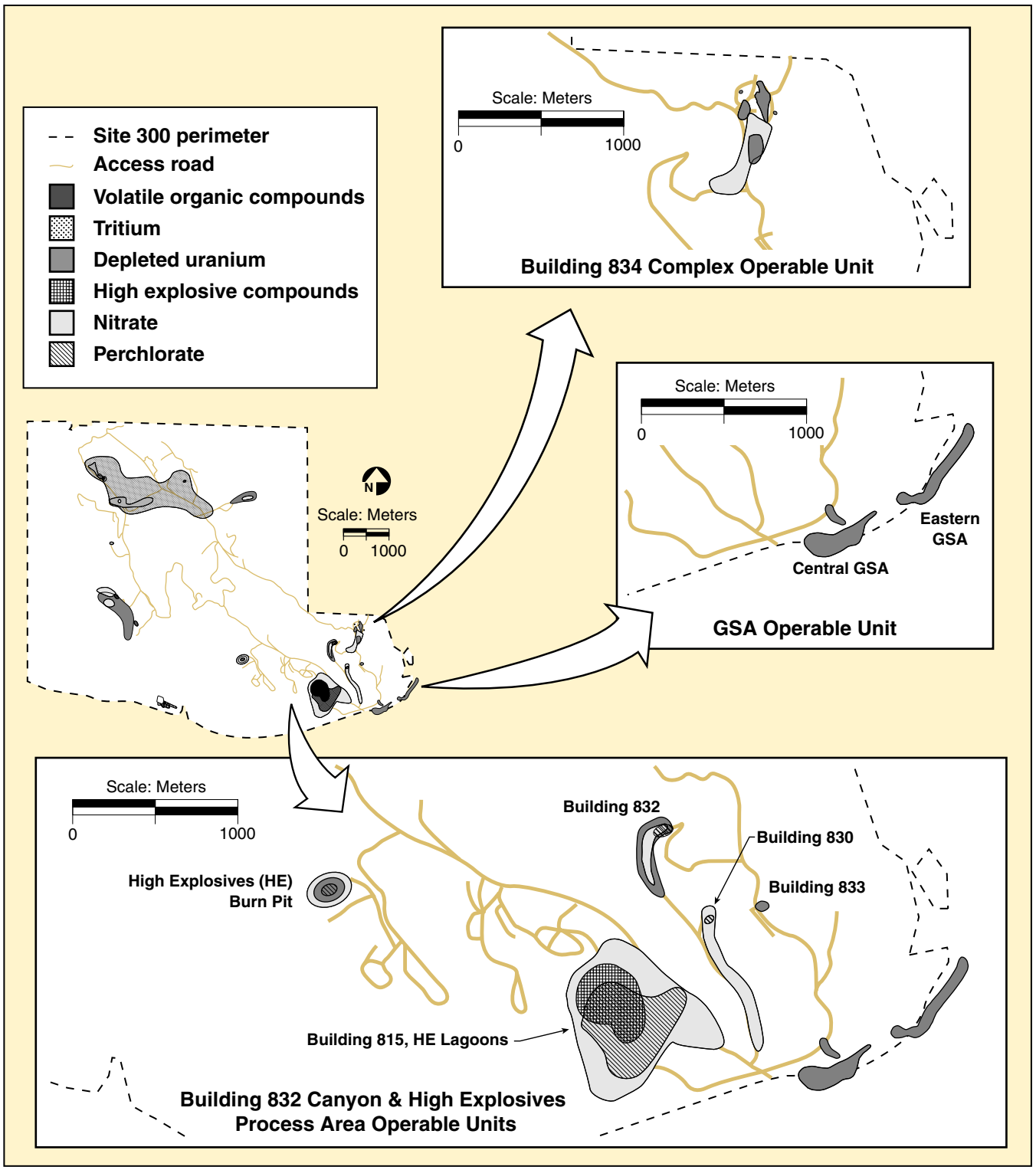


Figure 8-12. Extent of groundwater contamination at Site 300


Site 300 perimeter
Access road
Volatile organic compounds
Tritium
Depleted uranium
High explosive compounds
Nitrate
Perchlorate
Scale: Meters
0
1000
Building 834 Complex Operable Unit
N
Scale: Meters
0 1000
Scale: Meters
0
1000
Eastern GSA
Central GSA
GSA Operable Unit
Scale: Meters
0
1000
Building 832
Building 830
Building 833
High Explosives (HE) Burn Pit
Building 815, HE Lagoons
Building 832 Canyon & High Explosives Process Area Operable Units

one wells that extract only groundwater, 7 wells that extract only soil vapor, and 24 wells that extract both groundwater and soil vapor, operated during 2002. The 23 wells that extract only groundwater and the 24 wells that extract both groundwater and soil vapor yielded about 93.1 million L of groundwater. The 24 wells that extract both vapor and groundwater and the 7 wells that extract only vapor removed 795,960 m^3 of vapor. In 2002, the Site 300 treatment facilities removed approximately 9.5 kg of VOCs. Since remediation efforts began in 1990, more than 865 million L of groundwater and approximately 3.93 million m^3 of vapor have been treated, yielding about 231 kg of removed VOCs.

Table 8-6 summarizes 2002 and cumulative totals of volumes and masses of contaminants removed from groundwater and soil vapor at Site 300.

The central GSA, eastern GSA, and B830-Distal, South (B830-DISS) treatment facilities discharge to surface drainage courses. The B854-Proximal (B854-PRX) solar treatment unit/containerized wetland, B815-Distal (B815-DIS) aqueous phase granular activated carbon, and B830-Proximal, North (B830-PRXN) granular activated carbon treatment systems discharge to an infiltration trench. The other 5 treatment systems discharge to air by misting.

Table 8-6. Volumes of groundwater and masses of volatile organic compounds (VOCs) removed from groundwater and soil vapor at Site 300

Operable Unit	Startup date	2002		Cumulative total	
		Water treated (ML)[a]	VOCs removed (kg)	Water treated (ML)[a]	VOCs removed (kg)
Eastern GSA	1991	78.7	0.17	806.6	6.19
Central GSA	1993	4.19	0.59	29.16	10.66
Building 834	1995	0.11	0.81	0.93	31.84
High Explosives Process Area	1999	4.5	0.012	10.5	0.058
Building 854	1999	3.67	0.78	12.25	6.14
Pit 6	1998	—[b]	—[b]	0.268	0.0014
Building 832	1999	1.90	0.12	5.68	0.44
Total		93.1	2.48	865.4	55.33
		Soil vapor treated ($10^3 m^3$)	**VOCs removed (kg)**	**Soil vapor treated ($10^3 m^3$)**	**VOCs removed (kg)**
Central GSA	1994	293.58	1.54	1987.18	66.16
Building 834	1998	406.18	5.19	1657.56	108.26
Building 832	1999	96.2	0.28	282.5	1.39
Total		795.96	7.01	3927.44	175.81

a ML = 1 million liters

b Groundwater treatment is not routine at Pit 6. A hydraulic pump test was conducted there in 1998.

The following sections describe background information, a summary of characterization activities, and groundwater remediation activities for each of the OUs. See Chapter 9 for a discussion of 2002 groundwater monitoring.

General Services Area Operable Unit

In the GSA, past leaks of solvents from storage areas and buried debris have resulted in several plumes of VOCs in groundwater. There are three major TCE plumes and two treatment facilities located within the GSA OU: the central GSA and the eastern GSA.

The VOC groundwater plume in the eastern GSA is present in a subsurface stream channel alluvium (Qal) at 3 to 9 m below ground surface; the plume, as defined by the 4th quarter 2002 1 ppb concentration contour, is about 427 m long (**Figure 8-13**). Groundwater flows east and northeast through the alluvium within Corral Hollow Creek. The maximum 4th quarter 2002 total VOC concentration in groundwater taken from eastern GSA wells was 7.5 ppb. The Qal is hydraulically connected to the Neroly Formation lower blue sandstone ($Tnbs_1$) unit.

Two VOC groundwater plumes in the central GSA are present in terrace alluvium (Qt) and Neroly Formation upper blue sandstone ($Tnbs_2$), at a depth of 3 to 9 m below ground surface. These VOC plumes, as defined by the 1 ppb concentration contour, are about 107 m and 488 m long (**Figure 8-14**). The maximum 4th quarter 2002 total VOC alluvial groundwater concentration was 958 ppb. Deeper regional groundwater also contains total VOCs at a maximum 4th quarter 2002 concentration of 5 ppb. This groundwater occurs at depths of 11 to 56 m below ground surface.

Details of current and planned environmental restoration activities at the GSA are summarized in the *Final Remedial Design* document (Rueth et al. 1998). The remedial design document includes the Contingency Plan and Compliance Monitoring Plan for the GSA OU.

Following dewatering of bedrock through groundwater extraction, soil vapor extraction and treatment of VOCs began in 1994. During 2002, the soil vapor extraction and treatment system in the central GSA dry-well source area was continuously operated and maintained to reduce VOC concentrations in soil vapors, remediate dense nonaqueous-phase liquids in the soil, and mitigate the VOC inhalation risk inside Building 875. The groundwater extraction and treatment systems in the central and eastern GSA areas were continuously operated and maintained to reduce VOC concentrations in the groundwater to MCLs, prevent further migration of the contaminant plume, and dewater the shallow water-bearing zone in the Building 875 dry-well area to enhance soil vapor extraction.

Wells W-7R, W-7PS, and W-7P are being considered for modification as extraction wells for the second phase of planned expansion to the groundwater extraction and treatment facility at central GSA. This phase-two plan was presented to and accepted by the regulators at the Regional Project Managers meeting held on January 28, 2002. The addition of these extraction wells would enhance the system's ability to capture the contaminant plume and increase the mass removal.

Treatability tests are being scheduled to determine if passive venting of soil vapor extraction wells in the central GSA area would result in a suitable long-term remedial technology.

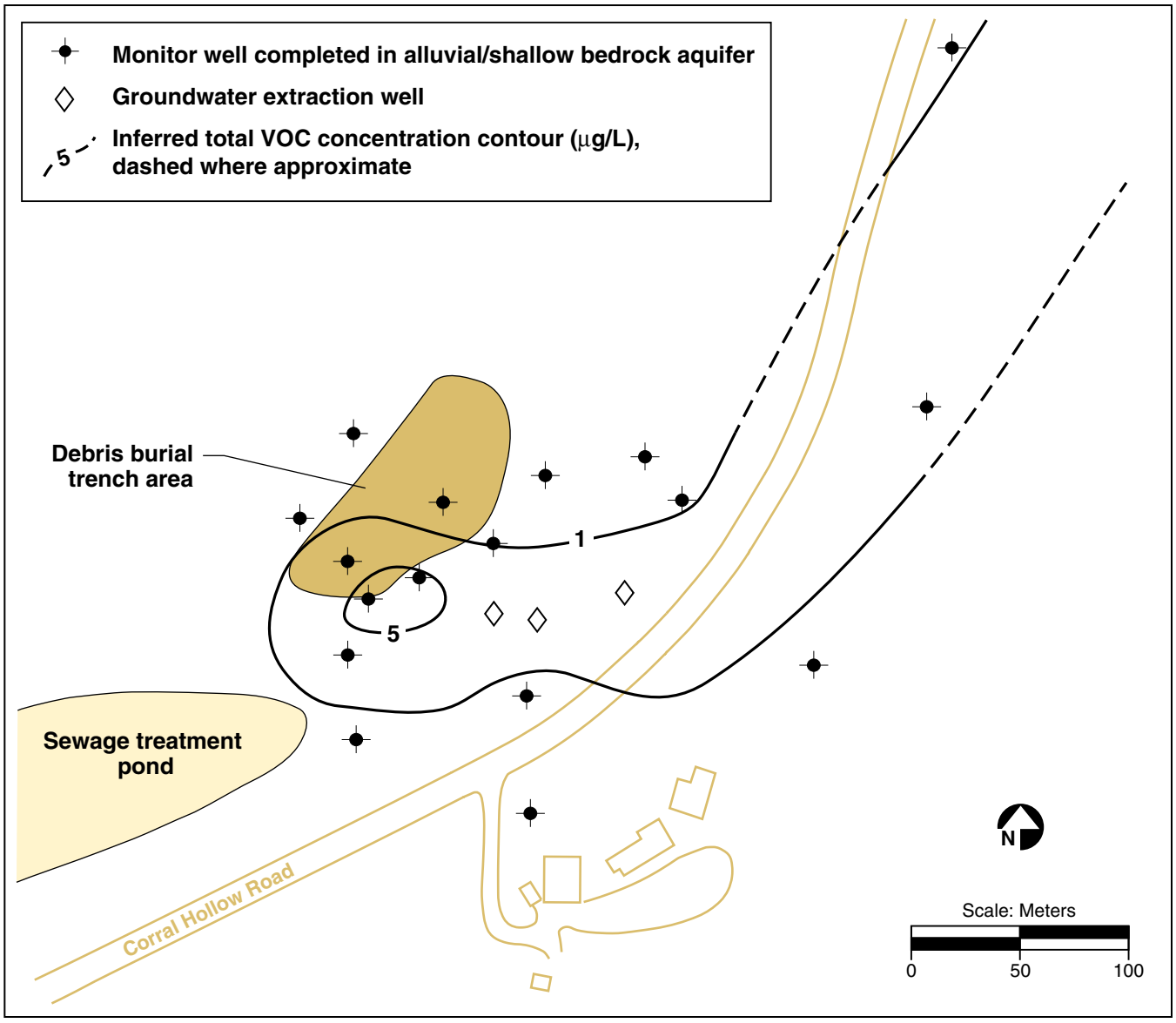


Figure 8-13. Total VOC concentrations in groundwater in the eastern GSA and vicinity (4th quarter, 2002)

Currently the eastern GSA treatment facility employs granular activated carbon canisters to remove VOCs from extracted groundwater. Extracted central GSA groundwater is run through an air-sparging PTU to remove VOCs. Extracted soil vapor at the central GSA is run through granular activated carbon canisters to remove VOCs.

Table 8-6 shows the amounts of groundwater treated and VOCs removed at both the eastern and central GSAs.

Groundwater treated at the eastern GSA groundwater treatment facility was discharged off site to Corral Hollow Creek, in accordance with Waste

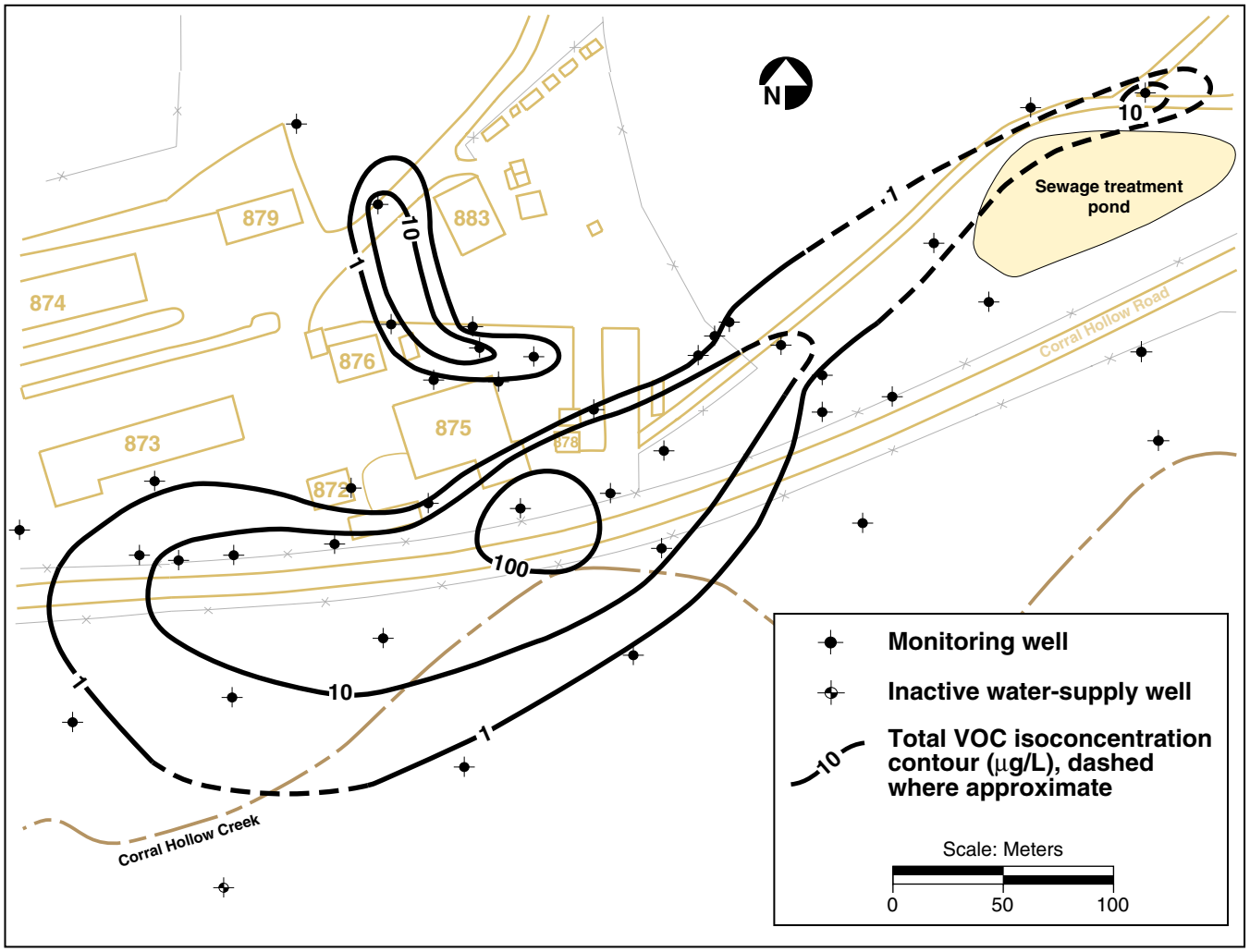


Figure 8-14. Total VOC concentrations in groundwater in the central GSA and vicinity (4th quarter, 2002)

Discharge Requirements Order No. 97-242 (WDR 97-242), National Pollutant Discharge Elimination System (NPDES) Permit No. CA0082651.

The central GSA groundwater treatment system is operating under substantive requirements for wastewater discharge issued by the CVRWQCB. Permit requirements for the central and eastern GSA groundwater treatment system are listed in Table 8-7. Both the central and eastern GSA treatment systems operated in compliance with regulatory requirements during 2002. LLNL submitted quarterly reports for the GSA treatment systems to the CalEPA and the CVRWQCB in accordance with the WDR 97-242 for the eastern GSA and the Substantive Requirements for Waste Discharge for the central GSA (Lamarre 2002a,b,c,d).

Building 834 Operable Unit

Since the late 1950s, the Building 834 facilities, consisting of twelve separate buildings, have been used for weapons testing activities. TCE was used as the primary heat transfer fluid in experiments involving thermal cycling of weapons components. TCE was pumped between buildings through

Table 8-7. General Services Area groundwater treatment system surface discharge permit requirements

Parameter[a]	Treatment facility[a]	
	Central General Services Area	Eastern General Services Area
VOCs	Halogenated and aromatic VOCs	Halogenated VOCs
Maximum daily	5.0 μg/L	5.0 μg/L
Monthly median	0.5 μg/L	0.5 μg/L
Dissolved oxygen	Discharges shall not cause the concentrations of dissolved oxygen in the surface water drainage course to fall below 5.0 mg/L.	Discharges shall not cause the concentrations of dissolved oxygen in the surface water drainage course to fall below 5.0 mg/L.
pH (pH units)	Between 6.5 and 8.5, no receiving water alteration greater than ±0.5 units	Between 6.5 and 8.5, no receiving water alteration greater than ±0.5 units
Temperature	No alteration of ambient receiving water conditions more than 3°C	No alteration of ambient receiving water conditions more than 3°C
Place of discharge	To groundwater during dry weather and to surface water drainage course in eastern GSA canyon during wet weather.	Corral Hollow Creek
Flow rate	272,500 L/day (30-day average daily dry weather maximum discharge limit)	272,500 L/day
Mineralization	Mineralization must be controlled to no more than a reasonable increment.	Mineralization must be controlled to no more than a reasonable increment.
Methods and detection limits for VOCs	EPA Method 601—detection limit of 0.5 μg/L EPA Method 602—method detection limit of 0.3 μg/L	EPA Method 601—detection limit of 0.5 μg/L

a See Acronyms and Abbreviations for list of acronyms.

aboveground pipes. Occasionally, TCE was mixed with silicone oils, tetrabutyl ortho silicate (TBOS), and tetrakis (2-ethylbutyl) silane (TKEBS) to prevent degradation of pump seals and gaskets. Several large spills of TCE to the ground, estimated at 550 gallons, and smaller releases of TBOS and TKEBS resulted in contamination of a shallow perched water-bearing zone beneath the site. Natural biodegradation of the TCE, in the form of anaerobic dehalogenation, has been occurring in discrete zones resulting in the formation of appreciable amounts of cis-1,2-dichloroethene (cis-1,2-DCE). This intrinsic biodegradation is facilitated by fermentation of TBOS and TKEBS, which yields the hydrogen required for microbial dechlorination of VOCs.

An isolated, discontinuous, perched water-bearing zone occurs in Pliocene non-marine gravels (Tpsg) and occurs at a maximum depth of 9 m below the center of the complex. LLNL believes that within this Tpsg unit there are multiple distinctive plumes that may be in hydraulic communication only during high groundwater elevations following

heavy rainfall events. The Tpsg is underlain by a clay perching horizon (Tps) that is also nearly saturated. The perched zone Tpsg and Tps strata crop out on all sides of the hill housing the Building 834 complex and are isolated from the underlying regional aquifer by more than 90 m of vadose zone. Although the maximum VOC groundwater concentrations within the Tpsg during 2002 was 87,000 µg/L, the highest VOC concentrations in groundwater were found in the Tps perching horizon. This perching horizon has a very low hydraulic conductivity, but does yield some groundwater. The highest concentration of VOCs in groundwater samples obtained from the Tps during 2002 was 220,000 µg/L, which was predominantly TCE. VOC distribution within the Tpsg is presented in **Figure 8-15**. The highest concentration of TBOS and TKEBS in groundwater during 2002 was 490,000 µg/L. High levels of nitrate (up to 280 mg/L) also occur in groundwater in the Building 834 OU, but the source is uncertain. Effluent from the septic system leach field has possibly contributed to elevated nitrate concentrations in groundwater. Additional natural and/or anthropogenic nitrate sources may exist.

Currently, groundwater and soil vapor extraction (SVE) and treatment, using air-sparging and granular activated carbon, respectively, are in progress. The well field consists of twelve dual-phase extraction wells and three additional wells used for only SVE. Work was initiated during 2002 to expand the well field to wells outside of the core area. Testing the use of aqueous phase granular activated carbon for VOC removal from the groundwater continued during 2002. Plans are being made for the replacement of the current air-sparging system with aqueous phase granular activated carbon. Groundwater treatment began during the 4th quarter of 1995, followed by soil vapor extraction and treatment during the 3rd quarter of 1998.

Two major documents, both RDWP milestones, became final during 2002 (see **Table 8-5**). One peer-reviewed journal article was released for publication in 2002: "Anaerobic Biotransformation of Trichloroethene Driven by Tetraalkoxysilanes at Site 300, Lawrence Livermore National Laboratory, CA" (Vancheeswaran et al. 2002).

In 2002, the groundwater and SVE treatment system were operated at full scale for the first half of the year. Equipment problems, followed by programmatic activities, prevented any facility operations for the remainder of the year. The Defense Technologies Evaluations Program (DTEP) began conducting experiments in October 2002, which due to the hazardous nature of these experiments, resulted in personnel being excluded from the area. These experiments have continued into 2003 and will likely affect future operations. LLNL had been observing a significant drop in both groundwater and soil vapor VOC concentrations in the Building 834 area over the last couple of years. These declining VOC concentrations and temporary suspension of treatment operation provided an opportune time to allow for rebound of contaminants. LLNL will be conducting detailed monitoring activities following completion of the DTEP experiments to evaluate potential contaminant rebound in both the vapor and aqueous phase. As mentioned previously, in situ biodegradation via reductive dechlorination of TCE occurs in areas within the Building 834 core area where sufficient amounts of silicon oils exist. However, it was demonstrated that this intrinsic microbial degradation is inhibited during periods of active soil vapor extraction because the soil vapor extraction system draws oxygen-rich vapors into the subsurface and the microbes become dormant. In essence, the SVE system acts like an on/off switch to control biodegradation. As such, allowing the system to remain off-line will promote biodegradation and will achieve some level of mass removal, although this mass is not easily quantified.

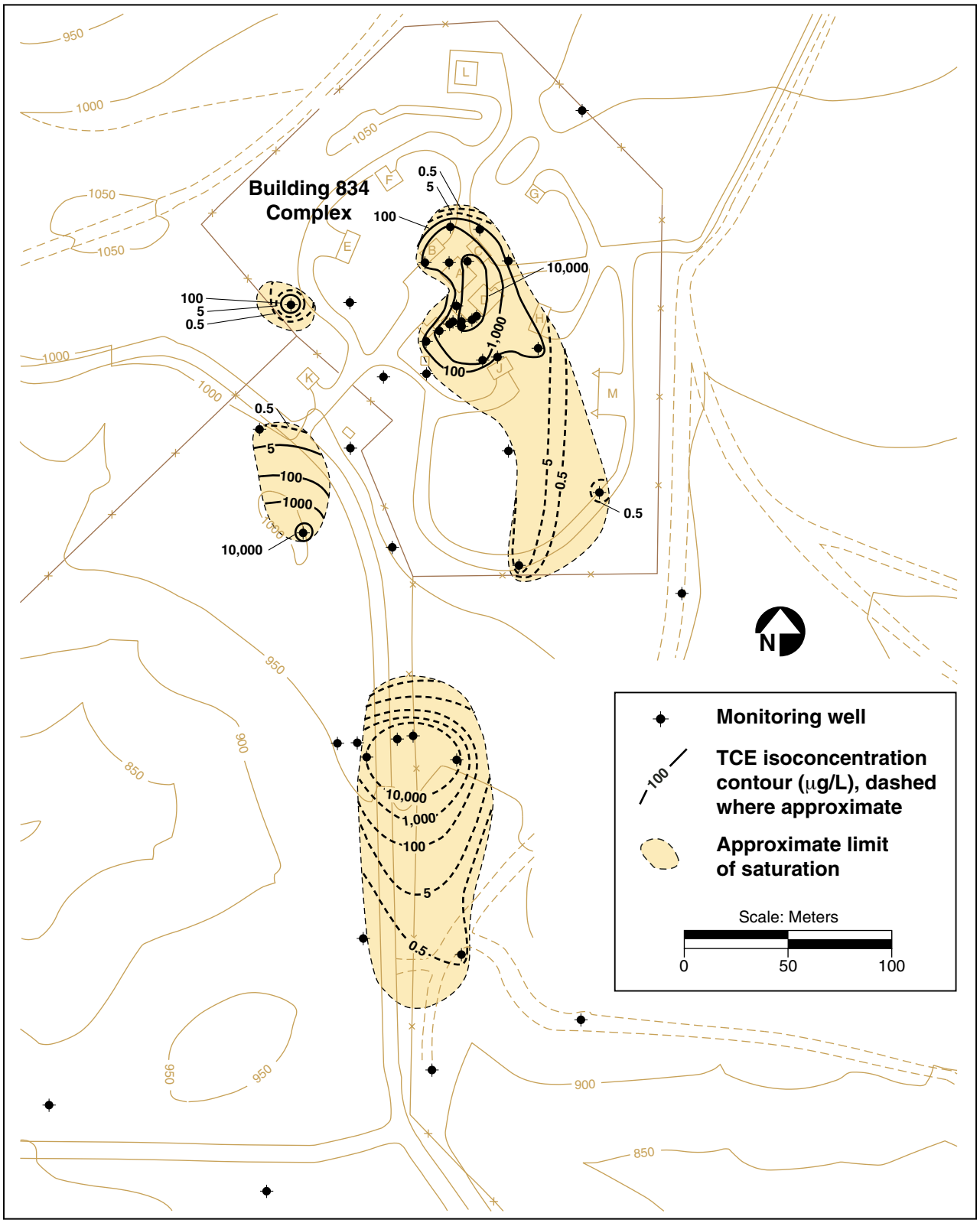


Figure 8-15. Isoconcentration contour map of TCE in groundwater in the Tpsg aquifer at the Building 834 complex (2nd quarter, 2002)

During 2001, the combined groundwater and soil vapor VOC mass removal at Building 834 was 31.96 kg. During 2002, the combined VOC mass removal at Building 834 was 6.0 kg. **Table 8-6** shows the volumes of water and soil vapor treated and masses of VOCs removed at Building 834. Quarterly reports for the Building 834 treatment facility were submitted to the EPA, CalEPA, and the CVRWQCB in accordance with the Substantive Requirements for Waste Discharge (Lamarre 2002e,f,g,h). Because treated groundwater is discharged to misters and is not discharged to the ground, there are no treatment system surface discharge permit requirements for Building 834.

High Explosives Process Area Operable Unit

The High Explosives Process Area was established in the 1950s to chemically formulate, mechanically press, and machine high explosives (HE) compounds into detonation devices that are tested in explosives experiments in the East and West Firing Areas of Site 300. Process waste water from HE machining operations containing HMX, RDX, nitrate, and possibly perchorate was discharged to nine former unlined lagoons at concentrations high enough to impact groundwater.

A TCE hardstand, located near the former Building 815 steam plant, is considered to be the primary source of TCE groundwater contamination. HMX and RDX are the most frequent and widespread HE compounds detected in soil and groundwater. TCE, nitrate, perchlorate, and RDX occur in groundwater within two separate water-bearing zones. One of the zones occurs in the Pliocene Tps Formation and the other occurs in the $Tnbs_2$ sandstone aquifer within the late Miocene Neroly Formation. Depth to groundwater ranges from 2 to 76 m beneath the area. The VOC (principally TCE) plume in Tps strata is about 200 m long; the VOC plume in the $Tnbs_2$ aquifer is about 900 m long (**Figure 8-16**). The RDX plume is about 200 m long and the perchlorate plume is about 600 m long in the $Tnbs_2$ aquifer. The extent of nitrate above the MCL in the $Tnbs_2$ aquifer is about 700 m long. The maximum 2002 concentrations of TCE, RDX, nitrate, and perchlorate were 80 µg/L, 93 µg/L, 130 mg/L, and 30 µg/L, respectively.

The remedial strategy for groundwater cleanup in the High Explosives Process Area was presented in the *Interim Remedial Design for the High Explosives Process Area Operable Unit at Lawrence Livermore National Laboratory Site 300* report (Madrid et al. 2002). This report was finalized in August 2002.

The High Explosives Process Area OU is divided into three treatment areas: (1) Source Area (SRC); (2) Proximal Area (PRX); and (3) Distal Site Boundary Area (DSB). The Source Area refers to the area around Buildings 806/807, 810, 815, and 817, where the majority of confirmed contaminant releases occurred. The Proximal Area is the area immediately downgradient (south) of the Building 815 Source Area to the vicinity of Buildings 818 and 823. The Distal Site Boundary Area is located in the southern part of the High Explosives Process Area, where the Site 300 boundary is located.

Contaminants, mainly the VOC TCE, the HE compound RDX, and perchlorate, reside in groundwater beneath the Source and Proximal Areas. TCE and RDX have also been detected in soil and bedrock samples collected from the vadose zone beneath the Source Area. The bulk of TCE mass in the $Tnbs_2$ aquifer resides beneath the Proximal Area. Distal Site Boundary Area contains TCE at low concentrations, generally below 30 µg/L; however, RDX and perchlorate are not present in this area at concentrations above EPA method detection limits for those chemicals.

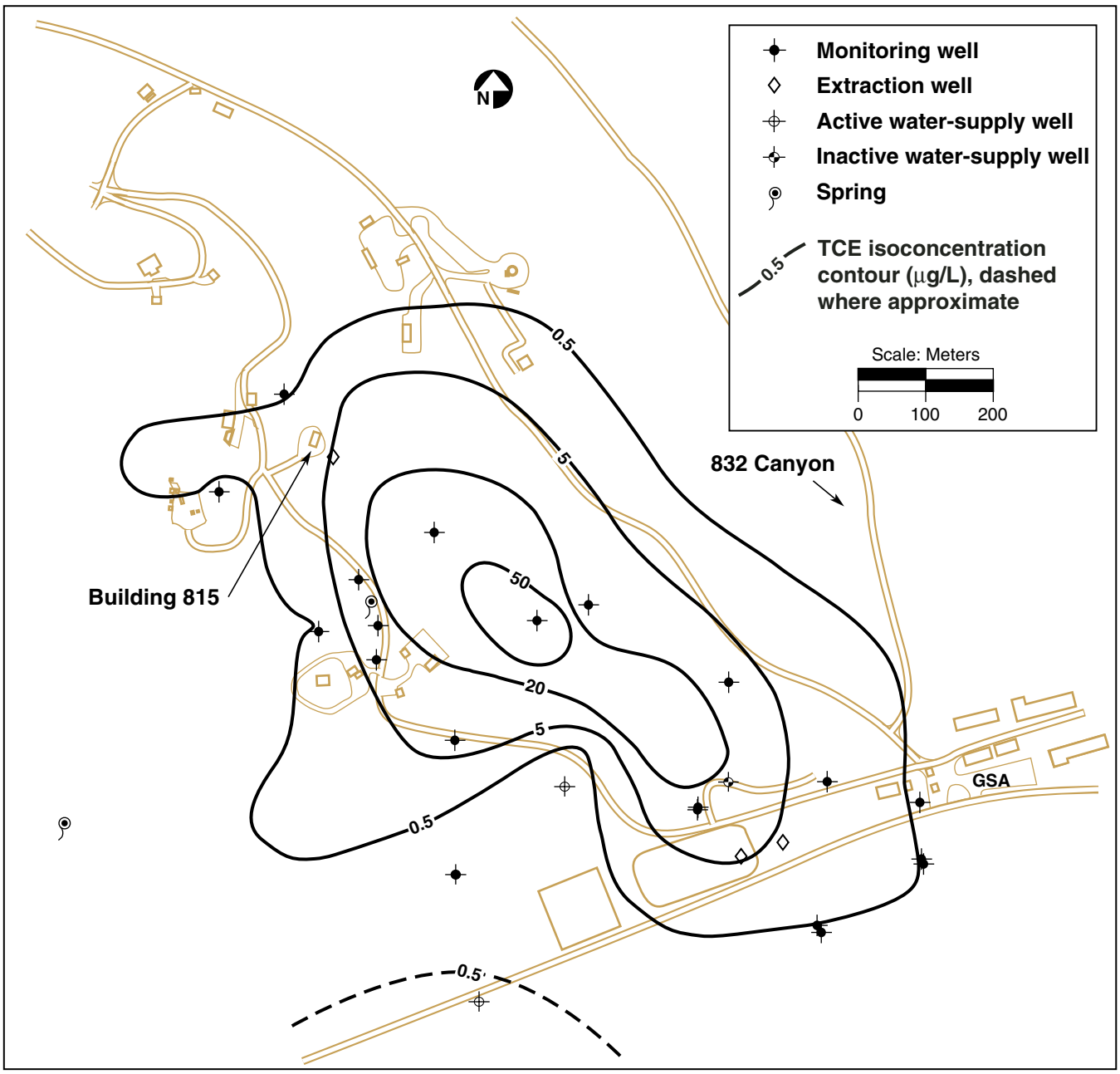


Figure 8-16. Isoconcentration contour map of trichloroethene (TCE) in groundwater in the $Tnbs_2$ aquifer in the High Explosives Process Area (2nd quarter, 2002)

The remediation strategy for the High Explosives Process Area OU is a phased, risk-based approach consistent with the Remedial Design Work Plan (RDWP) for Site 300 (Ferry et al. 2001c). In accordance with the RDWP, groundwater cleanup in the High Explosives Process Area will be implemented in the following four phases: (1) prevent off-site migration of groundwater contaminants;

(2) minimize influence of site boundary pumping on RDX plume; (3) maximize contaminant mass removal; and (4) clean up fine-grained source areas. Phase 1 began in 1999 with the installation of a treatment facility (B815-DSB) in the Distal Site Boundary Area. The purpose of this facility is to prevent off-site migration of TCE. Phase 2 began with the installation of a second treatment facility (B815-SRC) in 2000 at the Building 815 Source Area. The purpose of this facility is to begin cleanup of the TCE and RDX plumes and to minimize influence of Site Boundary pumping on upgradient plume migration.

In 2002, Phase 3 of the High Explosives Process Area remedial strategy was implemented with the installation of a third facility (B815-PRX). The extraction wells for this facility (W-818-08 and W-818-09) are located in the center of mass of the TCE plume and the primary objective of this facility is TCE mass removal. Extraction well W-818-08 is pumped at 3.8 L/min, while W-818-09, which has a higher sustainable yield, is pumped at 13 L/min. With the addition of the B815-PRX facility, the total number of groundwater extraction wells in the High Explosives Process Area is five and the total extraction flow rate is about 30 L/min.

In 2003, LLNL plans to expand the existing B815-SRC facility by connecting two additional wells (W-817-01 and W-815-04). These wells will be pumped at 3.8 L/min each for a total flow rate of 11 L/min at this facility. This additional pumping will increase the extraction well field capture zones in the Building 815 source area and significantly increase RDX mass removal. In addition to expanding the B815-SRC facility extraction well field, LLNL also plans to install an injection well upgradient of Building 815 to dispose of treated groundwater. Currently, treated effluent from the B815-SRC facility is discharged via a misting system located about 46 m south of Building 815. An alternative method for discharging treated groundwater is necessary because the ravine where Building 815 is located is not optimal for dispersing mist, especially under the increased flow rates planned for 2003.

Phase 4, which involves cleanup of fine-grained source areas, will begin in 2005 by using conventional pump-and-treat techniques to remediate shallow, perched groundwater beneath Building 815. If pump-and-treat proves impracticable, innovative techniques such as enhanced bioremediation will be considered. An enhanced bioremediation treatability test is planned for the Building 834 T2 area in 2003. If this test is successful, this technology will be considered for Building 815.

To date, more than 10 million liters of groundwater have been extracted and treated by the three existing facilities (B815-DSB, B815-SRC, and B815-PRX) in the High Explosives Process Area. As presented in **Table 8-6**, 4.5 million liters of groundwater were extracted and treated during 2002. In addition to removal of 0.027 kg of VOCs, 0.134 kg of RDX, and 0.034 kg of perchlorate have also been removed from extracted groundwater. Quarterly reports for the High Explosives Process Area treatment facilities were submitted to the EPA, CalEPA, and the CVRWQCB in accordance with the Substantive Requirements for Waste Discharge (Lamarre 2002 i,j,k,l).

Building 850/Pits 3 and 5 Operable Unit

Explosives experiments conducted at outdoor firing tables in the Building 850/Pits 3 and 5 area have generated wastes that in the past were disposed at several unlined landfills. Tritium has been released to groundwater from landfill Pits 3 and 5 and the Building 850 firing table (**Figure 8-17**). Depleted uranium has been released to groundwater from landfill Pits 3, 5, and 7 and the Building 850 firing table. Release of

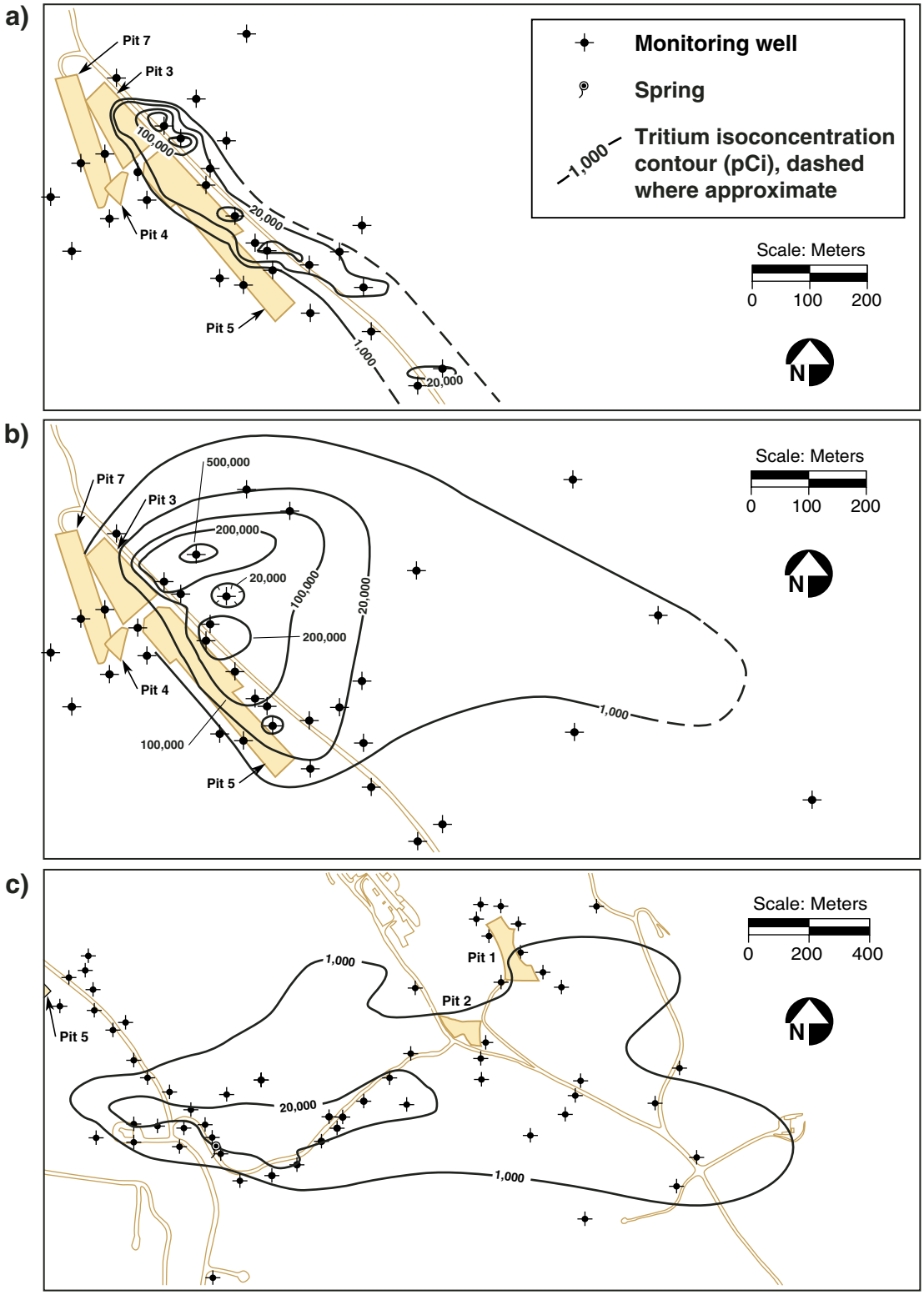


Figure 8-17. Distribution of tritium in groundwater in a) Pits 3 and 5 area alluvium, b) Pits 3 and 5 area bedrock ($Tnbs_0$), and c) Building 850/East Firing Area alluvium and bedrock (all for 2nd quarter, 2002).

tritium and uranium occurred from water-table rise and lateral flow of upgradient groundwater into the landfills and percolation of rainfall runoff water through the Building 850 firing table to underlying groundwater. The resulting plumes occur in a perched water-bearing zone within Qal alluvium and bedrock at the base of the Neroly Formation in the $Tnbs_0$ and in the regional aquifer in the area east of the western limit of the Elk Ravine Fault zone. The water-bearing zone occurs at depths of 5 to 20 m below surface. There are three overlapping plumes of tritium in groundwater.

The maximum 2002 groundwater tritium activity was about 26,148 Bq/L (706,000 pCi/L). The total length of the co-mingling tritium plumes was about 3000 m. The perched water-bearing zone is connected to the regional $Tnbs_1$ aquifer at the Elk Ravine Fault. Maximum 2002 groundwater tritium activities in this aquifer were about 878 Bq/L (23,700 pCi/L). There are two smaller plumes containing depleted uranium (predominantly uranium-238) emanating from the Pits 3, 5, and 7 area and the Building 850 area, with maximum measured 2002 total uranium activities of about 4366 Bq/L (118 pCi/L) and 377.4 Bq/L (10.2 pCi/L). The depleted uranium is confined principally to the alluvial portion of the perched water-bearing zone; the lengths of the two uranium plumes are about 390 m and 450 m, respectively. Computer modeling of contaminant fate and transport indicates that by the time the tritium and uranium in groundwater could reach the Site 300 boundary, these radionuclides will exist at near-background activities.

A remedial investigation/feasibility study (RI/FS) is in process for the Pits 3 and 5 area. The anticipated remedial technologies to be implemented at the landfill site include source isolation to prevent further release of tritium and uranium to groundwater. These technologies may include an upgradient groundwater interceptor trench and surface and shallow subsurface water diversion. LLNL is testing reactive media, such as cow bone char and fish bones (apatite mineral sources) and other novel sorbents, for possible deployment in a permeable reactive barrier for removal of depleted uranium from Pit 5 and 7 downgradient groundwater.

Although tritium continues to leach into groundwater from vadose zone sources at Building 850, the long-term trend in total groundwater tritium activity in this portion of the tritium plume is one of decreasing activity at approximately the radioactive decay rate of tritium. The extent of the 740 Bq/L (20,000 pCi/L) MCL contour for this portion of the plume is shrinking.

Nitrate and perchlorate in the Building 850/Pits 3 and 5 area occurred at maximum concentrations of 86 mg/L and 44 µg/L, respectively, in 2002. Trace amounts of TCE (less than 6.4 µg/L) are also present in groundwater near Pit 5.

To determine the appropriate remediation strategy for the Pits 3 and 5 landfills, LLNL is completing a water budget for the Pits 3 and 5 valley; continuing to build and calibrate a three-dimensional geological structural model and a finite element model of groundwater flow and contaminant transport; and evaluating several remediation strategies to keep water from entering the landfills. These techniques include subsurface groundwater interceptor trenches, shallow terraced drains, horizontal dewatering wells, landfill grouting, and other forms of permeability reduction, and in situ geochemical techniques using sorbents, such as bone apatite, to immobilize uranium in groundwater.

LLNL is also conducting field studies to determine how water recharges the perched water-bearing zone and enters the landfills. These studies included monitoring of wells completed at shallow depths, horizontal wells, and terraced drains, all completed in the hillslope west of the landfills

where much of the recharge that enters the landfills originates. Additionally, LLNL is conducting laboratory treatability tests of cow bone char and fish bone in removing uranium for Pits 3 and 5 groundwater. Cow bone char mixed with inert sand has been emplaced within a portion of the alluvial aquifer containing uranium at Pit 5 to test the in situ removal of uranium from area groundwater. Wells within and downgradient of this emplacement are being monitored to define the long-term chemical effectiveness and hydraulic characteristics of the emplaced material. If successful, this emplacement may be expanded as a long-term remedy for depleted uranium in groundwater. The Remedial Investigation/Feasibility Study for the Pits 3 and 5 area is scheduled for completion by March 2004.

Building 854 Operable Unit

TCE in groundwater was previously found to arise principally from leaks in the former overhead TCE brine system at Buildings 854E and 854F. TCE, nitrate, and perchlorate occur in groundwater in the Building 854 area in Neroly Formation $Tnbs_1$ strata at maximum 2002 concentrations of 270 µg/L, 57 mg/L, and 10 µg/L, respectively. The affected aquifer occurs at depths of 9 to 50 m below the surface. The TCE plume is about 1000 m long (**Figure 8-18**). TCE also occurs in underlying $Tnsc_0$ strata at a maximum concentration of 2.5 µg/L.

During 2002, LLNL continued to define the extent of TCE in groundwater and the conceptual hydrogeological model. Three new monitoring wells were installed within the central portion of the groundwater TCE plume.

In 1999, LLNL installed and began operating a solar-powered portable treatment unit at Building 854 to treat extracted groundwater containing VOCs and nitrate. A second treatment unit was installed in 2000. This treatment unit uses activated carbon and a containerized wetland, a modular, mobile unit that implements phytoremediation technology to treat VOCs, nitrate, and perchlorate.

Treatability studies are being conducted at the Building 854 complex to evaluate the effectiveness of groundwater remediation techniques to achieve source control, to remediate contaminant plumes, and to assess the effect of source control on downgradient groundwater contaminant concentrations. Treatability tests are currently being conducted at facilities in two areas: (1) adjacent to the release site of TCE at Building 854F (B854-SRC), and (2) downgradient and in the middle of the groundwater TCE plume (B854-PRX).

The Building 854 source area groundwater extraction and treatment system (B854-SRC), located adjacent to Building 854F, began operation on December 13, 1999. Groundwater is extracted at a rate of approximately 11 L/min from one well (W-854-02) and treated using an ion exchange unit to remove perchlorate, followed by a solar-powered aqueous-phase granular activated carbon treatment unit (STU) to remove VOCs. Treated water is discharged from misting nozzles that atomize the treated water. The discharge point for this system is located on the hillside west of the treatment facility.

The Building 854 proximal groundwater extraction and treatment system located southeast of Building 854F (B854-PRX) began operation on November 13, 2000. Groundwater is extracted at a rate of approximately 3.8 L/min from one well (W-854-03). The groundwater is treated using a solar-powered aqueous-phase treatment unit to remove VOCs, and a biotreatment unit (BTU) to remove nitrate and potentially perchlorate. An ion exchange unit follows the BTU to ensure perchlorate is removed prior to discharge. The treated

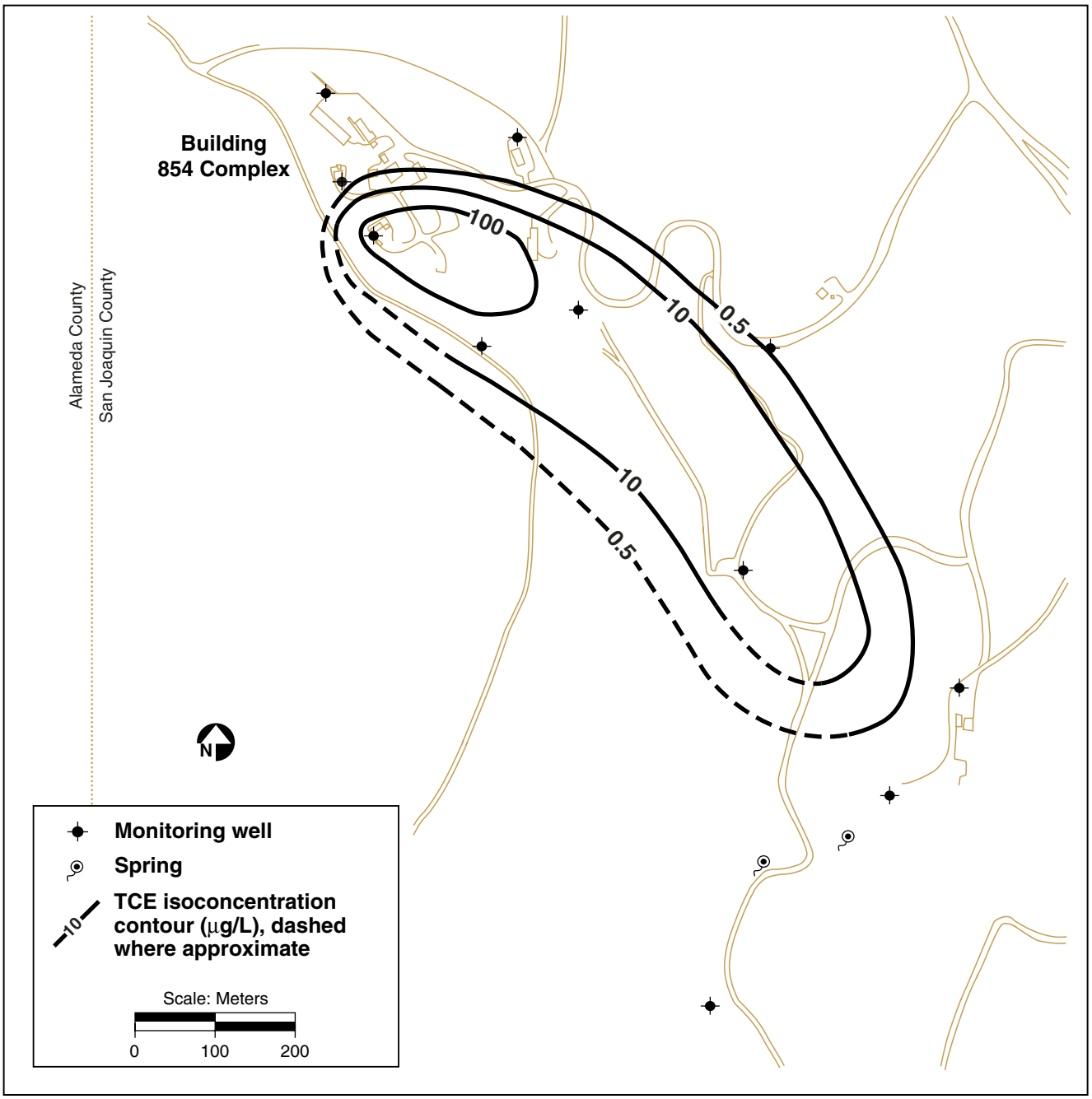


Figure 8-18. Distribution of trichloroethene (TCE) in groundwater in the $Tnbs_1$ aquifer in the Building 854 area (2nd quarter, 2002)

water is discharged to the ground via an infiltration trench located immediately south of the treatment facility. B854-PRX typically operates only a few hours per day based on solar power availability.

During 2002, 3.67 million L of groundwater were treated and discharged at the two treatment systems (**Table 8-6**). A mass of 780 g of VOCs, primarily TCE, was removed from this groundwater. The Building 854 OU discharges were in accordance with the Draft CVRWQCB Substantive Requirements for the Building 832 Canyon and Building 854 OUs. Analytical results from treatment system influent and effluent samples, monthly volumes of water treated and discharged, and total mass of contaminants removed at the two Building 854 OU treatment facilities are presented in quarterly Compliance Monitoring Reports for the Building 832 Canyon and the Building 854 OUs (Lamarre 2002m,n,o,p).

Pit 6 Operable Unit

A low concentration groundwater TCE plume occurs in a shallow water-bearing zone in terrace alluvium (Qt) and in the upper part of underlying $Tnbs_1$ sandstone (**Figure 8-19**).This shallow water-bearing zone occurs at depths of 0 to 25 m below the surface. The source of the TCE plume, which is about 200 m long, is likely the southeast portion of the capped Pit 6 landfill. Concentrations of TCE in the plume have declined fivefold since 1992. The 2002 maximum groundwater TCE concentration was 5.2 µg/L, which is similar to the previous three years. Tritium (**Figure 8-19**) at a maximum activity of 73 Bq/L (1970 pCi/L) and perchlorate at a maximum concentration of 15 µg/L also occur in the shallow water-bearing zone. The length of the tritium plume is 345 m. The length of the perchlorate plume was as much as 175 m in early 2002, but shrank to 60 m by the 4th quarter. While low in activity, the tritium plume is influenced by heavy pumping from off-site Carnegie State Vehicular Recreation Area water-supply wells and is being closely monitored. During 1997, a 2.4-acre engineered cap was constructed over the landfill as a CERCLA non-time-critical removal action.

Building 832 Canyon Operable Unit

At the Building 832 Canyon area (Buildings 830 and 832), solvents were released from weapons component test cells. TCE, perchlorate, and nitrate occur in groundwater primarily in Qal alluvium, and in Neroly Formation sandstone units within $Tnsc_1$ silty-sandstone strata at depths of 15 to 25 m. Groundwater TCE occurred at maximum 2002 concentration of 12,000 µg/L. The TCE plume emanates from both the Building 830 and 832 areas and is about 1400 m long (**Figure 8-20**). Perchlorate has also been detected at a maximum 2002 concentration of 11 µg/L. Nitrate concentrations in groundwater in 2002 reached a maximum of 190 mg/L. Well drilling conducted over the last four years indicates that the TCE contaminant plume emanating from the Building 832 complex is merging with the TCE in groundwater from the Building 830 area. A groundwater and soil vapor extraction and treatment system has been operating to remove contaminant mass at the Building 832 source area. Groundwater is also extracted and treated to remove VOCs, nitrate, and perchlorate at two remediation systems located downgradient of the Building 830 source area.

The *Treatability Study Report for the Building 832 Canyon Operable Unit at Lawrence Livermore National Laboratory Site 300* (Ziagos and Ko 1997) sets forth plans for groundwater and soil vapor TCE extraction and treatment, using portable treatment units, solar-powered water activated-carbon treatment units, and soil vapor extraction systems.

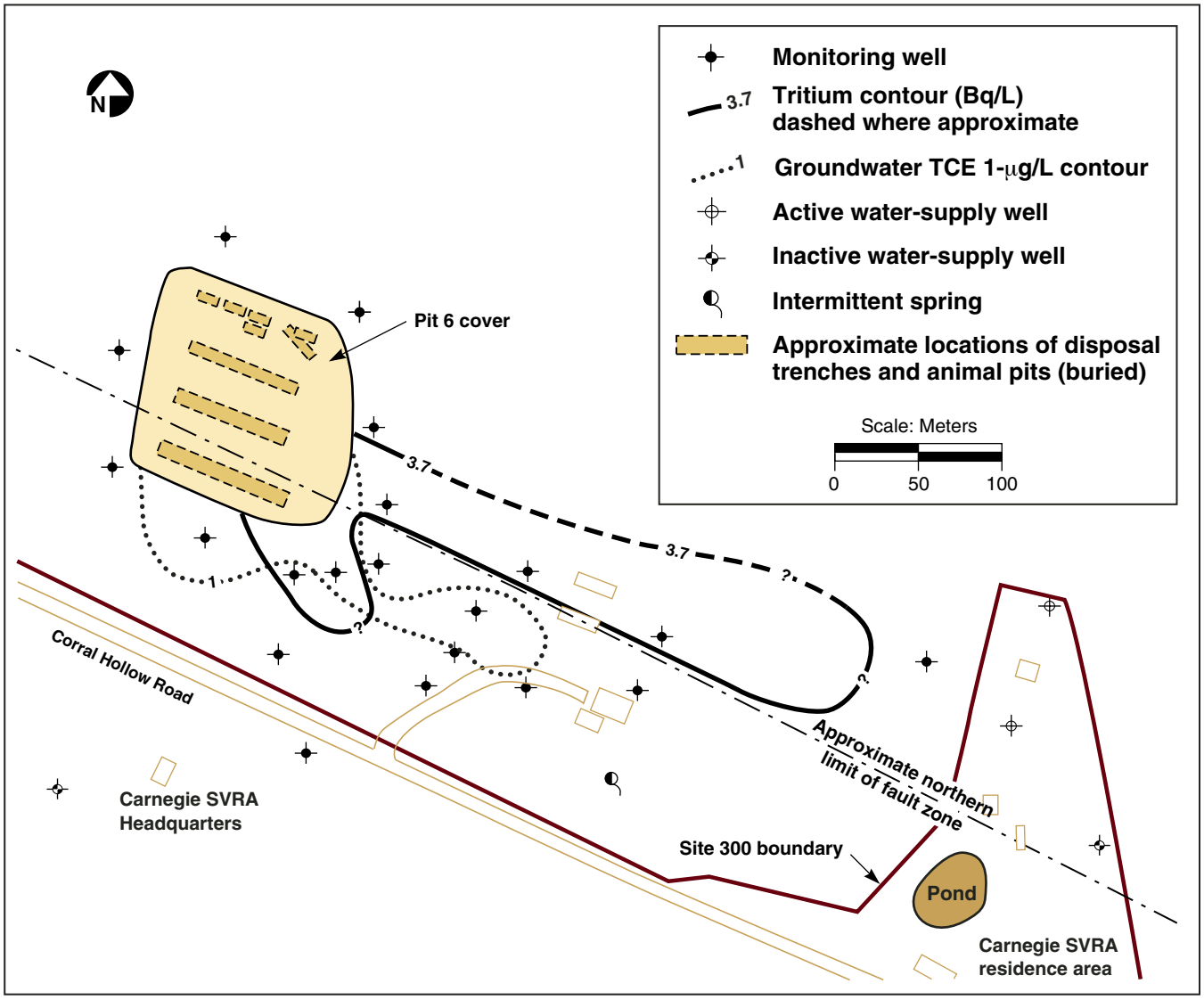


Figure 8-19. Distribution of TCE and tritium in groundwater in the Pit 6 area (4th quarter, 2002)

In 1999, the Building 832 Canyon groundwater and soil vapor treatment system (B832-SRC) began continuous operation. In June 2000, the Building 830 portable groundwater treatment system (B830-PRXN) began operation. This system uses granular activated carbon treatment. An iron filings treatment unit (B830-DISS), located near the mouth of the Building 832 Canyon, was completed and began operation in July 2000. This system also included a containerized wetland unit for the treatment and removal of nitrate. In March 2001, B830-DISS was converted to treat influent water with granular activated carbon and a bioreactor. The waste discharge requirements for these facilities were finalized during 2000. Table 8-6 shows the volume of water treated and the mass of VOCs removed in the treatment systems. The B830-DISS treatment

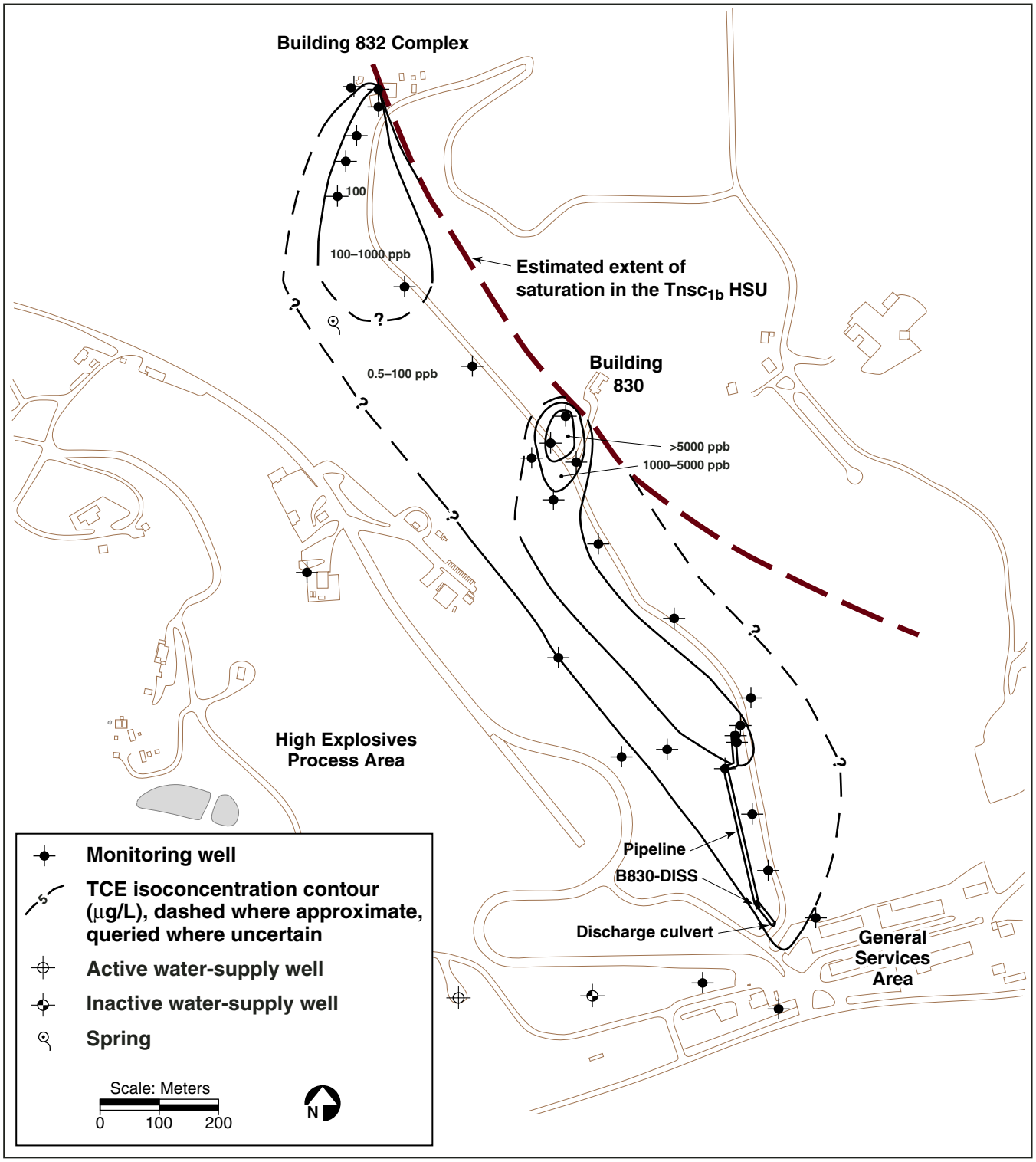


Figure 8-20. Distribution of TCE in groundwater in the Building 832 Canyon (4th quarter, 2002)

facility discharges to surface drainage courses; the B830-PRXN systems discharges to an infiltration trench; and the B830-SRC system discharges to air by misting. The Building 854 OU discharges were in accordance with the Draft CVRWQCB Substantive Requirements for the Building 832 Canyon and Building 854 OUs. Progress of the pump-and-treat systems and groundwater monitoring results are published quarterly (Lamarre 2002a,b,c,d).

Site 300 Operable Unit

The Site 300 OU consists of several small release sites where active remediation is not required, as well as several sites where characterization has yet to be completed. Sites in the OU include Building 801D dry well and Pit 8 Landfill, Building 833, Building 845 firing table and Pit 9 Landfill, Building 851 firing table, Building 812 firing table, Building 865 (Advanced Testing Accelerator), and Sandia Test Site.

VOCs have been detected in groundwater in the vicinity of the Building 801D dry well; however, concentrations are below drinking water standards (< 5 µg/L). Debris from the Building 801 firing table was buried in the Pit 8 Landfill. No contaminants have been detected in groundwater downgradient of the landfill. Groundwater monitoring will continue in this area to monitor the VOC concentrations and to detect any potential releases from the landfill.

Contaminant releases, such as spills and leaching from a disposal lagoon adjacent to Building 833, resulted in VOC contamination of the ephemeral perched water-bearing zone. VOC concentrations have decreased over time and the monitoring of groundwater will continue in this area.

Leaching of contaminants from the Building 845 firing table resulted in the contamination of subsurface soil and rock with depleted uranium, tritium, and HMX. Firing table debris from Building 845 was disposed in the Pit 9 Landfill in the late 1950s and early 1960s. No contamination has been detected in groundwater in the vicinity of the landfill or firing table. Groundwater monitoring will continue in this area to detect any future releases of contaminants from soils under the firing table or the landfill.

Explosive experiments at the Building 851 firing table resulted in the release of low concentrations of metals, RDX, tritium, and uranium to soil. Although isotopic ratios indicative of depleted uranium have been found in groundwater samples from three wells, groundwater has not otherwise been impacted. The maximum 2002 total uranium groundwater activity was 14.06 Bq/L (0.38 pCi/L). Monitoring will continue to evaluate any future impacts to groundwater from soil contaminants.

There are eight monitor wells at Building 812, a firing table where depleted uranium and thorium were used in explosives experiments. The maximum 2002 uranium activity found in groundwater containing depleted uranium is 1136 Bq/L (30.7 pCi/L). Remedial investigation field work, including well drilling and soil and groundwater analysis, will be completed during 2003.

LLNL continues to evaluate the nature and extent of Freon 113 at Building 865 (the closed Advanced Testing Accelerator). Freon 113 was used as a degreasing agent at the facility. Freon 113 was originally discovered in groundwater samples from wells in the Pit 1 monitoring network, downgradient and southeast of Building 865. Maximum Freon 113 concentrations in groundwater in this area are significantly less than the 1.2 mg/L MCL for Freon 113.

From 1959 to 1960, Sandia/California operated a small, temporary firing table in the East Firing Area of Site 300. Future characterization work is planned for this area.

Environmental Impact

This section discusses the environmental impacts of the Livermore site GWP and the Site 300 CERCLA activities.

Livermore Site Ground Water Project

Environmental Impact

In 2002, the decrease in concentrations observed in the Livermore site VOC plumes reflects the 108 kg of VOCs removed by the groundwater extraction wells during the year. The decline in VOC concentrations is primarily attributed to active groundwater extraction and remediation. Notable results of VOC analyses of groundwater received from the third quarter 2001 to the fourth quarter 2002 are discussed below.

VOC concentrations on the western margin of the site either declined or remained unchanged during 2002, indicating continued effective hydraulic control of the western site boundary plumes in the TFA, TFB, and TFC areas. Concentrations in the TFA and TFB source areas increased slightly, however. While the areal extent of the off-site TFA HSU 1B total VOC plume remained largely unchanged in 2002, the entire off-site TFA HSU 2 plume dropped below 50 ppb for the first time. All off-site TFA HSU 3A wells remained below MCLs for all VOCs of concern.

In the TFB area, VOC concentrations were lower in HSU 1B close to Vasco Road, where TCE declined from 23 ppb in 2001 to 14 ppb in 2002. However, Freon 113 concentrations increased in the TFB source area (280 ppb in SIP-141-203 in April 2002, up from 6.5 ppb in May 2001).

In the central to northern TFC area, the lateral extent of HSU 1B total VOC concentrations above 50 ppb decreased significantly. Total VOC concentrations decreased along the western margin of the TFC area where well W-1116 decreased from 26 ppb to 5 ppb TCE in 2002, and well W-1102 decreased from 23 ppb to 5 ppb TCE.

HSU 2 Freon 11 concentrations in the northern TFD area continued to decline in response to pumping at TFD-W. Freon 11 in well W-423 declined from 420 ppb in 2001 to 150 ppb in 2002, and from 83 ppb to 54 ppb in well W-375.

Concentrations began to decline in 2002 in a mobile HSU 2 plume located in the western TFE area in response to pumping at TFE-W. TCE in extraction well W-305 declined from 220 ppb TCE in 2001 to 76 ppb in 2002, while concentrations further downgradient at SIP-331-001, located west of TFE-W, declined from 20 ppb in 2001 to 15 ppb in 2002. The leading edge of this plume should be hydraulically contained once TFG-N, which will be located near well W-1807, is activated in 2003. TCE in the more proximal part of this plume declined in 2002, from 171 ppb to 64 ppb in well W-271 in response to pumping in the source area at TFE-E. Total VOC concentrations in the Old Salvage Yard source area, located near SIP-ETS-601, also known as the TFE Hotspot source area, increased significantly from 521 ppb in 2001 to 1684 ppb in 2002 at SIP-ETS-601. Source area cleanup at the TFE Hotspot source area is scheduled to begin in 2005.

HSU 3A total VOC concentrations continued to decline in the T5475 area in 2002 due to a combination of soil vapor extraction at VTF5475 and regional dewatering of HSU 3A. VOCs in HSUs 3A, 3B, and 4 declined in the south-central TFD area in response to pumping at TFD-S and PTU4. TCE in HSU 3 well W-1504 declined from 400 ppb in 2001 to 180 ppb in 2002, and TCE in

HSU 4 well W-1418 declined from 290 ppb in 2001 to 200 ppb in 2002. HSU 4 TCE concentrations also declined in the southwestern TFE area due to ongoing pumping at TFE-SW. TCE in HSU 4 wells W-354 and W-1520 declined from 83 ppb and 394 ppb in 2001 to 35 ppb and 161 ppb in 2002, respectively.

Significant decreases in HSU 5 VOC concentrations were observed in the TF406 area in 2002 in response to groundwater extraction, particularly at Sandia/California south of East Avenue. TCE in well W-509, positioned at the leading edge of a TCE plume, declined from 27 ppb in 2001 to less than 0.5 ppb in 2002. Closer to TF406, TCE in well W-1112 declined from 31 ppb to 9 ppb over the same period. The relatively rapid cleanup of this area suggests that the TF406 South facility proposed for 2006 may not be needed to achieve timely cleanup.

During 2002, tritium activities in groundwater from all wells in the T5475 area remained below the MCL and continued to decrease by natural decay. Only one well, UP-292-007, located north of TFC-E, remains slightly above the 741 Bq/L (20,000 pCi/L) MCL in the Building 292 area (763 Bq/L [20,600 pCi/L] in October 2002).

Site 300 CERCLA Activities

Influent TCE concentrations to the eastern GSA OU were reduced from 64 µg/L in January 1992 to 2.2 µg/L in December 2002. No longer do any off-site wells in the eastern GSA yield groundwater TCE concentrations in excess of the cleanup standards (MCL) of 5 µg/L. LLNL estimates that two more years of groundwater extraction and treatment will be required to achieve and maintain groundwater VOC concentrations below MCLs at the eastern GSA.

TCE concentrations in the central GSA OU influent have been reduced from 9400 µg/L in 1993 to 153 µg/L in December 2002. From 1994 through the end of 2002, total VOC concentrations in the central GSA soil vapor extraction influent stream were reduced from 450 mg/L to 3.9 mg/L. VOC concentrations in the central GSA soil vapor extraction influent stream were reduced from 450 mg/L to 6.3 mg/L. VOC concentrations in individual central GSA soil vapor extraction wells have also been significantly reduced.

Because of mostly decreased operation at the Building 834 OU in 2002, overall mass removal was down about 89% from the previous year. However, additional VOC mass was destroyed during 2002 through in situ bioremediation although this mass was not quantified.

LLNL proceeded to implement the next phase of the High Explosives Process Area OU remedial strategy; to develop an RI/FS for the Pits 3 and 5 portion of the Building 850 OU; and to define the extent of groundwater contamination at the Building 854 OU.

At the Pit 6 OU, maximum TCE concentrations are similar to the previous three years. By the end of the year, the length of the perchlorate plume was a third the size it was at the beginning of the year. In 2002, maximum contaminant concentrations at the Building 832 Canyon OU were less than or similar to those for 2001.

Contributing Authors Acknowledgment

Many authors significantly contributed to this chapter. We acknowledge here the work of Bill Daily, Valerie Dibley, Steve Gregory, Victor Madrid, and Stephen vonder Haar.