Granular Activated Carbon Filter Vessels at Former Firehouse Per- and Poly-fluoroalkyl Substances (PFAS) Plume Treatment System Building.

Chapter 7

Groundwater Protection

Brookhaven National Laboratory (BNL) implements aggressive pollution prevention measures to protect groundwater resources and uses an extensive groundwater monitoring well network to verify that prevention and restoration activities are effective.

During 2024, BNL collected groundwater samples from 765 permanent monitoring wells and 41 temporary wells. Seven groundwater remediation systems removed 41 pounds of volatile organic compounds (VOCs) and returned approximately 753 million gallons of treated water to the Upper Glacial aquifer. Since the beginning of active groundwater remediation in December 1996, the treatment systems have removed 7,914 pounds of VOCs by treating almost 33 billion gallons of groundwater. BNL started the operation of the Current Firehouse Per- and Poly-fluoroalkyl Substances (PFAS) Remediation System and the Former Firehouse PFAS Remediation System in October 2022 and January 2023, respectively. Since the start of their operations, the systems have removed approximately 1.3 pounds of total PFAS while treating 666 million gallons of groundwater. Also, one groundwater treatment system removed approximately 0.1 millicurie of strontium-90 (Sr-90) while remediating approximately 7 million gallons of groundwater. Since 2003, BNL has removed approximately 34.9 millicuries of Sr-90 from the groundwater while remediating approximately 297 million gallons of groundwater. As a result of the successful operation of these treatment systems, significant reductions in contaminant concentrations have occurred in both on-site and off-site areas.

7.1
The BNL Groundwater Protection Management Program

The primary goal of BNL's Groundwater Protection Program is to ensure that plans for groundwater protection, management, monitoring, and remediation are fully defined, integrated, and managed in a manner that is consistent with federal, state, and local regulations. The program helps to fulfill the environmental monitoring requirements outlined in various New York State operating permits and applicable Executive Orders (EO) and DOE Orders (DOE O). This program also satisfies the monitoring and remediation requirements defined in Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Records of Decision (RODs). The program consists of four interconnecting elements: 1) protecting groundwater resources, 2) monitoring the effectiveness of engineered and administrative controls at operating facilities, 3) restoring the environment by cleaning up contaminated soil and groundwater, and 4) communicating with stakeholders on groundwater protection issues. The Laboratory is committed to protecting groundwater resources from further chemical and radionuclide releases and remediating existing contaminated groundwater. A general description of the site hydrogeology is provided in Chapter 1, Section 1.6. Detailed information on the site's hydrogeology is presented in Site Environmental Report (SER) Volume II, Groundwater Status Report, and in Scorca et al. (1999).

7.1.1 Protection

As part of BNL's Environmental Management System, the Laboratory has implemented several pollution prevention activities that are designed to protect groundwater resources (see Chapter 2, Section 2.4.2). BNL has established a work control program that requires the assessment of all experiments and industrial operations to determine their potential impact on the environment. The program enables the Laboratory to integrate pollution prevention and waste minimization, resource conservation, and compliance into planning and decision making.

Efforts have been implemented to achieve or maintain compliance with regulatory requirements and to implement best management practices designed to protect groundwater (see Chapter 3, Sections 3.6 through 3.8). Examples include upgrading underground storage tanks, 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). BNL's comprehensive groundwater monitoring program is used to confirm that these controls are working.

7.1.2 Monitoring

The Laboratory's groundwater monitoring network is designed to evaluate the impacts of groundwater contamination from former and current operations and to track cleanup progress.

Each year, BNL collects groundwater samples from an extensive network of on- and off-site monitoring wells. Results from groundwater monitoring are used to verify that protection and remediation efforts are working. Groundwater monitoring is focused on two general areas: 1) Facility Monitoring, designed to satisfy DOE and New York State monitoring requirements for active research and support facilities; and 2) CERCLA monitoring related to the Laboratory's obligations under the Federal Facilities Agreement (FFA) (USEPA 1992).

These monitoring programs are coordinated to ensure completeness and to prevent duplication of effort in the installation, monitoring, and decommissioning of wells. The monitoring program elements include data quality objectives; plans and procedures; sampling and analysis; quality assurance; data management; and the installation, maintenance, and decommissioning of wells. These elements are integrated 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 Remediation

BNL was added to the National Priorities List in 1989. To help manage the restoration effort, 34 separate Areas of Concern are grouped into 11 Operable Units (OUs). Remedial and/or removal actions have been implemented for each OU. Contaminant sources for VOCs and radionuclides (e.g., contaminated soil and underground storage tanks) have been removed or remediated to prevent further contamination of groundwater. However, BNL continues to conduct groundwater and soil characterization efforts to fully identify the sources and extent of PFAS and 1,4-dioxane contamination. Beginning in late 2022, BNL has been remediating PFAS plumes originating from three former firefighter training locations. All groundwater characterization and remediation work are carried out under the FFA involving the U.S. Environmental Protection Agency (USEPA), the New York State Department of Environmental Conservation (NYSDEC), and DOE (USEPA 1992).

7.1.4 Communication

BNL's Stakeholder & Community Relations Office works with the Groundwater Protection Program to ensure that the Laboratory communicates groundwater protection issues and cleanup progress with its stakeholders in a consistent, timely, and accurate manner. This communications process is described in BNL's Community Involvement Plan (BNL 2024a). Several communication mechanisms are in place, such as press releases,

web pages, mailings, public meetings, briefings, and roundtable discussions. Specific examples include routine meetings with the Community Advisory Council (see Chapter 2, Section 2.5.2.1). Quarterly and annual technical reports that summarize data, evaluations, and program indices are prepared. In addition, the Laboratory has developed a Groundwater Protection Contingency Plan (BNL 2023) that provides formal processes to promptly communicate off normal or unusual monitoring results to BNL management, DOE, regulatory agencies, and other stakeholders, including the public and employees.

7.2 Groundwater Protection Performance

BNL has made significant investments in environmental protection programs over the past 33 years and continues to make progress in achieving its goal of preventing new impacts to groundwater quality and remediating previously contaminated groundwater. The Laboratory will continue efforts to prevent new groundwater impacts and is vigilant in measuring and communicating its performance. During 2024, monitoring conducted at BNL's active research and support facilities did not identify any new impacts to groundwater quality.

Brookhaven Graphite Research Reactor Sr-90 Groundwater Remediation System Ion-Exchange vessels.

7.3 Groundwater Monitoring Programs

BNL maintains an extensive network of groundwater monitoring wells that are located on-site and off-site. During 2024, the Laboratory collected groundwater samples from 765 of the wells to test for various contaminants that may be in the groundwater. Water levels were measured in about 185 of the wells to assess variations in the direction and velocity of groundwater flow. Groundwater flow directions near the Laboratory are shown on Figure 7-1. Elements of the groundwater monitoring program include installing permanent and temporary monitoring wells; planning and scheduling; developing and following quality assurance procedures; collecting and analyzing samples; verifying, validating, and interpreting data; and reporting. Monitoring wells are used to evaluate BNL's progress in restoring groundwater quality, comply with regulatory permit requirements, monitor active research and support facilities, and assess the quality of groundwater that enters and exits the site.

The Laboratory monitors research and support facilities where there is a potential for environmental impact, as well as areas where past waste handling practices or accidental spills have already degraded groundwater quality. The groundwater aquifers beneath the site are classified as a USEPA Sole Source Aquifer System,

and the groundwater is also classified by New York State as Class GA, which is defined as a source of potable water. As a result of these designations, Federal and New York State drinking water standards (DWS) also referred to as Maximum Contaminant Levels (MCLs), and New York State Ambient Water Quality Standards for Class GA groundwater are used as goals for groundwater protection and remediation. BNL evaluates the potential impact of radiological and non-radiological contamination by comparing analytical results to the regulatory standards. Contaminant concentrations that are below the standards are also compared to background values to evaluate the potential effects of facility operations. The detection of even low concentrations of facility-specific chemicals or radionuclides may provide important early indications of a contaminant release and allow for timely identification and remediation of the source.

7.3.1 Emerging Contaminants of Concern

During 2017, several PFAS were detected in water samples collected from three BNL water supply wells. Since that time, BNL identified nine areas where PFAS containing aqueous film forming foam (AFFF) had been used for firefighter training or fire suppression system maintenance from 1966 through 2008. Groundwater characterization confirmed the presence of PFAS in each of the nine areas. In each area, the PFAS chemicals perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) concentrations were found to exceed the 10 ng/L drinking water standards that were adopted for these chemicals by New York State in August 2020. The highest PFAS concentrations in groundwater are associated with firefighter training that occurred at the Former Firehouse (in operation from 1947-1985), the Current Firehouse, and the Building 170 areas. At the Former Firehouse area, the maximum PFOS and PFOA concentrations detected to date in the groundwater were 24,000 ng/L and 1,600 ng/L, respectively. At the Current Firehouse area, the maximum PFOS and PFOA concentrations detected to date were 16,000 ng/L and 1,200 ng/L, respectively. Near the Building 170 source area, the maximum PFOS and PFOA concentrations detected to date were 8,470 ng/L and 66 ng/L, respectively.

BNL operates two groundwater treatment systems to remediate the high concentration PFAS plumes associated with the former firefighter training areas. The Current Firehouse PFAS Treatment System (which also treats the Building 170 PFAS plume) went into operation in December 2022 and the Former Firehouse PFAS Treatment System went into operation in January 2023. BNL also installed 99 new monitoring wells to verify the effectiveness of the PFAS treatment systems.

Since 2017, BNL has also been characterizing the extent of 1,4-dioxane contamination in groundwater. 1,4-Dioxane was used as a chemical stabilizer for the solvent 1,1,1-trichloroethane (TCA). BNL has confirmed the presence of 1,4-dioxane in several on-site and off-site areas that have been impacted by TCA contamination, with a maximum concentration of 23.9 µg/L in a Western South Boundary area monitoring well. In August 2020, New York State adopted a drinking water standard for 1,4-dioxane of 1.0 µg/L. Long-term characterization and remedial actions for PFOS, PFOA, and 1,4-dioxane will be conducted under the CERCLA program as Operable Unit X.

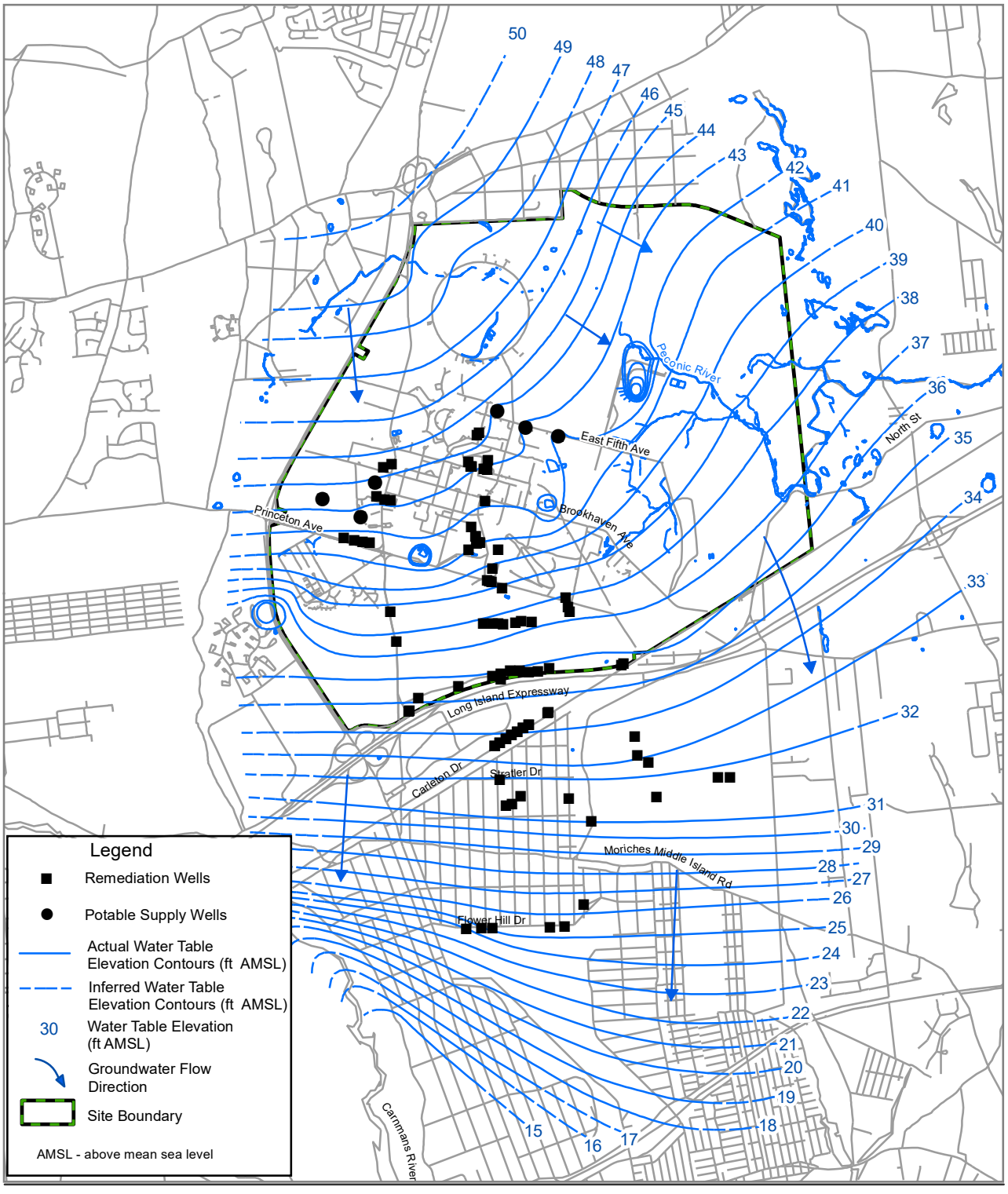

Figure 7-1. Groundwater Table Elevation Map for August 2024 Showing Groundwater Flow Directions and Locations of Supply and Remediation Wells.

7.4
Groundwater Monitoring Results

During 2024, the Facility Monitoring program monitored 108 permanent wells during 141 individual sampling events. The CERCLA groundwater monitoring program monitored 657 permanent wells during 1,327 individual groundwater sampling events. Forty-one temporary wells were also installed as part of the CERCLA program, for the continued characterization of several VOC, Sr-90, and PFAS plumes. Detailed descriptions and maps related to the groundwater monitoring programs can be found in SER Volume II, Groundwater Status Report. Maps that show changes over time of the main VOC plumes, radionuclide plumes, Current Firehouse PFAS plume, and Former Firehouse PFAS plume are provided as Figures 7-2 through 7-5, respectively.

Highlights of the groundwater monitoring programs for 2024 include the following:

- Monitoring conducted at BNL's major research facilities (e.g., Alternating Gradient Synchrotron, Brookhaven Linac Isotope Producer, Relativistic Heavy Ion Collider, and National Synchrotron Light Source II) and support facilities (e.g., Sewage Treatment Plant, Major Petroleum Facility and Waste Management Facility) did not identify any new impacts to groundwater quality resulting from current operations.
- As recommended in the 2021 CERCLA Five-Year Review (BNL 2021), BNL completed the planned injection of liquid carbon and zero-valent iron for in-situ treatment of residual tetrachloroethylene (PCE) contaminated soil at the Building 96 source area. Initial monitoring results indicate that the treatment is successfully reducing the mobility of the PCE. Long-term monitoring will be used to verify that the treatment is successfully degrading the residual contamination.
- Groundwater monitoring results for the OU III Middle Road and South Boundary treatment systems indicate that VOC concentrations are not declining at a rate that will definitively meet the ROD cleanup goal of meeting MCLs by 2030. In response, BNL has been performing groundwater model simulations to evaluate whether modifications to the system are required. The modeling results indicate that three additional extraction wells may be required.
- The Western South Boundary VOC groundwater treatment system was modified in 2019 with the addition of four new extraction wells. As a result of this effort, VOC concentrations and the extent of the plume have decreased significantly. During 2024, total VOC (TVOC) concentrations in plume core monitoring wells were below the treatment system capture goal of 20 µg/L. The concentrations of individual VOCs have also declined to below the applicable MCLs. As a result, BNL will prepare a petition for shutdown.
- Groundwater monitoring results for the off-site North Street East treatment system indicate that ethylene dibromide (EDB) concentrations and the extent of the EDB plume have decreased significantly following four years of groundwater remediation. During 2024, EDB concentrations in plume core wells continued to be below the 0.05 µg/L MCL. As a result, BNL will prepare a petition for shutdown.
- EDB concentrations in a number of the off-site OU VI treatment system monitoring wells continue to exceed the 0.05 µg/L MCL, with a maximum concentration of 1.0 µg/L. The two new extraction wells installed in 2023 to enhance the operations of the treatment system were operational throughout 2024. Additional monitoring will be required to evaluate the long-term effectiveness of the new extraction wells.
- Total VOC concentrations in plume core wells associated with the off-site Industrial Park and Long Island Power Authority (LIPA) treatment systems have remained below the 50 µg/L capture goals for each system. Furthermore, individual VOC concentrations in LIPA monitoring wells have

decreased to below their applicable MCLs. In 2024, a petition for closure for the LIPA treatment system (BNL 2024b) was approved, and a petition for closure of the Industrial Park system is anticipated to be submitted in 2025.

- High levels of PFAS continue to be detected in the groundwater near the Former Firehouse, Current Firehouse, and Building 170 PFAS source areas. In the Former Firehouse area, PFOS and PFOA were detected at concentrations up to 24,000 ng/L and 1,600 ng/L, respectively. In the Current Firehouse area, PFOS and PFOA were detected at concentrations up to 16,000 ng/L and 1,200 ng/L, respectively. Whereas at the Building 170 source area, PFOS, and PFOA were detected at concentrations up to 5,050 ng/L and 65 ng/L, respectively. Effluent monitoring results for the two PFAS treatment systems showed that the granular activated carbon filters were reducing PFOS and PFOA to non-detectable levels. During 2024, BNL installed 15 temporary wells to further characterize the downgradient migration of the Current Firehouse PFAS plume. The monitoring results confirmed that the PFAS contamination has migrated to the BNL southwestern boarder (Figure 7-4). Furthermore, analytical results from existing OU III monitoring wells confirmed that the Former Firehouse PFAS plume extends off-site to the Industrial Park area (Figure 7.5).
- Low levels of PFOS and PFOA continued to be detected in the southwest portion of the BNL site that is within the source water contributing area of the Suffolk County Water Authority's William Floyd Well Field. During 2024, PFOS and PFOA were detected in several permanent and temporary monitoring wells at concentrations up to 21 ng/L and 10 ng/L, respectively.

Detailed groundwater monitoring results including plume maps, hydrogeological cross sections, and trend charts are presented in SER Volume II, Groundwater Status Report.

Sampling a Groundwater Monitoring Well.

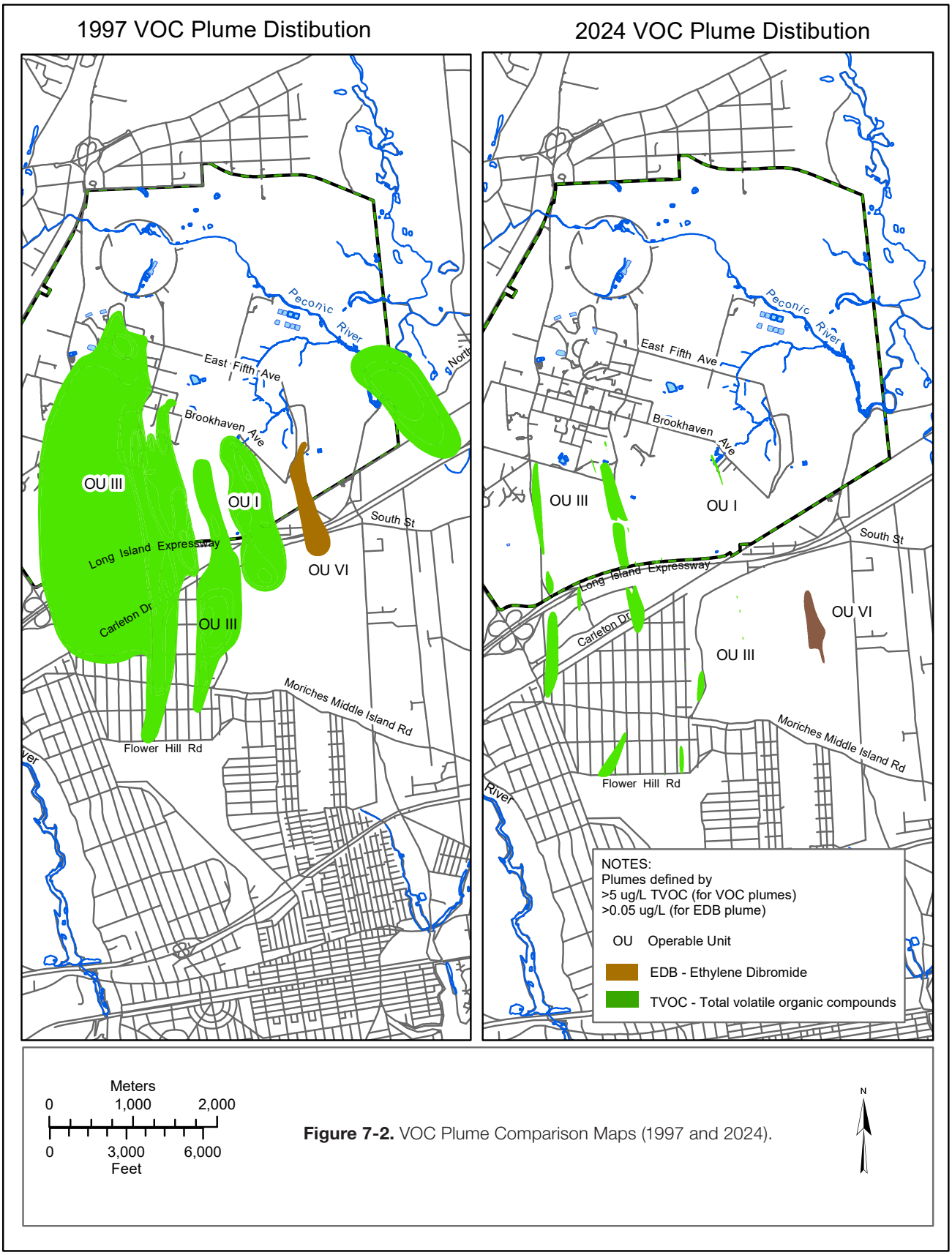

Figure 7-2. VOC Plume Comparison Maps (1997 and 2024).

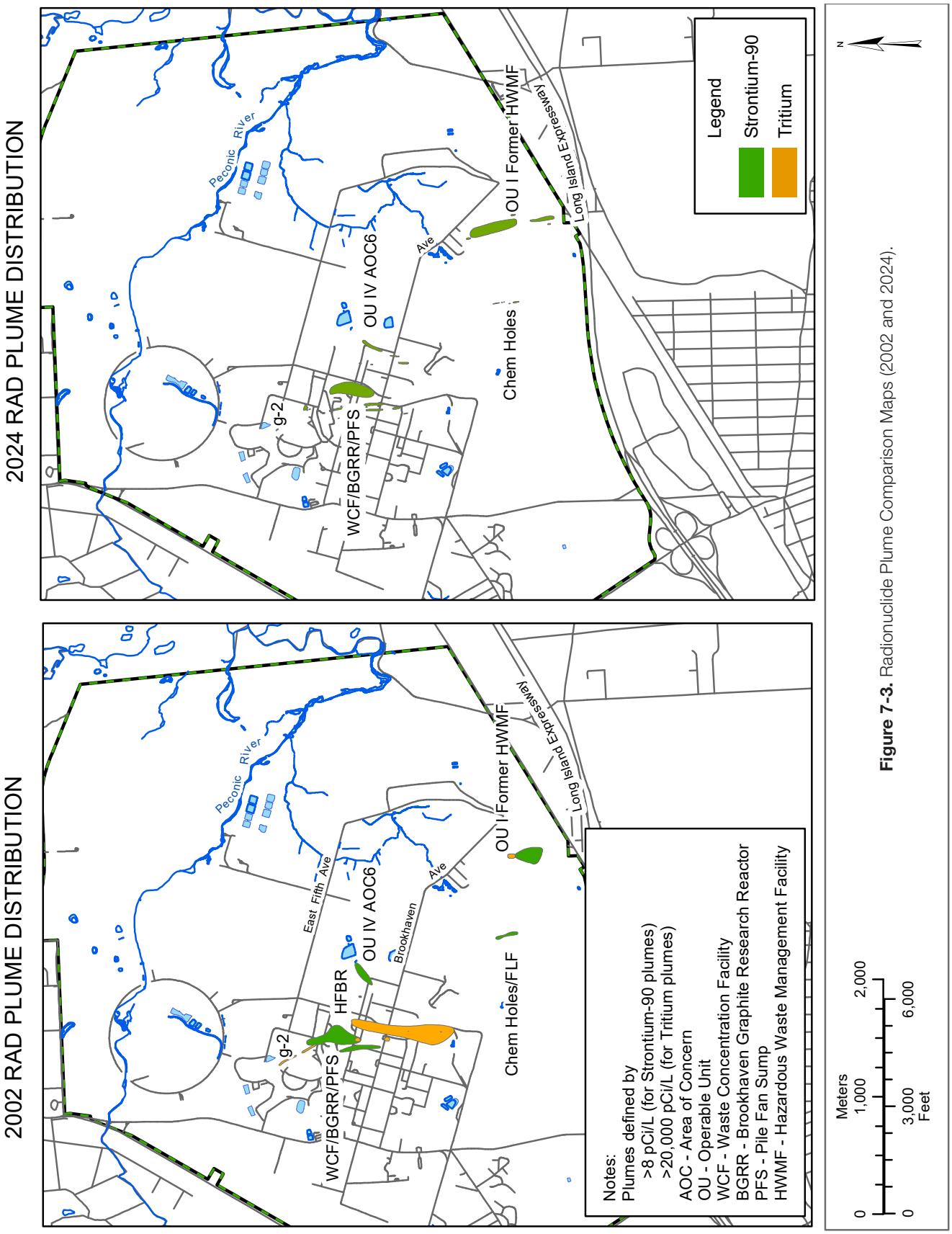

Figure 7-3. Radionuclide Plume Comparison Maps (2002 and 2024).

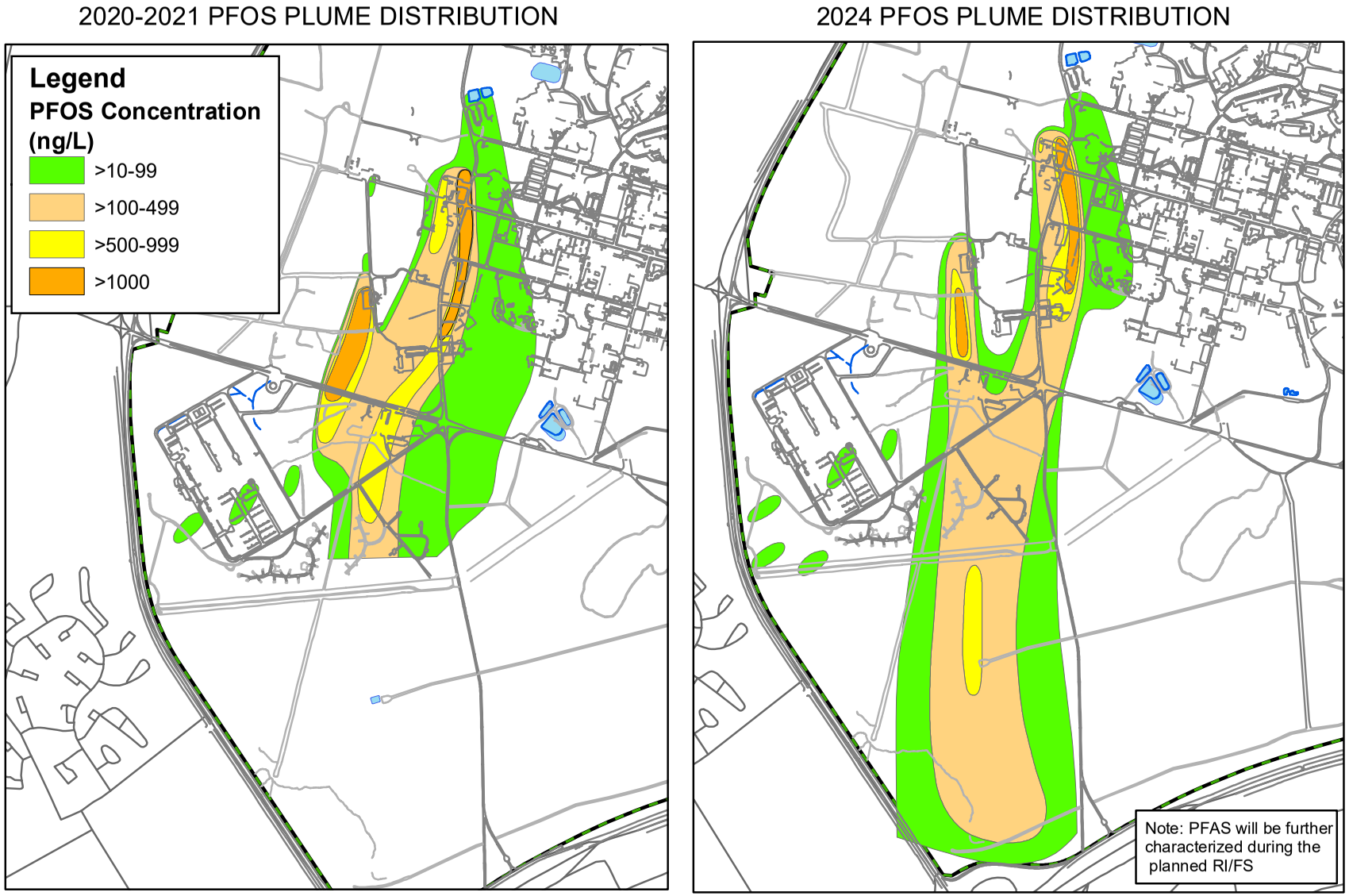

Figure 7-4. Current Firehouse and Building 170 PFOS Plume Comparisons (2020/21 and 2024).

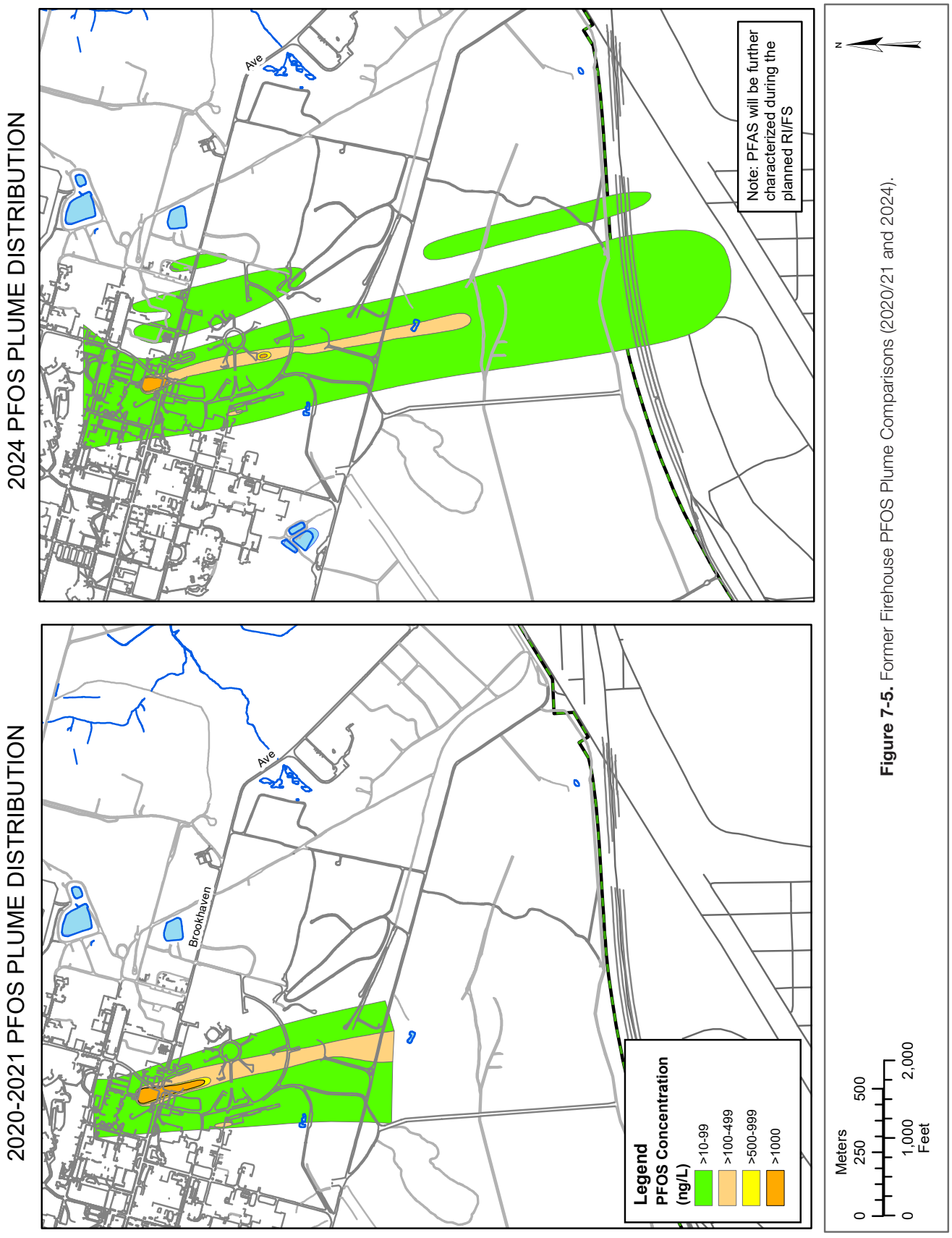

Figure 7-5. Former Firehouse PFOS Plume Comparisons (2020/21 and 2024).

7.5
Groundwater Treatment Systems

The primary mission of the CERCLA program is to operate and maintain groundwater treatment systems to remediate contaminant plumes both on- and off-site. Modifications to groundwater remediation systems are implemented, as necessary, based upon a continuous evaluation of monitoring data and system performance. The cleanup objectives that are defined in CERCLA RODs will be met by a combination of active treatment and natural attenuation. The specific cleanup goals are as follows:

- Achieve MCLs for VOCs in the Upper Glacial aquifer by 2030. The MCLs for most of the VOCs detected in the groundwater are typically 5.0 µg/L, whereas the MCL for EDB is 0.05 µg/L.
- Achieve MCLs for VOCs in the Magothy aquifer by 2065.
- Achieve the 8 pCi/L MCL for Sr-90 at the Brookhaven Graphite Research Reactor (BGRR) in the Upper Glacial aquifer by 2070.
- Achieve the MCL for Sr-90 at the Chemical Holes in the Upper Glacial aquifer by 2040.
- The cleanup goals for PFAS and 1,4-dioxane will be defined in the OU X ROD that will be prepared at the completion of a planned Remedial Investigation/Feasibility Study (RI/FS).

During 2024, BNL continued to make significant progress in restoring groundwater quality in several on-site and off-site areas (see Figures 7-2 through 7-5). Figure 7-6 shows the locations of the ten groundwater treatment systems currently in operation. Table 7-1 provides a summary of the amounts of VOCs, PFAS, and Sr-90 removed from the aquifer since the start of active remediation in December 1996. During 2024, approximately 41 pounds of VOCs, 0.7 pounds of total PFAS, and 0.1 mCi of Sr-90 were removed from the groundwater and nearly 1.1 billion gallons of treated groundwater were returned to the aquifer. To date, 7,914 pounds of VOCs have been removed from the aquifer and noticeable improvements in groundwater quality are evident in several on-site and off-site areas. Furthermore, two of the treatment systems have removed approximately 34.9 mCi of Sr-90, and two other systems have removed approximately 1.3 pounds of PFAS. Detailed information on the groundwater contaminant plumes and treatment systems can be found in SER Volume II, Groundwater Status Report.

Measuring depth to groundwater in a monitoring well.

In March 2023, New York State established Ambient Groundwater Quality Guidance Values for PFOS (2.7 ng/L), PFOA (6.7 ng/L), and 1,4-dioxane (0.35 µg/L) that are lower than the previously established drinking water standards. New York State is applying these values as Effluent Limitations for BNL's groundwater treatment systems. Monitoring conducted to date indicates that 1,4-dioxane concentrations exceed the 0.35 µg/L discharge standard at one on-site and two off-site groundwater treatment systems. Additionally, PFOS concentrations in the effluent from one on-site treatment system exceed the 2.7 ng/L standard. With the goal of bringing the discharges into compliance, BNL evaluated several commercially available treatment technologies. Because PFAS can be readily treated using granular activated carbon (GAC) filtration, the focus was on the treatment of 1,4-dioxane. The selected treatment technology was advanced oxidation process (AOP). BNL is continuing to monitor these systems for PFAS and 1,4-dioxane and in late 2024 BNL provided the regulatory agencies with a plan that outlines the proposed treatment system modifications.

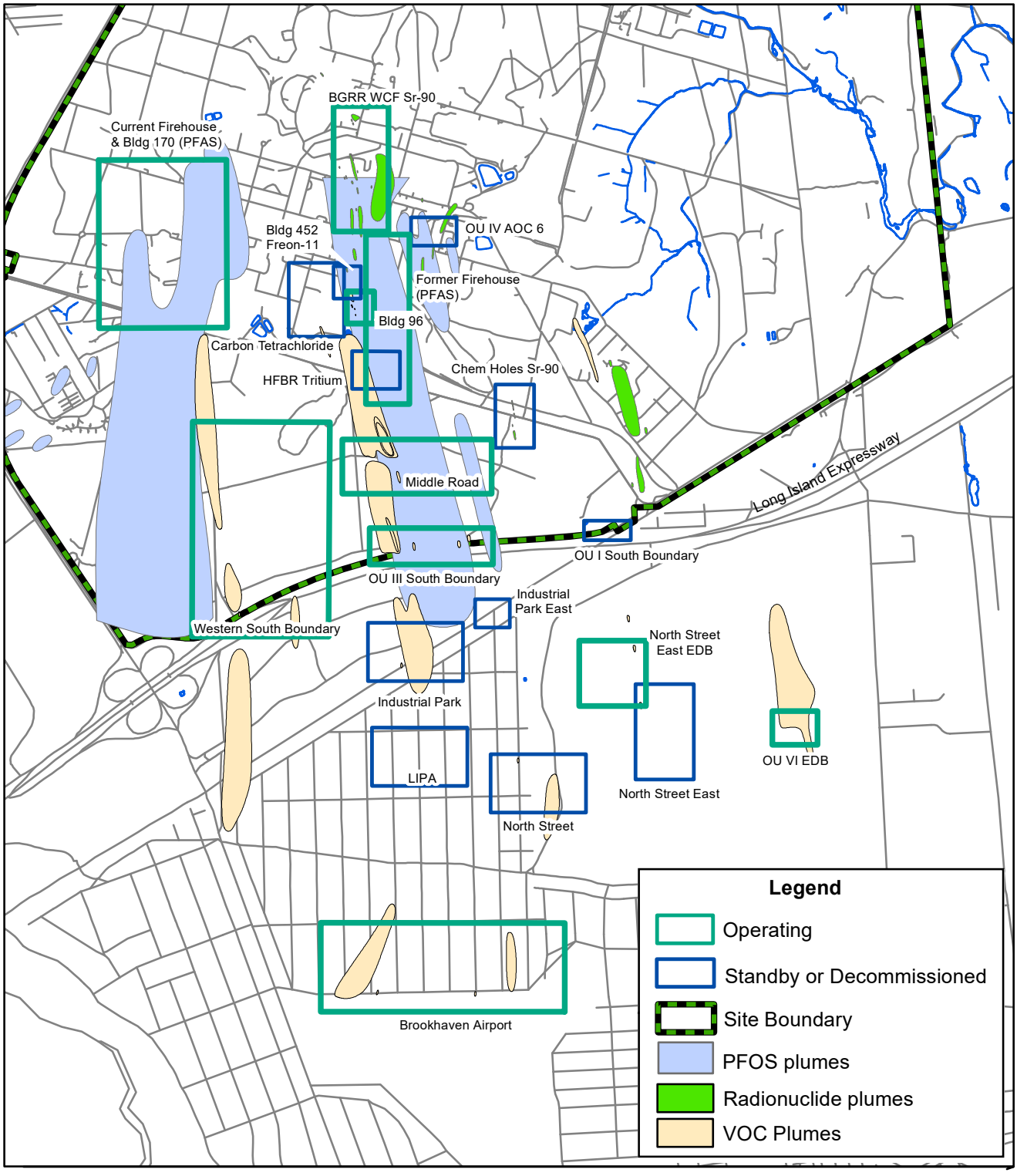

Figure 7-6. Locations of BNL Groundwater Remediation Systems.

Table 7-1. BNL Groundwater Remediation System Treatment Summary for 1997 through 2024.

VOC Remediation (start date)	1997-2023		2024	
	Water Treated (gallons)	VOCs Removed (pounds)(c)	Water Treated (gallons)	VOCs Removed (pounds)(c)
OU I South Boundary (Dec. 1996) (a)	4,177,473,000	369	(Closed)	0
OU III Carbon Tetrachloride (Oct. 1999) (e)	153,538,000	349	(Decommissioned)	0
OU III Building 96 (Feb. 2001)	620,697,000	147	6,512,800	0.1
OU III Building 452 Freon-11 (March 2012) (a)	124,997,000	106	(Closed)	0
OU III Middle Road (Oct. 2001)	4,272,547,000	1,378	186,000,000	21
OU III South Boundary (June 1997)	5,632,151,000	3,084	53,000,000	6
OU III W. South Boundary (Sept. 2002)	2,687,555,000	212	89,000,000	7
OU III Industrial Park (Sept. 1999)	2,577,662,000	1,077	(Standby)	0
OU III Industrial Park East (May 2004) (f)	357,192,000	38	(Decommissioned)	0
OU III North Street (June 2004)	1,680,942,000	342	(Closed)	0
OU III North Street East (June 2004) (g)	1,331,454,000	50	74,656,000	1
OU III LIPA/Airport (June 2004) (h)	4,377,067,620	505	209,922,620	6
OU III HFBR Tritium Plume (May 1997) (a)	721,795,000	180	(Closed)	0
OU IV AS/SVE (Nov. 1997)	NA (b)	35	(Decommissioned)	0
OU VI EDB (August 2004)	2,959,657,000	(d)	133,600,000	0.5 (d)
Totals	**31,674,727,620**	**7,873**	**752,691,420**	**41.1**
Sr-90 Remediation (start date)	**2003-2023**		**2024**	
	Water Treated (gallons)	Sr-90 Removed (mCi)	Water Treated (gallons)	Sr-90 Removed (mCi)
OU III Chemical Holes (Feb. 2003)	65,663,000	4.94	(Shutdown)	0.0
OU III BGRR (June 2005)	224,603,000	29.85	6,600,000	0.1
Totals	**290,266,000**	**34.79**	**6,600,000**	**0.1**
PFAS Remediation (start date)	**2022-2023**		**2024**	
	Water Treated (gallons)	PFAS Removed (lbs)	Water Treated (gallons)	PFAS Removed (lbs)
OU X Current Firehouse (Oct. 2022)	238,144,000	0.42	215,000,000	0.53
OU X Former Firehouse (Jan. 2023)	108,204,000	0.17	105,314,000	0.17
Totals	**346,348,000**	**0.59**	**320,314,000**	**0.70**

Notes:
(a) System was approved for closure in 2019.
(b) Air Sparging/Soil Vapor Extraction (AS/SVE) system performance measured by pounds of volatile organic compounds (VOCs) removed. System was decommissioned in 2003.
(c) Values rounded to the nearest whole number.
(d) Ethylene dibromide (EDB) cumulative mass removal calculation began with the startup of extraction wells EW-3E and EW-4E in January 2024.
(e) System was decommissioned in 2010.
(f) System was decommissioned in 2014.
(g) The North Street East System was restarted in July 2020 for treatment of the EDB plume. Pounds removed in 2020 include EDB and VOCs.
(h) The LIPA portion of the system was approved for closure in December 2024.
NA – Not applicable

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