2019
SITE ENVIRONMENTAL REPORT
VOLUME II
GROUNDWATER STATUS REPORT

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Environmental Protection Division
Groundwater Protection Group

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Acronyms and Abbreviations

These acronyms and abbreviations reflect the typical manner in which terms are used in Volume II of this document, and may not apply to all situations.

AGS	Alternating Gradient Synchrotron
AOC	Area of Concern
AS/SVE	Air Sparge/Soil Vapor Extraction
AWQS	NYS Ambient Water Quality Standards
BGD	Below Ground Ducts
BGRR	Brookhaven Graphite Research Reactor
BLIP	Brookhaven Linac Isotope Producer
bls	below land surface
BMRR	Brookhaven Medical Research Reactor
BNL	Brookhaven National Laboratory
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
cfm	cubic feet per minute
CFR	Code of Federal Regulations
Ci	curies
COC	Chain of Custody
Co-60	cobalt-60
CRDL	Contract Required Detection Limit
CSF	Central Steam Facility
DCA	1,1-dichloroethane
DCE	1,1-dichloroethylene
DCG	Derived Concentration Guide
DAR	Division of Air Resources
DOE	United States Department of Energy
DQO	Data Quality Objective
DTW	Depth to Water
DWS	Drinking Water Standards
EDB	ethylene dibromide
EDD	Electronic Data Deliverable
EIMS	Environmental Information Management System
EM	Environmental Management
EMS	Environmental Management System
EPA	United States Environmental Protection Agency
EPD	Environmental Protection Division
ER	Emissions Rate
ERP	Emissions Rate Potential
ES	Environmental Surveillance
ESD	Explanation of Significant Differences
EW	extraction well
FFA	Federal Facility Agreement
Freon-11	Trichlorofluoromethane
Freon-12	Dichlorodifluoromethane
ft	feet
ft msl	feet relative to mean sea level
GAC	granular activated carbon
gal/hr	gallons per hour
gpm	gallons per minute
HFBR	High Flux Beam Reactor
HWMF	Hazardous Waste Management Facility
IAG	Inter Agency Agreement
ID	identification
IPE	Industrial Park East
lb/gal	pounds per gallon
lb/hr	pounds per hour
lbs	pounds
LIE	Long Island Expressway
Linac	Linear Accelerator
LIPA	Long Island Power Authority
LISF	Long Island Solar Farm
mCi	milliCuries
MCL	Maximum Contaminant Level
MDA	Minimum Detectable Activity
MDL	Minimum Detection Limit
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MGD	millions of gallons per day
MPF	Major Petroleum Facility
mrem/yr	millirems per year
MS/MSD	Matrix Spike/Matrix Spike Duplicate
msl	mean sea level
MTBE	methyl tertiary-butyl ether
MW	monitoring well
Na-22	Sodium-22
NPL	National Priorities List
NSE	North Street East
NSLS-II	National Synchrotron Light Source II
NSRL	NASA Space Radiation Laboratory
NYCRR	New York Code of Rules and Regulations
NYS	New York State
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health

O&M	Operation and Maintenance
OU	Operable Unit
PCBs	polychlorinated biphenyls
PCE	tetrachloroethylene
pCi/L	picoCuries per liter
PFS	Pile Fan sump
PLC	programmable logic controller
QA/QC	Quality Assurance and Quality Control
RA V	Removal Action V
RCRA	Resource Conservation and Recovery Act
RHIC	Relativistic Heavy Ion Collider
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
RPD	Relative Percent Difference
RTW	Recirculating Treatment Well
RW	remediation well
SBMS	Standards Based Management System
SCDHS	Suffolk County Department of Health Services
SCWA	Suffolk County Water Authority
SDG	Sample Delivery Group
SDWA	Safe Drinking Water Act
SOP	Standard Operating Procedure
SPCC	Spill Prevention Control and Countermeasures
SPDES	State Pollutant Discharge Elimination System
Sr-90	strontium-90
STP	Sewage Treatment Plant
SU	standard unit
SVOC	semivolatile organic compound
TCA	1,1,1-trichloroethane
TCE	trichloroethylene
TVOC	total volatile organic compound
TW	temporary well
USGS	United States Geological Survey
UST	underground storage tank
UVB	Unterdruck-Verdampfer-Brunnen Technology (vacuum vaporizing well)
VOC	volatile organic compound
VP	vertical profile
µg/L	micrograms per liter
WCF	Waste Concentration Facility
WLA	Waste Loading Area
WMF	Waste Management Facility
WSB	Western South Boundary

2019 BROOKHAVEN NATIONAL LABORATORY

GROUNDWATER STATUS REPORT

Executive Summary

The *2019 BNL Groundwater Status Report* is a comprehensive summary of data collected during the 2019 calendar year supplemented with relevant investigation data collected during the first quarter 2020, an evaluation of Groundwater Protection Program performance, and recommendations for program changes. This is the twenty fourth annual groundwater status report issued by BNL. This document examines the performance of the program on a project-by-project basis.

GROUNDWATER RESTORATION (COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION AND LIABILITY ACT - CERCLA)

Table E-1 summarizes the status and progress of groundwater cleanup at BNL under the provisions of CERCLA. During 2019, seven volatile organic compound (VOC) groundwater remediation systems were in operation, along with one strontium-90 (Sr-90) treatment system. In 2019, 61 pounds of VOCs were removed from the Upper Glacial and Magothy aquifers by the treatment systems. To date, 7,650 pounds of VOCs have been removed from the aquifers. The Sr-90 treatment systems removed 0.8 milliCuries (mCi) of Sr-90 from the Upper Glacial aquifer in 2019, for a total of 33.64 mCi since operations began. Approximately 0.8 billion gallons of groundwater were treated in 2019.

There were 534 monitoring wells and 32 temporary wells sampled as part of the CERCLA Groundwater Monitoring Program, comprising a total of 1,583 groundwater samples. Eleven of the 32 temporary wells were installed in April and May 2019 as part of the Per- and Polyfluoroalkyl Substances (PFAS) Phase 3 Addendum Work Plan and the data were presented in the *2018 Groundwater Status Report*. Groundwater remediation activities will continue until the cleanup objectives for the plumes are met. The specific goals are as follows:

- Achieve maximum contaminant levels (MCLs) for VOCs in the Upper Glacial aquifer by 2030
- Achieve MCLs for VOCs in the Magothy aquifer by 2065
- Achieve the MCL of 8 pico Curies per liter (pCi/L) for Sr-90 at the BGRR in the Upper Glacial aquifer by 2070
- Achieve the MCL of 8 pCi/L for Sr-90 at the Chemical/Animal Holes in the Upper Glacial aquifer by 2040

The cleanup objectives will be met by a combination of active treatment and monitored natural attenuation. The comprehensive groundwater monitoring program measures remediation progress.

Table E-1.
BNL Groundwater Remediation System Treatment Summary for 1997 – 2019.

	1997 – 2018		2019	
VOCs Remediation (start date)	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	(Shutdown) 0	0
OU III Carbon Tetrachloride (Oct. 1999) (e)	153,538,000	349	Decommissioned	0
OU III Building 96 (Feb. 2001)	495,697,000	143	31,000,000	2
OU III Building 452 Freon-11 (March 2012) (a)	124,997,000	106	(Shutdown) 0	0
OU III Middle Road (Oct. 2001)	3,448,547,000	1,261	164,000,000	25
OU III South Boundary (June 1997)	5,112,151,000	3,048	87,000,000	6
OU III W. South Boundary (Sept. 2002)	1,769,555,000	143	143,000,000	13
OU III Industrial Park (Sept. 1999)	2,547,662,000	1,076	30,000,000	1
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	(Shutdown) 0	0
OU III North Street East (June 2004)	1,009,798,000	44	(Shutdown) 0	0
OU III LIPA/Airport (June 2004)	3,324,145,000	455	204,000,000	14
OU III HFBR Tritium Plume (May 1997) (a)	721,795,000	180	(Shutdown) 0	0
OU IV AS/SVE (Nov. 1997)	NA (b)	35	Decommissioned	0
OU VI EDB (August 2004)	2,269,057,000	NA(d)	91,000,000	NA (d)
Totals	27,192,549,000	7,589	750,000,000	61

	2003 – 2018		2019	
Sr-90 Remediation (start date)	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)	164,803,000	27.9	14,000,000	0.8
Totals	230,466,000	32.84	14,000,000	0.8

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) has been detected in the system influent since 2009 at levels slightly above the standard. Therefore, no removal of VOCs is reported.
(e) System was decommissioned in 2010.
(f) System was decommissioned in 2014.
NA – Not applicable

The locations and extent of the primary VOC and radionuclide plumes at BNL, as of the fourth quarter of 2019, are summarized on **Figures E-1** and **E-2**, respectively. The water table elevation increased up to seven feet in some areas of the site during 2018 due to the near historical high precipitation. The increased water table elevation followed several years of low precipitation. Some impact from this increase was observed on source area contaminant concentrations including the BGRR, WCF, Building 96 and former HWMF where a vadose zone flushing effect has been observed in the past. The source area wells will continue to be monitored closely.

Additional information on the groundwater restoration program is summarized in **Table E-2**.

INSTITUTIONAL CONTROLS

Institutional controls are in place at BNL to ensure effectiveness of all groundwater remedies. During 2019, the institutional controls continued to be effective in protecting human health and the environment. In accordance with the *BNL Land Use Controls Management Plan* (BNL 2013f) the following institutional controls continued to be implemented for the groundwater remediation program:

- Groundwater monitoring, including BNL potable supply systems and Suffolk County Department of Health Services (SCDHS) monitoring of Suffolk County Water Authority (SCWA) well fields closest to BNL;
- Implementing controls on the installation of new supply wells and recharge basins on BNL property;
- Continuing to offer private well testing (via SCDHS) for those homes in the previously defined hook-up area with private wells used for drinking water on properties that previously declined DOE's offer of public water hookups; and
- Maintaining property access agreements for treatment systems off the BNL property.

GROUNDWATER STATUS REPORT RECOMMENDATIONS AND HIGHLIGHTS

The data summarized in this report are the basis for optimizing operational and monitoring elements of the cleanup program. A summary of the highlights and significant changes follows (specific details of which are provided in **Section 5**).

- **OU I South Boundary Treatment System/Former Hazardous Waste Management Facility Sr-90 Plume** –
    - A petition for closure of the OU I South Boundary Treatment System was approved by the regulators in September 2019. A reduced post-closure program is in place to monitor the remaining low-level VOCs in groundwater. The treatment system, monitoring wells and extraction wells will be maintained for potential use in addressing emerging contaminants.
    - The leading edge of the higher concentration Sr-90 plume is approximately 1,000 feet south of the former Hazardous Waste Management Facility (HWMF) source area and continues to slowly migrate to the south.
    - Initial concentrations observed in the three former HWMF source area monitoring wells installed in 2019 were lower than expected. Several temporary wells will be installed to verify whether the wells are screened in the appropriate locations.
- **OU III Building 96 Treatment System –**
    - The increased pumping rate of extraction well RTW-1 has resulted in a westward expansion of the capture zone. This is evidenced by the significant decline of VOC concentrations in monitoring well 095-159 since the summer of 2019.
    - Re-establishing the capture of the western edge of the plume has resulted in reduced VOC concentrations in extraction well RTW-2 where they have remained below 5 μg/L since October 2018. This well will be placed in standby mode.

- **452 Freon-11 Source Area and Groundwater Plume –**
  - Since there has been no significant rebound in Freon-11 concentrations in any of the core monitoring or extraction wells since March 2017, a petition for system closure was submitted to the regulators in June 2019. The petition was approved in August 2019.
- **OU III Western South Boundary Treatment System –**
  - The operation of four new extraction wells to capture and treat deeper VOCs was initiated in March 2019. Based on recent data from monitoring and extraction wells the system is remediating these deeper VOCs.
- **OU III Industrial Park Treatment System –**
  - Individual VOC concentrations remained below ambient water quality standards (AWQS) since 2017 in extraction wells IP-EW-8 and IP-EW-9 and upgradient monitoring wells. The wells were placed on standby in July 2019. Standby status will continue along with monitoring for rebound of VOCs.
- **OU III North Street Treatment System –**
  - A petition for system closure of the system was submitted to the regulators in February 2020 as this system has met its cleanup goals.
- **OU III North Street East Treatment System –**
  - The system is being modified to remediate recently discovered ethylene dibromide (EDB). Two new extraction wells have been installed and the piping, electric, and communications are now in place. The work will be completed in 2020.
- **LIPA/Airport Treatment System –**
  - Airport extraction wells RTW-2A and RTW-3A can be shut down as they have achieved the capture goal.
- **BGRR/WCF Sr-90 Treatment System –**
  - A significant increase in BGRR source area Sr-90 groundwater concentrations was observed in 2019/2020 in response to the recent increase in water table elevation at the site. Extraction well SR-3 was placed back in operation and is capturing and treating this source area Sr-90.
  - Increasing Sr-90 concentrations were observed in groundwater immediately downgradient of Building 801 in 2019. Monitoring data will be evaluated, and groundwater modeling simulations performed if necessary, to predict the attenuation of these higher concentrations.
- **Chemical/Animal Holes Sr-90 Treatment System –**
  - The extraction wells continue to be maintained in standby. No significant rebound of Sr-90 concentrations in groundwater have been observed since system shutdown in July 2018.
- **HFBR Tritium Pump and Recharge System –**
  - Monitoring of the HFBR source area was conducted with a network of monitoring wells immediately south of the HFBR. No unexpected tritium concentrations were observed in groundwater in 2019.

- **Building 650 (Sump Outfall) Strontium-90 Monitoring –**
    - A slight southeast shift of the plume was verified by groundwater characterization in 2019. The removal of several wells from the monitoring program is recommended as they are now located to the west of the plume. Several existing wells will be added to the program including the installation of two new monitoring wells.
- **Operable Unit VI EDB Treatment System –**
    - The migration of the EDB plume continues to be slower than predicted. The geologic framework of the groundwater model in this area will be assessed and additional geologic data collected if necessary, to increase model accuracy. The model will then be used to evaluate whether cleanup goals can be attained with the current treatment system configuration.
- **Emerging Contaminants –**

    1,4-Dioxane and PFAS:
    - In early 2019, groundwater samples were collected for 1,4-dioxane and PFAS analyses from 33 permanent wells and 11 temporary wells positioned along the southern boundary. The results for these samples, along with the monitoring results for samples collected from 2017 through 2018, were summarized in the *2018 Groundwater Status Report* (BNL 2019). Additional groundwater characterization for these emerging contaminants will be conducted in 2020. Data available at the time of this report are summarized in **Sections 3.10 and 3.11**.

FACILITY MONITORING

BNL's Facility Monitoring Program includes groundwater monitoring at 12 active research facilities (e.g., accelerator beam stops and target areas) and support facilities (e.g., fuel storage and waste management facilities). Monitoring conducted at the former g-2 experiment area within the Alternating Gradient Synchrotron (AGS) facility, Brookhaven Linac Isotope Producer (BLIP), and Building 452 is used to verify the effectiveness of CERCLA corrective actions. During 2019, groundwater samples were collected from 91 wells during 121 individual sampling events.

Highlights of the Facility Monitoring Program are as follows:

- Monitoring conducted during 2019 at BNL's major accelerator facilities (e.g., AGS, Relativistic Heavy Ion Collider, National Synchrotron Light Source-II, and BLIP) has not identified any new impacts to groundwater quality.
- Monitoring conducted at support facilities (Sewage Treatment Plant, Waste Management Facility, Major Petroleum Facility and Motor Pool) has not identified any new impacts to groundwater quality.
- During 2019, all tritium concentrations in g-2 source area monitoring wells were less than the 20,000 pCi/L drinking water standard (DWS), with a maximum concentration of 18,600 pCi/L. Tritium concentrations in BLIP source area monitoring wells continued to be less than the DWS.

Table E-2.
Groundwater Restoration Progress.

Project	Target	Mode	Treatment Type	Expected System Shutdown	Highlights
OU I					
OU I South Boundary (RA V)	VOCs	Shutdown	Pump and Treat (P&T) with Air Stripping (AS)	2013 (Actual)	No rebound in VOC concentrations has been observed. Petition for Closure approved in Sept. 2019.
Current Landfill	VOCs tritium	Long Term Monitoring & Maintenance	Landfill capping	NA	Remaining issue is periodic VOC increases in monitoring well 088-110 adjacent to the landfill.
Former Landfill	VOCs Sr-90 tritium	Long Term Monitoring & Maintenance	Landfill capping	NA	No longer a continuing source of contaminants to groundwater.
Former HWMF	Sr-90	Long Term Monitoring & Maintenance	Monitoring	NA	Continue to monitor a plume of elevated Sr-90 concentrations.
OU III					
Chemical/Animal Holes	Sr-90	Standby	P&T with ion exchange (IE)	2018 (Actual)	Petition for Shutdown approved and system shut down in July 2018.
Carbon Tetrachloride former source area	VOCs (carbon tetra-chloride)	Decommis-sioned	P&T with carbon	2009 (Actual)	Treatment system was decommissioned in 2010.
Building 96	VOCs	Operational (RTW-3 and RTW-4 in standby)	Recirculation wells with AS for 3 of 4 wells. RTW-1 is P&T with AS.	2023	Monitoring persistent elevated PCE concentrations downgradient of source area. Increased pumping of RTW-1 captured western edge of plume.
Building 452	VOCs (Freon-11)	Shutdown	P&T with AS	2017 (Actual)	Petition for Closure approved in August 2019.
South Boundary	VOCs	Operational (EW-3, EW-5, EW-6, EW-7, EW-8 and EW-12 on standby)	P&T with AS	2023	Extraction well EW-17 is capturing and treating deep VOCs at site boundary. EW-4 is in pulsed pumping mode.
Middle Road	VOCs	Operational (RW-1, RW-4, RW-5, and RW-6 on standby)	P&T with AS	2025	Monitoring persistent elevated deep VOCs south of Princeton Avenue. RW-2, RW-3, RW-7 are effectively capturing and treating VOCs.

continued

Project	Target	Mode	Treatment Type	Expected System Shutdown	Highlights
OU III (cont.)					
Western South Boundary	VOCs	Operational (WSB-2 on standby)	P&T with AS	2026	Four new extraction wells became operational in March 2019 to address deeper VOCs to the west. The groundwater is treated at the Middle Road and South Boundary air strippers.
Industrial Park	VOCs	Standby	In-well stripping and P&T with carbon	2021	Due to low VOCs, extraction wells EW-8 and EW-9 were placed in standby in July 2019.
Industrial Park East	VOCs	Decommissi-oned	P&T with carbon	2009 (Actual)	Treatment system was decommissioned in 2014.
North Street	VOCs	Standby	P&T with carbon	2013 (Actual)	Since VOCs remain below capture goal, a Petition for Closure was submitted to regulators in February 2020.
North Street East	VOCs	Standby	P&T with carbon	2014 (Actual)	VOC system in standby. Two new extraction wells to address EDB will become operational in 2020.
Long Island Power Authority (LIPA) / Airport	VOCs	Operational (Standby: EW-1L, EW-2L, EW-3L, EW-4L, RTW-5A. Pulsed: RTW-2A, RTW-3A,)	P&T and recirculation wells with carbon	2017 LIPA (Actual) 2025 Airport	LIPA extraction wells in standby mode. Persistently elevated VOC concentrations in wells 800-94 and 800-95 may impact Airport system shutdown. RTW-1A, RTW-4A, RW-6A are effectively capturing and treating VOCs.
HFBR Tritium	Tritium	Shutdown	Pump and recharge	2012 (Actual)	A Petition for Closure was approved in March 2019.
BGRR/Waste Concentration Facility (WCF)	Sr-90	Operational (Standby: SR-4, SR-5, SR-6, SR-7. Pulsed SR-8)	P&T with IE	2026	Supplementing the current monitoring network with temporary wells. Increased Sr-90 detected downgradient of BGRR, Bldg. 801 and WCF source areas.
OU IV					
OU IV AS/SVE system	VOCs	Decommissioned	Air sparging/ soil vapor extraction	2003 (Actual)	System decommissioned in 2003.
Building 650 Sump Outfall	Sr-90	Long Term Monitoring	Monitored Natural Attenuation (MNA)	NA	Sr-90 plume continues to slowly attenuate. Temporary wells installed in 2019 verified a southeast shift in the plume.
OU V					
STP	VOCs, tritium	Completed	MNA	NA	Monitoring completed in 2014.

continued

Project	Target	Mode	Treatment Type	Expected System Shutdown	Highlights
OU VI					
Ethylene Dibromide (EDB)	EDB	Operational	P&T with carbon	2024	Update the groundwater model used to estimate the duration of the system operation.
g-2 and BLIP					
g-2 Tritium Plume	Tritium	Long Term Monitoring & Maintenance	MNA	NA	Tritium concentrations in source area were less than the DWS.
BLIP Tritium Plume	Tritium	Long Term Monitoring & Maintenance	MNA	NA	Tritium concentrations continue to be less than DWS.

1.0 INTRODUCTION AND OBJECTIVES

The mission of Brookhaven National Laboratory's Groundwater Protection Program is to protect and restore the aquifer system at Brookhaven National Laboratory (BNL). The program is built on four key elements:

- Pollution prevention: Preventing the potential pollution of groundwater at the source
- Restoration: Restoring groundwater that has been affected at the BNL site
- Monitoring: Monitoring the effectiveness of pollution-prevention efforts, as well as progress in restoring the quality of affected groundwater
- Communication: Communicating the findings and results of the program to regulators and stakeholders

The *BNL 2019 Groundwater Status Report* is a comprehensive summary of groundwater data collected in calendar year 2019 that provides an interpretation of information on the performance of the Groundwater Protection Program. This is the 24th annual groundwater status report issued by BNL. This document examines performance of the program on a project-by-project basis, as well as comprehensively.

How to Use This Document. This document is a detailed technical report that includes analytical laboratory data, as well as data interpretations conducted by BNL's Groundwater Protection Group. This document can also be obtained through BNL's website. Data are presented in four key subject areas:

- Improvements to the understanding of the hydrogeologic environment and surrounding areas
- Progress in cleaning contaminated groundwater
- Identification of any new impacts to groundwater quality due to BNL's active operations
- Proposed changes to the groundwater protection program

This document satisfies BNL's requirement to report groundwater data under the Interagency Agreement and partially fulfills the commitment of the Groundwater Protection Program to communicate the program's findings and progress to regulators and stakeholders.

Section 1 discusses the regulatory requirements of the data collection work in 2019, the site's groundwater classification, and the objectives of groundwater monitoring. **Section 2** discusses the hydrogeologic environment at BNL and its surrounding area. It also summarizes the dynamics of the groundwater flow system in 2019. In **Section 3**, the groundwater cleanup data and progress towards achieving the site's cleanup goals are described. **Section 4** outlines the groundwater surveillance data used to verify that operational and engineered controls are preventing further contamination from BNL's active experimental and support facilities. **Section 5** is a summary of the proposed recommendations to the Groundwater Protection Program identified in **Sections 3 and 4**.

Appendices A and **B** include hydrogeologic data that support the discussions in **Section 2**. **Appendix C** contains the analytical results for each sample obtained under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) program. **Appendix D** contains analytical results for each sample obtained under the Facility Monitoring program. Due to the volume of these data, the report appendices are included on a USB flash drive, which significantly reduces the size of this report in printed format. **Appendix E** contains information on sample collection, analysis, and Quality Assurance/Quality Control (QA/QC). **Appendix F** consists of data supporting the remediation system discussions in **Section 3**, and **Appendix G** is a compilation of data usability report forms. In addition to the appendices, this entire report is included on the USB flash drive with active links to tables and figures.

1.1 Groundwater Monitoring Program

1.1.1 Regulatory Requirements

Activities at BNL are driven by federal and state regulations as well as Department of Energy (DOE) Orders.

Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)

On December 21, 1989, BNL was included on the National Priorities List (NPL) of contaminated sites identified for priority cleanup. DOE, the United States Environmental Protection Agency (EPA), and the New York State Department of Environmental Conservation (NYSDEC) created a comprehensive Federal Facility Agreement (FFA) that integrated DOE's response obligations under CERCLA, the Resource Conservation and Recovery Act (RCRA), and New York State hazardous waste regulations. The FFA, also known as the Interagency Agreement (IAG), was finalized and signed by these parties in May 1992, and includes a requirement for groundwater monitoring (USEPA 1992).

New York State Regulations, Permits, and Licenses

The monitoring programs for the Current Landfill and Former Landfill are designed in accordance with post-closure Operation and Maintenance requirements specified in 6 NYCRR (New York Code of Rules and Regulations) Part 360, *Solid Waste Management Facilities*.

BNL's Major Petroleum Facility (MPF) is operated under NYSDEC Bulk Petroleum Storage License No. 01-1700. This license requires BNL to routinely monitor the groundwater. Together with approved engineering controls, the groundwater monitoring program verifies that storage operations for bulk fuel have not degraded the quality of the groundwater. The engineered controls and monitoring program for the MPF are described in the *BNL Spill Prevention, Control and Countermeasure Plan* (BNL 2016a).

BNL's Waste Management Facility (WMF) is a hazardous waste storage facility operated under NYSDEC RCRA Part B Permit No. 1-4722-00032/00102-0. The permit requires groundwater monitoring as a secondary means of verifying the effectiveness of the facility's administrative and engineered controls.

BNL's State Pollution Discharge Elimination System (SPDES) permit (NY0005835) requires the collection of annual groundwater samples in the vicinity of the Sewage Treatment Plant's recharge basins.

DOE Orders

BNL conducts groundwater monitoring at active research and support facilities in accordance with the environmental surveillance requirements defined in DOE Order 458.1, *Radiation Protection of the Public and the Environment* and DOE Order 436.1, *Departmental Sustainability*. Groundwater monitoring is conducted to: characterize pre-operational conditions; to detect, characterize, and respond to contaminant releases from site operations and activities; evaluate dispersal and attenuation patterns; and to characterize the potential pathways of exposure to members of the public.

1.1.2 Groundwater Quality and Classification

In Suffolk County, drinking water supplies are obtained exclusively from groundwater aquifers (e.g., the Upper Glacial aquifer, the Magothy aquifer, and, to a limited extent, the Lloyd aquifer). In 1978, EPA designated the Long Island aquifer system as a sole source aquifer pursuant to Section 1424(e) of the Safe Drinking Water Act (SDWA). Groundwater in the sole source aquifers underlying the BNL site is classified as "Class GA Fresh Groundwater" by the State of New York (6 NYCRR Parts 700–705); the best usage of Class GA groundwater is as a source of potable water. Accordingly, in establishing the goals for protecting and remediating groundwater, BNL followed federal Drinking Water Standards (DWS), New York State (NYS) DWS, and NYS Ambient Water Quality Standards (AWQS) for Class GA groundwater.

For drinking water supplies, the applicable federal maximum contaminant levels (MCLs) are set forth in 40 CFR (Code of Federal Regulations) 141 (for primary MCLs) and 40 CFR 143 (for secondary MCLs). In New York State, the SDWA requirements relating to the distribution and monitoring of public water supplies are promulgated under the NYS Sanitary Code (10 NYCRR Part 5), enforced by the Suffolk County Department of Health Services (SCDHS) as an agent for the New York State Department of Health (NYSDOH). These regulations apply to any water supply that has at least five service connections or that regularly serves at least 25 individuals. BNL supplies water to approximately 3,000 employees and visitors, and therefore must comply with these regulations. In addition, DOE Derived Concentration Guides (DCGs) are used for radionuclides not covered by existing federal or state regulations (DOE 2011). Although currently there are no specific federal or NYS drinking water standards for PFAS, the USEPA has established a Lifetime Health Advisory Level (HAL) of 70 ng/L for the combined concentrations of two PFAS compounds, perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA).

BNL evaluates the potential impact of radiological and nonradiological levels of contamination by comparing analytical results to NYS and DOE reference levels. Nonradiological data from groundwater samples collected from surveillance wells usually are compared to NYS AWQS (6 NYCRR Part 703.5). Radiological data are compared to the DWS for tritium, strontium-90 (Sr-90), gross beta; gross alpha, radium-226, and radium-228; and the 40 CFR 141/DOE DCGs for determining the 4 millirems per year (mrem/yr) dose for other beta- or gamma-emitting radionuclides.

Tables 1-1, 1-2, 1-3, and **1-4** show the regulatory and DOE "standards, criteria, and guidance" used for comparisons to BNL's groundwater data.

1.1.3 Monitoring Objectives

Groundwater monitoring is driven by regulatory requirements, DOE Orders, best management practice, and BNL's commitment to environmental stewardship. BNL monitors its groundwater resources for the following reasons:

Groundwater Resource Management

- To support initiatives in protecting, managing, and remediating groundwater by refining the conceptual hydrogeologic model of the site and maintaining a current assessment of the dynamic patterns of groundwater flow and water-table fluctuations.
- To determine the natural background concentrations for comparative purposes. The site's background wells provide information on the chemical composition of groundwater that has not been affected by BNL's activities. These data are a valuable reference for comparison with the groundwater quality data from affected areas. The network of wells also can warn of any contaminants originating from potential sources that may be located upgradient of the BNL site.
- To ensure that potable water supplies meet all regulatory requirements.

Groundwater Facility Monitoring

- Determine pre-operational/baseline groundwater quality at new facilities.
- To verify that administrative and engineered controls effectively prevent groundwater contamination.
- To demonstrate compliance with applicable DOE and regulatory requirements for protecting groundwater resources.

Groundwater - CERCLA Monitoring

- To track a dynamic groundwater cleanup problem when designing, constructing, and operating treatment systems.
- To measure the performance of the groundwater remediation efforts in achieving cleanup goals.
- To protect public health and the environment during the cleanup period.
- To define the extent and degree of groundwater contamination.
- To provide early warning of the arrival of a leading edge of a plume, which could trigger contingency remedies to protect public health and the environment.

The details of the monitoring are described in the *BNL 2019 Environmental Monitoring Plan* (BNL 2019). This plan includes a description of the source area, description of groundwater quality, criteria for selecting locations for groundwater monitoring, and the frequency of sampling and analysis. **Figure 1-1** highlights BNL's operable unit (OU) locations designated as part of the CERCLA program, and key site features. Details on the sampling parameters, frequency, and analysis by well are listed in **Tables 1-5** and **1-6**. Screen zone, total depth, and ground surface elevations have been summarized in **Table 1-7**. **Figure 1-2** shows the locations of wells monitored as part of the Laboratory's groundwater protection program. Detailed groundwater monitoring rationale can be found in the *BNL 2019 Environmental Monitoring Plan*. BNL's CERCLA groundwater monitoring has been streamlined into five general phases **(Table 1-8)**:

<u>Start-up Monitoring</u>

A quarterly sampling frequency is implemented on all wells for a period of two years. This increased sampling frequency provides sufficient data while the system's operation is in its early stages.

<u>Operations and Maintenance (O&M) Monitoring</u>

This is a period of reduced monitoring during the time when the system is in a routine operational state. The timeframe for each system varies. This phase is also utilized for several plume monitoring programs not requiring active remediation.

<u>Shutdown Monitoring</u>

This is a two-year period of monitoring implemented just prior to petitioning for system shut down. The increased sampling frequency provides the necessary data to support the shutdown petition.

<u>Standby Monitoring</u>

This is a period of reduced monitoring, up to a five-year duration, to identify any potential rebounding of contaminant concentrations. If concentrations remain below MCLs, the petition for closure and decommissioning of the system is recommended.

<u>Post Closure Monitoring</u>

This is a monitoring period of varying length for approximately 20 percent of the key wells in a given project following system closure. Monitoring continues until the Record of Decision (ROD) goal of meeting MCLs for VOCs in the Upper Glacial aquifer is reached. This is expected to occur by 2030. This phase is considerably longer for the Magothy and Sr-90 cleanups due to greater length of the time to reach MCLs required for those projects.

Since 2001, BNL uses a structured Data Quality Objective (DQO) process to continually review and refine the groundwater monitoring and remediation projects. The results of the DQO reviews are documented annually in updates to the BNL Environmental Monitoring Plan.

Modifications are implemented to specific wells to adjust sample frequencies or parameters in order to account for changing conditions or unexpected results. These modifications may temporarily alter the monitoring of a well from specifications associated with the general phase of monitoring stated for that well.

Table 1-8. CERCLA Groundwater Monitoring Program – Well Sampling Frequency.

Project Activity Phase	Well Type	Phase Duration (yrs.)	Sampling Freq. (events/yr.)****
Start-up Monitoring	Plume Core	2	4x
	Plume Perimeter	2	4x
	Sentinel/Bypass	2	4x
O&M Monitoring	Plume Core	End Start-up to Shutdown*	2x
	Plume Perimeter	End Start-up to Shutdown*	2x
	Sentinel/Bypass	End Start-up to Shutdown*	4x
Shutdown Monitoring	Plume Core	2	4x
	Plume Perimeter	2	4x
	Sentinel/Bypass	2	4x
Standby Monitoring	Key Plume Core	5	2x
	Plume Perimeter	5	1x
	Sentinel/Bypass	5	2x
Post Closure Monitoring***	20% of key wells	Up To 2030**	1x

Notes:
*- Varies by project, see Table 1-5.
** - Magothy: 2065, BGRR Sr-90: 2070, South Boundary Rad: 2038, Chem Holes Sr-90: 2040
*** - Verification monitoring for achieving MCLs.
****- Sr-90 monitoring projects use approximately half the defined sampling frequency.

The groundwater monitoring well networks for each program are organized into background, core, perimeter, bypass, and sentinel wells. The wells are designated as follows:

- Background –water quality results will be used to determine upgradient water quality
- Plume Core – utilized to monitor the high concentration or core area of the plume
- Perimeter – used to define the outer edge of the plume both horizontally and vertically
- Bypass – used to determine whether plume capture performance is being met
- Sentinel – An early warning well to detect the leading edge of a plume.

1.2 Private Well Sampling

In accordance with the OU III and OU VI RODs, DOE formally offers the owners that previously declined DOE's offer of public water hookups free testing of their private drinking water wells on an annual basis. SCDHS coordinates and performs the sampling and analysis. During 2019, there were five known residences south and east of BNL who continue to use their private wells for drinking water purposes. One of these homeowners hooked-up to public water in 2019. On December 17, 2019, all four homeowners had their wells sampled. One home had their private and agricultural well tested. In addition to the routine analyses typically performed, the wells were also analyzed for six per- and polyfluoroalkyl substances (PFAS). The SCDHS transmitted the PFAS results to the homeowners.

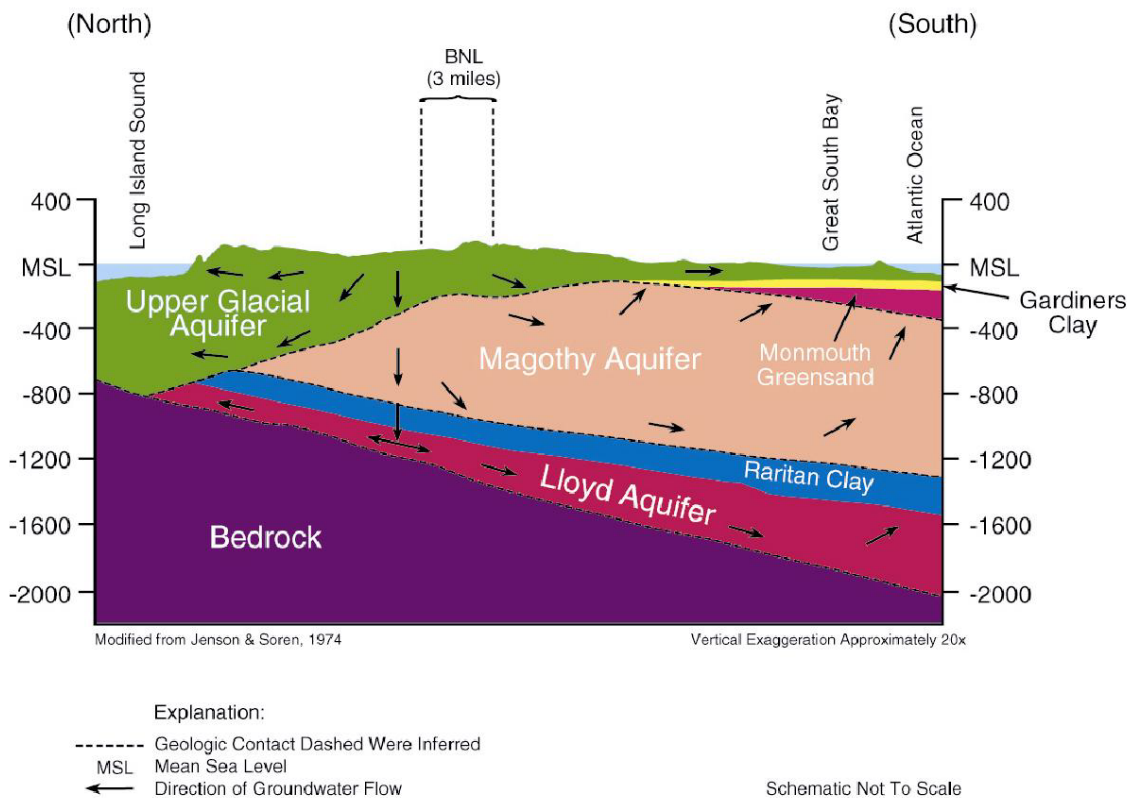
In May 2019, BNL and the SCDHS signed a Technical Services Agreement (TSA) to sample private drinking water supply wells that might be present on 111 properties located south of BNL, in Yaphank, Shirley, and Manorville. This list included the five properties that are part of the routine surveillance program described above. In January 2020, the TSA was modified to include an additional 50 properties, bringing the total to 161 properties to be evaluated. If it is determined that private wells are present on the properties, the water samples collected by SCDHS would be analyzed for six PFAS by BNL's contractor laboratory, and for 1,4-dioxane by the Suffolk County Public and Environmental Health Laboratory. Through April 2020, samples have been collected from 72 wells that are located on 70 properties. The SCDHS has communicated the analytical results to the property owners.

2.0 HYDROGEOLOGY

This section briefly describes the hydrogeologic environment at BNL and the surrounding area. It also summarizes the dynamics of the groundwater flow system in 2019, along with on-site pumping rates and rainfall recharge.

Detailed descriptions of the aquifer system underlying BNL and the surrounding areas are found in the U.S. Geological Survey (USGS) report by Scorca and others (1999), *Stratigraphy and Hydrologic Conditions at the Brookhaven National Laboratory and Vicinity, Suffolk County, New York, 1994–97,* and the USGS report by Wallace deLaguna (1963), *Geology of Brookhaven National Laboratory and Vicinity, Suffolk County, New York.* The stratigraphy below BNL consists of approximately 1,300 feet of unconsolidated deposits overlying bedrock (**Figure 2-1**). The current groundwater monitoring program focuses on groundwater quality within the Upper Pleistocene deposits (Upper Glacial aquifer), and the upper portions of the Matawan Group-Magothy Formation (Magothy aquifer).

Figure 2-1.
Generalized Geologic Cross Section in the Vicinity of Brookhaven National Laboratory.



The Pleistocene deposits are about 100–200 feet thick and are divided into two primary hydrogeologic units: undifferentiated sand and gravel outwash and moraine deposits, and the finer-grained, more poorly sorted Upton Unit. The Upton Unit makes up the lower portion of the Upper Glacial aquifer beneath several areas of the site. It generally consists of fine- to medium-grained white to greenish sand with interstitial clay. In addition to these two major hydrogeologic units, there are several other distinct hydrogeologic units within the Upper Glacial aquifer. They include localized, near-surface clay layers in the vicinity of the Peconic River (including the Sewage Treatment Plant [STP] area), and reworked Magothy deposits that characterize the base of the aquifer in several areas. The Gardiners Clay is a regionally defined geologic unit that is discontinuous beneath BNL and areas to the south. Typically, it is characterized by variable amounts of green silty clay, sandy and gravelly green clay, and clayey silt.

Where it exists, the Gardiners Clay acts as a confining or semi-confining unit that impedes the vertical flow and migration of groundwater between the Upper Glacial aquifer and the underlying Magothy aquifer.

The Magothy aquifer is composed of Cretaceous aged continental deltaic deposits. The Magothy aquifer at BNL is approximately 800 feet thick, and because it is composed of fine sand interbedded with silt and clay, it is generally less permeable than the Upper Glacial aquifer. The Magothy aquifer is highly stratified. Of particular importance at BNL is that the upper portion of the Magothy contains extensive, locally continuous layers of grey-brown clay (referred to herein as the Magothy Brown Clay). Regionally, the Magothy Brown Clay is not interpreted as being continuous; however, beneath BNL and adjacent off-site areas, it acts as a confining unit (where it exists), impeding the vertical flow and movement of groundwater between the Upper Glacial and Magothy aquifers.

Regional patterns of groundwater flow near BNL are influenced by natural and artificial factors. **Figure 2-2** shows the locations of pumping wells and recharge basins. Under natural conditions, recharge to the regional aquifer system is derived solely from precipitation. A regional groundwater divide exists immediately north of BNL near Route 25. It is oriented roughly east–west, and appears to coincide with the centerline of a regional recharge area. Groundwater north of this divide flows northward, ultimately discharging to the Long Island Sound (**Figure 2-1**). Shallow groundwater in the BNL area generally flows to the south and east. During high water-table conditions, groundwater can discharge into local surface water bodies such as the Peconic River and adjacent ponds. The BNL site is within a regional deep-flow recharge area, where downward flow helps to replenish the deep sections of the Upper Glacial aquifer, the Magothy aquifer, and the Lloyd aquifer. South of BNL, groundwater flow becomes more horizontal and ultimately flows upward as it moves toward regional discharge areas such as the Carmans River and Great South Bay. Superimposed on the natural regional field of groundwater flow are the artificial influences due to pumping and recharge operations.

2.1 Hydrogeologic Data

Various hydrogeologic data collection and summary activities were undertaken as part of the 2019 Groundwater Protection Program to evaluate groundwater flow patterns and conditions. This work is described in the following sections and includes the results of groundwater elevation monitoring, information on pumping and recharging activities on-site and off-site, and precipitation data.

2.1.1 Groundwater Elevation Monitoring

Synoptic water levels are obtained from a network of on-site and off-site wells screened within the shallow to middle sections of the Upper Glacial aquifer. These data are used to characterize the groundwater flow-field (direction and rate) and to evaluate seasonal and artificial variations in flow patterns.

Due to scheduling delays, the synoptic water-level measurement event for this report was conducted during January 8-10, 2020 using approximately 160 on-site and off-site wells. Water levels were measured with electronic water-level indicators following the BNL *Environmental Monitoring Standard Operating Procedure* EM-SOP-300. **Appendix A** provides the depth-to-water measurements and the calculated groundwater elevations for these measurements. Monitoring results for long-term and short-term hydrographs for select wells are discussed in **Section 2.2**.

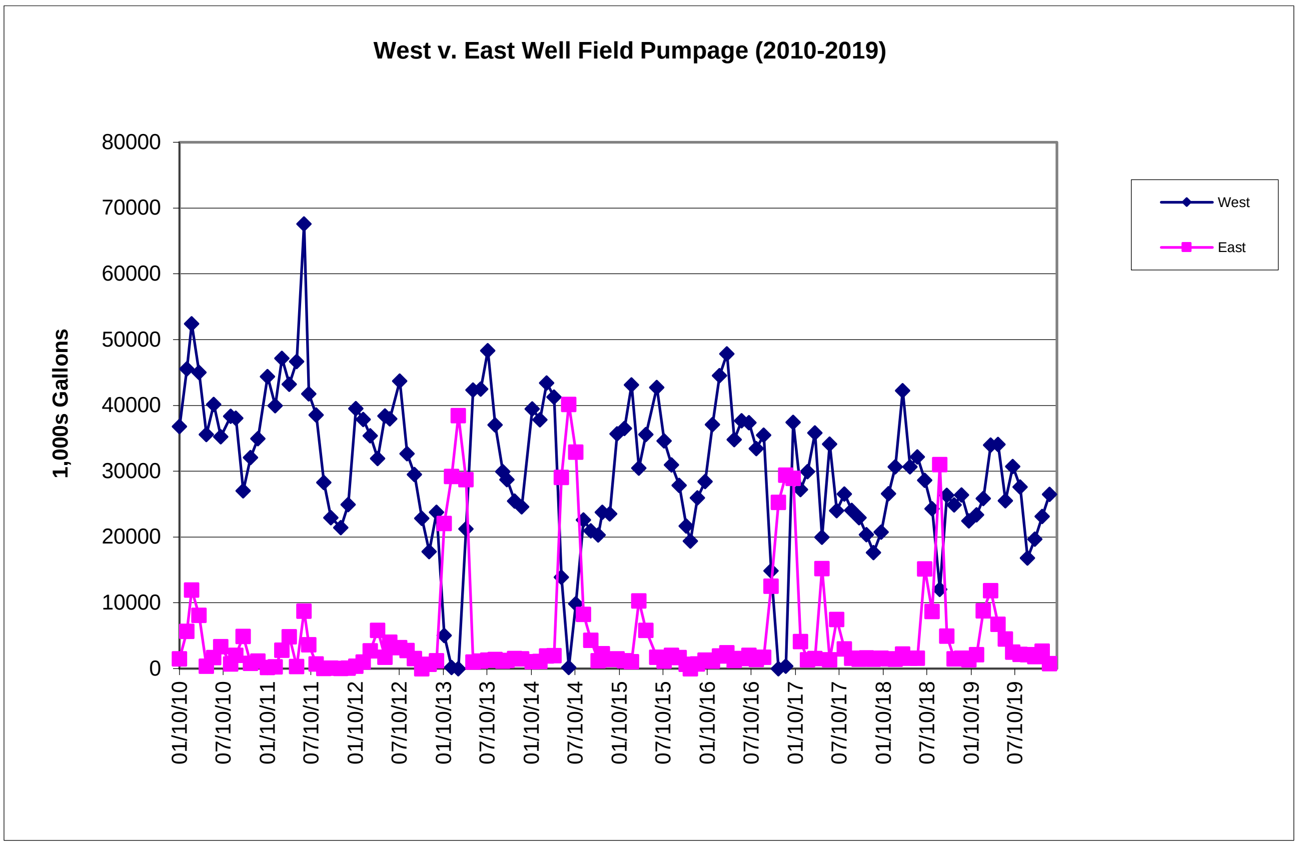
2.1.2 Pumpage of On-Site Water Supply and Remediation Wells

BNL has six water supply wells to provide potable and process cooling water, and 69 treatment wells used for the remediation of contaminated groundwater. All six water supply wells are screened entirely within the Upper Glacial aquifer. Twenty-six of the 69 treatment wells were in operation during some time in 2019 (**See Table 3.0-1**). The location and operational status of the treatment wells (full time operation, pulsed pumping, standby off) and treatment systems (operating, shut down, decommissioned) are shown on **Figure 3.0-1**. **Figure 2-2** show the locations of the water supply and remediation wells. The effects that the groundwater withdrawals have on the aquifer system are discussed in **Section 2.2**.

Table 2-1 provides the monthly and total water usage for 2019 for potable supply wells 4, 6, 7, 10, and 11. It includes information on each well's screened interval and pumping capacity. The variation in monthly pumpage reflects changes in water demand, and maintenance schedules for the water supply system. The western potable well field includes wells 4, 6, and 7; and the eastern field currently includes wells 10 and 11. Eastern supply well 12 has been out of service since October 2008. Pumpage from supply well 4 has been limited due to low yield resulting from age and iron fouling of the screen. Since the summer of 2018, the use of supply well 6 has been limited due to the detection of perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) at combined concentrations that were close to the current EPA Lifetime Health Advisory Level (HAL) of 70 ng/L.

Water supply operating protocols have been established by the BNL Water and Sanitary Planning Team to help minimize pumping induced changes in groundwater flow directions in the central portion of the BNL site. Under this protocol, the goal is to have the western well field provide 75 percent or more of the site-wide water supply. Water from these wells has naturally high levels of iron, and must be treated before distribution. **Figure 2-3** below summarizes monthly pumpage for the eastern and western well fields.

Figure 2-3.
Summary of Monthly Supply Well Pumpage from the Eastern and Western Well Fields 2010 through 2019.



Since 1999, the implementation of effective water conservation measures has resulted in a significant reduction in the amount of water pumped from the aquifer. During 2019, a total of 357 million gallons of water were withdrawn from the aquifer by BNL's potable supply wells. BNL was able to meet its goal of obtaining more than 75 percent of its total water supply from the western well field, which supplied approximately 87 percent of the water for 2019. **Table 2-2** summarizes the 2019 monthly water pumpage for the groundwater remediation systems. Additional details on groundwater remediation system pumping are provided in **Section 3** of this report.

2.1.3 Off-Site Water Supply Wells

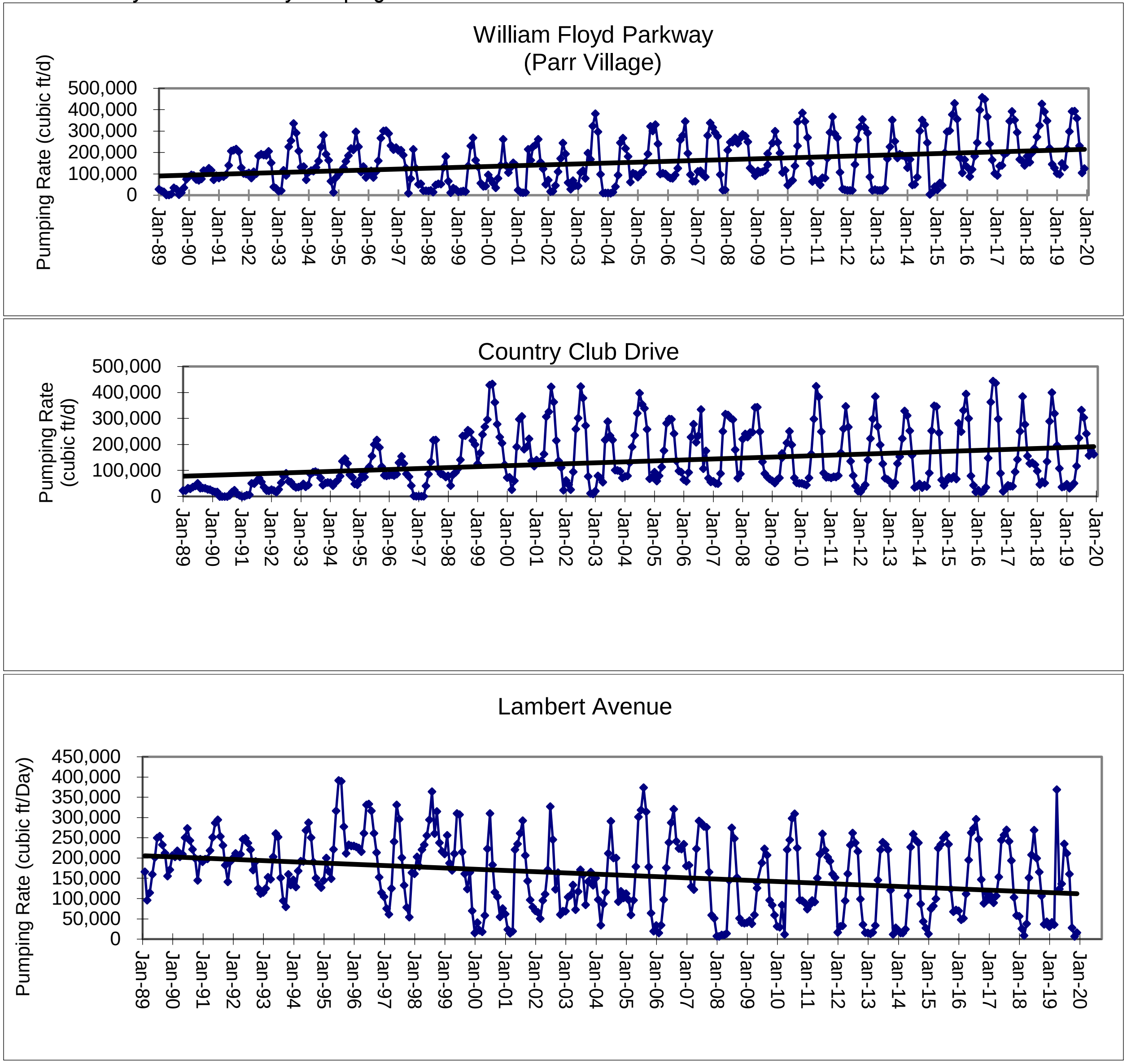
Several Suffolk County Water Authority (SCWA) well fields are located in the vicinity of BNL. The William Floyd Parkway Well Field is west/southwest of BNL (**Figures 2-2 and 2-3**) and consists of three water supply wells that withdraw groundwater from the mid to deep Upper Glacial aquifer. The Country Club Drive Well Field is south/southeast of BNL, and consists of three water supply wells that withdraw groundwater from the mid-section of the Upper Glacial aquifer. Pumpage information for 1989 through 2019 is provided as **Figure 2-4.** In 2019, the William Floyd Parkway (Parr Village) and Country Club Drive Well Fields produced 595 and 431 million gallons for the year, respectively. The Lambert Avenue Well Field, located south of BNL, produced 250 million gallons for the year.

2.1.4 Summary of On-Site Recharge and Precipitation Data

This section summarizes artificial (i.e., on-site recharge basins) and natural recharge from precipitation. **Table 2-3** summarizes the monthly and total flow of water through 10 on-site recharge basins during 2019. Their locations are shown on **Figure 2-2**. **Section 2.2** (Groundwater Flow) provides a discussion on the effects associated with recharge. Seven of the basins (HN, HO, HS, HT-W, HT-E, HX, and HZ) receive stormwater runoff and cooling water discharges. Flow into these basins is monitored monthly per NYSDEC State Pollutant Discharge Elimination System (SPDES) permit requirements. Generally, the amount of water recharging through the groundwater system to these basins reflects supply well pumpage. Annual water supply flow diagrams show the general relationships between recharge basins and the supply wells. Details on the SPDES program are provided in Volume I of the annual *Site Environmental Report (Chapter 5, Water Quality)*.

The remaining three basins (Removal Action V [RA V], OU III, and Western South Boundary) were constructed to recharge water processed through several of the groundwater remediation systems. Until September 2001, treated groundwater from the OU III South Boundary Pump and Treat System was discharged solely to the OU III basin along Princeton Avenue. After September 2001, treated groundwater from that system and the OU III Middle Road system was discharged equally to the OU III and RA V basins. Until 2013, water from the OU I South Boundary and the High Flux Beam Reactor (HFBR) system was discharged to the RA V basin. The HFBR and OU I treatment systems met their cleanup objectives, and their extraction wells were shut down in May and July 2013, respectively. Because reductions in water discharges to the RA V basin could have resulted in significant changes in local groundwater flow patterns, groundwater modeling was used to determine how to effectively divide the remaining treated water discharges toward the OU III and RA V basins in order to maintain stable groundwater flow directions (PW Grosser, 2013). Monitoring of groundwater flow patterns demonstrated that this effort was successful for several years. However, with additional reductions in water discharged from the OU III Treatment System, the groundwater flow direction in the Building 650 area has shifted more to the southeast (**Figure 2-2**). Starting in March 2019, the modification to the Western South Boundary Treatment System shifted the treatment of groundwater from this plume to the Middle Road/South Boundary Treatment System. As a result, the treated water has been redirected to the OU III and RA V basins. **Table 2-3** provides estimates of flow to the recharge basins. Other important sources of artificial recharge, not included on **Table 2-3**, include a stormwater retention basin referred to as HW (on Weaver Drive), and the sand filter beds and recharge basins at the STP. Until October 2014, treated water from the STP was discharged to sand filter beds, which contributed to localized mounding of the water table caused by shallow clay and silt deposits. Starting in October 2014, the STP discharge was re-directed to newly constructed groundwater recharge basins located along the eastern portion of the plant. Because the recharge basins are located in an area containing highly permeable soils, these discharges are not causing significant mounding of the water table below the recharge basins. A groundwater mound is still present in the former filter beds due to persistent perched water table conditions resulting from near surface clay and silt deposits.

Figure 2-4.
Suffolk County Water Authority Pumping Near BNL.



Precipitation provides the primary recharge of water to the aquifer system at BNL. Under long-term conditions in undeveloped areas of Long Island, about 50 percent of precipitation is lost through evapotranspiration and direct runoff to streams; the other 50 percent infiltrates the soil and recharges the groundwater system (Aronson and Seaburn 1974; Franke and McClymonds 1972). For 2019, it is estimated that the recharge at BNL was approximately 26 inches. **Table 2-4** summarizes monthly and annual precipitation results from 1949 to 2019 collected on site by BNL Meteorology Services. Variations in the water table generally can be correlated with seasonal precipitation patterns. As shown on **Table 2-4**, total annual precipitation in 2019 was 52.1 inches, which was slightly above the long-term yearly average of 48.99 inches.

2.2 Groundwater Flow

BNL routinely monitors horizontal and vertical groundwater flow directions and rates within the Upper Glacial aquifer by using water-level data collected from a large network of on-site and off-site monitoring wells. Short-term and long-term seasonal fluctuations of water levels are also evaluated using hydrographs for select wells, and trends in precipitation.

2.2.1 Water-Table Contour Map

Figure 2-2 is a groundwater elevation contour map representing the configuration of the water table for January 8-10, 2020. The contours were generated from the water-level data from shallow Upper Glacial aquifer wells. Localized hydrogeologic influences on groundwater flow were considered, including on-site and off-site pumping wells, and on-site recharge basins (summarized in **Section 2.1**).

Groundwater flow in the Upper Glacial aquifer is generally characterized by a southeasterly component of flow in the northern portion of the site, with a gradual transition to a more southerly direction at the southern boundary and beyond. Flow directions in the eastern portion of BNL are predominately to the east and southeast. The general groundwater flow pattern for early 2019 was generally consistent with historical flow patterns. As described in **Section 2.1.2**, the water supply operating protocols established by BNL in 2005 require that the western well field be used as the primary source of water, with a goal of obtaining 75 percent or more of the site's water supply from these wells. This protocol has generally been effective in maintaining a more stable south-southeast groundwater flow direction in the central portion of the site.

In addition to pumping induced cones of depression near groundwater supply and remediation wells, influences from water recharge activities can be observed as localized mounding of the water table, particularly around recharge basin OU III and the RA V basin (in the center of the site), and the STP. The degree of mounding is generally consistent with the monthly flows to recharge basins summarized in **Section 2.1**. Groundwater mounding is also evident at the Sewage Treatment Plant, and is a result of perched water table conditions resulting from near surface clay and silt deposits.

Other noteworthy features are the influence that surface water bodies have on groundwater flow directions. **Figure 2-2** shows groundwater flowing towards the Carmans River in areas south/southwest of BNL. This pattern is consistent with the fact that the Carmans River is a significant regional discharge boundary.

2.2.2 Well Hydrographs

Groundwater hydrographs are useful in estimating recharge rates and the location of the water table relative to contaminant sources. Long-term (typically 1950–2019) well hydrographs were constructed from water-level data that were obtained for select USGS and BNL wells. These hydrographs track fluctuations in water level over time. Precipitation data also were compared to natural fluctuations in water levels. **Appendix B** contains the well hydrographs, together with a map depicting the locations of these wells.

The long-term hydrographs indicate that typical seasonal water-table elevation fluctuations are on the order of 4 to 5 feet. Some of the water-table elevation changes have occurred during prolonged periods of low precipitation, where a maximum fluctuation of nearly 14 feet was observed during the regional drought of the early 1960s. As shown on the hydrograph for well 065-14, since 2010, when water levels at BNL reached the highest level on record, a nearly 10 foot variation in water table elevations has been observed. Generally, the highest groundwater elevations can be observed during the March-May time period in response to snow melt and spring rains. Normally, the position of the water table drops through the summer and into the fall.

A long-term hydrograph was constructed from historical water-level data from BNL well 065-14 (NYSDEC # S-5517.1; USGS Site Number 405149072532201). This well, installed by the USGS in the late 1940s, is screened in the Upper Glacial aquifer close to the water table. The USGS has collected monthly water-level information from this well from 1948 through 2005. In 2006, the USGS installed a real time continuous water-level recorder in the well. Data from this monitoring station can be accessed on the Web at: http://groundwaterwatch.usgs.gov/AWLSites.asp?S=405149072532201&ncd=rtn.

2.2.3 Groundwater Gradients and Flow Rates

Evaluation of the horizontal hydraulic gradients provides information on the driving force behind groundwater flow. These gradients can be used with estimates of aquifer parameters such as hydraulic conductivity (175 feet per day [ft/day]) and effective porosity (0.24) to assess the velocities of groundwater flow. The horizontal hydraulic gradient at the BNL site is typically 0.001 feet per foot (ft/ft), but in recharge and pumping areas it can steepen to 0.0024 ft/ft or greater. The natural groundwater flow velocity in most of the Upper Glacial aquifer is estimated to be approximately 0.75 ft/day, but velocities can be lower in some portions of the deep Upper Glacial aquifer where finer-grained sands are present. Flow velocities in recharge areas can be as high as 1.45 ft/day, and those in areas near BNL supply wells can be as high as 28 ft/day (Scorca et al. 1999).

2.3 New Geologic Data

During 2019, a number of new permanent monitoring wells were drilled for the North Street East (NSE) ethylene dibromide (EDB) plume characterization effort. The geologic information obtained during their installation was incorporated into the NSE EDB cross section.

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3.0 CERCLA GROUNDWATER MONITORING AND REMEDIATION

Section 3 gives an overview of groundwater monitoring and remediation efforts at BNL during 2019. The section is organized first by Operable Unit, and then by the specific groundwater remediation system and/or plume monitoring program. **Figure 1-2** shows the locations of monitoring wells throughout the site by project. Monitoring well location maps specific to particular monitoring programs are included throughout **Section 3**.

Report and Data on Flash Drive

Appendices C and D contain the analytical results for each sample. Due to the large volume of data, these appendices are included on a USB flash drive; this significantly reduces the size of the hardcopy of this report. The USB flash drive has a table of contents with active links, such that, by selecting the specific project and analytical suite, the user will be directed to the associated table of results. The groundwater results are arranged by specific monitoring project and then by analytical group [e.g., volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), metals, chemistry, pesticides/polychlorinated biphenyls (PCBs), and radionuclides]. The data are further organized by well identification (ID) and the collection date of the sample. Chemical/radionuclide concentrations, detection limits, and uncertainties are reported, along with a data verification, validation, and/or usability qualifier (if assigned), and/or a laboratory data qualifier. If a data verification/validation qualifier was not assigned, the laboratory data qualifier is presented. Results that exceed the corresponding groundwater standard or guidance criteria (**Section 1.1.1** [Regulatory Requirements) are in bold text. The complete analytical results are included to allow the reader the opportunity for detailed analysis.

Plume Maps

Maps are provided that depict the areal extent and magnitude of the contaminant plumes. In most cases, the VOC plumes were simplified by using the total VOC (TVOC) values for drawing the contours, except for those plumes that consist almost exclusively of one chemical, such as the OU III North Street East Ethylene Dibromide (EDB) plume and the OU VI EDB plume. TVOC concentrations are a summation of the individual concentrations of VOCs analyzed by EPA Method 524.2.

The extent of plumes containing VOC contamination was contoured to represent concentrations that were greater than the typical NYS AWQS of 5 micrograms per liter (µg/L) for most compounds. Radionuclide and EDB plumes were contoured to their appropriate DWS. **Figure 3.0-1** shows the VOC and radionuclide plumes as well as the location and operational status of the groundwater extraction wells and treatment systems.

Following the capping of the landfill areas and the beginning of active groundwater remediation systems in 1997, there have been significant changes in the size and concentrations of several of the VOC plumes. These changes can be attributed to the following:

- The beneficial effects of active remediation systems
- Source control and removal actions
- The impacts of BNL pumping and recharge on the groundwater flow system
- Radioactive decay, biological degradation, and natural attenuation

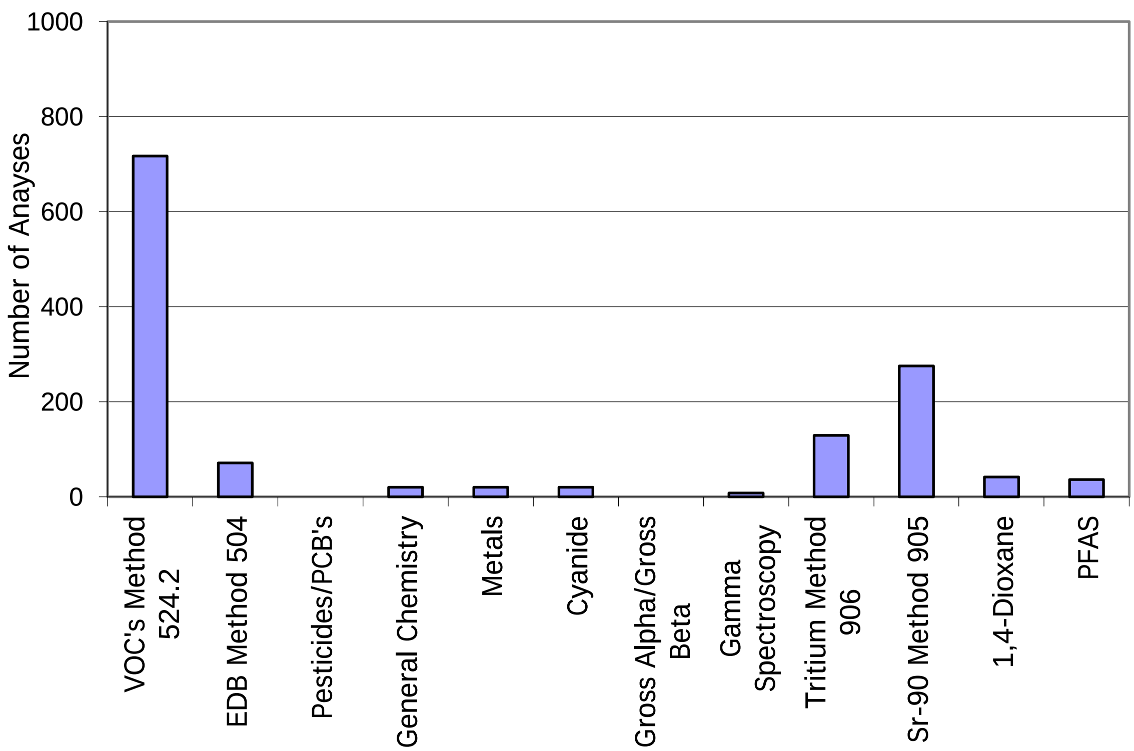
Additionally, BNL's ability to accurately depict these plumes has been enhanced over the years by the:

- installation of additional permanent monitoring wells to the existing well networks
- installation of temporary wells (vertical profiles and Geoprobes®) that helped to fill in data gaps
- updates to the groundwater model simulations

During 2019, 1,110 groundwater sampling events from 534 on-site and off-site permanent monitoring wells were used to track the contaminant plumes. From April 1, 2019 through March 31, 2020, 32 temporary wells were installed, and 473 samples were collected. Eleven of the 32 temporary wells were installed in April and May 2019 as part of the PFAS Phase 3 Addendum Work Plan and the data were presented in the *2018 Groundwater Status Report*. **Figure 3.0-2** below provides a summary of the number of analyses performed for the permanent monitoring wells arranged by analytical method. Unless otherwise noted, the extent of contamination for a given plume is depicted by primarily using 2019 data from permanent monitoring wells. Contaminant plumes associated with the Brookhaven Graphite Research Reactor (BGRR) and Building 650 Sr-90 projects were further defined in 2019 using temporary wells (i.e., direct push Geoprobes®).

A single representative round of monitoring data was usually chosen for each plume, typically from the last quarter of the year because it includes the most comprehensive sampling round for the year. This report also serves as the fourth quarter operations report for the remediation systems. Contaminant concentration trend plots for key monitoring wells in each plume are provided to identify significant changes. Data from monitoring wells sampled under BNL's Facility Monitoring Program are evaluated in **Section 4.0**.

Figure 3.0-2.
Summary of Laboratory Analyses Performed for the CERCLA Permanent Monitoring Well Program in 2019.



History and Status of Groundwater Remediation at BNL

Groundwater remediation systems have operated at BNL since 1997 beginning with the OU I South Boundary Pump and Treat System. The goal of groundwater remediation, as defined by the OU III Record of Decision, is to prevent or minimize plume growth and not to exceed MCLs in the Upper Glacial aquifer within 30 years or less (by 2030). Based on additional information obtained during the Strontium-90 Pilot Study, the *OU III Explanation of Significant Differences* (BNL 2005a) identified changes to the cleanup goal timeframes for the Sr-90 plumes. For the BGRR/WCF and Chemical Holes Sr-90 plumes, MCLs must be reached by 2070 and by 2040, respectively. In addition, cleanup of the Magothy aquifer VOC contamination must meet MCLs by 2065.

There are currently eight groundwater remediation systems in operation (as of December 2019). Three systems have met their cleanup goals and have been decommissioned: the OU IV Area of Concern (AOC) 5 Air Sparge/Soil Vapor Extraction System (OU IV AS/SVE); the Carbon Tetrachloride Pump and Treat System; and the Industrial Park East Treatment System. In 2019, three additional systems, the HFBR Tritium Pump and Recharge System, the Building 452 Freon-11 Treatment System and the OU I South Boundary Treatment System were approved for closure by the regulators. The HFBR and OU I systems will be maintained for potential use for emerging contaminants. The air stripper for the Building 452 Freon-11 System was reconfigured to treat water from Building 96 extraction well RTW-1. **Figure 3.0-1** shows the locations of the treatment systems. In addition to the groundwater treatment systems, two landfill areas (Current and Former) were capped and numerous soil source area removals were conducted, which minimizes the potential for further groundwater contamination.

BNL performs routine maintenance checks on the treatment systems in addition to their routine and non-routine maintenance. BNL's Groundwater Protection Group (GPG) Field Sampling Team collects the treatment system performance samples. In 2019, 556 treatment system samples were obtained from 83 sampling points. The data from the treatment system sampling are available in **Appendix F** tables.

In general, BNL uses two types of groundwater remediation systems to treat VOC contamination: pump and treat (with air stripping or carbon treatment), or recirculation wells (with air stripping or carbon treatment). Pump and treat remediation consists of pumping groundwater from the plume up to the surface and piping it to a treatment system, where the contaminants are removed by either air stripping or granular activated carbon. Treated water is then introduced back into the aquifer via recharge basins, injection wells, or dry wells. BNL utilizes pump and treat using ion-exchange treatment for remediating Sr-90. Pump and recharge (without treatment for tritium) was utilized to hydraulically contain the HFBR tritium plume.

Table 3.0-1 summarizes the existing remediation systems. As discussed in the following sections, groundwater modeling is also used as a tool to help determine if remediation of the plumes is proceeding as planned to meet the overall groundwater cleanup goals. When modifications to the remediation systems are necessary, the groundwater model is also used as a tool to aid in the design.

Groundwater Sampling Methodology Summary

Groundwater sampling, analysis methods, quality assurance reviews and database methodologies are detailed in **Appendix E**. A summary of the techniques used are as follows:

Monitoring well groundwater samples are collected using dedicated bladder pumps using a low flow purge technique. A minimum of two times the volume of the sample pump and tubing are purged prior to the sampling of the well. Samples are collected once water quality parameters (pH, specific conductance and dissolved oxygen) stabilize or when an amount of groundwater equal to 25 percent of a casing volume has been purged. Depending on the parameter, purge flow rates are adjusted to approximately 100 milliliters per minute for sample collection.

The collection of groundwater samples from temporary wells is dependent on the drilling method used. When using an auger rig, hollow stem augers are advanced to the deepest sampling interval. A stainless-steel well screen is connected to two-inch diameter steel well pipe and lowered through the center of the augers to the required sampling depth. The augers are then withdrawn above the well screen. A submersible pump is lowered to the well screen and three well volumes of groundwater are purged prior to sampling. Groundwater samples are collected from the operating pump discharge tubing into laboratory-supplied bottles and preserved according to analysis requirements. This procedure is repeated at each depth interval required by the work plan.

When collecting groundwater samples via a Geoprobe®, a screen is placed inside a sampler sheath and an expendable drive point is attached to the bottom of the sheath and then threaded onto a steel rod. The probe is advanced to the deepest sample collection level and the screen is released using a trip rod. Polyethylene tubing sized to fit inside the probe rods is attached to a check valve. The check valve and tubing are sent down the probe rod until they reach the bottom of the screen, and then withdrawn 12 inches. An inertial pump (e.g., Waterra®) is used to purge the Geoprobe® well. Three casing volumes of groundwater are typically removed prior to sampling. Samples are collected with the inertial pump running continuously.

Since the early 1990's, dedicated bladder pumps have been installed in all BNL monitoring wells that are sampled on a routine basis. The bladder pumps may contain internal components made from polytetrafluoroethylene (PTFE) also referred to as the trade name Teflon®. Furthermore, the pump discharge lines are constructed of Teflon®-lined polyethylene. Teflon® material is also present in ball valves and pipe sealant that are commonly used in BNL's groundwater treatment system piping, including the sample ports. Teflon® has been the preferred material for VOC sampling for many years because, compared to other materials, it does not interact with or adsorb these chemicals.

With the recent need to sample BNL's monitoring wells for the emerging contaminants known as Per- and Polyfluoroalkyl Substances (PFAS), there are concerns about potential cross contamination of groundwater samples by the dedicated sample pumps and discharge lines. Although published studies on possible sample cross contamination from Teflon® are limited, the current generally accepted practice for PFAS sampling is not to use products made of Teflon® because PFAS are used during its manufacture and residual amounts of this compound may be present in the finished product.

During 2018 and 2019, BNL conducted a limited comparison study where groundwater samples were collected using existing dedicated bladder pumps and discharge tubing and with Teflon®-free pumps and tubing. Although Teflon®-containing ball valves were not replaced at the treatment system piping, existing Teflon® or Tygon® flexible discharge tubing attached to the treatment system sample ports was replaced with silicone tubing. Although BNL's preliminary results indicate that the use of Teflon® components may on occasion release low levels of several PFAS compounds, some of the sample results showed no evidence of cross contamination. Additional comparison testing will be conducted in 2020, with the planned Phase 4 sampling of 350 on-site and off-site monitoring wells. Furthermore, the technical issues and regulatory concerns associated with utilizing the most appropriate pump and discharge tubing materials for wells that are sampled for both PFAS and VOCs must be resolved.

Table 3.0-1. 2019 Summary of Existing Groundwater Remediation Systems at BNL.

Operable Unit System	Type	Target Contam	No. of Wells	No. of Wells Oper in 2019[f]	Years in Operation	Recharge Method	Pounds VOCs Removed in 2019/Cumulative
Operable Unit I							
South Boundary[a]	P&T, AS	VOC	2	0	Shutdown Operated: 16 Standby: 5	Basin	0/369
Operable Unit III							
South Boundary	P&T, (AS)	VOC	8	2	22	Basin	6/3055
HFBR Pump and Recharge[a]	Pump and Recirculate	Tritium	4	0	Shutdown Operate: 9.0 Standby: 12	Basin	0/180
Industrial Park	Recirc. Well/ (AS/Carbon)	VOC	7	0	Operate: 17 Standby: 3	Recirc. Well	2/1065
	P&T (Carbon)	VOC	2	2	Operate: 4 Standby: 0.5	Wells	0.5/10
Building 96[d]	Recirc. Well (AS/Carbon)	VOC	4	2	Operate: 15 Standby: 3	Recirc. Well	2/145
Middle Road	P&T (AS)	VOC	7	3	18	Basin	25/1289
Western South Boundary[e]	P&T (AS)	VOC	6	5	17	Basin	13/157
Chemical Holes	P&T (IE)	Sr-90	3	0	Operate: 15 Standby: 1	Dry Well	0[b]/4.94
North Street	P&T (Carbon)	VOC	2	0	11 Standby: 4	Wells	0/342
North Street East	P&T (Carbon)	VOC	2	0	Operate:10 Standby: 5	Wells	0/44
LIPA/Airport	P&T and Recirc. Wells (Carbon)	VOC	10	5	15	Wells and Recirc. Well	14/471
BGRR/WCF	P&T (IE)	Sr-90	9	5	14	Dry Wells	0.8[b]/28.6
Building 452 Freon-11[a]	P&T (AS)	Freon-11	1	0	Shutdown Operate: 6 Standby: 2	Basin	0/106
Operable Unit VI							
EDB	P&T (Carbon)	EDB	2	2	15	Wells	NA[c]
		Total Wells	69	26			

Notes:

AS = Air Stripping
AS/SVE = Air Sparging/Soil Vapor Extraction
EDB = ethylene dibromide
IE = Ion Exchange
LIPA = Long Island Power Authority
NA = Not Applicable
a = Approved for Closure in 2019
P&T = Pump and Treat

b = Sr-90 removal is expressed in mCi.
c = No cumulative EDB calculations are performed based on the low concentrations detected.
d = Well RTW-1 was modified from a recirculation well to surface discharge in May 2008.
e = Four additional extraction wells for the Western South Boundary System became operational in 2019.
f = Includes wells in operation for any time during the year.

Recirculation = Double screened well with discharge of treated water back to the same well in a shallow recharge screen
In-Well = The air stripper in these wells is located in the well vault.

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3.1 Operable Unit I

The two sources of VOC groundwater contamination contained within the OU I project are the former Hazardous Waste Management Facility (HWMF) and the Current Landfill. The former HWMF was BNL's central RCRA receiving facility for processing, neutralizing, and storing hazardous and radioactive wastes for off-site disposal until 1997, when a new Waste Management Facility was constructed along East Fifth Avenue. Several hazardous materials spills were documented at the former HWMF. A facility demolition and soil remediation program were completed for this facility in September of 2005.

VOC plumes from the Current Landfill and former HWMF became commingled south of the former HWMF. The commingling was partially caused by the pumping and recharging effects of a spray aeration system, which operated from 1985 to 1990. This system was designed to treat VOC-contaminated groundwater originating from the former HWMF. The remnants of the VOC plume are depicted on **Figure 3.1-1** and the cross-sectional view in **Figure 3.1-2**.

The on-site segment of the Current Landfill/former HWMF plume was remediated by a groundwater pump and treat system consisting of two wells (EW-1, EW-2) screened in the deep Upper Glacial aquifer at the site property boundary (OU I South Boundary Treatment System). The extracted groundwater was treated for VOCs by air stripping and recharged to the ground at the RA V basin, located northwest of the Current Landfill. A second system (North Street East System) was built to treat the off-site portion of the plume. The off-site groundwater remediation system began operations in June 2004 and was included under the Operable Unit III Record of Decision (**Section 3.2.9**). That system was shut down in 2014 and placed in standby mode. The North Street East System is currently being modified to address recently discovered EDB contamination in the deep Upper Glacial Aquifer. A Petition for Shutdown of the OU I South Boundary Treatment System was approved by the regulatory agencies in July 2013. A Petition for Closure was approved by the regulatory agencies in September 2019 as the conditions for closure were satisfied as described in the *OU III ROD* (BNL, 2000a) and the *Operations and Maintenance Manual for the OU I South Boundary Treatment Facility* (BNL 2005b).

3.1.1 OU I South Boundary Treatment System

This section summarizes the operational and monitoring well data for 2019 from the OU I South Boundary Groundwater Treatment System. This system began operating in December 1996. A Petition for Closure of this system was submitted to the regulatory agencies in May 2013 and approved in September 2019.

3.1.2 System Description

For a complete description of the OU I South Boundary Treatment System, see the *Operations and Maintenance Manual for the OU I South Boundary Treatment Facility* (BNL 2005b).

3.1.3 Groundwater Monitoring

Well Network

Six monitoring wells are used for post-closure VOC monitoring of the OU I South Boundary area (**Figure 1-2)**. A total of 27 permanent wells are used to monitor the former HWMF Sr-90 plume supplemented by annual temporary wells as necessary. Due to manpower issues created by the PFAS characterization work and the COVID-19 Lab operations shutdown, the temporary well work was not performed as planned prior to the completion of this report. It is anticipated that this work will be completed following the resumption of normal work at BNL and the data will be summarized in the CERCLA Five- Year Review Report.

Sampling Frequency and Analysis

The wells are monitored for VOCs, and/or Sr-90 as per the schedule provided on **Table 1-5**.

3.1.4 Monitoring Well VOC Results

Figure 3.1-1 shows remnants of OU I VOC plume based on samples collected in the third and fourth quarters of 2019. The data posted on this figure were obtained from the six OU I Post Closure monitoring wells and the Current Landfill monitoring program wells. The primary VOCs detected in this plume consisted of chloroethane and 1,1-dichloroethane (DCA), which originated from the Current Landfill.

The landfill was capped in November 1995. A detailed discussion of the landfill monitoring well data is provided in the *2019 Environmental Monitoring Report, Current and Former Landfill Areas (BNL 2020d).* The downgradient portion of the OU I South Boundary VOC plume (as defined by TVOC concentrations greater than 5 µg/L) has been remediated by a combination of groundwater pump and treat, landfill capping and natural attenuation (**Figure 3.1-1**). The off-site portion of the plume is discussed in **Section 3.2.9**, the North Street East Treatment System.

Figure 3.1-3 gives the historical trends in VOC concentrations for key plume core and bypass wells. **Appendix C** has a complete set of 2019 analytical results. Significant findings for 2019 include:

- Current Landfill source area monitoring well 088-109 has exhibited the highest VOC concentrations over the past several years. This well is located immediately east of the Current Landfill footprint, and approximately 3,500 feet north of the BNL site boundary (**Figure 3.1-1**). TVOC concentrations decreased significantly in this well during 2019 with a concentration of 0.8 µg/L observed during the fourth quarter. Monitoring well 098-99 was installed to provide a sentinel monitoring point approximately 1,200 feet downgradient of the Current Landfill. TVOC concentrations in this well remained below 4 µg/L in 2019. This data confirms the attenuation of VOCs from the current landfill.
- Well 107-40 was located along the center line of the plume, approximately 500 feet north of the site boundary. TVOC concentrations in this well have been below the capture goal of 50 µg/L since 2013. The TVOC concentration in this well during the fourth quarter of 2019 was 5 µg/L.
- None of the remaining post-closure wells have individual VOC concentrations above the AWQS.

3.1.5 Radionuclide Monitoring Results

A subset of the OU I Monitoring Program wells is analyzed for tritium annually, Sr-90 semiannually, and gamma spectroscopy annually. The complete results for these wells are provided in **Appendix C**.

The tritium concentrations in this well network have diminished, with no detections observed since 2014.

Twenty-seven permanent wells are monitored for Sr-90 contamination from the former HWMF **(Table 1-5)**. Three new wells were installed to monitor higher concentrations at the source area in 2019 as per a recommendation in the *2018 Groundwater Status Report*. The locations of these new wells were coordinated with the highest temporary well source area concentrations. The highest Sr-90 detected in 2019 from a monitoring well was 41 pCi/L in well 098-30 during October (the Sr-90 DWS is 8 pCi/L). Due to manpower and equipment availability resulting from our focus on PFAS/1,4-dioxane characterization in 2019, the annual effort to enhance the permanent well network and track the migration of Sr-90 from the former HWMF was not performed. It is anticipated that once the Laboratory Min-Safe conditions are lifted, temporary well installation and sampling will be implemented. The results will be included in the Five-Year Review Report. The well locations are shown on **Figure 3.1-4.** Sr-90 trend plots are provided on **Figure 3.1-5.**

The location of the leading edge of the Sr-90 plume cannot be precisely determined due to the lack of temporary well data for 2019. In addition, the results from the three new source area wells 098-100, 098-101, and 098-102 are significantly lower than anticipated. The plume is extremely narrow at these locations and it is possible the screened intervals are not optimally located. Temporary wells will be installed at these locations to verify the locations of the plume core. It is important to note that the leading edge of the plume is approximately 1,400 feet north of the site boundary and migrates slowly, at the rate of 20 to 40 feet per year in this area, based on historical monitoring.

3.1.6 System Operations

The extraction wells are currently sampled quarterly as the system was in standby mode for 2019. **Table 3.1-2** provides the effluent limitations for meeting the requirements of the SPDES equivalency permit. Since the system was in standby mode in 2019 no influent/effluent samples were collected.

Table 3.1-1.
OU I South Boundary Treatment System
2019 SPDES Equivalency Permit Levels

Parameters	Permit Level (µg/L)	Max. Measured Value (µg/L)
pH	6.0 – 9.0 SU	NS
benzene	0.8	NS
chloroform	7.0	NS
chloroethane	5.0	NS
1,2-dichloroethane	5.0	NS
1,1-dichloroethene	5.0	NS
1,1,1-trichloroethane	5.0	NS
carbon tetrachloride	5.0	NS
1,2-dichloropropane	5.0	NS
methylene chloride	5.0	NS
trichloroethylene	5.0	NS
vinyl chloride	2.0	NS
1,2-xylene	5.0	NS
sum of 1,3- & 1,4-xylene	10.0	NS

Notes:
SU = Standard Units
NS = Not Sampled as the system was not operating

The following is a summary of the OU I system operations for 2019:

January–December 2019

The system remained in standby mode for the year . There was no increase in VOC concentrations observed in the extraction or monitoring well network that required the extraction wells to resume pumping.

3.1.7 System Operational Data

Extraction Wells

During 2019, the extraction wells did not operate. The wells were sampled quarterly during the year. VOC and tritium concentrations in samples from EW-1 and EW-2 are provided in **Table F-1**. Tritium was not detected in the extraction wells during 2019. TVOC levels in EW-1 and EW-2 remained low with maximum concentrations of 5.5 µg/L and 0.89 µg/L, respectively (**Figure 3.1-6**).

System Influent and Effluent

There were no influent or effluent samples as the system was in standby mode during 2019 (**Table F-2 and F-3**).

Cumulative Mass Removal

Approximately 369 pounds of VOCs were removed from the aquifer during system operation from 1996 through 2013 (**Figure 3.1-7 and Table F-4**).

Air Discharge

There were no air emissions as the system was in standby in 2019 (**Table 3.1-2**).

3.1.8 System Evaluation

Although the system remains in standby, post-closure groundwater monitoring continues, and no rebound of VOC concentrations has been observed. The OU I South Boundary Treatment System performance can be evaluated based on the decisions identified by applying the DQO process.

1. Is there a continuing source of contamination? If present, has the source area been remediated or controlled?

Current Landfill

VOCs continue to be observed immediately downgradient of the Current Landfill which is covered by an engineered cap. Due to high water table conditions it is suspected that the water table is continuing to periodically flush contaminants from the vadose zone and/or the bottom of the landfilled materials.

Table 3.1-2
OU I South Boundary
2019 Air Stripper VOC Emissions Data

Parameter	Allowable ERP* (lb/hr)	Actual** ERP* (lb/hr)
carbon tetrachloride	0.016	NS
chloroform	0.0086	NS
1,1-dichloroethane	10**	NS
1,2-dichloroethane	0.011	NS
1,1-dichloroethylene	0.194	NS
chloroethane	10**	NS
1,1,1-trichloroethane	10**	NS
trichloroethylene	0.119	NS

ERP = Emissions Rate Potential, stated in pounds per hour (lb/hr).
* ERP is based on NYSDEC DAR-1 Regulations.
** Actual rate reported is the average for the year.
*** 6 NYCRR Part 212 restricts emissions of VOCs to a maximum of 10 lb/hr without controls.
NS= Not Sampled

Former HWMF
2019 groundwater monitoring data included only a limited number of permanent wells as stated above. Based on historical data, we know that Sr-90 continues to slowly migrate south from this area. Temporary wells will be installed and sampled in 2020 to confirm the status of the plume.

2. Were unexpected levels or types of contamination detected?

Current Landfill
No unexpected results were observed.

Former HWMF
The Sr-90 levels in the three newly installed former HWMF were lower than anticipated. Temporary wells will be installed to verify whether these permanent wells are ideally located to monitor high concentration segments of the plume.

3. Has the downgradient migration of the plume been controlled?

Current Landfill VOCs
Yes, monitoring results indicate that the OU I onsite VOC plume has completed active remediation. VOCs periodically released from the Current Landfill are attenuating as they migrate south. The groundwater travel time from the Current Landfill to the BNL site boundary is approximately 12-15 years. Modeling simulations indicate that TVOC concentrations from the Current Landfill will attenuate to below 5 µg/L prior to reaching the site boundary. The modeling results are supported by the TVOC concentration data observed in sentinel monitoring well 098-99.

Former HWMF Sr-90
A plume of Sr-90 exceeding the 8 pCi/L DWS extends from the former HWMF yard to an area within the LISF, approximately 2,400 feet to the south. This plume is migrating slowly to the south as verified by monitoring data obtained over the past several years. As stated above, the annual temporary well installation has not been completed in time for this report. Sentinel wells downgradient of the leading edge of the plume continue to exhibit low Sr-90 concentrations.

Groundwater model simulations show the leading edge of the higher concentration area of Sr-90 arriving at the site boundary at levels above DWS in approximately 41 years (2058) and attenuating to below DWS by approximately 2081.

4. Can individual extraction wells or the entire VOC treatment system be shut down or placed in pulsed pumping operation?
Yes, the system was approved for closure by the regulators in September 2019. There has been no significant VOC concentration rebound observed in either the extraction wells or monitoring wells since system shutdown in 2013. There are no downgradient plume core wells exhibiting individual VOCs above the AWQS.

4a. Are TVOC/Sr-90 concentrations in plume core wells above or below 50 µg/L or 8 pCi/L, respectively?

TVOCs

Monitoring well 088-109, located immediately southeast of the Current Landfill, has periodically shown TVOC concentrations exceeding 50 µg/L over the past several years. TVOC concentrations dropped off in 2019 with a value of less than 1 µg/L observed during the fourth quarter. Based on plume core well data, TVOC concentrations throughout the downgradient portion of the plume have been less than the system capture goal of 50 µg/L since January 2013.

Sr-90

Yes, Sr-90 was detected above 8 pCi/L in the network of permanent wells during 2019. The permanent well locations are shown in **Figure 3.1-4**.

4b. Is there a significant concentration rebound in core wells and/or extraction wells following shutdown?

No significant rebound of VOCs has been observed in either monitoring or extraction wells since the system was shut down in July 2013.

5. Has the groundwater cleanup goal of meeting MCLs for VOCs by 2030 been achieved? Has the groundwater cleanup goal of 8 pCi/L for Sr-90 been achieved?

VOCs

No. MCLs have not been achieved for individual VOCs in all wells. Several Current Landfill area wells have displayed individual VOC concentrations in exceedance of MCLs. There were no exceedances of MCLs in the post-closure downgradient wells in 2019 and one exceedance in 2019. A comparison of groundwater quality conditions are shown on **Figure 3.1-8** which compares the VOC plume from 1997 to 2019.

Sr-90

No. Characterization and monitoring are underway and will continue to track the movement and attenuation of the Sr-90 plume.

3.1.9 Recommendations

The following recommendations are presented for the OU I South Boundary Treatment System and groundwater monitoring program:

- Maintain the VOC post-closure groundwater monitoring program of an annual sample collection from post-closure wells: 098-99, 107-40, 107-41, 115-13, 115-16, and 115-51. Maintain quarterly sampling of Current Landfill sentinel well 098-99.
- Install temporary wells as needed adjacent to monitoring wells 088-100, 088-101, and 088-102 to assess whether they are appropriately screened in the highest concentration segments of the Sr-90 plume immediately downgradient of the source area. Install temporary wells as needed to fill monitoring data gaps and characterize extent of Sr-90 plume. This temporary well data will be incorporated into the CERCLA Five-Year Review Report.
- Discontinue sampling of monitoring wells 115-41 and 115-42 for Sr-90. These wells have been monitored since 1997 and no detections of Sr-90 have been observed.
- Discontinue the annual tritium sampling of monitoring wells 087-21, 088-13, 088-14, 088-20, 088-26, 098-21, 098-30, 099-04, 107-24, 107-40, 108-08, 108-12, 108-13, 108-14, 108-17, 115-03, 115-

13, 115-14, 115-15, 115-16, 115-28, 115-29, 115-30, 115-31, 115-41, 15-42, 116-05, and 116-06. There have been no tritium detections in any of these wells since 2014 or longer.

3.2 Operable Unit III

There were a number of groundwater issues addressed under the OU III Remedial Investigation/Feasibility Study (RI/FS). VOC plumes originated from several sources, including Building 96, Building 452 Freon, and sources (some unknown) in the north-central developed portion of the site, the Former Landfill, OU IV, and the former carbon tetrachloride underground storage tank (UST). **Figure 3.2-1** is a representation of the plumes based on areas containing TVOC concentrations exceeding 5 µg/L. The eastern portion of **Figure 3.2-1** also includes the North Street (OU I/IV) plumes. **Figure 3.2-2** is cross-section B–B′, which is drawn through the north–south center-line of the primary OU III VOC plumes, as shown in **Figure 3.2-1**.

The primary chemical contaminants found in OU III groundwater are 1,1,1-trichloroethane (TCA), tetrachloroethylene (PCE), and carbon tetrachloride. These three chemicals are the primary VOCs detected in the OU III on-site monitoring wells. Off site, carbon tetrachloride and PCE are the main contaminants detected. BNL is currently implementing a phased characterization of PFAS and 1,4-dioxane contamination across the site. Additional information on this work can be found in **Section 3.10** and **Section 3.11**.

Figure 3.2-3 presents a comparison of the OU III plumes between 1997 and 2019. Several changes in the plumes can be observed in this comparison:

- Significant progress is evident in reducing the higher concentration segments of the plumes both on and off-site. This is due primarily to the source control and groundwater remediation that has been implemented, along with the effects of natural attenuation.
- Hydraulic control of the plumes by the OU III South Boundary Treatment System at the site boundary, Industrial Park and the LIPA/Airport system is evidenced by the segmentation of the plumes in these areas.
- VOC concentrations have been significantly reduced in the vicinity of the North Street System.
- Deeper VOC contamination was characterized in the Western South Boundary area over the past several years. Remediation of this contamination was enhanced by modifying the system to include four new extraction wells.
- While the NSE plume was addressed under OU III, it is the off-site portion of the OU I South Boundary plume and the plume comparison is included on **Figure 3.1-8**.

Three radiological plumes were addressed under OU III. The HFBR tritium plume, at its maximum extent had travelled several thousand feet south from the HFBR spent fuel pool. This plume has naturally attenuated and the pump and recharge system received regulatory approval for closure in March 2019. Sr-90 plumes are present downgradient of the former WCF and several sources related to the BGRR. A Sr-90 plume that is downgradient of the Chemical/Animal Holes area has been largely remediated and the system is currently in shutdown mode.

Sections 3.2.1 through **3.2.16** summarize and evaluate the groundwater monitoring and system operations data for the OU III VOC and radiological plumes, including both operational groundwater treatment systems and the monitoring-only programs.

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3.2.1 Building 96 Treatment System

This section summarizes the 2019 operational data from the OU III Building 96 Treatment System, which consists of three recirculation wells and one extraction well with air stripping and vapor-phase carbon treatment. It also presents conclusions and recommendations for future operation of the system. The system began operation in February 2001. For a history of the operation of these wells over the last 19 years, refer to previous Groundwater Status Reports. Starting in 2012, treatment well RTW-1 was used to treat the low-level downgradient portion of the Building 452 Freon-11 plume (See **Section 3.2.2** for further discussion of the Building 452 Freon-11 plume).

3.2.1.1 System Description

Recirculation wells RTW-2, RTW-3, and RTW-4, draw contaminated groundwater from the aquifer via a submersible well pump in a lower well screen, 48 to 58 feet below land surface (bls), near the base of the contaminant plume. The groundwater is pumped into a stripping tray adjacent to each of the three wells. After treatment, the clean water is recharged in wells RTW-2 through RTW-4 back to the upper screen, 25 to 35 feet bls. In May 2008, well RTW-1 was modified from a recirculation well to a pumping well with air stripping and hexavalent chromium ion exchange treatment, with discharge to the nearby surface drainage culvert. In January 2010 the ion exchange treatment was bypassed following a decline in hexavalent chromium concentrations below the AWQS and was decommissioned in 2018 following regulatory approval. In June, 2019 RTW-1 was off to install a new pump and motor in addition to being connected via pipe to the existing Freon 11 building. This building houses a larger air stripper to handle the increased flow. Well RTW-1 was restarted June 25th and the pumping rate was increased from 30 gallons per minute (gpm) to 60 gpm to increase capture of VOCs in the western portion of the plume. The contaminated air stream from the air stripper from the four treatment wells is routed to a treatment and control building, where it is passed through two vapor-phase granular activated carbon (GAC) units in series to remove the VOCs. Treated air is then discharged to the atmosphere. A complete description of the system is included in the *Operations and Maintenance Manual Building 96 Groundwater Treatment System* (BNL 2009a).

3.2.1.2 Source Area Remediation

The excavation of soil from the VOC contaminated source area in 2010 had a significant impact on groundwater VOC concentrations. RTW-1 concentrations have remained below 20 μg/L over the past three years. The recommendation from the *2017 Groundwater Status Report* to increase the pumping rate in this well was implemented in July 2019. The increased pumping rate appears to have had the intended effect of reducing the higher VOC concentrations on the western edge of the plume. The ROD cleanup goal for this groundwater plume is to meet drinking water standards by 2030.

Figure 3.2.1-1 shows the location of the excavated soil contamination area in relation to the 2019 VOC groundwater plume. **Figure 3.2.1-2** shows a hydrogeologic cross section of the area.

3.2.1.3 Groundwater Monitoring

A network of 32 wells is used to monitor the VOC plume and the effectiveness of the Building 96 groundwater remediation system (**Figure 3.2.1-1**). The permanent well network was supplemented with an additional well 095-325, installed in March 2019. Most of the wells are sampled quarterly and analyzed for VOCs as noted in **Table 1-5**. Well 095-159 has been sampled at a monthly frequency since April of 2019 to evaluate the effect of the increase in RTW-1 pumping on the western edge of the plume.

3.2.1.4 Monitoring Well Results

Complete VOC results are provided in **Appendix C**. The fourth quarter 2019 plume is shown on **Figure 3.2.1-1** and trends for several wells are presented on **Figure 3.2.1-3**. A summary of key monitoring well data for 2019 follows:

Former Source Area to RTW-1:

- The historical maximum TVOC concentration of 2,435 µg/L was observed in monitoring well 085-379 during 2011. Concentrations in this well have ranged between 65 µg/L and 135 µg/L since 2019. This well is located immediately south of the 2010 soil excavation area. This well straddles the water table to ensure that the release of any residual groundwater contamination from the former source area is identified during water table fluctuations.
- TVOC concentrations in core well 095-305, located approximately 100 feet downgradient of the former source area, have declined significantly since mid-2016. The maximum TVOC concentration was 48 µg/L in January 2018 and dropped off to 6 µg/L in April 2019. Well 085-347, located approximately 40 feet upgradient of the source area and screened at the same depth, has shown a sharp decline of TVOC concentrations following detections up to 3,000 µg/L in 2010. The TVOC concentration in this well was 3 µg/L in July 2019.
- The maximum TVOC concentration in well 095-84, located immediately upgradient of extraction well RTW-1 were 19 µg/L in the first quarter 2019. This is significantly lower than the historical maximum TVOC concentration in this well of 18,000 µg/L in 1998. As noted on **Figure 3.2.1-3**, since 2010, TVOC concentrations have significantly declined. This declining trend is also evident in core well 095-306. TVOC concentrations in 095-84 declined to 11 µg/L in October 2019.
- A new well, 095-325, was installed immediately north of well 095-306 to evaluate an increase in the plume depth due to changes in RTW-1 pumping over the years. It appears that the plume has shifted slightly deeper in this area in recent years based on results observed in a 2017 temporary well along with the shallower wells in the area discussed previously. The increased plume depth can be observed on **Figure 3.2.1-2.** This increase is evident when comparing this figure with the cross section from the 2012 *Groundwater Status Report* as show on **Figure 3.2.1-2a**.
- TVOC concentrations in monitoring wells 095-294, 095-307, 095-308, and 095-313 have continued a declining trend over the past several years. These wells monitor the slightly deeper VOC contamination that had been observed west of the main Building 96 plume.

RTW-1 to Downgradient Recirculation Wells RTW-2 through RTW-4:

- TVOC concentrations in well 095-159 decreased from 134 µg/L in August to 15 µg/L in March of 2020. This correlates well with the increased pumping rate for RTW-1 in July 2019 and indicates that capture of the western edge of the plume has been achieved.

Wells Downgradient of RTW-2 through RTW-4:

- TVOC concentrations observed in the three bypass wells, located immediately downgradient of RTW-2 (095-163, 095-165, 095-166) increased slightly during 2017-2018. No VOCs were detected in these wells during 2019.
- The maximum TVOC concentration in sentinel monitoring well 095-318, located on Weaver Drive, was 3 µg/L in October 2019. TVOC concentrations in this well have significantly declined since the well was installed in 2010 and a detection of 143 µg/L was observed.

Freon-11:

- As further described in **Section 3.2.2**, Building 96 extraction well RTW-1 is also being used to address the remaining low-level Freon-11 concentrations.

3.2.1.5 System Operations

Operating Parameters

Extraction wells RTW-1 and RTW-2 operated full time during 2019. Well RTW-3 has remained in stand-by mode since January 2016. RTW-4 has been in stand-by mode since October 2012.

January – September 2019

RTW-1 was off from May 23rd to June 5th for programming repair to the PLC. Well RTW-2 was off most of May due to electrical issues. RTW-1 was off from June 6th to June 24th to install a new pump and motor and re-piping of the system to the existing Freon-11 building to handle an increased pumping rate. Well RTW-1 was restarted June 25th and the pumping rate was increased from 30 gallons per minute (gpm) to 60 gpm to increase capture of VOCs in the western portion of the plume. The system operated normally during the remainder of this period and treated approximately 23 million gallons of water.

October – December 2019

Well RTW-1 was off October 1 to October 22 to repair a pipe leak and electrical issues. Well RTW-2 ran intermittently during October due to a clogged air flow intake. The system operated normally during the rest of the period. The system treated approximately 8 million gallons of water.

During 2019 the system treated approximately 31 million gallons of water (**Table F-7**).

Table 3.2.1-1
OU III Building 96 RTW-1 Treatment Well, 2019 SPDES Equivalency Permit Levels

Parameter	Permit Level (µg/L)	Max. Measured Value (µg/L)
pH range	5.0–8.5 SU	6.1–7. 9 SU
tetrachloroethylene	5.0	<0.5
1,1,1-trichloroethane	5.0	<0.5
thallium	Monitor	1.8
trichlorofluoromethane	5.0	<0.5
methyl bromide	5.0	<0.5
methyl chloride	5.0	<0.5
methylene chloride	5.0	<0.5

Note: Required effluent sampling frequency is monthly following a period of 24 consecutive weekly with no exceedances. *Weekly* for pH.
SU = Standard Units

3.2.1.6 System Operational Data

Recirculation/Treatment Well Influent and Effluent

Table F-5 lists the monthly influent and effluent VOC concentrations for well RTW-1, and the influent concentrations for wells RTW-2 through RTW-4. The highest TVOC concentration from the influent of these wells was 15 µg/L in RTW-1 in the third quarter of 2019. **Figures 3.2.1-4 and 3.2.1-5** show the TVOC concentrations in the treatment wells over time. **Table 3.2.1-1** shows the maximum measured effluent contaminant concentrations compared to the SPDES equivalency permit for well RTW-1. The system met all equivalency parameters for operation in 2019.

Air Discharge

In 2019, quarterly air sampling was performed from the GAC vessels before treatment (influent), between the two vessels (midpoint), and after the second vessel (effluent). The analytical data are available on **Table F-6**, and the VOC emission rates are summarized on **Table 3.2.1-2.** The findings are utilized to monitor the efficiency of the GAC units and to determine when a carbon change-out is required. Airflow rates, measured for each air-stripping unit inside the treatment building, show that they typically range between 250 and 450 cubic feet per minute (cfm) for each of the four wells. Assuming a total airflow rate of 1,200 cfm, all compounds detected in the carbon effluent during the operating year were well below the New York State Division of Air Resources (DAR)-1 Air Toxics Assessment limits for the worst-case potential impacts to the public.

Table 3.2.1-2
OU III Building 96 Area
2019 Average VOC Emission Rates

Parameter	Allowable ERP* (lb/hr)	Actual** ER (lb/hr)
dichlorodifluoromethane	0.0000187	0.00000219
acetone	0.000674	0
methylene chloride	0.000749	0
2-butanone	0.000187	0
benzene	0.000112	0.00000401
tetrachloroethylene	0.000165	0.0000529
m,p-xylene	0.0000116	0
isopropylbenzene	0.000243	0
n-propylbenzene	0.0000599	0
1,3,5-trimethylbenzene	0.000375	0
1,2,4-trimethylbenzene	0.000225	0
4-isopropyltoluene	0.00000749	0
naphthalene	0.0000225	0
carbon disulfide	0.0000487	0
styrene	0.00000637	0
trans-1,3-dichloropropane	0.0000157	0

Notes:

ER = Emissions Rate
ERP = Emissions Rate Potential, stated in lb/hr.
* ERP is based on NYSDEC Air Guide 1 Regulations.
** Actual rate reported is the average for the year.

Cumulative Mass Removal

Table 3.2.1-3 shows the monthly extraction well pumping rates. The annual average pumping rate for the system was 58 gpm. The pumping and mass removal data are summarized on **Table F-7**. In 2019, approximately 1.6 pounds of VOCs were removed. Since February 2001, the system has removed approximately 143.5 pounds of VOCs.

3.2.1.7 System Evaluation

The Building 96 Treatment System performance can be evaluated based on the decisions identified by applying the DQO process.

1. Is there a continuing source of contamination? If present, has the source area been remediated or controlled?
Yes, PCE concentrations in source area groundwater declined significantly following the excavation effort but have been fluctuating in the range of 50 µg/L to 100 µg/L over the past several years.

2. Were unexpected levels or types of contamination detected?
No, there were no unexpected levels detected.

3. Has the downgradient migration of the plume been controlled?
Yes, through a combination of RTW-1 and RTW-2, the PCE plume is controlled. Increased pumping of RTW-1 appears to have resulted in the capture of the western edge of the plume as evidenced by declining TVOC concentrations in well 095-159. See **Figure 3.2.1-6** for a comparison of the plume from 2000 to 2019. VOC concentrations have remained low in sentinel well 095-318, located on Weaver Drive, indicating the plume is not reaching this location.

4. Can individual extraction wells or the entire treatment system be shut down or placed in pulsed pumping operation?
The system has not met all shutdown requirements. RTW-1 did not exceed the TVOC capture goal in 2019, however, core monitoring wells have.
Influent TVOC concentrations in downgradient recirculation wells RTW-3 and RTW-4 have been below 50 µg/L since 2008. TVOC concentrations in RTW-2 briefly increased up to 65 µg/L in 2018 followed by a steep decline to a maximum concentration of 3 µg/L in 2019. Due to these consistently low levels, extraction wells RTW-3 and RTW-4 have remained in standby mode.

4a. Are TVOC concentrations in plume core wells above or below 50 µg/L?
TVOC concentrations in three of 21 core wells were above 50 µg/L in 2019 which is a decrease from six wells in 2018. The highest TVOC concentration in 2019 was 233 µg/L in well 095-159.

4b. Is there a significant concentration rebound in core wells and/or extraction wells following shutdown?
The TVOC concentration in RTW-2 increased to 65 µg/L in October 2018. This was above the 50 µg/L TVOC capture goal and resulted in placing the well back in operation. TVOC concentrations in this well from December 2018 through 2019 have been below 5 µg/L. RTW-1 has been kept in operational mode given the elevated VOC concentrations in wells 085-379 and 095-159.

5. Has the groundwater cleanup goal of meeting MCLs been achieved?
MCLs have not been achieved for individual VOCs in all plume core wells.

3.2.1.8 Recommendations

The following are recommendations for the OU III Building 96 Groundwater Remediation System and monitoring program:

- Maintain full time operation of treatment well RTW-1. Monitor VOC concentrations in wells 085-379 and 095-159 to determine when this well can be shut down. Maintain a monthly sampling frequency of the influent and effluent.
- Place treatment well RTW-2 back in standby mode based on TVOC concentrations remaining below 5 µg/L since November 2018.
- Maintain a monthly monitoring frequency for well 095-159 to verify the westward expansion of the RTW-1 capture zone.
- Add former Building 452 Freon-11 monitoring well 085-386 to the Building 96 monitoring program. It will serve as a background well between the two source areas.
- Maintain treatment wells RTW-3 and RTW-4 in standby mode, and restart the wells if extraction or monitoring well data indicate that TVOC concentrations exceed 50 µg/L.

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3.2.2 Building 452 Freon-11 Treatment System

In April 2011, BNL detected the refrigerant Freon-11in Building 96 area groundwater monitoring well 085-378. From April through early August 2011, temporary groundwater monitoring wells were installed to characterize the vertical and horizontal extent of Freon-11 in the groundwater. The plume was found to extend from the site maintenance facility Building 452 area approximately 600 feet downgradient to former Building 96 groundwater extraction well RTW-1 (**Figure 3.2.2-1**). A network of monitoring wells was installed for long-term surveillance of the source area and plume. The maximum Freon-11 concentration detected during 2011 was 38,800 µg/L in well 085-382, located approximately 100 feet downgradient of Building 452. Following the characterization of the plume, the Building 452 Freon-11 Source Area and Groundwater Plume were designated Area of Concern 32. Remedial actions for the plume were documented as an Explanation of Significant Differences (ESD) under the OU III ROD (BNL 2012a).

The Building 452 freon-11 treatment system consisted of extraction well EW-18, which was positioned to capture the highest Freon-11 concentration portions of the plume near the source area, and Building 96 extraction well RTW-1, which captured lower Freon-11 concentrations in the downgradient portion of the plume. The treatment system was in full-time operation from March 2012 until February 2015, when it was placed in a pulsed-pumping mode. Pulsed pumping continued until March 2016 when the system was approved for shutdown (BNL 2016). Due to a rebound in Freon-11 concentrations, the system was placed back into full-time operation in November 2016. The system was placed back into standby in March 2017 and was maintained in an operationally ready state. Because Freon-11 concentrations remained below the 50 µg/L capture goal, a Petition for Closure was submitted to the regulatory agencies in June 2019 (BNL 2019). The petition was approved by the agencies in August 2019.

3.2.2.1 System Description

Due to the high levels of Freon-11 detected in groundwater and the extent of the plume, it was determined that active remediation of the plume was required to ensure that the OU III ROD cleanup objectives are met. To achieve the cleanup objectives, operation of extraction well EW-18 and Building 96 Groundwater Treatment System extraction well RTW-1 were used to remediate the Freon-11 plume. The goal of the remediation system was to reduce Freon-11 concentrations to <50 µg/L, which would then be followed by a period of monitored natural attenuation.

Groundwater from extraction well EW-18 was treated using a tray air stripper system located in a treatment building located adjacent to the treatment building for RTW-1 (**Figure 3.2.2-1**). Groundwater from extraction well RTW-1 is also treated using a tray air stripper system (**Section 3.2.1**). The treated water from extraction wells EW-18 and RTW-1 was discharged to a nearby stormwater culvert which leads to BNL Recharge Basin HS. The discharges for this system were regulated under two NYSDEC SPDES equivalency permit. Review of the potential atmospheric emissions following the New York State air emissions modeling (DAR-1) process showed that the release of Freon-11 from this system would not pose short-term or long-term impacts. A complete description of the system is presented in the *Operations and Maintenance Manual Building 452 Groundwater Treatment System* (BNL 2012b). As discussed in **Section 3.2.1**, following the closure of the Building 452 treatment system, the EW-18 air stripping system was reconfigured to treat water from Building 96 extraction well RTW-1.

3.2.2.2 Groundwater Monitoring

Well Network

The monitoring well network for the Building 452 program consists of 13 wells, all of which are screened in the shallow portion of the Upper Glacial aquifer (**Figure 3.2.2-1**). Monitoring results from twelve Building 96 wells are also used to evaluate the effectiveness of the treatment system.

Sampling Frequency and Analysis

During 2019, eleven Building 452 monitoring wells were sampled in the first quarter, and two source area wells (085-382 and 085-383) were sampled during the fourth quarter. The samples were analyzed for VOCs (**Table 1-6**). Twelve Building 96 monitoring wells that are also used to track Freon-11 concentrations in this area were sampled quarterly (**Table 1-5**).

3.2.2.3 Monitoring Well Results

Complete VOC results are provided in **Appendix C**. Monitoring results for the first quarter 2019 are shown on **Figure 3.2.2-1**. Freon-11 concentration trends for key monitoring wells are presented on **Figure 3.2.2-2**. A summary of key monitoring results for 2019 follows:

Building 452 Source Area:

- Freon-11 concentrations in all source area monitoring wells have been less than the 50 µg/L capture goal since the third quarter of 2014. During 2019, all Freon-11 concentrations were below the 5 µg/L AWQS, with a maximum concentration of 1.47 µg/L detected in well 085-382 during the first quarter.

Plume Core Wells:

- Plume core wells 085-385 and 085-386 are located within the capture zone of EW-18. Freon-11 concentrations in wells 085-385 and 085-386 have been less than the 50 µg/L capture goal since May 2014, and have been below the 5 µg/L AWQS since February 2016 and February 2017, respectively. During the first quarter 2019, the maximum Freon-11 concentration was detected in well 085-386 at 1.9 µg/L.
- Wells 085-387, 085-348, 095-306 and 095-313 are located downgradient of EW-18 and upgradient of RTW-1. Freon-11 concentrations in these wells have been below the 50 µg/L capture goal since March 2015, and below the 5 µg/L AWQS since August 2017. During the first quarter of 2019, Freon-11 was not detected in any of the wells.
- During the first quarter of 2019, the Freon-11 concentration in extraction well EW-18 was 1.4 µg/L. Freon-11 concentrations in RTW-1 have been below the 5 µg/L AWQS since December 2015 and decreased to non-detectable levels by 2019.

Bypass Wells:

- During the first quarter 2019, Freon-11 was detected in bypass wells 095-314, 095-315 and 095-162 at concentrations of 2.7 µg/L, 42 µg/L and 1.5 µg/L, respectively. Freon-11 concentrations in these wells had been below 5 µg/L from August 2015 through the end of 2018.
- During 2019, Freon-11 was only occasionally detected at trace levels in the Building 96 extraction wells RTW-2, RTW-3 and RTW-4, and in the nearby monitoring wells.

3.2.2.4 System Operations

Operating Parameters

The treatment system was placed in standby mode in March 2017, and was maintained in an operational ready state until August 2019 when the regulatory agencies approved the Petition for Closure. Operating conditions for Building 96 extraction well RTW-1 are presented in Section 3.2.1.

3.2.2.5 System Operational Data

Treatment Well Influent and Effluent

Table F-8 lists the quarterly influent and **Table F-9** lists the quarterly effluent VOC concentrations for extraction well EW-18. Because the system was in standby mode during 2019, extraction well

EW-18 was only turned on long enough to collect quarterly influent samples. The highest Freon-11 influent concentration was 3.0 µg/L in April. **Figures 3.2.2-3 and 3.2.2-4** show the Freon-11 treatment system influent concentrations over time.

Table 3.2.2-1 shows the SPDES equivalency permit requirements for the treatment system. No effluent samples were collected during 2019 because the treatment system was maintained in standby mode until August when the Petition for Closure was approved by the regulatory agencies.

During 2019, the maximum Freon-11 influent concentration in Building 96 extraction well RTW-1 was 1.5 µg/L. Freon-11 was detected in the other Building 96 treatment well RTW-2 at concentrations up to 0.82 µg/L.

Table 3.2.2-1
Building 452 EW-18 Treatment Well
2019 SPDES Equivalency Permit Levels

Parameter	Permit Level (µg/L)	Max. Measured Value (µg/L)
pH range	5.0–8.5 SU	NS
benzene	1.0	NS
bromodichloromethane	50.0	NS
carbon tetrachloride	5.0	NS
chloroform	7.0	NS
dichlorodifluoromethane	5.0	NS
1,1-dichloroethylene	5.0	NS
4-isopropyltoluene	5.0	NS
methyl chloride	5.0	NS
methylene chloride	5.0	NS
tetrachloroethylene	5.0	NS
toluene	5.0	NS
1,2,3-trichlorobenzene	5.0	NS
1,1,1-trichloroethane	5.0	NS
trichlorofluoromethane	5.0	NS
1,2,4-trimethylbenzene	5.0	NS
xylenes (m+p)	5.0	NS

SU: Standard Units
NS: Parameter not sampled or measured

Cumulative Mass Removal

The Building 452 treatment system was not in operation during all of 2019. When the system was in operation, the average pumping rate for EW-18 was typically 50 gpm. The pumping and mass removal data for the Building 452 treatment system are summarized on **Table F-10**. While the Building 452 treatment system was in operation from March 2012 through March 2017, approximately 101 pounds of Freon-11 were removed from the aquifer. Furthermore, from December 2010 – March 2017, the Building 96 extraction well RTW-1 removed approximately 5.4 pounds of Freon-11 from the aquifer. Combined, the two treatment systems removed approximately 106 pounds of Freon-11. During 2019, Freon-11 was either not detected or at trace levels in Building 96 influent samples, therefore a mass removal calculation was not performed.

3.2.2.6 System Evaluation

The Building 452 Freon-11 Treatment System performance can be evaluated based on the decisions identified by applying the DQO process.

1. Is there a continuing source of contamination? If present, has the source area been remediated or controlled?
There is no continuing source of contamination. Freon-11 concentrations in source area monitoring wells are below the 5 µg/L AWQS.

2. Were unexpected levels or types of contamination detected?
No. Most Freon-11 concentrations are presently below the 5 µg/L AWQS.

3. Has the downgradient migration of the plume been controlled?
Yes. The Freon-11 plume has been successfully remediated by the combined operations of extraction wells EW-18 and RTW-1.

4. Can individual extraction wells or the entire treatment system be shut down or placed in pulsed pumping operation?
Yes. Building 452 treatment system operations ended following regulatory agency approval of the Petition for Closure in August 2019.   The treatment system is currently being used to treat water from Building 96 extraction well RTW-1.

5. Has the groundwater cleanup goal of meeting MCLs been achieved?
The 5 µg/L MCL for Freon-11 has been achieved in the source area and in most downgradient areas. Remaining Freon-11 is expected be captured by the Building 96 treatment system or to decrease to less than the MCL via natural attenuation.

3.2.2.7 Recommendations

The following are recommendations for the Building 452 Freon-11 extraction well EW-18 and monitoring wells:

- The monitoring program for the Building 452 treatment system has concluded. Incorporate monitoring wells 085-386 and 095-313 into the Building 96 monitoring program.
- Postpone decisions to abandon extraction well EW-18 and the remaining monitoring wells until the PFAS plume originating from the former firehouse area has been fully characterized.

3.2.3 Middle Road Treatment System

The Middle Road Treatment System began operating in October 2001. This section summarizes the operational data from the Middle Road System for 2019 and presents conclusions and recommendations for future operation. The analytical data from the monitoring wells are also evaluated in detail.

3.2.3.1 System Description

The Middle Road Treatment System has seven extraction wells and air-stripping treatment to remove VOCs from the groundwater. The system is currently operating utilizing wells RW-2, RW-3, and RW-7. A complete description of the system is included in the *Operation and Maintenance Manual for the OU III Middle Road and South Boundary Groundwater Treatment Systems, Revision 2* (BNL 2014a).

3.2.3.2 Groundwater Monitoring

The Middle Road Monitoring Program consists of a network of 33 monitoring wells located between Weaver Drive and the OU III South Boundary Pump and Treat System (**Figure 1-2**). The locations of these wells are shown on **Figure 3.2.3-1**. The 33 Middle Road wells are sampled and analyzed for VOCs (**Table 1-5**).

3.2.3.3 Monitoring Well Results

The complete VOC results are provided in **Appendix C**. The highest plume concentrations are found in the area between extraction wells RW-7 and RW-2 (**Figure 3.2.3-1**). TVOC concentrations in monitoring wells east of RW-2 are well below the 50 µg/L capture goal for this system. The highest TVOC concentration in Middle Road monitoring wells during 2019 was 330 µg/L in well 105-68 during the April sampling round. This monitoring well is located approximately 500 feet north of extraction well RW-7.

Figure 3.2.3-2 shows the vertical distribution of contamination running along an east–west line through the extraction wells; the location of this cross section (E–E') is shown on **Figure 3.2.3-1**. VOC contamination in the western portion of the remediation area (RW-7 through RW-3) extends to the deep Upper Glacial aquifer/shallow portions of the Magothy aquifer. **Figure 3.2.3-3** shows plots of the VOC concentrations versus time for key monitoring wells associated with the Middle Road Treatment System. Results for key monitoring wells are as follows:

- Plume core well 104-37 (screened in the deep Upper Glacial aquifer) is approximately 2,000 feet upgradient of RW-7, just south of Princeton Avenue. The TVOC concentration in April 2019 for this well was 98 µg/L. TVOC concentrations in this well were much higher historically, followed by a significant decline. They have remained at its current level for the past few years.
- Well 105-68 was installed approximately 500 feet north of the extraction well RW-7 in 2013. This well contains elevated TVOC concentrations with the highest concentration in 2019 of 330 µg/L in April 2019. The data from this location along with data from monitoring wells 104-37 and 121-49 indicate that there is a zone of VOC contamination, primarily PCE and carbon tetrachloride, in the deep Upper Glacial aquifer extending from Princeton Avenue to the Middle Road and then south of RW-7 to the South Boundary (**Figure 3.2.3-1** and **Figure 3.2.3-4**).
- Plume core monitoring wells 105-66 and 105-67 continued to show elevated TVOC concentrations in 2019 with maximum values in April of 215 µg/L and 76 µg/L, respectively.
- TVOC concentrations in monitoring wells in the vicinity of extraction wells RW-4, RW-5, and RW-6 were below the system capture goal of 50 µg/L in 2019.
- Wells 095-322 and 095-323 were installed along Weaver Drive in 2014 (**Figure 3.2.3-1**). These wells were installed to monitor VOCs in the deep Upper Glacial aquifer. Well 095-323 had a

TVOC concentration of 23 µg/L in February 2019 and well 095-322 had a TVOC concentration of 43 µg/L in February 2019.

- Trends for the majority of the monitoring wells within the Middle Road network continue to show a decrease in overall TVOC concentrations.

3.2.3.4 System Operations

The effluent sampling parameters for pH and VOCs follow the requirements for monthly sampling, as per the SPDES equivalency permit (**Table 3.2.3-1**). The effluent concentrations from the treatment system during this period of operation were below equivalency permit levels. Approximately 164 million gallons of water were treated in 2019 by the Middle Road Treatment System.

The following is a summary of the Middle Road System operations for 2019.

January – September 2019

The system operated normally with RW-2, RW-3 and RW-7 operating full time, and RW-1, RW-4, RW-5 and RW-6 in standby mode. RW-7 was down for a week in January and a week in February to repair the drop pipe. In March well RW-7 was shut down for ten days for repairs and adjustments, and RW-2, and RW-3 were off for five days for pipe maintenance. In September the system was down for five days for maintenance. Approximately 128.5 million gallons of water were treated.

October – December 2019

The system was operational for the fourth quarter. The effluent sample was taken from the sample port of the operational air stripper tower for each sampling event. During the fourth quarter the system pumped and treated approximately 35.5 million gallons of water.

Table 3.2.3-1.
Middle Road Air Stripping Tower
2019 SPDES Equivalency Permit Levels

Parameters	Permit Limit (µg/L)	Max. Observed Value (µg/L)
pH range (SU)	6.5–8.5	6.9 – 7.5
carbon tetrachloride	5	<0.5
chloroform	7	<0.5
dichlorodifluoromethane	5	<0.5
1,1-dichloroethane	5	<0.5
1,1-dichloroethylene	5	<0.5
methyl chloride	5	<0.5
tetrachloroethylene	5	<0.5
toluene	5	<0.5
1,1,1-trichloroethane	5	<0.5
1,1,2-trichloroethane	5	<0.5
trichloroethylene	10	<0.5

Notes: SU = Standard Units
Required sampling frequency is monthly for VOCs and pH.

3.2.3.5 System Operational Data

System Influent and Effluent

Figure 3.2.3-6 plots the TVOC concentrations in the extraction wells versus time. Results of the extraction well samples are found on **Table F-11.** The influent VOC concentrations showed slight variations over the reporting period. The average TVOC concentration in the influent during 2019 was 20 µg/L. The results of the influent and effluent sampling are summarized on **Tables F-12** and **F-13**, respectively.

Cumulative Mass Removal

Mass balance was calculated for the period of operation to determine the mass removed from the aquifer by the extraction wells. Average flow rates for each monthly monitoring period were used, in combination with the TVOC concentration in the air-stripper influent, to determine the pounds removed. Flow averaged 316 gpm during 2019 (**Table 3.2.3-3**, and **Table F-14**), and approximately 25 pounds of VOCs were removed. Approximately 1,289 pounds of VOCs have been removed since the system began operations in October 2001. The cumulative total of VOCs removed vs. time is plotted on **Figure 3.2.3-5.**

Air Discharge

Table 3.2.3-2 shows the air emissions data from the system for the OU III Middle Road air stripper tower during 2019 and compares the values to levels stipulated in NYSDEC DAR-1 regulations. Emission rates are obtained through mass-balance calculations for the water treated during that time (**Table F-12**). The concentration of each constituent was averaged for 2019, and those values were used in determining the emissions rate. The air emissions for the Middle Road System were below permitted limits.

Extraction Wells

The system is currently operating utilizing wells RW-2, RW-3, and RW-7. Extraction wells RW-4 and RW-5 were shut down in September 2003 and placed on standby due to low concentrations of VOCs. RW-6 was shut down in September 2006. Well RW-1 was shut down in November 2015. The extraction wells are sampled quarterly. TVOC concentrations in wells RW-1, RW-4, RW-5 and RW-6 are all below the capture goal of 50 µg/L in 2019 with a maximum concentration of 14.6 µg/L in well RW-1 in January. The maximum concentration observed in the operating wells in 2019 was in well RW-7 with a peak TVOC concentration of 45 µg/L in April. See **Figure 3.2.3-6** for a plot of the TVOC concentrations for the seven extraction wells. **Table 3.2.3-3** shows the monthly extraction well pumping rates.

Table 3.2.3-2.
Middle Road Air Stripper
2019 Average VOC Emission Rates

Parameter	Allowable ERP* (lb/hr)	Actual** (lb/hr)
carbon tetrachloride	0.022	0.0002
chloroform	0.0031	0
1,1-dichloroethane	10***	0
1,2-dichloroethane	0.008	0
1,1-dichloroethylene	0.034	0
cis-1,2-dichloroethylene	10***	0
trans-1,2-dichloroethylene	10***	0
tetrachloroethylene	0.387	0.0026
1,1,1-trichloroethane	10***	0.0001
trichloroethylene	0.143	0.0001

Notes:
ERP = Emission Rate Potential. Reported in lb/hr.
*ERP based on NYSDEC DAR-1 Regulations.
** Rate reported is the average rate for the year.
*** 6 NYCRR Part 212 restricts emissions of VOCs to a maximum of 10 lb/hr without controls.

3.2.3.6 System Evaluation

The Middle Road Treatment System performance can be evaluated based on the decisions identified for this system from the groundwater DQO process.

1. Is there a continuing source of contamination? If present, has the source area been remediated or controlled?

The known source areas for contamination at the Middle Road are the Building 96 area and the former carbon tetrachloride source area and they have been remediated or controlled. The elevated VOC concentrations in monitoring well 104-37 (that is screened in the deep Upper Glacial aquifer) are of concern and could indicate that contaminant migration is slower than originally predicted in the Upton Unit.

2. Has the downgradient migration of the plume been controlled?

Yes, the plume in the deep Upper Glacial aquifer is being captured by extraction wells RW-2, RW-3 and RW-7. The VOCs that have migrated past Middle Road prior to the installation of RW-7 will be captured by the South Boundary Treatment System.

3. Can individual extraction wells or the entire treatment system be shut down or placed in pulsed pumping operation?

Extraction wells RW-1, RW-4, RW-5 and RW-6 have been in standby. Low TVOC concentrations below the 50 µg/L capture goal continued to be observed in the vicinity of these wells. Extraction wells RW-2, RW-3 and RW-7 will continue operating.

3a. Are TVOC concentrations in plume core wells above or below 50 µg/L?

Seven plume core wells have TVOC concentrations above the capture goal of 50 µg/L.

3b. Is there a significant concentration rebound in core wells and/or extraction wells following shutdown?

There has been no rebound in the extraction wells that are shut down and no rebound in the monitoring wells in this area.

4. Has the groundwater cleanup goal of meeting MCLs been achieved?

No. The cleanup goals have not been achieved.

3.2.3.7 Recommendations

The following recommendations are made for the Middle Road Treatment System and groundwater monitoring program:

- Maintain extraction wells RW-1, RW-4, RW-5 and RW-6 in standby mode. Restart the well(s) if extraction or monitoring well data indicate that TVOC concentrations exceed the 50 µg/L capture goal.
- Continue operation of RW-2, RW-3 and RW-7.

3.2.4 OU III South Boundary Treatment System

This section summarizes the operational data from the South Boundary Treatment System for 2019, and provides conclusions and recommendations for future operation. Also included within this section is an evaluation of the extraction and monitoring well sampling data.

3.2.4.1 System Description

This system began operation in June 1997. It utilizes air-stripping technology for treatment of groundwater contaminated with chlorinated solvents. There are eight extraction wells. The system is currently operating utilizing two extraction wells. The system is currently operating with wells EW-4 and EW-17. EW-4 was placed into a pulsed pumping mode in October 2017. The remainder of the wells are in standby mode. A complete description of the system is included in the *Operation and Maintenance Manual for the OU III Middle Road and South Boundary Groundwater Treatment Systems, Revision 2* (BNL 2014a).

3.2.4.2 Groundwater Monitoring

The OU III South Boundary monitoring well network consists of a total of 45 monitoring wells and was designed to monitor the VOC plume(s) in this area of the southern site boundary, as well as the efficiency of the groundwater remediation system (**Figure 3.2.4-1**). During 2019, 36 South Boundary wells were sampled and analyzed for VOCs and 31 wells were analyzed for radionuclides at frequencies detailed on **Table 1-5**. The OU III South Boundary wells that were analyzed for radionuclides are detailed in **Section 3.2.13**.

3.2.4.3 Monitoring Well Results

The South Boundary segment of the OU III VOC plume continued to be bounded by the existing monitoring well network. VOCs were detected in the deep Upper Glacial aquifer in the vicinity of the site boundary, as depicted on **Figure 3.2-2, Figure 3.2.3-4, Figure 3.2.4-1,** and **Figure 3.2.4-2.** As discussed in **Section 3.2.13** there continues to be no radionuclides detected in this area. **Appendix C** has the complete groundwater monitoring well results for 2019.

The plume core wells continued to show a trend of decreasing VOC concentrations. Elevated VOC concentrations remain in the deep Upper Glacial aquifer upgradient of wells EW-4 and EW-17, as can be seen on **Figure 3.2.4-2**, which is a cross section (G–G') drawn along the south boundary. The VOC concentration trends for specific key wells are shown on **Figure 3.2.3-3**. Results for key monitoring wells are as follows:

- Bypass detection well 121-43, located several hundred feet south of extraction wells EW-4 and EW-17, historically had shown **e**levated levels of VOCs. Extraction well EW-17 was installed to address the historical high VOC concentrations that had been observed in well 121-43 (**Figure 3.2.4-1**) and cut off the deeper portion of the VOC plume at the boundary. EW-17 began operations in July 2012. In April 2011 the TVOC concentration in well 121-43 was 338 µg/L and has declined to 1.1 µg/L in November 2019.
- Three monitoring wells are used to monitor the performance of extraction well EW-17. They are 121-47 a western plume perimeter well, 121-48 an eastern plume perimeter well, and 121-49 located upgradient of this extraction well. The upgradient monitoring well 121-49 showed elevated TVOC concentrations in 2019 with the highest concentration in April of 267 µg/L. However, TVOC concentrations show an overall decreasing trend from 740 µg/L in 2017 to 140 µg/L in November 2019 (**Figure 3.2.3-3**).
- Monitoring well 121-45 was installed to monitor the plume between the Middle Road and South Boundary. TVOC concentrations were at 8.3 µg/L in November. This is a significant reduction from the initial concentration of 613 µg/L in 2006 (**Figure 3.2.3-3**).

- Well 121-54 was installed in 2014 to monitor VOC concentrations upgradient of extraction well EW-17. This well had TVOC concentrations of up to 188 µg/L in November 2019. Well 121-53 was also installed upgradient of EW-17 and it showed a peak TVOC concentration of 83 µg/L in February.
- Well 122-05 is a Magothy monitoring well west of EW-8. TVOC concentrations in this well showed a slight increase to 26 µg/L in 2018 and since dropped to a concentration of 11 µg/L in November 2019.

3.2.4.4 System Operations

The individual extraction wells are sampled quarterly and analyzed for VOCs. The effluent sampling parameters of pH and VOCs are obtained monthly, in accordance with SPDES equivalency permit requirements (**Table 3.2.4-1**). In addition, samples are analyzed for tritium with each system-sampling event. Tritium from these samples continues to be non-detect. Effluent VOC concentrations from the treatment system during this period of operation were below equivalency permit requirements. In 2019, approximately 87 million gallons of water were treated by the South Boundary System. Well EW-12 has not been sampled since April 2012. This is because the installation of well EW-17 utilized some of the equipment from this well. In the unlikely event this well is needed, a modification could be made to make this well operational. This determination will be made based on the monitoring well data in the vicinity of EW-12. The following is a summary of the South Boundary System operations for 2019.

Table 3.2.4-1.
OU III South Boundary Air Stripping Tower
2019 SPDES Equivalency Permit Levels

Parameters	Permit Limit* (µg/L)	Max. Observed Value (µg/L)
pH range (SU)	6.5 – 8.5	6.9–7.5
carbon tetrachloride	5	<0.5
chloroform	7	<0.5
dichlorodifluoromethane	5	<0.5
1,1-dichloroethane	5	<0.5
1,1-dichloroethylene	5	<0.5
methyl chloride	5	<0.5
tetrachloroethylene	5	<0.5
toluene	5	<0.5
1,1,1-trichloroethane	5	<0.5
1,1,2-trichloroethane	5	<0.5
trichloroethylene	10	<0.5

Notes:

*Maximum allowed by requirements equivalent to a SPDES permit. Required sampling frequency is monthly for VOCs and pH.

SU – Standard units.

January – September 2019

Approximately 65 million gallons of water were pumped and treated. In February, extraction well EW-4 was pulsed pumped and continued through the year with a one month on, one-month off schedule. In June EW-17 was off for three weeks for maintenance and replace a faulty flow meter. In July the pump and motor were replaced and EW-17 was off for the month. In September, the EW-4 was off for 10 days for electrical repair.

October – December 2019

In November the system was down for 10 days for maintenance. The OU III South Boundary System pumped and treated approximately 22 million gallons of water.

3.2.4.5 System Operational Data

System Influent and Effluent

Figures 3.2.4-3 and 3.2.4-4 plot the TVOC concentrations in the extraction wells versus time. The overall influent water quality and the individual extraction wells show a declining trend in concentrations. System influent and effluent sampling results are summarized on **Tables F-16** and **F-17**, respectively.

Cumulative Mass Removal

Average flow rates for each monthly monitoring period were used, in combination with the TVOC concentration in the air-stripper influent, to calculate the mass removal (**Table F-18**). The cumulative total of VOCs removed by the treatment system versus time is plotted on **Figure 3.2.4-5**. The 2019 total was approximately 6 pounds. Cumulatively, the system has removed approximately 3,055 pounds since it was started in June 1997.

Air Discharge

Table 3.2.4-2 shows the air emissions data from the OU III South Boundary system for 2019, and compares the values to levels stipulated in NYSDEC DAR-1 regulations. Emission rates are obtained through mass-balance calculations for water treated during that time (**Table F-16**). The concentration of each constituent was averaged for the year, and that value was used in the calculation. System air emissions were below allowable levels.

Table 3.2.4-2.
OU III South Boundary Air Stripper
2019 Average VOC Emission Rates

Parameter	Allowable ERP*	Actual** ER
carbon tetrachloride	0.022	0.0001
chloroform	0.0031	0
1,1-dichloroethane	10***	0
1,2-dichloroethane	0.008	0
1,1-dichloroethylene	0.034	0
cis-1,2-dichloroethylene	10***	0
trans-1,2-dichloroethylene	10***	0
tetrachloroethylene	0.387	0.0006
1,1,1-trichloroethane	10***	0.0001
trichloroethylene	0.143	0

Notes:
ERP = Emissions Rate Potential, stated in lb/hr.
* ERP is based on NYSDEC DAR-1 Regulations.
** Actual emission rate reported is the average for the year.
*** 6 NYCRR Part 212 restricts emissions of VOCs to a maximum of 10 lb/hr without controls.

Extraction Wells

There are two extraction wells currently operating. Well EW-4 continued to show slowly decreasing TVOC concentrations in 2019 from 8.4 µg/L in July to 1.2 µg/L in October. EW-17 showed TVOC concentrations ranging from 15.3 µg/L in January to 17.5 µg/L in October. This well is located slightly downgradient and deeper than well EW-4. EW-4 was placed into a pulsed pumping mode in October 2017. **Table F-15** summarizes the data for the extraction wells. **Table 3.2.4-3** shows the monthly extraction well pumping rates. The system averaged 168 gpm in 2019.

3.2.4.6 System Evaluation

The OU III South Boundary Treatment System performance can be evaluated based on the major decisions identified for this system resulting from the groundwater DQO process.

1. Were unexpected levels or types of contamination detected?
No. Unexpected concentrations were not detected.

2. Has the downgradient migration of the plume been controlled?
Yes, extraction well EW-17 is capturing the higher concentrations that were migrating beneath well EW-4. This has resulted in reduced VOC concentrations in bypass well 121-43 (**Figure 3.2.4-1**). Western plume perimeter well 121-08 had a TVOC concentration of 2.44 µg/L in November. Eastern perimeter well 114-07 has been non-detect since early 2018. Individual VOC concentrations in the remaining plume perimeter wells were less than 5 µg/L in the fourth quarter of 2019.

3. Can individual extraction wells or the entire treatment system be shut down or placed in pulsed pumping operation?
Six of the eight extraction wells have been shut down as they have achieved the capture goal for this system. The two wells will continue to operate to capture VOCs in this area. Well EW-4 will continue

to be pulsed pumped one month on and one month off. Well EW-17 continues to operate on a full-time basis.

4. Are TVOC concentrations in plume core wells above or below 50 µg/L?
There are still three upgradient plume core wells with persistent TVOC concentrations above 50 µg/L in the capture zones of wells EW-4 and EW-17.

5. Is there a significant concentration rebound in core wells and/or extraction wells following shutdown?
A significant concentration rebound has not been observed in the monitoring or extraction wells in the eastern segment of this system. Two of the western extraction wells are still operating.

6. Has the groundwater cleanup goal of meeting MCLs been achieved?
No, MCLs have not been achieved to date.

3.2.4.7 Recommendations

The following are recommendations for the OU III South Boundary Treatment System and groundwater monitoring program:

- Maintain wells EW-3, EW-5, EW-6, EW-7, EW-8, and EW-12 in standby mode. The system's extraction wells will continue to be sampled on a quarterly basis, with the exception of EW-12. The wells will be restarted if extraction or monitoring well data indicate TVOC concentrations exceed the 50 µg/L capture goal.
- Continue to operate well EW-17 on a full-time basis. Continue pulsed pumping of well EW-4 one month on and one month off.
- Reduce sample frequency of wells 114-06, 114-07, 121-20, 121-23, 122-09 and 122-22 for VOCs from semi-annually to annually. TVOC concentrations in these wells have been non-detect to barely detectable for the past six years.

3.2.5 Western South Boundary Treatment System

The Western South Boundary Treatment System was designed to capture VOCs in the Upper Glacial aquifer along portions of the BNL western south boundary. The capture goal for the system is TVOC concentrations exceeding 20 µg/L. The system was designed to reduce additional off-site migration of the contamination, and potential impacts of the VOC plume to the Carmans River. The system began operating in September 2002 and was changed to pulsed pumping mode in late 2005, one month on and two months off. Based on increasing VOC concentrations in an upgradient monitoring well, extraction well WSB-1 was put back into full-time operation starting in November 2008. Extraction well WSB-2 was placed in standby in October 2016. During 2018 four new extraction wells were added to this system. They began operations in March 2019. Details are provided below on the new wells.

3.2.5.1 System Description

A complete description of the Western South Boundary (WSB) Treatment System is contained in the *Operations and Maintenance Manual for the Western South Boundary Treatment System, Rev. 3* (BNL 2020e). A modification to this system to add four new extraction wells was undertaken beginning in June 2018 (see BNL 2018d) and was completed in March 2019. The four new wells and the two existing wells were connected to the Middle Road/South Boundary Treatment System. A schematic of the new well configuration and piping is included as **Figure 3.2.5-7.** The existing Western South Boundary air stripper will no longer be needed and will be decommissioned in the future. The Western South Boundary extraction well effluent water discharge will now be monitored under the Middle Road and South Boundary Treatment System SPDES Equivalency permit. The new wells began startup testing in March 2019 and began full time operation in April 2019.

3.2.5.2 Groundwater Monitoring

A network of 35 wells is used to monitor this plume. The well locations are shown on **Figure 3.2.5-1**. A total of 21 temporary vertical profile wells and 17 monitoring wells were installed from late 2016 through 2018 to characterize and monitor the extent of deeper VOC contamination in the WSB plume area. The wells are sampled at the O&M phase frequency (**Table 1-5** for details).

The primary VOCs associated with this plume are dichlorodifluoromethane (Freon-12), TCA, and DCE. These VOCs were first observed in vertical profile wells installed throughout the WSB area in the late 1990s as part of the OU III RI/FS. TVOC concentrations ranging from 20 µg/L to 40 µg/L were encountered at depths between 120-170 ft bls throughout the area at that time.

Monitoring of this plume has identified several specific areas of higher VOC concentrations than were observed during the RI/FS. An area of VOC concentrations higher than previously seen (up to 170 µg/L TVOC concentrations) was characterized beginning in 2008, from the Middle Road area south to WSB-1 at the south boundary. This plume segment of higher concentrations was primarily focused at depths between 130 and 150 feet bls. During 2008 and 2009 an area of Freon-12, with concentrations up to 55 µg/L, was characterized in the deep Upper Glacial aquifer at depths of 180-200 feet bls approximately 800 feet south of Princeton Avenue.

During characterization efforts in 2016-2017 to define the southern extent of the deeper Freon-12, a zone of high VOC concentrations was encountered with most of the plume at slightly greater depths than previously seen in this area (140-210 feet bls). The primary VOCs were TCA and DCE, although Freon-12 was observed at concentrations up to 69 µg/L. A total of 21 temporary vertical profile wells were installed from 2016 through the end of 2018 to characterize these VOCs and a total of 17 new monitoring wells were installed.

3.2.5.3 Monitoring Well Results

Figure 3.2.5-1 presents fourth quarter 2019 monitoring well concentrations. **Figure 3.2.5-2** provides a north-south cross section (H- H') of the plume. **Figure 3.2.5-6** provides an east-west cross section (H1-H1') along the site boundary and **Figure 3.2.5-3** provides trend graphs for key monitoring wells. **Section 3.10 and 3.11** discuss PFAS and 1,4 Dioxane results from monitoring wells located in the Western South Boundary. A summary of key monitoring well data for 2019 follows:

- Based on the monitoring well and characterization data, the areas of higher TCA and DCE concentrations are slugs of contamination that may have originated from periodic releases. The deeper zones of elevated Freon-12 are even more isolated. **Figure 3.2.5-2** is a vertical cross section from north to south that depicts the data collected. It clearly shows this area of deeper VOC contamination at the Western South Boundary, with some areas of contamination below the Gardiners Clay.
- **Figure 3.2.5-6** shows an east west cross section near the BNL site boundary. This figure shows that the higher concentrations are slightly deeper than the original extraction well WSB-1 and further to the west.
- Well 126-20 had a peak TVOC concentration in 2019 of 84 µg/l in August. This is a significant reduction from the 2018 peak of 150 µg/l. These contaminants are expected to be captured by the extraction wells WSB-5 and WSB-6.
- Upgradient monitoring wells 103-18 and 103-19 located near Princeton Avenue showed low TVOC concentrations during 2019 with a peak concentration of 16 µg/L in April in well 103-18.
- Monitoring well 126-18 is located upgradient of extraction wells WSB-5 and WSB-6. It is screened at a depth similar to well WSB-5, the shallower of the two extraction wells. TVOC concentrations in this well were 106 µg/L in November. This is a significant reduction from last year when the peak concentration was 203 µg/L.
- Downgradient monitoring wells 130-09, 130-10 and 130-11 located south of extraction wells WSB-5 and WSB-6 showed a maximum TVOC concentration of 42.4 µg/L in well 130-10 in March, however subsequent sampling in November showed concentrations were not detectable in this well. This reduction is likely due to the start of pumping in March 2019. Well 130-11 had a concentration of 16.6 µg/L in November.
- The area of higher TCA and DCE concentrations that was identified in 2008-2009, extending at that time from well 119-06 at the Middle Road south to WSB-1, has now decreased to a small area in the vicinity of WSB-1. VOC concentrations in wells 119-06 and 126-17 are now below AWQS. The plume segment has migrated towards WSB-1 as shown on **Figure 3.2.5-1**.
- TVOC concentrations in well 126-14 ranged between 94 µg/L and 140 µg/L in 2019. This well is approximately 200 feet north of WSB-1. The well is showing a downward trend from a peak concentration in 2018 of 170 µg/L to 70 µg/L in January 2020.
- Three off-site monitoring wells located on the west end of Carleton Drive and are identified as 000-558, 000-559, 000-560. The maximum TVOC concentration in these wells was 18.6 µg/L in well 000-558 in January. No individual VOCs exceeded the AWQS in 2019 in any of these wells. These wells are intended to monitor the leading edge of the plume.

3.2.5.4 System Operations

During 2019 the extraction wells were sampled weekly during start up testing which began on March 25th and the influent and effluent of the air stripping tower were sampled daily for the first five days. Extraction well WSB-1 continued full-time operation in March once the system was restarted after construction was completed. Extraction well WSB-2 continued in standby mode in 2019 based on the TVOC concentrations being below the capture goal of 20 µg/L. The newly installed extraction wells WSB-3, WSB-4, WSB-5, and WSB-6 continued full-time operation through most of 2019 after startup testing was completed. System samples were collected, and extraction wells were sampled weekly and analyzed for VOCs for the first month of operation. In addition, the effluent was analyzed for pH weekly in April and then twice a month until November. **Table 3.2.5-1** provides the effluent limitations for meeting the requirements of the SPDES equivalency permit. The Western South Boundary is now operating under the same SPDES equivalency permit as the Middle Road and South Boundary projects. The system's effluent discharges met the SPDES equivalency permit requirements during 2019. The system operations are summarized below.

January – September 2019

Extraction well WSB-1 was restarted beginning March 25, 2019 after the completion of the construction activities related to the four new extraction wells. The WSB-2 extraction well remained in standby mode. Construction was completed on March 25th and startup testing on the four new wells EW-3, EW-4, EW-5, and EW-6 began. In July the system was down for one week for maintenance. In August the system was off for two weeks for programming updates. In September the system was off for 10 days for maintenance. During the first three quarters, the system treated approximately 92 million gallons of water.

October – December 2019

The system operated normally for the majority of the fourth quarter. WSB-1, WSB-3, WSB-4, WSB-5, WSB-6 remained in operation, and WSB-2 remained in standby mode. The system treated approximately 51 million gallons of water.

Table 3.2.5-1
Western South Boundary Treatment System (South Boundary and Middle Road) 2019 SPDES Equivalency Permit Levels

Parameter	Permit Level (µg/L)	Max. Measured Value (µg/L)
pH range	6.5–8.5 SU	6.8-7.5 SU
carbon tetrachloride	5	<0.5
chloroform	7	<0.5
dichlorodifluoromethane	5	<0.5
1,1-dichloroethane	5	<0.5
1,1-dichloroethylene	5	<0.5
methyl chloride	5	<0.5
tetrachloroethylene	5	<0.5
toluene	5	<0.5
1,1,1-trichloroethane	5	<0.5
1,1,2-trichloroethane	5	<0.5
trichloroethylene	10	<0.5

Note:

Required effluent sampling frequency is monthly for VOCs and monthly for pH.

SU = Standard units

3.2.5.5 System Operational Data

Extraction Wells

During 2019, the Western South Boundary System treated approximately 143 million gallons of water, with an average flow rate of approximately 276 gpm. **Table 2-2** gives monthly pumping data for the six extraction wells. **Table 3.2.5-2** shows the monthly extraction well pumping rates. VOC concentrations for extraction wells WSB-1, WSB-2, WSB-3, WSB-4, WSB-5, WSB-6 are provided in **Table F-19**. TVOC concentrations for extraction wells WSB-1 and WSB-2 have remained below the capture goal of 20 µg/L since 2006. TVOC concentrations for extraction wells WSB-3, WSB-4, WSB-5, WSB-6 showed a maximum concentration in well WSB-3 of 74 µg/L. All four extraction wells show a decreasing trend since startup in March 2019 as shown on **Figure 3.2.5-4.**

System Influent and Effluent

Influent TVOC concentrations increased with the addition of the four new extraction wells to a maximum of 26 µg/L. Individual VOC concentrations were above the AWQS during the year, with a maximum TCA value of 5.3 µg/L in April 2019, and maximum DCE value of 12 µg/L in March (**Table F-20**).

The air stripping system effectively removed the contaminants from the influent groundwater. The system's effluent data were below the analytical method detection limit and below the regulatory limit specified in the equivalency permit conditions (**Table F-21**). There were no detections of tritium in the effluent in 2019.

Cumulative Mass Removal

Average flow rates for each monthly monitoring period were used, in combination with the TVOC concentration in the influent, to calculate the pounds of VOCs removed per month (**Table F-22**). The cumulative mass of VOCs removed by the treatment system is provided on **Figure 3.2.5-5**. During 2019, thirteen pounds of VOCs were removed. A total of 157 pounds have been removed since the start-up of the system in 2002.

Air Discharge

Table 3.2.5-3 presents the VOC air emission data for 2019 and compares the values to levels stipulated in NYSDEC DAR-1 regulations. Emission rates are calculated through mass balance for water treated during operation. The VOC air emissions were well below allowable levels.

Table 3.2.5-3
Western South Boundary
2019 Air Stripper VOC Emissions Data

Parameter	Allowable ERP* (lb/hr)	Actual ERP (lb/hr)
carbon tetrachloride	0.016	0
chloroform	0.0086	0.0001
1,1-dichloroethane	10**	0
1,2-dichloroethane	0.011	0
1,1-dichloroethene	0.194	0
chloroethane	10**	0
1,1,1-trichloroethane	10**	0.0005
trichloroethylene	0.119	0.0001

Notes:
ERP = Emissions Rate Potential, stated in lb/hr.
* Based on NYSDEC DAR-1 Regulations.
** 6 NYCRR Part 212 restricts emissions of VOCs to a maximum of 10 lb/hr without controls.

3.2.5.6 System Evaluation

The Western South Boundary Treatment System performance can be evaluated based on decisions identified for this system from the groundwater DQO process.

1. Were unexpected levels or types of contamination detected?
There were no unexpected levels or types of contamination.

2. Has the downgradient migration of the plume been controlled?
The four new extraction wells are addressing the migration of the recently identified deeper contamination. The bypass wells at the site boundary and sentinel monitoring wells on Carleton Drive continue to remain low indicating the leading edge of the plume is controlled.

3. Can individual extraction wells or the entire treatment system be shut down or placed in pulsed pumping operation?
The WSB extraction wells WSB-1 and WSB-2 were originally intended to target specific areas of elevated VOCs near the site boundary and were not intended to provide for complete capture of contaminants at the site boundary. WSB-2 is currently in standby mode and VOC concentrations in this area are well below the capture goal of 20 µg/L. TVOC concentrations in WSB-1 have declined to below the capture goal. However continued operation of WSB-1 is necessary to ensure the capture of the high VOC concentrations migrating south from well 126-14. The four new extraction wells began operation in late March and it is to early to evaluate their continued operation.

3a. Are TVOC concentrations in plume core wells above or below 20 µg/L?
The recent characterization has identified a large area of groundwater contamination significantly above the 20 µg/L capture goal, along with well 126-14 immediately upgradient of well WSB-1.

3b. Is there a significant concentration rebound in core wells and/or extraction wells following pulsed pumping or shutdown?
No significant rebound was observed during pulsed pumping of extraction well WSB-2 or since the placement of this well in standby.

4. Has the groundwater cleanup goal of meeting MCLs been achieved?
MCLs have not been achieved for individual VOCs in plume core wells. With the addition of the four new extraction wells, the groundwater cleanup goals are expected to be met.

3.2.5.7 Recommendations

The following are recommendations for the OU III Western South Boundary Treatment System and groundwater monitoring program:

- Continue full-time operation of extraction well WSB-1 based on elevated concentrations persisting at well 126-14.
- Based on the low TVOC concentrations below the capture goal of 20 µg/L, maintain extraction well WSB-2 in standby mode. If TVOC concentrations greater than 20 µg/L are observed in WSB-2 or the adjacent monitoring wells, extraction well WSB-2 may be put into full time operation.
- Continue operation of the four new extraction wells. With the addition of these wells the groundwater cleanup goal of meeting MCLs by 2030 are expected to be met.
- Continue the current monitoring frequency for the Western South Boundary monitoring wells as shown in **Table 1-5**.

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3.2.6 Industrial Park Groundwater Treatment System

This section summarizes the operational data from the Industrial Park Groundwater Treatment System for 2019 and presents conclusions and recommendations for its future operation. The Industrial Park system was designed to contain and remediate a portion of the OU III plume between BNL's southern boundary and the Industrial Park. **Figure 3.2.6-1** illustrates the extent of the OU III contaminant plume in the vicinity of the Industrial Park, located south of the Long Island Expressway. The primary VOCs associated with this portion of the OU III plume are TCA, PCE, and carbon tetrachloride.

The system began operation in September 1999. A Petition for Shutdown was submitted to the regulators in February 2013 (BNL, 2013a). After receiving approval from the regulators, the system was shut down in May 2013. In March 2014, wells UVB-3 through UVB-6 were returned to full time operation due to a rebound of VOC concentrations. It was again shut down in January 2017.

3.2.6.1 System Description

The original Industrial Park system consisted of a line of seven in-well air stripping treatment wells. Each treatment well is constructed with two well screens separated by an inflatable packer. Contaminated groundwater is withdrawn from the aquifer via submersible pump through a lower screen (extraction) set at the base of the treatment well. The groundwater is pumped to a stripping tray located in a below ground vault over the wellhead. After passing through the stripping tray, treated groundwater flows back down the well and is recharged to a shallower portion of the aquifer through an upper screen (recharge). Some of the treated groundwater that is recharged through the upper screen recirculates through the cell and is drawn back into the extraction screen for further treatment, while the balance flows in the direction of regional groundwater flow.

A closed-loop air system through a single blower keeps the vault under a partial vacuum. The vacuum draws air from below the stripping tray as contaminated groundwater is discharged on top. VOCs are transferred from the liquid phase to the vapor phase as contaminated groundwater passes through the stripping tray. The contaminated air stream is carried from the vault to a treatment and control building, where it is passed through two GAC units in series to remove the VOCs. Treated air is then recirculated back to the wellhead. The carbon units, system blower, and system control panel are all housed in a one-story masonry treatment building. A complete description of the system is included in the *Operations and Maintenance Manual for the OU III Offsite Removal Action* (BNL 2000b).

In 2014 a modification to the Industrial Park System was initiated which included the installation of two new groundwater extraction wells. They are shown on **Figure 3.2.6-1** as IP-EW-8 and IP-EW-9. These wells became operational in January 2015. The wells are screened deeper than the adjacent UVB wells to capture deeper VOC contamination identified just upgradient of this area (**Figure 3.2-2**). These wells are utilizing liquid phase carbon to treat the water rather than in-well air stripping. A complete description of the Industrial Park Modification is included in the *Operations and Maintenance Manual for the OU III Modification to the Industrial Park Groundwater Treatment System* (BNL 2015a).

3.2.6.2 Groundwater Monitoring

Well Network

The monitoring well network consists of 48 wells and is designed to monitor the VOCs in the vicinity of the Industrial Park, and the effectiveness of the groundwater treatment system.

Sampling Frequency and Analysis

Wells are sampled for VOCs as per the schedule in **Table 1-5**.

3.2.6.3 Monitoring Well Results

The complete analytical results are included in **Appendix C**. VOC concentrations in the plume perimeter wells that monitor the width of the plume remained below AWQS during 2019. Based on these data, the plume is effectively bounded by the current well network. **Figure 3.2.6-1** shows the plume distribution based on fourth quarter 2019 data. The vertical extent of contamination is shown on **Figure 3.2.6-2**. The location of this cross section (I–I') is illustrated on **3.2.6-1**. Concentration trend graphs for key monitoring wells are shown on **Figure 3.2.6-3.** Significant findings for 2019 include:

Plume Core Wells

- TVOC concentrations in wells 127-08, 127-09, 000-537, and 000-538 located in the northern portion of the industrial park, continued to show stable or slowly decreasing trends, but the higher concentrations detected in 2015 (up to 266 µg/L) have migrated beyond this area. The highest concentration detected in 2019 was 58 µg/L in well 000-537 in March. These wells are monitoring the trailing edge of a deeper VOC slug of contamination originally characterized in 2013, which is located between the Long Island Expressway (LIE) and the Industrial Park Treatment System recirculation well array.
- Well 000-548, installed in 2015 to supplement the monitoring of the deeper VOCs, is located between well 000-528 and extraction well IP-EW-9. TVOC concentrations in this well where detected up to 30 µg/L in 2019.
- Well 000-529 is located 300 feet south of 000-548. TVOC concentrations in this well ranged up to 28 µg/L in 2019.
- Well 000-541 located upgradient of IPE-EW-9 showed TVOC concentrations ranging from 12 µg/L to 40 µg/L in 2019.

Plume Bypass Wells

- Wells 000-432 and 000-544 provide bypass monitoring points downgradient of extraction wells IP-EW-8 and IP-EW-9, respectively. TVOC concentrations have been slightly above detectable levels in 000-432 over the past several years. TVOC concentrations in well 000-544 ranged between 13 µg/L and 31 µg/L in 2019.

3.2.6.4 System Operations

In 2019, wells UVB-1 through UVB-7 remained in standby mode. Wells IP-EW-8 and IP-EW-9 which were in a one month on, one month off pulsed pumping mode were put into standby mode July 2019 as concentrations dropped below the capture goal of 50 µg/L in the extraction and core monitoring wells. These wells pumped a total of approximately 30 million gallons of water in 2019.

Operating Parameters

Water samples were obtained monthly when the system was operating from each of the seven recirculation wells before air stripping in each UVB tray and then after treatment. Influent samples from these wells are obtained on a quarterly basis during shutdown. Samples are obtained quarterly from IP-EW-8 and IP-EW-9. The samples are analyzed for VOCs. These sample results are used to determine the systems removal efficiency and performance. Based on these results, operational adjustments are made to optimize system performance.

System Operations

System extraction well pumping rates are included on **Table 3.2.6-1**. Extraction wells IP-EW-8 and IP-EW-9 operate under a SPDES Equivalency Permit (**Table 3.2.6-2).** The system is sampled on a monthly basis for VOCs and weekly for pH. Effluent VOC concentrations from the treatment system during this period of operation were below equivalency permit requirements. The following summarizes the system operations for 2019:

January – September 2019
Wells UVB-1 through UVB-7 remained in stand-by mode. Wells IP-EW-8 and IP-EW-9 were pulsed pumped until placed in standby during July. The system treated a total of approximately 30 million gallons of water during this period.

October – December 2019
Wells UVB-1 through UVB-7 and wells IP-EW-8 and IP-EW-9 remained in standby.

Table 3.2.6.2
OU III Industrial Park Treatment System
2019 SPDES Equivalency Permit Levels

Parameters	Permit Limit (µg/L)	Max. Measured Value (µg/L)
pH (range)	5.0 – 8.5 SU	5.5 – 7.0 SU
carbon tetrachloride	5.0	<0.50
chloroform	7.0	<0.50
1,1-dichloroethylene	5.0	<0.50
1,2-dichloroethane	5.0	<0.50
tetrachloroethylene	5.0	<0.50
1,1,1-trichloroethane	5.0	<0.50
trichloroethene	5.0	<0.50

Notes:
Required sampling frequency is monthly for VOCs and weekly for pH.
SU = Standard Units

3.2.6.5 System Operational Data

Well Influent and Effluent
During 2019, influent TVOC concentrations in the treatment system wells were below the capture goal of 50 µg/L (**Figure 3.2.6-4**). The effluent and influent concentrations are shown on **Figure 3.2.6-5 and Table F-26**. The removal efficiencies for the air strippers in the extraction wells UVB-1 through UVB-7 for 2019 where not calculated since the wells are not operating. Historical data is shown in **Table F-23**.

Cumulative Mass Removal
Calculations were performed to determine the VOC mass removed from the aquifer by the remediation wells during the year. The average estimated flow rates for each monthly monitoring period were used, in combination with the influent and effluent TVOC concentrations. **Table F-24** summarizes these data. During 2019, flow averaged approximately 224 gpm with only wells IP-EW-8 and IP-EW-9 operating. **Figure 3.2.6-6** plots the total pounds of VOCs removed by the treatment system vs. time. During 2019, approximately 0.5 pounds of VOCs were removed from the aquifer, with a total of 1,076 pounds of VOCs removed since 1999.

Air Treatment System
Air samples were not collected as UVB-1 to UVB-7 were in stand-by mode (**Table F-25**).

3.2.6.6 System Evaluation

The Industrial Park Treatment System performance can be evaluated based on the major decisions identified for this system resulting from the groundwater DQO process.

1. Were unexpected levels or types of contamination detected?
No, there were no unusual or unexpected VOC concentrations observed in the monitoring wells or extraction wells associated with the OU III Industrial Park System during 2019. Lower than expected concentrations continue to be observed in the vicinity of extraction wells IP-EW-8 and IP-EW-9.

2. Has the downgradient migration of the plume been controlled?
Yes, an analysis of the plume perimeter and bypass well data reveals that there were no TVOC concentrations above the capture goal of the system in 2019. A comparison of the plume from 1997 to 2019 is provided on **Figure 3.2.6-7.** The higher concentration portion of the plume is attenuating as it moves from the northern portion of the industrial park toward wells IP-EW-8 and IP-EW-9.

3. Can individual extraction wells or the entire treatment system be shut down or placed in pulsed pumping operation?
Concentrations in two upgradient core monitoring wells are slightly above the capture goal of 50 µg/L. The UVB wells have been in stand-by since January 2017.

Two extraction wells were added in 2014 (IP-EW-8 and IP-EW-9) to capture deeper upgradient VOCs. Since operation of these wells was initiated in 2015, the highest TVOC concentrations reported for wells IP-EW-8 and IP-EW-9 are 6 µg/L and 10 µg/L, respectively. TVOC concentrations in these extraction wells during 2019 where below 5 µg/L. Individual VOCs have been below AWQS since 2017. The deeper VOCs seem to be migrating very slowly and attenuating as it moves south. IP-EW-8 and IP-EW-9 were subsequently placed in standby mode in July 2019.

4. Are TVOC concentrations in plume core wells above or below 50 µg/L?
There were two plume core wells slightly above the 50 µg/L TVOC capture goal in 2019. The maximum TVOC concentration in a plume core well was 58 µg/L in well 000-537 in March. This well is located over 1000 feet upgradient of the extraction wells.

5. Is there a significant concentration rebound in core wells and/or extraction wells following shutdown?

Wells UVB-3 through UVB-6 were restarted in March 2014 due to a rebound in concentrations above the 50 µg/L capture goal. These wells were placed back in standby in January 2017. There was no additional rebound of concentrations in the plume core wells associated with these recirculation wells in 2019. No rebound of concentrations has been observed in the vicinity of wells IP-EW-8 and IP-EW-9 since they were shut down in July, 2019.

6. Has the groundwater cleanup goal of meeting MCLs been achieved?
No, MCLs have not yet been achieved, but are expected to be by 2030.

3.2.6.7 Recommendations

The following are recommendations for the Industrial Park Treatment System and groundwater monitoring program:

- Maintain the seven UVB wells in standby. If TVOC concentrations exceed the 50 µg/L capture goal in these UVB wells or associated monitoring wells, they may be restarted.
- Maintain IP-EW-8 and IP-EW-9 in standby and continue to monitor for rebound of VOCs. If TVOC concentrations approach the capture goal of 50 µg/L in the vicinity of the extraction wells the system will be evaluated for restart.

3.2.7 Industrial Park East Monitoring Program

As noted in the *Petition for Closure, Industrial Park East Groundwater Treatment System* (BNL 2013b), the system has met the criteria established in the *Operations and Maintenance Manual for the Industrial Park East Offsite Groundwater Remediation System* (BNL 2004a) for system closure and was decommissioned. The two extraction wells and four of the monitoring wells were decommissioned in 2013. The treatment building, including the carbon units and controls, and the recharge wells have been repurposed to support the remediation of the deep volatile organic compound (VOC) plume in the Industrial Park to the west. Remediation of this plume is further discussed in **Section 3.2.6,** Industrial Park.

Based on the recommendation from the *2017 Groundwater Status Report,* all monitoring requirements for the Industrial Park East Groundwater Monitoring Program have been satisfied and sampling was discontinued in 2018.

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3.2.8 North Street Treatment System

The North Street Treatment System addresses a VOC plume that originated at the Former Landfill/Chemical Holes area. The VOC plume is presently located south of the site boundary, with the leading edge extending south to Flower Hill Drive (**Figure 3.2.8-1**). The groundwater treatment system began operating in May 2004. In June 2013, a *Petition for Shutdown OU III North Street Groundwater Treatment System* (BNL 2013c) was submitted to the regulators for review and approval. The system was shut down in August 2013 after receiving approval from the regulators. The system was restarted in June 2014 due to a rebound in VOC concentrations in several monitoring wells above the 50 µg/L TVOC concentration capture goal. The system was again shut down in July 2015 due to a reduction in VOC concentrations. In August 2015, well NS-1 was restarted due to elevated VOC concentrations in a monitoring well located immediately up-gradient of this well. Well NS-1 was shut down in August 2016 due to a reduction in VOC concentrations. In February 2020, a *Petition for Closure for the OU III North Street Groundwater Treatment System* (BNL 2020c) was submitted to the regulators for review and approval.

The groundwater treatment system consists of two extraction wells, which are currently in standby mode. The system captured the higher concentration portion of the VOC plume (i.e., TVOC concentrations greater than 50 µg/L) in the Upper Glacial aquifer and minimized additional VOC migration into the Magothy aquifer. The North Street plume has been divided into two segments for remediation purposes. The area to the north of extraction well NS-2 is being addressed by the North Street remediation system, whereas the Airport System captures and treats contaminated groundwater in the area to the south (**Figure 3.0-1**). The Airport System was constructed in part to address the leading edge of this plume (**Section 3.2.10**).

3.2.8.1 System Description

The North Street system consists of two extraction wells. Extracted groundwater is piped through two 20,000-pound GAC units located in Building OS-5 on a parcel of land owned by DOE and discharged to four injection wells located downgradient along North Street. Both the North Street and North Street East systems share the four injection wells. Extraction wells NS-1 and NS-2 can operate at a rate of up to 200 gpm each. A complete description of the system is contained in the *Operations and Maintenance Manual for the North Street/North Street East Offsite Groundwater Treatment Systems* (BNL 2004b).

3.2.8.2 Groundwater Monitoring

Well Network

A network of 18 wells monitors the North Street VOC plume (**Figure 1-2 and Figure 3.2.8-1**). Wells sampled under the Airport program are also utilized for tracking the North Street VOC plume.

Sampling Frequency and Analysis

Sampling of the 18 monitoring wells for VOCs is performed as per the schedule on **Table 1-5**.

3.2.8.3 Monitoring Well Results

The primary VOCs associated with this plume are carbon tetrachloride, TCE, TCA, and chloroform. **Figure 3.2-1** and **Figure 3.2.8-1** depict the TVOC plume distribution. The complete groundwater monitoring well data for 2019 are included in **Appendix C**. A north–south hydrogeologic cross section (J–J') of the plume is provided on **Figure 3.2.8-2. Figure 3.2.8-3** shows time-concentration plots for key monitoring wells. A summary of key monitoring well data for 2019 follows:

- Plume core well 000-465 is located 100 feet upgradient of extraction well NS-1. This well had historically shown the highest VOC concentrations (primarily carbon tetrachloride) in the North

Street area. TVOC concentrations were as high as 1,796 µg/L in 2004. In November 2019 the concentration was 11 µg/L.

- TVOC concentrations in core well 000-474, located approximately 500 feet upgradient of extraction well NS-2, were 13 µg/L in May and 9 µg/L in November.
- VOC concentrations in plume core well 000-463, located approximately 200 feet north of NS-1, were below their respective AWQS during 2019.
- Plume core well 000-154 had historically shown high VOC concentrations (primarily carbon tetrachloride). TVOC concentrations of approximately 1,000 µg/L were observed in this well in 1997 and 1998. However, they have steadily declined since then, and VOC concentrations have been below AWQS for several years. The trailing edge of the higher concentration segment of this plume has migrated south of this location.
- The plume continues to be bounded as shown on **Figure 3.2.8-1** by the plume perimeter wells.
- **Figure 3.2.8-6** compares the TVOC plume from 1997 to 2019. The southern portion of the plume that migrated south of the North Street system prior to system start-up is being captured by the Airport Treatment system eastern extraction wells.

3.2.8.4 System Operations

Table 3.2.8-1 provides the effluent limitations for meeting the requirements of the SPDES equivalency permit. The extraction wells are sampled quarterly for VOCs and tritium.

January – December 2019

Both extraction wells NS-1 and NS-2 remained in standby mode in 2019.

3.2.8.5 System Operational Data

The system was in standby mode in 2019.

Extraction Wells

Table F-27 has monthly pumping data and mass removal data and **Table 3.2.8-2** monthly extraction well pumping rates. There are no new data in these tables for 2019 as the system was in standby for the year. Well NS-1 and NS-2 were in standby mode in 2019, however they were sampled on a quarterly basis. **Figure 3.2.8-4** shows the plot of the TVOC concentrations from the extraction wells over time. VOC concentrations for the extraction wells are provided on **Table F-28**. TVOC values in well NS-1 have steadily dropped from a high of 599 µg/L in 2004 to approximately 4 µg/L in 2019. TVOC concentrations in well NS-2 remained below 15 µg/L in 2019 with the highest individual VOC detection of 6.1 µg/L of PCE in April. There was no tritium detected in the extraction wells in 2019.

Table 3.2.8-1
OU III North Street Treatment System
2019 SPDES Equivalency Permit Levels

Parameters	Permit Limit (µg/L)	Max. Observed Value (µg/L)
pH (range)	5.5 – 8.5 SU	NS
carbon tetrachloride	5	NS
chloroform	5	NS
1,1-dichloroethane	5	NS
1,2-dichloroethane	5	NS
1,1-dichloroethylene	5	NS
tetrachloroethylene	5	NS
toluene	5	NS
1,1,1-trichloroethane	5	NS
trichloroethylene	10	NS

Notes:
NS = Not Sampled as the system was not operating.
SU= Standard Units

System Influent and Effluent

There were no influent or effluent samples as the system was in standby mode during 2019 (**Table F-29 and F-30**).

Cumulative Mass Removal

The mass of VOCs removed from the aquifer by the North Street Treatment System was calculated using the average flow rates for each monthly monitoring period, in combination with the TVOC concentration in the carbon unit's influent, to calculate the pounds removed per month. The cumulative mass of VOCs removed by the treatment system vs. time is plotted on **Figure 3.2.8-5**. Since May 2004, the system has removed 342 pounds of VOCs. The mass removal data are summarized on **Table F-27**.

The downgradient portion of the plume that was south of the North Street system prior to start-up is being captured by the Airport Treatment System's eastern extraction wells. Further detail on the Airport system is provided in **Section 3.2.10**.

3.2.8.6 System Evaluation

The North Street Treatment System can be evaluated from the decision rules identified in the groundwater DQO process.

1. Were unexpected levels or types of contamination detected?

No. There were no unusual or unexpected concentrations of contaminants observed in monitoring wells associated with the North Street plume in 2019.

2. Has the downgradient migration of the plume been controlled?

Yes, the plume perimeter and bypass wells show that there have been no significant increases in VOC concentrations in 2019; therefore, the plume continues to be controlled. A segment of the plume passing through well 800-90 was beyond the capture zone of the North Street extraction well NS-1 at the time of system start-up. As described in **Section 3.2.10**, this portion of the plume is being addressed by the Airport extraction wells directly downgradient.

3. Can individual extraction wells or the entire treatment system be shut down or placed in pulsed pumping operation?

Wells NS-1 and NS-2 remained in standby in 2019. A Petition for Closure of the system was submitted to the regulators in February 2020.

3a. Are TVOC concentrations in plume core wells above or below 50 µg/L?

None of the 11 plume core wells of the North Street system showed TVOC concentrations greater than 50 µg/L during 2019.

3b. Is there a significant concentration rebound in core wells and/or extraction wells following shutdown?

No rebound in concentrations was detected in NS-1 or NS-2 since 2016. All monitoring wells associated with the plume are below the capture goal.

4. Has the groundwater cleanup goal of meeting MCLs been achieved?

MCLs have not been achieved for individual VOCs in all North Street plume core wells. During 2019, three of 11 core wells had VOCs above the MCL. MCLs are expected to be achieved in all wells by 2030.

3.2.8.7 Recommendations

The following are recommended for the North Street Treatment System and groundwater monitoring program:

- If TVOC concentrations in any core monitoring wells increase to over the 50 µg/L capture goal, the extraction well(s) may be restarted.
- NS-1 and NS-2 will remain in standby.
- A Petition for Closure was submitted for this system to the Regulators in February 2020, as this system has met its cleanup goals. Seven of the 12 core monitoring wells are proposed for continued annual monitoring until the results for individual VOCs are consistently below MCLs. Sampling of the remaining 11 monitoring wells will be discontinued but the wells will be retained until the completion of the PFAS and 1,4-dioxane characterization at the BNL site.
- Until regulatory approval is received, the system will remain in an operationally-ready mode, and the extraction and monitoring wells will continue to be sampled at its current frequency.

3.2.9 North Street East Treatment System

This section summarizes the 2019 operational and monitoring well data for the OU III North Street East (NSE) Treatment System. The system began operation in June 2004 to provide capture and control of the downgradient portion of the OU I VOC plume, which has migrated beyond the BNL site boundary. As further described below, this system was shut down in 2014 and placed in stand-by mode following approval from the regulators. In September 2019, a modification to the North Street East Groundwater Treatment System was submitted to the regulators. This includes the addition of two new extraction wells to remediate the ethylene dibromide (EDB) plume that was characterized and delineated in 2018.

3.2.9.1 System Description

The original NSE Treatment System consists of two extraction wells. The water is pumped through two 20,000-gallon GAC units and the treated water is discharged to four injection wells located on North Street. The North Street and NSE carbon treatment units and control systems are located in the same building along North Street. Extraction well NSE-1 and NSE-2 are designed to operate at approximately 200 gpm and 100 gpm, respectively. Extraction well NSE-2 has been shut down and in standby mode since 2010. Following approval from the regulators on the *Petition for Shutdown for the OU III North Street East Groundwater Treatment System* (BNL 2014b), the system was shut down in June 2014 and placed in stand-by mode. A complete description of the system is contained in the *Operations and Maintenance Manual for the North Street/North Street East Offsite Groundwater Treatment Systems* (BNL 2004b).

Starting in July 2019, two new extraction wells and four new monitoring wells were installed to address the EDB plume. Installation of the remediation infrastructure (piping, electric, communications) was initiated. The extracted groundwater will be treated with GAC at the existing NSE System. Due to the COVID-19 related site closure, system start-up has been delayed. It is anticipated to begin operations in 2020 following the resumption of normal work at BNL.

3.2.9.2 Groundwater Monitoring

The monitoring network consists of 19 wells. Twelve of the 19 wells monitor the EDB plume and are sampled and analyzed for EDB using EPA Method 504. The remaining seven wells monitor the remnants of the original VOC plume. As recommended in the *2018 Groundwater Status Report*, since the OU I South Boundary bypass monitoring well 115-42 is screened at the correct depth to monitor any potential EDB coming from upgradient, this well was added to the NSE EDB monitoring program. See **Figure 3.2.9-1** for the location of the 19 wells and which program they are sampled under. Four of the wells (000-563, 000-564, 000-565, 000-566) were installed in August 2019 to enhance the monitoring of the EDB plume.

The sampling frequency for the EDB plume monitoring wells is quarterly, except for upgradient perimeter well 115-42 which is sampled semi-annually. The remaining wells are sampled annually for VOCs using EPA Method 524.2. See **Table 1-5** for details.

3.2.9.3 Monitoring Well Results

Figure 3.2.9-2 shows the extent of the NSE EDB plume and the location of the two new extraction wells (NSE-EDB-EW-3 and NSE-EDB-EW-4). The trace levels of VOCs identified in the remnants of the original plume are discussed below and the data are provided in **Appendix C.**

Figure 3.2.9-3 depicts the vertical distribution of EDB within the deep Upper Glacial aquifer. The north-south transect line for cross section K–K' is shown on **Figure 3.2.9-2**. **Figure 3.2.9-4** presents the historical trends for EDB in the five monitoring wells that have detected EDB. **Appendix C** contains a complete set of 2019 analytical results for the NSE program wells. A summary of key monitoring well data for 2019 follows:

NSE VOC Monitoring:

- Since 2011, individual VOCs continue to remain below AWQS in all monitoring wells, except for three detections in well 000-394 in 2017 (maximum PCE concentration of 7.9 µg/L). In 2019, one well, 000-552 detected PCE above the AWQS at a concentration of 7.0 µg/L in the fourth quarter.
- In 2019, methyl tert-butyl ether (MTBE) was detected in three monitoring wells with a maximum concentration of 8.6 µg/L in well 000-552. The AWQS for MTBE is 10 µg/L. Historically, there have been sporadic low level detections of MTBE in several of the NSE monitoring wells below the AWQS.

NSE EDB Plume:

- As shown on **Figure 3.2.9-4**, since August 2015 EDB has consistently been detected above the DWS of 0.05 µg/L in well 000-394, with a maximum concentration of 1.06 µg/L in the fourth quarter 2017. The maximum EDB detection in this well in 2019 was 0.59 µg/L in the first quarter with concentrations dropping off to 0.17 µg/L in the fourth quarter.
- The nine new permanent wells installed to provide long term monitoring of the EDB plume were sampled in 2019 and the data are posted on **Figure 3.2.9-2**. Only three of the nine wells detected EDB concentrations above the DWS. The maximum EDB concentration in these wells in 2019 was 0.215 µg/L in March in well 000-554.
- The two upgradient perimeter wells (115-42 and 000-138) and five wells downgradient of new extraction well NSE-EDB-EW-4 did not detect EDB in 2019. Based on the EDB delineation on **Figure 3.2.9-2**, the new treatment system is in position to capture the plume.

3.2.9.4 System Operations

The extraction wells were sampled for the first three quarters of 2019 for VOCs, EDB and tritium. Extraction well NSE-1 is also sampled for EDB using Method 504. The fourth quarter extraction well samples could not be collected due to the shutdown of the system to allow connection of the two new extraction wells. **Table 3.2.9-1** provides the effluent limitations for meeting the requirements of the SPDES equivalency permit.

Table 3.2.9-1.
OU III North Street East Treatment System
2019 SPDES Equivalency Permit Levels

Parameters	Permit Limit (µg/L)	Max. Observed Value (µg/L)
pH range	5.5–8.5 SU	NS
carbon tetrachloride	5	NS
chloroform	5	NS
1,1-dichloroethane	5	NS
1,2-dichloroethane	5	NS
1,1-dichloroethylene	5	NS
tetrachloroethylene	5	NS
toluene	5	NS
1,1,1-trichloroethane	5	NS
trichloroethylene	10	NS

Notes:
ND = Not Detected above method detection limit of 0.50 µg/L.
Required effluent sampling freq. is monthly for VOCs and pH.
NS = Not Sampled as the system was not operating

3.2.9.5 System Operational Data

The system was shut down and placed in standby mode in June 2014.

January through December 2019

The system remained shut down and in standby mode.

Extraction Wells

During 2019, the extraction wells did not operate except to obtain the quarterly samples. **Table 2-2** shows no monthly pumping data for the two extraction wells as they were on standby for the year. **Table 3.2.9-2** pumping rates reflect that NSE-1 and NSE-2 remained in standby mode. **Figure 3.2.9-5** plots the TVOC concentrations in the extraction wells. VOC concentrations for NSE-1 and NSE-2 are provided in **Table F-31**. TVOC levels in NSE-1 remained steady in 2019 with a maximum concentration of 7.4 µg/L. TVOC concentrations in NSE-2 remained low during 2019, with concentrations below 2 µg/L. All individual VOCs were below their AWQS, and EDB was not detected in either extraction well. Tritium was not detected in the extraction wells in 2019.

System Influent and Effluent

No influent and effluent samples were collected since the system was in standby mode (**Table F-32 and F-33**).

Cumulative Mass Removal

The cumulative mass of VOCs removed by the treatment system versus time is noted on **Figure 3.2.9-6**. A cumulative total of 44 pounds of VOCs were removed from the aquifer during system operation. No additional data was collected as the system remained in standby mode during 2019 (**Table F-34**).

3.2.9.6 System Evaluation

The system began operation in 2004 and was predicted to run for approximately 10 years. The system operated as designed and was shut down and placed in standby mode in June 2014.
The NSE Treatment System performance can be evaluated based on decisions identified for this system from the groundwater DQO process.

1. Were unexpected levels or types of contamination detected?

Original VOC Plume:

No. Sporadic low level detections of VOCs are expected as the original plume attenuates over time to below AWQS.

EDB Plume:

No. The temporary vertical profiles installed in 2018 delineated the extent of the EDB plume that was first identified in this area in 2015.

2. Has the downgradient migration of the plume been controlled?

Original VOC Plume:

The system operated for ten years, as originally intended. An analysis of the plume core, perimeter and bypass wells shows that there have been no significant increases in VOC concentrations since the system was shut down in 2014, indicating that the plume has not grown and is controlled. TVOC concentrations in the monitoring wells between extraction wells NSE-1 and NSE-2 have been below 5 µg/L since 2007. **Figure 3.1-8** shows the overall plume size reduction from 2004 to 2019.

EDB Plume:

For the recently delineated NSE EDB plume identified on **Figure 3.2.9-2**, two additional extraction wells (NSE-EDB-EW-3 and NSE-EDB-EW-4) were installed in late 2019 to provide capture and control. This system will become operational in 2020.

3. Can individual extraction wells or the entire treatment system be shut down or placed in pulsed pumping operation?

Original VOC Plume:

The treatment system met its goals in 2014 with no significant rebound identified. Although a formal petition was not submitted to the regulators for approval, this system has met all closure requirements identified in the *Operations and Maintenance Manual for the North Street/North Street East Offsite Groundwater Treatment Systems* (BNL 2004b).

EDB Plume:
No, the two new extraction wells will become operational in 2020.

3a. Are TVOC concentrations in plume core wells above or below 50 ug/L and are EDB concentrations above or below 0.05 ug/L?
Original VOC Plume:
TVOC concentrations in all monitoring wells and extraction wells are below 50 μg/L. The maximum TVOC concentration detected in 2019 was in monitoring well 000-552 at 16.5 μg/L in the fourth quarter. The maximum TVOC concentration in the 17 vertical profiles was 15.6 μg/L in VP14-2018 in July 2018. VP14-2018 was located approximately 500 feet upgradient of 000-552.

EDB Plume:
EDB was detected above the DWS in four of the 12 monitoring wells in 2019. The two new extraction wells will capture this contamination.

3b. Is there a significant concentration rebound in core wells and/or extraction wells following shutdown?
Original VOC Plume:
Significant rebounding of VOCs in the monitoring or extraction wells was not evident as a result of the shutdown of NSE-2 in late 2010 or as a result of the entire system shutdown in June 2014. As noted previously, well 000-394 identified elevated EDB concentrations starting in 2015, however it was not related to shutdown of the system. Extraction well NSE-1 has never detected EDB.

EDB Plume:
The two new extraction wells will become operational in 2020.

4. Has the groundwater cleanup goal of meeting MCLs been achieved?
Original VOC Plume:
Since 2018, only one of the 19 monitoring wells (000-552) detected VOCs above MCLs (7 μg/L of PCE).

EDB Plume:
MCLs have not been achieved.

3.2.9.7 Recommendations
The following recommendations are made for the NSE Treatment Systems and groundwater monitoring program:

Original VOC Plume:

- The original NSE VOC treatment system (including extraction wells NSE-1 and NSE-2) met its goals in 2014 with no significant rebound identified. A formal petition for closure will not be prepared for the original VOC treatment system since the infrastructure will be used for remediation of the EDB plume. However, it is recommended that this system be administratively closed for its originally designed purpose. Until administrative approval for closure is received, this treatment system will be maintained in standby mode. The extraction wells will continue to be sampled on a quarterly basis for VOCs via Method 524.2 and NSE-1 for EDB using Method 504. One or both extraction wells can be restarted if TVOC concentrations in the core monitoring wells or extraction wells rebound to concentrations above the capture goal of 50 μg/L, or if EDB is detected in NSE-1.

- Discontinue VOC monitoring using EPA Method 524.2 on the following eight wells since there have been no detections exceeding AWQS for the last 10 years. However, these wells will be retained until the completion of the PFAS and 1,4-dioxane characterization at the BNL site:
    - 000-124, 000-138, 000-477, 000-478, 000-479, 000-480, 000-481 and 000-525
- Continue annual VOC sampling using Method 524.2 for the remaining two monitoring wells 000-394 and 000-552.
- Sampling for tritium will be discontinued since there have been no detections in the monitoring wells or extraction wells since 2013.

<u>EDB Plume:</u>

- Complete the connection of the two new EDB extraction wells and begin start-up testing in 2020 following the resumption of normal work at BNL. Submit a revised Operations and Maintenance Manual to the regulators.
- Maintain the quarterly sampling frequency for the 12 EDB monitoring wells using Method 504, except for upgradient perimeter well 115-42 which is sampled semi-annually.

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3.2.10 LIPA/Airport Treatment System

This section summarizes the 2019 operational and monitoring well data for the LIPA/Airport Treatment System and presents conclusions and recommendations for its future operation. The LIPA system was designed to provide capture and control of the downgradient portion of the plume of VOCs in the Upper Glacial and Magothy aquifers that had migrated south of the Industrial Park System before that system became operational in 1999. The Airport Treatment System was designed to capture the leading edge of the OU III and OU I/IV VOC plumes and to prevent further migration of the plumes, which have migrated past the LIPA extraction wells and the North Street extraction wells.

3.2.10.1 System Description

The three components of the LIPA/Airport Treatment System are as follows:

1. The Magothy extraction well (EW-4L) on Stratler Drive (**Figure 3.2.10-1**) addressed high-level VOCs identified in the Magothy aquifer immediately upgradient of this well on Carleton Drive. The capture goal for this well is 50 µg/L TVOCs. The capture goal for this well has been met and it is currently in standby mode.
2. The other three LIPA extraction wells (EW-1L, EW-2L, and EW-3L) were installed to address high concentrations of VOCs in the Upper Glacial aquifer that had migrated past the Industrial Park System before that system became operational in 1999. The capture goal for these extraction wells of 50 µg/L TVOC has been met and these wells are in standby mode.
3. The six extraction wells in the Airport System were installed to address the leading edge of the plumes which have migrated past the LIPA extraction wells and the North Street extraction wells prior to their installation. The sixth well (RW-6A) was added in 2007 to address VOCs observed to the west of extraction well RTW-1A. The Airport system wells have a capture goal of 10 µg/L TVOC. RTW-4A also addresses Magothy aquifer contamination. Extraction wells RTW-1A, RTW-4A and RW-6A are in full time operation. Extraction wells RTW-2A and RTW-3A, are in pulsed pumping operation, and well RTW-5A is shutdown.

The water from the four LIPA wells is pumped to the treatment plant, about one mile south on Brookhaven [Town] Airport property, where it is combined with the water from the six airport extraction wells (RTW-1A through RW-6A) and treated via granular activated carbon. The treated water is released back to the ground via a series of shallow reinjection wells located on Brookhaven Airport.

A more detailed description of this system is contained in the *Operations and Maintenance Manual for the LIPA/Airport Groundwater Treatment System* (BNL 2008a).

3.2.10.2 Groundwater Monitoring

Well Network

The monitoring network consists of 49 wells. The Magothy extraction well (EW-4L) on Stratler Drive has six monitoring wells associated with its operation. There are 12 wells associated with the Upper Glacial portion of the LIPA plume. South of the OU III Industrial Park system. The Airport system has 31 monitoring wells, which monitor the portions of the plume south of the LIPA and the North Street systems. All of these wells are used to evaluate the effectiveness and progress of the cleanup associated with these three components of the system. **Figure 1-2 and Figure 3.2.10-1** identify the monitoring wells for these plumes.

Sampling Frequency and Analysis

The monitoring wells for LIPA are currently on a quarterly and semiannual sampling schedule for VOCs. The Airport wells are sampled quarterly for VOCs (**Table 1-5**).

3.2.10.3 Monitoring Results

The primary VOCs associated with these portions of the plume are carbon tetrachloride, TCA, TCE, and DCE. Groundwater monitoring for these systems was initiated in 2004. Fourth quarter 2019 well data are posted on **Figure 3.2.10-1** and **Figure 3.2.10-2**. The complete analytical results are in **Appendix C.** Results for key monitoring wells and extraction wells are as follows:

LIPA Monitoring

- During 2019 TVOC concentrations for the Magothy extraction well EW-4L on Stratler Drive were between 6 µg/L and 8 µg/L. This well was shut down in January 2017 as it achieved its TVOC capture goal of 50 µg/L.
- The Magothy monitoring wells located in the vicinity of extraction well EW-4L all detected TVOC concentrations below 5 µg/L during 2019. The highest TVOC concentration observed during 2019 was in well 000-425 at 3 µg/L.
- All of the LIPA monitoring wells are below the TVOC capture goal of 50 µg/L. The highest TVOC concentration was 13 µg/L in well 000-131 in May 2019.
- The maximum TVOC concentration in extraction well EW-3L in 2019 was 2 µg/L. Extraction well EW-2L detected TVOC concentrations up to 7 µg/L in January. TVOC concentrations in extraction well EW-1L ranged from 15 µg/L in January to 5 µg/L in October. **Figure 3.2.10-3** plots the TVOC trends for the LIPA extraction wells.

Airport Monitoring

- Monitoring wells 800-94 and 800-95, are approximately 1,500 feet north of extraction wells RTW-1A, RTW-2A, and RW-6A. In 2019, well 800-94 had TVOC concentrations of 73 µg/L in January and well 800-95 had a maximum concentration of 28 µg/L in May (**Figure 3.2.10-6**). Both of these wells have had persistently elevated TVOC concentrations over the past several years.
- **Figure 3.2.10-4** plots the TVOC influent trends for the Airport extraction wells. Five of the six airport extraction wells had TVOC concentrations below the capture goal of 10 µg/L in 2019. Extraction well RW-6A showed TVOC concentrations up to 11 µg/L in 2019.
- Well 800-96 detected a maximum TVOC concentration of 46 µg/L in May. The maximum individual VOC concentration in this sample was carbon tetrachloride at 26 µg/L (**Figure 3.2.10-1**, **Figure 3.2.10-6**).
- None of the bypass wells installed downgradient of this area detected VOCs above AWQS.
- Well 800-92, located upgradient of extraction wells RTW-3A and RTW-4A had TVOC concentrations above the capture goal for the past several years. However, this year the maximum TVOC concentration was 5 µg/L. The concentrations are showing a downward trend. This is a slug of contamination that was south of the North Street extraction wells prior to the system start-up. These contaminants are being captured by the Airport extraction wells. Well 800-90, co-located near well 800-92, but screened deeper, detected TVOC concentrations up to 10 µg/L in January.
- Well 800-101, located directly upgradient of extraction well RTW-4A, has shown an increasing TVOC concentration trend over the past several years. The concentration ranged up to 34 µg/L in 2019. This is above the TVOC capture goal of 10 µg/L for the Airport extraction wells and warrants the continued operation of well RTW-4A, a Magothy extraction well (**Figure 3.2.8-2** in **Section 3.2.8**).

- Monitoring well 800-138 was installed adjacent to well 800-59 and screened about 40 feet deeper than this well (from 245 feet to 255 feet bls). This well is used to monitor concentrations of VOCs identified in upgradient well 800-92. VOC concentrations in this well were below AWQS in 2019.

3.2.10.4 System Operations

In 2019, the Airport and LIPA extraction wells were sampled quarterly. The influent, midpoint, and effluent of the carbon units were sampled two times per month. All system samples were analyzed for VOCs. Two of the Airport extraction wells are on a pulsed pumping schedule (RTW-2A, RTW-3A), being pumped one week per month. Well RTW-5A is shut down. Wells RTW-1A, RTW-4A and RW-6A are pumped on a full-time basis. All four LIPA extraction wells are in standby since TVOC concentrations remained below the capture goal of 50 µg/L. The four LIPA wells are currently shut down as they have achieved the cleanup goals.

The following is a summary of the Airport/LIPA Treatment System operations for 2019:

January – September 2019

The Airport System was operational in the first three quarters with RTW-1A, RTW-4A, and EW-6A operating on a full-time basis. Extraction well RTW-5A, and all four LIPA extraction wells were in standby. Extraction wells RTW-2A and RTW-3A at the Airport System were run one week per month on a pulsed pumping schedule. In February, extraction well RTW-3A was not pulsed pumped due to repair work. In March, the system was off for approximately two days for a scheduled carbon change-out. Extraction well RTW-4A was off in May for ten days as a precaution due to nearby trenching for a solar project being done for Brookhaven Town on the Airport property. In June, extraction wells RTW-2A and RTW-3A were not pulsed pumped due to the trenching activities, and RTW-4A was off due to trenching activities. The system was off for three days for a scheduled carbon change-out in July.

October – December 2019

The Airport/LIPA system operated normally in the fourth quarter. In December, the system was down for two days for a scheduled carbon change-out.

Extraction Wells Operational Data

During 2019, approximately 205 million gallons of groundwater were treated by the Airport/LIPA system, with an average flow rate of 396 gpm (**Table 3.2.10-2)**. **Table F-35** summarizes the system's mass removal. VOC concentrations for the Airport and LIPA extractions wells are provided in **Table F-36.**

3.2.10.5 System Operational Data

System Influent and Effluent

VOC concentrations for the carbon influent and effluent in 2019 are summarized on **Tables F-37** and **F-38,** respectively.

The carbon vessels for the system effectively removed the contaminants from the influent groundwater. System effluent samples were below the regulatory limit specified in the SPDES equivalency permit (**Table 3.2.10-1**)

Cumulative Mass Removal

The mass of VOCs removed from the aquifer by the Airport/LIPA Treatment System was calculated using the average flow rates for each monitoring period (**Table F-35**) in combination with the TVOC concentration in the carbon unit's influent, to calculate the pounds per month removed.

The plot of cumulative mass of VOCs removed vs. time shows that 14 pounds of VOCs were removed during 2019, with a total of 471 pounds removed since system start-up (**Figure 3.2.10-5)**.

3.2.10.6 System Evaluation

The Airport/LIPA system performance can be evaluated based on the decision rules identified for this system resulting from the groundwater DQO process.

Table 3.2.10-1
OU III LIPA/Airport Treatment System
2019 SPDES Equivalency Permit Levels

Parameters	Permit Level (µg/L)	Max. Measured Value (µg/L)
pH	5.5–7.5 SU	5.5-6.5 SU
carbon tetrachloride	5	<0.5
chloroform	7	1.31
1,1-dichloroethane	5	<0.5
1,1-dichloroethylene	5	<0.5
methylene chloride	5	<0.5
1,1,1-trichloroethane	5	<0.5
trichloroethylene	10	<0.5

Notes:
ND = Not detected above method detection limit of 0.50 µg/L.
Sampling required an a monthly basis
SU= Standard Units

1. Were unexpected levels or types of contamination detected?
No, there were no unusual or unexpected VOC concentrations observed in the monitoring wells for the LIPA/Airport Treatment System during 2019.

2. Has the downgradient migration of the plume been controlled?
Yes. The monitoring data clearly show that the capture goal of 50 µg/L TVOC at the LIPA Upper Glacial and Magothy wells is being met (**Figure 3.2-1**). No TVOC concentrations above the 10 µg/L capture goal have been detected in the bypass monitoring wells at the Airport. Based upon these data, plume migration is being controlled.

3. Can individual extraction wells or the entire treatment system be shut down or placed in pulsed pumping operation?
Yes, currently all four LIPA wells are shut down as they have reached their capture goals. Two of the six Airport extraction wells are being pulsed pumped and one is shut down.

4. Are TVOC concentrations in plume core wells above or below 50 µg/L *for LIPA and 10 ug/L for the Airport?*
TVOC concentrations are all below 50 µg/L for all of the LIPA monitoring wells. Several Airport core wells are above a TVOC concentration of 10 µg/L. Well 800-96 located in the vicinity of well RW-6A continues to show elevated levels of TVOC concentrations up to 46 µg/L. Well 800-130 located between well RW-6A and RTW-1A had TVOC concentrations of up to 67 µg/L in January. Wells 800-94 and 800-95 showed maximum TVOC concentrations of 73 µg/L and 28 µg/L, respectively. Well 800-90 showed a peak TVOC concentration of 10 µg/L.

4a. Is there a significant concentration rebound in core wells and/or extraction wells following shutdown?
No, all four LIPA extraction wells VOC concentrations remained below MCLs in 2019, except for a detection of TCA in RTW-1A in January of 5.8 µg/L

5. Has the groundwater cleanup goal of meeting MCLs been achieved?
No, the cleanup goal has not been met. Based on monitoring results, MCLs are expected to be achieved by 2030 for the Upper Glacial aquifer, and in the Magothy aquifer by 2065, as required by the OU III ROD and ESD.

3.2.10.7 Recommendations

The following recommendations are made for the LIPA/Airport Treatment System and groundwater monitoring program:

- Shutdown the Airport extraction wells RTW-2A and RTW-3A currently being pulsed pumped one week per month. There are no TVOC concentrations detected in the vicinity of these wells above the capture goal of 10 µg/L. Continue full time operation of wells RTW-1A, RTW-4A and RW-6A. Keep well RTW-5A in standby mode. If concentrations above the capture goal of 10 µg/L TVOC are observed in any of the extraction wells or the monitoring wells adjacent to wells that are not operating, the well(s) will be put back into full-time operation.
- Maintain LIPA wells EW-1L, EW-2L, EW-3L and EW-4L in standby mode. These extraction wells may be restarted if TVOC concentrations rebound above the 50 µg/L capture goal in either the plume core monitoring wells or the extraction wells. If no significant change in concentrations for the LIPA system occur in 2020, submit a petition for closure of the LIPA system in 2021.
- No changes to the current monitoring schedule are recommended at this time for the Airport System. Increase the monitoring sampling frequency for the LIPA monitoring wells to quarterly to support the decision for a petition for closure in 2021.
- Reduce the sampling frequency of the carbon treatment system from twice a month to monthly. This is consistent with the SPDES Equivalency permit frequency of monthly.

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3.2.11 Magothy Monitoring

This section provides a brief summary of the Magothy Aquifer Groundwater Monitoring and Cleanup Program and the remedial approach for addressing VOC contamination. The Record of Decision (ROD) states that the cleanup goal for the Magothy aquifer is to reach MCLs by 2065. The forty monitoring wells and nine extraction wells used to monitor the Magothy are shown on **Figure 3.2.11-1**. Ten of these wells are no longer sampled due to having achieved AWQS.

Detailed descriptions of the monitoring well analytical results and remediation progress are presented in the following sections of this report: Western South Boundary, Middle Road, LIPA/Airport, North Street, OU III South Boundary, Industrial Park, Industrial Park East and William Floyd Well Field sentinel monitoring. A brief summary of the results is provided on **Table 3.2.11-1 and Figure 3.2.11-2**.

Table 3.2.11-1. Magothy Aquifer Contamination (Historical and 2019).

	Max. TVOC (in µg/L)			
Location	2019	Historical	Primary VOCs	Results
Western South Boundary	<0.5	.9	None	Magothy not impacted. A monitoring well 130-04 is located near the southwest site boundary and has no detections of VOCs in 2019.
William Floyd Well Field Sentinel	0	3.9	DCA	Wells 109-12 and 109-13 serve as outpost sentinel wells for the William Floyd Well Field. There were no detection's of VOCs in these wells in 2019.
Middle Road to South Boundary	64	340	PCE, CCl_4	VOCs identified in upper 20 to 40 feet of Magothy at the Middle Road area where Magothy brown clay is absent (**Figure 3.2-2**). Well 113-09 had 64 µg/L TVOC in April, and well 113-19 had 33 µg/L in April. VOCs not detected at South Boundary beneath the clay.
Industrial Park	58	268	PCE, TCA	VOCs identified in the upper Magothy south of the OU III South Boundary system. Two Magothy extraction wells were installed in the Industrial Park in 2014 to capture and treat this contamination. Maximum TVOC concentrations were detected in well 000-537 at 58 µg/L and well 127-08 of 50 µg/L in March.
North Street to Airport	34	123	TCE, DCA	VOCs have been detected in localized areas in the upper 30 feet of the Magothy aquifer along North Street and downgradient near Vita Drive (**Figure 3.2.8-2**). Well 800-90 had a TVOC concentration of 9.6 µg/L in January. The leading edge of this contamination is at the eastern portion of the Airport system, with 34 µg/L TVOC in well 800-101 in June, which is adjacent to Airport extraction well RTW-4A. Low VOC concentrations have been detected from the BNL South Boundary to North Street below the Magothy brown clay, at approximately 40 to 150 feet into the upper Magothy. A TVOC concentration of 11 µg/L was detected in well 000-343 in January 2019.
South Boundary to Industrial Park East	24	570	TCA, CCl_4	TVOC concentrations were less than 25 µg/L at the south boundary and off site in the Industrial Park East area, where the Magothy brown clay is absent. Magothy and Upper Glacial contamination is continuous in the Industrial Park. A TVOC concentration of 24 µg/L was detected in well 122-05 located at the south boundary in February and was 11 µg/L in November. This is the highest TVOC concentration identified in this area in 2019.
South of Carleton Drive	25	7,200	CCl_4	Historically high VOC concentrations just south of Carleton Drive where the Magothy brown clay is absent had been detected. However recent data shows these high concentrations are no longer present in this area. Contamination is continuous between Magothy and Upper Glacial aquifers. Well 000-130 which had 7200 µg/L in 1998, showed a maximum TVOC concentration of 2 µg/L in January 2019. Well 000-460 located on Stratler Drive showed VOC concentrations below detection limits in 2019. Well 000-544 showed a high TVOC concentration of 25 µg/L in August. This well is located downgradient of the extraction well IP-EW-9. These concentrations have declined significantly from the historical highs.

The Magothy remedy identified in the *OU III Explanation of Significant Differences* (BNL, 2005a) document calls for the following:

1. Reaching MCLs in the Magothy aquifer by 2065 by active groundwater treatment and natural attenuation.
2. Operation of the nine extraction wells until cleanup objectives are met as part of the treatment systems that provide capture of Magothy VOC contamination at Middle Road (RW-7 and RW-3), South Boundary [EW-17 and EW-8 (shutdown)], Airport (RTW-3A and RTW-4A), Industrial Park (IP-EW-8 and IP-EW-9 (shutdown in 2019), and LIPA [EW-4L (shutdown)].
3. Continued evaluation of monitoring well data to ensure protectiveness. **Table 3.2.11-2** describes how each of the Magothy investigation areas is addressed by the selected Magothy aquifer remedy.
4. Institutional controls and five-year reviews.

Table 3.2.11-2. Magothy Remedy.

Area Investigated	Status of Selected Remedy
Western South Boundary	Continue monitoring and evaluate data.
William Floyd Well Field Sentinel Monitoring	Continue monitoring and evaluate data
Middle Road to South Boundary	Continue operation of the Magothy extraction wells at Middle Road (RW-3 and RW-7). Continue to monitor the three Magothy monitoring wells at Middle Road and five at the South Boundary until cleanup goals are met. Continue to operate South Boundary well EW-17.
North Street to Airport	The Airport extraction wells (RTW-3A and RTW-4A) to continue to operate to capture contaminants. Continue monitoring and evaluate data.
North Street East	Continue monitoring and evaluate data.
South Boundary to Industrial Park East	Continue monitoring and evaluate data.
South of Carlton Drive	The LIPA Magothy extraction well (EW-4L) on Stratler Drive has met cleanup goals and is now in standby. Continue monitoring until MCLs are met.
Industrial Park	The two industrial park extraction wells (IP-EW-8 and IP-EW-9) were placed in standby in 2019. Continue monitoring and data evaluation. Wells will be restarted if any significant rebound in concentrations is observed.

3.2.11.1 Monitoring Well Results

See the appropriate sections for detailed discussion of the monitoring well results.

3.2.11.2 Recommendations

The following are recommendations for the Magothy groundwater monitoring program:

- Continue the current monitoring schedule for the Magothy monitoring program. See **Table 1-5**.
- Continue pumping the Magothy extraction wells at Middle Road, South Boundary and the Airport. The two IP extraction wells were placed in standby in July 2019 and continue to be monitored for rebound of VOCs. The North Street, North Street East, OU III South Boundary EW-8 and LIPA Magothy extraction wells are currently in standby as they have reached the OU III capture goals identified for shutdown of these wells. The IPE extraction well was abandoned as it had reached its cleanup goal.

3.2.12 William Floyd Wellfield Sentinel Monitoring

The Suffolk County Water Authority operates the William Floyd Parkway Well Field located west of the BNL site. The well field currently contains three Upper Glacial aquifer supply wells (**Section 2.0**). Because the source water contributing area for this well field extends into the BNL property, four sentinel wells are used to monitor groundwater quality within on-site portion of the contributing area.

3.2.12.1 Groundwater Monitoring

Well Network

The monitoring well network is comprised of Upper Glacial wells 109-03 and 109-04 and Magothy aquifer wells 109-12 and 109-13 (**Figure 3.2.12-1**).

Sampling Frequency and Analysis

Wells 109-03 and 109-04 are jointly sampled by BNL and the SCDHS on a quarterly basis for VOCs, gamma spectroscopy, tritium, and Sr-90 (**Table 1-5**). Wells 109-12 and 109-13 are sampled by BNL quarterly for VOCs. Complete monitoring results are presented in **Appendix C**.

3.2.12.2 Monitoring Well Results

Monitoring results for 2019 are summarized below:

Upper Glacial Wells 109-03 and 109-04: The only parameter detected was chloroform in well 109-03 at a maximum concentration of 0.7 µg/L. The AWQS for chloroform is 7.0 µg/L

Magothy Wells 109-12 and 109-13: No VOCs were detected in either well.

3.2.12.3 Groundwater Monitoring Program Evaluation

The evaluation of the OU III Central Monitoring Program is based on the decision rule established for this program using the groundwater DQO process.

1. Have the SCWA William Floyd Well Field sentinel wells remained below the MCLs?
Yes. During 2019, no VOCs or radionuclides were detected at concentrations exceeding the MCLs.

3.2.12.4 Recommendation

No changes are recommended for the William Floyd Wellfield Sentinel Monitoring.

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3.2.13 OU III South Boundary Radionuclide Monitoring Program

The South Boundary Radionuclide Monitoring Program is used to confirm that radionuclides are not currently migrating south of the BNL site above DWS. The sampling was conducted in conjunction with the OU III South Boundary and Western South Boundary Programs. The OU I portion of the south boundary is discussed in **Section 3.1**.

3.2.13.1 Groundwater Monitoring

A network of 42 monitoring wells is used to monitor radionuclides from the OU III South Boundary, and OU III Western South Boundary programs. The well locations along the southern property boundary are shown on **Figure 3.2.13-1**.

Sampling Frequency and Analysis

The OU III South Boundary Radionuclide Monitoring Program wells were sampled annually for tritium, Sr-90, and gamma spectroscopy (**Table 1-5**).

3.2.13.2 Monitoring Well Results

The radionuclide analytical results for the wells can be found in **Appendix C**. There were no confirmed detections of radionuclides in the OU III South Boundary Radionuclide Monitoring Program wells in 2019. There have been no confirmed detections of radionuclides exceeding the DWS over the last 20 years. There have been no detections of tritium greater than 1,000 pCi/L for the last 19 years and no confirmed detections since 2013. There have been no detections of Sr-90 greater than 0.5 pCi/L since 2004 and no detections above 1.0 pCi/L historically.

3.2.13.3 Groundwater Monitoring Program Evaluation

The OU III South Boundary Radionuclide Monitoring Program can be evaluated based on the decision rule identified for this program resulting from applying the groundwater DQO process.

1. Were unexpected levels or types of contaminants detected?

No. There were no unexpected detections of contaminants in the OU III South Boundary Radionuclide Groundwater Monitoring Program during 2019.

3.2.13.4 Recommendations

Due to the lack of radionuclide detections above the DWS for the last 20 years, it is recommended that further sampling be eliminated.

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3.2.14 BGRR/WCF Strontium-90 Treatment System

The Brookhaven Graphite Research Reactor (BGRR)/ Waste Concentration Facility (WCF) Treatment System addresses the Sr-90 plumes in groundwater downgradient of these facilities. The BGRR/ WCF remedy consists of:

1. Operation of nine extraction wells using ion exchange to remove Sr-90, with discharge of the treated water to dry wells,
2. Operation of the system to minimize plume growth and meet DWS by 2070,
3. Continued monitoring and evaluation of data to ensure protectiveness, and
4. Institutional controls and five-year reviews

The analytical results indicate three primary areas of elevated Sr-90 in groundwater: one extending south from the former WCF area, one extending south from the BGRR (Building 701)/ Below Ground Ducts (BGD) and former Canal House, and another that is south of the former Pile Fan Sump (PFS)/Building 801 Area (**Figure 3.2.14-1**).

3.2.14.1 System Description

Operation of this treatment system began in January 2005. There are two extraction wells (SR-1 and SR-2) located south of the former WCF, and three extraction wells (SR-3, SR-4, and SR-5) located south of the BGRR. SR-4 and SR-5 were placed in standby mode in 2016. Four extraction wells (SR-6, SR-7, SR-8, and SR-9) were installed in 2010 to address higher Sr-90 concentrations located in the downgradient portion of the former WCF plume (in the vicinity of the HFBR) and began operation in 2011. SR-6 was placed in a pulsed pumping mode in 2016. During 2017, wells SR-4, SR-5 and SR-6 were placed in stand-by mode. Wells SR-3 and SR-7 operated on a one month on, one month off pulsed pumping schedule. In October 2018 wells SR-3 and SR-7 were also placed in stand-by mode and well SR-8 was placed in a one month on, one month off pulsed pumping mode.

Groundwater from the extraction wells is piped to an ion exchange treatment system inside Building 855 (within the BNL Waste Management Facility). The vessels of ion exchange media are designed to treat groundwater contaminated with Sr-90 to below the 8 pCi/L DWS. In addition, the influent is also treated for low-level concentrations (less than 10 µg/L) of VOCs using liquid-phase activated carbon.

Effluent is recharged to the Upper Glacial aquifer via three drywells located approximately 850 feet west of Building 855. A SPDES equivalency permit regulates this discharge. A complete description of the system is included in the *Operations and Maintenance Manual for the Sr-90 BGRR/ WCF/PFS/Building 801 Area Groundwater Treatment System* (BNL 2012c).

3.2.14.2 Groundwater Monitoring

Well Network

A network of 69 monitoring wells is used to monitor the Sr-90 plumes associated with the BGRR, former WCF, and PFS/Building 801 areas. Sixteen temporary wells (see **Figure 3.2.14-1** for locations) were installed in 2019 to augment the permanent well network and fill plume data gaps.

Sampling Frequency and Analysis

The well samples are analyzed for Sr-90. As noted in **Table 1-5**, several of the wells are also monitored for other programs. Monitoring well results are tabulated in **Appendix C**. In 2019, the sampling frequency for all three of the Sr-90 plume segments (BGRR, PFS/Building 801 area and former WCF), was either annual or semi-annual for most wells. Source area monitoring well 075-701was sampled monthly to monitor Sr-90 releases from underneath Building 701/BGDs resulting from high water table conditions.

3.2.14.3 Monitoring Well/Temporary Well Results

The Sr-90 plume distribution map is shown on **Figure 3.2.14-1**. The distribution of Sr-90 throughout the BGRR, former WCF, and PFS/Building 801 areas is depicted based on groundwater data obtained from the fourth-quarter 2019 sampling round supplemented with data from temporary wells which were sampled May 2018 through October 2019. **Table 3.2.14-1** contains the temporary well data obtained during the September-October 2019 time frame. Hydrogeologic cross-sections drawn along the center line of each of the plumes from the three Sr-90 source areas are shown on **Figures 3.2.14-2, 3.2.14-3, and 3.2.14-4**. In addition, historical Sr-90 concentration trends for key wells are plotted on **Figure 3.2.14-5**.

Historically, the highest Sr-90 concentration observed in these plumes (3,150 pCi/L) was during 2003 in a temporary well installed approximately 185 feet south of Building 701, and slightly upgradient of the location of extraction well SR-3. The highest historical Sr-90 concentration in the former WCF area (1,560 pCi/L) occurred in 2003 in a temporary well installed immediately downgradient of the six former underground storage tanks (USTs A/B), and approximately 25 feet northwest of the former WCF (Building 811). The highest historical Sr-90 concentration associated with the former PFS/Building 801 (566 pCi/L) occurred in 1997 in a temporary well installed immediately downgradient of this area.

A comparison of the plume from 2004 through 2019 is provided on **Figure 3.2.14-10.** The three Sr-90 plumes were characterized extensively for the first time using numerous temporary wells in 1998. The permanent monitoring network was enhanced significantly in 2004 prior to the startup of groundwater treatment operations. Groundwater flow conditions have changed significantly in this area since the late 1990s. This is due to changes in supply, process, and remediation pumping and recharge in the east-central portion of the site. Flow has shifted from a southerly to southeasterly direction in response to the changes. As a result, a number of permanent wells are no longer in optimal locations for monitoring Sr-90. Some older wells have been dropped from the monitoring network over the past several years and temporary wells are increasingly required to fill data gaps. A periodic effort to supplement the permanent monitoring network with temporary wells was carried out over 2018 and 2019. The following is a summary of the 2019 monitoring data for the three Sr-90 plumes:

WCF Plume

The removal of Building 811 and associated radiologically contaminated structures and soils was completed in 2016. Extraction wells SR-1 and SR-2 have been effective at capturing source area contamination and preventing any southward migration of the plume as can be viewed on **Figure 3.2.14-1**. **Section 3.2.14-6** discusses Sr-90 concentration increases in SR-1 that may have been related to the 2016 remediation activities (these activities including removing above and below ground structures, pavement and contaminated soils). The downgradient portion of this plume over the past several years has been influenced by an easterly shift in groundwater flow, particularly in the vicinity of the HFBR and areas just to the west of that building.

- Monitoring well 065-175 has historically shown the highest Sr-90 concentrations immediately downgradient of the former WCF source area. Following a general slow decline in concentrations since 2000, the Sr-90 concentration in this well increased to 355 pCi/L in April 2014. The Sr-90 concentration in this well has decreased since with a detection of 16 pCi/L observed in October 2019 **(Figure 3.2.14-5).** Well 065-174 located approximately 40 feet to the west also showed a concentration of 16 pCi/L in October of 2019 which was the highest value observed over the past several years.
- An east-west transect of four temporary wells was installed in 2019 to supplement the permanent wells and obtain data to determine whether Sr-90 was continuing to migrate from the former WCF yard. Sr-90 concentrations in these temporary wells ranged in concentration from 29 pCi/L in BGRR-GP-159 to 278 pCi/L in BGRR-GP-157. BGRR-GP-157 is located 50 feet north and

west of well 065-175 and demonstrates how narrow the plumes of contamination are in this area. The highest detections were at or just below the water table indicating a local Sr-90 source (see **Table 3.2.14-1**).

- Sr-90 concentrations in monitoring wells located immediately downgradient of extraction wells SR-1 and SR-2 were below the 8 pCi/L DWS indicating that the extraction wells are capturing Sr-90 migrating south from the source area.
- Twenty-three temporary wells were installed along east-west transects in the area just south of the HFBR and immediately south of Temple Place in 2018. This helped fill data gaps in the well network and defined the leading edge of the Sr-90 plume that originated at the former WCF. In 2019, a transect of 12 temporary wells was installed from Renaissance Road to the west side of the HFBR Annex (see **Figure 3.2.14-1**). The data from these temporary wells demonstrated that the plume has not shifted significantly east in this area. The highest Sr-90 concentration in this transect was 46 pCi/L in GP-BGRR-95, located immediately north of the HFBR.

BGRR (Building 701 Area) Plume

- Source area monitoring well 075-701 (screened across the water table from 48-68 ft. bls) has been sampled on a monthly basis since late 2012. The monthly data has resulted in an understanding of the relationship between water table elevation and Sr-90 concentration increases in the source area as shown on **Figure 3.2.14-6**. This figure plots water table elevation data from a nearby USGS monitoring well against 075-701 Sr-90 concentrations over time, and shows a correlation between high water table periods and increased Sr-90 concentrations in well 075-701. The water table elevation across the site began to rebound in 2017 following an eight-year period of decline. Well 075-701 Sr-90 concentrations began to increase during the first quarter of 2019. The concentration peaked in October of 2019 at 1,170 pCi/L. This was the highest concentration recorded since this well was installed in 2011. Concentrations have declined to 279 pCi/L in March of 2020. This decrease coincides with the approximately 2.5-foot decline in water table elevation during 2019. Source area well 075-664 (screened 65-75 ft. bls) is located adjacent to well 075-701 but screened slightly deeper. Sr-90 concentrations in well 075-664 were slightly above detectable levels from 2014 through late 2018. The well is currently sampled quarterly and following a detection of 0.5 pCi/L in November 2018, concentrations steadily increased to 423 pCi/L in January of 2020.
- The BGRR cap monitoring wells have now been in place for eight years. Sr-90 concentrations in monitoring wells 075-699 and 075-700 have been largely below the DWS. Initially, concentrations observed in these wells were 40 pCi/L (April 2012) and 104 pCi/L (April 2013), respectively. The concentration in 075-700 increased to 10 pCi/L in October 2019 which was the first detection to exceed the DWS since 2012 in this well. Sr-90 concentrations in well 075-699 remained below the DWS in 2019.
- Wells 085-398 and 085-403 monitor the leading edge of the Building 701 Sr-90 plume. Concentrations have been steadily increasing in both wells from barely detectable levels several years ago to 13 pCi/L in 085-398 and 35 pCi/L in 085-403 during October 2019.

Former Pile Fan Sump/Building 801 Plume

- Sr-90 concentrations have increased in several wells located in the area just south of the former Pile Fan Sump and Building 801 during 2019. The sharpest increase was observed in well 065-325 (**Figure 3.2.14-1**) where the concentration ranged from 22 pCi/L in October 2018 up to 186 pCi/L in January 2020 which is a historical high concentration for this well (**Figure 3.2.14-5**). The well was installed in 2002 in response to an incident that had occurred in 2001 resulting in the flooding of the basement of Building 801 stormwater. Some of this water became contaminated with Sr-90 after coming in contact with the floor and eventually migrated down to the water table. This well is immediately upgradient of the former Pile Fan Sump which was associated with the BGRR. Underground piping and Sr-90 contaminated soils related to this structure were removed back in 2000 as part of a BGRR removal action. Well 065-405 located approximately 40 feet to the south, has started to show an increase in Sr-90 concentrations from <MDA in 2017 to 46 pCi/L in October 2019.

3.2.14.4 System Operations

In accordance with the SPDES equivalency permit, the required frequency for Sr-90 and VOC sampling is monthly, and the pH measurement is weekly. The influent was also analyzed for tritium. Extraction well Sr-90 concentrations from 2019 are summarized on **Table F-39**. System influent and effluent concentrations are summarized on **Tables F-40** and **F-41**. **Table F-42** contains the monthly Sr-90 removal totals for the system. Operating details are given in the O&M manual for this system (BNL 2012c).

Below is a summary of the system operations for 2019:

January – September 2019

From January to September 2019, wells SR-4, SR-5, SR-6 and SR-7 were in stand-by mode. Well SR-8 operated on a one month on, one month off pulsed pumping schedule. The system was off from November 2 to January 10 for a resin vessel change out and repairs. The system was off again from September 12 to October 1 for a resin vessel change-out. The system treated approximately 10 million gallons of water during this period.

October – December 2019

From October to December 2019, wells SR-4, SR-5, SR-6 and SR-7 were in stand-by mode. Well SR-8 operated in a one month on, one month off pulsed pumping schedule. The system was off from November 20 to December 2 to install five new flow meters. The system treated approximately 3.5 million gallons of water during this period.

Extraction Well Operational Data

During 2019, approximately 13.5 million gallons of water were treated by the remediation system, with an average flow rate of 26 gpm. **Table 3.2.14-2** shows the monthly extraction well pumping rates while **Table F-39** shows Sr-90 concentrations.

Table 3.2.14-3
BGRR Sr-90 Treatment System
2019 SPDES Equivalency Permit Levels

Parameter	Permit Level	Max. Measured Value
pH range	5.5–8.5 SU	5.8–7.4 SU
Sr-90	8.0 pCi/L	2.4
Chloroform	7.0 µg/L	<0.5
1,1-Dichloroethane	5.0 µg/L	<0.5
Ethylbenzene	5.0 µg/L	<0.5
Methyl Chloride	5.0 µg/L	<0.5
Methylene Chloride	5.0 µg/L	<0.5
Toluene	5.0 µg/L	<0.5
1,2,3-Trichlorobenzene	5.0 µg/L	<0.5
1,1,1-Trichloroethane	5.0 µg/L	0.5
1,2,4-Trimethylbenzene	5.0 µg/L	<0.5
Xylene, total	10.0 µg/L	<0.5

Notes:
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SU = Standard Units
Required sampling frequency is monthly for Sr-90 and VOCs, and weekly for pH.

3.2.14.5 System Operational Data

During 2019, system influent concentrations of Sr-90 ranged from 11.5 pCi/L to 21 pCi/L. The highest influent tritium concentration during 2019 was 455 pCi/L in April (**Table F-40**). During 2019, Sr-90 was detected in the effluent at a maximum concentration of 2.4 pCi/L. There were no VOCs or Sr-90 detected above the SPDES Equivalency Permit discharge limits in the 2019 effluent samples (**Table 3.2.14-3**).

Extraction Wells

Maximum Sr-90 concentrations in each of the extraction wells during 2019 were as follows:

- SR-1 59.5 pCi/L in April
- SR-2 31.2 pCi/L in April
- SR-3 26.8 pCi/L in December
- SR-4 No detections in 2019
- SR-5 2.8 pCi/L in April
- SR-6 3.1 pCi/L in October
- SR-7 7.1 pCi/L in April
- SR-8 12.7 pCi/L in April
- SR-9 18.4 pCi/L in August

Cumulative Mass Removal

Average flow rates for each monitoring period were used, in combination with the Sr-90 influent concentrations, to calculate the number of milliCuries (mCi) removed. During 2019, the flow averaged 26 gpm. Approximately 0.8 mCi of Sr-90 was removed during 2019, for a total of 28.6 mCi removed since system start-up in 2005 (**Table F-42**). Cumulative mass removal of Sr-90 is shown on **Figure 3.2.14-7**. **Figures 3.2.14-8** and **3.2.14-9** show the Sr-90 concentrations over time for the extraction wells.

3.2.14.6 System Evaluation

The BGRR/ WCF Strontium-90 Treatment System and Monitoring Program can be evaluated in the context of the decisions established for this program using the groundwater DQO process:

1. Is there a continuing source of contamination? If present, has the source area been remediated or controlled?

WCF Plume: Buildings 810 and 811, located in the eastern portion of the former WCF yard, were demolished in 2015. Contaminated piping and soils located underneath and adjacent to the buildings were also removed and sent to an approved disposal facility following the building demolition. Some paved areas were also removed. The excavated areas were backfilled in September 2016. Sr-90 concentration increases were observed in extraction well SR-1 in 2018 and 2019. Source area temporary wells installed in 2019 confirmed that Sr-90 is still present at elevated concentrations in the source area. It appears that the remediation work resulted in the release of Sr-90 to the water table. The source area remains controlled by extraction wells SR-1 and SR-2 which capture the plume migrating south from this area. Increasing Sr-90 concentrations in SR-1 have been observed over the past several years.

BGRR Plume: The source area is capped by Building 701 and an engineered cap that was completed in 2011. The source area is being monitored for any continued releases of Sr-90 from beneath the building. Based on Sr-90 increases in well 075-701 (during 2019) and extraction well SR-3 (up to 42 pCi/L during the second quarter of 2020), it appears that the water table elevation increase during 2018-2019 has resulted in flushing of residual Sr-90 inventory beneath the Building 701 area. Monthly monitoring will continue in this area in 2020. The downgradient migration of the Sr-90 is controlled by extraction well SR-3.

PFS/Building 801 Area Plume: Sr-90 concentrations increased in source area monitoring wells in 2019, particularly in well 065-325 which has increased from 22 pCi/L in October 2018 to 186 pCi/L in January 2020. This is the highest detection in this well since it was installed in 2013.

2. Were unexpected levels or types of contamination detected?

WCF Plume: There were elevated levels of Sr-90 at the source area which were anticipated due to the recent remediation work in the area.

BGRR Plume: Source area monitoring well 075-701 showed a sharp Sr-90 concentration increase in 2019. However, this was expected due to the increasing water table elevation.

PFS/Building 801 Area Plume: Yes, unexpected levels of Sr-90 were observed immediately downgradient of the Building 801 area.

3. Has the downgradient migration of the plume been controlled?

WCF Plume: The downgradient migration of the plume has been controlled. The eastward shift in the downgradient segment of this plume over the years has resulted in part of the plume bypassing the capture zone of SR-9. The Sr-90 concentrations to the south and east of SR-9 are well below the system capture goal of 175 pCi/L and are expected to naturally attenuate and meet the ROD cleanup goals.

BGRR Plume: Extraction well SR-3 is positioned to capture the migration of Sr-90 from the source area. This well is currently fully operational due to the elevated Sr-90 concentrations in well 075-701.

PFS/Building 801 Area Plume: This plume is not being actively remediated. The plume is expected to attenuate and meet the ROD cleanup goals.

4. Can individual extraction wells or the entire treatment system be shut down or placed in pulsed pumping operation?

WCF Plume: The cleanup goal has not yet been met. The extraction wells are capturing source area residual Sr-90 contamination immediately downgradient of the former WCF. Extraction well SR-6 is currently in stand-by mode and concentrations remained low in 2019. SR-7 is currently in stand-by mode and Sr-90 concentrations have remained low over the past year. SR-8 is in a pulsed-pumping mode with generally low concentrations observed in 2019 although concentrations reported for several monthly samples increased to just above the DWS.

BGRR Plume: SR-3 was placed back in operation during in January 2019 due to increasing source area Sr-90 concentrations. This well will continue to operate in 2020. Extraction wells SR-4 and SR-5 will be maintained in standby mode.

PFS/Building 801 Area Plume: This plume is not being actively remediated.

4a. Are the Sr-90 concentrations in the plume core wells above or below 8 pCi/L?

Sr-90 concentrations for specific core wells in all three of the Sr-90 plumes are above 8 pCi/L.

4b. Has there been a significant concentration rebound in core wells and/or extraction wells following shutdown?

This system is still operational. No significant Sr-90 concentration rebound has been observed in Building 701/BGD extraction wells SR-4, SR-5, SR-6, and SR-7. There was a rebound in concentrations observed in SR-3.

5. Has the Groundwater Cleanup goal of meeting MCLs been achieved?

The groundwater cleanup goal of meeting MCLs has not been achieved for these plumes.

3.2.14.7 Recommendations

The following are recommendations for the BGRR/WCF Building 801Groundwater Treatment System and Monitoring Program:

- Increase the sampling frequency of source area monitoring wells 065-325 and 065-405 to quarterly. Assess the elevated Sr-90 concentrations downgradient of Building 801. Perform groundwater modeling simulation if necessary, to determine natural attenuation of recent Sr-90 concentrations.
- Maintain SR-8 in pulsed pumping mode (one month on and one month off) based on low, but fluctuating, Sr-90 concentrations.
- Maintain a source area monitoring frequency of monthly for BGRR source area well 075-701. Increase sampling frequency of 075-664 back to monthly.
- Continue operating wells SR-1, SR-2, SR-3 and SR-9 in full time operational mode. Maintain wells SR-4, SR-5, SR-6, and SR-7 in standby mode.
- Install a temporary well downgradient of 085-403 to identify the location of the leading edge of the plume.
- Install several temporary wells along Temple Place to supplement monitoring of the downgradient segment of the WCF plume.

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3.2.15 Chemical/Animal Holes Strontium-90 Treatment System

This section summarizes the operational data from the Chemical/Animal Holes Strontium-90 Treatment System for 2019 and gives conclusions and recommendations for future operation. This system began operation in February 2003. Due to the declining Sr-90 concentrations over the last several years, a *Petition for Shutdown of the OU III Chemical Holes Strontium-90 Groundwater Treatment System* was submitted to the regulators in March 2018 and subsequently approved. In July 2018, the system was placed in standby mode.

3.2.15.1 System Description

The Chemical/Animal Holes were located in the south-central portion of the BNL property (**Figure 1-1** and **3.2.15-1**). The area consisted of 55 pits east of the Former Landfill that were used for the disposal of a variety of laboratory chemicals and animal remains. The buried waste was excavated in 1997.

The elements of the Sr-90 groundwater remediation at the Chemical/Animal Holes are:

1. Three extraction wells pumping into an ion exchange treatment system to remove Sr-90 from the extracted groundwater, and on-site discharge of the clean water into two drywells.
2. Operation of the system to minimize plume growth, in conjunction with monitored natural attenuation to meet the 8 pCi/L DWS by 2040.
3. Continued monitoring and evaluation of the data to ensure protectiveness.

Details of operations are provided in the *Chemical/Animal Holes Strontium-90 Groundwater Treatment System Operation and Maintenance Manual* (BNL 2008b).

3.2.15.2 Groundwater Monitoring

Well Network

The Chemical/Animal Holes monitoring network consists of 29 wells. **Figures 1-2** and **3.2.15-1** show the monitoring well locations.

Sampling Frequency and Analysis

The sampling frequency for the monitoring wells was annual (standby phase) in 2019, except for the three upgradient wells that monitor the former source area which were sampled semi-annually.

3.2.15.3 Monitoring Well Results

Figure 3.2.15-1 shows the Sr-90 plume distribution. The plume depiction is derived from third quarter 2019 monitoring well data.

The area of highest concentration is currently located in the former source area upgradient of extraction well EW-1. Monitoring well 097-14 detected 37 pCi/L in February 2019 and 64 pCi/L in January 2020. Lower concentrations are identified south of the Princeton Avenue firebreak. Overall, the plume concentrations have significantly decreased since 2006. To date, the highest Sr-90 concentration observed in groundwater in this area was 4,720 pCi/L at well 106-99 in 2005. Sr-90 concentrations in the plume have been below 50 pCi/L since mid-2015. See **Figure 3.2.15-2** for concentration trends of key monitoring wells and **Figure 3.2.15-3** for a cross-sectional view. The complete monitoring results for all wells in this program are in **Appendix C**.

Sr-90 concentrations in monitoring wells have been significantly reduced over the last ten years. Low precipitation conditions from 2015 through 2017 resulted in the lowering of the water table which may impact flushing of Sr-90 from the vadose zone in the former source area. This could influence the Sr-90 concentrations in the monitoring wells between the former source area and EW-1. Although there was a significant increase in the water table elevation in 2018, there has not been a significant corresponding rebound in Sr-90 concentrations. Sr-90 concentrations in the monitoring wells in 2019 were generally consistent with 2018 results.

A summary of key monitoring well data for 2019 follows:

- Sr-90 concentrations in plume core wells have declined over the past several years as shown in the trend charts. However, since mid-2018, Sr-90 concentrations in well 097-314 began to increase slightly to a maximum of 37 pCi/L in February 2019. This was the maximum Sr-90 concentration detected in the plume in 2019. After dropping to 20 pCi/L in July, the January 2020 sample from 097-314 detected 64 pCi/L of Sr-90. Wells 097-313 and 097-315, also located in the former source area, did not detect Sr-90 above the DWS in 2019.
- Sr-90 concentration trends in plume core wells 106-16,106-94, 106-95 and 106-99 have significantly declined over time and have remained less than 25 pCi/L since 2016. These wells are located immediately upgradient of EW-1. As shown on the plume comparison on **Figure 3.2.15-6**, the plume has become discontinuous and Sr-90 concentrations have been significantly reduced as a result of the groundwater remediation efforts in this area.
- All remaining plume monitoring wells were less than the DWS in 2019.

3.2.15.4 System Operations

The system remained in standby mode in 2019. Therefore, the influent, midpoint, and effluent locations were not sampled since the system was shut down (**Table 3.2.15-1**). The three extraction wells were sampled quarterly for Sr-90 (**Table F-43**). The maximum Sr-90 concentration in the extraction wells in 2019 was 22 pCi/L in EW-1.

Tables F-44, 45 and 46 contain no data since the system was shut down in 2019.

Table 3.2.15-1.
Chemical Holes Sr-90 Treatment System
2019 SPDES Equivalency Permit Levels

Parameter	Permit Level	Max. Measured Value
pH range (SU)	5.0–8.5	NS
Sr-90 (pCi/L)	8.0	NS

Notes:
pCi/L = pico Curies per liter
SU = Standard Units
MDA = Minimal detectable activity
NS = Not sampled since the system was not operating
Required sampling frequencies are monthly for Sr-90 and pH.

3.2.15.5 System Operational Data

Concentrations of Sr-90 in EW-1 have steadily dropped-off since 2009, however there was a slight increase in 2019. This is likely due to capture of the elevated Sr-90 detected in former source area well 097-314. Sr-90 concentrations in EW-2 have decreased as expected since this well became operational. Upon start-up, up to 139 pCi/L of Sr-90 was detected in EW-2 and the concentration has steadily dropped to less than the DWS since 2012. When EW-3 became operational in November 2007, concentrations were already low at 13 pCi/L. They remained low through late 2011 and then started increasing slightly for several sampling rounds. Sr-90 concentrations in EW-2 and EW-3 have remained below the DWS since 2014. **Figure 3.2.15-4** presents the Sr-90 extraction well data over time.

Cumulative Mass Removal

The system remained in stand-by mode in 2019. The cumulative total mass of Sr-90 removed during system operations from 2003 through July 2018 is approximately 4.94 mCi (**Figure 3.2.15-5**).

3.2.15.6 System Evaluation

The Chemical/Animal Holes Sr-90 Treatment System performance can be evaluated based on decisions identified for this system as part of the DQO process.

1. Is there a continuing source of contamination? If present, has the source area been remediated or controlled?

The former Chemical/Animal Holes, located upgradient of extraction well EW-1 were excavated in 1997. The inventory of Sr-90 that remains in the vadose zone in this area is decreasing based on the monitoring data. The temporary well soil and groundwater samples obtained in this area in late 2015 did not identify a continuing source of Sr-90. As shown by the trends in **Figure 3.2.15-2**, Sr-90 concentrations in monitoring wells immediately upgradient of EW-1 have been significantly reduced over the last ten years. This is indicative of the remediation progress. However, there was a slight increase in Sr-90 concentrations in former source area well 097-314 in 2018 and 2019 with a maximum of 64 pCi/L in January 2020. This may be associated with the significant rise in the water table in 2018 following three years of low precipitation conditions, resulting in flushing of Sr-90 from the vadose zone. This area will continue to be monitored in 2020 for potential significant increasing trends.

2. Were unexpected levels or types of contamination detected?

No. As part of the Phase 3 PFAS characterization effort, the three extraction wells were sampled for PFAS compounds in January 2019. The results for PFOA and PFOS were below the proposed State standard of 10 ng/L.

3. Has the downgradient migration of the plume been controlled?

Yes. The monitoring data from plume perimeter wells to the west and east as well as the system bypass wells indicate that the main portion of the plume is controlled by extraction well EW-1. Operation of EW-2 and EW-3 controlled the downgradient portion of the plume.

4*. Can individual extraction wells or the entire treatment system be shut down or placed in pulsed pumping operation?*

Following regulatory approval, the system was shut down and placed in standby mode in July 2018 and will continue to be monitored for potential rebound.

4a. Are Sr-90 concentrations in plume core wells above or below 8 pCi/L?

Sr-90 concentrations in only four of 21 core wells were above 8 pCi/L in 2019 with a maximum of 37 pCi/L. The maximum Sr-90 concentration further increased to 64 pCi/L in January 2020. The number of core wells above the MCL have been significantly reduced from the nine identified in 2018.

4b. Is there a significant concentration rebound in core wells and/or extraction wells following shutdown?

There was a slight increase in Sr-90 concentrations in former source area monitoring well 097-314 in 2019 and the first quarter of 2020, as well as extraction well EW-1. Monitoring will continue in 2020 to evaluate any significant rebound and increasing trends.

5*. Has the groundwater cleanup goal of meeting drinking water standards been achieved?*

No. The DWS has not been achieved for Sr-90 in all plume core wells. However, based on the projected attenuation of the remaining Sr-90 concentrations, the DWS is expected to be achieved before 2040. Comparison of the current plume with a series of plume snapshots dating back to 2002 is provided in **Figure 3.2.15-6.**

3.2.15.7 Recommendations

The following are the recommendations for the Chemical/Animal Holes Strontium-90 Treatment System and groundwater monitoring program:

- Maintain the system in standby mode and maintain quarterly sampling of the extraction wells. If significant rebound in either the extraction wells or monitoring wells is identified, these extraction wells may be restarted.
- Maintain the annual monitoring well sampling frequency (standby phase), except for former source area wells 097-313, 097-314, 097-315, which will remain at a semi-annual.

3.2.16 HFBR Tritium Pump and Recharge System

In late 1996, tritium was detected in monitoring wells near the HFBR. The source of the release was traced to the HFBR spent fuel pool. In response, the fuel rods were removed and the spent fuel pool was drained. In May 1997, a three-well groundwater pump and recharge system was constructed on the Princeton Avenue firebreak road, approximately 3,700 feet downgradient of the HFBR to capture the leading edge of the tritium plume should it be necessary to prevent off site migration of the plume. Extracted water was recharged at the RA V Recharge Basin. The extraction system was placed on standby status in September 2000, as groundwater monitoring data demonstrated that the plume was attenuating to concentrations well below DWS in the vicinity of the extraction wells.

As described in the OU III ROD, the selected remedy to address the HFBR tritium plume included implementing monitoring and low-flow extraction programs to prevent or minimize the plume's growth. Beginning in June 2000 and ending April 2001, 20 low-flow extraction events removed 95,000 gallons of tritiated water with concentrations greater than 750,000 pCi/L. This water was sent off site for disposal.

The OU III ROD contingencies are defined as either a detection of tritium above 25,000 pCi/L in monitoring wells at the Chilled Water Facility Road, or above 20,000 pCi/L in monitoring wells along Weaver Drive. The OU III ROD contingency of exceeding 20,000 pCi/L at Weaver Drive was triggered with a detection of 21,000 pCi/L in November 2006. In 2007, extraction well EW-16 was installed to supplement the three existing extraction wells and the system was restarted in November 2007 as per the ROD contingency.

The *Petition For Shutdown, High Flux Beam Reactor, Tritium Plume Pump and Recharge System* (BNL 2013d) was submitted to the regulatory agencies in March 2013 based on satisfaction of the criteria established in the *2008 Groundwater Status Report* (BNL, 2009b) and documented in the *Operations and Maintenance Manual for the High Flux Beam Reactor Tritium Plume Pump and Recharge System (*BNL, 2009c). The petition was approved by the regulatory agencies in May 2013 and the extraction wells were placed in standby mode. A Petition for Closure (BNL, 2019d) of this system was submitted to the regulators in July 2018 and approved in March 2019. The extraction wells are now shut down.

3.2.16.1 System Description

Extraction wells EW-9, EW-10, EW-11, and EW-16 are no longer in use and will be decommissioned upon a determination that they will not be needed for use related to emerging contaminants. For a complete description of the HFBR Tritium Pump and Recharge System, see the *Operations and Maintenance Manual for the High Flux Beam Reactor Tritium Plume Pump and Recharge System* (BNL 2009c).

3.2.16.2 Groundwater Monitoring

Well Network

A monitoring well network of 10 wells is utilized to monitor source area concentrations immediately downgradient of the HFBR (**Figure 1-2 and 3.2.16-1**).

Sampling Frequency and Analysis

Sampling details for the well network are provided on **Table 1-5**.

3.2.16.3 Monitoring Well Results

The fourth quarter 2019 data is posted on **Figure 3.2.16-1** for each of the wells in the monitoring network. In 2019 the plume monitoring was scaled back to the area immediately south of the HFBR, due to the attenuation of the downgradient portion of the plume. The highest tritium concentration observed in 2019 was 35,900 pCi/L in well 075-806 in October 2019. **Appendix C** contains the complete set of monitoring well data.

Elevated tritium concentrations in wells located immediately downgradient of the HFBR have been observed to correlate with high water-table elevation events. This results in water-table flushing of the remaining tritium inventory in the unsaturated zone beneath the HFBR. The correlation is evident when comparing water table elevations immediately downgradient of the HFBR with peak tritium concentrations in the monitoring wells located in this area as shown in **Figure 3.2.16-2**. High water table conditions have been present at BNL since 2018. The correlation between the water table and increased tritium concentrations is shown on **Figure 3.2.16-2**. The figure demonstrates how the magnitude and frequency of the peak tritium concentrations has diminished over the 20 years of monitoring. Based on the decreasing concentration trend, the inventory of tritium beneath the HFBR has significantly decreased over the past 23 years.

3.2.16.4 System Operations

Table F-50 shows VOC concentrations in the extraction wells. Extraction wells EW-9, EW-10, EW-11, and EW-16 were sampled during the first three quarters of 2019 prior to the regulatory approval for system closure. Tritium was not detected in any of these samples.

3.2.16.5 System Evaluation

The OU III HFBR Tritium Pump and Recharge System and Monitoring Program can be evaluated based on the decision rules established for this program using the groundwater DQO process.

1. Is there a continuing source of contamination? If present, has the source area been remediated or controlled?
Yes. However, the inventory of tritium that remains in the unsaturated zone beneath the HFBR building is decreasing based on monitoring data from groundwater immediately downgradient of the building. The highest concentration observed in the source area during 2019 was 35,900 pCi/L in monitoring well 075-806. The long term decline in peak tritium concentration trend in wells immediately downgradient of the HFBR and the water table elevation is shown in **Figure 3.2.16-2**. Several tritium detections in monitoring wells above the DWS over the past two years are attributable to the increase in water table conditions over that period.

2. Were unexpected levels of contamination detected?
No. There were no unusual or unexpected concentrations/types of contaminants observed in the monitoring wells during 2019.

3. Is the plume attenuating as expected?
Yes. Tritium exceeding the 20,000 pCi/L DWS is observed intermittently in individual wells immediately downgradient of the HFBR. **Figure 3.2.16-2** demonstrates the decline in source area concentrations over the years.

4. Has the downgradient migration of the plume been controlled?
Yes. The downgradient segment of the plume has been successfully remediated by a combination of pump and recharge and natural attenuation to levels below the DWS.

5. Can individual extraction wells or the entire treatment system be shut down or placed in pulsed pumping operation?
The regulatory agencies approved the Petition for Closure of this system in March 2019.

5a. Are tritium concentrations in extraction wells above or below the 20,000 pCi/L DWS?
The extraction wells are no longer operational as the system has been approved for closure. All extraction well tritium concentrations in 2019 were below the MDA.

5b. Is there a significant concentration rebound in extraction wells following shutdown?
No significant rebound of tritium concentrations was observed in 2019.

6. Has the groundwater cleanup goal of meeting MCLs been achieved?
MCLs have been attained except for the area immediately downgradient of the HFBR.

3.2.16.6 Recommendations

The following are recommendations for the HFBR Tritium Pump and Recharge System and monitoring program:

- Continue to monitor the source area with the ten wells located immediately downgradient of the HFBR.
- Maintain the monitoring and extraction wells until a determination is made on their utilization related to emerging contaminants.

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3.3 OPERABLE UNIT IV

This section summarizes the data from the Building 650 and Sump Outfall Strontium-90 Monitoring Program that monitors a Sr-90 plume and offers conclusions and recommendations for monitoring.

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3.3.1 Building 650 and Sump Outfall Strontium-90 Monitoring Program

The Building 650 and Sump Outfall Strontium-90 Monitoring Program monitors a Sr-90 plume that derived from a remediated source area known as the former Building 650 Sump Outfall Area. This former source consisted of a depression (sump outfall) at the terminus of a discharge pipe from the building. The pipe conveyed discharges from a concrete pad located approximately 1,200 feet to the west, where radioactively contaminated clothing and equipment were decontaminated beginning in 1959 (**Figure 3.3.1-1**).

3.3.1.1 Groundwater Monitoring

The network consists of 20 wells used to monitor Sr-90 concentrations originating from the former Building 650 sump outfall area (**Figure 1-2 and 3.3.1-1**). During 2019, the monitoring wells were sampled either annually or semiannually, and the samples were analyzed for Sr-90 (**Table 1-5**). During 2019, five (OU4-GP01-2019 through OU4-GP05-2019) temporary wells were installed to evaluate the eastward shift of the plume, to further evaluate the southern extent of the plume, and to fulfill the recommendations set forth in the *2018 Groundwater Status Report.* These additional temporary wells are depicted on **Figure 3.3.1-1.**

3.3.1.2 Monitoring Well Results

The complete monitoring well radionuclide sampling results can be found in **Appendix C**. The Sr-90 plume continues to attenuate as it migrates away from the former Building 650 sump outfall area. The locations of the monitoring wells and the Sr-90 concentrations are shown on **Figure 3.3.1-1**. The leading edge of the plume, as defined by the 8 pCi/L DWS is presently located in the area immediately north of the NSLS II Facility.

Sr-90 concentrations in source area wells 076-13 and 076-168 have remained below DWS over the past year (**Figure 3.3.1-2**). There has been a shift in the groundwater flow direction to the southeast in this area as shown on **Figure 2-2**. This shift is attributable to the reduction of treated water discharging into the RA V basin. This shift could also be contributing to the decrease in concentrations in some of the plume core wells (076-24, 076-415, 076-182, and 076-416) over the past several years. Well 076-184, located to the east of wells 076-182 and 076-416, increased to its historical high of 13.5 pCi/L in 2019. Well 076-184 showed an increase from 3.8 pCi/L in 2018 to 13.5 pCi/L in 2019. These Sr-90 concentrations may be the result of fluctuating groundwater elevations in the area.

Monitoring well 076-25 has seen a decrease in Sr-90 concentrations from a high of 12 pCi/L in 2018 to 2.2 pCi/L in 2019. This well is located approximately 160 feet to the south-southeast of Building 650. Again, this decrease in concentrations may be the result of plume shift.

Five additional temporary wells (OU4-GP01-2019 through OU4-GP05-2019) were installed to further track the southeast shift in the plume along the length on the suspected plume path. Strontium-90 detections were observed in each of the five wells with a high of 37.2 pCi/L being observed at a depth of 66 feet bls in OU4-GP05-2019 at the leading edge of the plume. Wells OU4-GP01-2019 through OU4-GP04-2019 showed peak detections of 2.0 pCi/L, 26.6 pCi/L, 27.1 pCi/L, and 1.7 pCi/L respectively. The results of these temporary wells are summarized in **Table 3.3.1.1.**

3.3.1.3 Groundwater Monitoring Program Evaluation

The monitoring program can be evaluated based on the decision rules identified from the groundwater DQO process.

1. Is there a continuing source of contamination? If present, has the source area been remediated or controlled?

The source area was remediated in 2002 yet there are still persistent detections of Sr-90 in the sump outfall area at levels near or above the DWS. Based on the Sr-90 concentrations in source area monitoring wells, any residual contamination that may remain at depth in the unsaturated zone above the water table appears to be minimal. Any residual contamination continues to be flushed by the rising and falling of the water table and precipitation. Water table elevations increased during 2019. The groundwater flow has also shifted in this area to the southeast due to a reduction of discharge water entering HO and RA V basins. Characterization work conducted during 2019 verified that there has been a shift of the plume resulting from the aforementioned changes.

2. Were unexpected levels or types of contamination detected?
No. All Sr-90 detections in 2019 were within the expected concentration range.

3. Is the plume naturally attenuating as expected?
The groundwater model conducted in 2010 predicts that the plume will attenuate to below the 8 pCi/L DWS by approximately 2034. The leading edge of the plume, as defined by the DWS, is predicted to advance approximately 250 feet south of Brookhaven Avenue.

4. Has the groundwater cleanup goal of meeting MCLs been achieved?
No. The performance objective for this project is to achieve Sr-90 concentrations below the 8 pCi/L DWS. There was one monitoring well exceeding this limit in 2019 (076-184) and three temporary wells (OU4-GP02-2019, OU4-GP03-2019 and OU4-GP05-2019) therefore, the performance objectives have yet to be achieved. The groundwater plume continues to degrade due to natural attenuation (i.e., radioactive decay and dispersion).

3.3.1.4 Recommendations

The following are recommendations for the Building 650 and Sump Outfall Strontium-90 Monitoring Program:

- Remove wells 076-09, 076-263 and 076-417 from the Building 650 Sr-90 Monitoring Program. Wells 076-09 and 076-263 have not exceed the DWS in twenty years. Well 076-417 has not exceeded the DWS standard since it was installed ten years ago. These wells are no longer ideally located due to the change in local groundwater flow conditions. The wells will be maintained should they be needed in the future due to shifting groundwater flow or to monitor for emerging contaminants.
- Add wells 076-04, 076-06 and 076-20 to the Building 650 Sr-90 Monitoring Program and sample on an annual basis due to plume migration and detections from temporary well data collected in 2019. Wells 076-04 and 076-06 had previously been part of the OU IV AOC 5 VOC monitoring program but due to the change in groundwater flow may now be useful to monitor for Sr-90. Well 076-20 was originally part of the Building 650 Sr-90 program and was dropped several years ago when it was determined the plume was further to the west.
- Install two temporary wells along North Sixth Street north of Brookhaven Avenue and if significant concentrations of Sr-90 are detected follow up with permanent wells to monitor the downgradient segment of the plume. This work is contingent on access due to a concentration of underground utilities in the area.

3.4 OPERABLE UNIT V

3.4.1 OU V Monitoring Program

The Sewage Treatment Plant (STP) processes sanitary wastewater from BNL's research and support facilities. Treated effluent from the STP was discharged to the Peconic River under a NYSDEC SPDES permit until September 2014. Since October 2014, BNLs STP effluent has been discharged to groundwater recharge basins. Historically, BNL's STP received discharges of contaminants from routine operations. Releases of low-level contaminants to groundwater (in particular, VOCs, metals, and radionuclides) occurred via the STP sand filter beds and discharges to the Peconic River. The OU V program monitored the identified groundwater contamination downgradient of the STP. Following regulatory concurrence, this monitoring was completed in 2013.

Groundwater quality in the immediate vicinity of the STP is currently monitored under the Facility Monitoring Program, which is discussed in **Section 4.4** of this document.

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3.5 OPERABLE UNIT VI EDB TREATMENT SYSTEM

The OU VI EDB Treatment System addresses an EDB plume in groundwater extending from south of North Street for approximately 2,500 feet. EDB was used during the 1970s as a fumigant for the BNL Biology Department's biology fields located in the southeastern portion of the site (**Figure 3.5-1**). In 1995 and 1996, low levels of EDB were detected in groundwater near the fields. Higher levels were found migrating toward the southern site boundary and off site to the south. In addition, the depth of the plume increased within the Upper Glacial aquifer to the south. EDB has not been detected on BNL property since 2009 and on-site monitoring was discontinued in 2016.

3.5.1 System Description

A groundwater remediation system to address the off-site EDB plume began routine operations in August 2004. The OU VI EDB Treatment System consists of two extraction wells and two recharge wells. A complete description of the system is included in the *Operations and Maintenance Manual for the OU VI EDB Groundwater Treatment System* (BNL 2004c).

3.5.2 Groundwater Monitoring

Well Locations

A network of 18 wells monitor the EDB plume from North Street to locations on private property south of North Street and west of Weeks Avenue (**Figure 3.5-1**). These include two monitoring wells (000-549 and 000-550) installed in January 2019.

Sampling Frequency and Analysis

The OU VI EDB plume monitoring program is in the O&M phase (**Table 1-8**). The sampling frequency for 12 of the plume core and perimeter wells is semi-annual (**Table 1-5**). Three perimeter wells located upgradient of the plume are sampled annually. The remaining three wells are sampled quarterly. In December 2019, the monitoring frequency for wells 000-549, 000-550 and 000-500 was changed from semi-annual to quarterly to provide additional data to evaluate the rate of plume migration. The wells are analyzed for EDB using EPA Method 504. The federal DWS for EDB is 0.05 µg/L.

3.5.3 Monitoring Well Results

Appendix C contains the complete analytical results of the OU VI EDB monitoring well sampling program. The distribution of the EDB plume for the fourth quarter of 2019 is shown on **Figure 3.5-1**. The leading edge of the plume is being captured by extraction wells EW-1E and EW-2E. The plume is located in the deep Upper Glacial aquifer as depicted on cross section Q–Q' (**Figure 3.5-2)**. See **Figure 3.5-3** for historical EDB trends for key monitoring wells. A summary of key monitoring well data for 2019 follows:

- Core wells 000-283 and 000-284, located approximately 1,700 feet upgradient of the extraction wells, detected the maximum historical EDB concentrations in the plume of 7.6 µg/L and 6.8 µg/L in 2001 and 2003, respectively. These wells have seen a steady drop in EDB concentrations since 2005. However, they continue to detect values above the DWS with up to 0.14 µg/L in well 000-283 in June 2019.
- The maximum EDB concentration in the plume in 2019 was 0.41 µg/L in well 000-549. This well was installed in January 2019 as a follow-up to a temporary vertical profile well installed in December 2018. This well was installed in the centerline of the plume to enhance the monitoring of EDB upgradient of well 000-507. The EDB result is consistent with the vertical profile well data.
- In 2012, EDB concentrations in core well 000-507 reached an historical high of 1.67 µg/L. Since 2013, concentrations have dropped with a maximum EDB value of 0.14 µg/L in 2019. This well

is approximately 250 feet upgradient of extraction well EW-1E. This decline is consistent with the reduced EDB concentrations observed in upgradient core well 000-283 starting in 2007.

- EDB concentrations in all core wells upgradient of well 000-178 have declined significantly over the past several years. Upgradient wells 000-173, 000-175 and 000-209 have remained below the DWS since 2015. EDB in well 000-178 increased from late 2006 through 2012, indicating movement of the higher concentration portion of the plume south. A 2012 sample detected 4.8 µg/L of EDB, which is an historical high for this well since it was installed in 1998. Since 2012, concentrations have decreased to 0.17 µg/L in 2019. This well is approximately 1,000 feet upgradient of EW-2E.
- Core well 000-500, located downgradient of well 000-178 and approximately 250 feet upgradient of EW-2E, has detected gradually decreasing levels of EDB since December 2016. The maximum 2019 EDB concentration was 0.19 µg/L in June.
- EDB in the eastern perimeter monitoring well 000-524 remained below the DWS since it was installed in 2012. This indicates that the eastern extent of the plume continues to be captured.
- The three bypass monitoring wells have not had any confirmed detections of EDB since 2005.

The southern migration of the plume is observed by analyzing the trends on **Figure 3.5-3**. Comparing the plume's distribution from 1999 to 2018 (**Figure 3.5-4**), as well as the EDB concentrations in monitoring wells just south of North Street, helps to illustrate the southern movement of the plume as well as the reduction in plume extent. Overall, peak EDB concentrations declined from 7.6 µg/L in 2001 (in well 000-283) to 0.41 µg/L in 2019 (in recently installed well 000-549).

3.5.4 System Operational Data

The sampling frequency of the extraction wells is quarterly. In conformance with the SPDES equivalency permit, the sampling frequency for the influent and effluent is monthly. All OU VI system samples were analyzed for VOCs and EDB, and the effluent sample was analyzed weekly for pH. **Table 3.5-1** provides the effluent limitations for meeting the requirements of the SPDES equivalency permit. During 2019, equivalency permit limits were not exceeded. The system was off approximately 20% of the time for repairs and diffusion well development.

January – September 2019

The system was off March 12 for a routine carbon change-out and remained off until April 10th to develop the diffusion wells. Extraction well EW-2 was off April 17th to April 30th to replace the pump and motor. The system was shut down again from May 9th to May 26th to complete development of the diffusion wells. The system was shut off July 16th for a carbon change out and remained off until August 20th to repair and replace the PLC screen. The system ran normally for the remainder of this period. The system treated approximately 84 million gallons of water during this period.

Table 3.5-1
OU VI EDB Treatment System
2019 SPDES Equivalency Permit Levels

Parameters	Permit Limit (µg/L)	Max. Measured Value (µg/L)
pH (range)	5.0 – 8.5 SU	5.3 – 7.0 SU
ethylene dibromide	0.03	<0.02
chloroform	7.0	1.34
1,1-dichloroethene	5.0	<0.50
1,1,1-trichloroethane	5.0	<0.50
methyl chloride	5.0	<0.50
methylene chloride	5.0	<0.50

Notes:
Required sampling frequency is monthly for VOCs and weekly for pH.
SU = Standard Units

October – December 2019

The system was off Oct 10th to December 26th to replace the panel view screen and for upgrades to the control system. The system treated approximately 7 million gallons of water for this period.

Extraction Wells

During 2019, the system treated approximately 91 million gallons of water, with an average flow rate of approximately 175 gpm. **Table 2-2** contains the monthly pumping data for the two extraction wells, and **Table 3.5-2** shows the pumping rates. VOC concentrations for EW-1E (000-503) and EW-2E (000-504) are provided on **Table F-47**. In 2019, EDB was detected in all four quarterly samples in EW-2 and in two quarterly samples in EW-1. In 2019, the extraction wells had a maximum EDB detection of 0.048 µg/L in EW-2E in October, which is below the DWS. No other VOCs were detected in the extraction wells above the AWQS.

Figure 3.5-5 shows the EDB concentrations in the extraction wells over time. EDB levels in EW-1E remained relatively stable from 2008 through 2013, just above the DWS. Since then, concentrations diminished to below the DWS. EDB in EW-2E has remained steady since 2011, with detections just below the DWS.

System Influent and Effluent

EDB was detected in all of the monthly sampling events of the system influent throughout 2019, except for June. The maximum influent concentration was 0.034 µg/L. During 2019, the system effluent was below the regulatory limits specified in the SPDES equivalency permit of 0.03 µg/L (**Table 3.5-1**). Influent and effluent results are reported on **Tables F-48** and **F-49,** respectively.

Cumulative Mass Removal

No cumulative mass removal calculations were performed because of the low detections of EDB historically below the DWS in the system influent. The last influent detection exceeding the DWS was 0.07 µg/L in 2014.

3.5.5 System Evaluation

The OU VI EDB System performance can be evaluated based on decisions identified in the groundwater DQO process.

1. Is there a continuing source of contamination? If present, has the source area been remediated or controlled?
No. There is no continuing source.

2. Were unexpected levels or types of contamination detected?
There were no unexpected levels or types of contamination detected.

3. Has the downgradient migration of the plume been controlled?
Yes. The hydraulic capture of the system is operating as designed as evidenced by the low but steady EDB concentrations in the extraction wells. Based on trace detections of EDB in western perimeter well 000-498, and the lack of detections in the eastern perimeter well 000-524, the width of the plume is defined. There have been no confirmed EDB detections in bypass monitoring well 000-527 since it was installed in 2013, which ensures that the deeper portion of the plume is being captured by the extraction wells. EDB was not detected in the remaining three bypass wells since 2005. Downgradient wells 000-500, 000-507, and the bypass wells will continue to be monitored to ensure that the deeper EDB identified in 000-549 is ultimately captured by EW-2E.

4. Can individual extraction wells or the entire treatment system be shut down or placed in pulsed pumping operation?

No, the system has not met all shutdown requirements. Although EDB concentrations in EW-2E are below the DWS, the higher concentration portion of the plume is still evident near well 000-178 and newly installed well 000-549. The plume has moved slower than originally simulated in the 2000 groundwater model update. It was originally envisioned that the system would need to operate between eight to ten years. The system is operating longer because the plume is migrating slower than anticipated.

4a. Are EDB concentrations in plume core wells above or below 0.05 μg/L?
In 2019, eight of eleven plume core wells had concentrations greater than the 0.05 μg/L DWS.

4b. Is there a significant concentration rebound in core wells and/or extraction wells following shutdown?
The OU VI EDB system has not been pulsed pumped or shut down.

5. Has the groundwater cleanup goal of meeting MCLs been achieved?
No. The MCL has not been achieved for EDB based on the data from plume core wells.

3.5.6 Recommendations

The following recommendations are made for the OU VI EDB Treatment System and groundwater monitoring program:

- Maintain full time operation of the treatment system and continue quarterly sampling of the extraction wells.
- The observed migration rate for EDB is significantly slower than originally predicted during treatment system design. Contaminant migration at the base of the Deep Upper Glacial aquifer and system capture of this deep contamination also requires a re-evaluation. Assess the groundwater model geologic framework for this area and if needed, collect additional data (soil borings/gamma logs) to address any data gaps. Perform a plume migration simulation utilizing any updated data. Based on this additional data and the recently characterized deep EDB identified in wells 000-549 and 000-550, the model will better determine if the existing treatment system will remediate the EDB plume to below the DWS by 2030, as required by the OU VI ROD. If needed, the model will be used to evaluate modifications which may include additional extraction wells and/or modifications to extraction well pumping rates.

3.6 SITE BACKGROUND MONITORING

Background water quality has been monitored since 1990. Historically, low levels of VOCs were routinely detected in several background wells that are screened in the deeper portions of the Upper Glacial aquifer. Background monitoring is used to define the quality of groundwater that is completely unaffected by BNL operations.

3.6.1 Groundwater Monitoring

Well Network

The 2019 program included 10 wells in the northwestern portion of the BNL property (**Figure 1-2**) hydraulically upgradient of Laboratory operations.

Sampling Frequency and Analysis

The samples are collected annually and analyzed for VOCs (**Table 1-5**).

3.6.2 Monitoring Well Results

The complete groundwater analytical data are provided in **Appendix C**. There were low level detections of VOCs in three site background wells, which were below AWQS. The highest concentration detected was 2.2 μg/L of chloroform in well 018-01 (AWQS of 7.0 μg/L). Methyl tert-butyl ether (MTBE) was detected at a concentration of 1.1 μg/L in well 034-03 (AWQS of 10 μg/L).

While radionuclides are no longer analyzed in background wells, historic results are presented for reference purposes. **Table 3.6-1** summarizes the range of radionuclide values detected in background wells from 1996 through 2001.

Table 3.6-1.
Radiological Background Monitoring, 1996 – 2001

Parameter	Activity Range (pCi/L)	Contract-Required Detection Limit (pCi/L)
Cesium-137	<MDA to 7.24	12.0
Gross alpha	<MDA to 2.66	2.0
Gross beta	<MDA to 6.41	4.0
Strontium-90	<MDA to 3.84	0.8
Tritium	<MDA to 835	500.0

Note:
<MDA = Less than minimum detectable activity

3.6.3 Groundwater Monitoring Program Evaluation

The program can be evaluated using the decision rule developed as part of the groundwater DQO process.

1. Were unexpected levels or types of contamination detected?

No. There were no VOCs detected in site background wells above AWQS during 2019. Based on these results, there is no current impact to BNL groundwater quality from upgradient contaminant sources.

3.6.4 Recommendation

The following are recommended for the site background groundwater monitoring program:

- Discontinue sampling well 063-09 in 2020 since it was originally installed to monitor the Water Treatment Plant recharge basin that receives filter backwash water. It was previously documented that the plant operations have not impacted groundwater. Except for aluminum, iron and manganese detections above AWQS in 2001, well 063-09 has not detected any compounds exceeding AWQS since the well was installed in 1994.
- As part of the Phase 4 PFAS Work Plan, several background wells will be sampled in 2020 for emerging contaminants (PFAS and 1,4-dioxane).

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3.7 Current and Former Landfill Groundwater Monitoring

Groundwater monitoring data from both the Current and Former Landfills are discussed in detail in the *BNL 2019 Environmental Monitoring Report, Current and Former Landfill Areas* (BNL 2020a). The complete groundwater monitoring results for these programs are included in **Appendix C**.

3.7.1 Current Landfill Summary

Groundwater data shows that in general, contaminant concentrations have been decreasing following the capping of the landfill in 1995. By the end of 2019, the landfill had been capped for 24 years. Groundwater quality has been slowly improving. The trend in the data suggests that the cap is effective in mitigating groundwater contamination. Groundwater monitoring wells for the Current Landfill are shown on **Figure 3.7-1**. The following is a summary of the results from the samples collected during 2019:

- Benzene was detected in downgradient well 087-11 at concentrations slightly above the AWQS with a maximum concentration of 2.4 µg/L. The other VOCs detected above the AWQS were chloroethane and 1,1-dichloroethane (DCA) during 2019. DCA was detected in monitoring well 088-109 above the standard of 5 µg/L, with a maximum concentration of 5.3 µg/L. During 2019, chloroethane was detected above AWQS in wells 088-22, 088-109, 088-110 with concentrations ranging up to 15.1 µg/L indicating that VOCs continue to emanate from the landfill. These concentrations are naturally attenuating and are no landfill related detections at the site boundary above the drinking water standard **Figure 3.1-1**.
- Concentrations of landfill water chemistry parameters and metals such as ammonia and iron in several downgradient wells were above background values. This suggests that leachate continues to emanate from the landfill into groundwater. Ammonia was detected above the AWQS of 2 mg/L in downgradient well 087-11 at a maximum concentration of 5.2 mg/L.
- During 2019, iron and chromium in the background well, and aluminum, iron, manganese, and sodium in several downgradient wells were detected above their respective AWQS.
- Strontium-90 was the only radionuclide detected during 2019. Strontium-90 was detected below the DWS of 8 pCi/L with a concentration of 1.3 pCi/L in well 088-21. Tritium was not detected during 2019. Strontium-90 and tritium have not exceeded the DWS in the Current Landfill wells since 1998.
- Although low levels of contaminants continue to be detected, the cap has been effective at improving the quality of groundwater downgradient of the landfill.

3.7.1.1 Current Landfill Recommendations

The monitoring well network for the Current Landfill is sufficient. No changes to the network or the sampling frequency are warranted at this time.

3.7.2 Former Landfill Summary

Monitoring data shows that contaminant concentrations decreased following the capping of the landfill in 1996. Contaminant concentrations downgradient of this landfill were relatively low prior to capping. All Former Landfill Area wells are scheduled to be sampled every two years. In 2019, five wells were sampled once for Sr-90. Groundwater monitoring wells for the Former Landfill are shown on **Figure 3.7-2**. The following is a summary of the results from the samples collected during 2019:

- The trend of increasing strontium-90 concentrations, which was observed in well 097-64 from 2011 through 2016 was not observed from 2017 through 2019. The data from well 097-64 indicated a decreased strontium-90 concentration from 6.6 pCi/L in 2016 to not detect in 2019. The strontium-90 concentrations for this monitoring well have remained below the DWS of 8 pCi/L since 2000. Strontium-90 was detected in well 106-44 at a concentration of 3.2 pCi/L and has not been detected above the DWS since 2001. All remaining wells have not exceeded the DWS since 2001.

3.7.2.1 Former Landfill Recommendations

The monitoring well network and sampling schedule for the Former Landfill are sufficient. No changes are warranted at this time. A full round of monitoring will be conducted in 2020.

3.8 g-2 TRITIUM SOURCE AREA AND GROUNDWATER PLUME

In November 1999, tritium was detected in the groundwater near the former g-2 experiment within the Alternating Gradient Synchrotron facility, at concentrations above the 20,000 pCi/L DWS. Sodium-22 was also detected in the groundwater, but at concentrations well below the 400 pCi/L DWS. An investigation into the source of the contamination revealed that the tritium and sodium-22 originated from activated soil shielding located adjacent to the g-2 target building, where approximately five percent of the beam was inadvertently striking one of the beam line magnets (magnet VQ-12). Rainwater was able to infiltrate the activated soils and leach the tritium and sodium-22 into the groundwater. To prevent additional rainwater infiltration into the activated soil shielding, a concrete cap was constructed over the area in December 1999. The g-2 experiment was decommissioned in April 2001.

The g-2/BLIP/former UST ROD (BNL 2007a) requires routine inspections and maintenance of the impermeable cap, and groundwater monitoring of the source area to verify the continued effectiveness of the stormwater controls. Monitoring of the source area will continue for as long as the activated soils have the potential to impact groundwater quality. Contingency actions would be developed if tritium levels in groundwater monitoring wells exceed 1,000,000 pCi/L.

3.8.1 g-2 Tritium Source Area and Plume Groundwater Monitoring

Well Network

The g-2 tritium source area is monitored using two upgradient wells (054-65 and 054-66) and five downgradient wells (054-07, 054-126, 054-184, 054-185, and 064-95) approximately 200 feet downgradient of the source area near Building 912A. Several other nearby wells (054-67, 054-68, 054-124, 054-126 and 065-126) are used to monitor the effectiveness of the cap installed over the adjacent former g-2 beam stop, which is another area that contains activated soil shielding. Twelve wells located approximately 600 feet downgradient of the source area near Building 912 are used to verify the attenuation of tritium released from the source area (**Figure 3.8-1**).

Sampling Frequency and Analysis

During 2019, the source area wells were monitored two times, and the samples were analyzed for tritium (**Table 1-6**). The wells monitoring the former beam stop area and those located near Building 912 were sampled once during the year, and the samples were analyzed for tritium. The water samples are preferentially tested for tritium because it is more leachable than sodium-22, migrates at the same rate as groundwater, and is therefore a better indicator of the effectiveness of the cap.

3.8.2 g-2 Tritium Source Area and Plume Monitoring Well Results

The extent of the g-2 tritium plume during the fourth quarter of 2019 is depicted on **Figure 3.8-1**.

Source Area Monitoring Results

The maximum tritium concentration in source area wells was 18,600 pCi/L in well 054-07 during the fourth quarter. **Figure 3.8-2** provides tritium trend charts for wells that monitor the g-2 source area. Tritium was not detected in the wells that monitor the beam stop area.

Tritium that is traceable to the g-2 source area continues to be detected in monitoring wells located downgradient of Building 912. The maximum tritium concentration in this area was 6,230 pCi/L in a sample from well 065-122 collected during the fourth quarter.

3.8.3 g-2 Tritium Source Area and Plume Groundwater Monitoring Program Evaluation

The 2019 monitoring data were evaluated using the following DQO statements.

1. Is there a continuing source of contamination? If present, has the source been remediated or controlled?
Although the activated soil shielding remains a potential threat to groundwater quality, the overall reduction in tritium concentrations observed in the groundwater since 1999 indicates that the cap is effectively preventing rainwater from infiltrating the soil. A comparison of tritium levels in the source area monitoring wells and water-table elevation data suggests that periodic natural fluctuations in the water table continue to release residual tritium from the deep vadose zone. There appears to be good correlation between high tritium concentrations detected in monitoring wells immediately downgradient of the source area and the water-table elevation about one year before the sampling (**Figure 3.8-3** and **Figure 3.8-4**). It is believed that this tritium was mobilized to the deep vadose zone soil close to the water table before the cap was constructed in December 1999. Once the cap was in place, the lack of additional rainwater infiltration kept the tritium in the vadose zone from migrating into the groundwater until a significant rise in water table can mobilized it. Over time, the amount of tritium remaining in the vadose zone near the water table will decrease by means of the natural water table flushing mechanism and by natural radioactive decay.

2. Were unexpected levels of tritium detected?
No, the observed tritium levels in the source area monitoring wells are consistent with previous surveillance results.

3. Is the plume naturally attenuating as expected?
Yes. With the effectiveness of the source area controls, the plume segment immediately downgradient of the source area is attenuating as expected.

4. Has the groundwater cleanup goal of meeting MCLs been achieved?
No. Tritium concentrations in groundwater downgradient of the g-2 source area periodically exceed the MCL.

3.8.4 g-2 Tritium Source Area and Plume Recommendations

The following are recommended for the g-2 tritium source area and plume groundwater monitoring program:

- Continue routine inspections of the g-2 cap.
- Continue semiannual monitoring of source area wells near Building 912A, and annual monitoring of wells located downgradient of the former beam stop and Building 912.

3.9 BROOKHAVEN LINAC ISOTOPE PRODUCER (BLIP)

When the Brookhaven Linac Isotope Producer (BLIP) is operating, the Linear Accelerator (Linac) delivers a beam of protons that strike a series of metal targets positioned at the bottom of a 30-foot deep underground tank, referred to as the BLIP target vessel. The targets rest inside a water-filled, 18-inch-diameter shaft that runs the length of the tank, and are cooled by a 300-gallon, closed-loop primary cooling system. During irradiation of the targets, radionuclides are produced in the cooling water and the soil immediately outside the tank by the neutrons created at the target.

In 1998, tritium concentrations of 52,000 pCi/L and sodium-22 up to 151 pCi/L were detected in the groundwater approximately 40 feet downgradient of the BLIP target vessel. The drinking water standard for tritium is 20,000 pCi/L, and the standard for sodium-22 is 400 pCi/L. Due to the activation of the soil shielding surrounding the BLIP target vessel and the detection of tritium and sodium-22 in groundwater, the BLIP facility was designated as sub-AOC 16K under the IAG.

In 1998, BNL made improvements to the stormwater management program at BLIP in an effort to prevent rainwater infiltration into the activated soil below the building. In 2000, BNL undertook additional protective measures by injecting colloidal silica grout (also known as a Viscous Liquid Barrier) into the activated soil. The grout reduces the permeability of the soil, thus further reducing the ability of rainwater to leach tritium and sodium-22 from the activated soils should the primary stormwater controls fail.

In late 2004, BNL constructed a protective cap over the beam line that runs from the Linac to the BLIP facility. The cap was installed because direct soil measurements and beam loss calculations indicated that the tritium and sodium-22 concentrations in soils surrounding this beam line could result in stormwater leachate concentrations that exceed the criteria described in the *Accelerator Safety* SBMS (Standards Based Management System) subject area.[1] During 2015, this cap section was extended in several areas to provide protection of soil shielding that is expected to become activated following planned changes in beam line operations.

A ROD was signed in early 2007 (BNL 2007a). The ROD requires continued routine inspection and maintenance of the impermeable cap, and groundwater monitoring to verify the continued effectiveness of the stormwater controls. Maintenance of the cap and groundwater monitoring will continue for as long as the activated soils have the potential to impact groundwater quality.

3.9.1 BLIP Groundwater Monitoring

Well Network

The monitoring well network for the BLIP facility consists of one upgradient and three downgradient wells (**Figure 3.9-1**).

Sampling Frequency and Analysis

During 2019, the three wells located immediately downgradient of the BLIP facility (064-47, 064-48, 064-67) were monitored twice, and the upgradient well (064-46) was sampled once. The groundwater samples are preferentially analyzed for tritium because it is more leachable than sodium-22, it migrates at the same rate as groundwater, and is the best early indicator of a possible release (**Table 1-6**).

3.9.2 BLIP Monitoring Well Results

Monitoring results indicate that the stormwater controls are effective in preventing the release of tritium from the activated soil surrounding the BLIP target vessel. Since April 2006, tritium levels have remained below the 20,000 pCi/L DWS (**Figure 3.9-1**). During 2019, the maximum tritium

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[1] The BNL *Accelerator Safety* SBMS subject area requires stormwater controls where rainwater infiltration into activated soil shielding could result in leachate concentrations that exceed five percent of the drinking water standard for tritium (1,000 pCi/L) or 25 percent of the drinking water standard for sodium-22 (100 pCi/L).

concentration was 5,000 pCi/L in the second quarter sampling of well 064-48. The maximum tritium concentration during the fourth quarter was 1,940 pCi/L in well 064-67.

3.9.3 BLIP Groundwater Monitoring Program Evaluation

The 2019 monitoring data were evaluated using the following DQO statements.

1. Is there a continuing source of contamination? If present, has the source been remediated or controlled?

Yes, however the source is being controlled. Although low levels of tritium continue to be detected in the groundwater downgradient of BLIP, the tritium concentrations have remained below the 20,000 pCi/L DWS since early 2006. The decline in tritium concentrations indicates that the stormwater controls are effectively preventing the leaching of tritium from the activated soils.

2. Were unexpected levels of contamination detected?

No, the observed tritium levels are consistent with previous surveillance results.

3. Has the groundwater cleanup goal of meeting MCLs been achieved?

Yes. However, the activated soil shielding below the BLIP facility needs to be protected from rainwater infiltration. Therefore, the cap needs to be maintained and groundwater surveillance is required to verify the continued effectiveness of the stormwater controls.

3.9.4 BLIP Recommendation

The following is recommended for the BLIP groundwater monitoring program:

- As required by the ROD, BNL will continue to conduct routine inspections of the cap, and to monitor groundwater quality downgradient of the BLIP facility.
- No changes to the groundwater monitoring program are recommended.

3.10 CHARACTERIZATION OF 1,4-DIOXANE IN GROUNDWATER

The chemical 1,4-dioxane is an emerging contaminant of concern in areas across the United States. It has been broadly used in numerous commercial and personal care products, including as a stabilizer for the solvent 1,1,1-trichloroethane (TCA). At BNL, past releases of TCA have impacted groundwater quality in several on-site and off-site areas. Although there isn't a specific federal or NYS drinking water standard for 1,4-dioxane, the current NY State drinking water standard 50 µg/L for Unspecified Organic Contaminants would apply. It is anticipated that by the end of 2020, the NYS Department of Health will promulgate a 1.0 µg/L drinking water standard for 1,4-dioxane. To date, only a single trace level of 1,4-dioxane has been detected in samples collected from BNL's potable water supply wells.

The initial characterization of 1,4-dioxane in the groundwater at BNL followed a request from the NYSDEC to obtain baseline data for the presence or absence of this chemical. In January 2017, twenty-two on-site and off-site groundwater monitoring wells that have or had detected TCA were sampled. Seventeen of the 22 samples collected had detectable levels of 1,4-dioxane, with a maximum concentration of 18.6 µg/L in OU III Industrial Park monitoring well 000-530.

In late 2017 and early 2018, BNL collected additional samples from groundwater treatment system effluent, the Sewage Treatment Plant (STP) effluent, and from monitoring wells downgradient from the Former Landfill, the Current Landfill and the STP. The highest 1,4-dioxane concentration was 9.08 µg/L, detected in off-site monitoring well 000-122 located in the former OU V monitoring program area. 1,4-Dioxane was detected in four of the five treatment system effluent samples, with a maximum concentration of 7.14 µg/L detected in the effluent from the OU III Industrial Park Treatment System. 1,4-Dioxane was not detected in the STP effluent.

In early 2019, samples were collected from 33 permanent wells and 11 temporary wells positioned along the southern boundary (see BNL 2019). In addition to analyzing the samples for 1,4-dioxane, the samples were also tested for per- and polyfluoroalkyl substances PFAS. The highest 1,4-dioxane concentrations were detected in the OU III Western South Boundary area, with a maximum concentration of 15.2 µg/L in deep Upper Glacial monitoring well 126-18. In the OU III South Boundary area, the maximum 1,4-dioxane concentration was 6.2 µg/L in deep Upper Glacial monitoring well 121-47.

The monitoring results for 2017 through early 2019 are summarized in the *2018 Groundwater Status Report* (BNL 2019).

3.10.1 1,4-Dioxane Groundwater Monitoring

Well Network

A permanent monitoring program has not been established specifically for tracking 1,4-dioxane. As described above, since 2017 BNL has been collecting baseline 1,4-dioxane data from select on-site and off-site monitoring wells and extraction wells where TCA had been or is currently detected. As a continuation of this effort, in 2020 BNL will conduct a comprehensive sampling of approximately 350 on-site and off-site monitoring wells and five off-site treatment systems for 1,4-dioxane and PFAS. The scope of this work is described in the *Phase 4 Work Plan* (BNL 2020).

Sampling Frequency and Analysis

All 1,4-dioxane monitoring conducted during 2019 was described in the *2018 Groundwater Status Report* (BNL 2019). During 2020, BNL will sample approximately 350 on-site and off-site monitoring wells and five off-site treatment systems for 1,4-dioxane (BNL 2020). The samples will be analyzed for 1,4-dioxane using EPA Method 522.

3.10.2 Monitoring Results

The WSB extraction wells were sampled for 1,4-dioxane in September 2019. As noted above, in

2020 BNL began a comprehensive sampling of on-site and off-site monitoring wells as part of the Phase 4 Work Plan for emerging contaminants of concern. Although a separate, comprehensive report will be prepared for the Phase 4 monitoring results, data for several key areas are available for presentation in this report, and are summarized below:

3.10.2.1 OU III Western South Boundary (WSB) Area

1,4-Dioxane concentrations greater than1.0 µg/L were detected in WSB extraction wells and monitoring wells extending from Princeton Avenue (on-site) to the off-site Carleton Drive area (**Table 3.10-1, Figure 3.10-1**). Most of the WSB wells with detectable levels of 1,4-dioxane are screened in the deep portions of the Upper Glacial aquifer.

- In September 2019, 1,4-dioxane was detected in all six WSB extraction wells at concentrations above 1 µg/L, with concentrations ranging from 2.9 µg/L to 7.6 µg/L.
- The maximum 1,4-dioxane concentration on-site was 23.9 µg/L in monitoring well 119-11.
- At the site boundary the highest 1,4-dioxane concentration was 14.9 µg/L, detected in well 126-18.
- 1,4-Dioxane was detected in all three off-site monitoring wells along Carleton Drive, with a maximum concentration of 7.6 µg/L detected in well 000-558.

3.10.2.2 OU III Industrial Park/Industrial Park East (IP/IPE) Area

1,4-Dioxane was detected in most of the IP/IPE area monitoring wells and extraction wells (**Table 3.10-2, Figure 3.10-2**). These wells are screened in the deep portions of the Upper Glacial aquifer.

- The maximum 1,4-dioxane concentration in the IP/IPE monitoring wells was 6.7 µg/L in monitoring well 000-530. The 1,4-dioxane concentration in this same well was 18.6 µg/L when it was sampled in 2017.
- The maximum 1,4-dioxane concentration in the IP extraction wells was 4.3 µg/L in IP-EW-9.

3.10.2.3 Sewage Treatment Plant (STP) and Downgradient OU V Areas

Low concentrations of 1,4-dioxane were detected in several shallow monitoring wells near the former filter beds and the current recharge basins, and at higher levels in deep Upper Glacial wells located along the site boundary and several off-site locations (**Table 3.10-3, Figure 3.10-3**).

- In shallow Upper Glacial wells in the STP area, the maximum 1,4-dioxane concentration was 0.39 µg/L in well 048-08.
- The maximum 1,4-dioxane concentration at the site boundary was 2.2 µg/L in deep Upper Glacial well 050-01.
- In off-site areas, 1,4-dioxane was detected in deep Upper Glacial wells 000-122 and 000-123, at 5.4 µg/L and 7 µg/L, respectively. In the remaining off-site wells, 1-4-dioxane was either not detected or found at only trace levels.

3.10.3 1,4-Dioxane Groundwater Monitoring Program Evaluation

The monitoring data were evaluated using the following general DQO statement.

<u>*1. Is there a continuing source of 1,4-dioxane contamination? If present, has the source been remediated or controlled?*</u>

BNL is still in the early stages of the 1,4-dioxane characterization effort, and the need to remediate the contaminated groundwater will be determined once federal or state drinking water standards have been established and following discussions with the regulatory agencies. The 1,4-dioxane detected in groundwater is likely to have originated from the previously identified VOC source areas where the solvent TCA had been released. These source areas have been undergoing various remediation efforts for the past 20 years, and significant progress has been made in reducing or eliminating continued contaminant releases from these areas. The concentrations of 1,4-dioxane detected to date do not exceed the current New York State standard of 50 µg/L for Unspecified Organic Contaminants.

3.10.4 1,4-Dioxane Monitoring Recommendations

The following are recommended for the 1,4-dioxane monitoring program:

- Complete the Phase 4 Work Plan (BNL 2020a) for the comprehensive sampling of approximately 350 on-site and off-site monitoring wells and five off-site groundwater treatment systems.
- Complete the Phase 5 Work Plan (BNL 2020b) for detailed characterization of the high concentration segments of the PFAS plumes associated with BNL's current and former firehouse facilities. Select sample locations/sample intervals will also be tested for 1,4-dioxane.

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3.11 CHARACTERIZATION OF PFAS IN GROUNDWATER

Per- and Polyfluoroalkyl Substances (PFAS) are emerging contaminants of concern across the United States. Although PFAS have been used in a wide variety of industrial processes and commercial products, at BNL the impact that PFAS is having on groundwater quality is the result of the past use and handling of Class B firefighting foam that contained fluorinated surfactants. Although currently there are no specific federal or NYS drinking water standards for PFAS, the US EPA has established a Lifetime Health Advisory Level (HAL) of 70 ng/L for the combined concentrations of two PFAS compounds, perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA). Furthermore, it is anticipated that by the end of 2020, the NYS Department of Health will promulgate individual drinking water standards of 10 ng/L for PFOS and PFOA.

In 2017, the BNL potable water supply wells were sampled for PFAS for the first time. The samples were collected by the Suffolk County Department of Health Services and were analyzed for the same six PFAS compounds that were evaluated under the Third Unregulated Contaminant Monitoring Rule (UCMR3) program. PFAS were detected in samples from three of the five BNL potable supply wells (potable wells 6, 10 and 11). Following these detections, BNL searched available records on the use of firefighting foam at the site. This effort identified eight areas where foam had been released to the ground during the period of 1966 through 2008 (BNL 2019). To determine whether foam releases at these eight areas had impacted groundwater quality, BNL began a multiphase characterization effort:

Phase 1: In May 2018, BNL installed seven temporary (Geoprobe®) wells to characterize the distribution of PFAS within the 2-year (travel time) source water contributing areas of the BNL supply wells (BNL 2018c). The primary goal of the effort was to determine whether PFAS concentrations in the source water contributing areas are at high enough levels to potentially affect future supply well operations.

Phase 2: From August through November 2018, thirty temporary groundwater monitoring wells were installed in the eight areas where firefighting foam had been released to soil (BNL 2018d).

Phase 3: From December 2018 through January 2019, BNL collected samples from on-site groundwater treatment systems, in groundwater downgradient of two closed landfills, in the Sewage Treatment Plant (STP) effluent, and in select Operable Unit V monitoring wells located downgradient of the STP (BNL 2018e). As an addendum to the Phase 3 Work Plan, in February 2019 BNL sampled 33 existing monitoring wells and installed 11 temporary wells positioned along the southern site boundary (BNL 2019a).

The monitoring results for 2018 through early 2019 are summarized in the 2019 *Groundwater Status Report* (BNL 2019). The characterization conducted to date has shown that PFOS and PFOA concentrations exceed the proposed 10 ng/L DWS for PFOS and PFOA in all eight known foam release areas, and in the shallow groundwater near the STP and Current Landfill areas. The highest PFOS and PFOA concentrations were detected near the Laboratory's current firehouse area, with concentrations of 12,200 ng/L and 240 ng/L, respectively. The site with the second highest PFOS and PFOA concentrations was the former firehouse area, with concentrations of 5,210 ng/L and 736 ng/L, respectively. PFOS and PFOA were also detected at concentrations greater than10 ng/L in permanent and temporary monitoring wells positioned along the southern boundary, and in one off-site monitoring well located to the southeast of the Laboratory.

3.11.1 PFAS Groundwater Monitoring

Well Network

A permanent monitoring program has not been established specifically for tracking PFAS. As described above, since 2018 BNL has been characterizing the extent of PFAS using available permanent wells and by installing temporary wells in known firefighting foam release areas and in areas downgradient of the release areas. As a continuation of this effort, in 2020 BNL is conducting a comprehensive sampling of approximately 350 on-site and off-site monitoring wells and five off-site treatment systems for PFAS and 1,4-dioxane. The scope of this work is described in the *Phase 4 Work Plan* (BNL 2020).

Sampling Frequency and Analysis

All PFAS monitoring conducted during 2019 are described in the *2018 Groundwater Status Report* (BNL 2019). During 2020, BNL is sampling approximately 350 on-site and off-site monitoring wells and five off-site treatment systems for PFAS (BNL 2020). The groundwater samples will be analyzed by EPA Method 537.1 for 23 PFAS compounds.

3.11.2 Preliminary Phase 4 Monitoring Results

Although a separate, comprehensive report will be prepared for the Phase 4 monitoring results, available data for several key areas is summarized below:

3.11.2.1 OU III Western South Boundary (WSB) Area

Although low levels of PFAS were detected in several WSB monitoring wells, only one well had PFOS or PFOA at a concentration >10 ng/L (**Table 3.11-1**, **Figure 3.11-1**). Most of the WSB wells are screened in the deep portions of the Upper Glacial aquifer.

- In the on-site wells, the highest PFOS concentration was detected in monitoring well 103-10 at a concentration of 13.6 ng/L. The highest PFOA concentration was detected in well 111-15 at a concentration of 6.4 ng/L.
- In off-site monitoring wells, the highest PFOS and PFOA concentrations were detected in monitoring well 127-07 at concentrations of 4.1 ng/L and 2 ng/L, respectively. Neither PFOS or PFOA were detected in the three off-site wells along Carleton Drive.

3.11.2.2 OU III Industrial Park/Industrial Park East (IP/IPE) Area

Although PFAS were detected in most of the IP/IPE area monitoring wells and extraction wells, only one well had a PFOS concentration greater than 10 ng/L (**Table 3.11-2**, **Figure 3.11-2**). These wells are screened in the deep portions of the Upper Glacial aquifer or upper portions of the Magothy aquifer.

- The highest PFOS and PFOA concentrations were detected in IP extraction well UVB-4 at 18.1 and 4.35 ng/L, respectively. This well is screened in the deep Upper Glacial aquifer.
- In IP/IPE monitoring wells, the highest PFOS concentration was 9.56 ng/L in well 000-265, and the highest PFOA concentration was 3.83 ng/L in well 000-529.

3.11.2.3 Sewage Treatment Plant (STP) and Downgradient OU V Areas

In the STP area, PFOS and PFOA were detected at concentrations greater than 10 ng/L in a number of shallow monitoring wells near former filter beds and the current water recharge basins, and in deep Upper Glacial aquifer wells located along the site boundary and several off-site locations (**Table 3.11-3**, **Figure 3.11-3**).

- In shallow Upper Glacial wells in the STP area, the highest PFOS concentration was detected in well 039-08 at 152 ng/L. The highest PFOA concentration was detected in well 039-87 at 39.3 ng/L.

- At the site boundary, the highest PFOS and PFOA concentrations were detected in deep Upper Glacial well 061-05 at 82.7 ng/L and 18 ng/L, respectively.
- In off-site areas, the highest PFOS concentration was detected in deep Upper Glacial well 000-122 at 28.1 ng/L, and the highest PFOA concentration was 41 ng/L in upper Magothy well 600-24.

3.11.3 PFAS Groundwater Monitoring Program Evaluation

The 2019 monitoring data were evaluated using the following general DQO statement.

1. Is there a continuing source of PFAS contamination? If present, has the source been remediated or controlled?

PFAS are detected in the groundwater downgradient of the eight identified firefighting foam release areas and in the STP area at concentrations that would exceed the proposed 10 ng/L DWS (BNL 2019). Impacts from PFAS releases have also been identified at the STP and the Current Landfill. The persistent, long-term impacts to soil and groundwater quality from the release of firefighting foam at BNL has been clearly demonstrated by the sampling conducted to date. BNL is still in the early stages of the PFAS characterization effort. The need for source controls and remediation of contaminated groundwater will be determined once federal or state drinking water standards have been established, and following discussions with the regulatory agencies.

3.11.4 PFAS Monitoring Recommendations

The following are recommended for the PFAS monitoring program for 2020:

- Complete the Phase 4 Work Plan (BNL 2020a) for the comprehensive sampling of approximately 350 on-site and off-site monitoring wells and five off-site groundwater treatment systems. Because most of the monitoring wells will be sampled with existing Teflon®-containing pumps and discharge tubing, collect additional samples using Teflon®-free equipment from select wells that have unexpected levels of PFAS.
- Complete the Phase 5 Work Plan (BNL 2020b) for detailed characterization of the high concentration segments of the PFAS plumes associated with BNL’s current and former firehouse facilities. Select sample locations/sample intervals will also be tested for 1,4-dioxane.

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4.0 FACILITY MONITORING PROGRAM SUMMARY

During 2019, the Facility Monitoring Program at BNL monitored groundwater quality at 12 research and support facilities. New York State operating permits require groundwater monitoring at the Major Petroleum Facility, Waste Management Facility, and the Sewage Treatment Plant; the remaining research and support facilities are monitored in accordance with DOE Orders 458.1 (Radiation Protection of the Public and the Environment) and 436.1 (Departmental Sustainability) or CERCLA Records of Decision. DOE Orders require the Laboratory to establish environmental monitoring programs at facilities that can potentially impact environmental quality, and to demonstrate compliance with DOE requirements and the applicable federal, state, and local laws and regulations. CERCLA Records of Decision define the monitoring requirements and remedial actions for the Building 452 Freon-11 plume, g-2 tritium source area and plume, and the BLIP source area. BNL uses monitoring data to determine whether current engineered and administrative controls effectively protect groundwater quality, determine whether additional corrective actions are needed, and to determine the effectiveness of remedial actions.

During 2019, 91 groundwater monitoring wells were sampled during 121 sampling events for facility surveillance required by state operating permits and DOE Orders. Twenty facility wells were also sampled during 30 monitoring events for compliance with CERCLA monitoring requirements for the g-2 Tritium Source Area and Plume, BLIP facility, and the Building 452 Freon-11 Groundwater Treatment System. **Table 1-6** summarizes the Facility Monitoring Program by project. Complete analytical results from groundwater samples collected in 2019 are provided in **Appendix D**. Monitoring results for the Building 452 Freon-11 plume, g-2 source area and tritium plume, and BLIP source area are presented in **Sections 3.2.2, 3.8, and 3.9**, respectively. Information on groundwater quality at each of the remaining monitored research and support facilities is described below.

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4.1 ALTERNATING GRADIENT SYNCHROTRON (AGS) COMPLEX

The structures that constitute the AGS Complex include the AGS Ring, Linear Accelerator (Linac), BLIP, Building 912, AGS Booster Beam Stop, 914 Transfer Tunnel, former g-2 experimental area, former E-20 Catcher, former U-Line Beam Target, and the J-10 Beam Stop. Activated soil has been created near a number of these areas as the result of secondary particles (primarily neutrons) produced at beam targets and beam stops. A number of radionuclides can be produced by the interaction of secondary particles with the soil that surrounds these experimental areas. Once produced in the soils, some of these radionuclides can be leached from the soils by rainwater, and carried to the groundwater. Of the radionuclides formed in the soil, only tritium (half-life = 12.3 years) and sodium-22 (half-life = 2.6 years) are detected in groundwater. Of these two radionuclides, tritium is more easily leached from activated soils by rainwater, and once tritium enters the water table it migrates at the same rate as groundwater flow (approximately 0.75 feet per day). Sodium-22 does not leach out of the soil as readily as tritium, and migrates at a slower rate in the aquifer. The DWS for tritium is 20,000 pCi/L, and the standard for sodium-22 is 400 pCi/L.

To prevent rainwater from leaching these radionuclides from the soil, impermeable caps have been constructed over the activated soil shielding areas that have the potential to impact groundwater quality. Specifications for evaluating potential impacts to groundwater quality and the need for impermeable caps over beam loss areas are defined in the BNL *Accelerator Safety* subject area.[1] BNL uses 57 groundwater monitoring wells to evaluate the impact of current and historical operations at the AGS beam stop and target areas, and an additional 14 wells to monitor beam loss areas associated with the Relativistic Heavy Ion Collider (RHIC) (discussed in **Section 4.2**). The locations of monitoring wells are shown on **Figure 4.1-1**. The wells are routinely monitored for tritium because it is the best early indicator of a possible release because tritium is more leachable than sodium-22, and it migrates at the same rate as groundwater.

In the late 1990’s, BNL detected four tritium plumes that originated from activated soil shielding within the AGS complex: the former g-2 experimental area (**Section 3.8**), the BLIP facility (**Section 3.9**), the former U-Line beam stop (**Section 4.1.8**), and the former E-20 Catcher (**Section 4.1.4**). The subsequent installation of impermeable caps over these soil activation areas resulted in a reduction of tritium levels to less than the 20,000 pCi/L DWS in the BLIP, former U-Line beam stop, and E-20 Catcher areas. Tritium continues to be periodically detected downgradient of the g-2 soil activation area at concentrations that exceed 20,000 pCi/L.

4.1.1 AGS Building 912

Building 912 consists of five interconnected structures that were used to house four experimental beam lines (A, B, C, and D lines). These beam line operations ended in 2002.

Beam losses at the target areas resulted in the activation of the adjacent floor, and probably the soil beneath the floor. The highest levels of soil activation beneath Building 912 are expected at the former C-Line target cave. Stormwater infiltration around the building is controlled by paving and stormwater drainage systems that direct most of the water to recharge basins located north of the AGS complex.

4.1.1.1 AGS Building 912 Groundwater Monitoring

Well Network

Twenty-three shallow Upper Glacial aquifer wells are positioned upgradient and downgradient of Building 912 (**Figure 4.1-1**). Upgradient wells are positioned to monitor potential tritium contamination from sources such as the g-2 area and the former U-Line experimental area. The downgradient wells are

[1] The BNL *Accelerator Safety* SBMS subject area requires stormwater controls where rainwater infiltration into activated soil shielding could result in leachate concentrations that exceed five percent of the drinking water standard for tritium (i.e., 1,000 pCi/L) or 25 percent of the drinking water standard for sodium-22 (i.e., 100 pCi/L).

positioned to monitor the significant (former) beam stop and target areas in Building 912. Some of the downgradient wells are also used to track the leading edge of the g-2 tritium plume that has migrated underneath Building 912 (**Section 3.8**).

Sampling Frequency and Analysis

During 2019, the Building 912 wells were sampled one time. The groundwater samples were analyzed for tritium (**Table 1-6**).

4.1.1.2 AGS Building 912 Monitoring Well Results

As in past years, tritium that is traceable to the g-2 source area continues to be detected in some of the wells located downgradient of Building 912 (**Figure 4.1-1**). During 2019, tritium from the g-2 plume was detected in four wells (065-122, 065-322, 065-323 and 065-324), with a maximum concentration of 6,230 pCi/L detected in the sample collected from well 065-122. Tritium was not detected in the groundwater samples collected from the remainder of the Building 912 area wells.

4.1.1.3 AGS Building 912 Groundwater Monitoring Program Evaluation

The 2019 monitoring data were evaluated using the following Data Quality Objective statement.

1. Is there a continuing source of contamination? If present, has the source been remediated or controlled?

Activated soils are present below the floor slab at Building 912. Other than tritium associated with the g-2 tritium plume, there were no detections of tritium that could be directly linked to activated soil located at Building 912. This indicates that the building and associated stormwater management operations are effectively preventing rainwater infiltration into the activated soil below the experimental hall.

4.1.1.4 AGS Building 912 Recommendations

The following is recommended for the AGS Building 912 groundwater monitoring program:

- For 2020, continue sampling all Building 912 monitoring wells annually.

4.1.2 AGS Booster Beam Stop

The AGS Booster is a circular accelerator that is connected to the northwest portion of the main AGS Ring and to the Linac. The AGS Booster, which has been in operation since 1994, is used to accelerate protons and heavy ions before injecting them into the main AGS ring. In order to dispose of the beam during studies, a beam stop system was originally constructed at the 10 to 11 o'clock portion of the Booster. In 1999, the beam stop was repositioned to the south side (6 o'clock section) of the Booster ring to allow for the construction of the NASA Space Radiation Laboratory (NSRL) tunnel. A geomembrane cap was constructed over the original beam stop region to prevent stormwater infiltration into the activated soil. When the beam stop was repositioned to the 6 o'clock region of the Booster, a coated concrete cap was constructed over the area.

4.1.2.1 AGS Booster Groundwater Monitoring

Well Network

Two shallow Upper Glacial aquifer monitoring wells (064-51 and 064-52) are used to monitor the Booster beam stop area (**Figure 4.1-1**).

Sampling Frequency and Analysis

Due to access restrictions while the accelerator was in operation during the planned fourth quarter monitoring period, sampling of the Booster area wells was postponed until February 2020. The samples were analyzed for tritium (**Table 1-6**).

4.1.2.2 AGS Booster Monitoring Well Results

Although low levels of tritium were detected in the Booster area wells during 2001 and 2002 (up to 1,340 pCi/L in well 064-52), tritium has not been detected in these wells since that time at concentrations above the typical 300 pCi/L method detection limit (**Figure 4.1-2**).

4.1.2.3 AGS Booster Groundwater Monitoring Program Evaluation

The groundwater monitoring results were evaluated using the following Data Quality Objective statement.

1. Is there a continuing source of contamination? If present, has the source been remediated or controlled?
Activated soil shielding is present in the areas of the current and former Booster beam stops. The low levels of tritium detected in groundwater during 2001 and 2002 were related to a short-term uncovering of activated soil shielding near the former booster beam stop during the construction of the tunnel leading from the Booster to the NSRL facility. This work, which began in September 1999 and was completed by October 1999, allowed rainwater to infiltrate the low-level activated soil shielding.[2] Because tritium has not been detected in the Booster area monitoring wells since 2002, it is apparent that the caps have been effectively preventing rainwater infiltration into the activated soil shielding.

4.1.2.4 AGS Booster Recommendation

The following is recommended for the AGS Booster groundwater monitoring program:

- For 2020, the monitoring frequency for the Booster area monitoring wells will continue to be annually.

4.1.3 NASA Space Radiation Laboratory (NSRL)

The NSRL is jointly managed by the U.S. Department of Energy and NASA's Johnson Space Center. The NSRL uses beams of heavy ions extracted from Booster accelerator for radiobiology studies. NSRL became operational in 2003. Although the secondary particle interactions with the surrounding soil shielding are expected to result in only a minor level of soil activation, a geomembrane cap was constructed over the entire length of the beam line and the beam stop region to prevent stormwater infiltration into the soil shielding.

4.1.3.1 NSRL Groundwater Monitoring

Well Network

This facility is monitored by shallow Upper Glacial aquifer monitoring wells 054-08, 054-62 and 054-191 (**Figure 4.1-1**).

Sampling Frequency and Analysis

During 2019, the NSRL monitoring wells 054-62 and 054-191 were sampled one time. Due to access restrictions while the accelerator was in operation during the planned fourth quarter monitoring period, sampling of well 054-08 was postponed until February 2020. The samples were analyzed for tritium (**Table 1-6**).

4.1.3.2 NSRL Monitoring Well Results

During 2019, tritium was not detected in the NSRL monitoring wells 054-62 and 054-191. Tritium was not detected in the February 2020 sample from well 054-08.

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[2] Before construction of the NSRL tunnel commenced, soil samples were collected by drilling through the tunnel wall near the former booster beam stop to verify that the tritium and sodium-22 levels were within acceptable limits for worker safety and environmental protection.

4.1.3.3 NSRL Groundwater Monitoring Program Evaluation
The groundwater monitoring results were evaluated using the following Data Quality Objective statement.

1. Is there a continuing source of contamination? If present, has the source been remediated or controlled?
Activated soil shielding at the NSRL is being protected by an impermeable cap. Based on monitoring conducted to date, NSRL beam line operations have not impacted groundwater quality in the area.

4.1.3.4 NSRL Recommendation
The following is recommended for the NSRL groundwater monitoring program:

- For 2020, the monitoring frequency for the NSRL wells will continue to be annually.

4.1.4 Former AGS E-20 Catcher
The E-20 Catcher was in operation from 1984 to 1999, and was located at the 5 o'clock position of the AGS ring (**Figure 4.1-1**). The E-20 Catcher was used to pick up or "scrape" protons that moved out of acceptable pathways.

Following the installation of monitoring wells in late 1999 and early 2000, tritium and sodium-22 were detected at levels greater than their applicable DWS, with concentrations up to 40,400 pCi/L and 704 pCi/L, respectively. In April 2000, a temporary impermeable cap was installed over the E-20 Catcher area, and a permanent cap was constructed by October 2000. Tritium and sodium-22 concentrations in groundwater dropped to below the DWS soon after the cap was installed.

4.1.4.1 Former AGS E-20 Catcher Groundwater Monitoring

Well Network
To verify the continued effectiveness of the impermeable cap over the former E-20 Catcher, the area is monitored by three shallow Upper Glacial aquifer wells (064-55, 064-56, and 064-80) (**Figure 4.1-1**).

Sampling Frequency and Analysis
During 2019, the former E-20 Catcher wells were monitored one time, and the samples were analyzed for tritium (**Table 1-6**). Since 2002, groundwater samples from this area have only been analyzed for tritium.

4.1.4.2 Former AGS E-20 Catcher Monitoring Well Results
Following the installation of the cap in 2000, tritium and sodium-22 concentrations decreased to levels below applicable DWS. During 2019, tritium was detected only in well 064-80, at a concentration of 721 pCi/L (**Figure 4.1-3**).

4.1.4.3 Former AGS E-20 Catcher Groundwater Monitoring Program Evaluation
The 2019 monitoring data were evaluated using the following Data Quality Objective statement.

1. Is there a continuing source of contamination? If present, has the source been remediated or controlled?
Activated soil shielding at the former E-20 Catcher is being protected by an impermeable cap. The reduction in tritium concentrations since the impermeable cap was constructed in 2000 indicates that the cap has been effective in preventing rainwater infiltration into the activated soil that surrounds this portion of the AGS tunnel.

4.1.4.4 Former AGS E-20 Catcher Recommendation

The following is recommended for the AGS E-20 Catcher groundwater monitoring program:

- For 2020, the monitoring frequency for the former E-20 Catcher wells will continue to be annually.

4.1.5 AGS Building 914

Building 914 houses the beam transfer line between the AGS Ring and the Booster. Due to beam loss near the facility's extraction (kicker) magnet, the extraction area of Building 914 is heavily shielded with iron. Because the extraction area is housed in a large building, most soil activation is expected to be below the floor of the building, where it is protected from rainwater infiltration.

4.1.5.1 AGS Building 914 Groundwater Monitoring

Well Network

Groundwater quality downgradient of the AGS Building 914 transfer line area is monitored by shallow Upper Glacial aquifer wells 064-03, 064-53, and 064-54 (**Figure 4.1-1**).

Sampling Frequency and Analysis

During 2019, the AGS Building 914 area wells were monitored one time, and samples were analyzed for tritium (**Table 1-6**).

4.1.5.2 AGS Building 914 Monitoring Well Results

Tritium was not detected in the samples collected during 2019, and has not been detected in the Building 914 groundwater monitoring wells since 2008 (**Figure 4.1-4**).

4.1.5.3 AGS Building 914 Groundwater Monitoring Program Evaluation

The 2019 monitoring data were evaluated using the following Data Quality Objective statement.

1. Is there a continuing source of contamination? If present, has the source been remediated or controlled?

The lack of detectable levels of tritium since 2008 indicates that the building structure and associated stormwater controls are effectively preventing rainwater infiltration into activated soil below the building. Continued surveillance of groundwater quality in the Building 914 area is required.

4.1.5.4 AGS Building 914 Recommendation

The following is recommended for the AGS Building 914 groundwater monitoring program:

- For 2020, the monitoring frequency for the AGS Building 914 area wells will continue to be annually.

4.1.6 Former g-2 Beam Stop

The g-2 experiment operated from April 1997 until April 2001. The g-2 Beam Stop is composed of iron and is covered by soil shielding. To prevent rainwater from infiltrating the soil surrounding the beam stop, BNL installed a gunite cap over the stop area before the start of beam line operations.

In November 1999, tritium and sodium-22 were detected in groundwater monitoring wells approximately 200 feet downgradient of the g-2 beam stop area (see **Section 3.8**). An investigation into the source of the contamination revealed that the tritium originated from activated soil shielding adjacent to the g-2 beam stop. This section of the beam line was not a designed beam loss area, and therefore was not protected by the gunite cap installed over the beam stop. In December 1999, an impermeable cap was installed over the activated soil shielding, and joined to the beam stop cap. The monitoring program for the g-2 tritium source area and plume are described in **Section 3.8**.

4.1.6.1 Former g-2 Beam Stop Groundwater Monitoring

Well Network

Groundwater quality downgradient of the former g-2 beam stop is monitored using wells 054-67, 054-124, 054-125, and 054-126 (**Figure 4.1-1**). These wells are cross gradient of the g-2 tritium source area monitoring wells described in **Section 3.8**.

Sampling Frequency and Analysis

During 2019, former g-2 Beam Stop wells 054-67 and 054-125 were monitored once, and the samples were analyzed for tritium. Wells 054-124 and 054-126 were sampled twice for tritium under the g-2 tritium plume source area program (**Table 1-6**).

4.1.6.2 Former g-2 Beam Stop Monitoring Well Results

During 2019, tritium was not detected in any of the wells.

4.1.6.3 Former g-2 Beam Stop Groundwater Monitoring Program Evaluation

The 2019 monitoring data were evaluated using the following Data Quality Objective statement.

1. Is there a continuing source of contamination? If present, has the source been remediated or controlled?

Overall monitoring results for the past 23 years indicate that the cap over the former beam stop is effectively preventing rainwater from infiltrating the activated soil shielding.

4.1.6.4 Former g-2 Beam Stop Recommendation

The following is recommended for the former g-2 beam stop groundwater monitoring program:

- During 2020, g-2 beam stop area wells 054-67 and 054-125 will continue to be monitored on an annual basis, whereas wells 054-124 and 054-126 will continue to be monitored semiannually under the g-2 tritium plume source area program.

4.1.7 AGS J-10 Beam Stop

In 1998, BNL established a beam stop at the J-10 (12 o'clock) section of the AGS Ring, replacing the E-20 Catcher as the preferred repository for any beam that might be lost in the AGS Ring (**Figure 4.1-1**). The J-10 beam stop area of the AGS Ring is covered by layers of soil-crete (a sand and concrete mixture), which reduce the ability of rainwater to infiltrate the potentially activated soil shielding. A gunite cap was constructed over a small section of the J-10 region that did not have a soil-crete cover before beam stop operations began.

4.1.7.1 AGS J-10 Beam Stop Groundwater Monitoring

Well Network

The monitoring well network for the J-10 beam stop consists of downgradient wells 054-63 and 054-64 (**Figure 4.1-1**).

Sampling Frequency and Analysis

During 2019, the J-10 beam stop wells were monitored one time and the samples were analyzed for tritium (**Table 1-6**).

4.1.7.2 AGS J-10 Beam Stop Monitoring Well Results

Although tritium had not been detected in the J-10 area wells since 2010, in 2019 a trace level of tritium was detected in well 054-65 at 383+/-246 pCi/L, with an MDL of 373 pCi/L (**Figure 4.1-5**).

4.1.7.3 AGS J-10 Beam Stop Monitoring Program Evaluation

The 2019 monitoring data were evaluated using the following Data Quality Objective statement.

1. Is there a continuing source of contamination? If present, has the source been remediated or controlled?

Groundwater monitoring results indicate that the engineered controls in place at J-10 are preventing significant rainwater infiltration into the activated soil shielding. Continued groundwater monitoring is required to verify the long-term effectiveness of the controls.

4.1.7.4 AGS J-10 Beam Stop Recommendation

The following is recommended for the AGS J-10 Beam Stop groundwater monitoring program:

- During 2020, the J-10 Beam Stop area wells will continue to be sampled on an annual basis.

4.1.8 Former AGS U-Line Beam Target and Stop Areas

The U-Line beam target area was in operation from 1974 through 1986. The entire assembly was in a ground-level tunnel covered with an earthen berm. Although the U-Line beam target has not been in operation since 1986, the associated tunnel, shielding, and overlying soil remain in place.

In late 1999, BNL installed monitoring wells downgradient of the former U-Line target area to evaluate whether residual activated soil shielding was impacting groundwater quality. Low levels of tritium and sodium-22 were detected, but at concentrations well below the applicable DWS. In early 2000, temporary wells were installed 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. During 2000, an impermeable cap was installed over the former U-Line beam stop area to prevent rainwater infiltration and the continued leaching of radionuclides out of the soil shielding.

4.1.8.1 Former AGS U-Line Groundwater Monitoring

Well Network

The former U-Line area is monitored by one upgradient well (054-127), three downgradient wells that monitor the former U-Line target area (054-66, 054-129, and 054-130), and three wells that monitor downgradient of the former U-Line beam stop area (054-128, 054-168, and 054-169) (**Figure 4.1-1**).

Sampling Frequency and Analysis

During 2019, the former U-Line area wells were monitored one time, and the samples were analyzed for tritium (**Table 1-6**).

4.1.8.2 Former AGS U-Line Groundwater Monitoring Well Results

Former U-Line Target Area

During 2019, tritium was not detected in the former U-Line Target area wells (**Figure 4.1-6**).

Former U-Line Beam Stop Area

Tritium has not been detected in the former U-Line Beam Stop area wells since 2011 (**Figure 4.1-7**).

4.1.8.3 Former AGS U-Line Groundwater Monitoring Program Evaluation

The 2019 monitoring data were evaluated using the following Data Quality Objective statement.

1. Is there a continuing source of contamination? If present, has the source been remediated or controlled?

The significant decrease in tritium concentrations in groundwater since 2000 indicates that the impermeable cap installed over the former U-Line Beam Stop has been effective in stopping rainwater infiltration into the residual activated soil.

4.1.8.4 Former AGS U-Line Recommendation

The following is recommended for the former AGS U-Line groundwater monitoring program:

- For 2020, the former U-Line area wells will continue to be monitored for tritium on an annual basis.

4.2 RELATIVISTIC HEAVY ION COLLIDER (RHIC)

Beam line interactions at the Relativistic Heavy Ion Collider (RHIC) Collimators and Beam Stops produce secondary particles that interact with soil surrounding the 8 o'clock and 10 o'clock portions of the RHIC tunnel and the W-Line Stop (**Figure 4.2-1**). These interactions can result in the production of tritium and sodium-22 in the nearby soil shielding, which can be leached out of the soil by rainwater. Although the level of soil activation is expected to be minor, before RHIC operations began in 2000 BNL installed impermeable caps over these beam loss areas to prevent potential impact to groundwater quality.

4.2.1 RHIC Groundwater Monitoring

Well Network

Thirteen shallow wells are used to verify that the impermeable caps at the RHIC beam stops and collimators are effective in protecting groundwater quality. Six of the monitoring wells are located in the 10 o'clock beam stop area, six wells are in the collimator area, and one well is downgradient of the W-Line Beam Stop (**Figure 4.2-1**). As part of BNL's Environmental Surveillance program, surface water samples are also collected semiannually from the Peconic River downstream of the beam stop area at sample location HV (sample location 026-03). These monitoring results are used to verify that potentially contaminated groundwater is not entering the Peconic River stream bed as base flow during high water-table conditions.

Sampling Frequency and Analysis

During 2019, groundwater samples were collected from the RHIC monitoring wells on a semiannual schedule, and the samples were analyzed for tritium (**Table 1-6**). Routine analysis for sodium-22 was discontinued starting in 2002 because tritium is the best indicator of possible cap failure (i.e., tritium is more leachable than sodium-22, and it migrates at the same rate as groundwater). Semiannual surface water samples collected at location HV were analyzed for tritium and by gamma spectroscopy.

4.2.2 RHIC Monitoring Well Results

During 2019, tritium was not detected in any of the RHIC monitoring wells. Furthermore, neither tritium or sodium-22 were detected in the two surface water samples collected from downstream location HV.

4.2.3 RHIC Groundwater Monitoring Program Evaluation

The 2019 monitoring data were evaluated using the following Data Quality Objective statement.

<u>1. Has the source of potential contamination been controlled?</u>

Groundwater and surface water monitoring data continue to demonstrate that the impermeable caps installed over the RHIC beam stop and collimator areas are effectively preventing rainwater infiltration into the activated soil shielding.

4.2.4 RHIC Recommendation

The following is recommended for the RHIC groundwater monitoring program:

- During 2020, groundwater samples will continue to be collected on a semiannual basis. Surface water samples will also continue to be collected as part of the Environmental Surveillance program.

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4.3 BROOKHAVEN MEDICAL RESEARCH REACTOR (BMRR)

The Brookhaven Medical Research Reactor (BMRR) was a 3-megawatt light water reactor used for biomedical research. Research operations at the BMRR ended in December 2000. All fuel was removed in 2003 and the primary cooling water system was drained.

When it was operating, the BMRR primary cooling water system contained 2,550 gallons of water that contained approximately 5 curies (Ci) of tritium. Unlike the HFBR, the BMRR did not have a spent fuel storage canal or pressurized imbedded piping systems that contained radioactive liquids. Historically, fuel elements that required storage were either stored within the reactor vessel, or they were transferred to the HFBR spent fuel canal. The BMRR primary cooling water system piping is fully exposed in the containment structure, and was accessible for routine visual inspections while it was operating.

In 1997, tritium was detected in groundwater directly downgradient (within 30 feet) of the BMRR. The maximum tritium concentration observed during 1997 was 11,800 pCi/L, almost one-half of the 20,000 pCi/L DWS. The highest observed tritium concentration since the start of groundwater monitoring was 17,100 pCi/L in October 1999. The tritium detected in groundwater is believed to have originated from the historical discharge of small amounts of BMRR primary cooling water to a basement floor drain and sump system that may have 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 (non-radioactive) cooling water until 1997. The infiltration of this water may have promoted the movement of residual tritium from the soil surrounding the floor drain piping system to the groundwater. The floor drains were permanently sealed in 1998.

4.3.1 BMRR Groundwater Monitoring

Well Network

The monitoring well network for the BMRR facility consists of one upgradient and three downgradient wells (**Figure 4.3-1**).

Sampling Frequency and Analysis

The BMRR wells are sampled once every two years. The last samples were collected in 2018. Groundwater samples are currently only analyzed for tritium (**Table 1-6**). No samples were collected during 2019.

4.3.2 BMRR Monitoring Well Results

Monitoring conducted since 1997 has shown that tritium concentrations in the BMRR wells have always been below the 20,000 pCi/L DWS (**Figure 4.3-2**). Previous analyses for gamma, gross alpha, and gross beta did not indicate the presence of any other reactor-related radionuclides.

4.3.3 BMRR Groundwater Monitoring Program Evaluation

Monitoring data were evaluated using the following Data Quality Objective statement.

1. Is there a continuing source of contamination? If present, has the source been remediated or controlled?

Tritium concentrations in groundwater downgradient of the BMRR have never exceeded the 20,000 pCi/L DWS. Tritium concentrations were <5,000 pCi/L from September 2000 through 2010, <600 pCi/L during the 2012, 2014 and 2016 sample periods, and tritium was not detected during the 2018 sample period. Groundwater monitoring results indicate that the BMRR structure is effectively preventing rainwater infiltration into the underlying soils, or that the amount of residual tritium in the vadose zone has been significantly reduced.

4.3.4 BMRR Recommendation

The following is recommended for the BMRR groundwater monitoring program:

- The monitoring frequency for the BMRR wells will continue to be once every two years, with the next set of samples being collected in 2020.

4.4 SEWAGE TREATMENT PLANT (STP)

The STP processes sanitary wastewater from BNL research and support facilities. Until October 2014, treated effluent from the STP was discharged to the Peconic River under a NYSDEC SPDES permit (NY-0005835). Treated wastewater from the STP is now released to nearby groundwater recharge basins (SPDES Outfall 001) (**Figure 4.1.1**).

On average, 0.5 million gallons per day (MGD) of wastewater are processed during the summer and 0.3 MGD of water are processed during the rest of the year. Before discharge into the recharge basins, the sanitary waste stream is treated by: 1) primary clarification to remove settleable solids and floatable materials; 2) aerobic oxidation for secondary removal of the biological matter and nitrification of ammonia; 3) secondary clarification; and 4) filtration for final effluent polishing. Oxygen levels are regulated during the treatment process to remove nitrogen biologically, using nitrate-bound oxygen for respiration. As required by the NYS SPDES permit, monitoring wells are used to evaluate groundwater quality near the recharge basins.

Two emergency hold-up ponds are located east of the former sand filter beds. The hold-up ponds are used to store sanitary waste in the event of mechanical problems at the plant or if the influent contains contaminants in concentrations exceeding BNL administrative limits and/or SPDES permit effluent release criteria. The hold-up ponds have a combined holding capacity of nearly six million gallons of water and provide BNL with the ability to divert all sanitary system effluent for approximately one week. The hold-up ponds are equipped with fabric-reinforced plastic liners that are heat-welded along all seams. In 2001, improvements were made with the addition of new primary liners and a leak detection system. The older liners now serve as secondary containment.

4.4.1 STP Groundwater Monitoring

Well Network

In addition to the comprehensive influent and effluent monitoring program at the STP, the groundwater monitoring program is designed to provide a secondary means of verifying that STP operations are not impacting groundwater quality. One upgradient well (039-87) and six downgradient wells (039-88, 039-89, 039-115, 048-08, 048-09 and 048-10) are used to monitor groundwater quality in the recharge basin area (**Figure 4.4-1**). Monitoring results from three wells (039-88, 039-89, and 039-90) are also used to evaluate groundwater quality in the holding pond area, when necessary.

Sampling Frequency and Analysis

In accordance with the SPDES permit, the STP recharge basin area monitoring wells are sampled annually (**Table 1-6**). Samples were collected in November 2019. As required by the permit, the samples are analyzed for the following metals: copper, iron, lead, nickel, silver, zinc and mercury.

In January 2020, samples from STP and downgradient (Operable Unit V) monitoring wells were tested for per- and polyfluoroalkyl substances (PFAS) and 1,4-dioxane as part of Phase 4 of the Laboratory's ongoing characterization of emerging contaminants of concern. The preliminary results for the Phase 4 effort are summarized in **Sections 3.10 and 3.11**.

4.4.2 STP Monitoring Well Results

All metals concentrations tracked under the SPDES permit were below the applicable AWQS. As in previous years, sodium was detected at concentrations above the 20 mg/L AWQS in the STP recharge basin area wells. During 2019, sodium levels exceeded 20 mg/L in five wells, with maximum concentration of 59.8 mg/L in well 039-88.

4.4.3 STP Groundwater Monitoring Program Evaluation

The 2019 monitoring data were evaluated using the following Data Quality Objective statement.

1. Are STP operations impacting groundwater quality?

Monitoring results for 2019 continue to indicate that current STP operations are not having a significant impact on groundwater quality, and that the BNL administrative and engineered controls continue to be effective.

4.4.4 STP Recommendation

For 2020, the following is recommended for the STP groundwater monitoring program:

- In accordance with the SPDES permit, the STP groundwater monitoring wells will be sampled annually, and the samples will be analyzed for the metals specified in the permit.

4.5 MOTOR POOL AREA

The Motor Pool (Building 423) consists of a five-bay automotive repair shop, which includes office and storage spaces (**Figure 4.5-1**). The facility has been used continuously since 1947.

Potential environmental concerns at the Motor Pool include 1) the use of USTs to store gasoline, diesel fuel, and waste oil, 2) hydraulic fluids used for lift stations, and 3) the use of solvents for parts cleaning. In August 1989, the gasoline and waste oil USTs, pump islands, and associated piping were upgraded to conform to Suffolk County Article 12 requirements for secondary containment, leak detection devices, and overfill alarms. The present tank inventory includes two 8,000-gallon USTs used to store unleaded gasoline, one 260-gallon above ground storage tank used for waste oil, and one 3,000-gallon UST for No. 2 fuel oil. The Motor Pool facility has five vehicle-lift stations. The hydraulic fluid reservoirs for the lifts are located above ground.

4.5.1 Motor Pool Area Groundwater Monitoring

Well Network

The groundwater monitoring program for the Motor Pool's UST area is used to confirm that the current engineered and institutional controls are effective in preventing contamination of the aquifer. Shallow Upper Glacial aquifer wells 102-05 and 102-06 are used to monitor for potential contaminant releases from the UST area (**Figure 4.5-1**). As needed, groundwater quality downgradient of Building 423 can also be monitored using shallow wells 102-10, 102-11, 102-12, and 102-13.

Sampling Frequency and Analysis

During 2019, the two UST area wells were monitored annually, and the samples were analyzed for VOCs (**Table 1-6**). The wells were also checked for the presence of floating petroleum hydrocarbons. The remaining Building 423 monitoring wells were not sampled.

4.5.2 Motor Pool Monitoring Well Results

Underground Storage Tank Area

During 2019, chloroform was detected in both wells, with a maximum concentration of 1.4 µg/L in well 102-06. As in previous years, no floating product was detected in the wells.

4.5.3 Motor Pool Groundwater Monitoring Program Evaluation

The 2019 monitoring data were evaluated using the following Data Quality Objective statement.

<u>*1. Is there a continuing source of contamination? If present, has the source been remediated or controlled?*</u>

During 2019, there were no reported gasoline or motor oil losses or spills from the USTs or from Building 423 that could affect groundwater quality. Furthermore, all waste oils and used solvents generated from current operations are being properly stored and recycled. The gasoline USTs have electronic leak detection systems, and there is a daily product reconciliation (i.e., an accounting of the volume of gasoline stored in USTs and volume of gasoline dispensed).

4.5.4 Motor Pool Recommendations

The following are recommendations for the Motor Pool area monitoring program for 2020:

- The sampling frequency for the UST area wells 102-05 and 102-06 will continue to be annually.

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4.6 ON-SITE SERVICE STATION

Building 630 was a commercial automobile service station, privately operated under a contract with BNL. The station was built in 1966 and was used for automobile repair and gasoline sales until January 2018. Potential environmental concerns at the Service Station included the use of USTs for the storage of gasoline and waste oil, hydraulic fluids used for lift stations, and the use of solvents for parts cleaning. In August 1989, the USTs, pump islands, and associated piping were upgraded to conform to Suffolk County Article 12 requirements for secondary containment, leak detection devices, and overfill alarms. The tank inventory included three 8,000-gallon USTs for storing unleaded gasoline and one 500-gallon UST used for waste oil. The facility had three hydraulic vehicle-lift stations. In early 2018, the underground storage tanks were emptied of their contents, and hydraulic oils were draining from the lift stations. In September 2018, the underground storage tanks were excavated and removed from the site for proper disposal. During the removal of the underground storage tanks, there were no reported gasoline or motor oil losses or spills that could affect groundwater quality. Furthermore, no contaminants were detected in end-point soil samples at concentrations above 6 NYCRR Part 375 cleanup guidelines.

4.6.1 Service Station Groundwater Monitoring

Well Network

Groundwater quality in the service station area was monitoring using four shallow Upper Glacial wells. The monitoring program was used to confirm that the engineered and institutional controls in place are effective in preventing contamination of the aquifer and to evaluate continued impacts from historical spills (**Figure 4.6-1**).

Sampling Frequency and Analysis

No groundwater samples were collected during 2019.

4.6.2 Service Station Monitoring Well Results

Although groundwater water quality at the Service Station had been impacted by a variety of VOCs that were related to historical vehicle maintenance and refueling operations, monitoring conducted during 2015 through 2017 indicated a significant drop in VOC concentrations. During 2017, the highest VOC concentration was detected in well 085-17, with tetrachloroethylene at 3.7 µg/L, which was below the NYS AWQS of 5 µg/L.

4.6.3 Service Station Groundwater Monitoring Program Evaluation

Monitoring data collected to date were evaluated using the following Data Quality Objective statement.

1. Is there a continuing source of contamination? If present, has the source been remediated or controlled?

Based upon the last set of monitoring data collected in 2017, VOC concentrations for individual compounds have declined to less than applicable AWQS. During the removal of the underground storage tanks, there were no reported gasoline or motor oil losses or spills that could affect groundwater quality. Furthermore, no contaminants were detected in end-point soil samples at concentrations above 6 NYCRR Part 375 cleanup guidelines.

4.6.4 Service Station Groundwater Monitoring Program Recommendation

Because the Service Station facility has been decommissioned, and recent groundwater monitoring results indicated that VOC concentrations declined to less than the NYS AWQS, the monitoring program has been discontinued. The monitoring wells will be retained for possible future use.

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4.7 MAJOR PETROLEUM FACILITY (MPF)

The MPF is the storage area for fuel oil used at the Central Steam Facility (CSF). The fuel oil is held in a network of seven above ground storage tanks, which have a combined capacity of up to 1.7 million gallons of No. 6 fuel oil and 60,000 gallons of No. 2 fuel oil. The tanks are connected to the CSF by above ground pipelines that have secondary containment and leak detection devices. The fuel storage tanks are positioned in bermed containment areas that have a capacity to hold >110 percent of the volume of the largest tank located there. The bermed areas have bentonite clay liners consisting of either Environmat™ (bentonite clay sandwiched between geotextile material) or bentonite clay mixed into the native soil to form an impervious soil/clay layer. Fuel-unloading operations occur in a centralized building that has secondary containment features. The MPF is operated under NYSDEC Permit #1-1700 and, as required by law, a Spill Prevention Control and Countermeasures (SPCC) Plan and a Facility Response Plan have been developed for the facility. Groundwater quality near the MPF has been impacted by several oil and solvent spills: 1) the 1977 fuel oil/solvent spill east of the MPF that was remediated under the FFA (OU IV); 2) a historical fuel/solvent spill discovered in 2013 near MPF storage tank #3; 3) historical solvent spills near the CSF; and 4) solvent spills that occurred in the Building 650 area.

4.7.1 MPF Groundwater Monitoring

Well Network

Eight shallow Upper Glacial aquifer wells are used to confirm that the engineered and institutional controls in place are effective in preventing contamination of the aquifer (**Figure 4.7-1**).

Sampling Frequency and Analysis

Groundwater contaminants from the fuel oil products stored at the MPF can travel both as free product and in dissolved form in groundwater. Based upon these factors, the NYSDEC Special License Conditions for the MPF requires semiannual monitoring for VOCs and SVOCs and monthly monitoring for floating petroleum (**Table 1-6**).

4.7.2 MPF Monitoring Well Results

During 2019, the MPF wells were monitored monthly for the presence of floating petroleum, and groundwater samples were collected in April and October. The groundwater samples were analyzed for SVOCs and VOCs. As in the past, no SVOCs were detected, and no floating product was observed. Although low levels of VOCs (e.g., chloroform up to 0.88 µg/L and tetrachloroethylene up to 1.1 µg/L) not associated with fuel storage activities continued to be detected in some of the downgradient wells, all VOC concentrations were less than the applicable AWQS (**Figure 4.7-1**). Tetrachloroethylene and chloroform were also detected in upgradient well 076-25 at concentrations up to 3.0 µg/L and 1.4 µg/L, respectively. The tetrachloroethylene is likely to have originated from the Building 650 area located immediately upgradient of the MPF.

4.7.3 MPF Groundwater Monitoring Program Evaluation

The 2019 monitoring data were evaluated using the following Data Quality Objective statement.

1. Are the potential sources of contamination being controlled?

Groundwater monitoring at the MPF continues to show that fuel storage and distribution operations are not impacting groundwater quality. VOCs that are periodically detected in the groundwater are likely to have originated from historical solvent spills near the Central Steam Facility (Building 610) and the Building 650 area to the north. A number of historical spill sites near the CSF were identified during the 1990s, and the contaminated soils were excavated and disposed of in accordance with regulatory requirements.

4.7.4 MPF Recommendation

For 2020, monitoring will continue as required by the NYS operating permit, with semiannual monitoring for VOCs and SVOCs, and monthly testing for floating product.

4.8 WASTE MANAGEMENT FACILITY (WMF)

The WMF is designed to safely handle, repackage, and temporarily store BNL-derived wastes prior to shipment to off-site disposal or treatment facilities. The WMF is a state-of-the-art facility, with administrative and engineered controls that meet all applicable federal, state, and local environmental protection requirements. The WMF consists of three buildings: the Operations Building, Reclamation Building (for radioactive waste), and the RCRA Building.

Groundwater monitoring is a requirement of the RCRA Part B permit issued for WMF operations. The groundwater monitoring program for the WMF is designed to supplement the engineered and institutional controls by providing additional means of detecting potential contaminant releases from the facility. Because of the close proximity of the WMF to BNL potable supply wells 11 and 12, it is imperative that the engineered and institutional controls implemented at the WMF are effective in ensuring that waste handling operations do not degrade the quality of the soil and groundwater in this area. (Note: Potable water supply well 12 has been out of service since 2008.)

4.8.1 WMF Groundwater Monitoring

Well Network

During 2019, groundwater quality at the WMF was monitored using eight shallow Upper Glacial aquifer wells. Two wells (055-03 and 055-10) are used to monitor background water quality. During 2019, six wells were used to monitored groundwater quality near the two main waste handling and storage facilities. Wells 056-21, 066-220 and 066-221 are located near the RCRA Building, and wells 056-22, 066-222 and 066-223 are located near the Reclamation Building. Periodically adjustments are made to the list of downgradient wells that are monitored due to transient changes in groundwater flow directions caused by the operations of the nearby supply wells. BNL discontinued sampling of well 066-224 following the 2012 closure of the former Mixed Waste Building. Locations of the monitoring wells are shown on **Figure 4.8-1**.

Sampling Frequency and Analysis

During 2019, the WMF wells were sampled in February and August. Groundwater samples were analyzed twice for VOCs, tritium, gamma spectroscopy, gross alpha, and gross beta, and one time for strontium-90, metals and anions (e.g., chlorides, sulfates, and nitrates) (**Table 1-6**). A complete set of monitoring data are presented in the *2019 Groundwater Monitoring Report for the Waste Management Facility* (BNL 2020).

4.8.2 WMF Monitoring Well Results

Radiological Analyses

Gross alpha and beta levels in samples from both upgradient and downgradient monitoring wells were consistent with background concentrations. During 2019, low level cobalt-60 (Co-60) was detected in monitoring well 066-220 at a concentration of 6.9+/-5.4 pCi/L (MDL = 5.8 pCi/L), which is approximately 3% of the 200 pCi/L DWS. Based upon documented waste management operations, the Co-60 is not the result of releases from the WMF.

As in previous years, low levels of strontium-90 (Sr-90) continued to be detected in several downgradient monitoring wells. The maximum Sr-90 concentration was detected in well 066-220 at 0.57+/-0.17 pCi/L (MDL = 0.21 pCi/L), which is approximately 7% of the 8 pCi/L DWS. The likely source of the Sr-90 is historical leakage of wastewater from the sanitary line that ran through the current WMF area before it was re-routed south of the facility. During construction of the WMF, portions of the old sanitary line were abandoned in place. Low levels of Sr-90 were also detected in pre-operation (baseline) samples collected in May 1997 in both upgradient and downgradient wells at concentrations up to 5.4 pCi/L. The only operation at the WMF that could potentially contribute Sr-90 to the environment is the BGRR/WCF groundwater treatment system located in Building 855. However, the pipeline in the WMF area is double lined, and is monitored by a leak detector. There are no indications that this piping system has leaked.

Non-Radiological Analyses

All anions (chlorides, sulfates, and nitrates) and most metals concentrations were below applicable ambient NYS AWQS or DWS. As in previous years, sodium was detected at concentrations above the 20 mg/L AWQS. Sodium was detected at concentrations above the standard in upgradient well 055-10 at concentration of 32.5 mg/L, and in four downgradient wells (056-22, 066-220, 066-221, and 066-222) at concentrations up to 47.6 mg/L. The elevated sodium concentrations are likely the result of road salting operations. Although trace levels of chloroform continue to be detected in several of the WMF's upgradient and downgradient wells, all concentrations were below the AWQS.

4.8.3 WMF Groundwater Monitoring Program Evaluation

The 2019 monitoring data were evaluated using the following Data Quality Objective statement.

1. Are potential sources of contamination within the WMF being controlled?

Groundwater monitoring results for 2019 continued to show that WMF operations are not affecting groundwater quality. Furthermore, there were no outdoor or indoor spills at the facility during 2019 that could have affected soil or groundwater quality.

4.8.4 WMF Recommendation

The following are recommended for 2020:

- Continue monitoring the wells at a semiannual frequency as required by the RCRA Part B Permit.

4.9 NATIONAL SYNCHROTRON LIGHT SOURCE II (NSLS-II)

The NSLS-II is an electron accelerator that began full-time operations in 2014. High-energy particle interactions in water, air, and soil can produce radioactivity from spallation reactions or neutron capture in nitrogen, oxygen, or other materials. In high-energy proton accelerators, such as BNL's AGS, BLIP and RHIC, these interactions can produce significant activation of the soil shielding. However, electron accelerators such as the NSLS-II have significantly reduced potential for environmental impacts and can produce only about one to five percent of the induced activity of a proton accelerator. As required by the BNL SBMS *Accelerator Safety* subject area, analyses have been conducted to estimate the rate of formation of tritium and sodium-22 in the surrounding soils during the operation of the NSLS-II's Linac, Booster, and Storage Ring. The results of these analyses indicate that interactions of neutrons with the soils below the tunnel floor and surrounding soil shielding (berm) have the potential to create very low levels of tritium and sodium-22 in the soil. However, because the soil beneath the concrete floor will not be exposed to rainfall, the potential leaching of radioactive isotopes from the soil to the water table at these locations will be minimal. There is also the potential to create very low levels of tritium in the water used to cool the magnets and other accelerator components.

4.9.1 NSLS-II Groundwater Monitoring

Well Network

Four monitoring wells are located downgradient of the facility's Linac, Booster and Storage Ring area where beam line operations may result in low level activation of the surrounding soil shielding (**Figure 4.9-1**). Two nearby MPF monitoring wells (076-18 and 076-19) are used as upgradient/background wells for the NSLS-II facility.

Sampling Frequency and Analysis

During 2019, the four NSLS-II monitoring wells and the two MPF wells were sampled one time, and the samples were analyzed for tritium (**Table 1-6**).

4.9.2 NSLS-II Monitoring Well Results

No tritium was detected in the groundwater samples collected during 2019.

4.9.3 NSLS-II Groundwater Monitoring Program Evaluation

The 2019 monitoring data were evaluated using the following Data Quality Objective statement.

1. Are the engineered and operational controls effective at preventing or reducing the leaching of radionuclides from activated soils to the groundwater?

Monitoring results for 2019 indicate that NSLS-II beam line operations conducted to date have not affected groundwater quality.

4.9.4 NSLS-II Recommendations

For 2020, the four NSLS-II and two MPF (background) monitoring wells will continue to be monitored annually for tritium.

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5.0 SUMMARY OF RECOMMENDATIONS

This section is provided as a quick reference to recommendations for monitoring and remediation program changes described in **Sections 3** and **4**. **Table 5-1** summarizes the changes to the monitoring well sampling programs.

5.1 OU I South Boundary Treatment System

- Maintain the VOC post-closure groundwater monitoring program of an annual sample collection from post-closure wells: 098-99, 107-40, 107-41, 115-13, 115-16, and 115-51. Maintain quarterly sampling of Current Landfill sentinel well 098-99.
- Install temporary wells as needed adjacent to monitoring wells 088-100, 088-101, and 088-102 to assess whether they are appropriately screened in the highest concentration segments of the Sr-90 plume immediately downgradient of the source area. Install temporary wells as needed to fill monitoring data gaps and characterize extent of Sr-90 plume. This temporary well data will be incorporated into the CERCLA Five-Year Review Report.
- Discontinue sampling of monitoring wells 115-41 and 115-42 for Sr-90. These wells have been monitored since 1997 and no detections of Sr-90 have been observed.
- Discontinue the annual tritium sampling of monitoring wells 087-21, 088-13, 088-14, 088-20, 088-26, 098-21, 098-30, 099-04, 107-24, 107-40, 108-08, 108-12, 108-13, 108-14, 108-17, 115-03, 115-13, 115-14, 115-15, 115-16, 115-28, 115-29, 115-30, 115-31, 115-41, 15-42, 116-05, and 116-06. There have been no tritium detections in any of these wells since 2014 or longer.

5.2 Building 96 Treatment System

- Maintain full time operation of treatment well RTW-1. Monitor VOC concentrations in wells 085-379 and 095-159 to determine when this well can be shut down. Maintain a monthly sampling frequency of the influent and effluent.
- Place treatment well RTW-2 back in standby mode based on TVOC concentrations remaining below 5 µg/L since November 2018.
- Maintain a monthly monitoring frequency for well 095-159 to verify the westward expansion of the RTW-1 capture zone.
- Add former Building 452 Freon-11 monitoring well 085-386 to the Building 96 monitoring program. It will serve as a background well between the two source areas.
- Maintain treatment wells RTW-3 and RTW-4 in standby mode, and restart the wells if extraction or monitoring well data indicate that TVOC concentrations exceed 50 µg/L.

5.3 452 Freon-11 Source Area and Groundwater Plume

- The monitoring program for the Building 452 treatment system has concluded. Incorporate monitoring wells 085-386 and 095-313 into the Building 96 monitoring program.
- Postpone decisions to abandon extraction well EW-18 and the remaining monitoring wells until the PFAS plume originating from the former firehouse area has been fully characterized.

5.4 Middle Road Treatment System

- Maintain extraction wells RW-1, RW-4, RW-5 and RW-6 in standby mode. Restart the well(s) if extraction or monitoring well data indicate that TVOC concentrations exceed the 50 µg/L capture goal.
- Continue operation of RW-2, RW-3 and RW-7.

5.5 OU III South Boundary Treatment System

- Maintain wells EW-3, EW-5, EW-6, EW-7, EW-8, and EW-12 in standby mode. The system's extraction wells will continue to be sampled on a quarterly basis, with the exception of EW-12. The wells will be restarted if extraction or monitoring well data indicate TVOC concentrations exceed the 50 µg/L capture goal.
- Continue to operate well EW-17 on a full-time basis. Continue pulsed pumping of well EW-4 one month on and one month off.
- Reduce sample frequency of wells 114-06, 114-07, 121-20, 121-23, 122-09 and 122-22 for VOCs from semi-annually to annually. TVOC concentrations in these wells have been non-detect to barely detectable for the past six years.

5.6 Western South Boundary Treatment System

- Continue full-time operation of extraction well WSB-1 based on elevated concentrations persisting at well 126-14.
- Based on the low TVOC concentrations below the capture goal of 20 µg/L, maintain extraction well WSB-2 in standby mode. If TVOC concentrations greater than 20 µg/L are observed in WSB-2 or the adjacent monitoring wells, extraction well WSB-2 may be put into full time operation.
- Continue operation of the four new extraction wells. With the addition of these wells the groundwater cleanup goal of meeting MCLs by 2030 are expected to be met.
- Continue the current monitoring frequency for the Western South Boundary monitoring wells as shown in **Table 1-5**.

5.7 Industrial Park Treatment System

- Maintain the seven UVB wells in standby. If TVOC concentrations exceed the 50 µg/L capture goal in these UVB wells or associated monitoring wells, they may be restarted.
- Maintain IP-EW-8 and IP-EW-9 in standby and continue to monitor for rebound of VOCs. If TVOC concentrations approach the capture goal of 50 µg/L in the vicinity of the extraction wells the system will be evaluated for restart.

5.8 Industrial Park East Treatment System

All monitoring requirements for the Industrial Park East Groundwater Monitoring Program have been satisfied and sampling was discontinued in 2018.

5.9 North Street Treatment System

- If TVOC concentrations in any core monitoring wells increase to over the 50 µg/L capture goal, the extraction well(s) may be restarted.
- NS-1 and NS-2 will remain in standby.

- A Petition for Closure was submitted for this system to the regulators in February 2020, as this system has met its cleanup goals. Seven of the 12 core monitoring wells are proposed for continued annual monitoring until the results for individual VOCs are consistently below MCLs. Sampling of the remaining 11 monitoring wells will be discontinued but the wells will be retained until the completion of the PFAS and 1,4-dioxane characterization at the BNL site.
- Until regulatory approval is received, the system will remain in an operationally-ready mode, and the extraction and monitoring wells will continue to be sampled at its current frequency.

5.10 North Street East Treatment System

Original VOC Plume:

- The original NSE VOC treatment system (including extraction wells NSE-1 and NSE-2) met its goals in 2014 with no significant rebound identified. A formal petition for closure will not be prepared for the original VOC treatment system since the infrastructure will be used for remediation of the EDB plume. However, it is recommended that this system be administratively closed for its originally designed purpose. Until administrative approval for closure is received, this treatment system will be maintained in standby mode. The extraction wells will continue to be sampled on a quarterly basis for VOCs via Method 524.2 and NSE-1 for EDB using Method 504. One or both extraction wells can be restarted if TVOC concentrations in the core monitoring wells or extraction wells rebound to concentrations above the capture goal of 50 µg/L, or if EDB is detected in NSE-1.
- Discontinue VOC monitoring using EPA Method 524.2 on the following eight wells since there have been no detections exceeding AWQS for the last 10 years. However, these wells will be retained until the completion of the PFAS and 1,4-dioxane characterization at the BNL site:
    - 000-124, 000-138, 000-477, 000-478, 000-479, 000-480, 000-481 and 000-525
- Continue annual VOC sampling using Method 524.2 for the remaining two monitoring wells 000-394 and 000-552.
- Sampling for tritium will be discontinued since there have been no detections in the monitoring wells or extraction wells since 2013.

EDB Plume:

- Complete the connection of the two new EDB extraction wells and begin start-up testing in 2020 following the resumption of normal work at BNL. Submit a revised Operations and Maintenance Manual to the regulators.
- Maintain the quarterly sampling frequency for the 12 EDB monitoring wells using Method 504, except for upgradient perimeter well 115-42 which is sampled semi-annually.

5.11 LIPA/Airport Treatment System

- Shutdown the Airport extraction wells RTW-2A and RTW-3A currently being pulsed pumped one week per month. There are no TVOC concentrations detected in the vicinity of these wells above the capture goal of 10 µg/L. Continue full time operation of wells RTW-1A, RTW-4A and RW-6A. Keep well RTW-5A in standby mode. If concentrations above the capture goal of 10 µg/L TVOC are observed in any of the extraction wells or the monitoring wells adjacent to wells that are not operating, the well(s) will be put back into full-time operation.
- Maintain LIPA wells EW-1L, EW-2L, EW-3L and EW-4L in standby mode. These extraction wells may be restarted if TVOC concentrations rebound above the 50 µg/L capture goal in either the plume core monitoring wells or the extraction wells. If no significant change in

concentrations for the LIPA system occur in 2020 submit a petition for closure of the LIPA system in 2021.

- No changes to the current monitoring schedule are recommended at this time for the Airport System. Increase the monitoring sampling frequency for the LIPA monitoring wells to quarterly to support the decision for a petition for closure in 2021.
- Reduce the sampling frequency of the carbon treatment system from twice a month to monthly. This is consistent with the SPDES Equivalency permit frequency of monthly.

5.12 Magothy Monitoring

- Continue the current monitoring schedule for the Magothy monitoring program.
- Continue pumping the Magothy extraction wells at Middle Road, South Boundary and the Airport. The two IP extraction wells were placed in standby in July 2019 and continue to be monitored for rebound of VOCs. The North Street, North Street East, OU III South Boundary EW-8 and LIPA Magothy extraction wells are currently in standby as they have reached the OU III capture goals identified for shutdown of these wells. The IPE extraction well was abandoned as it had reached its cleanup goal.

5.13 William Floyd Wellfield Sentinel Monitoring

No changes are recommended for the William Floyd Wellfield Sentinel Monitoring Program.

5.14 OU III South Boundary Radionuclide Monitoring Program

Due to the lack of radionuclide detections above the DWS for the last 20 years, it is recommended that further sampling be eliminated.

5.15 BGRR/WCF Strontium-90 Treatment System

- Increase the sampling frequency of source area monitoring wells 065-325 and 065-405 to quarterly. Assess the elevated Sr-90 concentrations downgradient of Building 801. Perform groundwater modeling simulation if necessary, to determine natural attenuation of recent Sr-90 concentrations.
- Maintain SR-8 in pulsed pumping mode (one month on and one month off) based on low, but fluctuating, Sr-90 concentrations.
- Maintain a source area monitoring frequency of monthly for BGRR source area well 075-701. Increase sampling frequency of 075-664 back to monthly.
- Continue operating wells SR-1, SR-2, SR-3 and SR-9 in full time operational mode. Maintain wells SR-4, SR-5, SR-6, and SR-7 in standby mode.
- Install a temporary well downgradient of 085-403 to identify the location of the leading edge of the plume.
- Install several temporary wells along Temple Place to supplement monitoring of the downgradient segment of the WCF plume.

5.16 Chemical/Animal Holes Strontium-90 Treatment System

- Maintain the system in standby mode and maintain quarterly sampling of the extraction wells. If significant rebound in either the extraction wells or monitoring wells is identified, these extraction wells may be restarted.

- Maintain the annual monitoring well sampling frequency (standby phase), except for former source area wells 097-313, 097-314, 097-315, which will remain at a semi-annual.

5.17 HFBR Tritium Pump and Recharge System

- Continue to monitor the source area with the ten wells located immediately downgradient of the HFBR.
- Maintain the monitoring and extraction wells until a determination is made on their utilization related to emerging contaminants.

5.18 Building 650 (Sump Outfall) Strontium-90 Monitoring

- Remove wells 076-09, 076-263 and 076-417 from the Building 650 Sr-90 Monitoring Program. Wells 076-09 and 076-263 have not exceeded the DWS in twenty years. Well 076-417 has not exceeded the DWS standard since it was installed ten years ago.
- Add wells 076-04, 076-06 and 076-20 to the Building 650 Sr-90 Monitoring Program and sample on an annual basis due to plume migration and detections from temporary well data collected in 2019.
- Install two temporary wells along North Sixth Street north of Brookhaven Avenue and if significant concentrations of Sr-90 are detected, follow up with permanent wells to monitor the downgradient segment of the plume.

5.19 Operable Unit VI EDB Treatment System

- Maintain full time operation of the treatment system and continue quarterly sampling of the extraction wells.
- The observed migration rate for EDB is significantly slower than originally predicted during treatment system design. Contaminant migration at the base of the Deep Upper Glacial aquifer and system capture of this deep contamination also requires a re-evaluation. Assess the groundwater model geologic framework for this area and if needed, collect additional data (soil borings/gamma logs) to address any data gaps. Perform a plume migration simulation utilizing any updated data. Based on this additional data and the recently characterized deep EDB identified in wells 000-549 and 000-550, the model will better determine if the existing treatment system will remediate the EDB plume to below the DWS by 2030, as required by the OU VI ROD. If needed, the model will be used to evaluate modifications which may include additional extraction wells and/or modifications to extraction well pumping rates.

5.20 Site Background Monitoring

- Discontinue sampling well 063-09 in 2020 since it was originally installed to monitor the Water Treatment Plant recharge basin that receives filter backwash water. It was previously documented that the plant operations have not impacted groundwater. Except for aluminum, iron and manganese detections above AWQS in 2001, well 063-09 has not detected any compounds exceeding AWQS since the well was installed in 1994.
- As part of the Phase 4 PFAS Work Plan, several background wells will be sampled in 2020 for emerging contaminants (PFAS and 1,4-dioxane).

5.21 Current Landfill Groundwater Monitoring

No changes to the monitoring program are warranted at this time.

5.22 Former Landfill Groundwater Monitoring

No changes to the monitoring program are warranted at this time. A full round of monitoring will be conducted in 2020.

5.23 g-2 Tritium Source Area and Groundwater Plume

- Continue routine inspections of the g-2 cap.
- Continue semiannual monitoring of source area wells near Building 912A, and annual monitoring of wells located downgradient of the former beam stop and Building 912.

5.24 Brookhaven Linac Isotope Producer (BLIP) Facility

- As required by the ROD, BNL will continue to conduct routine inspections of the cap, and to monitor groundwater quality downgradient of the BLIP facility.
- No changes to the groundwater monitoring program are recommended.

5.25 Characterization of 1,4-Dioxane in Groundwater

- Complete the Phase 4 Work Plan for the comprehensive sampling of approximately 350 on-site and off-site monitoring wells and five off-site groundwater treatment systems.
- Complete the Phase 5 Work Plan for detailed characterization of the high concentration segments of the PFAS plumes associated with BNL's current and former firehouse facilities. Select sample locations/sample intervals will also be tested for 1,4-dioxane.

5.26 Characterization of PFAS in Groundwater

- Complete the Phase 4 Work Plan for the comprehensive sampling of approximately 350 on-site and off-site monitoring wells and five off-site groundwater treatment systems. Because most of the monitoring wells will be sampled with existing Teflon®-containing pumps and discharge tubing, collect additional samples using Teflon®-free equipment from select wells that have unexpected levels of PFAS.
- Complete the Phase 5 Work Plan for detailed characterization of the high concentration segments of the PFAS plumes associated with BNL's current and former firehouse facilities. Select sample locations/sample intervals will also be tested for 1,4-dioxane.

5.27 Alternating Gradient Synchrotron (AGS) Complex

The groundwater monitoring program is adequate at this time, and no changes are required.

5.28 Relativistic Heavy Ion Collider (RHIC) Facility

During 2020, groundwater samples will continue to be collected on a semiannual basis. Surface water samples will also continue to be collected as part of the Environmental Surveillance program.

5.29 Brookhaven Medical Research Reactor (BMRR) Facility

The groundwater monitoring program is adequate at this time, and no changes are required. The BMRR wells will continue to be once every two years, with the next set of samples being collected in 2020.

5.30 Sewage Treatment Plant (STP) Facility

In accordance with the SPDES permit, the STP groundwater monitoring wells will be sampled annually, and the samples will be analyzed for the metals specified in the permit.

5.31 Motor Pool Area

The sampling frequency for the UST area wells 102-05 and 102-06 will continue to be annually.

5.32 On-Site Service Station

Because the Service Station facility has been decommissioned, and recent groundwater monitoring results indicated that VOC concentrations declined to less than the NYS AWQS, the monitoring program has been discontinued. The monitoring wells will be retained for possible future use.

5.33 Major Petroleum Facility (MPF) Area

For 2020, monitoring will continue as required by the NYS operating permit, with semiannual monitoring for VOCs and SVOCs, and monthly testing for floating product.

5.34 Waste Management Facility (WMF)

Continue monitoring the wells at a semiannual frequency as required by the RCRA Part B Permit.

5.35 National Synchrotron Light Source II (NSLS-II)

For 2020, the four NSLS-II and two MPF (background) monitoring wells will continue to be monitored annually for tritium.

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