Chapter 7

Groundwater Protection

The Groundwater Protection Management Program is made up of four elements: prevention, monitoring, restoration, and communication. BNL is implementing aggressive pollution prevention measures to protect groundwater resources. An extensive groundwater monitoring well network is used to verify that prevention and restoration activities are effective. In 2001, BNL collected groundwater samples from 714 monitoring wells during 2,739 individual sampling events. Six volatile organic compound plumes and eight radionuclide plumes were tracked. Recent characterization work at the Brookhaven Graphite Research Reactor detected higher than expected strontium-90 contamination in the shallow groundwater beneath the reactor's belowground ducts. This legacy contamination is being addressed as part of the cleanup program. During 2001, six groundwater remediation systems removed approximately 609 pounds of volatile organic compounds and returned more than one billion gallons of treated water to the Upper Glacial aquifer.

7.1 THE BNL GROUNDWATER PROTECTION MANAGEMENT PROGRAM

U.S. Department of Energy Order 5400.1 (DOE 1988), *General Environmental Protection Program,* requires development and implementation of a groundwater protection program. The primary goal of the BNL Groundwater Protection Management Program is to ensure that plans for groundwater protection, management, monitoring, and restoration are fully defined, integrated, and managed in a cost-effective manner that is consistent with federal, state, and local regulations. This program is described in the *BNL Groundwater Protection Management Program Description* document (Paquette *et al.* 1998). The BNL Groundwater Protection Program consists of four interconnecting elements: 1) preventing pollution of the groundwater, 2) monitoring the effectiveness of engineered and administrative controls at operating facilities and groundwater treatment systems, 3) restoration of the environment by cleaning up contaminated soil and groundwater, and 4) communicating with interested parties on groundwater protection issues (Figure 7-1). BNL is committed to protecting groundwater resources from further chemical and radionuclide releases, and remediating existing contaminated groundwater.

Figure 7-1. BNL's Groundwater Protection Program.

7.1.1 Prevention

BNL has conducted a three-phased project to prevent further groundwater contamination. The first phase was to identify past or current activities with the potential to affect groundwater quality. This effort resulted in the implementation of operational and engineered controls at potential source areas and the installation of nearly 85 new monitoring wells to confirm that these controls are working. The second phase resulted in a Laboratory-wide review of all experiments and industrial-type operations to determine the potential impacts of those activities on the environment and to integrate Pollution Prevention/Waste Minimization, Resource Conservation, and Compliance into planning, decision making, and implementation. Finally, phase three was to develop and implement an Environmental Management System (EMS), which was finalized when BNL received ISO 14001 certification in 2001. The continuous improvement aspects of the EMS and ongoing reviews are designed to prevent further pollution of the sole source aquifer underlying the BNL site and are described in Chapter 2. In addition, as described in Chapter 3, efforts are being made to achieve or maintain compliance with regulatory requirements and to implement best management practices designed to protect groundwater. Examples include upgrading underground storage tanks (USTs), closing cesspools, adding engineered controls (*e.g.*, barriers to prevent rainwater infiltration that could move contaminants out of the soil and into groundwater), and administrative controls (*e.g.*, reducing the toxicity and volume of chemicals in use or storage).

7.1.2 Monitoring

BNL's groundwater monitoring network is designed to evaluate the impacts of groundwater contamination from historical and current operations and to track cleanup progress. Groundwater monitoring is a means of verifying that protection and restoration efforts are working. Groundwater monitoring is focused in two general areas: 1) Environmental Surveillance (ES), designed to satisfy DOE and New York

State monitoring requirements for active research and support facilities, and 2) Environmental Restoration (ER) monitoring related to BNL's obligations under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). This monitoring is coordinated to ensure completeness and to prevent any duplication of effort in the installation, monitoring, and abandonment of wells. Furthermore, the monitoring program elements have been integrated, including the data quality objectives, plans and procedures, sampling and analysis, quality assurance, data management, and installation, maintenance, and abandonment of wells. This integration was done in order to create a cost-effective monitoring system and to ensure that water quality data are available for review and interpretation in a timely manner.

7.1.3 Restoration

BNL was added to the National Priorities List in 1989 (see Chapter 2 for a discussion of BNL's ER Program). The restoration effort was organized into 30 Areas of Concern (AOC), which were grouped into six Operable Units (OU); see Figure 2-11. Remedial Investigation/ Feasibility Studies have been conducted for each OU, and the focus is now on designing and implementing cleanup systems. Contaminant sources (*e.g*., contaminated soil, underground storage tanks, and decommissioned reactor facilities) are being removed or remediated to prevent further contamination of groundwater. All remediation work is carried out under the Interagency Agreement involving EPA, the New York State Department of Environmental Conservation (NYSDEC), and DOE.

7.1.4 Communication

BNL's Community Education, Government and Public Affairs Program ensures that BNL communicates with the community in a consistent, timely, and accurate manner. A number of communication mechanisms are in place, such as web pages, mailings, public meetings, briefings, and roundtable discussions. Specific examples include the Community Advisory Council and the Brookhaven Executive Roundtable. Technical reports summarizing data, evaluations, and program indices are prepared annually. In addition, BNL has developed a *Groundwater Protection Contingency Plan* (BNL 2000b) that provides a formal process to communicate off-normal or unusual monitoring results to BNL's management, DOE, regulatory agencies, and other stakeholders in a timely manner.

7.2 GROUNDWATER PROTECTION PERFORMANCE

Since 1998, the BNL Groundwater Protection Management Program has been tracking progress toward eliminating new contamination of the aquifer system. The Laboratory has made significant investments in environmental and groundwater protection since 1998 and is making real progress in achieving its goal of preventing any new groundwater impacts. A "new" groundwater impact is defined as the detection of unusual or off-normal groundwater monitoring results. BNL is currently in a transition period, and it is expected to take several more years before the recent investments in environmental and groundwater protection allow BNL to reach its "zero" groundwater impact goal. The *Groundwater Protection Contingency Plan* (BNL 2000b) is designed to ensure that appropriate and timely actions are taken if unusual or off-normal results are observed. The contingency plan provides guidelines for evaluating the source of the problem, notifying stakeholders, and implementing appropriate corrective actions.

From 1998 through 2001, BNL installed several hundred permanent and temporary monitoring wells as a result of a comprehensive evaluation of known or potential contaminant source areas. Using this enhanced monitoring system, BNL has identified ten new groundwater impacts (Figure 7-2). It is important to note, however, that five of the ten identified impacts were determined to be from historical (or "legacy") contaminant releases. These newly discovered legacy issues include low-level petroleum hydrocarbon contamination in groundwater near the BNL Service Station, tritium near the former U-Line target area at the AGS, 1,1,1-trichloroethane (TCA) near Building 830 and the BNL Motor Pool, and higher than expected strontium-90 contamination at the BGRR beneath the belowground ducts.

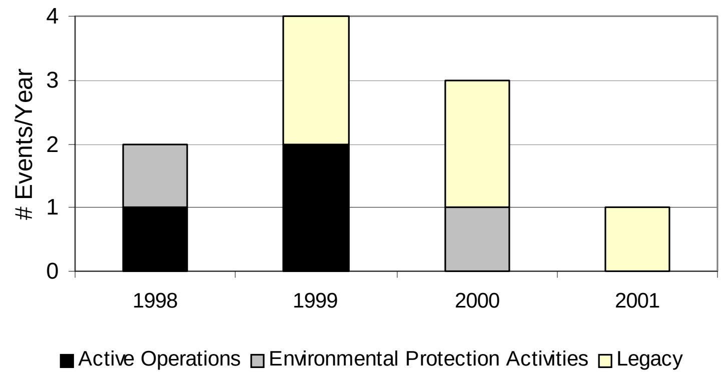

Figure 7-2. Groundwater Protection Performance during 2001.

The five remaining cases are related to active science operations and environmental protection activities. Three small tritium plumes that originated from active experimental areas at the AGS (the g-2 and E-20 Catcher areas) and the BLIP facility were discovered in 1998 and 1999. Activities associated with the Laboratory's environmental protection programs resulted in two new groundwater impacts. One was the inadvertent release of carbon tetrachloride during the removal of an underground storage tank, and the second was caused by an unexpected displacement of tritium during an innovative grout injection process designed to protect groundwater quality by stabilizing activated soils at the BLIP facility. In all ten cases, BNL thoroughly investigated the cause of the contamination and took corrective actions as necessary to eliminate or limit the scale of these impacts.

BNL will continue efforts to prevent new groundwater impacts, and is vigilant in measuring and communicating its performance.

7.3 GROUNDWATER MONITORING

Groundwater Monitoring Program elements include installing monitoring wells; planning and scheduling; developing and following quality assurance measures; collecting (see Figure 7-3) and analyzing samples; verifying, validating, and interpreting data; and reporting. Monitoring wells

Figure 7-3. Sampling a Groundwater Monitoring Well.

(which are not used for the drinking water supply) are used to evaluate BNL's progress in restoring groundwater quality, to comply with regulatory permit requirements, to monitor active research and support facilities, to assess the quality of groundwater entering and leaving the BNL site, and to ensure that corrective measures designed to protect and restore groundwater are, in fact, working as planned.

BNL monitors research and support facilities where there is a potential for environmental impact and in areas where past waste handling practices or accidental spills have already degraded groundwater quality. The groundwater beneath the BNL site is classified by New York State as Class GA groundwater, defined as a source of potable water supply and suitable for drinking. Federal drinking water standards, New York State Drinking Water Standards (NYS DWS), and New York State Ambient Water Quality Standards (NYS AWQS) for Class GA groundwater are used as groundwater protection and remediation goals. BNL evaluates the potential impact of radiological and nonradiological levels of contamination by comparing analytical results to New York State and DOE reference levels and background water quality levels. Nonradiological analytical results from groundwater samples collected from surveillance wells are usually compared to NYS AWQS. Radiological data are compared to NYS DWS (for tritium, gross beta, and strontium-90), NYS AWQS (for gross alpha and radium-226/228), and Safe Drinking Water Act (SDWA)/DOE Derived Concentration Guides (for determining the 4 mrem dose for other beta/gamma-emitting radionuclides). Contaminant concentrations that are below these standards are also compared to background values to evaluate the potential effects from facility operations. The detection of low concentrations of facility-specific volatile organic compounds (VOCs) or radionuclides may provide important early indications of a contaminant release and allow for timely identification and remediation of the source.

Groundwater quality at BNL is routinely monitored through a network of approximately 714 on-site and off-site surveillance wells (see Figure 7-4). In addition to water quality assessments, water levels are routinely measured in more than 875 on-site and off-site wells to assess variations in directions and velocities of groundwater flow. Groundwater flow directions in the vicinity of BNL are shown on Figure 7-5.

Active and inactive facilities that have groundwater monitoring programs include the Sewage Treatment Plant/Peconic River area, Biology Agricultural Fields, Former Hazardous Waste Management Facility (HWMF), new Waste Management Facility (WMF), two former landfill areas, Central Steam Facility/Major Petroleum Facility (CSF/MPF), Alternating Gradient Synchrotron (AGS), Waste Concentration Facility (WCF), Supply and Material, and several other smaller facilities. As the result of detailed groundwater investigations conducted over the past fifteen years, six significant VOC plumes and eight radionuclide plumes have been identified (Figures 7-6 and 7-7).

7.4 SUPPLEMENTAL MONITORING OF POTABLE AND PROCESS SUPPLY WELLS

As discussed in Chapter 3, BNL is a public water purveyor and maintains water supply wells and associated treatment facilities for the distribution of potable water on the site. The BNL potable and cooling water supply well network consists of six supply wells (wells 4, 6, 7, 10, 11, and 12). Supply well 9 supplies process water to a facility where biological research on fish is conducted. Supply well 105 supplied cooling water to the Brookhaven Medical Research Reactor (BMRR) facility for the first six months of 2001. Because the BMRR is permanently shutdown, well 105 will be sealed in 2002. The locations of the supply wells are shown on Figure 7-5.

The quality of the BNL potable water supply is monitored as required by the Safe Drinking Water Act (SDWA), and the analytical results are reported to the Suffolk County Department of Health Services. As required by the SDWA, BNL also prepares an annual *Water Quality Consumer Confidence Report* (BNL 2002a) that is distributed to all employees and guests.

Groundwater quality is routinely monitored at all active water supply wells. All supply wells are screened within the Upper Glacial aquifer. Because of the proximity of BNL's potable

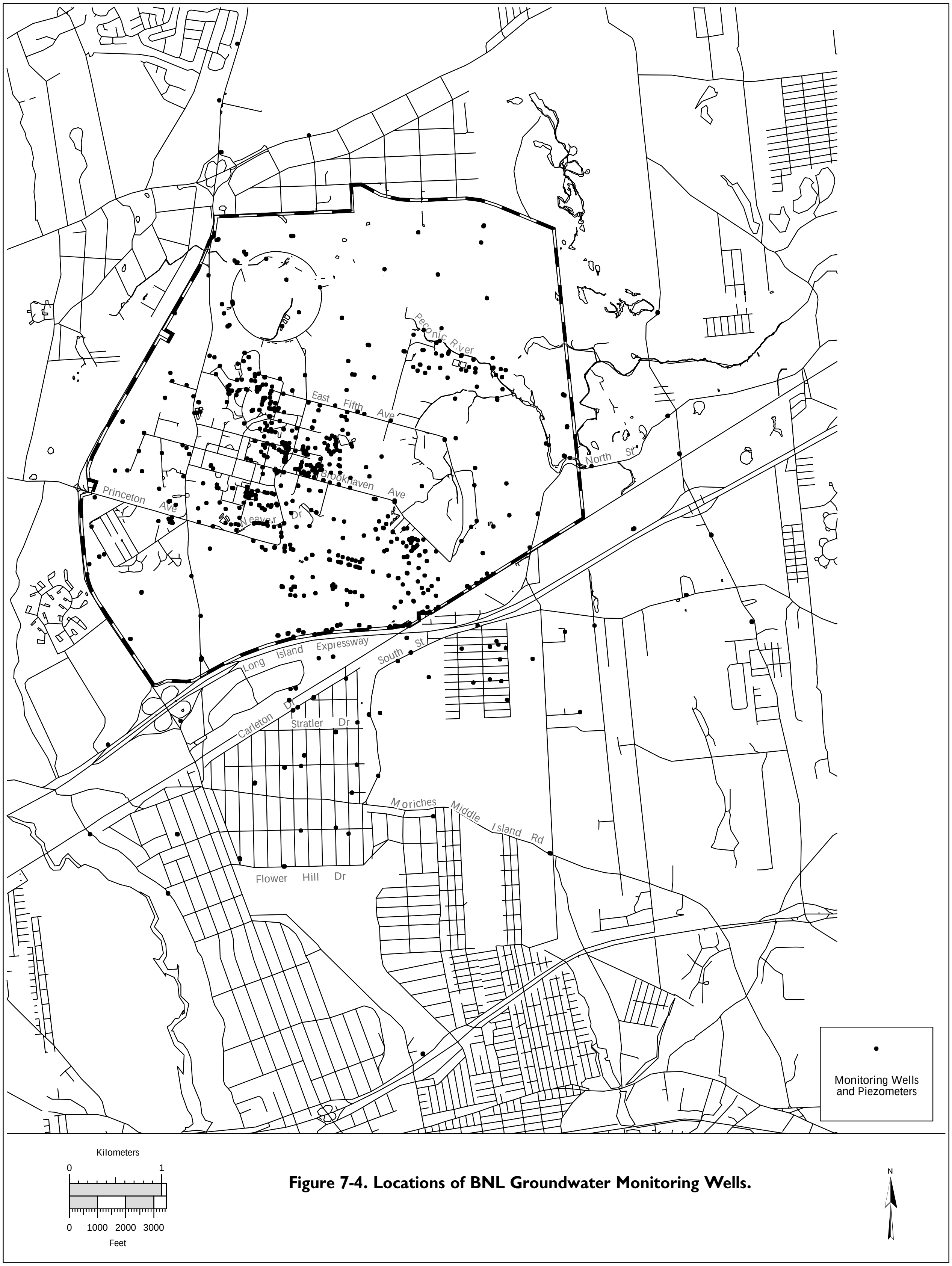

Figure 7-4. Locations of BNL Groundwater Monitoring Wells.

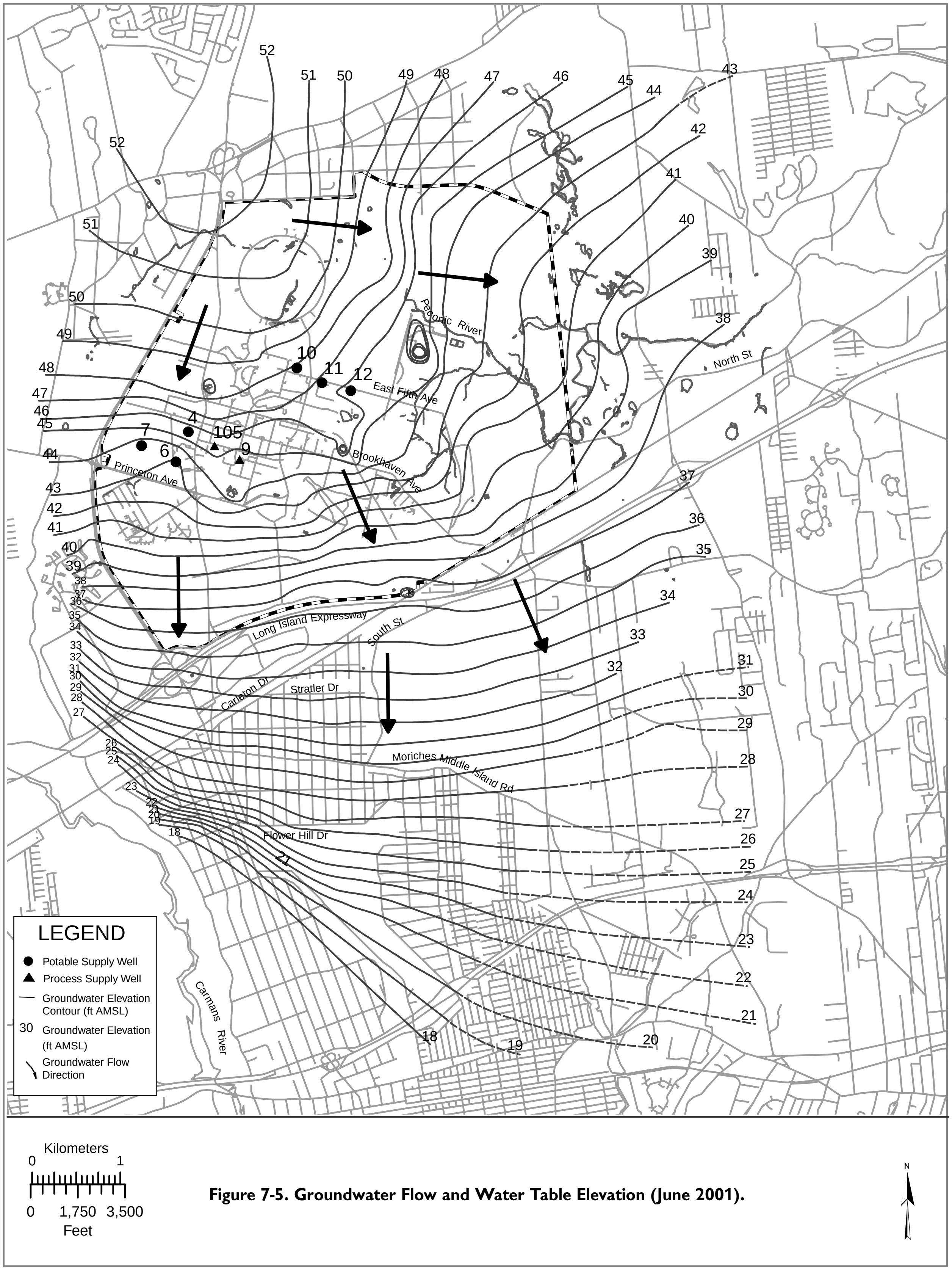

Figure 7-5. Groundwater Flow and Water Table Elevation (June 2001).

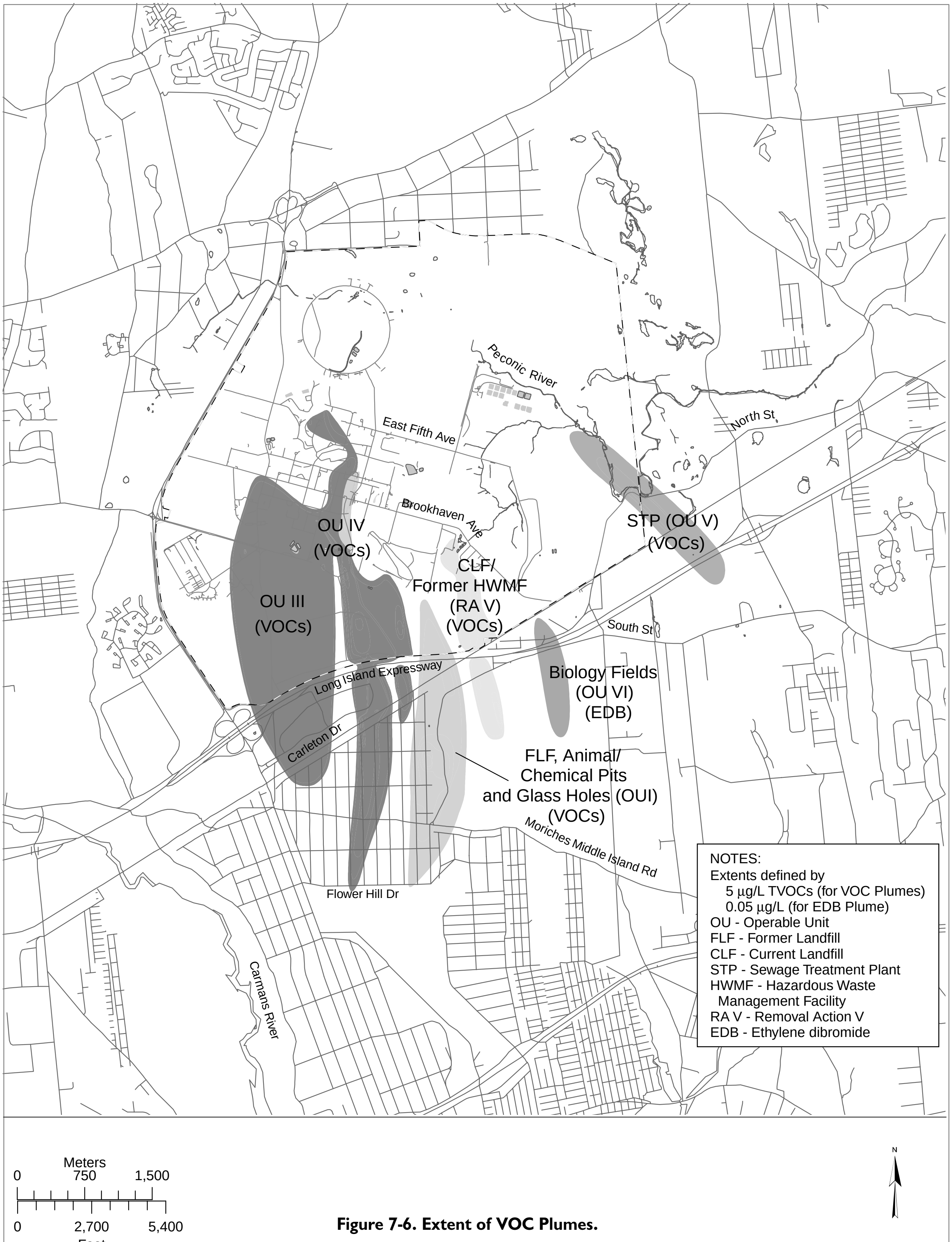

Figure 7-6. Extent of VOC Plumes.

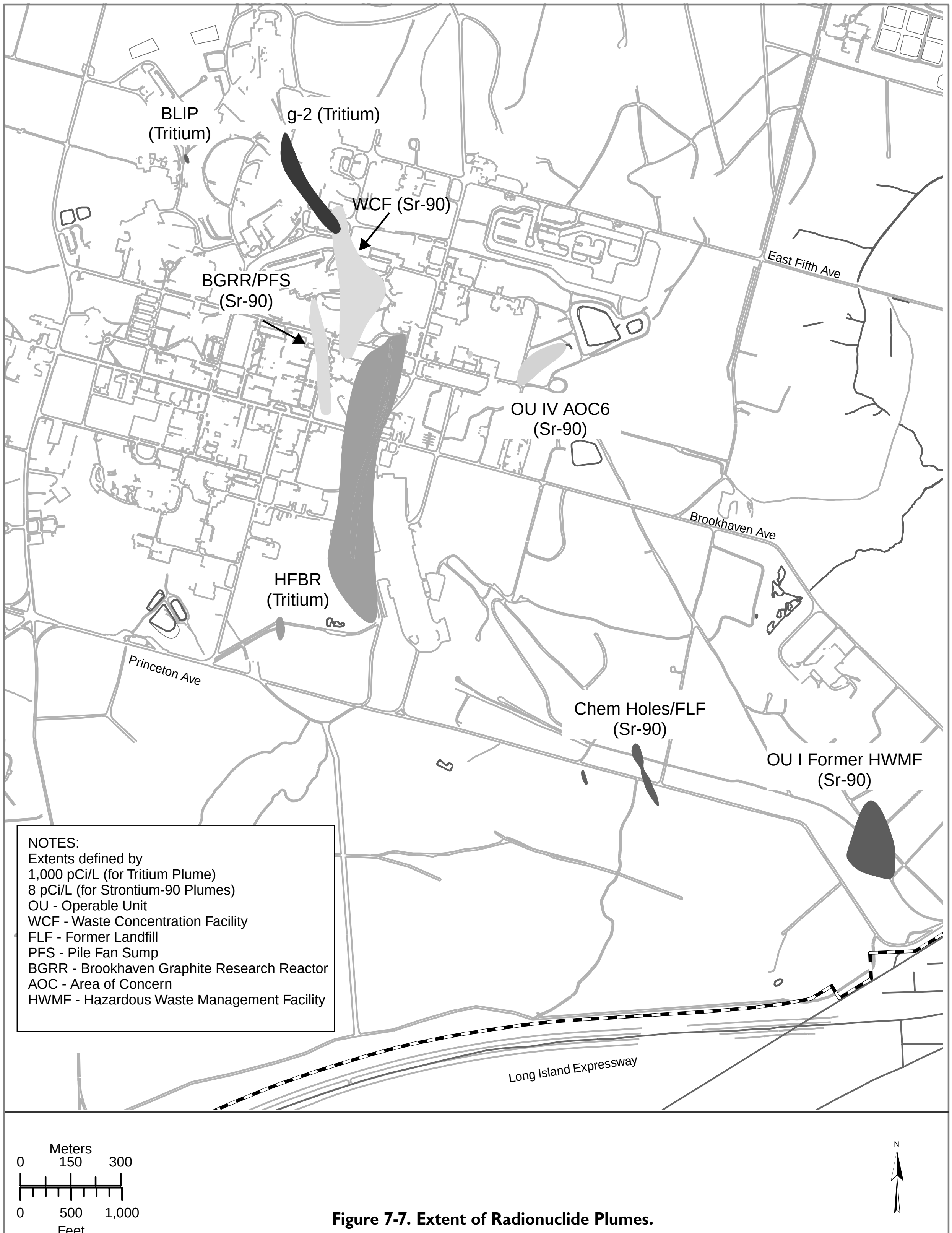

Figure 7-7. Extent of Radionuclide Plumes.

supply wells to known or suspected groundwater contamination plumes and source areas, BNL conducts a supplemental potable supply well monitoring program. Results of the SWDA-required monitoring are described in Chapter 3. Supplemental monitoring of the potable and process supply wells in 2001 included VOCs and radiological parameters. During 2001, the BNL potable water system fully complied with all drinking water requirements. To better understand the geographical source of BNL's drinking water and to identify potential sources of contamination within these geographical areas, BNL prepared the report titled *Source Water Assessment for Drinking Water Supply Wells* (Bennett *et al*. 2000). The source water assessment is designed to serve as a management tool in further protecting the sole source aquifer system underlying the BNL site.

7.4.1 Radiological Results

Potable well water was sampled and analyzed for gross alpha and gross beta activity, tritium, and strontium-90; the results are listed in Table 7-1. In addition, tap water samples were collected daily from Building 490 (the Analytical Services Laboratory) and analyzed for gross alpha and beta activity and tritium. Nuclide-specific gamma spectroscopy was also performed for potable well samples, supplementing the requirements of the SDWA, which does not require this analysis unless gross beta activity exceeds 50 pCi/L. Average gross activity and tritium levels in the potable water wells were

Table 7-1. Potable and Process Well Radiological Analytical Results.

Potable Well ID[(a)]		Gross Alpha (pCi/L)	Gross Beta (pCi/L)	Tritium (pCi/L)	Sr-90 (pCi/L)
4 (FD)	Value	< 0.8	< 2.2	< 315	< 0.8
6 (FF)	N	4	4	4	4
	Max.	1.7 ± 0.6	3.0 ± 1.4	< 306	< 0.8
	Avg.	0.6 ± 0.6	0.8 ± 1.5	-17 ± 27	< 0.8
7 (FG)	N	5	5	5	5
	Max.	1.4 ± 0.6	1.8 ± 1.2	< 315	< 0.8
	Avg.	0.8 ± 0.5	1.2 ± 0.4	-62 ± 83	< 0.8
11 (FP)	N	4	4	4	4
	Max.	< 0.8	< 2.2	< 300	< 0.8
	Avg.	0.1 ± 0.3	0.8 ± 0.6	54 ± 38	< 0.8
12 (FQ)	N	7	7	7	7
	Max.	2.5 ± 0.7	3.1 ± 1.5	< 315	< 0.8
	Avg.	0.4 ± 0.8	1.9 ± 0.5	69 ± 65	< 0.8
Tap Water[(b)]	N	243	243	243	NS
Bldg 490	Max.	8.4 ± 3.1	13.0 ± 5.5	394 ± 230	
(FN)	Avg.	2.4 ± 0.2	3.6 ± 0.4	-5 ± 15	
SDWA Limit		15[(c)]	50[(d)]	20,000	8

Notes:
See Figure 7-5 for well locations.
All values shown with 95% confidence interval.
No anthropogenic gamma-emitting radionuclides were detected in samples collected from these wells in 2001
N = Number of samples collected.
NS = Not sampled for this analyte.
[(a)]Historic ID shown in parentheses.
[(b)]The gross activity values for FN are elevated compared with the other potable wells due to differences in the analytical procedure (smaller sample volumes and shorter counting times) used to obtain the activity values.
[(c)]Excluding radon and uranium.
[(d)]Screening level above which analysis for individual radionuclides is required.
Potable Well #10 was shut down and therefore not sampled during 2001 due to its possible effect on a nearby groundwater tritium plume.

consistent with those of typical background water samples. Neither strontium-90 nor any man-made gamma-emitting radionuclides were observed above the minimum detection limit (MDL) in any of the potable water samples.

7.4.2 Nonradiological Results

Samples collected from supply wells 6, 7, 11, and 12 were analyzed for VOCs following EPA Standard Method 624. (Note: Well 4 was out of service during 2001. Well 10 was used infrequently during 2001, and was only sampled under the compliance monitoring program described in Chapter 3.) This method tests for 38 organic compounds, including halogenated and aromatic hydrocarbons. The only parameter detected above the MDL was chloroform, found once during the year in both wells 7 and 12 at trace levels (< 2 µg/L). The chloroform concentrations were below the ambient water quality standard of 7 µg/L and well below the drinking water standard of 80 µg/L.

7.5 ENVIRONMENTAL SURVEILLANCE PROGRAM

BNL's Environmental Surveillance Program includes groundwater monitoring at active research facilities (*e.g*., research reactor areas, accelerator beam stop and target areas, greenhouse areas) and support facilities (*e.g*., fuel storage facilities and water treatment facilities). During 2001, 120 groundwater surveillance wells were monitored during 350 individual sampling events. All wells sampled during 2001 are listed in Appendix E. Results for these programs are summarized below. For detailed descriptions and maps related to groundwater monitoring in the Environmental Surveillance Monitoring Program, refer to the *2001 BNL Groundwater Status Report* (BNL 2002b).

7.5.1 Research Facilities

7.5.1.1 Alternating Gradient Synchrotron Complex

Activated soils have been created near a number of Alternating Gradient Synchrotron experimental areas as the result of secondary particles (primarily neutrons) produced at beam targets and beam stops. Radionuclides, such as tritium and sodium-22, have been produced by the interaction of these secondary particles with the soils that surround the experimental areas. Furthermore, historical surface spills and discharges of solvents to cesspools and recharge basins near the AGS have contaminated soils and groundwater with VOCs. VOC contamination is monitored under the ER Program's OU III Central Areas Project (see Section 7.6.3).

During 2001, 44 groundwater wells were monitored to evaluate groundwater quality near potential soil activation areas within the AGS Complex (*e.g*., Building 912, AGS Booster Beam Stop, 914 Transfer Tunnel, g-2 experimental area, E-20 Catcher, former U-Line Target, and the new J-10 Beam Stop). Following the installation of thirty-nine new wells in the AGS area during 1999–2000, BNL detected three tritium plumes (*i.e*., groundwater with tritium concentrations greater than the drinking water standard of 20,000 pCi/L). These plumes originated from activated soil shielding at the g-2 experimental area, the former U-Line area, and the Former E-20 Catcher region of the AGS Complex (see Figure 7-8). Following these discoveries, BNL installed impermeable caps over the soil activation areas to prevent rainwater from infiltrating the soil and leaching tritium into the groundwater. Monitoring conducted during 2001 showed that these caps have effectively reduced tritium concentrations to below the drinking water standard at the former U-Line and former E-20 Catcher areas. However, tritium continues to be detected at concentrations above the drinking water standard downgradient of the g-2 and BLIP facilities (Figure 7-8).

g-2 Experimental Area. In November 1999, monitoring wells approximately 250 feet downgradient of the g-2 experimental area detected the presence of tritium and sodium-22 in groundwater. A sample from well 054-67 collected in October 1999 had a tritium concentration of 41,700 pCi/L. A groundwater investigation conducted during November and December 1999 revealed a narrow tritium plume of approximately 20 to 30 feet wide and 250 to 300 feet long (see plume map presented

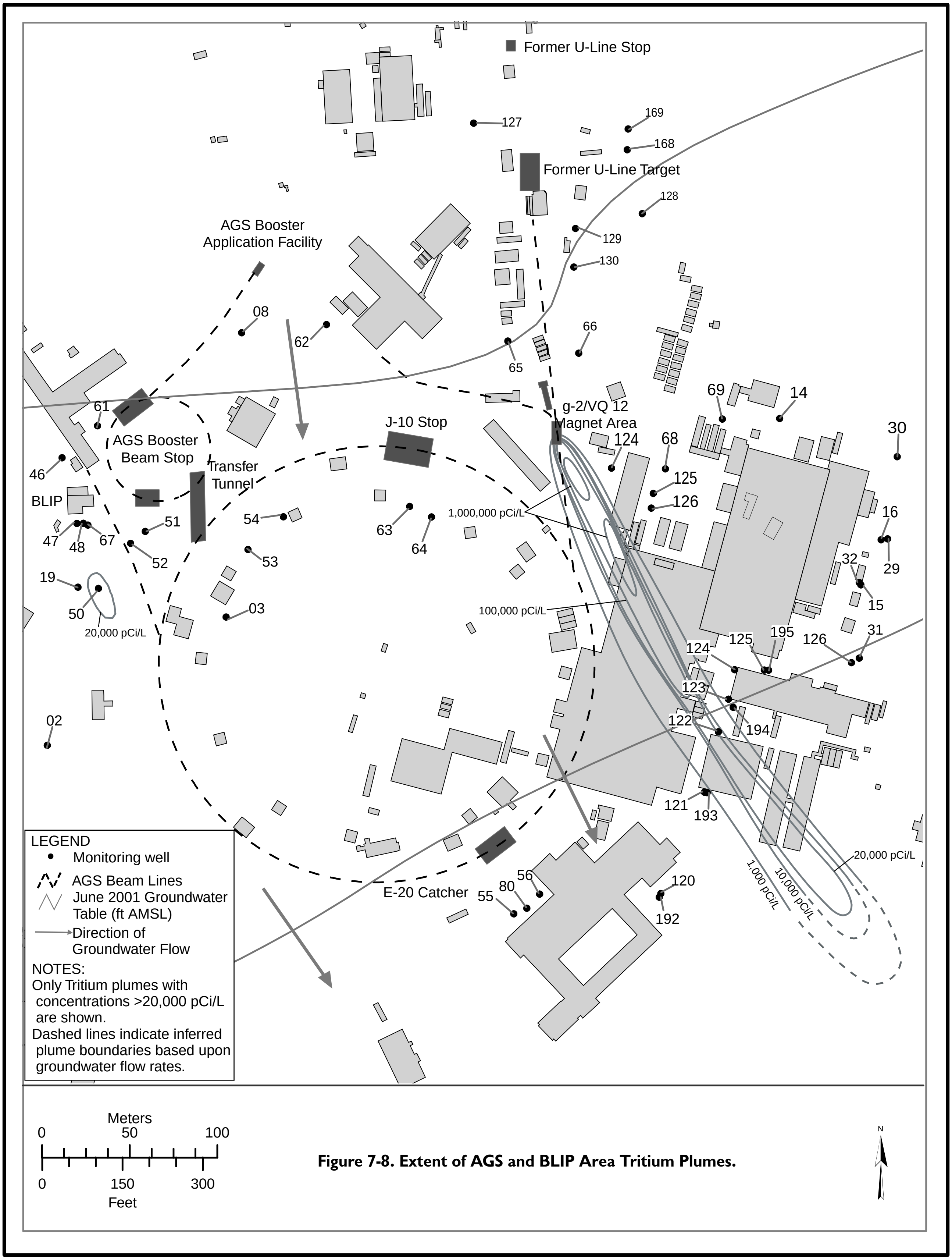

Figure 7-8. Extent of AGS and BLIP Area Tritium Plumes.

in BNL 2000a). The maximum radionuclide concentrations were detected in temporary well 054-116, approximately 70 feet downgradient of the g-2 beam line, with a tritium concentration of 1,800,000 pCi/L and sodium-22 concentration of 60 pCi/L. (Note: The drinking water standard for sodium-22 is 400 pCi/L.)

Following this discovery, an investigation into the source of the contamination revealed that the tritium originated from activated soil shielding adjacent to the g-2 experiment's VQ-12 Magnet. In December 1999, an impermeable Gunite™ cap was installed over the soil activation area to prevent rainwater infiltration and the continued leaching of radionuclides out of the soil and into the groundwater. In September 2000, the activated soil shielding and the associated tritium plume were designated as "Sub-Area of Concern 16T." Following this designation, DOE agreed to prepare an Engineering Evaluation/Cost Analysis (EE/CA) to evaluate the adequacy of the corrective actions taken to date, and the need for further actions. During 2001, BNL conducted additional characterization work designed to obtain the necessary plume concentration and position data required to prepare the EE/CA.

In February 2001, BNL installed eight temporary wells to monitor this plume. The effort focused on two main areas, the area just west of Building 912A and the area just east of Building 912. The results from the temporary well samples taken west of Building 912A indicated tritium concentrations up to 170,000 pCi/L. The results from the temporary well samples collected east of Building 912 indicated tritium concentrations up to 67,500 pCi/L. Based on these results, the leading edge of the g-2 tritium plume was found to be situated east of Building 912, positioned entirely within the shallow portion of the Upper Glacial aquifer. Anticipating that higher levels of tritium would eventually migrate to the east of Building 912, BNL obtained regulatory agency concurrence that an additional year of monitoring was required before the EE/CA can be finalized.

In November 2001, BNL installed nine additional temporary wells. The effort again focused on the same areas west of Building 912A and east of Building 912. The results from the temporary well samples taken west of Building 912A indicated tritium concentrations up to 1,820,000 pCi/L. The results from the temporary well samples collected east of Building 912 indicated that the leading edge of the g-2 tritium plume was now approximately 100 feet southwest of the WCF, a distance of approximately 1,000 feet from the VQ-12 source area (Figure 7-8). Tritium concentrations up to 79,500 pCi/L were observed in a temporary well installed directly east of Building 912, and tritium concentrations up to 25,500 pCi/L were detected in a temporary well approximately 100 feet southwest of the WCF. Based on these findings, BNL installed three additional permanent monitoring wells near Building 912A to allow for improved long-term monitoring of the source area. The evaluation of various control/cleanup options for this plume will be completed by early 2003.

Former E-20 Catcher. During 1999–2000, tritium and sodium-22 were detected at concentrations above their applicable drinking water standards in wells approximately 100 feet downgradient of the former E-20 Catcher. The location of the E-20 Catcher is shown in Figure 7-8. The highest levels of tritium (40,400 pCi/L) and sodium-22 (704 pCi/L) were found in temporary well 064-65. In April 2000, a temporary impermeable cap was installed over the E-20 Catcher soil activation area to prevent rainwater infiltration and the continued leaching of radionuclides out of the soils and into groundwater. A permanent cap was constructed by October 2000.

During 2001, all tritium and sodium-22 concentrations were found to be well below drinking water standards, with a maximum tritium concentration of 2,070 pCi/L and a maximum sodium-22 concentration of 163 pCi/L. The reduction in tritium and sodium-22 concentrations since the impermeable cap was constructed indicates that the cap has been effective in preventing additional rainwater infiltration into the activated soils that surround that portion of the AGS tunnel.

Former U-Line Target and Stop Areas. In 1999, BNL installed new monitoring wells downgradient of the former U-Line target area to evaluate whether residual activated soil shielding was affecting groundwater quality. The locations of the former U-Line target and beam stop areas are shown on Figure 7-8. Subsequent monitoring found low levels of tritium and sodium-22, but at concentrations well below the applicable drinking water standards. In early 2000, BNL installed four Geoprobe™ wells downgradient of the former U-Line beam stop, which is approximately 200 feet north of the target area. Tritium was detected at concentrations up to 71,600 pCi/L. Sodium-22 was not detected in any of the samples. In May 2000, a temporary impermeable cap was installed over the U-Line stop soil activation area. By October 2000, a permanent cap was constructed and two additional permanent wells were installed to provide improved long-term monitoring of this source area.

During 2001, low levels of tritium and sodium-22 continued to be detected in wells downgradient of the former U-Line target and stop areas, but at concentrations below drinking water standards. The highest tritium concentration during 2001 was detected approximately 400 feet downgradient of the stop area, in well 054-128 (6,330 pCi/L). The highest sodium-22 concentration was detected approximately 550 feet downgradient of the target area, in well 054-69 (26.6 pCi/L). Low-level contamination from the former U-Line area reaches to well 055-32, approximately 1,000 feet downgradient of the target area. There, the maximum tritium and sodium-22 concentrations were 3,820 pCi/L and 7.5 pCi/L, respectively. As noted earlier, the low levels of tritium and sodium-22 detected in two of the nearby g-2 beam stop monitoring wells (054-67 and 054-68) are likely to have originated from the former U-Line target area.

Although low levels of tritium and sodium-22 continue to be detected in groundwater downgradient of the former U-Line target, these concentrations are well below drinking water standards. Furthermore, the significant decrease in tritium concentrations since 2000 indicates that the impermeable cap has been effective in stopping rainwater infiltration into the residual activated soils surrounding the beam stop.

7.5.1.2 Brookhaven Linac Isotope Producer (BLIP)

The BLIP facility is at the southern end of the Linac (Figure 7-8). When the BLIP is operating, the Linac delivers a beam of protons that impinges on a series of eight targets within the BLIP target vessel. During irradiation, activation of the soils immediately outside of the vessel occurs, due to the creation of secondary particles produced at the target.

In February 1998, elevated levels of tritium (52,000 pCi/L) and sodium-22 (151 pCi/L) were detected in wells downgradient of the BLIP. To prevent rainwater from infiltrating the activated soils below the building, the BLIP building's roof drains were redirected away from the building, paved areas were resealed, and an extensive Gunite™ cap was installed on three sides of the building. Groundwater monitoring data collected from January 1999 to July 2000 indicated that these corrective actions were highly effective in preventing the release of tritium and sodium-22 from the activated soils surrounding the BLIP target vessel. Tritium and sodium-22 were not detected in samples collected in April 2000.

In June 2000, BNL took an additional protective measure by using an innovative silica grouting technique to reduce the permeability of the activated soils. Soon after the activated soils were treated with the silica grout injection process, significant increases in tritium and sodium-22 concentrations were observed in groundwater samples. In early July 2000, samples collected from wells within 40 feet of the target area, downgradient of the BLIP, contained tritium up to 5,700 pCi/L. By October 2000, tritium concentrations increased to 56,500 pCi/L. In accordance with the *BNL Groundwater Protection Contingency Plan* (BNL 2000b), BNL and DOE notified the regulatory agencies of this situation and increased the sampling frequency for the wells. The maximum sodium-22 concentration was 299 pCi/L, detected in well 064-67 on December 1, 2000. By December 21, 2000, tritium concentrations dropped to below the 20,000 pCi/L drinking water standard in the wells immediately downgradient of the BLIP. Concurrently, as the slug of tritium continued to migrate downgradient of the BLIP, concentrations in well 064-50 increased to 20,000 pCi/L by December 28, 2000. This well is approximately 150 feet downgradient of the BLIP.

During 2001, tritium concentrations in wells located 40 feet downgradient of the BLIP did not exceed 7,000 pCi/L. Tritium concentrations in well 064-50 reached a maximum of 60,800 pCi/L in July 2001, then declined to less than 20,000 pCi/L by November 2001. The pattern of decreasing tritium concentrations in wells directly downgradient of the BLIP indicates a short-term (pulsed) tritium release and that the plume has dissipated quickly in the aquifer. There was good correlation between modeled and observed tritium concentrations in well 064-50 during 2001, and it is expected that peak tritium concentrations in the plume will drop below the drinking water standard at all locations by September 2002.

Although the grouting process had a short-term impact on groundwater quality, it is believed that the process will provide long-term benefits in reducing the permeability of the contaminated soil shielding. Information on the potential for displacing residual pore water will be used to improve this innovative grouting technology.

7.5.1.3 Relativistic Heavy Ion Collider

Within the RHIC facility, there are three areas where low levels of radionuclides could be produced in the soils outside of the collider tunnel. The first area contains two beam stops that are located at the 10 o'clock position of the ring, the second contains two collimators that are located at the 8 o'clock region, and the third is a beam stop located at the 6 o'clock position. Secondary particles created at the internal beam stop and collimator areas have the potential to activate the soils immediately surrounding those areas. Even though the predicted soil activation is expected to be very small, BNL installed impermeable caps over these areas as a precautionary measure. Thirteen monitoring wells are used to provide a means of verifying that the engineered (*i.e.*, impermeable caps) and operational controls designed into the RHIC beam stops and collimators are effective in protecting groundwater quality.

Groundwater samples were collected from the thirteen RHIC monitoring wells on a semi-annual schedule during 2001. Surface water samples were also collected from the Peconic River both upstream and downstream of the beam stop area. As in previous years, no tritium or sodium-22 was detected in any of the groundwater or surface water samples.

7.5.1.4 Brookhaven Medical Research Reactor

During a 1997 evaluation of groundwater quality near the BMRR, low levels of tritium (up to 11,800 pCi/L) were detected in the groundwater downgradient of the reactor building. After inspecting the facility and reviewing historical records, BNL concluded that the tritium might have originated from past discharges of small amounts of BMRR primary cooling water to a basement floor drain and sump system that leaked. Although the last discharge of primary cooling water to the floor drain system occurred in 1987, the floor drains continued to be used for secondary (nonradioactive) cooling water until 1997. The infiltration of this water may have promoted the movement of residual tritium from the soils surrounding the floor drain piping system to the groundwater. The floor drains were permanently sealed in 1998 to prevent any future accidental releases to underlying soils.

During 2001, tritium concentrations continued to be well below the drinking water standard of 20,000 pCi/L. Detectable levels of tritium were observed in all three downgradient wells, with the maximum value of 1,550 pCi/L in well 084-27. As in past years, no other reactor-related radionuclides were detected in the groundwater. Compared to the initial monitoring results from 1997, tritium concentrations in groundwater have shown a steady decline. Discontinuing the use of the BMRR's floor drains has apparently helped to reduce the movement of residual tritium from the soils surrounding the floor drain piping system to the groundwater.

7.5.2 Surveillance Monitoring of Support Facilities

7.5.2.1 Sewage Treatment Plant Area

As described in Chapters 1 and 3, the Sewage Treatment Plant processes sanitary sewage from BNL facilities. Approximately 15 percent of the treated effluent released to the

STP's sand filter beds either evaporates or directly recharges to groundwater; the remaining water is discharged to the Peconic River.

The STP groundwater surveillance program is designed to evaluate whether current operations are affecting groundwater quality. During 2001, six wells were used to monitor groundwater quality in the filter bed area and three wells were monitored in the holding pond area. Groundwater quality impacts resulting from historical STP discharges are currently being monitored as part of the OU V monitoring program, using wells that are at the site boundary and off-site areas (see Section 7.6.5).

Groundwater monitoring results for 2001 indicate that STP operations are not significantly affecting groundwater quality and that BNL's administrative and engineered controls designed to prevent the discharge of chemicals and radionuclides to the sanitary system have been highly effective.

Radionuclides. Radioactivity levels in samples collected from the STP wells were generally typical of ambient (background) levels, with the exception of low levels of tritium detected in several wells during 2001. In the filter bed area, one sample from well 039-08 had a tritium concentration of 392 pCi/L. The drinking water standard for tritium is 20,000 pCi/L. Slightly higher levels of tritium (up to 1,420 pCi/L) were detected in well 039-89, downgradient of the holding ponds. Because the ponds have not been used recently to hold tritiated waste water and the wells are also downgradient of the filter bed area, it is likely that the tritium originated from past water releases to the filter beds. An elevated gross alpha concentration of 23.8 pCi/L was detected in the June 2001 sample from well 039-86. This value exceeds the 15 pCi/L standard. This value was inconsistent with previous results, and the well was re-sampled in July to confirm the June sample result. Analysis of the July sample indicated a gross alpha value of less than the minimum detectable level of 0.7 pCi/L. It is likely that the elevated gross alpha concentration in the June sample was due to an erroneous measurement or cross-contamination of the sample. If the July groundwater sample had confirmed the elevated gross alpha result, BNL would have conducted radionuclide-specific analyses to identify possible alpha-emitting radionuclides.

Volatile Organic Compounds, Metals, and Anions. During 2001, all water quality readings and most metal concentrations were below the applicable New York State Ambient Water Quality Standards (NYS AWQS). Sodium was detected at concentrations slightly above the NYS AWQS of 20 mg/L in three filter bed area wells. Wells 039-07, 039-08, and 039-86 had maximum sodium concentrations of 28.5 mg/L, 29.3 mg/L, and 30.5 mg/L, respectively. One sample from well 039-87 had an aluminum concentration of 0.11 mg/L, which is slightly above the 0.1 mg/L standard. Although low-level nitrates were detected in most STP area wells, with a maximum concentration of 6.5 mg/L detected in monitoring well 039-08 (in the filter bed area), these concentrations were below the NYS AWQS of 10 mg/L. No VOCs were detected in any of the monitoring wells.

7.5.2.2 Water Treatment Plant

At the direction of the New York State Department of Environmental Conservation, five shallow Upper Glacial aquifer surveillance wells were installed at the Water Treatment Plant (WTP) in 1993 to assess potential leaching of iron from the plant's recharge basin (Basin HX) into the groundwater. Naturally high levels of iron in the groundwater pumped for potable and process supply is removed at the WTP, and the precipitated iron is discharged to the recharge basin during filter backflushing operations.

The groundwater monitoring wells in the WTP's recharge basin area were sampled in June 2001. Analytical results indicate that anion and metal concentrations (including iron) were below the applicable NYS AWQS. Since the beginning of the WTP groundwater monitoring program in 1992, iron has rarely been detected above the typical detection limit of 0.075 mg/L in groundwater near Basin HX, and has never exceeded the 0.3 mg/L water quality standard. Following anticipated 2002 changes to BNL's SPDES permit, the Laboratory will discontinue monitoring iron levels in WTP discharges to Basin HX. Concurrent with this change in

SPDES permit requirements, BNL will discontinue the collection of groundwater samples from wells near the basin. BNL will maintain the wells for the collection of water level measurements and for potential future collection of water samples to periodically verify water quality.

7.5.2.3 Motor Pool Facility

Building 423 serves as the site Motor Pool, where BNL's fleet vehicles are repaired and refueled. Gasoline is stored in two 8,000-gallon capacity underground storage tanks (USTs), and waste oil is stored in one 500-gallon capacity underground storage tank. Although the USTs and associated distribution lines meet Suffolk County Article 12 requirements for secondary containment, leak detection, and high-level alarms, BNL initiated a groundwater monitoring program in 1996 as a means of verifying that groundwater quality is not being affected by current Motor Pool operations.

Groundwater surveillance at the Motor Pool facility during 2001 continued to indicate that releases from historical operations have impacted groundwater quality. Several activities were conducted and determined that the groundwater contamination came from historical, not current, operations. Monitoring of the leak detection systems and the wells downgradient of the Motor Pool's UST area indicates that the tanks and their associated distribution lines are not leaking. Furthermore, evaluation of current vehicle maintenance operations indicates that all waste oils and used solvents are being properly stored and recycled. Therefore, it is believed that the solvents detected in groundwater originate from historical vehicle maintenance activities at the Motor Pool, and are not related to current operations.

Underground Storage Tank Area. During 2001, no chemicals related to gasoline products — benzene, ethylbenzene, toluene, xylenes, or methyl tertiary butyl ether (MTBE)—were detected in groundwater downgradient of the gasoline UST area. The solvent 1,1,1-trichloroethane (TCA) was detected in both downgradient wells, but at concentrations below the NYS AWQS of 5 µg/L. The TCA contamination is probably due to historical parts degreasing operations at the Motor Pool facility. Wells 102-05 and 102-06 were also tested for the presence of floating petroleum hydrocarbons. As in previous years, no floating product was observed.

Motor Pool Building. During 2001, TCA was detected in all four downgradient wells at concentrations ranging from 6.0 µg/L to 77.3 µg/L. In well 102-12, 1,1-dichloroethane (DCA) was detected at concentrations up to 14.5 µg/L. The NYS AWQS for TCA and DCA is 5 µg/L. The gasoline additive MTBE was detected in all four wells, with a maximum observed concentration of 73.8 µg/L. The NYS standard for MTBE is 10 µg/L. It is believed that the TCA and DCA originate from historical vehicle maintenance/part degreasing operations. MTBE has been used as a gasoline additive since 1977. This compound has been detected at low levels (generally <10 µg/L) in the Motor Pool wells since the monitoring program began in 1996.

7.5.2.4 Upton Service Station

Building 630 is a commercial automobile repair and gasoline station for the BNL site. Gasoline is stored in two 8,000-gallon capacity and one 6,000-gallon capacity USTs, and waste oil is stored in one 500-gallon capacity UST. Although the storage tanks and associated distribution lines meet Suffolk County Article 12 requirements for secondary containment, leak detection, and high-level alarms, BNL initiated a groundwater monitoring program in 1996 as a means of verifying that groundwater quality is not being affected by current operations.

Groundwater quality in the Service Station area has been impacted by historical small-scale spills of oils, gasoline, and solvents, and by carbon tetrachloride contamination associated with a nearby underground storage tank that was used as part of an experiment conducted in the 1950s. The carbon tetrachloride contamination is being remediated as part of the Laboratory's Environmental Restoration Program (see Section 7.6.3.1). During 2001, carbon tetrachloride continued to be observed in Service Station monitoring wells. The maximum carbon tetrachloride concentration was 1,621 µg/L, observed in well 085-16. These concentrations are less than those observed in 2000, when carbon tetrachloride concentrations in wells near the Service Station approached 4,400 µg/L. The NYS AWQS for carbon tetrachloride is 5 µg/L.

Compared to monitoring results for 2000 (when high levels of petroleum hydrocarbon-related compounds were detected in several downgradient wells), only low levels of xylenes (8.3 µg/L total xylenes) were detected during 2001. Low levels of the solvent tetrachloroethylene (up to 9.8 µg/L) were also detected. (The NYSAWQS for these compounds is 5 µg/L.) The gasoline additive MTBE continued to be detected in wells 085-236 and 085-237. MTBE levels increased from approximately 5 µg/L in 2000, to a maximum concentration of 64 µg/L in 2001. MTBE has been in use as a gasoline additive since 1977, and it is likely that the MTBE detected in the Service Station wells is related to historical small-scale spillage during vehicle refueling or maintenance operations. The NYS AWQS for MTBE is 10 µg/L.

7.5.2.5 Major Petroleum Facility

The Central Steam Facility (CFS) supplies steam for heating to all major facilities of the Laboratory through an underground distribution system. The Major Petroleum Facility (MPF) is the storage area for most fuels used at the Central Steam Facility. Five shallow Upper Glacial aquifer wells monitoring the MPF were initially installed as part of the licensing requirements for this facility, and are screened across the water table so that potential free product (oil floating on top of the groundwater) can be detected. Three additional surveillance wells were installed in early 2000 to improve monitoring of the MPF area. Additional surveillance wells are in the CSF area. The CSF area wells are used to monitor groundwater contamination resulting from a 1977 leak of approximately 25,000 gallons of Alternative Liquid Fuel (a mixture of fuel oil and spent solvent). Contaminated soils and groundwater near the 1977 spill site have been undergoing active remediation since 1997 (see Section 7.6.4.1).

Semivolatile Organic Compounds. In accordance with the special license conditions for the MPF, groundwater samples are analyzed semi-annually for the polynuclear aromatic and base neutral compounds covered by EPA Test Method 625. During 2001, none of the target compounds were detected. The MPF wells were tested monthly for the presence of floating petroleum hydrocarbons. As in previous years, no floating petroleum product was observed.

7.5.2.6 Waste Management Facility

In 1997, BNL began operating its new Waste Management Facility (WMF), designed and operated in a manner that meets all applicable federal, state, and local environmental protection requirements. Nevertheless, BNL established a voluntary groundwater monitoring program as a secondary means of verifying the effectiveness of the facility's administrative and engineered controls. The WMF is monitored by eight shallow Upper Glacial aquifer wells. Groundwater monitoring results for 2001 are consistent with previous monitoring, and continue to show that WMF operations are not impacting groundwater quality.

Volatile Organic Compounds, Metals, and Anions. In 2001, all water quality and most metals concentrations were below the applicable NYS AWQS. As in past years, sodium was detected at concentrations above the NYS AWQS of 20 mg/L in upgradient well 055-03 (at a maximum concentration of 59.1 mg/L). Low levels of 1,1,1-trichloroethane (TCA) and chloroform continue to be detected in several wells, but at concentrations below NYS AWQS. The gasoline additive MTBE was detected in well 056-22 at concentrations up to 6.2 µg/L. The NYS water quality standard for MTBE is 10 µg/L. There are no reports of gasoline spillage at the WMF or nearby areas; therefore, a source for the MTBE has not been identified.

In 2000, TCA (153 µg/L) and DCE (35 µg/L) had been detected in upgradient well 066-07. During 2001, TCA concentrations in this well dropped to a maximum of 2.6 µg/L, and DCE was not detected in any of the samples. It is believed that the TCA and DCE contamination originated from historical releases from Building 830. In late 2000 and early 2001, BNL conducted an investigation into current and historical operations at Building 830 (see Section

7.5.2.10). Although TCA had been used during metal cleaning operations at Building 830, BNL could not identify a continuing source for the contamination. It is unlikely that contamination from this facility will significantly affect groundwater quality in the WMF area.

Radionuclides. Radioactivity levels in samples collected from the WMF wells were generally typical of ambient (background) levels. No Laboratory-related radionuclides were detected in the WMF wells during 2001.

7.5.2.7 Biology Department Greenhouse Area

The Biology Department facility includes 11 greenhouses where various types of plants are grown for biological research. Eight of the greenhouses have dirt floors and three have concrete floors. Pesticides and fertilizers have been routinely used in the greenhouses. Records indicate that copper sulfate was applied to the dirt floors on an annual basis until the mid-1980s. The pesticide Endosulphan II was detected in soil samples collected from a dry well within Greenhouse 10. Analysis of groundwater samples collected to date does not indicate that greenhouse operations have affected groundwater quality.

In September 2001, the greenhouse area wells were sampled and tested for pesticides, metals, and anions. Pesticides were not detected, and all water quality concentrations were below the applicable NYS AWQS. Sodium was the only metal detected at a concentration above the NYS AWQS of 20 mg/L, with a maximum concentration of 24.3 mg/L in well 084-36. The detection of low levels of sodium is not uncommon in wells within the developed area of the site, and could be related to road salting operations.

7.5.2.8 Shotgun Range

The BNL Shotgun Range, established in 1974, is used for trap and skeet target shooting by the Brookhaven Employees Recreation Association. The range is in an isolated, wooded area north of the new Waste Management Facility. Clay targets are thrown south from the trap house into an open field that is approximately 200 feet east–west by 400 feet north–south. Although most of the shot falls within the cleared range, shooting from several of the trap line positions deposits some shot in nearby wooded areas.

From 1974 until 2000, the shotgun shells used at the facility typically contained lead pellets. It is estimated that as many as 30,000 shotgun rounds per year have been used at the range. At an average of 1.125 oz. per round, as much as 2,100 pounds of lead may have been deposited on the surface of the range annually. To prevent additional deposition of lead, in early 2000, BNL implemented a rule that allows only steel shot to be used at the range.

Groundwater monitoring data continue to indicate that Shotgun Range operations have not affected groundwater quality. In March of 2001, the groundwater monitoring wells at the Shotgun Range were sampled. All metal concentrations were below the applicable NYS AWQS and were consistent with established background levels. Lead was not detected in any of the groundwater samples.

7.5.2.9 Live Fire Range

The BNL Live-Fire Range consists of a six-position, 100-yard, bermed, outdoor small arms range. The Live-Fire Range was constructed in 1986 and is immediately north of the BNL Sewage Treatment Plant's filter bed area. The eastern half of the range extends to within 200 feet of the Peconic River. The bullet stop at the range is an earthen berm, and bullets are known to have a typical penetration depth of approximately two to three inches into the berm. The soil of the berm is periodically screened to a depth of approximately one foot. The lead shot recovered during the screening process and the spent brass cartridges are disposed of, off site, by a commercial scrap metal waste handler.

Groundwater monitoring conducted to date does not indicate that range operations are affecting groundwater quality. During 2001, all metal concentrations were below the applicable NYS AWQS and were consistent with established background levels. Lead was not detected in any of the samples.

7.5.2.10 Building 830

In 2000, BNL's groundwater monitoring program for the Waste Management Facility detected the presence of the volatile organic compounds TCA and DCE at concentrations that exceed NYS AWQS in background well 066-07, which is near Building 830. TCA and DCE were detected at concentrations as high as 154 µg/L and 34 µg/L, respectively. These findings were considered unusual, and resulted in the implementation of the *BNL Groundwater Protection Contingency Plan* (BNL 2000b). As required by that plan, BNL and DOE notified the regulatory agency stakeholders.

Operations within Building 830 started in 1963, when the High Intensity Radiation Development Laboratory was opened. The hot cells and associated laboratories were used to fabricate high-intensity cobalt-60 sources for food irradiation and other programs. In 1970, the Low Dosimetry Facility (currently known as the Gamma Irradiation Facility) was added to the northeast end of the building. This facility included a gamma irradiation pool and a machine shop. Building 830 is currently used by the Environmental Research and Technology Division, and provides analytical and electron microscopy labs and office and administrative space.

Based on an evaluation of current and historical operations in the Building 830 area, the TCA and DCE appear to have originated from historical metal cleaning activities at Building 830. Previous analysis of liquids that were contained in two former underground radioactive liquid waste storage tanks near Building 830 indicated the presence of high levels of both TCA and DCE. The waste lines that lead from Building 830 to the tanks are known to have leaked. While the tanks, exterior piping, and contaminated soils were removed, portions of the piping still remain beneath the building.

During 2001, TCA and DCE concentrations were <5 µg/L in samples collected from wells 066-07 and 066-08. In February 2001, TCA and DCE concentrations in well 066-09 increased to nearly 80 µg/L and 25 µg/L, respectively. All VOC concentrations dropped to <5 µg/L for the remainder of 2001. To further characterize groundwater quality near Building 830, BNL installed six temporary wells during July 2001. No VOCs were detected in temporary well samples at concentrations greater than the NYS AWQS of 5 µg/L (see BNL 2001c).

The groundwater investigation conducted during 2000–2001 concluded that Building 830 is not a significant or a continuing source of groundwater contamination. This conclusion is consistent with the earlier findings of the OU III Remedial Investigation. It is probable that historic, low-level VOCs releases from Building 830 have been contaminating the groundwater for many years. Very low levels of TCA have been detected in untreated water from nearby potable water supply wells 11 and 12 since the late 1980s. (Note: Water from potable wells 11 and 12 is treated using granular activated carbon filters before it is distributed for use.) Because the Building 830 area lies within the capture zones (or zones of contribution) for these supply wells, it is likely that TCA released from this facility was a contributing source of this contamination. One scenario for the source of the contamination is that some soil contamination went undetected during the exterior pipeline and D-tank removal projects. In 1998, pavement near the leaking D-waste pipes was removed, exposing the underlying soils to several heavy rain events. This may have caused leaching of residual soil contamination.

7.6 ENVIRONMENTAL RESTORATION GROUNDWATER MONITORING PROGRAM

The mission of the Environmental Restoration (ER) Groundwater Monitoring Program is to monitor the various contaminant plumes on site and off site, as well as to monitor the progress that the groundwater treatment systems are making toward plume remediation. The information below provides an overview of ER groundwater monitoring and remediation activities for 2001. In this period, a total of 594 groundwater surveillance wells were monitored during 2,389 individual sampling events. All wells sampled during 2001 are listed in Appendix E. Well-specific information on analytical parameters, as well as detailed analytical results for the ER Program, are provided in the *2001 BNL Groundwater Status Report* (BNL 2002b).

Maps showing the main VOC and radionuclide plumes are provided as Figures 7-6 and 7-7.

For each significant contaminant source area and plume described below, specific groundwater contaminant distribution maps are provided. Associated cross-sections showing the vertical distribution or extent of contamination, as well as the hydrogeology for the BNL site and surrounding areas, are also described in the *2001 BNL Groundwater Status Report* (BNL 2002b).

7.6.1 Background Monitoring

Background groundwater quality for the BNL site is monitored through a network of 13 wells in the northern portion of the site and in off-site areas to the north. The off-site background wells provide information on the chemical and radiological composition of groundwater that has not been affected by activities at BNL. These background data are a valuable reference for comparison with groundwater quality data from areas that have been affected. This well network can also provide warning of any contaminants originating from potential sources located upgradient of the BNL site.

There were no significant detections of VOCs in background wells. Historically, low concentrations of VOCs have been detected in some background wells. All radionuclide concentrations were consistent with natural levels.

7.6.2 Operable Unit I

7.6.2.1 Former Landfill, Animal/Chemical Pits, and Glass Holes

The Former Landfill area was initially used by the U.S. Army as a landfill area during World Wars I and II. BNL used the southeast corner of the landfill from 1947 through 1966 for disposal of construction and demolition debris, sewage sludge, chemical and low-level radioactive waste, used equipment, and animal carcasses. From 1960 through 1966, BNL waste, glassware containing chemical and radioactive waste, and animal carcasses containing radioactive tracers were disposed of in shallow pits in an area directly east of the Former Landfill. From 1966 through 1981, BNL disposed of used glassware in shallow pits directly north of these chemical/animal pits. The Former Landfill was capped in 1996 and the Animal/Chemical Pits and Glass Holes were excavated in 1997.

A network of eight monitoring wells monitors the Former Landfill area. This monitoring program is designed in accordance with post-closure operation and maintenance requirements specified in 6 NYCRR Part 360, "Solid Waste Management Facilities." The objective of this program is to verify that the cap effectively prevents the continued leaching of contaminants from the landfill, and to document anticipated long-term improvements to groundwater quality. In addition to these wells, BNL established a separate network of 24 wells to monitor the Animal/Chemical Pits and Glass Holes areas and the downgradient portions of the Former Landfill plume. The downgradient portions of these VOC plumes are currently being monitored as part of the OU III North Street Monitoring Program.

Former Landfill Monitoring Results. The areal extent of VOC contamination from the Former Landfill – Animal/Chemical Pits and Glass Holes area is shown in Figure 7-9. The primary VOCs that are consistently detected in the Former Landfill Monitoring Program wells are TCA, 1,1-DCA, and chloroform. A detailed evaluation of VOCs, radionuclides, leachate parameters, metals, and pesticides/PCBs is provided in the *Former Landfill Five-Year Evaluation Report* (P.W. Grosser 2002). The contaminants of concern for the Former Landfill wells are VOCs and strontium-90.

VOC concentrations have been low in all of the Former Landfill wells over the past five years with minimal exceedances of the NYS AWQS. Few or no VOCs have been detected in upgradient wells 87-22, 87-72, and 86-42. TCE and 1,1-DCA consistently were detected in the downgradient wells (97-17, 97-64, 106-02, and 106-30), though NYS AWQS for these compounds were not exceeded in 2001, nor have they been since 1998 (in well 106-30).

Historically, strontium-90 has been detected in shallow well 97-64, less than 100 feet downgradient of the landfill footprint. Strontium-90 concentrations in this well have been steadily declining since 1998, when it was last detected at a concentration of 12 pCi/L, above

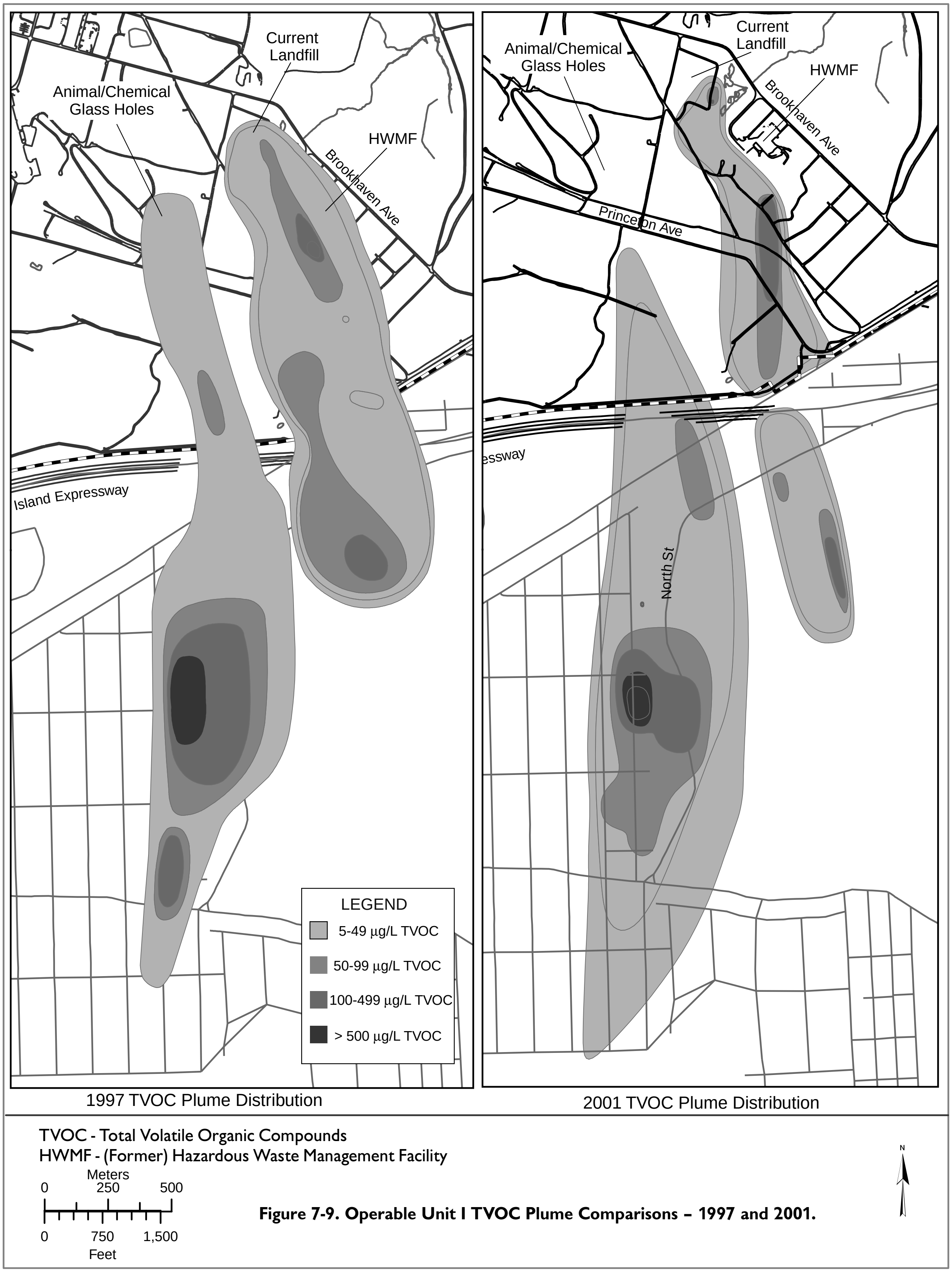

Figure 7-9. Operable Unit I TVOC Plume Comparisons – 1997 and 2001.

the NYS AWQS of 8 pCi/L. The highest concentration in this well during 2001 was 3 pCi/L, in January.

The declining VOC and strontium-90 concentration trends in downgradient wells suggest that the landfill cap is performing as planned. VOC concentrations in nearby wells remain below NYS AWQS. The trailing edge of the VOC plume emanating from the Former Landfill has migrated south of the monitoring well network (Figure 7-9). The strontium-90 plume has also shifted south of well 97-64 and the Former Landfill network, as shown in Figure 7-10. The capping of the landfill and the passage of time since the landfill was last in use (1966) are contributing factors to the reduction in plume concentrations in the vicinity of the landfill.

Animal/Chemical Pits and Glass Holes Monitoring Results. This plume was extensively characterized in 2001 in anticipation of a pilot study to remediate strontium-90 in groundwater from this source. Groundwater samples were obtained from 30 temporary and 24 permanent monitoring well locations around and downgradient of the source areas during 2001. An active groundwater treatment system for this area has been designed, based on information gathered during the characterization effort. Construction of the pilot study treatment system will take place in 2002. Detailed results of the 2001 groundwater characterization can be found in the *Strontium-90 Pilot Study Work Plan/ 90 Percent Design Report* (IT Corporation 2001).

Figure 7-10 shows the strontium-90 plume distribution. The highest strontium-90 concentration observed during 2001 was 1,770 pCi/L in well 106-16, which is immediately south of the Animal Pits. This well has historically shown the highest strontium-90 concentrations in this area (see trend plot on Figure 7-10). The sharp increase in strontium-90 in this well appears to be correlated with the excavation of the Animal Pits area in 1997. The excavation process is believed to have released additional strontium-90 to the groundwater.

A strontium-90 plume with concentrations greater than 100 pCi/L extends from approximately 75 feet northwest of well 106-16 to approximately 125 feet south of the Princeton Avenue firebreak road (Figure 7-10). The leading edge of the plume, as defined by the NYS AWQS of 8 pCi/L, is approximately 275 feet south of this firebreak road. A second, smaller plume occurs south of the Former Landfill (and the Princeton Avenue firebreak road). A concentration of 17 pCi/L was detected in a temporary well installed south of the firebreak road.

7.6.2.2 Current Landfill

The Current Landfill operated from 1967 through 1990. (Note: This landfill is called the Current Landfill to distinguish it from the older [Former] landfill that closed in 1966.) It was used for disposal of putrescible waste, sludge containing precipitated iron from the Water Treatment Plant, and anaerobic digester sludge from the Sewage Treatment Plant. The latter contained low concentrations of radionuclides, and possibly metals and organic compounds. BNL also disposed of limited quantities of laboratory wastes containing radioactive and chemical material at the landfill. As a result, the Current Landfill is a source of groundwater contamination. Permanent closure (capping) of this landfill was completed in November 1995 as part of the ER Program.

The Current Landfill post-closure groundwater monitoring program consists of a network of 11 monitoring wells adjacent to the landfill in both upgradient and downgradient locations. These wells are monitored quarterly to determine the cap's effectiveness in preventing the continued leaching of contaminants from the landfill, and to document the anticipated long-term improvements to groundwater quality. The monitoring well network was designed in accordance with New York State-specified landfill post-closure Operation and Maintenance requirements. Data collected to date show that, in general, contaminant concentrations have been decreasing following the capping of the landfill in 1995, as described below.

Volatile Organic Compounds. The primary VOCs that have been consistently detected in wells at the Current Landfill are chloroethane and benzene. The highest total volatile organic compound (TVOC) value (primarily consisting of chloroethane) was 87 µg/L in well 88-109, which

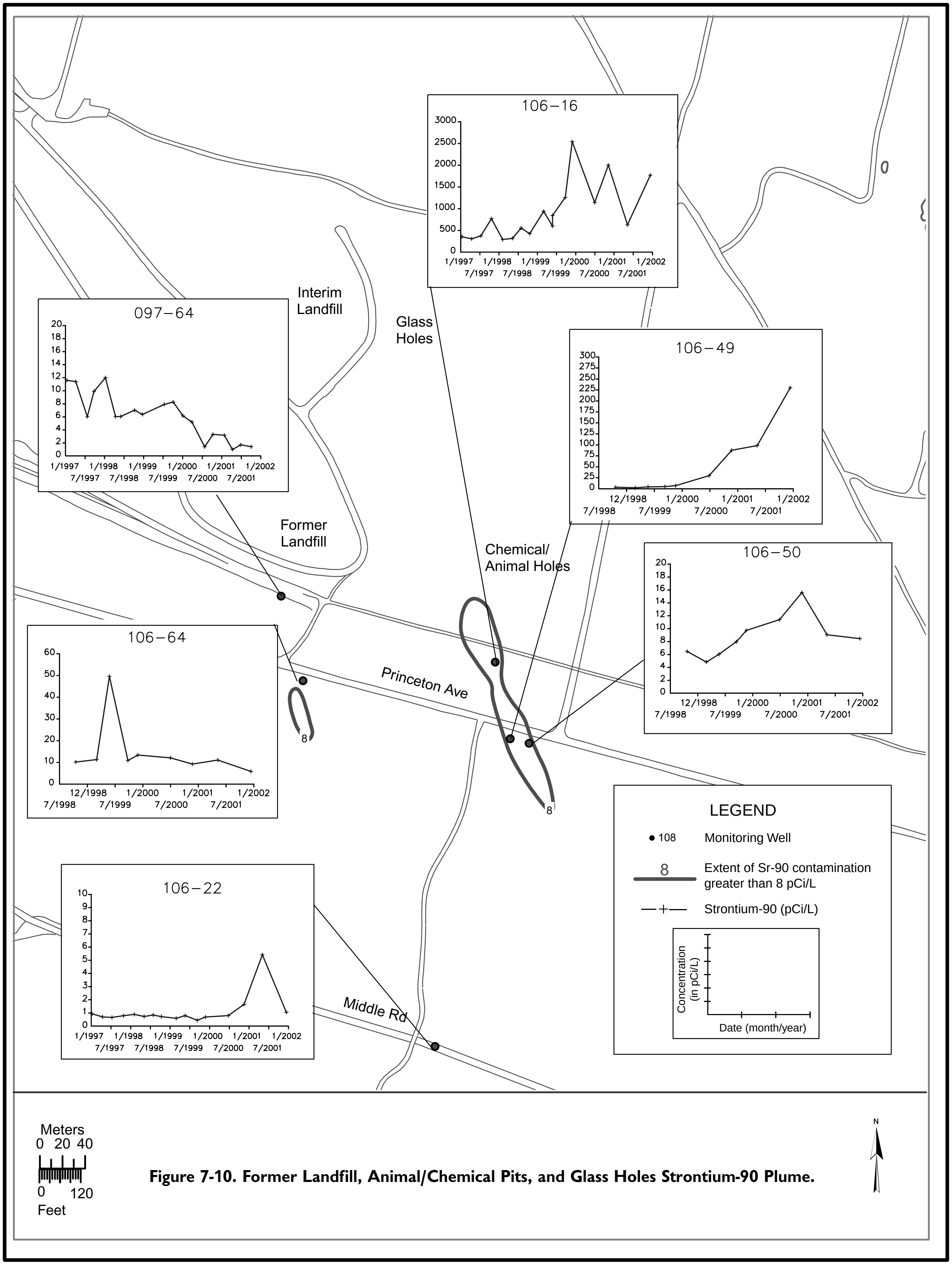

Figure 7-10. Former Landfill, Animal/Chemical Pits, and Glass Holes Strontium-90 Plume.

is adjacent to the southeast side of the landfill. (Note: TVOC is a summation of all individual VOC concentrations for a particular well sample.) This concentration was observed in the fourth quarter, following three previous quarters of levels below 10 µg/L. VOC trends in other Current Landfill wells were stable or slightly decreased in 2001. The extent of the Current Landfill VOC plume is shown in Figure 7-9.

Radionuclides. As in previous years, low levels of tritium and strontium-90 were detected in Current Landfill monitoring wells during 2001, but at concentrations well below their applicable drinking water standards of 20,000 pCi/L and 8 pCi/L, respectively. The highest tritium value was 2,360 pCi/L, detected in well 087-11, and the highest strontium-90 value was 4.67 pCi/L, in well 088-21.

Leachate Parameters and Metals. Most conventional landfill leachate parameters (*e.g.*, alkalinity, sulfates, chlorides, total nitrogen, nitrates, nitrites, TKN, total dissolved solids, and total suspended solids) were below applicable NYS AWQS, except for ammonia. Ammonia concentrations exceeded the NYS AWQS of 2 mg/L, with the highest concentrations detected in well 88-109, at 7 mg/L. Ammonia is a common landfill contaminant and is generated by the degradation of organic material. As in past years, the metals iron and magnesium were also detected above NYS AWQS in many of the Current Landfill wells in 2001.

7.6.2.3 Current Landfill/HWMF Plume

Groundwater contamination originating from the downgradient section of the Current Landfill plume and the former Hazardous Waste Management Facility (HWMF) is being monitored under the OU I South Boundary program. That program uses a network of 62 monitoring wells (15 of which also are used for the Current Landfill and the OU III North Street monitoring programs), downgradient of the Current Landfill and former HWMF. Until 1997, the former HWMF was BNL's central facility for processing, neutralizing, and storing hazardous and radioactive wastes before off-site disposal. As a result of past waste handling and storage practices, groundwater at the former HWMF is contaminated with both chemicals and radionuclides at concentrations that exceed NYS AWQS or DWS.

The Current Landfill and former HWMF plumes become commingled south of the HWMF. The Current Landfill/HWMF plume is being remediated using a groundwater extraction and treatment system consisting of two wells screened in the deep portion of the Upper Glacial aquifer at the site boundary. This system provides hydraulic containment of those on-site portions of the plume that have TVOC concentrations greater than 50 µg/L.

Volatile Organic Compounds. Total volatile organic compound concentration distributions for the Current Landfill/HWMF plume are shown in Figure 7-9. The primary VOCs found on site include chloroethane and DCA (the signature contaminants for the Current Landfill), whereas TCA, 1,1-dichloroethene (DCE), trichloroethene (TCE), and chloroethane are prevalent in the off-site segment of the plume. DCA and chloroethane are primarily detected in the Shallow Glacial aquifer near the source areas, and in the deep Upper Glacial aquifer at the site's boundary and off site. TCA, DCE, TCE, chloroethane, and chloroform are found in the mid to deep Upper Glacial aquifer off site south of North Street.

The Current Landfill/HWMF plume (defined by TVOC concentrations greater than 5 µg/L) extends south from the Current Landfill to an area approximately 2,250 feet south of North Street (approximately 7,300 feet long, as measured from the Current Landfill). Its maximum width is about 1,300 feet at the southern site boundary. The areas of the plume displaying the highest VOC concentrations (greater than 100 µg/L) are approximately 500 feet downgradient of the former HWMF (at well 98-59), and off site, south of well 000-124. Eleven vertical profile wells were installed during 2001 to delineate the extent of the TVOC plume in the area south of North Street, near well 000-124. The maximum TVOC concentration detected was 165 µg/L in a temporary well approximately 600 feet south of well 000-124. Additional characterization studies planned for 2002 will define the leading edge of the plume, defined by concentrations greater than 5 µg/L. Complete groundwater characterization data will be given in the *OU III North Street East Groundwater Treatment System 90% Design Report*, which is scheduled for completion in November 2002.

There have been several changes in the distribution of the plume from 1997 through 2001, shown in its current configuration on Figure 7-9. Groundwater characterization work performed in 2001 indicates that the core of the high concentration slug of contamination previously observed at well 000-124 continues to migrate south and generally to decrease in concentration. The south boundary pump-and-treat system appears to have created a break in the plume, characterized by a region of low-level TVOCs from south of the extraction wells to just south of the Long Island Expressway (LIE). A new groundwater treatment system (North Street East) is scheduled to be constructed in 2003. This treatment system is designed to remediate the high concentration portion of the VOC plume located off site (see Figure 7-18).

Radionuclides. Tritium has historically been detected in Current Landfill/HWMF plume wells below the NYS AWQS of 20,000 pCi/L. The maximum detection during 2001 was 11,400 pCi/L in well 98-30, which is 800 feet south of the former HWMF. Low levels of tritium continue to be detected off site in this plume. The maximum off-site tritium concentration observed in 2001 was 4,370 pCi/L, in well 000-138.

Strontium-90 has historically been detected on site at concentrations above the drinking water standard of 8 pCi/L in two wells within and downgradient of the former HWMF (wells 88-26 and 98-21). In 2001, additional groundwater characterization work was performed using thirteen temporary wells downgradient of the former HWMF. The highest strontium-90 detection was observed in temporary well 108-30, at 65.4 pCi/L. The extent of strontium-90 concentrations that are greater than the 8 pCi/L drinking water standard is shown in Figure 7-11. The leading edge of this plume was defined as being north of temporary well locations 108-38 and 108-42. Sentinel monitoring wells are planned for installation in 2002, downgradient of the leading edge of the plume. Historical strontium-90 trends for key monitoring wells in this area are provided in Figure 7-11.

7.6.3 Operable Unit III

The monitoring well network established to monitor the OU III VOC and radionuclide source areas and associated contaminant plumes is composed of approximately 180 monitoring wells positioned from the north-central portion of the site to the southern site boundary and off site. The OU III groundwater monitoring program is specifically designed to address the following groundwater contamination and plume remediation issues:

- Monitor VOC plumes with identified or suspected sources in the AGS Complex, Paint Shop, former carbon tetrachloride underground storage tank area, former Building 96 area, and the Supply and Material area.
- Monitor the tritium plume associated with the High Flux Beam Reactor (HFBR) and strontium-90 plumes associated with the Waste Concentration Facility and the formerly operated Brookhaven Graphite Research Reactor (BGRR).
- Evaluate the effectiveness of the OU III South Boundary, Middle Road, Carbon Tetrachloride, Industrial Park, and Building 96 groundwater treatment systems. These monitoring programs characterize the effects of the pumping on the contaminant plumes and provide the data necessary for making decisions on the future operations of the remediation systems.
- Monitor the off-site segment of the OU III plume and "sentinel" wells to the south (downgradient) of the defined extent of the off-site VOC plume, to provide data on future downgradient migration of the plume. Outpost wells are also situated in the southwestern portion of BNL, directly upgradient of the Suffolk County Water Authority's Parr Village Well Field near the William Floyd Parkway. These sentinel wells would provide an early warning if contaminants from BNL were to migrate toward the Suffolk County Water Authority wells.

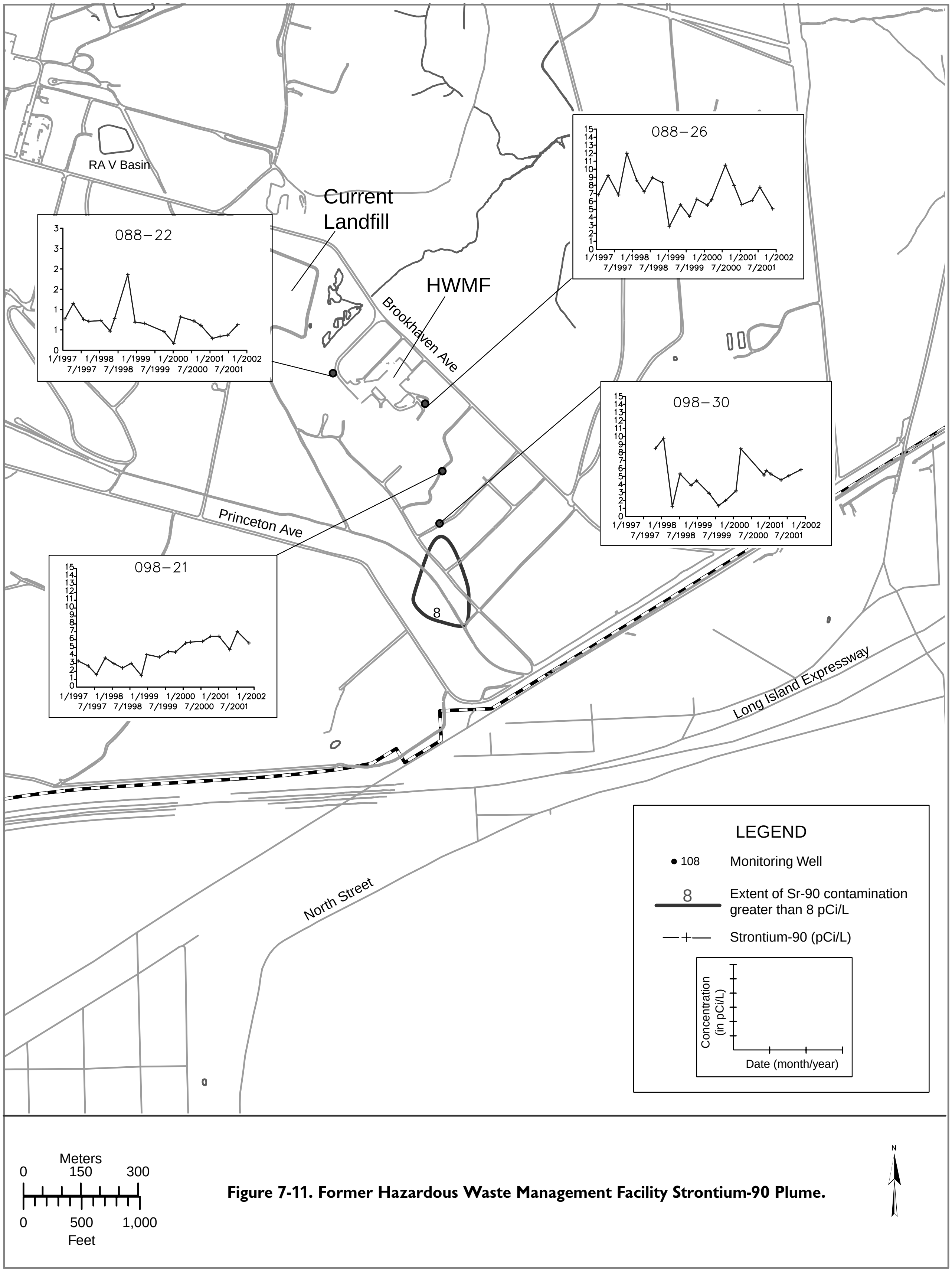

Figure 7-11. Former Hazardous Waste Management Facility Strontium-90 Plume.

7.6.3.1 OU III Volatile Organic Compound Plumes

Figure 7-12 shows the areal extent of the OU III VOC plume, which extends from the AGS Complex area in the central part of the site south to the vicinity of Flower Hill Drive in North Shirley, a distance of approximately 18,000 feet.

The OU III VOC plume consists of multiple commingled plumes originating from a number of source areas located in the central areas of the BNL site. The primary VOCs detected in on-site monitoring wells include TCA, PCE, and carbon tetrachloride. Carbon tetrachloride and PCE are the primary VOCs detected in off-site groundwater monitoring wells.

On-site portions of the plume displaying the highest VOC concentrations during 2001 were the former carbon tetrachloride UST area (with carbon tetrachloride values up to 2,800 µg/L) and the former Building 96 area (primarily PCE and lower concentrations of TCA, with TVOC values of up to 1,794 µg/L). From the former Building 96 area, high levels of VOCs continue south to Princeton Avenue, where TVOC concentrations greater than 500 µg/L were observed. High levels of VOCs were also observed in wells from the Industrial Park to Carleton Drive, where TVOC levels range up to 9,780 µg/L (composed primarily of carbon tetrachloride and PCE).

In general, PCE, TCA, and carbon tetrachloride occur in the shallow Upper Glacial aquifer in the central portion of OU III, and in the deep Upper Glacial aquifer at the southern site boundary and off site. Monitoring results from wells 000-249 and 000-130 suggest that there is significant carbon tetrachloride and PCE contamination off site in the Upper Magothy aquifer. Characterization of the Magothy aquifer in this area began in 2000 and will be completed in 2002. Vertical profiles have been completed at 16 locations and monitoring wells have been installed in six locations. Data obtained from these vertical profiles have been used to help draw the various OU III contaminant plume maps. The highest carbon tetrachloride and PCE concentrations occurred in wells 000-253 and 000-130, with maximum TVOC concentrations of 2,161 µg/L and 1,142 µg/L, respectively. A comparison of the OU III plumes between 1997 and 2001 is provided in Figure 7-12. A summary of significant source areas and groundwater treatment areas is provided below.

OU III Central Area. The OU III Remedial Investigation identified several low-level (less than 100 µg/L) source areas and nonpoint source contamination within the developed central areas of the BNL site. These areas are monitored under the OU III Central project.

The monitoring well network established for the central area of the site consists of 21 wells. This network also is supplemented with Environmental Surveillance program wells that are used to monitor active research and support facilities. During 2001, VOC concentrations in most of the OU III Central wells were near or below the NYS AWQS. Significant observations for 2001 are described below.

- TVOCs in shallow well 65-05 (in the AGS area) peaked at a concentration of 123 µg/L in September 2000, then decreased to 17 µg/L during the fourth quarter of 2001. The VOCs are likely to have originated from historical discharges to cesspools near Building 914.
- VOC concentrations (primarily TCA) in shallow well 066-09 (southeast of Building 830) significantly increased during late 2000 and early 2001, peaking at 112 µg/L TVOC in February 2001. VOC concentrations during the final three quarters of 2001 dropped to below NYS AWQS. A preliminary investigation identified several potential sources in Building 830; however, a subsequent geoprobe investigation during the summer of 2001 revealed little or no VOC contamination near the building (see Section 7.5.2.10).
- Well 83-02 is near the intersection of Brookhaven Avenue and Upton Road and is screened in the mid to deep Upper Glacial aquifer. Since 1997, this well consistently has contained 10 to 25 µg/L of chloroform. Potential sources of this contamination may be in the AGS area of the site.
- SCDHS wells 109-03 and 109-04 serve as

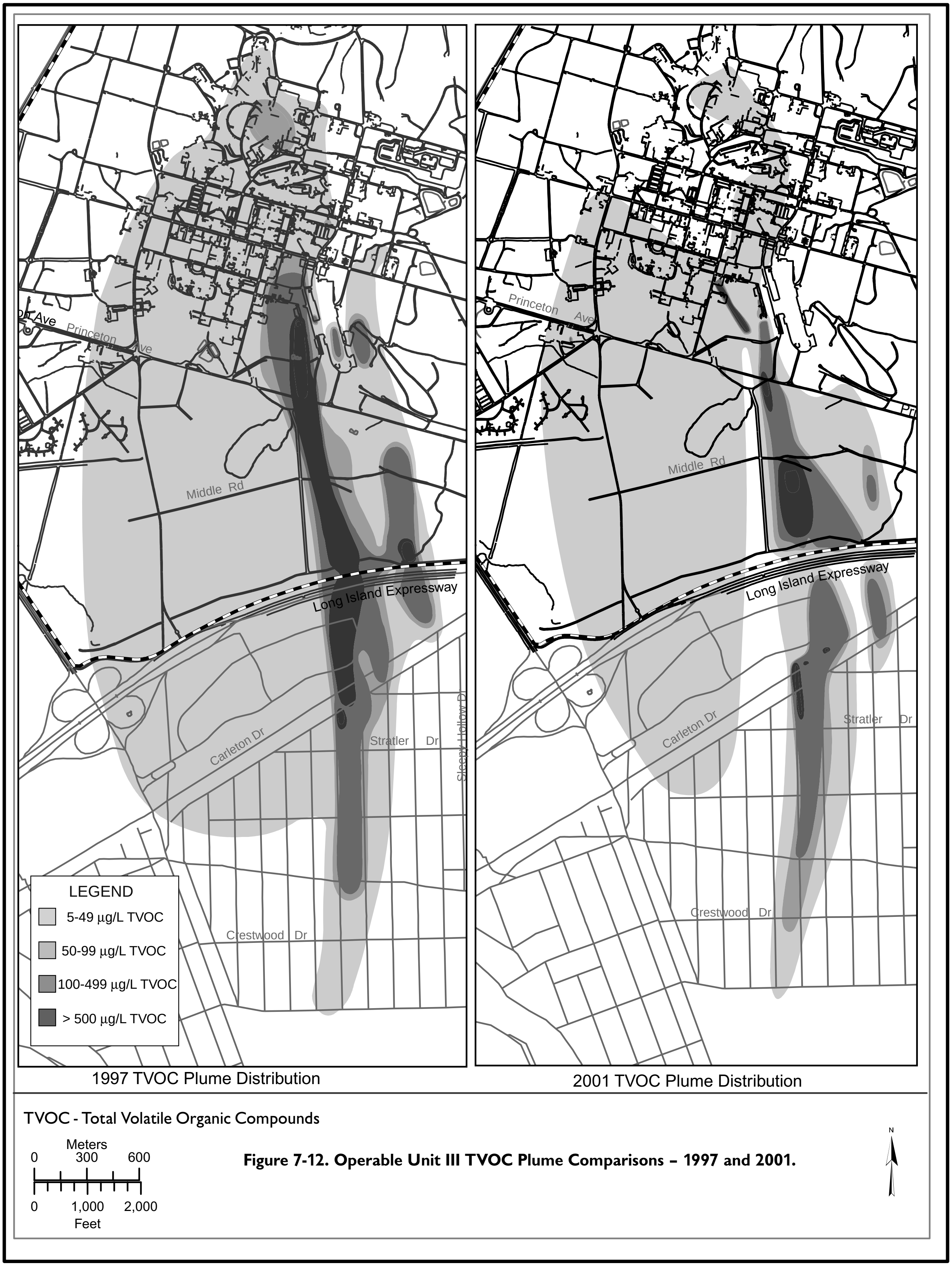

Figure 7-12. Operable Unit III TVOC Plume Comparisons – 1997 and 2001.

sentinel wells for the SCWA William Floyd Well Field and are near the eastern BNL site property boundary. There were no detections of either VOCs or radionuclides in these wells during 2001.

Former Building 96 Area. The OU III RI/FS identified the Building 96 area as a significant source of the PCE detected in the OU III plume. The Building 96 area encompasses four distinct areas: Building 96 and associated leaching structures, Building 96 Scrapyard, Former Building T-239 and associated leaching structures, and the former truck wash area.

An in-well air sparging system to remediate the Building 96 VOC source area began in February 2001 (see Figure 7-18). The VOC plume consists primarily of PCE and lower concentrations of TCA. The maximum observed TVOC concentration during 2001 was 4,870 µg/L in temporary well 095-263. The NYS AWQS for PCE and TCA was 5 µg/L. The Building 96 groundwater treatment system consists of four recirculation treatment wells. During 2001, the Building 96 area VOC plume was monitored using 17 permanent wells and seven temporary wells. Monitoring data collected during 2001 indicate the size of the plume has decreased in response to the groundwater treatment system.

Carbon Tetrachloride UST Area. In April 1998, an inactive underground storage tank used for the storage of carbon tetrachloride was excavated and removed. This tank was approximately 200 feet northeast of the Upton Service Station (at the corner of Rowland Street and Rochester Street). Although groundwater samples collected from a nearby well had shown low-level concentrations of carbon tetrachloride since 1995, samples collected in June 1998 revealed levels approaching 100,000 µg/L. The NYS AWQS for carbon tetrachloride is 5 µg/L. It is now apparent that the increase in contaminant concentration was probably due to the spillage of residual carbon tetrachloride during removal of the underground storage tank. A groundwater remediation system consisting of two extraction wells screened in the shallow Upper Glacial aquifer began operation in October 1999. A third extraction well began operation in December 2001. The effects of the pump-and-treat system on the source area are apparent in the sharp decline in carbon tetrachloride concentrations in wells near the former UST area.

The carbon tetrachloride contamination extends from the former UST southeast to the vicinity of the Weaver Road recharge basin, a distance of approximately 1,300 feet (Figure 7-12). The width of the plume, as defined by the 50 µg/L isocontour, is approximately 120 feet. In 1999, carbon tetrachloride concentrations in groundwater immediately downgradient of the former UST were greater than 150,000 µg/L (in well 85-98). Carbon tetrachloride concentrations in this area steadily decreased following the start of groundwater treatment system pumping, and were only 7 µg/L during the fourth quarter of 2001. Carbon tetrachloride concentrations were also observed to decrease in wells near the Service Station. For example, carbon tetrachloride concentrations in well 85-17 dropped from 3,760 µg/L in February 2001 to 602 µg/L by November 2001.

Although the groundwater treatment system was highly effective in these areas, high carbon tetrachloride concentrations continued to be detected in downgradient wells that were beyond the capture zone of the extraction wells. To further define the downgradient extent of the carbon tetrachloride plume, six temporary vertical profiles were installed from April through July 2001 (see BNL 2001b). The leading edge of the shallow, high concentration portion of the carbon tetrachloride plume was delineated for purposes of locating an additional groundwater extraction well. The southernmost vertical profile installed along the plume centerline, well 095-248, contained carbon tetrachloride at 106 µg/L in the deepest sample interval (79 to 83 feet below land surface). Concentrations greater than 200 µg/L were detected in well 095-88. Using these data, a third extraction well was constructed in the vicinity of the Weaver Drive recharge basin. Start-up of this well took place in December 2001. A work plan will be developed for additional characterization of the deep carbon tetrachloride contamination in 2002.

Middle Road Treatment Area. Six groundwater extraction wells are used to hydraulically control the OU III VOC plume located near the Middle Road (Figure 7-18). This system began operating in October 2001. The Middle Road Monitoring Program consists of a network of 26 monitoring wells, eleven of which were installed during 2001.

The highest TVOC concentrations are found immediately south of extraction wells RW-2 and RW-3, in monitoring wells 113-11 (823 µg/L) and 113-17 (1,466 µg/L). The contamination was present before the Middle Road treatment system was installed and will ultimately be captured by the OU III South Boundary system. TVOC concentrations in monitoring wells east of RW-3 are below 100 µg/L.

TVOC concentrations in plume core well 105-23, approximately 2,000 feet upgradient of RW-1 near Princeton Avenue, were as high as 1,794 µg/L during 2001. VOC concentrations in this well declined during operation of the HFBR remediation system in 1997 through 2000, then rapidly increased after the HFBR system was put on standby in September 2000.

Southern Boundary Treatment Area. Hydraulic control of the OU III plume at the site boundary has been attained using seven extraction wells, which pump water from the deep portions of the Upper Glacial aquifer to an air stripper for treatment. This system began operation June 1997. VOC concentrations in groundwater along the site's southern property line are stratified vertically and horizontally. The seven recovery wells are screened at the depths showing the highest VOC concentrations. The effectiveness of the Southern Boundary treatment system is monitored using a network of 40 wells. During 2001, TVOC concentrations in monitoring wells near the extraction well system were generally less than 200 µg/L.

Western South Boundary Treatment Area. The Western South Boundary pump-and-treat system will be in operation in 2002. The system will have two extraction wells and is designed to capture the western portion of the OU III VOC plume, which contains VOC concentrations generally less than 50 µg/L. Left untreated, these VOCs could potentially discharge into the Carmans River. In 2001, the OU III Western South Boundary area was monitored using four wells. During 2001, the maximum VOC concentration was 28 µg/L, in well 130-02. In late 2001 and early 2002, BNL installed an additional 12 wells to enhance the monitoring program near the extraction wells and provide for monitoring of the newly constructed recharge basin.

Industrial Park Area. The OU III Industrial Park Treatment system was designed to contain and remediate the portion of the OU III plume existing between BNL's southern boundary and the Parr Industrial Park (Figure 7-18). This portion of the plume consists primarily of carbon tetrachloride that is in the deep portions of the Upper Glacial aquifer and upper portion of the Magothy aquifer. A groundwater treatment system, consisting of seven in-well air stripping treatment wells, was initiated in the Industrial Park in wells installed in 1999, to treat VOC contamination in the deep Upper Glacial aquifer.

The monitoring well network for this area consists of 39 wells that extend from the Industrial Park to Carleton Drive. These wells are used to monitor the effectiveness of the in-well air stripping groundwater treatment system. The highest VOC concentrations in the Industrial Park area were observed between remediation wells UVB-1 and UVB-3, with the maximum concentration of 3,853 µg/L observed in monitoring well 000-256 during the first quarter of 2001. There has been a steady decline in VOC concentrations in plume core well 000-112 (immediately upgradient of UVB-1 and UVB-2) since 1999. Concentrations have decreased from a historical high of 1,898 µg/L in 1997, to 24 µg/L in October of 2001. Monitoring wells downgradient of the treatment system, along Carleton Avenue, showed stable or decreasing VOC concentrations during 2001.

Two new groundwater remediation systems are being planned to clean up the southern extent of the OU III plume not remediated by the Industrial Park treatment system. The treatment systems will be located along the northern edge of the Town of Brookhaven Airport and along the Long Island Power Authority (LIPA) right-of-way south of Carleton Drive (see Figure 7-18). These systems will be constructed by 2004.

North Street Monitoring. The North Street monitoring program (formerly known as OU I/IV monitoring program) addresses both a VOC plume that is primarily south of the site boundary and the issue of radiological contaminants that may have been introduced to groundwater in the OU IV portion of the site (particularly the Building 650 and 650 Sump Outfall areas).

Volatile Organic Compounds. A network of 25 monitoring wells monitors the downgradient portion of the OU IV, Former Landfill, Animal/ Chemical Pits, and Glass Holes VOC plumes. Wells sampled under the OU III South Boundary and Industrial Park Programs are also utilized for mapping this plume. The VOC plume extends from just south of the Chemical/Animal Hole area southward to the vicinity of the Brookhaven Airport (Figure 7-12). The primary VOCs associated with this plume are carbon tetrachloride, PCE, and TCA. Monitoring well 000-154 has historically shown the highest VOC concentrations (primarily carbon tetrachloride) in the North Street area. TVOC concentrations greater than 1,000 µg/L were observed in 1997 and 1998 but have steadily declined since that time. This high concentration area has migrated south of monitoring well 000-154, as evidenced by the 2,020 µg/L of TVOC detected in vertical profile well 000-381, which was installed in the deep Upper Glacial aquifer approximately 700 feet to the south. The leading edge of the North Street VOC plume is near the northern boundary of the Brookhaven Airport near Flower Hill Drive, where TVOC concentrations up to 7 µg/L were detected in well 800-76, which is screened in the deep Upper Glacial aquifer. Detailed groundwater characterization data can be found in the *North Street Groundwater Remediation System 90% Design Report* (Arcadis G&M 2002) and the *OU III Airport Groundwater Treatment System 90% Design Documents* (Holzmacher 2002a).

The North Street VOC plume will be remediated using two groundwater treatment systems. The first system will be located near Stratler Drive in North Shirley and is currently planned to consist of a two-well extraction and four-well recharge system (Figure 7-18). This system will capture the higher concentration portion of the VOC plume within the Upper Glacial aquifer that contains concentrations greater than 50 µg/L. This system will help to minimize the potential for VOC migration to the Magothy aquifer. Details on the pre-design groundwater characterization and the planned groundwater treatment system can be found in the *North Street Groundwater Remediation System 90% Design Report* (Arcadis G&M 2002). This treatment system is scheduled to start operations in November 2003. The second groundwater remediation system is to be located at the Brookhaven Airport. This system is being designed to remediate the leading edge of this plume, as well as the leading edge of the OU III VOC plume to the west (Figure 7-18). Details on the proposed remediation system and pre-design characterization activities can be found in the *OU III Airport Groundwater Treatment System 90% Design Documents* (Holzmacher, 2002a). Construction of the system is scheduled to begin in January 2003.

Radionuclides. Low levels of tritium have been detected off site in localized areas of the deep Upper Glacial aquifer at concentrations well below the 20,000 pCi/L drinking water standard. Tritium has been detected in this area since the monitoring program started in 1998. The maximum tritium concentration observed in 2001 was 2,560 pCi/L, in well 000-153. Tritium was also detected in seven of the fifteen temporary vertical profile wells installed in 2001 and 2002. In six of the seven vertical profiles, tritium was detected at concentrations less than 1,000 pCi/L. The highest tritium concentration was detected in temporary well 000-337, at 9,130 pCi/L, located approximately 300 feet north of well 000-153. Potential sources for this tritium, as well as other radionuclides, are located in the Former Landfill/ Chemical/Animal Holes and OU IV Building 650 areas of the site.

7.6.3.2 OU III Radionuclide Plumes

HFBR Tritium Plume. In late 1996, tritium was detected in wells near the High Flux Beam Reactor. The source of the release was traced to the HFBR spent fuel pool. In response, the fuel rods were removed from the pool for off-site disposal, the spent fuel pool was drained, and the

HFBR was removed from service in 1997. Also, numerous monitoring wells were constructed to characterize the tritium plume downgradient of the HFBR. In May 1997, operation of a three-well groundwater extraction system began. This system was constructed on Princeton Avenue approximately 3,500 feet downgradient of the HFBR to capture the leading edge of the tritium plume. Extracted water was recharged at the RA V recharge basin. Groundwater modeling predicts that the tritium plume will naturally attenuate to below drinking water standards before reaching the site boundary. Three years of monitoring data showed that the plume had reached a relative steady-state due to natural attenuation and that it was not growing significantly. As a result, the extraction system was turned off and placed on standby status in September 2000.

The selected remedy for the HFBR tritium plume includes monitoring and low-flow extraction programs to prevent or minimize the plume's growth. During 2000 and 2001, low-flow extraction was applied to the highest concentration area of the plume. The low-flow extraction removed a total of 95,000 gallons of tritiated water that was sent off site for disposal. Low-flow pumping reduced the high concentrations from about 1,180,000 pCi/L to less than 750,000 pCi/L.

A monitoring well network of 157 wells (including 22 wells installed in 2001) was designed to follow the extent of the plume, the source area, and the effectiveness of the groundwater remediation system. Due to the closeness of the HFBR to artificial pumping and recharge locations, the plume is subjected to changing hydraulic stresses, which have warranted an extensive monitoring network. BNL's Regional Groundwater Model was utilized to assist with the placement of the wells. The extent of the tritium plume, determined from data collected during the fourth quarter of 2001, is shown on Figure 7-13. By the end of 2001, the highest concentration of tritium detected was 447,000 pCi/L, in well 75-418. This well is just east of the BNL National Synchrotron Light Source (NSLS) facility, a distance of about 750 feet from the HFBR. The leading edge of the >20,000 pCi/L portion of the tritium plume is just north of temporary well 095-262, which is screened in the mid to deep Upper Glacial aquifer. The highest concentration in this temporary well was 18,500 pCi/L. The outer edge of the main body of the plume (as defined by concentrations >1,000 pCi/L) is just north of Weaver Drive. There were no detections of tritium in excess of 1,000 pCi/L during 2001 south of Weaver Drive.

WCF and BGRR Area Sr-90 Plumes.

Historical waste handling operations at the Waste Concentration Facility and operations at the former BGRR and associated Pile Fan Sump and Stack resulted in the release of strontium-90 to the groundwater below these facilities. The strontium-90 plumes from these facilities are monitored using 57 wells. During 2001, additional groundwater characterization work was conducted near the BGRR Below Ground Ducts area using 24 temporary wells, and in the vicinity of the HFBR stack using three temporary wells.

Analytical results from monitoring wells and temporary wells show two separate areas of elevated strontium-90, one emanating from the WCF and extending south approximately 1,500 feet, and the other beginning south of the BGRR and extending south approximately 600 feet toward Brookhaven Avenue (Figure 7-14). Variability in groundwater flow directions, due to changes in pumping and recharge patterns in the plume vicinity over time, has caused some lateral spreading of the contamination.

There are three areas of strontium-90 concentration greater than 50 pCi/L within the plumes. The first is in the vicinity of the Below Ground Ducts, where an August 2001 groundwater sample from a temporary well contained strontium-90 levels at 540 pCi/L. Concentrations greater than 50 pCi/L extend south of this area to well 75-190, which is just south of Cornell Avenue.

In the WCF area, high strontium-90 levels were detected immediately south of the former "D" tanks area. The highest strontium-90 concentration observed in this well during 2001 was 760 pCi/L, in December; strontium-90 concentrations have exceeded 800 pCi/L since this well was installed in 1997.

A third area of high strontium-90 concentrations was discovered in 2001 in the vicinity of

Figure 7-13. High Flux Beam Reactor Tritium Plume Comparisons – 1997 and 2001.

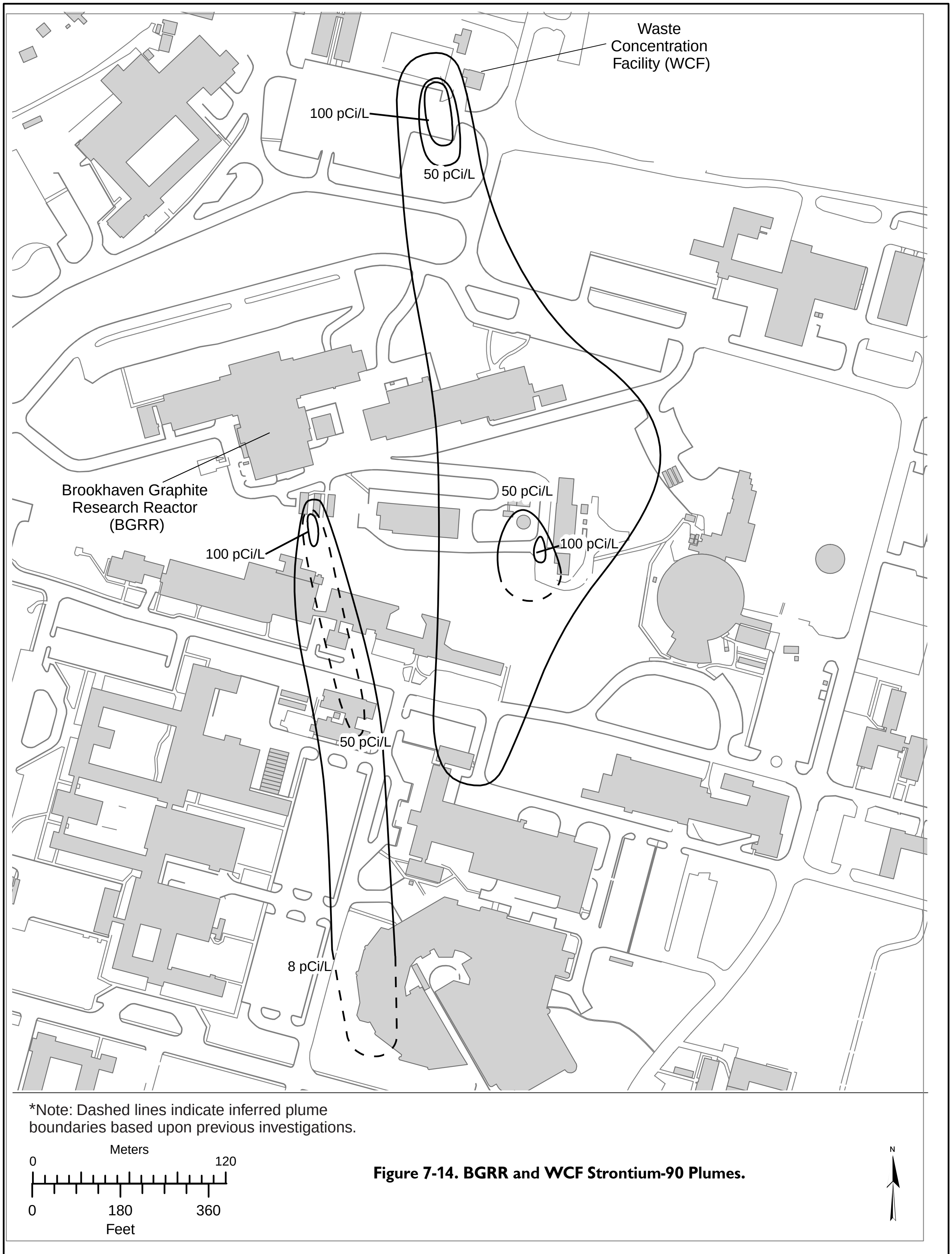

Figure 7-14. BGRR and WCF Strontium-90 Plumes.

the HFBR stack. Strontium-90 was detected in a temporary well downgradient of the stack in 2001, at a concentration of 392 pCi/L.

7.6.4 Operable Unit IV

The Operable Unit IV area contains two significant source areas: the 1977 fuel oil/solvent spill site (Area if Concern 5), and the Building 650 Sump and Sump Outfall area (AOC 6).

7.6.4.1 1977 Oil-Solvent Spill Site

In 1977, between 23,000 and 25,000 gallons of a mixture of Number 6 fuel oil and mineral spirits were released when a pipe ruptured as the contents of an underground storage tank were being transferred to aboveground storage tanks at the Central Steam Facility. The primary chemical contaminants that were found in the OU IV plume near this 1977 spill site were TCA, PCE, DCE, TCE, toluene, ethylbenzene, and xylenes. In addition, several small spills of Number 6 fuel oil from the CSF fuel unloading area were documented between 1988 and 1993; it also is suspected that small volumes of solvents such as PCE were released to the ground near the CSF.

Since November 1997, BNL has operated an air sparging/soil vapor extraction (AS/SVE) system to remediate soil and groundwater contamination associated with the 1977 spill. The performance goals for soil cleanup were achieved in 1998, and the goals for groundwater cleanup were met in August 2000. A formal petition for shutdown was submitted to EPA and NYSDEC, and approval was received in January 2001. The system was shut down on January 10, 2001. However, following the shutdown, groundwater monitoring results for well 076-04 showed a rebound in concentrations for several VOC parameters (indicative of fuel oil). This well is in the area where the original fuel oil/solvent spill occurred and it had shown VOC levels below MDLs for nearly two years prior to system shutdown. As a result of this finding, portions of the AS/SVE system near well 076-04 were pulsed on and off on a weekly basis starting in February 2001. During the following months, analytical results from the monthly sampling showed a decreasing trend in VOC concentrations. In addition to pulsing the AS/SVE system, BNL used an enhanced biodegradation process with an oxygen-releasing compound (ORC) during July 29 to July 31, 2001. The objective of this action was to further reduce any residual VOCs (primarily ethylbenzene, xylenes, and trimethylbenzenes). During this process, a slurry of a mixture of magnesium peroxide powder and water was injected under pressure at seven locations around well 076-04 into the water table. The system was shut down in August 2001 and further monitoring was continued as per *OU IV Remediation Area 1 Proposed Supplemental Remedial Effort – Work Plan, May 2001* (BNL 2001a).

Low levels of VOCs were detected in several wells (076-23 and 076-06) that are outside the area of influence of the AS/SVE system. Well 076-23 is west of the AS/SVE system and south of the CSF, and had a maximum TVOC concentration (consisting primarily cis-1,2-dichloroethylene) of 45 µg/L. It is likely that the cis-1,2-dichloroethylene, which is a breakdown product of the solvent tetrachloroethylene, originates from an historical spill that occurred near the CSF. Well 76-06 is east of the AS/SVE system. TVOC concentrations (primarily BTEX compounds) were greater than 10 µg/L during the first and fourth quarters of 2001.

7.6.4.2 Building 650 and 650 Sump Outfall Areas (AOC 6)

Building 650 was used as a decontamination facility for radioactively contaminated clothing and equipment. Drainage from an exterior heavy equipment decontamination pad was piped to a natural depression approximately 800 feet to the northeast, near recharge basin HO. As a result of these operations, soils and groundwater were contaminated at the decontamination pad and the sump outfall. Remediation of the soils associated with the Building 650 sump outfall and the pipe leading to the outfall will be excavated and disposed of off site during the spring and summer of 2002.

The overall extent of the strontium-90 plume originating from the Building 650 sump outfall did not change significantly from 2000 to 2001 (Figure 7-15). The highest strontium-90 concentrations were detected in well 76-13 (28 pCi/L) in February 2001. Low levels of strontium-90 (14 pCi/L) were also detected in well 076-28, immediately north of Building 650 adjacent to a former decontamination pad.

7.6.5 Operable Unit V

Historically, Brookhaven's Sewage Treatment Plant received discharges of contaminants from routine operations. Releases of VOCs, metals, and radionuclides to groundwater occurred via the STP sand filter beds and discharges to the Peconic River. In addition, trace levels of pesticides were detected in some wells. The OU V monitoring program uses 34 monitoring wells downgradient of the STP. These wells monitor VOC and tritium contamination resulting from historical releases at the STP. Surveillance of groundwater quality near the STP filter beds and emergency holding pond areas is performed as part of the BNL Environmental Surveillance Program for the STP (see Section 7.5.2.1).

Volatile Organic Compounds, Metals, and Pesticides. The extent of the OU V VOC plume is shown on Figure 7-16. The highest TVOC concentration observed during 2001 was 28 µg/L in well 61-05, which is near the eastern site boundary.

Three pesticides were detected during 2001: 4,4'-dichlorodiphenyltrichloroethane (4,4'-DDT), aldrin, and dieldrin. 4,4'-DDT was detected in five wells at a maximum estimated concentration of 0.12 µg/L. Aldrin and dieldrin were detected in well 000-123, at estimated concentrations of 0.016 µg/L and 0.011 µg/L, respectively, during the March sampling event; they were not detected during the August sampling event.

Aluminum, antimony, iron, manganese, sodium, and thallium were detected at concentrations above applicable NYS AWQS levels. Aluminum was detected in 11 wells above the NYS AWQS of 0.2 mg/L, with the highest concentration (2.76 mg/L) detected in well 061-03. Antimony was detected above the NYS AWQS of 0.003 mg/L in well 037-04 at a concentration of 0.0058 mg/L. Iron was detected in 18 wells above the NYS AWQS of 0.3 mg/L, with the highest concentration of 25.9 mg/L detected in well 050-02. Manganese was detected in nine wells above the NYS AWQS of 0.3 mg/L, with the highest concentration (1.27 mg/L) detected in well 061-04. Sodium was detected above the NYS AWQS of 20 mg/L in five wells, with the highest concentration in well 600-21 (107 mg/L). Thallium was detected in well 049-05 at a concentration of 0.0048 mg/L, which exceeds the NYS AWQS of 0.0005 mg/L.

Radionuclides. Detectable levels of tritium were found in a number of wells near BNL's southeastern site boundary, but the concentrations were well below the drinking water standard of 20,000 pCi/L. In wells near the southeastern site boundary, a maximum tritium concentration of 1,710 pCi/L was detected in well 50-02. Tritium was not detected in any of the off-site monitoring wells. A detailed discussion on the distribution of tritium within the OU V plume is provided in the *2001 BNL Groundwater Status Report* (BNL 2002b).

7.6.6 Operable Unit VI, Biology Fields

Ethylene dibromide (EDB) was used as a fumigant in the BNL Biology Department's agricultural fields in the southeast portion of the site. Available records indicate that the application of EDB in this area took place in the 1970s. As a result of these historical releases of EDB, a contaminant plume (as defined by concentrations greater than the 0.05 µg/L drinking water standard for EDB) extends approximately 3,900 feet, from near BNL's southeastern site boundary to an area south of the Long Island Expressway (see Figure 7-17). EDB is the only contaminant of concern for the Biology Fields plume. The leading edge of the plume appears to be in the vicinity of temporary wells 000-383 and 000-385. The plume is located in the deep Upper Glacial aquifer. The highest EDB concentration observed during 2001 was 7.6 µg/L, in well 000-283. The federal drinking water standard for EDB is 0.05 µg/L. The wells were also sampled for radionuclides and, as in past years, no radionuclides were detected.

A groundwater remediation system to address the off-site EDB plume is being designed, and system construction is planned for November 2002. Pre-design groundwater characterization work was performed in 2001 and consisted of installing five temporary wells.

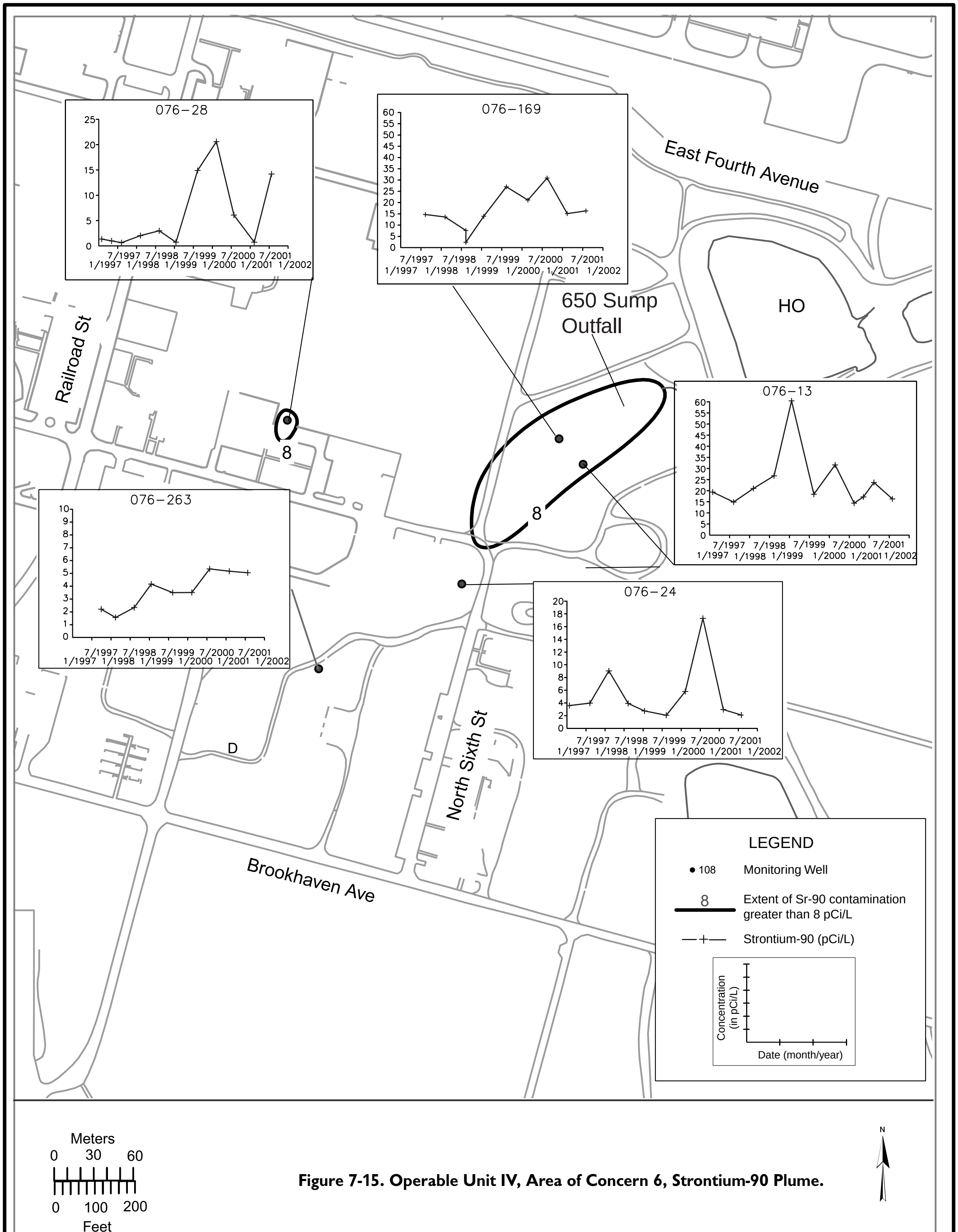

Figure 7-15. Operable Unit IV, Area of Concern 6, Strontium-90 Plume.

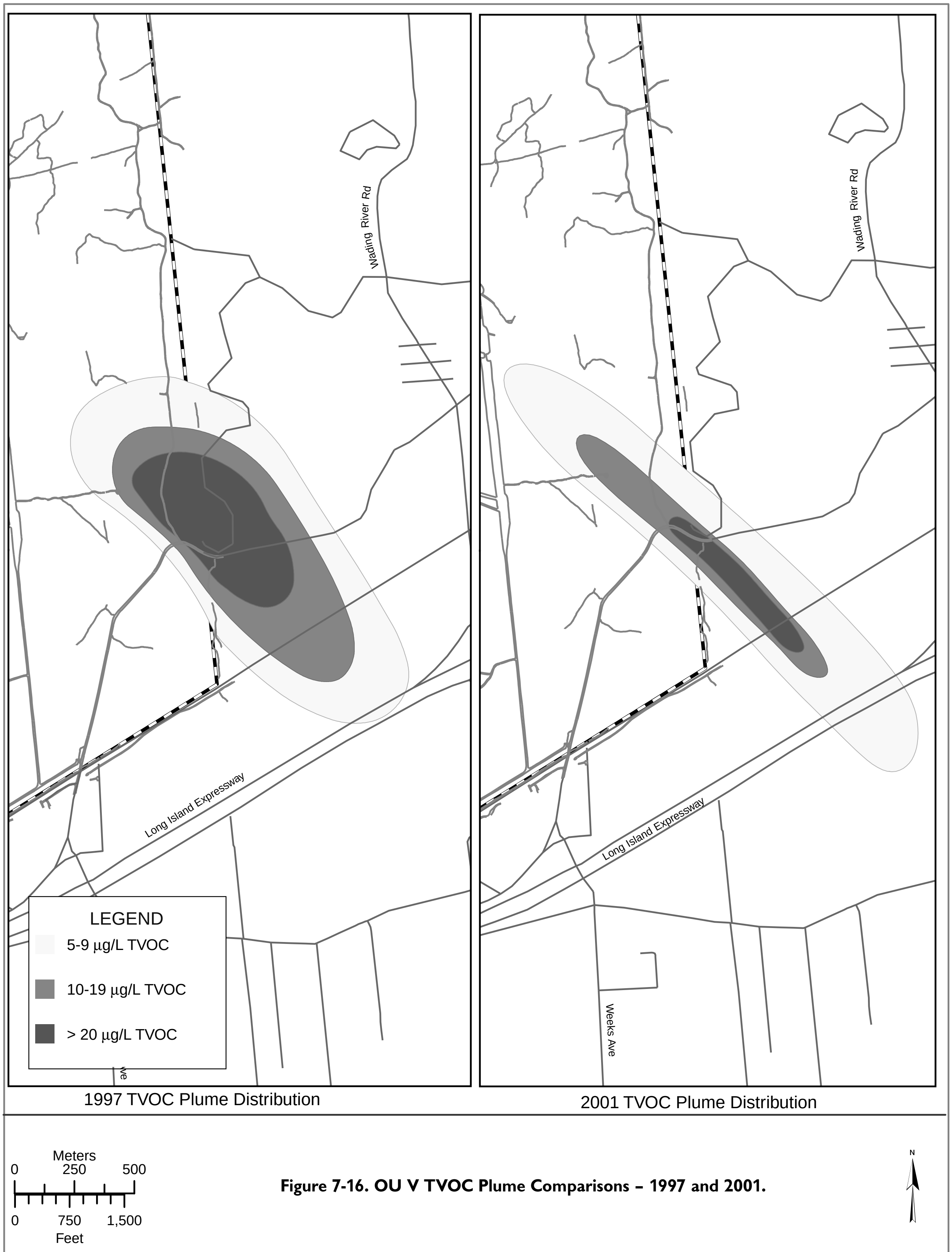

Figure 7-16. OU V TVOC Plume Comparisons – 1997 and 2001.

Figure 7-17. OU VI EDB Plume Comparisons – 1997 and 2001.

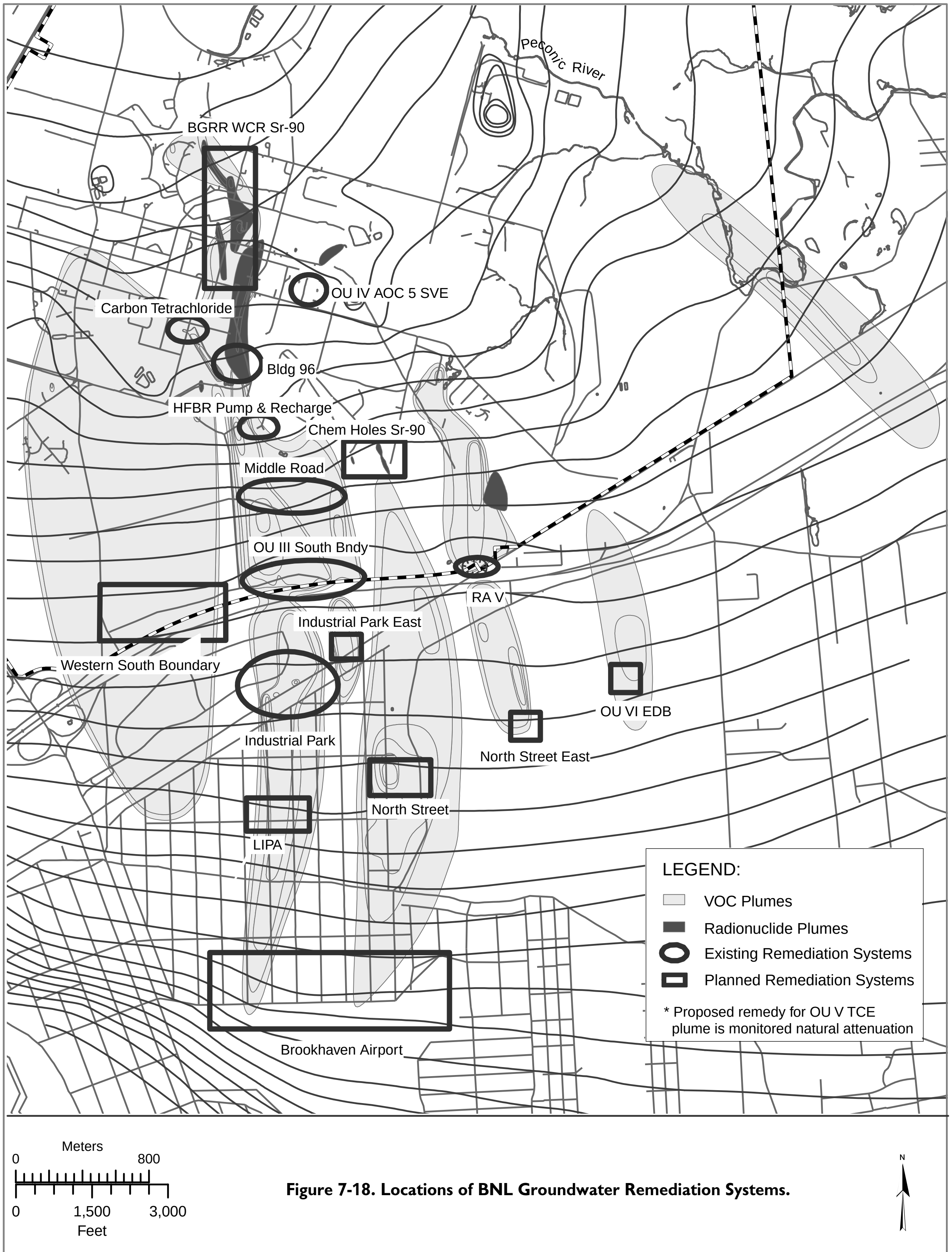

Figure 7-18. Locations of BNL Groundwater Remediation Systems.

Table 7-2. Groundwater Remediation Systems Treatment Summary for 1997 – 2001.

Remediation System	1997-2000 Water Treated (Gallons)	1997-2000 VOCs Removed (Pounds)	2001 Water Treated (Gallons)	2001 VOCs Removed (Pounds) [d]
OU III South Boundary	1,219,028,400	1,424	339,408,450	285
OU III Industrial Park [a]	227,573,000	240	163,120,000	208
Carbon Tetrachloride [a]	49,173,000	219	39,164,300	17
OU I South Boundary	1,329,540,000	229	411,399,000	25
HFBR Tritium Plume	241,528,000[b]	180	0	0
OU IV AS/SVE [c]	—	47	—	0
Building 96	0	0	24,238,416	35
Middle Road	0	0	55,353,550	39
Total	3,066,842,400	2339	1,032,683,716	609

Notes:
[a] Treatment system not installed/operational until 1999.
[b] System was shut down and placed in standby mode on September 29, 2000.
[c] Air Sparging/Soil Vapor Extraction system performance measured by pounds of VOC removed per cubic feet of air treated.
[d] Values rounded to the nearest whole number.

Detailed information and data obtained during this investigation are presented in the *OU VI EDB Plume Groundwater Remediation System 90 Percent Design Documents* (J.R. Holzmacher, Inc. 2002b).

7.7 GROUNDWATER TREATMENT SYSTEMS

The primary mission of BNL's Environmental Restoration Program is remediating soil and groundwater contamination and preventing additional contamination from migrating off the BNL site. The cleanup goals are to: 1) prevent or minimize plume growth, and 2) reduce contaminant concentrations in the Upper Glacial aquifer to below regulatory standards within 30 years. In 2001, BNL continued to make significant progress in characterizing and restoring groundwater quality at the site. Six groundwater remediation systems were in operation by the end of 2001 with the addition of the OU III Middle Road system. Eight of the seventeen planned groundwater treatment plants have been constructed. Two systems remained in standby mode in 2001, as they substantially met their cleanup goals: the OU IV Air Sparging/Soil Vapor Extraction system, and the HFBR Pump & Recharge System. An additional extraction well was constructed for the OU III Carbon Tetrachloride pump-and-treat system and was operational in December 2001. Compared to 2000, the total groundwater cleanup treatment capacity was increased from 1,945 gpm to 2,575 gpm. Ultimately, the total groundwater cleanup capacity will be approximately 4,500 gpm. Figure 7-18 shows the locations of the current and planned groundwater treatment systems. Table 7-2 provides a summary of pounds of VOCs removed and gallons of water treated since the first treatment system became operational in 1997. During 2001, 609 pounds of VOCs were removed from the groundwater and more than one billion gallons of treated groundwater were returned to the aquifer. Detailed information on these treatment systems can be found in the *2001 BNL Groundwater Status Report* (BNL 2002b).

Groundwater remediation is expected to take up to ten years of aquifer treatment before widespread improvements in groundwater quality at BNL are achieved. Even so, some noticeable improvements in groundwater quality are evident in OU IV, the OU III South Boundary area, and the OU I South Boundary area. Groundwater remediation activities are expected to continue until approximately 2025 to meet the ultimate cleanup objective.

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