2018
SITE ENVIRONMENTAL REPORT
VOLUME II
GROUNDWATER STATUS REPORT

June 14, 2019

Environmental Protection Division
Groundwater Protection Group

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is dedicated to John Burke (July 10, 1964 – September 10, 2018).
The high quality of environmental data, development of the
environmental database and user tools to track and access data, and the
ability to create high-quality maps for the Environmental
Protection Division and Groundwater Cleanup Program are largely
due to John's determination and effort over the past 17 years.
His contributions to the Site Environmental Report and the cleanup program
will be his enduring Brookhaven National Laboratory legacy.
A good friend and beloved husband and father,
he will be missed greatly by his colleagues and family.

Report Contributors

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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
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 Facilities 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	Interagency 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
ng/L	nanograms per liter
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

2018 BROOKHAVEN NATIONAL LABORATORY

GROUNDWATER STATUS REPORT

Executive Summary

The *2018 BNL Groundwater Status Report* is a comprehensive summary of data collected during the 2018 calendar year supplemented with relevant investigation data collected during the first quarter 2019, an evaluation of Groundwater Protection Program performance, and recommendations for program changes. This is the twenty third 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 2018, seven volatile organic compound (VOC) groundwater remediation systems were in operation, along with two strontium-90 (Sr-90) treatment systems. The Sr-90 Chemical Holes Treatment System was placed in standby mode in July 2018. In 2018, 62 pounds of VOCs were removed from the Upper Glacial and Magothy aquifers by the treatment systems. To date, 7,589 pounds of VOCs have been removed from the aquifers. The Sr-90 treatment systems removed 0.61 milliCuries (mCi) of Sr-90 from the Upper Glacial aquifer in 2018, for a total of 32.84 mCi since operations began. Approximately 0.8 billion gallons of groundwater were treated in 2018.

There were 569 monitoring wells and 121 temporary wells sampled as part of the CERCLA Groundwater Monitoring Program, comprising a total of 1,400 groundwater samples. Thirty seven of the 121 temporary wells were installed to help characterize the extent of Per- and Polyfluoroalkyl Substances (PFAS) in groundwater at BNL. 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 – 2018.

	1997 – 2017		2018	
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)	478,697,000	142	17,000,000	1
OU III Building 452 Freon-11 (March 2012)	124,997,000	106	(Shutdown) 0	0
OU III Middle Road (Oct. 2001)	3,276,547,000	1,229	172,000,000	32
OU III South Boundary (June 1997)	5,007,151,000	3,041	105,000,000	7
OU III W. South Boundary (Sept. 2002)	1,692,055,000	140	77,500,000	3
OU III Industrial Park (Sept. 1999)	2,479,662,000	1,074	68,000,000	2
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)	3,121,145,000	438	203,000,000	17
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)	2,107,057,000	NA(d)	162,000,000	NA (d)
Totals	**26,388,049,000**	**7,527**	**804,500,000**	**62**

	2003 – 2017		2018	
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)	64,963,000	4.93	700,000	0.01
OU III BGRR (June 2005)	149,803,000	27.3	15,000,000	0.6
Totals	**214,766,000**	**32.23**	**15,700,000**	**0.61**

Notes:
(a) System was placed in standby mode in 2013.
(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 2018, are summarized on **Figures E-1** and **E-2**, respectively. The fourth quarter 2018 sampling round was delayed and some samples were not collected until January 2019. 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 2018, 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 significant changes follows (specific details of which are provided in **Section 5**).

- **OU I South Boundary Treatment System** –
    - There has been no significant rebound in VOC concentrations since system shutdown in 2013. A petition for closure of the OU I South Boundary Treatment System will be submitted to the regulators in 2019.
    - Install three shallow monitoring wells to provide permanent monitoring points where the highest Sr-90 concentrations were observed at locations in and adjacent to former sources at the former Hazardous Waste Management Facility (FHWMF). Install temporary wells as needed to fill monitoring data gaps and characterize extent of Sr-90 plume.
- **OU III Building 96 Treatment System –**
    - The pumping rate was modified in June 2019 to expand the capture zone of RTW-1 to ensure that VOCs to the west are being fully captured.
    - A soil vapor extraction (SVE) pilot study conducted in 2018 determined that SVE treatment would not be a viable method of further reducing the persistent residual contamination in the former source area.
    - Total volatile organic compound (TVOC) concentrations exceeded the 50 μg/L system capture goal in RTW-2 at 65 μg/L in October 2018. Concentrations also remained elevated in monitoring wells immediately upgradient of RTW-2 resulting in the re-start of this extraction well in November 2018.

  - o Install a monitoring well at the location of B96-GP02-2019 and screen from 15 to 25 feet mean sea level to track the slightly deeper portion of the plume in this area.

- **452 Freon-11 Source Area and Groundwater Plume**
  - o 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 will be submitted to the regulators in 2019.
- **OU III Western South Boundary Treatment System –**
  - o Following regulatory approval of a system modification submitted to the regulators in 2018, the installation of four new extraction wells and associated piping and controls was completed which will capture and treat deeper VOCs and result in achieving the OU III ROD cleanup goals.
- **OU III Industrial Park Treatment System –**
  - o Due to individual VOC concentrations remaining below ambient water quality standards (AWQS) since 2017 in extraction wells IP-EW-8 and IP-EW-9, and the low VOCs identified in the recently installed vertical profile well (maximum of 27 µg/L of carbon tetrachloride), place these wells on standby in July 2019 and continue to monitor for rebound.
- **OU III North Street Treatment System –**
  - o Submit a petition for system closure in 2019 as this system has met its cleanup goals.
- **OU III North Street East Treatment System –**
  - o Based on the ethylene dibromide (EDB) vertical profile characterization performed and the fate and transport model simulations, begin the design for modification of the treatment system for two additional extraction wells. Submit a design modification to the regulators.
- **BGRR/WCF Sr-90 Treatment System –**
  - o Supplement the current monitoring network with temporary well data north of the HFBR and just south of the WCF, as well as the leading edge of the BGRR Sr-90 plume in order to get a comprehensive status of the plumes and account for well network gaps and groundwater flow related plume shifting.
- **Chemical/Animal Holes Sr-90 Treatment System –**
  - o Due to the declining Sr-90 concentrations over the last several years, a petition for shutdown was submitted to the regulators in March 2018 and subsequently approved. The system was placed in standby mode in July 2018.
- **HFBR Tritium Pump and Recharge System –**
  - o A petition for closure of this system was submitted to the regulators in July 2018 and approved in March 2019.
  - o Seven new monitoring wells were installed immediately downgradient of the HFBR in September 2018. As noted on **Table 3.2.17-1** of the *2017 Groundwater Status Report*, 47 monitoring wells were decommissioned in October 2018. Fourteen HFBR monitoring wells were retained for potential future monitoring of PFAS downgradient of the former firehouse.

- **Building 650 (Sump Outfall) Strontium-90 Monitoring –**
  - Install up to eight temporary wells to verify whether there has been any southeast shift of the plume due to changes in groundwater flow direction in the area.
- **Operable Unit VI EDB Treatment System –**
  - Two vertical profiles and two monitoring wells were installed in the center of the plume upgradient of the extraction wells. The groundwater model will be updated in 2019 based on the vertical profile results to refine the estimate for the time required to remediate the EDB plume to below the drinking water standard
- **Emerging Contaminants –**

  1,4-Dioxane:
  - In accordance with the Addendum to the Phase 3 Work Plan (BNL 2019a), in February 2019, samples were collected from 33 existing southern boundary deep monitoring wells that are part of the Western South Boundary and OU III South Boundary monitoring programs. Furthermore, during April-May 2019, samples were collected from 11 temporary wells installed along the site boundary to characterize the shallower sections of the aquifer. The samples were analyzed for 1,4-dioxane and PFAS. 1,4-Dioxane was detected in 27 of the 33 permanent wells and in all 11 temporary wells, with a maximum concentration of 15.2 µg/L detected in a Western South Boundary monitoring well.

  PFAS:
  - Following the 2017 detection of PFAS in samples from three of the five BNL potable supply wells, BNL searched available records and conducted employee interviews 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. To determine whether foam releases at these eight areas had impacted groundwater quality, BNL began a multiphase characterization effort starting in May 2018. This effort included the installation and sampling of temporary wells, permanent monitoring wells, and on-site groundwater treatment systems.
  - During 2018 and early 2019, approximately 460 groundwater samples were collected. The groundwater samples were analyzed by EPA Method 537 for 21 PFAS compounds. Monitoring at two of the eight identified foam release areas (the current and former firehouses) identified concentrations of combined concentrations of PFOS/PFOA significantly above the EPA health advisory level (HAL) of 70 ng/L, with a maximum combined concentration of 12,440 ng/L. Two of the remaining six areas, identified combined PFOS/PFOA concentrations above the HAL, with levels up to 128 ng/L.
  - To date, high levels of PFAS were not identified in the monitoring wells or treatment system extraction wells along the site boundary. Only one well, located near the BNL eastern boundary, had a combined PFOS/PFOA concentration above 70 ng/L. This result was 122.9 ng/L. During April-May 2019, eleven temporary monitoring wells were also installed to characterize PFAS concentrations in the shallower sections of the aquifer along the site boundary. Combined PFOS/PFOA concentrations in all 11 temporary wells were less than the 70 ng/L HAL.

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 2018, groundwater samples were collected from 77 wells during 104 individual sampling events.

Highlights of the Facility Monitoring Program are as follows:

- Monitoring conducted during 2018 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 five support facilities (Sewage Treatment Plant, Waste Management Facility, Major Petroleum Facility and Motor Pool) has not identified any new impacts to groundwater quality.
- During 2018, tritium continued to be detected in g-2 source area monitoring wells at concentrations above the 20,000 pCi/L drinking water standard (DWS), with a maximum concentration of 35,500 pCi/L.

Table E-2.
Groundwater Restoration Progress.

Project	Target	Mode	Treatment Type	Expected System Shutdown	Highlights
OU I					
OU I South Boundary (RA V)	VOCs	Standby	Pump and Treat (P&T) with Air Stripping (AS)	2013 (Actual)	No rebound in VOC concentrations has been observed. Petition for Closure being submitted in 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	Operational (EW-1 pulsed pumping)	P&T with ion exchange (IE)	2018 (Actual)	Petition for Shutdown approved and system shut down in July 2018.
Carbon Tetrachloride source control	VOCs (carbon tetra-chloride)	Decommis-sioned	P&T with carbon	2009 (Actual)	Treatment system was decommissioned in 2010.
Building 96 source control	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.	2020	Monitoring persistent elevated PCE concentrations downgradient of source area. SVE pilot test performed in 2018, determined SVE not viable. RTW-2 restarted in 2018.
Building 452	VOCs (Freon-11)	Standby	P&T with AS	2017 (Actual)	System remains in standby and no rebound evident. Submit closure petition in 2019.
South Boundary	VOCs	Operational (EW-3, EW-5, EW-6, EW-7, EW-8 and EW-12 on standby)	P&T with AS	2021	Extraction well EW-17 is capturing and treating deep VOCs at site boundary. EW-4 is pulsed pumping.
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 installed in 2018 will become operational in 2019 to address deeper VOCs and plume to the west. The groundwater will be treated at the Middle Road and South Boundary air strippers.
Industrial Park	VOCs	EW-8 and EW-9 Operational (UVB-1 through UVB-7 on standby)	In-well stripping and P&T with carbon	2020	Due to low VOCs in EW-8 and EW-9, place these extraction wells 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 VOC's remain below capture goal, submit petition for closure in 2019.
North Street East	VOCs	Standby	P&T with carbon	2014 (Actual)	System in standby. Groundwater characterization in 2018 and groundwater modeling identified a need for active treatment of elevated EDB.
Long Island Power Authority (LIPA) Right of Way/ 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 system shutdown.
HFBR Tritium	Tritium	Standby	Pump and recharge	2012 (Actual)	Seven new monitoring wells installed on HFBR lawn. 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.
OU IV					
OU IV AS/SVE system	VOCs	Decommis-sioned	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. Monitor east shift in groundwater flow directions in this area due to changes in on-site pumping and recharge.
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	2021	Update the groundwater model with 2018 temporary well data to estimate the operational duration to meet the DWS.
g-2 and BLIP					
g-2 Tritium Plume	Tritium	Long Term Monitoring & Maintenance	MNA	NA	Tritium concentrations in source area continue to be above the DWS.
BLIP Tritium Plume	Tritium	Long Term Monitoring & Maintenance	MNA	NA	Tritium concentrations continue to be less than DWS.

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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 2018 Groundwater Status Report* is a comprehensive summary of groundwater data collected in calendar year 2018 that provides an interpretation of information on the performance of the Groundwater Protection Program. (Note: The fourth quarter 2018 sampling round was delayed and many of these samples were not collected until January 2019). This is the 23rd annual groundwater status report issued by BNL. This document examines performance of the program on a project-by-project (facility-by-facility) 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 2018, 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 2018. 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, all of 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**, **Appendix G** is a compilation of data usability report forms, and **Appendix H** includes the *BNL North Street East EDB Plume Fate and Transport Modeling Results*, dated November 20, 2018 (PWG, 2019b), and the *Soil Vapor Extraction Pilot Test Report OUIII Building 96 Area TVOC Plume*, dated March 2019 (PWG, 2019a). 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.

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).

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 2018 Environmental Monitoring Plan* (BNL 2018a). 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 2018 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

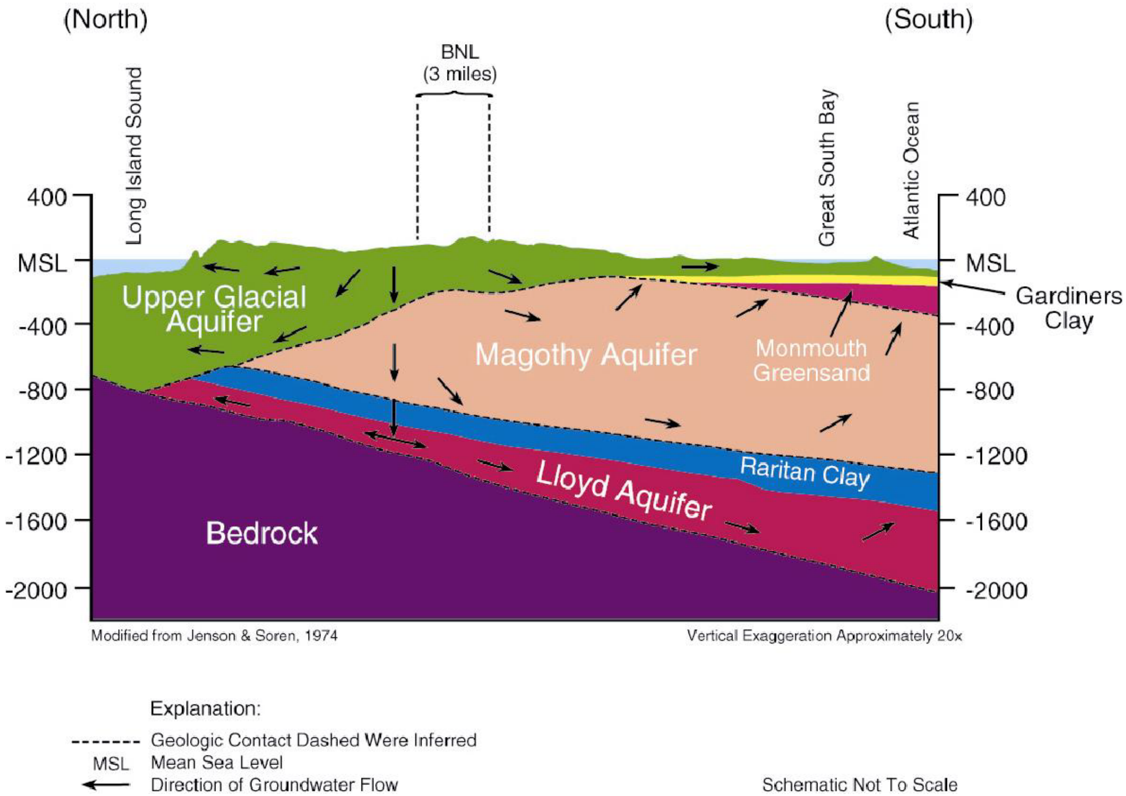
During 2018, there were five known residences south and east of BNL who continue to use their private wells for drinking water purposes. In accordance with the OU III and OU VI RODs, DOE formally offers the owners that previously declined DOE's offer of public water hookups free testing of their private drinking water wells on an annual basis. SCDHS coordinates and performs the sampling and analysis. On October 1st and 2nd 2018, all five homeowners had their wells sampled. In addition to the routine analyses typically performed, the wells were also analyzed for six per- and polyfluoroalkyl substances (PFAS). In late November and early December, the SCDHS transmitted the PFAS results to the homeowners. The combined perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) results from each of the five wells were less than the current lifetime health advisory level of 70 ng/L established by EPA. The analytical results for the remaining routine parameters were not yet available to include in this report.

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 2018, 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. **Figures 2-2 and 2-3** show 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, that 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 2018 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 28 – February 1, 2019 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

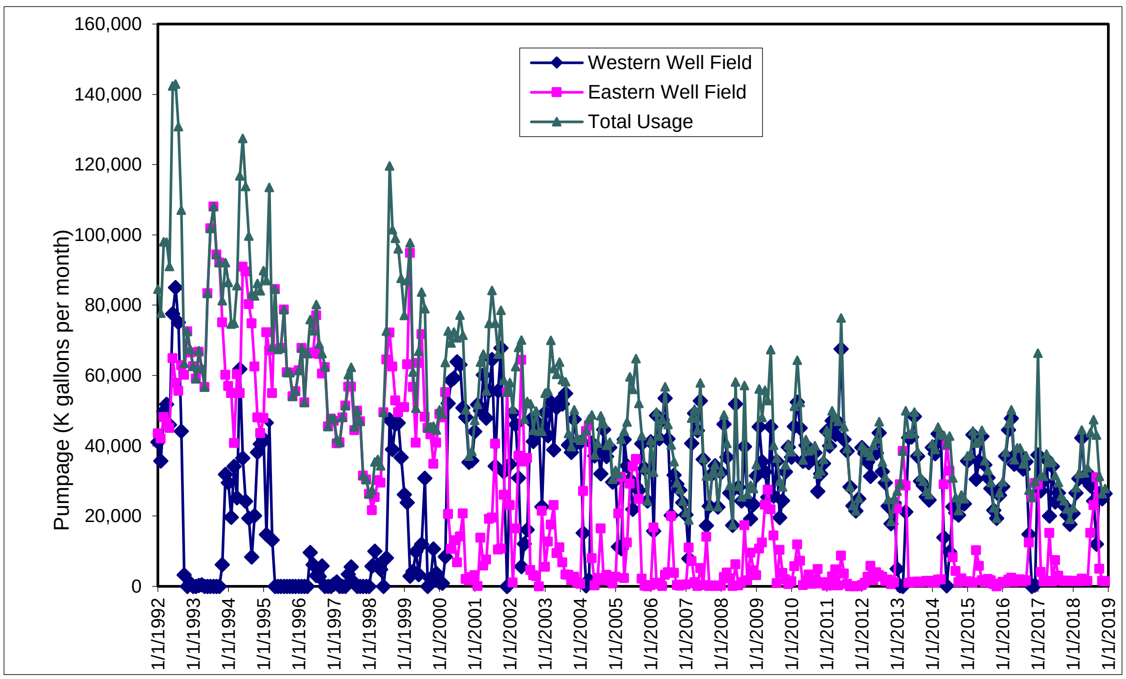
BNL has six water supply wells to provide potable and process cooling water, and 65 treatment wells used for the remediation of contaminated groundwater. All six water supply wells are screened entirely within the Upper Glacial aquifer. Twenty-four of the 65 treatment wells were in operation during some time in 2018. 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 2018 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 10 has been limited since 2000 due to the impacts it might have on contaminant plume flow directions in the central portion of the site (specifically on the Waste Concentration Facility Sr-90 plume). However, with well 12 being out of service, well 10 is used for short periods of time. During 2018, the use of wells 4 and 6 were limited due to the detection of per- and polyfluoroalkyl substances (PFAS).

The water supply operating protocols have been established by the BNL Water and Sanitary Planning Team to minimize pumping induced changes in groundwater flow directions. 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 BNL Supply Well Pumpage 1992 through 2018.



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 2018, a total of 413 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 79 percent of the water for 2018. **Table 2-2** summarizes the 2018 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

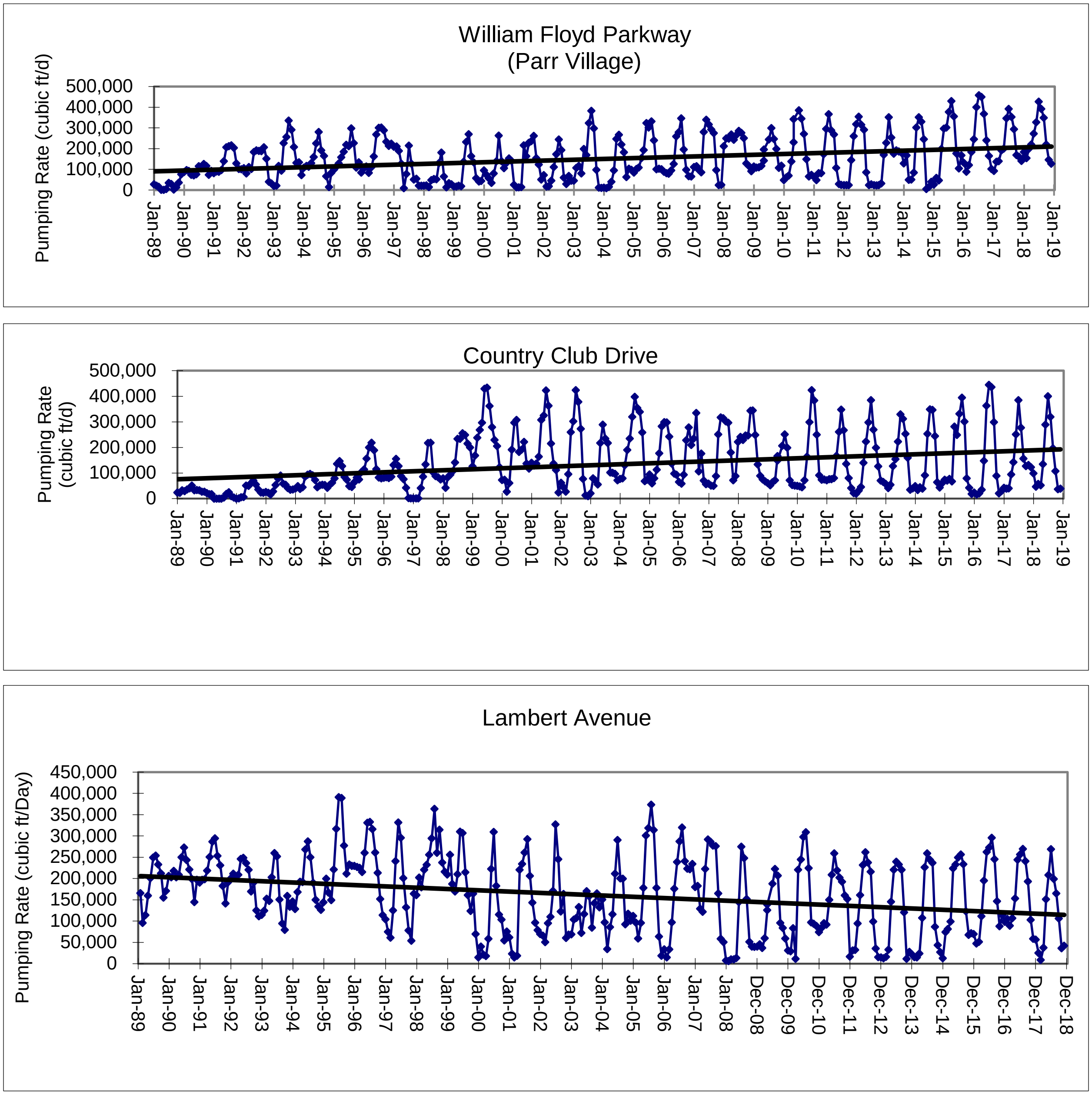
Several Suffolk County Water Authority (SCWA) well fields are located in the vicinity of BNL. The William Floyd Parkway Well Field is west/southwest of BNL (**Figures 2-2 and 2-3**) and consists of three water supply wells that withdraw groundwater from the mid to deep Upper Glacial aquifer. The Country 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 2018 is provided as **Figure 2-4.** In 2018, the William Floyd Parkway (Parr Village) and Country Club Drive Well Fields produced 687 and 406 million gallons for the year, respectively. The Lambert Avenue Well Field, located south of BNL, produced 299 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 2018. 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 over the past several years (**Figure 2-2**).   **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 2018, it is estimated that the recharge at BNL was approximately 34 inches. **Table 2-4** summarizes monthly and annual precipitation results from 1949 to 2018 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 2018 was 68.53 inches, which was significantly above the long-term yearly average of 48.94 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 28 - February 1, 2019. 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 1950–2018) 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. 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 was installed by the USGS in the late 1940s. The well is located near the BNL Brookhaven Center building, and 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 2018, a number of new permanent monitoring wells and temporary vertical profile wells were drilled for the Western South Boundary plume characterization effort. The geologic information obtained during their installation was incorporated into Western South Boundary cross section.

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3.0 CERCLA GROUNDWATER MONITORING AND REMEDIATION

Chapter 3 gives an overview of groundwater monitoring and remediation efforts at BNL during 2018. The chapter is organized first by Operable Unit, and then by the specific groundwater remediation system and/or 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 Trichlorofluoromethane (Freon-11) plume and the OU VI Ethylene Dibromide (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

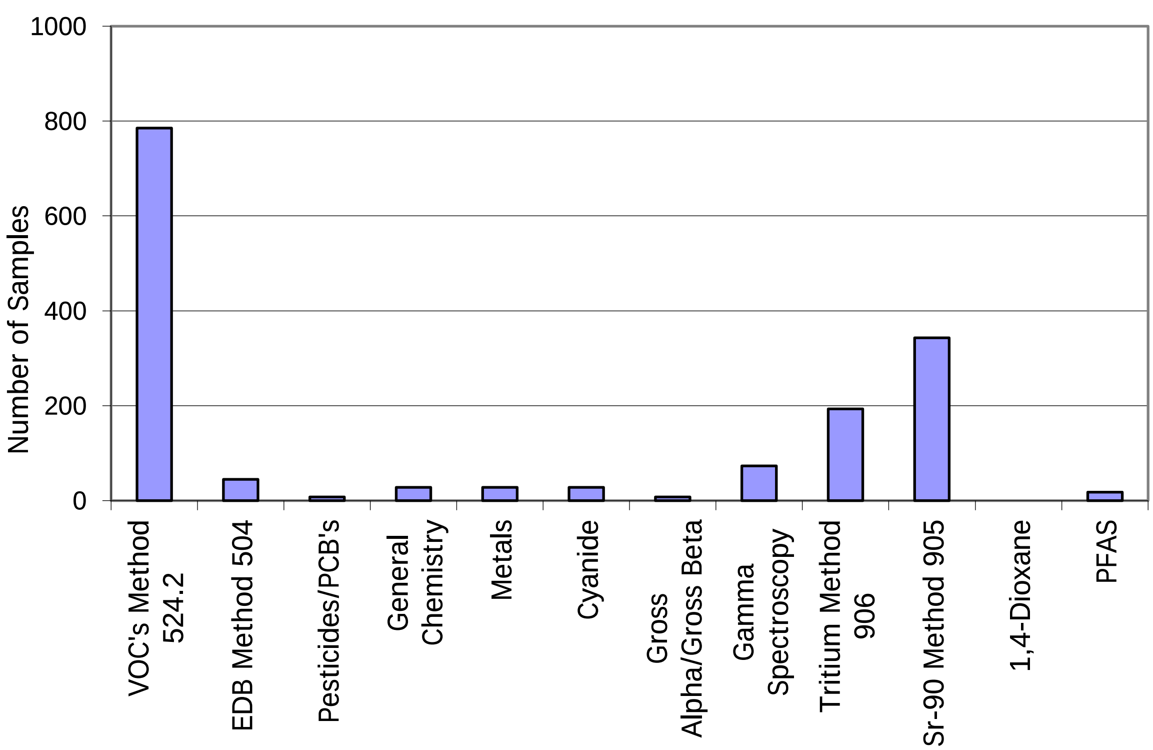
Additionally, BNL's ability to accurately depict these plumes has been enhanced over the years by the:

- 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 2018, and through January 2019, the contaminant plumes were tracked by collecting 1,017 groundwater samples obtained from 569 on-site and off-site permanent monitoring wells. From April 1, 2018 through March 31, 2019, 121 temporary wells were installed and 383 samples were collected. **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 2018 data from permanent monitoring wells. Contaminant plumes associated with Building 96, Middle Road, OU I South Boundary, Industrial Park, North Street East, OU VI, OU III South Boundary, and Brookhaven Graphite Research Reactor (BGRR) projects were further defined in 2018 using temporary wells (i.e., direct push Geoprobes® or vertical profiles).

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. (Note: The fourth quarter 2018 sampling round was delayed and many of these samples were not collected until January 2019). 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 2018.



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 2018). 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. **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 2018, 741 treatment system samples were obtained from 90 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) 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 from 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 a 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 volatile organic compound (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® primarily because perfluorooctanoic acid (PFOA) was used during its manufacture and residual amounts of this compound may be present in the finished product. In the US, the manufacture and use of PFOA were phased out by late 2015.

During 2018, 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 results in the release of no to very low levels of several PFAS compounds, additional comparison testing is needed (see BNL 2019a). 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. 2018 Summary of Existing Groundwater Remediation Systems at BNL.

Operable Unit System	Type	Target Contam	No. of Wells	No. of Wells Oper in 2018	Years in Operation	Recharge Method	Pounds VOCs Removed in 2018/Cumulative
Operable Unit I							
South Boundary	P&T, AS	VOC	2	0	Operated: 16 Standby: 5	Basin	0/369
Operable Unit III							
South Boundary	P&T, (AS)	VOC	8	2	21	Basin	7/3048
HFBR Pump and Recharge	Pump and Recirculate	Tritium	4	0	Operate: 9.0 Standby: 12	Basin	0/180
Industrial Park	Recirc. Well/P&T (AS/Carbon)	VOC	9	2	19	Recirc. Well	2/1075
****Building 96	Recirc. Well (AS/Carbon)	VOC	4	2	Operate: 15 Standby: 3	Recirculation Well	1/142
Middle Road	P&T (AS)	VOC	7	3	17	Basin	32/1261
Western South Boundary	P&T (AS)	VOC	2	1	16	Basin	3/144
Chemical Holes	P&T (IE)	Sr-90	3	1	16	Dry Well	0.01**/4.94
North Street	P&T (Carbon)	VOC	2	0	11 Standby: 3	Wells	0/342
North Street East	P&T (Carbon)	VOC	2	0	Operate:10 Standby: 4	Wells	0/44
LIPA/Airport	P&T and Recirc. Wells (Carbon)	VOC	10	5	14	Wells and Recirc. Well	14/455
Industrial Park East	P&T (Carbon)	VOC	2*		Shutdown Operate: 5 Standby: 4	Wells	0/37
BGRR/WCF	P&T (IE)	Sr-90	9	6	12	Dry Wells	0.6**/27.9
Building 452 Freon-11	P&T (AS)	Freon-11	1	0	Operate: 6 Standby: 2	Basin	0/106*****
Operable Unit VI							
EDB	P&T (Carbon)	EDB	2	2	14	Wells	NA***
		Total Wells	65	24			

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
* Wells abandoned in 2014
P&T = Pump and Treat
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.

** Sr-90 removal is expressed in mCi.
*** No cumulative EDB calculations are performed based on the low concentrations detected.
**** Well RTW-1 was modified from a recirculation well to surface discharge in May 2008.
*****Total Freon-11 mass is sum of Building 96 and Building 452 treatment systems.

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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 soil remediation program was 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 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**). A Petition for Shutdown of the OU I South Boundary Treatment System was approved by the regulatory agencies in July 2013 as the conditions for shutdown 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 2018 from the OU I South Boundary Groundwater Treatment System. This system began operating in December 1996. A Petition for Shutdown of this system was submitted to the regulatory agencies in May 2013 and approved in July 2013.

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

The OU I South Boundary monitoring program uses a network of 46 monitoring wells (**Figure 1-2)** to assess the groundwater treatment system and its effects on the plume**.**

Sampling Frequency and Analysis

The wells are monitored for VOCs, tritium, 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 the areal extent of VOC contamination from the Current Landfill/former HWMF area based on the samples collected in the third and fourth quarters of 2018. The primary VOCs detected in the on-site segment of this plume include 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 *2018 Environmental Monitoring Report, Current and Former Landfill Areas (BNL 2019a).* The downgradient portion of the OU I South Boundary plume (as defined by TVOC concentrations greater than 5 µg/L) has been remediated due to groundwater remediation, 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 2018 analytical results. Significant findings for 2018 include:

- Monitoring well 088-109 is the only remaining Current Landfill source area well consistently exhibiting VOC concentrations above 5 µg/L. 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**). In 2018, TVOC concentrations in this well ranged from 15 µg/L to 71 µg/L. Monitoring well 098-99 (OUI-MW01-2017) was installed to provide a monitoring point approximately 1,200 feet downgradient of the Current Landfill and well 088-109. TVOC concentrations in this well have ranged from 2 µg/L to 7 µg/L. 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 2018 was 0.4 µg/L.
- None of the remaining downgradient plume core wells have individual VOC concentrations above AWQS. However, the TVOC concentration in well 115-16 was 9.2 µg/L. This consisted primarily of chloroethane at 4.5 µg/L and 1,2-Dichloroethane at 4.3 µg/L (**Figure 3.1-3**).
- There were no detections of VOCs above AWQS in perimeter monitoring wells.

3.1.5 Radionuclide Monitoring Results

A subset of the OU I Monitoring Program wells is analyzed for tritium and 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.

Forty permanent wells are monitored for Sr-90 contamination from the former HWMF **(Table 1-5)**. The highest Sr-90 detected in 2018 from a monitoring well was 42 pCi/L in well 098-30 during October (the Sr-90 DWS is 8 pCi/L). Fourteen temporary wells were installed during April-May 2018 as part of an annual effort to enhance the permanent well network and track the migration of Sr-90 from the former HWMF. An additional six temporary wells were installed during September-October 2018 to locate the leading edge of Sr-90 contamination and optimal locations for the installation of three new sentinel monitoring wells. The well locations are shown on **Figure 3.1-4.** Sr-90 trend plots are provided on **Figure 3.1-5.** The data are included in **Table 3.1-1**.

The results from the 2018 temporary wells indicate that the leading edge of the higher Sr-90 segment of the plume, that tracks back to the former HWMF source area, is approaching the temporary well transect that was installed within the Long Island Solar Farm (LISF) (**Figure 3.1-4)**. Specifically, the leading edge is represented by GP-71which had a concentration of 73 pCi/L. This is an increase from 50 pCi/L, when this location was last sampled in 2016. Sr-90 concentrations for temporary wells GP-88, GP-89, and GP-90 were all below 8 pCi/L. These wells were located approximately 400 feet to the south of GP-71. Based on the low concentrations in GP-88, GP-89, and GP-90 there is a break in the plume which separates it from the leading, lower Sr-90 concentration plume segment.

3.1.6 System Operations

The extraction wells are currently sampled quarterly as the system was in standby mode for 2018. **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 2018 no influent/effluent samples were collected.

The following is a summary of the OU I system operations for 2018:

January–December 2018
The system remained in standby mode for the year **(Table 3.1-4)** . 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 2018, 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 2018. TVOC levels in EW-1 and EW-2 remained low with maximum concentrations of 6.2 µg/L and 1.3 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 2018 (**Table F-2 and F-3**).

Table 3.1-2.
OU I South Boundary Treatment System
2018 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

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 2018 (**Table 3.1-3**).

3.1.8 System Evaluation

Although the system remains in standby, groundwater monitoring is ongoing 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 emanating from the northeast portion of the Current Landfill as observed in monitoring well 088-109. The source area is covered by an engineered cap. However, it is

Table 3.1-3
OU I South Boundary
2018 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

suspected that the water table is continuing to flush contaminants from the vadose zone and/or the bottom of the landfilled materials.

Former HWMF
2018 groundwater monitoring data indicate that the area of higher Sr-90 concentrations initially characterized during 2015, from the former HWMF south to the LISF, continues to slowly migrate south. Temporary well locations in 2018 were focused on the downgradient segments of the plume and no new data was collected within the boundary of the former HWMF.

2. Were unexpected levels or types of contamination detected?

Current Landfill
No unexpected results were observed.

Former HWMF
No unexpected results were observed.

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

Current Landfill
Yes, monitoring results indicate that the OU I onsite VOC plume has been remediated. 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. Updated modeling results of VOCs obtained from the 2015/2016 temporary well data set indicate that VOC concentrations from the Current Landfill will attenuate to below 5 µg/L TVOC prior to reaching the site boundary. The modeling results are supported by the TVOC concentration in monitoring well 098-99.

Former HWMF
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. Six temporary wells were installed in 2018 approximately 250 feet north of the site boundary. The purpose of these wells was to characterize Sr-90 concentrations in this area and provide data to guide in the placement of three new sentinel monitoring wells that were subsequently installed. This area of Sr-90 contamination comprises a low-level slug that is separated from the higher concentration plume that extends from the former HWMF source area south to the LISF.

Groundwater model simulations show the leading edge of higher concentration area of Sr-90 arriving at the site boundary at levels above DWS in approximately 42 years (2058) and attenuating to below DWS by approximately 2081.

4. Can individual extraction wells or the entire treatment system be shut down or placed in pulsed pumping operation?
Yes, the system was placed in standby mode in July 2013 following regulatory approval of the Petition for Shutdown. There has been no significant VOC concentration rebound observed in either the extraction wells or monitoring wells since system shutdown. There are only two plume core wells exhibiting individual VOCs (slightly) above the AWQS. Based on the data obtained during the period of system shutdown, a Petition for Closure will be submitted in 2019 for this system.

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

Current Landfill
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. 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.

Former HWMF
Yes, Sr-90 is detected above 8 pCi/L. A combination of temporary and permanent wells define a plume of Sr-90 concentrations exceeding 8 pCi/L as 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?
No. MCLs have not been achieved for individual VOCs in all wells. Well 088-109 exceeded MCLs for individual VOCs with the highest concentration of 9.6 µg/L of chloroethane detected in the fourth quarter of 2018 (collected in January 2019). A comparison of groundwater quality conditions are shown on **Figure 3.1-8** which compares the VOC plume from 1997 to 2018.

3.1.9 Recommendations

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

- Based on the lack of significant rebound in VOC concentrations since system shutdown in 2013 and very low remaining VOC concentrations in area monitoring wells, submit a petition for closure of the OU I South Boundary Treatment System in 2019.
- Maintain the VOC groundwater monitoring program of an annual sample collection from plume core wells: 107-40, 107-41, 115-13, 115-16, and 115-51. Maintain quarterly sampling of well 098-99.
- Install three shallow monitoring wells at the locations of GP-30, GP-40 and GP-42 to provide permanent monitoring points where the highest Sr-90 concentrations were observed at locations in and adjacent to the former source at the FHWMF. Install temporary wells as needed to fill monitoring data gaps and characterize extent of Sr-90 plume.
- Discontinue Sr-90 sampling for monitoring wells 099-04, 107-10, 107-24, 107-26, 107-40, 115-03, 115-13, 115-14, 115-15, 115-16, 115-28, 115-29, 115-30, and 115-31. Sr-90 concentrations have been either non-detect or barely detectable for at least five years in these wells. In addition,

several of the wells are located significantly to the west of the plume location or are significantly deeper than the observed plume depth.

3.2 OPERABLE UNIT III

There were several VOC, Sr-90, and tritium plumes addressed under the OU III Remedial Investigation/Feasibility Study (RI/FS). The VOC plumes originated from a variety of sources, including Building 96, Building 452 Freon, and various small sources 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 using TVOC concentrations. 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.

Figure 3.2-3 presents a comparison of the OU III plumes between 1997 and 2018. 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 will be performed by modifying the system to include four new extraction wells.

Three radiological plumes were addressed under OU III. The HFBR tritium plume had travelled several thousand feet south from the HFBR spent fuel pool. This plume has naturally attenuated and the pump and recharge system has received regulatory approval for closure. 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 **3.2.17** 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 2018 operational data from the OU III Building 96 Treatment System, which consists of three recirculation wells and one pumping 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 17 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

For recirculation wells RTW-2, RTW-3, and RTW-4, contaminated groundwater is drawn 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 then 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 resin treatment was bypassed following a decline in hexavalent chromium concentrations below the AWQS and was decommissioned in 2018 following regulatory approval. 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 the VOC contaminated soil source area in 2010 had a significant impact on VOC concentrations in source area groundwater. RTW-1 concentrations have decreased significantly over the past two years with only a couple of isolated TVOC concentrations greater than 10 μg/L occurring during that time. The recommendation to increase the pumping rate in this well from the *2017 Groundwater Status Report* was implemented in May 2019. It is anticipated that this increased pumping rate will expand the capture zone westward, which should result in the capture of higher VOC concentrations on the west edge of the plume. The ROD cleanup goal for this groundwater plume is to meet drinking water standards by 2030.

A soil vapor extraction (SVE) pilot test was performed in 2018. The purpose of the study was to evaluate the feasibility of constructing and operating an SVE system to treat VOC soil-gas concentrations in the source area, and further reduce persistent VOCs in source are groundwater. This study was a recommendation in the *2017 Groundwater Status Report*. The report is included as **Appendix H**. Based upon the calculated recovery rate of 1.15 lbs/year, an SVE system would not be a cost-effective option to address residual soil contamination in this area.

Figure 3.2.1-1 shows the location of the excavated soil contamination area in relation to the 2018 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 31 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 one temporary well, B96-GP02-2019, installed in March 2019. The majority of the wells are sampled quarterly and analyzed for VOCs as noted in **Table 1-5**.

3.2.1.4 Monitoring Well Results

Complete VOC results are provided in **Appendix C**. The fourth quarter 2018 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 2018 follows:

<u>Former Source Area to RTW-1:</u>

- Since detecting a maximum TVOC concentration of 2,435 μg/L in 2011, concentrations declined in monitoring well 085-379 and have fluctuated between 58 μg/L and 135 μg/L since 2016. This well is located immediately south of the 2010 soil excavation area. This well straddles the water table with a 20 foot screen in order to ensure that any residual groundwater contamination from the former source area is identified during fluctuations in the water table.
- 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 8 µg/L in April 2019.
- Maximum TVOC concentrations in well 095-84, located immediately upgradient of extraction well RTW-1 were 30 µg/L in the fourth quarter 2018. 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 this well declined to 48 μg/L in October 2018.
- Temporary well B96-GP-02-2019 was installed immediately north of well 095-306 to evaluate the maximum vertical extent of VOCs identified at the bottom of a temporary well installed at this same location in 2018 (as reported in the *2017 Groundwater Status Report*). A maximum TVOC concentration of 252 μg/L was observed at a depth of 43 feet below ground surface as shown in **Table 3.2.1-4** It appears that the plume has shifted slightly deeper in this area in recent years based on results observed in this temporary well and some of the shallower wells in the area discussed previously (see **Figure 3.2.1-2**). This could be due to the effects of pumping at RTW-1 over the previous 18 years in establishing a steeper vertical hydraulic gradient near the source area.
- TVOC concentrations in monitoring wells 095-294, 095-307, 095-308, and 095-313 have been declining over the past several years. These wells monitor the slightly deeper VOC contamination that had been observed west of the main Building 96 plume.

<u>RTW-1 to Downgradient Recirculation Wells RTW-2 through RTW-4:</u>

- Elevated VOC concentrations continue to be detected in monitoring well 095-159, located downgradient of RTW-1. The maximum TVOC concentration in this permanent well (and the entire Building 96 plume) during 2018, was 207 μg/L in July. TVOC concentrations dropped off to 35 μg/L in October and then rebounded to 111 μg/L in February 2019. This contamination is migrating towards RTW-2 which is capturing and treating the VOCs.

<u>Wells Downgradient of RTW-2 through RTW-4:</u>

- 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, but no VOCs were detected during the first two quarters of 2019.

- The maximum TVOC concentration in sentinel monitoring well 095-318, located on Weaver Drive, was 7 µg/L in July 2018. TVOC concentrations in this well have significantly declined since the well was installed in 2010 and a detection of 143 µg/L was observed. This contamination will be addressed by the Middle Road treatment system.

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.

PFAS Monitoring

- As part of the Per- and Polyfluoroalkyl Substances (PFAS) source area characterization effort, BNL collected samples of the groundwater in 2018 and 2019 for PFAS analyses. The results of the sampling are presented in Section 3.11.

3.2.1.5 System Operations

Operating Parameters

Extraction well RTW-1 operated full time during 2018. Extraction well RTW-2 was placed back in full time operation November 2018 due to increasing VOCs (above the capture goal of 50 µg/L) in upgradient monitoring wells. Well RTW-3 remained in stand-by mode since January 2016. RTW-4 has been in stand-by mode since October 2012.

January – September 2018

The system operated normally during this period and treated approximately 13 million gallons of water.

October – December 2018

Well RTW-1 and RTW-2 operated normally during this period and treated approximately 4 million gallons of water.

During 2018 the system treated approximately 17 million gallons of water (**Table F-7**).

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 65 µg/L in RTW-2 in the fourth quarter of 2018. **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 2018.

There was no detection of hexavalent chromium in the effluent of RTW-1 in 2018.

Table 3.2.1-1
OU III Building 96 RTW-1 Treatment Well, 2018 SPDES Equivalency Permit Levels

Parameter	Permit Level (µg/L)	Max. Measured Value (µg/L)
pH range	5.0–8.5 SU	6.1–7.8 SU
chromium (hexavalent)	100	<0.5
tetrachloroethylene	5.0	1.0
1,1,1-trichloroethane	5.0	<0.5
thallium	Monitor	<0.5
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

Air Discharge

In 2018, 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
2018 Average VOC Emission Rates

Parameter	Allowable ERP* (lb/hr)	Actual** ER (lb/hr)
dichlorodifluoromethane	0.0000187	0.00000574
acetone	0.000674	0
methylene chloride	0.000749	0
2-butanone	0.000187	0
benzene	0.000112	0.0000169
tetrachloroethylene	0.000165	0.0000033
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 (RTW-1) was 33 gpm. The pumping and mass removal data are summarized on **Table F-7**. In 2018, approximately 0.7 pounds of VOCs were removed. Since February 2001, the system has removed approximately 142 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?

Although the previously identified high PCE concentrations in soil were excavated in the summer of 2010, there continues to be residual contamination persisting in the vadose zone and the silt and sand lenses. 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.

A SVE pilot study conducted in 2018 determined that SVE treatment of the source area would not be a viable method of further reducing source area elevated residual groundwater concentrations.

2. Were unexpected levels or types of contamination detected?

TVOC concentrations exceeded the capture goal in RTW-2 at 65 μg/L in October of 2018. Concentrations also remained elevated in monitoring wells immediately upgradient of RTW-2 resulting in the re-start of this extraction well in November 2018.

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. An area of elevated

PCE located in well 095-159 has resulted in the re-start of extraction well RTW-2 in 2018. See **Figure 3.2.1-6** for a comparison of the plume from 2000 to 2018. VOC concentrations have remained low in sentinel well 095-318 located on Weaver Drive.

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-2 exceeded the capture goal of 50 µg/L in October 2018 with a TVOC concentration of 65 µg/L and was re-started. RTW-1 has not exceeded the TVOC capture goal in 2018, however, core monitoring wells have. A recommendation from the *2017 Groundwater Status Report* to increase pumping of RTW-1 was implemented in May 2019. It is anticipated that by increasing the capture zone of RTW-1, the VOCs migrating to the west through well 095-159 will be captured and treated. This would also ultimately allow for the return of RTW-2 to stand-by mode.

Influent TVOC concentrations in downgradient recirculation wells RTW-3 and RTW-4 have been below 50 µg/L since 2008. The maximum TVOC concentration detected since 2016 in RTW-2 was 21 µg/L in April 2017. The maximum TVOC concentration detected in nearby up-gradient monitoring wells 095-312 and 095-172 over the past two years was 40 µg/L (in October 2017). Due to these consistently low levels, extraction wells RTW-2 through RTW-4 have remained in standby mode.

4a. Are TVOC concentrations in plume core wells above or below 50 µg/L?
TVOC concentrations in six of 21 core wells were above 50 µg/L in 2018 which is a decrease from eight wells in 2017.

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 April 2019 have been below 5 µg/L. RTW-1 has been kept in operational mode given the elevated VOC concentrations in well 095-159 which is located immediately upgradient.

5. Has the groundwater cleanup goal of meeting MCLs been achieved?
MCLs have not been achieved for individual VOCs in all plume core wells. Future monitoring results for well 095-159 will be used to evaluate the increased pumping and extent of capture zone expansion for RTW-1 in 2019.

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 wells RTW-1 and RTW-2. Maintain a monthly sampling frequency of the influent and effluent. Continue operating RTW-2 based on influent TVOC concentrations and concentrations observed in upgradient well 095-159.
- Increase monitoring frequency of well 095-159 to monthly to evaluate the influence of increased pumping rate of RTW-1 and westward expansion of capture zone.
- 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.
- Install a monitoring well at the location of B96-GP02-2019 and screen from 15 to 25 feet mean sea level (ft. msl.).

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3.2.2 Building 452 Freon-11 Treatment System

This section summarizes the 2018 operational data from the Building 452 Freon-11 Treatment System, which consists of one pumping well with air stripping treatment. It also presents conclusions and recommendations for future operation of the 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**). Twelve monitoring wells were 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).

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 main portion of the Freon-11 plume. The goal of the remediation system is to reduce Freon-11 concentrations to <50 µg/L, which would then be followed by a period of monitored natural attenuation.

The Building 452 treatment system began operation in March 2012. Groundwater from extraction well EW-18 is 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 is discharged to a nearby stormwater culvert which leads to BNL Recharge Basin HS. The discharges are regulated under two NYSDEC SPDES equivalency permits. 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 included in the *Operations and Maintenance Manual Building 452 Groundwater Treatment System* (BNL 2012b).

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 2018, eleven of the Building 452 monitoring wells were sampled two times, and the samples were analyzed for VOCs (**Table 1-6**). The twelve Building 96 monitoring wells 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 third quarter 2018 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 2018 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. Monitoring results for the third quarter 2018 indicate that all Freon-11 concentrations were below the 5 µg/L AWQS.

Plume Core Wells:

- Plume core wells 085-385 and 085-386 are located within the capture zone of EW-18. Freon-11 concentrations in these wells have been less than the 50 µg/L capture goal since May 2014 and were less than the 5 µg/L AWQS during the third quarter of 2018.
- During 2018, the maximum influent Freon-11 concentrations in extraction wells EW-18 and RTW-1 were 17.6 µg/L and 0.65 µg/L, respectively. Influent concentrations in EW-18 decreased to less than the 5 µg/L AWQS by January 2019.

Bypass Wells:

- Freon-11 was not detected in the by-pass wells during the third quarter 2018.
- Low levels of Freon-11 were detected in Building 96 treatment well RTW-2, with an estimated concentration of 0.19 µg/L detected during the third fourth quarter of 2018. Freon-11 was not detected in RTW-3, RTW-4, or in the nearby monitoring wells.

Detection of Per- and Polyfluoroalkyl Substances (PFAS):

- In December 2018, samples collected from the five extraction wells associated with the Building 452 Freon-11 and Building 96 treatment systems were analyzed for 21 PFAS compounds. PFAS compounds were detected in all five extraction wells. The monitoring results are described in **Section 3.11**.

3.2.2.4 System Operations

Operating Parameters

From February 2015 until March 2016, extraction well EW-18 operated in a pulsed pumping mode of one month on, one month off. Because Freon-11 concentrations remained below the 50 µg/L cleanup goal during the pulsed-pumping operation, the system was placed in standby mode in March 2016 (BNL 2016a). However, due to a rebound of Freon-11 concentrations in extraction well EW-18 to 91.7 µg/L in October 2016, the system was placed back into full time operation in November 2016, and remained in full time operation until March 2017 when Freon-11 concentrations decreased to less than 8 µg/L. Operating conditions for Building 96 extraction well RTW-1 are presented in **Section 3.2.1**.

During 2018, the Building 452 Freon-11 groundwater treatment system remained in standby mode (**Table 2-2**).

January – December 2018

The system remained in standby mode.

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 all of 2018, extraction well EW-18 was only turned on long enough to collect quarterly influent samples. The highest Freon-

11 influent concentration was 17.6 µg/L in July. **Figures 3.2.2-3 and 3.2.2-4** show the Freon-11 concentrations in the extraction well over time.

Table 3.2.2-1 shows the maximum measured effluent contaminant concentrations compared to the SPDES equivalency permit for the treatment system. No effluent samples were collected during 2018 because the treatment system was in standby mode during the entire year.

During 2018, the maximum Freon-11 influent concentration in Building 96 extraction well RTW-1 was 0.65 µg/L. Freon-11 was detected in the other Building 96 treatment well RTW-2 at concentrations up to 0.19 µg/L (**Section 3.2.1**).

Table 3.2.2-1
Building 452 EW-18 Treatment Well
2018 SPDES Equivalency Permit Levels

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

SU: Standard Units
NA: Parameter not analyzed
Note: Required effluent sampling frequency is monthly following a period of 24 consecutive weekly with no exceedances. *Weekly* for pH.

Cumulative Mass Removal

The Building 452 treatment system was not in operation during all of 2018 (**Table 3.2.2-2)**. 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**. Since the start of treatment operations in March 2012, approximately 101 pounds of Freon-11 have been removed. The system has also remediated low concentrations of several other VOCs (e.g., chloroform, trichloroethene, and 1,1,1-trichloroethane) for a total removal of approximately 106 pounds of VOCs. The cumulative total of VOCs removed over time is plotted on **Figure 3.2.2-5**. Low levels of Freon-11 have been continuously detected in Building 96 treatment well RTW-1 since December 2010. Approximately 5.4 pounds of Freon-11 has been removed by this treatment system. Combined, the two treatment systems have removed approximately 106 pounds of Freon-11 from the aquifer as of March 2017 when the system was placed in standby. During 2018, 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?

Although low levels of Freon-11 are still entering the groundwater from the vadose zone in the source area, the resulting concentrations are below the 5 µg/L AWQS. All Freon-11 concentrations in source area monitoring wells have been below the 5 µg/L AWQS since August 2017. **Figure 3.2.2-6** shows a comparison of the extent of the plume in 2011 and the third quarter 2018 when all Freon-11 concentrations were below the 5 µg/L AWQS.

2. Were unexpected levels or types of contamination detected?
No. After March 2017, when the Freon-11 treatment system was placed back into standby mode, all Freon-11 concentrations in groundwater have been less than the 50 µg/L treatment system capture goal. Furthermore, most Freon-11 concentrations are presently below the 5 µg/L AWQS.

3. Has the downgradient migration of the plume been controlled?
Yes. Plume migration was successfully controlled by the combined operations of extraction wells EW-18 and RTW-1. During 2018, all Freon-11 concentrations in monitoring wells downgradient of RTW-1 were less than the 5 µg/L AWQS.

4. Can individual extraction wells or the entire treatment system be shut down or placed in pulsed pumping operation?
The treatment system was placed back into standby mode in late March 2017, and since that time all Freon-11 concentrations have been below the 50 µg/L capture goal. Because Freon-11 concentrations in source area and most downgradient monitoring wells have declined to below or the 5 µg/L AWQS, the treatment system can be closed.

4a. Are Freon-11 concentrations in plume core wells above or below 50 µg/L?
During 2017 and 2018, Freon-11 concentrations in all plume core wells and extraction wells EW-18 and RTW-1 were below the 50 µg/L TVOC capture goal. As noted above, all Freon-11 concentrations have been reduced to less than the 5 µg/L AWQS since the 3rd Quarter of 2017.

4b. Was there a significant concentration rebound in core wells and/or extraction wells following shutdown?
Since March 2017, when the treatment system was returned to shutdown mode, there has been no significant rebound in Freon-11 concentrations in any of the core wells or extraction wells.

5. Has the groundwater cleanup goal of meeting MCLs been achieved?
Based upon current data, the 5 µg/L MCL for Freon-11 has been achieved in the source area, and in most downgradient areas.

3.2.2.7 Recommendations

The following are recommendations for the Building 452 Freon-11 remediation system and monitoring program:

- Maintain the Building 452 Treatment System in standby mode. If there isn't a significant rebound in Freon-11 concentrations, with concentrations exceeding 50 µg/L, prepare a Petition for Closure by mid-2019. It is anticipated that the Building 96 treatment well RTW-1 will remain in full-time operation for several more years. The Freon-11 tray air stripper is being repurposed to treat some of the water extracted from RTW-1.
- Following regulatory agency approval of the Petition for Closure, discontinue the Building 452 monitoring program. Select monitoring wells located downgradient of extraction well EW-18 may be incorporated into the Building 96 program. Furthermore, any decisions to abandon extraction well EW-18 and the monitoring wells will be made after the PFAS plume originating from the former firehouse area has been fully characterized (see **Section 3.11**).

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 2018 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 at a total pumping rate of 332 gpm. 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**). During 2018, four (MR-VP01-2018 through MR-VP04-2018) temporary vertical profile wells were installed upgradient of well 104-37 to determine the cause for the persistently elevated VOCs observed in this well. These vertical profile locations are depicted on **Figure 3.2.3-1** and North-South cross section (F-F') **Figure 3.2.3-4**.

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 2018 was 421 µg/L in well 105-68 during the January 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 January 2018 for this well was 263 µg/L. TVOC concentrations decreased to 101 µg/L in November 2018.
- 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 of 421 µg/L in January 2018. 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 2018 with maximum values in May of 227 µg/L and 100 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 2018.

- 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 24 µg/L in January 2018 and well 095-322 had a TVOC concentration of 44 µg/L in November 2018.
- VOC detections were observed in vertical profile wells (MR-VP01-2018 through MR-VP04-2018). TVOC concentrations were within expected values for their respective locations within the upgradient plume core. Maximum TVOC concentrations up to 52 µg/L were observed with the primary VOC being PCE at 40 µg/L at a depth of 207 feet bls in vertical profile MR-VP02-2018. Data for these vertical profile wells are summarized in **Table 3.2.3-4.**

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 172 million gallons of water were treated in 2018 by the Middle Road Treatment System.

The following is a summary of the Middle Road System operations for 2018.

January – September 2018

The system was down for five days in January due to a snow event. In February, the system operated normally with RW-2, RW-3 and RW-7 Operating. In May well RW-7 was shut down for repair. In July the RW-7 was repaired and restarted the last week of July. In August RW-7 was off for one week for plumbing repairs. In September the RW-2, and RW-3 were off for 10 days for repairs conducted on Building 516 piping. Approximately 130 million gallons of water were treated.

Table 3.2.3-1.
Middle Road Air Stripping Tower
2018 SPDES Equivalency Permit Levels

Parameters	Permit Limit (µg/L)	Max. Observed Value (µg/L)
pH range (SU)	6.5–8.5	6.8 – 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.

October – December 2018

The system was operational for most of the fourth quarter of 2018. The system was off for approximately 2 weeks for repair of RW-7 in the month of October. A new pump and flow meter were installed. 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 42 million gallons of water.

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 a slight decrease over the reporting period. The average TVOC concentration in the influent during 2018 was 22 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 332 gpm during 2018 (**Table 3.2.3-3**, and **Table F-14)**, and approximately 32 pounds of VOCs were removed. Approximately 1,261 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 2018 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 2018, 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 2018 with a maximum concentration of 25 µg/L in well RW-6 in January. The maximum concentration observed in the operating wells in 2018 was in Well RW-7 with a peak TVOC concentration of 48 µg/L in January. 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
2018 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	0.0010
1,1,1-trichloroethane	10***	0
trichloroethylene	0.143	0

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 a source of contamination is still present upgradient of this well. This may be due to either the slower than expected movement of groundwater in this deeper zone or to a continuing upgradient source.

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 and RW-7. The VOC's 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 operations.

3a. Are TVOC concentrations in plume core wells above or below 50 µg/L?
A number of the 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 achived.

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 2018, 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 at a pumping rate of 204 gallons per minute 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 2018, 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 3.2.14**. During 2018 an additional temporary vertical profile well (SB-VP01-2018) was installed to help characterize and delineate VOC concentrations within the plume core. SB-VP01-2018 was installed approximately 250 feet north of well 121-53 and is depicted on **Figure 3.2.4-1** and north-south cross section (F-F’) **Figure 3.2.3-4.**

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 3.2.14** there continues to be no radionuclides detected in this area. **Appendix C** has the complete groundwater monitoring well results for 2018.

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 1.4 µg/L in December 2018.
- 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 2018 with the highest concentration in May of 575 µg/L. However, TVOC concentrations show an overall decreasing trend from 2017 to present.

- Monitoring well 121-45 was installed to monitor the plume between the Middle Road and South Boundary. TVOC concentrations were at 22 µg/L in November. This is a significant reduction from the initial concentration of 613 µg/L in 2006.
- 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 194 µg/L in May 2018. Well 121-53 was also installed upgradient of EW-17 and it showed a peak TVOC concentration of 103 µg/L in May.
- Plume core well 122-05 is a Magothy monitoring well west of EW-8. TVOC concentrations in this well have shown a slight increase with a concentration of 26 µg/L in November 2018.
- Vertical profile well SB-VP01-2018 was installed in November. TVOC concentrations up to 165 µg/L were detected in the 217 feet bls sample. This was comprised primarily of carbon tetrachloride at 73 µg/L and PCE at 80 µg/L. The data for this vertical profile is summarized in **Table 3.2.4-4.**

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.

Table 3.2.4-1.
OU III South Boundary Air Stripping Tower
2018 SPDES Equivalency Permit Levels

Parameters	Permit Limit* (µg/L)	Max. Observed Value (µg/L)
pH range (SU)	6.5 – 8.5	6.8–7.5
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.

System Operations

In 2018, approximately 105 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.

January – September 2018

Approximately 84 million gallons of water were pumped and treated. In January the system was off for five days for a snow event. In February, extraction well EW-4 was pulsed pumped and continued through the year with a one month on, one-month off schedule. In August, EW-17 was off for two weeks for a flow meter repair. In September, the system was off for about 10 days for repairs to piping in Building 516.

October – December 2018

The OU III South Boundary System pumped and treated approximately 21 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.

Table 3.2.4-2.
OU III South Boundary Air Stripper
2018 Average VOC Emission Rates

Parameter	Allowable ERP*	Actual** ER
carbon tetrachloride	0.022	0.0001
chloroform	0.0031	0.0000
1,1-dichloroethane	10***	0.0000
1,2-dichloroethane	0.008	0
1,1-dichloroethylene	0.034	0.0000
cis-1,2-dichloroethylene	10***	0.0000
trans-1,2-dichloroethylene	10***	0
tetrachloroethylene	0.387	0.0017
1,1,1-trichloroethane	10***	0.0001
trichloroethylene	0.143	0.0000

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.

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 2018 total was approximately 7 pounds. Cumulatively, the system has removed approximately 3,048 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 2018, 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.

Extraction Wells

There are two extraction wells currently operating. Well EW-4 continued to show slowly decreasing TVOC concentrations in 2018 from 2.5 µg/L in January to 1.7 µg/L in October. EW-17 showed TVOC concentrations ranging from 17.4 µg/L in January to 15.8 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 204 gpm in 2018.

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 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 3.6 µg/L in November. Eastern perimeter well 114-07 was non-detect in November. Individual VOC concentrations in the remaining plume perimeter wells were less than 5 µg/L in the fourth quarter of 2018.

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 pulse 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 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. 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.
- Maintain the current routine O&M monitoring frequency. .

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 reduces 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.

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* (BNL 2002a). A modification to this system to add four new extraction wells was undertaken beginning in June 2018 (*Modification To Western South Boundary Treatment System BNL, June 2018*). The system was shutdown in October 2018 to complete this modification. The four new wells and the two existing wells are being tied into 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.

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 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.

3.2.5.3 Monitoring Well Results

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 (WSB-VP-16-2017). 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. **Figure 3.2.5-1** presents fourth quarter 2018 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. A summary of key monitoring well data for 2018 follows:

- Ten new monitoring wells were added in 2018 as part of the new extraction well installations. Below is a list of these wells and their rationale:
  103-18 Upgradient monitoring of the plume
  103-19 Upgradient monitoring of the plume
  126-20 Plume monitoring between WSB-4 and WSB-5 and WSB-6
  111-16 Upgradient plume monitoring of WSB-3
  119-12 Upgradient plume monitoring of WSB-4
  126-21 Plume monitoring between WSB-4 and WSB-5 and WSB-6
  126-22 Plume monitoring upgradient of WSB-5 and WSB-6
  130-09 Downgradient plume monitoring for WSB-5 and WSB-6
  130-10 Downgradient plume monitoring for WSB-5 and WSB-6
  130-11 Downgradient plume monitoring for WSB-5 and WSB-6
- 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 19.4 µg/L in well 000-558. Only Chloroform at 5.2 µg/L exceeded the MCL. These wells are intended to monitor the leading edge of the plume. Well 126-20 had significant VOC concentrations in 2018 with a concentration of 150.4 µg/l in the fourth quarter. These contaminants are expected to be captured by the new extraction wells WSB-5 and WSB-6. Upgradient monitoring wells 103-18 and 103-19 located near Princeton Avenue showed low TVOC concentrations during 2018 with a peak concentration of 13 µg/L in May in well 103-18.
- 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.
- **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.
- 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 203 µg/L in December.
- 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 26 µg/L in well 130-09. With the start of the extraction wells in March 2019 it is expected these concentrations will be reduced in the future.
- The area of higher TCA and DCE concentrations that was first characterized 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. TVOC concentrations in wells 119-06 and 126-17 have significantly declined as the plume segment has migrated towards WSB-1 as shown on **Figure 3.2.5-3**.
- TVOC concentrations in well 126-14 ranged between 103 µg/L and 142 µg/L in 2018. This well is approximately 200 feet north of WSB-1. This appears to be the end of the area of higher TVOC concentrations tracked from well 126-17 which has been low for several years. This contamination seems to be migrating slowly towards the extraction well.

3.2.5.4 System Operations

During 2018 the extraction wells were sampled quarterly and the influent and effluent of the air stripping tower were sampled twice per month. Extraction well WSB-1 continued full-time operation through most of 2018. Extraction well WSB-2 continued in standby mode in 2018 based on the TVOC concentrations below the capture goal of 20 µg/L. System samples were analyzed for VOCs. In addition, the effluent was analyzed for pH twice a month. **Table 3.2.5-1** provides the effluent limitations for meeting the requirements of the SPDES equivalency permit. The system's effluent discharges met the SPDES equivalency permit requirements during 2018. The system operations are summarized below.

Table 3.2.5-1
Western South Boundary Treatment System
2018 SPDES Equivalency Permit Levels

Parameter	Permit Level (µg/L)	Max. Measured Value (µg/L)
pH range	6.5–8.5 SU	6.6-7.8 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 2x/month for VOCs and monthly for pH.

SU = Standard units

January – September 2018

WSB-1 extraction well operated normally. The WSB-2 extraction well remained in standby mode. In January WSB-1 was off for five days during a snow event. In September WSB-1 was off for two and a half weeks for construction work on the modification to the treatment system. During the first three quarters, the system treated approximately 72 million gallons of water.

October – December 2018

The system was off for the most of the fourth quarter due to construction activities related to the new extraction wells. The system treated approximately 5.5 million gallons of water.

3.2.5.5 System Operational Data

Extraction Wells

During 2018, the Western South Boundary System treated approximately 77.5 million gallons of water, with an average flow rate of approximately 150 gpm. **Table 2-2** gives monthly pumping data for the two extraction wells. **Table 3.2.5-2** shows the monthly extraction well pumping rates. VOC concentrations for extraction wells WSB-1 and WSB-2 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. Individual VOC compounds in extraction wells WSB-1 and WSB-2 were below AWQS in 2018. VOC levels in both wells have remained relatively constant since system start-up in 2002. **Figure 3.2.5-4** provides a graph of extraction well trends over time.

System Influent and Effluent

Influent TVOC concentrations continued to remain below 20 µg/L. Individual VOC concentrations were slightly below the AWQS during the year, with a maximum TCA value of 2.4 µg/L in January 2018, and maximum DCE value of 2.8 µg/L in December (**Table F-20**). These levels are consistent with the historical influent concentrations.

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 2018.

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 2018, three pounds of VOCs were removed. A total of 144 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 2018 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
2018 Air Stripper VOC Emissions Data

Parameter	Allowable ERP* (lb/hr)	Actual ERP (lb/hr)
carbon tetrachloride	0.016	0
chloroform	0.0086	0.0000
1,1-dichloroethane	10**	0.0000
1,2-dichloroethane	0.011	0
1,1-dichloroethene	0.194	0
chloroethane	10**	0
1,1,1-trichloroethane	10**	0.0001
trichloroethylene	0.119	0.0000

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?

Yes, unexpected levels of TCA, DCE and Freon-12 were detected at various locations as shown on (**Figure 3.2.5-1***)* as described in the *2017 Groundwater Status Report.* Four new extraction wells were installed in 2018 to address this contamination.

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

TVOC concentrations during the fourth quarter of 2018 increased to 128 µg/L in well 126-14 located just to the north of WSB-1 within the capture zone of this extraction well. The four new extraction wells will address the migration of the recently identified plume to the west and slightly deeper than well WSB-1.

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 insure the capture of the high VOC concentrations migrating south from well 126-14.

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 of meeting MCLs by 2030 will 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 core monitoring wells, extraction well WSB-2 may be put into full time operation.
- Begin operation of the four new extraction wells in March 2019. 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 2018 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. This 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).

During 2014, two new groundwater extraction wells were installed in the Industrial Park. 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. One temporary vertical profile well (IP-VP01-2018) was installed in 2018 to enhance the monitoring network.

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 2018. 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 2018 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 2018 include:

Plume Core Wells

- TVOC concentrations in wells 127-08, 127-09, 000-537, and 000-538 continued to show stable or slowly decreasing trends. 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 have ranged between 25 µg/L and 43 µg/L since 2016.
- Well 000-529 is located 300 feet south of 000-548. TVOC concentrations in this well have ranged between 6 µg/L and 31 µg/L since 2016.
- Temporary vertical profile well IP-VP01-2018 was installed to collect additional data in the vicinity of the plume center-line. The maximum TVOC concentration observed in this well was 45 µg/L (**Table 3.2.6-3**).
- Wells 000-541 and 000-530 have shown slightly increasing TVOC concentrations in 2018.

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 000-544 ranged between 8 µg/L and 38 µg/L in 2018.

3.2.6.4 System Operations

In 2018, wells UVB-1 through UVB-7 remained in standby mode. Wells IP-EW-8 and IP-EW-9 started a one month on, one month off pulsed pumping mode in February. These wells pumped a total of approximately 68 million gallons of water in 2018.

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 after 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 the system's 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 2018.

January – September 2018

Wells UVB-1 through UVB-7 remained in stand-by mode in January 2017. Wells IP-EW-8 and IP-EW-9 were pulsed pumped during this period. The system treated a total of approximately 56 million gallons of water during this period.

October – December 2018

Wells UVB-1 through UVB-7 remained in standby. Wells IP-EW-8 and IP-EW-9 were pulse pumped during this period. The system treated a total of approximately 12 million gallons of water during this period.

Table 3.2.6.2
OU III Industrial Park Treatment System
2018 SPDES Equivalency Permit Levels

Parameters	Permit Limit (µg/L)	Max. Measured Value (µg/L)
pH (range)	5.0 – 8.5 SU	5.6 – 6.5 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 2018, influent TVOC concentrations in the treatment system wells were below the capture goal of 50 µg/L (**Figure 3.2.6-4**). The corresponding 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 for 2018 are 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 2018, flow averaged approximately 128 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 2018, approximately 1.5 pounds of VOCs were removed from the aquifer, with a total of 1,075 pounds of VOCs removed since 1999.

Air Treatment System

Air samples were not collected as UVB-1 to UVB-7 were 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.

<u>*1. Were unexpected levels or types of contamination detected?*</u>

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 2018. Lower than expected concentrations continue to be observed in the vicinity of the new extraction wells IP-EW-8 and IP-EW-9.

<u>*2. Has the downgradient migration of the plume been controlled?*</u>

Yes, an analysis of the plume perimeter and bypass well data reveals that there are no TVOC concentrations above the capture goal of the system in 2018. A comparison of the plume from 1997 to 2018 is provided on **Figure 3.2.6-7**

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

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 2018 were below 4 µg/L. Individual VOCs have been below AWQS since 2017. The deeper VOC slug seems to be migrating very slowly and attenuating as it moves south. IP-EW-8 and IP-EW-9 will be placed in standby mode in July 2019.

4. Are TVOC concentrations in plume core wells above or below 50 µg/L?
There were several plume core wells slightly above the 50 µg/L TVOC capture goal in 2018. The maximum TVOC concentration in a plume core well was 58 µg/L in well 000-537.

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 2018.

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.
- Due to individual VOC concentrations remaining below AWQS since 2017 in IP-EW-8 and IP-EW-9, place wells on standby in July 2019 and continue to monitor for rebound of VOCs.

3.2.7 Industrial Park East Monitoring Program

This section summarizes the 2018 monitoring well data for the Industrial Park East (IPE) plume. 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 16 monitoring wells were decommissioned in October 2013. Any remaining contaminants in the downgradient portion of the plume have already attenuated to below MCLs in the Upper Glacial and Magothy aquifers before the required 2030 and 2065 cleanup timeframes, respectively.

The treatment building, including the carbon units and controls, and the recharge wells have been repurposed to support the remediation of the deep VOC plume in the Industrial Park to the west. Remediation of the deep volatile organic compound (VOC) plume is further discussed in **Section 3.2.6** Industrial Park.

3.2.7.1 Groundwater Monitoring

As recommended in the *2017 Groundwater Status Report*, since monitoring wells 000-494, 000-526, 000-427, and 000-429 have been below the MCLs for a minimum of four consecutive sampling events, further monitoring was discontinued. However, a sample was collected in July 2018 from well 000-494 and analyzed for VOCs. The data from well 000-494 was also evaluated as part of the Magothy monitoring program.

3.2.7.2 Monitoring Well Results

The primary VOCs associated with this portion of the OU III plume have been TCA, TCE, carbon tetrachloride, and DCE. **Figure 3.2.7-1** presents the maximum individual VOC data for well 000-494 in 2018. Individual VOCs were below MCLs in 2018.

Volatile organic compound results from well 000-494 have remained below MCLs since 2011. This indicates that the plume has dissipated. **Figure 3.2.7-2** provides the VOC trends for this well.

3.2.7.3 Groundwater Monitoring Program Evaluation

This system was designed to achieve the overall OU III ROD objectives of minimizing plume growth and meeting MCLs in the Upper Glacial aquifer by 2030. According to the *OU III Explanation of Significant Differences* (BNL 2005a), MCLs within the Magothy aquifer must be met by 2065. As noted in the Petition for Closure, the system addressed the highest VOC concentration portion of the plume (above 50 μg/L TVOC).

The Industrial Park East Groundwater Monitoring Program can be evaluated based on decisions established for the program using the groundwater DQO process:

1. Were unexpected levels or types of contamination detected?
No, there were no unusual or unexpected VOC concentrations observed in monitoring well 000-494 for the Industrial Park East Monitoring Program during 2018.

2. Is the plume naturally attenuating as expected?
Yes, the plume has attenuated to below MCLs.

3. Has the downgradient migration of the plume been controlled?
VOC concentrations in the plume segment in the Upper Glacial and Magothy aquifers have been reduced to less than MCLs.

4. Has the groundwater cleanup goal of meeting MCLs been achieved?
Yes, individual VOC concentrations have been below MCLs since 2015.

3.2.7.4 Recommendations

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 is discontinued.

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.

Groundwater treatment consists of two extraction wells, however the system is 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 the potential for 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 handles 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 2018 are included in **Appendix C**. A north–south hydrogeologic cross section (J–J') of the plume is provided on **Figure 3.2.8-2.** The location for the cross section is shown on **Figure 3.2-1**. **Figure 3.2.8-3** shows time-concentration plots for key monitoring wells. A summary of key monitoring well data for 2018 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 May 2018 the concentrations were 38 µg/L, subsequent samples collected in August and December showed concentrations of 13 µg/L and 6 µg/L respectively.

- TVOC concentration in core well 000-474, located approximately 500 feet upgradient of extraction well NS-2, 19.7 µg/L in November, with the highest individual VOC concentration of was 6.9 µg/L of PCE.
- VOC concentrations in plume core well 000-463, located approximately 200 feet north of NS-1, were below AWQS during 2018.
- 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. 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 2018. 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 2018

Both extraction wells NS-1 and NS-2 remained in standby mode in 2018.

3.2.8.5 System Operational Data

The system was in standby mode in 2018.

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 is no new data in these tables for 2018 as the system was in standby for the year. Well NS-1, and NS-2 were in standby mode in 2018, 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 5 µg/L. Well NS-2 remained below 15 µg/L in 2018 with the highest individual VOC detection of 5.8 µg/L of PCE in July. There was no tritium detected in the extraction wells in 2018.

Table 3.2.8-1
OU III North Street Treatment System
2018 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 2018 (**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 2018.

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 2018; 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 2018.

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 2018.

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

No rebound in concentrations was detected during 2018 in NS-1or NS-2. All monitoring wells associated with the extraction wells are below the capture goal and the wells remained in standby mode.

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 2018, six of 11 core wells had VOCs above the MCL but below the system capture goal. Based on these data and groundwater modeling simulations, 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.
- Submit a Petition for Closure in 2019 as this system has met its cleanup goals.

3.2.9 North Street East Treatment System

This section summarizes the 2018 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.

3.2.9.1 System Description

The 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. The extraction well pump for 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).

3.2.9.2 Groundwater Monitoring

The monitoring network consists of 15 wells (**Figure 1-2**). Five of the 15 wells were installed in November 2018 as a follow-up to the EDB groundwater characterization performed. As recommended in the *2017 Groundwater Status Report*, because VOCs have not been detected above AWQS in wells downgradient of extraction NSE-1 since 2005, further monitoring of these wells was discontinued in 2018. These wells are 000-482, 000-483, 000-484, 000-485, and 000-486. In addition, because VOCs have not been detected above AWQS in shallow perimeter well 000-137 since 2000, further monitoring of this well was also discontinued.

The monitoring program was designed to monitor the VOC plume off site, south of the OU I South Boundary Treatment System, as well as the efficiency of the NSE groundwater remediation system. As recommended in the *2016 Groundwater Status Report*, because AWQS have been achieved in all monitoring wells (except for 000-394) since 2011, the sampling frequency for the remaining semi-annual wells was reduced to annual starting in the fourth quarter 2017. However, due to the detection of EDB in perimeter well 000-394 above the DWS since August 2015, this well is sampled quarterly for EDB using Method 504, and annually for VOCs using Method 524.2. The five new monitoring wells (000-551, 000-552, 000-553, 000-554, 000-555) will be sampled quarterly for EDB using Method 504. See **Table 1-5** for details.

3.2.9.3 Monitoring Well Results

Figure 3.2.9-1 shows the extent of the VOC contamination (not including EDB). The plume contaminants originated from the Current Landfill and former HWMF (sources in OU I). See **Figure 3.1-1** for the extent of the on-site portion of the OU I plume. **Figure 3.2.9-2** shows the extent of the EDB plume, including the temporary vertical profile wells installed in 2018.

Figure 3.1-2 depicts the vertical distribution of VOCs within the deep Upper Glacial aquifer. The transect line for cross section A–A' is shown on **Figure 3.1-1**. **Figure 3.1-3** gives the historical trends in VOC concentrations for key core and bypass wells along the NSE area. **Appendix C** contains a complete set of 2018 analytical results for the NSE program wells. A summary of key monitoring well data for 2018 follows:

- Since 2011, individual VOCs continue to remain below AWQS in all monitoring wells, except for upgradient well 000-394. This well is located just south of the LIPA right-of-way. In 2017, there were three detections of PCE exceeding the AWQS with a maximum concentration of 7.9

µg/L. The maximum VOC detected in 2018 was 4.4 µg/L of PCE in well 000-394 in January 2019 (due to scheduling delays, the fourth quarter samples were not collected until January).

- As seen on **Figure 3.1-3**, 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 well 000-394 in 2018 was 0.96 µg/L in the first quarter with concentrations dropping off to 0.49 µg/L in the fourth quarter.
- Since EDB concentrations in well 000-394 have continued to remain elevated in 2017 and 2018, groundwater characterization of this area was performed in 2018. A total of 17 temporary vertical profile wells were installed between March and October up and downgradient of well 000-394 (**Figure 3.2.9-2)**. Samples were collected at 10-foot intervals at each location and analyzed for EDB using Method 504 and other VOCs using Method 524.2. Between 11 to 12 samples were obtained at each location. The data collected identified EDB upgradient of well 000-394 between 140 feet and 195 feet bls. Four of the ten locations upgradient of well 000-394 exceeded the DWS, with a maximum EDB concentration of 0.46 µg/L in VP06-2018. Seven vertical profiles were installed between well 000-394 and extraction well NSE-1, with EDB detected in two locations above the DWS. The maximum EDB detection in these vertical profiles was 0.57 µg/L in VP13-2018. As a result of the characterization effort, the lateral extent and depth of the EDB plume has been delineated. The vertical profile data are provided in **Table 3.2.9-1** and the maximum EDB detected at each location is posted on **Figure 3.2.9-2**. **Figure 3.2.9-3** is a north-south cross section of the EDB plume. Five permanent monitoring wells were installed in November 2018 to provide long term monitoring of the EDB plume. These wells were initially sampled in March 2019 and the data are posted on Figure 3.2.9-2. Groundwater fate and transport modeling was performed in November 2018 using the EDB data from the vertical profiles. The results are discussed in **Section 3.2.9.6** below.

  In addition to EDB, detections of PCE, DCA and TCA above the AWQS were identified in several of the vertical profiles. The concentrations of these compounds were up to 15.6 µg/L of PCE in VP14-2018, up to 7.2 µg/L of DCA in VP03-2018, and up to 5.9 µg/L of TCA in VP16-2018. The maximum PCE detection in 2017 and 2018 was 7.9 µg/L in well 000-394. Monitoring for VOCs will continue.

3.2.9.4 System Operations

The extraction wells were sampled quarterly throughout the year for VOCs, EDB and tritium. **Table 3.2.9-2** provides the effluent limitations for meeting the requirements of the SPDES equivalency permit.

3.2.9.5 System Operational Data

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

January through December 2018

The system remained shut down and in standby mode.

Table 3.2.9-2.
OU III North Street East Treatment System
2018 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

Extraction Wells

During 2018, the extraction wells did not operate. **Table 2-2** shows no monthly pumping data for the two extraction wells as they were on standby for the year. **Table 3.2.9-3** pumping rates reflect that NSE-1 and NSE-2 remained in standby mode. **Figure 3.2.9-4** 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 2018 with a maximum concentration of 9.9 µg/L. TVOC concentrations in NSE-2 remained low during 2018, with concentrations below 2.5 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 2018.

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 3.2.9-5**. 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 2018 (**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?

As noted in **Section 3.2.9.3**, EDB continued to be detected in well 000-394 in 2017 and 2018 above the DWS, at a slight increase from 2016 values. EDB had not been detected historically in the off-site NSE plume. The temporary vertical profiles installed in 2018 delineated the extent of the EDB plume in this area.

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

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 3.2.9-6** shows the overall plume size reduction from 2004 to 2018.

However, based on the elevated concentrations of EDB identified in well 000-394 since 2015 and the results of the vertical profile characterization performed in 2018, the extent of the EDB plume has been identified. The leading edge of this plume is migrating south between VP11-2018 and VP15-2018 at a depth of approximately 140 feet and 195 feet bls. EDB was not detected in NSE-1 in the 2017 and 2018 quarterly samples using Method 504. Based on the fate and transport modeling performed in November 2018, options of natural attenuation or use of extraction well NSE-1 alone will not achieve complete capture of the EDB plume and therefore not meet the cleanup goal of reaching the DWS by 2030. Installing one new extraction well at the leading edge of the plume and a second extraction well within the plume core appears to be the most efficient option for plume capture and remediation. It is projected that groundwater cleanup goals using this active remediation approach would be achieved in four years. The groundwater modeling report is included in **Appendix H**.

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

As noted in **Section 3.2.9.1**, following regulatory approval, the system has been shut down since June 2014 and has remained in standby mode. Since 2014, there has been no rebound of VOCs in any of the monitoring wells or extraction wells, and there were no exceedances above the AWQS in 2018 except for EDB. Due to the detections of EDB above the DWS in well 000-394 since August 2015 and in the vertical profiles, the NSE system will be modified to capture this newly identified plume.

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?

TVOC concentrations in all monitoring wells and extraction wells are below 50 μg/L. The maximum TVOC concentration detected in 2018 was in monitoring well 000-394 at 7.2 μg/L. The maximum TVOC concentration in the 17 vertical profiles was 15.6 μg/L in VP14-2018. EDB was detected above the DWS in six of the 17 vertical profile wells and well 000-394. Prior to the November 2018 installation of five new monitoring wells, there were no existing monitoring wells that were screened deep enough to detect the EDB identified in well 000-394.

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

Significant rebounding of the 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 not detected EDB.

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

No. MCLs have been achieved for individual VOCs in 14 of the 15 plume monitoring wells from 2011 through 2018. However, EDB has been detected above the DWS in well 000-394 since 2015 and in six of the 17 vertical profile wells installed in 2018.

3.2.9.7 Recommendations

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

- Maintain the existing treatment system in standby mode. The extraction wells will continue to be sampled on a quarterly basis for VOCs, EDB, and tritium. 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.
- Based on the EDB vertical profile characterization performed and the fate and transport model recommendation, begin the design for modification of the treatment system for two additional extraction wells. Submit a design modification to the regulators.
- Sample the five new monitoring wells on a quarterly basis using EDB Method 504.
- 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, add this well to the NSE monitoring program and perform quarterly sampling for EDB using Method 504.

3.2.10 LIPA/Airport Treatment System

This section summarizes the 2018 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-2Aand 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 and former Dowling College property.

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 that were installed to monitor the VOC 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 2018 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 2018 TVOC concentrations for the Magothy extraction well EW-4L on Stratler Drive were between 6 µg/L and 10 µg/L. This well was shut down in January 2017 due to achieving its capture goal of 50 µg/L TVOC concentrations.
- The Magothy monitoring wells located in the vicinity of extraction well EW-4L all detected concentrations below 50 µg/L TVOC during 2018. The highest TVOC concentration observed during 2018 was in well 000-460 at 8 µg/L in the fourth quarter.
- All of the LIPA monitoring wells are below the capture goal of 50 µg/L. The highest TVOC concentration was 28 µg/L in well 000-131 in August 2018.
- Well EW-3L remained below AWQS throughout 2018 other then a detection of toluene that is believed to be from sample contamination, since toluene is not detected in any adjacent monitoring wells. Extraction well EW-2L detected TVOC concentrations up to 18 µg/L in January, however subsequent quarterly samples showed concentrations below AWQS. Well EW-1L had TVOC concentrations ranging from 17 µg/L in October to 30 µg/L in January. **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 wells RTW-1A, RTW-2A, and RW-6A. In 2018, well 800-94 had TVOC concentrations of 73 µg/L in the fourth quarter and well 800-95 had a maximum concentration of 51 µg/L in July (**Figure 3.2.10-6**).
- **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 2018. Extraction well RW-6A showed TVOC concentrations up to 11 µg/L in 2018.
- Well 800-96 detected carbon tetrachloride concentrations ranging up to 44 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. The TVOC concentration ranged from 5 µg/L to 11 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 will be captured by the Airport extraction wells. Well 800-90 co-located near well 800-92, but screened deeper, detected TVOC concentrations up to 27 µg/L in June 2018.
- Well 800-101, located directly upgradient of extraction well RTW-4A, has shown an increasing TVOC concentration trend over the past several years. The concentrations averaged 26 µg/L in 2018. This is above the capture goal of 10 µg/L for the Airport extraction wells and warrants the continued operation of well RTW-4A, a Magothy extraction well.
- 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 is used to monitor higher concentrations of VOCs identified in upgradient well 800-92. VOC concentrations in this well were below AWQS in 2018.

3.2.10.4 System Operations

In 2018, 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 2018:

January – September 2018

The Airport System was operational in the first three quarters with RTW-1A, RTW-4A, and EW-6A operating on a full-time basis. The RTW-5A, and all four LIPA extraction wells were in standby. The remainder of the extraction wells at the Airport System were run one week per month on a pulsed pumping schedule. In January, the Airport system was off for five days due to a snow storm. In March the system was off for approximately one week for a carbon change-out. The system was off in April for three weeks to complete a repair on well RTW-4A. The system was off for three days for a scheduled carbon change-out in June. In July and August, RTW-3A was not pulsed pumped due to electrical repairs. In September the system was down for two days for a carbon change-out.

October – December 2018

The Airport/LIPA system operated normally in the fourth quarter.

Extraction Wells Operational Data

During 2018, approximately 203 million gallons of groundwater were treated by the Airport/LIPA system, with an average flow rate of 394 gpm (**Table 3.2.10-2)**. **Table F-35** summarizes the system's mass removal. VOC concentrations for the Airport and LIPA extractions wells is 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 2018 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**).

Table 3.2.10-1
OU III LIPA/Airport Treatment System
2018 SPDES Equivalency Permit Levels

Parameters	Permit Level (µg/L)	Max. Measured Value (µg/L)
pH	5.5–7.5 SU	5.6-6.4 SU
carbon tetrachloride	5	<0.5
chloroform	7	.75
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

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 15 pounds of VOCs were removed during 2018, with a total of 455 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.

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 2018. However tolune was detected in two of the LIPA extraction wells above MCLs but the data could not be reproduced.

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 ug/L for LIPA and 10 ug/L for the Airport?
TVOC concentrations are below 50 µg/L for all of the monitoring wells on the LIPA plume. Several Airport core wells are above a TVOC concentration of10 µg/L. Well 800-96 located in the vicinity of well RW-6A continues to show elevated levels of TVOC concentrations up to 38 µg/L. Wells 800-94 and 800-95 showed maximum TVOC concentrations of 73 µg/L and 51 µg/L, respectively. Well 800-90 showed a peak TVOC concentration of 27 µg/L.

4a. Is there a significant concentration rebound in core wells and/or extraction wells following shutdown?
No, although some increase in LIPA extraction wells EW-1L and EW-2L had been noted in 2016 and 2017, concentrations are now well below the capture goal of 50 µg/L. In the 4th quarter of 2018, TVOC concentrations in EW-1L and EW-2L were 16 µg/L and 6 µg/L, respectively.

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:

- Continue the Airport extraction wells pulsed pumping schedule of pumping one week per month for wells RTW-2A and RTW-3A and 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.

- No changes to the current monitoring schedule is recommended at this time for the LIPA and Airport Systems.

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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 40 monitoring wells and nine extraction wells used to monitor the Magothy are shown on **Figure 3.2.11-1**.

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 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 2018).

Location	Max. TVOC (in µg/L) 2018	Max. TVOC (in µg/L) Historical	Primary VOCs	Results
Western South Boundary		<0.5	None	Magothy not impacted. Two monitoring wells serve as outpost/sentinel wells for Suffolk County Water Authority William Floyd Well Field.
William Floyd Sentinel Well Field	3.9	3.9	DCA	Maximum TVOC concentration of 5.8 µg/L in October. With 3.9 µg/L of DCA in well 109-12. However subsequent sampling in March 2019 showed all concentrations to be ND.
Middle Road to South Boundary	73	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 73 µg/L TVOC in May, and well 113-19 had 39 µg/L in August . VOCs not detected at South Boundary beneath the clay.
Industrial Park	57	268	PCE TCA	VOCs identified in the upper Magothy south of the 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 57 µg/L in August 2018.
North Street	36	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 27 µg/L in June . The leading edge of this contamination is at the eastern portion of the Airport system, with 28 µg/L TVOC in well 800-101 in August , 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 (fourth quarter 2018 sample).
South boundary Industrial Park East	26	570	TCA, CCl_4	TVOC concentrations were less than 50 µg/L at the south boundary and off site in the Industrial Park East, where the Magothy brown clay is absent. Magothy and Upper Glacial contamination is continuous in the Industrial Park. A TVOC concentration of 26 µg/L was detected in well 122-05 located at the south boundary. This is the highest TVOC concentration identified in this area in 2018.
South of Carleton Drive	38	7,200	CCl_4	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 showed a maximum TVOC concentration of 2 µg/L in January 2018. Well 000-460 located on Stratler Drive showed a TVOC concentration of 5 µg/L in January. Well 000-544 showed a high TVOC concentration of 38 µg/L in June 2018. 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), 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	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	The Airport extraction wells (RTW-3A and RTW-4A) to continue to capture contaminants that were past the North Street extraction wells prior to system operation. 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	Continue operation of the two industrial park extraction wells (IP-EW-8 and IP-EW-9). Continue monitoring and data evaluation. Wells will be shut down in July 2019 if no 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, Airport and the two IP wells. The two IP extraction wells will be 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 2018 are summarized below:

Upper Glacial Wells 109-03 and 109-04: Due to scheduling issues with SCDHS, third quarter 2018 samples were not collected. Although low levels of VOCs were detected in both wells, the concentrations did not exceed the applicable AWQS. The highest VOC detected was 0.8 µg/L of chloroform in well 109-03 during the fourth quarter. There were no detections of radionuclides.

Magothy Wells 109-12 and 109-13: Although low levels of several VOCs were detected in both wells, the concentrations did not exceed applicable AWQS. The maximum VOC concentrations were detected in the third quarter sample from well 109-12, with a DCA concentration of 3.9 µg/L and chloroethane at a concentration of 1.9 µg/L.

PFAS Monitoring Results: During December 2018 and January 2019, samples were collected from wells 109-03 and 109-04 to test for the presence of PFAS compounds. To determine whether sample pumps that contain Teflon® components can be used to collect PFAS samples without cross contaminating the samples, groundwater samples were collected in mid-December 2018 from wells 109-03 and 109-04 with the existing sample pumps and discharge tubing that have Teflon® components. These wells were then sampled for a second time in early January 2019 with newly installed Teflon®-free sample pumps and discharge lines.

In the December 2018 samples, the two primary PFAS of concern, PFOS and PFOA, were not detected. However, trace levels of PFAS compounds PFBS and PFHxS were detected in the sample from well 109-03 that was collected using the Teflon®-containing sampling equipment. There were no PFAS compounds detected in the January 2019 samples collected with the Teflon®-free equipment. For more information on sitewide PFAS sampling see **Section 3.11**.

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.

<u>*1. Have the SCWA William Floyd Well Field sentinel wells remained below the MCLs?*</u>
Yes. During 2018, 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.

3.2.13 Emerging Contaminants of Concern

The chemical 1,4-dioxane and a class of chemicals called Per- and Polyfluoroalkyl Substances (PFAS) are emerging contaminants of concern in areas across the United States.

1,4-Dioxane has been broadly used as a stabilizer in certain chlorinated solvents (e.g., 1,1,1-trichloroehane), paint strippers, greases and waxes. It may also be present in certain laundry detergent, shampoos, food additives, and food packaging materials.

PFAS are widely manufactured chemicals that have been used in a variety of common products including non-stick pans, water-repellent clothing, and firefighting foam. The use of firefighting foam has caused PFAS contamination of groundwater in areas across Long Island.

3.2.13.1 1,4-Dioxane Sampling

Following a request from the NYSDEC to obtain baseline data on the presence or absence of 1,4-dioxane in groundwater, in 2017 BNL began to collect samples from on-site and off-site groundwater monitoring wells and extraction wells that have or had detectable levels of TCA. The monitoring results are summarized in **Section 3.10**.

3.2.13.2 PFAS Sampling

Following the 2017 detection of PFAS in several of BNL's drinking water supply wells, BNL reviewed available historical records and conducted employee interviews to determine where PFAS-containing materials had ben used. BNL identified eight on-site areas where firefighting foam had been used. Starting in 2018, BNL installed temporary wells in the eight areas to determine whether groundwater has been impacted. Additional samples were collected from on-site groundwater extraction wells and from groundwater monitoring wells located downgradient of the former landfill areas, the Sewage Treatment Plant, and along the southern site boundary. The monitoring results are summarized in **Section 3.11**.

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3.2.14 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. 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**.

3.2.14.1 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 3.2.14-1**.

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**).

3.2.14.2 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 2018.

3.2.14.3 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 2018.

3.2.14.4 Recommendations

No changes are recommended for the OU III South Boundary Radionuclide Groundwater Monitoring Program.

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3.2.15 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 WCF area, one extending south of 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 3.2.15-1**).

3.2.15.1 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 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 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).

3.2.15.2 Groundwater Monitoring

Well Network

A network of 69 monitoring wells is used to monitor the Sr-90 plumes associated with the BGRR, WCF, and PFS/Building 801 areas. Forty-two temporary wells (see **Figure 3.2.15-1** for locations) were installed in 2018/2019 to augment the permanent well network and fill in 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 for other programs. Monitoring well results are tabulated in **Appendix C**. In 2018, the sampling frequency for all three of the Sr-90 plume segments (BGRR, PFS/Building 801 area and WCF), was in the O&M phase (annual) for most wells. The monthly sampling frequency for source area monitoring wells 075-664 and 075-701 continued in order to monitor for potential Sr-90 releases from underneath Building 701/BGDs resulting from a rising water table.

3.2.15.3 Monitoring Well/Temporary Well Results

The Sr-90 plume distribution map is shown on **Figure 3.2.15-1**. The distribution of Sr-90 throughout the BGRR, WCF, and PFS/Building 801 areas is depicted based on groundwater data obtained from the fourth-quarter 2018 sampling round supplemented with data from the temporary wells which were sampled May 2018 through March 2019. **Table 3.2.15-1** contains the temporary well data. Hydrogeologic cross-section drawn along the center line of each of the plumes from the three Sr-90 source areas are shown on **Figures 3.2.15-2, 3.2.15-3, and 3.2.15-4**. In addition, historical Sr-90 concentration trends for key wells are plotted on **Figure 3.2.15-5**.

Historically, the highest overall Sr-90 concentration (3,150 pCi/L) occurred 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 2018 is provided on **Figure 3.2.15-10.** The three Sr-90 plumes were characterized extensively for the first time with 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. The following is a summary of the 2018 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 further migration of the plume as can be viewed on **Figure 3.2.15-10**. **Section 3.2.15-6** discusses Sr-90 concentration increases in SR-1 that may have been related to the 2016 remediation activities. The downgradient portion of this plume over the past several years has been influenced by the 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 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 had subsequently decreased to 33 pCi/L since October 2015 **(Figure 3.2.15-5)** until May of 2018, when concentrations increased to 56 pCi/L. This increase may be attributable to the building decommissioning and soil remediation work in the WCF yard that was completed in 2016.
- Monitoring well 065-160 had a concentration of 27 pCi/L in October 2017. There was an uptick in Sr-90 concentrations in this well during 2017. The increase is likely due to the shutdown of extraction well SR-1 (located between the well and the source area) for six months during 2016. The shutdown was due to a steam leak which was heating the subsurface in the vicinity of SR-1. Following the re-start of SR-1, the concentration in 065-160 decreased to 8 pCi/L in May 2018.
- Twenty-three temporary wells were installed along east-west transects in the area just south of the HFBR and immediately south of Temple Place. This helped fill data gaps in the well network and

defined the leading edge of the Sr-90 plume that originated at the WCF. The data confirmed Sr-90 levels in the vicinity of the HFBR and characterized the leading edge of higher Sr-90 concentrations just south of Temple Place. The Sr-90 detection from locations on the eastern end of the transects confirm that changing groundwater flow conditions in this area have resulted in Sr-90 migration further to the east than originally expected.

BGRR (Building 701 Area) Plume

Source area monitoring wells 075-664 (screened 65-75 ft. bls) and 075-701 (screened 48-68 ft. bls) have been sampled on a monthly basis since late 2012. The increased sample frequency is to obtain sufficient data to understand the relationship between water table elevations and Sr-90 concentration increases in the source area. Sr-90 concentrations in well 075-664 have been slightly above detectable levels since January 2016. Concentrations in well 075-701 were been below the DWS over the same time period, with the exception of one sampling event. Data from this well for the first quarter of 2019 shows a significant increase with a high of 228 pCi/L in February which is the highest value observed in this well since 2014. This data correlates with the steadily increasing water table elevation observed over the past year on site and indicates that water table flushing of residual Sr-90 inventory in the vadose zone continues.

- **Figure 3.2.15-6** plots water table elevation data against SR-3 Sr-90 concentrations over time and shows a correlation between high water table periods and increased Sr-90 concentrations in the source area monitoring wells and SR-3. The water table elevation across the site began to rebound in 2017 following an eight-year period of decline. SR-3 Sr-90 concentrations have begun to increase during the first quarter of 2019. A significant Sr-90 concentration has been observed during the first quarter of 2019 in source area well 075-701 as mentioned above. This well is approximately 50 feet upgradient of SR-3. Several temporary wells were installed in the vicinity of well 075-701 in early 2019 to better define the plume. Sr-90 concentrations in these wells were all below 5 pCi/L confirming the narrow width of this plume in this area.
- The BGRR cap monitoring wells have now been in place for seven years. Sr-90 concentrations in monitoring wells 075-699 and 075-700 have decreased significantly. Initially, concentrations observed in these wells were 40 pCi/L (April 2012) and 104 pCi/L (April 2013), respectively. Concentrations over the past four years are just over detectable levels. The network was supplemented with temporary well BGRR-GP-153 in 2018 which was installed to evaluate the shifting groundwater flow conditions in this area and any impact to contaminant migration. That maximum concentration observed in this well was 5 piC/L. Based on this data, the well network appears to be adequate.
- Data gaps in the monitoring well network were addressed during 2018 immediately north and south of Building 725 (see **Figure 3.2.15-1** and **Figure 3.2.15-2**). The data confirmed that the plume continues to naturally attenuate in these areas and that the highest plume concentrations are relegated to the source area at Building 701.
- 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 11 pCi/L in 085-398 and 31 pCi/L in 085-403 during October 2018.

Former Pile Fan Sump/Building 801 Plume

- Sr-90 concentrations have remained low in the area just south of the former Pile Fan Sump and Building 801 during the past several years. Three temporary wells were installed approximately 150 feet south of Building 801 in early 2019 (**Figure 3.2.15-1**). The data from these temporary wells did not show any unexpected increase in Sr-90 concentrations in this area.

3.2.15.4 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 2018 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 2018:

January – September 2018

From January to September 2018, wells SR-4, SR-5 and SR-6 were in stand-by mode. Wells SR-3 and SR-7 operated in 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.The system was off from January 3 to January 8 due to a snow storm. In May, the system was off to repair a broken pipe. During this period, wells SR-3 and SR-7 ran on a one month on, one month off pulsed pumping schedule while wells SR-4, SR-5 and SR-6 remained in standby. The system treated approximately 14 million gallons of water during this period.

October – December 2018

In October well SR-3 and SR-7 were placed in stand-by mode and well SR-8 was placed on a one month on, one month off pulsed pumping schedule. On November 2 the system was shut off for a resin vessel change out and remained off the remainder of November and December due to multiple pipe replacements and repairs to the system. The system treated approximately 1 million gallons of water during this period.

Extraction Well Operational Data

During 2018, approximately 15 million gallons of water were treated by the remediation system, with an average flow rate of 28 gpm. **Table 3.2.15-2** shows the monthly extraction well pumping rates while **Table F-39** shows Sr-90 concentrations.

3.2.15.5 System Operational Data

During 2018, influent concentrations of Sr-90 ranged from 3.3 pCi/L to 19.4 pCi/L. The highest influent tritium concentration during 2018 was 398 pCi/L in June (**Table F-40**). During 2018, Sr-90 was detected in the effluent at a maximum concentration of 2.0 pCi/L. There were no VOCs or Sr-90 detected above the SPDES Equivalency Permit discharge limits in the 2018 effluent samples (**Table 3.2.15-3**).

Table 3.2.15-3
BGRR Sr-90 Treatment System
2018 SPDES Equivalency Permit Levels

Parameter	Permit Level	Max. Measured Value
pH range	5.5–8.5 SU	6.0–6.8 SU
Sr-90	8.0 pCi/L	2.0
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	0.7
1,2,4-Trimethylbenzene	5.0 µg/L	<0.5
Xylene, total	10.0 µg/L	<0.5

Notes:

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

Extraction Wells

Maximum Sr-90 concentrations in each of the extraction wells during 2018 were as follows:

- SR-1 33.5 pCi/L in January
- SR-2 27.7 pCi/L in May
- SR-3 9.4 pCi/L in November
- SR-4 No detections in 2018
- SR-5 1.8 pCi/L in April
- SR-6 5.0 pCi/L in January
- SR-7 3.9 pCi/L in March
- SR-8 13.6 pCi/L in August
- SR-9 14.1 pCi/L in May

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 2018, the flow averaged 28 gpm. Approximately 0.6 mCi of Sr-90 was removed during 2018, for a total of 27.9 mCi removed since system start-up in 2005 (**Table F-42**). Cumulative mass removal of Sr-90 is shown on **Figure 3.2.15-7**. **Figures 3.2.15-8** and **3.2.15-9** show the Sr-90 concentrations over time for the extraction wells.

3.2.15.6 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 WCF yard, were demolished in 2015. Contaminated piping and soils located underneath and adjacent to the building 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 in monitoring well 065-175 and extraction well SR-2 in 2018 may be a result of Sr-90 releases to the water table resulting from this work.

BGRR Plume: The source area is capped by a combination of 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 075-701during the first quarter of 2019 and extraction well SR-3 (up to 9 pCi/L) during the fourth quarter of 2018, it appears that the water table elevation increase during 2018 has resulted in flushing of residual Sr-90 inventory beneath the Building 701 area. Monthly monitoring will continue in this area in 2019.

PFS/Building 801 Area Plume: Sr-90 concentrations in source area monitoring wells showed slight increases in 2018. Sr-90 concentrations in this plume are expected to attenuate and meet the ROD cleanup goal.

2. Were unexpected levels or types of contamination detected?

WCF Plume: There were no unexpected levels of Sr-90.

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

PFS/Building 801 Area Plume: There were no unexpected levels of Sr-90.

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 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 was placed back in full-time operation due to increasing 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 from the WCF source. Extraction well SR-6 is currently in stand-by mode and concentrations remained low in 2018. 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 and low concentrations continue to slowly decrease. This well should be evaluated for shutdown in 2019.

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 2019. 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.

3.2.15.7 Recommendations

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

- Maintain SR-8 in pulsed pumping mode (one month on and one month off) based on low, but slightly increasing, Sr-90 concentrations.
- Maintain a source area monitoring frequency of monthly for BGRR source area wells 075-664 and 075-701.
- Continue operating wells SR-1, SR-2, SR-3 and SR-9 in full time mode. Maintain wells SR-4, SR-5, and SR-6, and SR-7 in standby mode.

- Install a temporary well downgradient of 085-403 to re-establish the location of the leading edge of the plume.
- Reduce sampling frequency of WCF well 065-160 to annual following re-start of SR-1 and decline of Sr-90 concentrations in 2018. Discontinue sampling of wells 065-03, 065-04, and 065-161 due to lack of significant detections in these wells since late 1990s.
- Install up to 15 temporary wells to fill in monitoring network data gaps north of the HFBR and just south of the WCF.
- Maintain well 065-175 semi-annual sampling frequency to monitor for Sr-90 migrating south from the WCF yard.

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3.2.16 Chemical/Animal Holes Strontium-90 Treatment System

This section summarizes the operational data from the Chemical/Animal Holes Strontium-90 Treatment System for 2018 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.

3.2.16.1 System Description

The Chemical/Animal Holes were located in the south-central portion of the BNL property (**Figure 1-1** and **3.2.16-1**). 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 and 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).

3.2.16.2 Groundwater Monitoring

Well Network

The Chemical/Animal Holes monitoring network consists of 29 wells. As recommended in the *2017 Groundwater Status Report*, due to Sr-90 concentrations remaining less than DWS for several years, monitoring of four wells were discontinued in the fourth quarter 2018 (106-22, 106-23, 106-62, and 106-63). **Figures 1-2** and **3.2.16-1** show the monitoring well locations.

Sampling Frequency and Analysis

To help support a decision for shutdown, the sampling frequency for the monitoring wells was semi-annual (shutdown phase) for most of 2018. As recommended in the *2017 Groundwater Status Report*, following system shutdown, the sampling frequency for the monitoring wells was changed to the standby phase (annual) in the fourth quarter 2018. However, the three upgradient wells that monitor the former source area were sampled three times in 2018 and will be reduced to semi-annual in 2019.

3.2.16.3 Monitoring Well Results

Figure 3.2.16-1 shows the Sr-90 plume distribution. The plume depiction is derived from third and fourth quarter 2018 monitoring well data.

The area of highest concentration (39 pCi/L) is currently located immediately upgradient of extraction well EW-1. 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. As shown on **Figure 3.2.16-6**, the plume is now discontinuous as a result of the operation of the treatment system. See **Figure 3.2.16-2** for concentration trends of key monitoring wells and **Figure 3.2.16-3** 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 have an effect on the Sr-90 concentrations in the monitoring wells between the former source area and EW-1. From system startup in 2003 through 2017, the water table elevation in the Chemical Holes area has decreased from approximately 40 feet above mean sea level (MSL) to 33 feet above MSL. However, due to historical high precipitation in 2018, the water table increased to 40 feet above MSL. Sr-90 concentrations in the monitoring wells in 2018 were generally consistent with 2017 results.

A summary of key monitoring well data for 2018 follows:

Former Source Area to EW-1:

- Sr-90 concentrations in all plume core wells have declined over the past several years as evidenced in the trends. The maximum Sr-90 concentration detected in a monitoring well in 2018 was 39 pCi/L in 106-94. This well is located between the former source area and EW-1. As seen on the plume comparison on **Figure 3.2.16-6**, the plume has become discontinuous and Sr-90 concentrations have been significantly reduced as a result of the groundwater remediation efforts in this area.
- Sr-90 concentrations in plume core well 106-95, located between 106-94 and EW-1 have maintained a decline following a spike in concentration in 2015 of 178 pCi/L. The maximum Sr-90 concentration in this well in 2018 was 30 pCi/L in January.
- Sr-90 concentration trends in plume core wells 106-16 and 106-99 have significantly declined over time and have remained less than 25 pCi/L since 2016. These wells are also located immediately upgradient of EW-1.
- From 2016 to 2017, Sr-90 concentrations in well 097-314 were less than the DWS. However, starting in June 2018, Sr-90 concentrations began to increase slightly, to a maximum of 29 pCi/L. Wells 097-313 and 097-315 did not detect Sr-90 above the DWS in 2018.

Downgradient of EW-1:

- Sr-90 concentrations in perimeter monitoring well 106-135 remained less than the DWS since 2014. The temporary well installed at this location in 2010 identified Sr-90 at 85 pCi/L. Monitoring well 106-136, installed in June 2015 south of Princeton Avenue further defines the plume segment downgradient of well 106-135. Sr-90 was detected in well 106-136 up to 17 pCi/L during 2018.
- Plume core well 106-125, located upgradient of EW-2, detected a peak concentration of 498 pCi/L of Sr-90 in 2007, and has remained below 30 pCi/L since 2011. Sr-90 was detected in this well in 2018 up to 7 pCi/L in the first quarter. Plume core well 106-119, located upgradient of the southern-most extraction well EW-3 has remained below the DWS since 2013.

By-pass Wells:

- Sr-90 was only detected three times in bypass wells 106-120, 106-121, and 106-122 since 2013. Well 106-121 detected 2 pCi/L and 0.8 pCi/L in 2015 and 2016, respectively. Sr-90 was detected once in well 106-122 in 2018 at 1.2 pCi/L. These wells are approximately 100 feet downgradient of EW-3.

3.2.16.4 System Operations

In April 2016, extraction well EW-1 began to run in a one month on, one month off pulsed pumping mode. In October 2016, wells EW-2 and EW-3 were placed in stand-by mode. In July 2018, all three extraction wells were placed in standby mode and the extraction wells continued to be sampled quarterly for Sr-90 (**Table F-43).** During 2018, the influent, midpoint, and effluent locations were sampled twice per month for Sr-90 when the system was operating. The maximum Sr-90 concentration in the extraction wells in 2018 was 6.9 pCi/L in EW-1.

Sr-90 concentrations for the system influent and effluent in 2018 are presented in **Tables F-44** and **F-45**. The maximum Sr-90 influent concentration in 2018 was 5.1 pCi/L. There were no Sr-90 detections in the system effluent (**Table 3.2.16-1**). **Table F-46** contains a summary of the monthly Sr-90 mass removal for the system.

Table 3.2.16-1.
Chemical Holes Sr-90 Treatment System
2018 SPDES Equivalency Permit Levels

Parameter	Permit Level	Max. Measured Value
pH range (SU)	5.0–8.5	5.4–6.4
Sr-90 (pCi/L)	8.0	<0.5

Notes:
pCi/L = pico Curies per liter
SU = Standard Units
MDA = Minimal detectable activity
Required sampling frequencies are monthly for Sr-90 and pH.

Summarized below are the system operations data for 2018.

January – September 2018

Extraction well EW-1 ran in a one month on one month off pulsed pumping mode from January to July when it was placed in standby mode. Well EW-2 and EW-3 remained in standby mode. The system treated approximately 0.7 million gallons of water from January through September.

October – December 2018

The system remained in standby mode. The equivalency permit renewal request was approved by NYSDEC in November.

3.2.16.5 System Operational Data

Concentrations of Sr-90 in EW-1 have steadily dropped-off since 2009 and remained below the DWS in 2018. This is consistent with the reduced Sr-90 levels detected in monitoring wells upgradient of EW-1 since 2012. 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 3.2.16-4** presents the Sr-90 extraction well data over time. The 2018 analytical data show that combined influent Sr-90 concentrations ranged from 0.9 pCi/L to 5.1 pCi/L (**Table F-44**). The effluent samples had no Sr-90 detections.

Cumulative Mass Removal

Average flow rates for each monitoring period were used, in combination with the Sr-90 influent concentration, to calculate the mCi removed. System flow averaged 5 gpm while it was in operation during 2018. **Table 3.2.16-2** shows the monthly extraction well pumping rates. The cumulative total mass of Sr-90 removed was approximately 0.007 mCi during 2018, with a total of approximately 4.94 mCi removed since 2003 (**Figure 3.2.16-5**).

3.2.16.6 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 temporary well soil and groundwater samples obtained in this area in late 2015 did not

identify a continuing source of Sr-90. As seen by the trends in **Figure 3.2.16-2**, 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 at a maximum of 29 pCi/L.
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 for potential increasing trends

2. Were unexpected levels or types of contamination detected?
No.

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?*
The conditions outlined in the *Operation and Maintenance Manual for the Chemical Holes Groundwater Treatment System* (BNL 2008b) for shutdown have been met. As a result, a Petition for Shutdown was approved by the regulators. 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 9 of 21 core wells were above 8 pCi/L in 2018 with a maximum of 39 pCi/L.

4b. Is there a significant concentration rebound in core wells and/or extraction wells following shutdown?
The system was placed in standby mode in July 2018. In 2018, Sr-90 concentrations in the monitoring and extraction wells have been less than 50 pCi/L and 20 pCi/L, respectively.

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 3.2.16-6.**

3.2.16.7 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 is identified, these extraction wells may be restarted.
- Maintain the annual monitoring well sampling frequency (standby phase), except for wells 097-313, 097-314, 097-315, which will remain at a semi-annual.

3.2.17 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 of this system was submitted to the regulators in July 2018 and approved in March 2019.

3.2.17.1 System Description

Extraction wells EW-9, EW-10, EW-11, and EW-16 were sampled at a quarterly frequency. 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).

3.2.17.2 Groundwater Monitoring

Well Network

A monitoring well network of 30 wells was used to monitor the source area and verify the predicted attenuation of the plume (**Figure 1-2 and 3.2.17-1**). Seven new monitoring wells were installed immediately downgradient of the HFBR as recommended in the *2017 Groundwater Status Report*. The HFBR monitoring network for 2019 will consist of the following ten wells: 075-11, 075-40, 075-288, 075-802, 075-803, 087-804, 075-805, 075-806, 075-807, and 075-808. As noted on Table 3.2.17-1 of the 2017 Groundwater Status Report, 47 monitoring wells were decommissioned in October 2018. Fourteen HFBR monitoring wells were retained for potential future monitoring of PFAS downgradient of the former firehouse.

Sampling Frequency and Analysis

Sampling details for the well network are provided on **Table 1-5**. Select wells are also analyzed for VOCs.

3.2.17.3 Monitoring Well Results

Figure 3.2.17-1 displays postings of fourth quarter 2018 data for each of the wells in the monitoring network. In 2015 the plume monitoring was scaled back to the area form Cornell Avenue to the HFBR, due to the attenuation of the downgradient portion of the plume. The only tritium detections above the DWS were in well 075-44 with concentrations of 22,400 pCi/L in February and 57,300 pCi/L in March. Appendix C contains the complete set of monitoring well data.

Comprehensive annual summaries of monitoring well data for this plume since the pump and recharge system was placed in standby in 2013 can be found in the annual BNL Groundwater Status Reports. The most recent detection of tritium in the plume above the DWS was 57,300 pCi/L in well 075-44 in March 2018. This well is located on the lawn of the HFBR. This is also the maximum tritium concentration identified in the monitoring wells since 2013. This monitoring well was decommissioned in 2018 and replaced with well 075-803 (located approximately 75 feet due north). The February 2019 result for 075-803 was 18,000 pCi/L. This was the highest concentration in the monitoring network for the first quarter of 2019.

Elevated tritium concentrations directly downgradient of the HFBR have been observed to correlate with high water-table elevation events. This results in water-table flushing of 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 3.2.17-2. The March 2018 detection of 57,300 pCi/L in well 075-44 appears to be in response to the two foot increase in water table elevation that occurred slightly less than a year prior. The figure also demonstrates how the magnitude and frequency of these events has diminished over the 20 years of monitoring. Based on the decreasing concentration trend, the inventory of tritium beneath the HFBR that is affected by the water-table flushing has significantly decreased over the years.

The lowering of the water table over most of the previous eight years has had an impact on the flushing of tritium from the vadose zone under the HFBR. This has probably affected tritium concentrations in the monitoring wells downgradient of the HFBR. From 2013 through 2016, the water table elevation immediately downgradient of the HFBR was lowered from approximately 43 feet above mean sea level (MSL) to 37 feet above MSL. There was an approximately three foot rise in the water table elevation in 2017 to 40 feet MSL. This correlates with the spike to 57,300 pCi/L in well 75-44 from the March 2018 sample round. A four-foot water table increase was observed at the site during 2018. The wells downgradient of the HFBR will be monitored for a tritium concentration increase in response to the latest water table changes.

All data from permanent and temporary wells indicate that the downgradient tritium plume segment attenuated to less than the DWS in 2010 and 2011, prior to system shutdown. The HFBR Tritium Pump and Recharge System Petition for Closure includes additional analyses which demonstrate the attenuation of the HFBR tritium plume.

3.2.17.4 System Operations

Table F-50 shows VOC and tritium concentrations in the extraction wells. Extraction wells EW-9, EW-10, EW-11, and EW-16 were sampled quarterly and analyzed for tritium and VOCs in 2018. The treatment system was in standby mode throughout 2018. All extraction well tritium concentrations in 2018 were below 750 pCi/L.

3.2.17.5 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 the decreases in tritium concentrations in groundwater immediately downgradient of the building. The highest concentration observed in the source area during 2018 was 57,300 pCi/L in monitoring well 075-44. This monitoring well was decommissioned in 2018 and replaced with well 075-803 (located approximately 75 feet due north). The February 2019 result for 075-803 was 18,000 pCi/L. This was also the highest concentrations in the monitoring network for the first quarter of 2019.

The steadily declining peak tritium concentration trend in wells immediately downgradient of the HFBR and the water table elevation are shown in **Figure 3.2.17-2**. A four foot water table increase was observed at the site during 2018. The wells downgradient of the HFBR will be monitored for any tritium concentration increase in response to the latest water table changes.

2. Were unexpected levels or types of contamination detected?
No. There were no unusual or unexpected concentrations/types of contaminants observed in the monitoring wells during 2018.

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 3.2.17-2** 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 treat and natural attenuation to levels below the DWS.

5. Can individual extraction wells or the entire treatment system be shut down or placed in pulse 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 2018 were below 750 pCi/L.

5b. Is there a significant concentration rebound in extraction wells following shutdown?
No rebound of tritium concentrations was observed in 2018.

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

3.2.17.6 Recommendations

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

- Monitor the source area with a combination of the seven new monitoring wells and three existing wells listed in **Section 3.2.17.2**. The monitoring data will continue to be documented in the annual Groundwater Status Report.

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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

Well Network

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**).

Sampling Frequency and Analysis

During 2018, the wells were monitored either annually or semiannually, and the samples were analyzed for Sr-90 (**Table 1-5**).

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 migrate away from the former Building 650 sump outfall area as it attenuates. 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, based on the results from monitoring wells 076-181 and 076-182 and the three temporary wells installed in 2015.

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 over the past several years 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, decreased to 4 pCi/L in 2018 after a slight increase to 7 pCi/L detected in 2017.

Monitoring well 076-25 has seen a steady increase in Sr-90 concentrations and was up to 12 pCi/L in October of 2018. This well is located approximately 160 feet to the south-southeast of Building 650. The increase in concentrations may be the result of plume shift and historical discharges from Building 650 decontamination pad.

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.

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

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 2018. The groundwater flow has also shifted in this area to the southeast over the past several years due to a reduction of discharge water entering HO and RA V basins. Characterization work has been recommended in this report to verify whether there has been any shift of the plume resulting from these changes.

2. Were unexpected levels or types of contamination detected?
All Sr-90 detections in 2018 were within the expected concentration range except for 076-25 which has had a slight increase in Sr-90 concentrations.

3. Is the plume naturally attenuating as expected?
Decrease of concentrations in the plume core have been faster than expected. A shift in the plume due to changing groundwater flow conditions could be at least partially responsible for this. The groundwater model 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 well exceeding this limit in 2018 (076-25) therefore, the performance objectives have yet to be achieved. The removal of contaminated soils in 2002 addressed the predominate source of groundwater contamination. 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:

- Continue the current monitoring frequency stated in **Table 1-5**, except for the following. Increase sampling frequency to semi-annual for well 076-25 in response to Sr-90 concentration increases in this well during 2018. Decrease well 076-13 from quarterly to semi-annually.
- Install up to eight temporary wells to verify whether there has been any southeast shift of the plume due to changes in groundwater flow direction in the area. Temporary wells will be located southeast of monitoring wells 076-168, 076-24, 076-415, and south of Brookhaven Avenue (leading edge of plume).

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.

In accordance with the Phase 3 PFAS Sampling Work Plan, five wells from the former OU V groundwater monitoring program were sampled in early January 2019 to determine whether PFAS contaminated water had been discharged to the sanitary system. These are the same five wells that were sampled for 1,4-dioxane during 2017. PFAS were detected in four of the five wells. The highest PFOS and PFOA concentrations were detected in STP area monitoring well 039-08 at 261 ng/L and 77.6 ng/L, respectively. PFAS were also detected in off-site monitoring well 000-122, with PFOS and PFOA concentrations of 19.5 ng/L and 9.7 ng/L, respectively. The results are further discussed in **Section 3.11**.

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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 3,000 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 (see **Figure 3.5-1**). 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. As recommended in the *2017 Groundwater Status Report*, since EDB concentrations have remained less than DWS since 2012, sampling of upgradient well 000-110 was discontinued in the fourth quarter 2018. The federal DWS for EDB is 0.05 µg/L.

Sampling Frequency and Analysis

The OU VI EDB plume monitoring program is in the O&M phase (**Table 1-8**). The sampling frequency for the plume core and perimeter wells is semi-annual (**Table 1-5**). However, the three bypass wells were sampled at a quarterly frequency for the year. Since EDB concentrations have remained less than DWS since 2015, the sampling frequency of wells 000-173, 000-175, and 000-209 was reduced from semi-annual to annual in the fourth quarter. The wells are analyzed for EDB according to EPA Method 504.

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 2018 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 2018 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 0.22 µg/L in well 000-283 in 2018.
- EDB concentrations in all core wells upgradient of well 000-178 have declined significantly over the past several years. 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 0.21 µg/L in 2018. 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 increasing levels of EDB above the DWS since 2007. The maximum 2018 EDB concentration was 0.37 µg/L in the third quarter, which is also the high for all plume monitoring wells this year.
- 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 0.06 µg/L in 2018. 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.

  As recommended in the *2017 Groundwater Status Report*, to enhance the monitoring of EDB upgradient of well 000-507, two temporary vertical profile wells were installed in December 2018 to the west of well 000-178. The maximum EDB concentration in EDBVP-01-2018 was 0.57 µg/L between 144 feet and 148 feet bls. The deepest sample interval for this profile at 156 feet to 160 feet bls detected EDB at 0.05 µg/L. The maximum EDB concentration in EDBVP-02-2018 was 0.42 µg/L, between 124 feet and 128 feet bls. The next sample at 136 feet to 140 feet bls detected EDB at 0.36 µg/L. The two deepest sample intervals for this profile at 144 feet to 148 feet bls and 156 feet to 160 feet bls did not detect EDB. **Table 3.5-3** presents the data for the vertical profiles. In January 2019, two permanent monitoring wells were installed at these locations. The location of the vertical profiles and the new monitoring wells is shown on **Figure 3.5-1**.
- EDB in the eastern perimeter monitoring well 000-524 remained below the DWS since it was installed in 2012. This indicates that the lateral 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. EDB has been below the DWS in well 000-173, located south of North Street since 2015. Overall, peak EDB concentrations declined from 7.6 µg/L in 2001 (in well 000-283) to 0.57 µg/L in 2018 (in EDBVP-01-2018).

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.

Table 3.5-1
OU VI EDB Treatment System
2018 SPDES Equivalency Permit Levels

Parameters	Permit Limit (µg/L)	Max. Measured Value (µg/L)
pH (range)	5.0 – 8.5 SU	54 – 7.4 SU
ethylene dibromide	0.03	<0.02
chloroform	7.0	1.0
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

January – September 2018

The system was off for three days in March and again in July for carbon change-outs. The system was also off for 10 days in mid-March for electrical repairs. The system ran normally for the remainder of this time. The system treated approximately 118 million gallons of water during this period.

October – December 2018

The system operated normally for this period. The system treated approximately 44 million gallons of water.

Extraction Wells

During 2018, the system treated approximately 162 million gallons of water, with an average flow rate of approximately 329 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**. EDB was detected in all four 2018 quarterly samples in both extraction wells. In 2018, the extraction wells had a maximum EDB detection of 0.039 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 2018, except for January. The maximum influent concentration was 0.029 µg/L. During 2018, 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

No operating difficulties were experienced beyond normal maintenance in 2018, and the equivalency permit was not exceeded.

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. However, EDB was detected in vertical profile EDBVP-01-2018 slightly deeper than expected. Bypass monitoring well 000-527 is screened directly above the Gardiners Clay Unit and continued monitoring of this well will provide an indication if the deeper contamination were to migrate on top of the clay and below the capture zone of EW-2E.

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 eastern perimeter well 000-524, and the lack of detections in the western perimeter well 000-498, the width of the plume is defined. EDB was not detected in bypass monitoring well 000-527 in 2018 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 EDBVP-01-2018 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 the recently installed vertical profiles. 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. In June 2015, the groundwater model was updated using more recent data to better refine the remaining time required to remediate the EDB plume to below the DWS. The model projected the system will need to operate to 2020.

4a. Are EDB concentrations in plume core wells above or below 0.05 µg/L?

In 2018, six of nine 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. However, it is expected to be achieved by 2030, as required by the OU VI ROD. The system is currently projected to operate through 2020.

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.
- Update the groundwater model based on the analytical results from the two vertical profiles installed in December 2018 to better refine the remaining time required to remediate the EDB plume to below the DWS.

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 quality is defined as the quality of groundwater that is completely unaffected by BNL operations.

3.6.1 Groundwater Monitoring

Well Network

The 2018 program included 10 wells in the northwestern portion of the BNL property (**Figure 1-2**) hydraulically upgradient of lab 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 two low level detections of VOCs in the site background wells, which were below AWQS. The highest concentration detected was 0.62 μg/L of methyl tert-butyl ether 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
Cesium-137	<MDA to 7.24	12
Gross alpha	<MDA to 2.66	1.5
Gross beta	<MDA to 6.41	4.0
Strontium-90	<MDA to 3.84	0.8
Tritium	<MDA to 835	300

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 2018. 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 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.

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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 2018 Environmental Monitoring Report, Current and Former Landfill Areas* (BNL 2019a). The complete groundwater monitoring results for these programs are included in **Appendix C**.

3.7.1 Current Landfill Summary

Groundwater data show that, in general, contaminant concentrations have been decreasing following the capping of the landfill in 1995. By the end of 2018, the landfill had been capped for 23 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 2018:

- Benzene was detected in downgradient well 087-11 at concentrations slightly above the AWQS with a maximum concentration of 1.7 µg/L. The other VOCs detected above the AWQS were chloroethane and 1,1-dichloroethane (DCA) during 2018. DCA was detected in monitoring wells 088-109 and 098-99 above the standard of 5 µg/L. The maximum concentration of DCA during 2018 was 10 µg/L. During 2018, chloroethane concentrations ranged up to 47 µg/L indicating that VOCs continue to emanate from the landfill. These concentrations are naturally attenuating and are not detected at the site boundary above the drinking water standard.
- 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 088-109 at a maximum concentration of 5.9 mg/L.
- During 2018, iron, sodium and manganese in the background well, and aluminum, arsenic, iron, manganese, and sodium in several downgradient wells were detected above their respective AWQS.
- Strontium-90 and tritium were not detected in 2018 and have not exceeded the DWS in any 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 show 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 2018, eight wells were sampled once for VOCs, pesticides/PCBs, general chemistry, metals and radionuclides. The remaining six 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 2018:

- The Former Landfill Area is not a source of VOC contamination. No VOCs were detected above groundwater standards since 1998.

- Water chemistry parameters were detected at concentrations approximating those of historic background monitoring well results, indicating that leachate is not being generated. No 2018 results exceeded the applicable groundwater standards.
- All metal detections were below AWQS during 2018 except for sodium in background well 086-42 (70,200 μg/L) and iron in well 106-02 (1,180 μg/L).
- There were no detections of pesticides or polychlorinated biphenyls (PCBs) during 2018. The last detection of pesticides was in 2002 and the last PCB detection was in 2008.
- The trend of increasing strontium-90 concentrations, which was observed in well 097-64 over the past several years, was not observed in 2017 and 2018. The data from well 097-64 indicated a decreased strontium-90 concentration from 6.6 pCi/L in 2016 to 1.4 pCi/L in 2017 and was not detected in 2018. The strontium-90 concentrations for this monitoring well have remained below the DWS of 8 pCi/L since 2000. Strontium-90 has not been detected above the DWS in the remaining wells since 2001. Tritium was not detected in any wells during 2018.

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.

3.7.3 Per- and Polyfluoroalkyl Substances (PFAS) Monitoring

As part of the Per- and Polyfluoroalkyl Substances (PFAS) source area characterization effort, BNL collected samples of the groundwater in 2018 and 2019 for PFAS analyses. As part of the Phase 3 characterization, five of the monitoring wells were sampled in January 2019 and are located downgradient of the Current and Former Landfill Areas. The results of the sampling are presented in **Section 3.11**.

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 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 continued routine inspection 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, five downgradient wells approximately 200 feet downgradient of the source area near Building 912A, and 12 wells located approximately 600 feet downgradient of the source area near Building 912 (**Figure 3.8-1**).

Sampling Frequency and Analysis

During 2018, the source area wells were monitored two times, and the samples were analyzed for tritium (**Table 1-6**). The wells located near Building 912 were sampled once during the year, and the samples were analyzed for tritium. The wells are monitored 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 2018 is depicted on **Figure 3.8-1**.

Source Area Monitoring Results

The maximum tritium concentration in source area wells was 35,500 pCi/L in well 054-184 during the fourth quarter. **Figure 3.8-2** provides tritium trend charts for wells that monitor the g-2 source 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 7,420 pCi/L in a sample from well 065-323 collected during the fourth quarter.

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

The 2018 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 tritium continues to be detected in the groundwater downgradient of the g-2 source area at concentrations that exceed the 20,000 pCi/L DWS, the overall reduction in tritium concentrations since 1999 indicates that the cap is effectively preventing rainwater from infiltrating the activated soil shielding. 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 have released residual tritium from the deep vadose zone (i.e., unsaturated soil immediately above the water table). 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 mobilized it.

2. Were unexpected levels of tritium detected?
The observed tritium levels in the source area monitoring wells are consistent with previous surveillance results. 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.

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?
Not at this time. Tritium concentrations in groundwater immediately downgradient of the g-2 source area continue to routinely 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 Building 912.

3.9 BROOKHAVEN LINAC ISOTOPE PRODUCER (BLIP)

When the Brookhaven Linac Isotope Producer (BLIP) is operating, the Linac delivers a beam of protons that strike a series of targets in the BLIP target vessel, positioned at the bottom of a 30-foot underground tank. 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 2018, 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 were analyzed for tritium (**Table 1-6**). Because tritium is more leachable than sodium-22, and it migrates at the same rate as groundwater, it is the best early indicator of a possible release.

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

[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).

remained below the 20,000 pCi/L DWS (**Figure 3.9-1**). During 2018, the maximum tritium concentration was 1,250 pCi/L in the fourth quarter sampling of well 064-48.

3.9.3 BLIP Groundwater Monitoring Program Evaluation

The 2018 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 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?

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 1,4-Dioxane Sampling

The chemical 1,4-dioxane is an emerging contaminant of concern in areas across the United States and has been broadly used as a stabilizer in certain chlorinated solvents (e.g., the solvent 1,1,1-trichloroethane), paint strippers, greases and waxes. It is also used in cosmetics, deodorants, fumigants, and automotive coolant liquid. Its residue may also be present in laundry detergent, shampoos, food additives, and food packaging materials

Following a request from the NYSDEC to obtain baseline data for the presence or absence of 1,4-dioxane in groundwater, in January 2017 twenty-two on-site and off-site groundwater monitoring wells that have or had detected TCA were sampled (**Figure 3.10-1**). The samples were analyzed for 1,4-dioxane using USEPA Method 522 to obtain the required low-level detection limits. All results were below the current NY State drinking water standard 50 µg/L for Unspecified Organic Contaminants. 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. The monitoring results were reported in the *2016 Annual Groundwater Status Report*.

After reviewing the initial results, the SCDHS requested BNL to obtain additional baseline data, with the collection of 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 (**Figure 3.10-1**). The samples were collected in December 2017 and January 2018. All 1,4-dioxane results were below the current NY State drinking water standard 50 µg/L for Unspecified Organic Contaminants. The highest 1,4-dioxane results 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. These monitoring results were reported in the *2017 Annual Groundwater Status Report*.

3.10.1 1,4-Dioxane Groundwater Monitoring

Well Network

A permanent monitoring program has not been established specifically for tracking 1,4-dioxane. To obtain baseline data, for the past two years BNL has collected samples from select monitoring wells and extraction wells where TCA had been or is currently detected. In February 2019, samples were collected from 33 existing southern boundary monitoring wells that are part of the Western South Boundary and OU III South Boundary monitoring programs. Although most of the wells are screened in the middle to deep portions of the Upper Glacial aquifer, four of the wells are screened in the upper portion of the Magothy aquifer. During April and May 2019, 11 temporary wells were installed along the south boundary to obtain samples from the shallower portions of the Upper Glacial aquifer. In addition to analyzing the samples for 1,4-dioxane, the samples from the permanent and temporary wells were also tested for PFAS compounds (see **Section 3.11**).

Sampling Frequency and Analysis

No samples were collected for 1,4-dioxane analyses during 2018. During the 2019 sampling events described above, samples were collected from 33 permanent and 11 temporary groundwater monitoring wells (**Tables 3.10-1** through **3.10-12**). The groundwater samples were analyzed for 1,4-dioxane using EPA Method 522.

3.10.2 South Boundary Monitoring Well Results

The locations of the 33 wells and 11 temporary wells are shown on **Figure 3.10-2**. The analytical results for the 33 permanent wells are presented in **Table 3.10-1** and the analytical results for the 11 temporary wells are presented in **Tables 3.10-2** through **3.10-12**. The results are also posted on hydrogeologic cross sections **Figures 3.10-3 and 3.10-4**. A summary of the results follows:

- 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 detected 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.
- Trace levels of 1,4-dioxane were detected in the four Magothy wells located in the OU III South Boundary area, with concentrations ranging between 0.1J µg/L and 0.8 µg/L.

3.10.3 1,4-Dioxane Groundwater Monitoring Program Evaluation

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

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

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. 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.

3.10.4 1,4-Dioxane Monitoring Recommendations

The following are recommended for the 1,4-dioxane monitoring program for 2019:

- During the spring of 2019, BNL completed the installation of eleven temporary monitoring wells along the BNL south boundary to characterize the extent of 1,4-dioxane and PFAS (described in **Section 3.10.1**).
- In September 2019, samples from the newly installed Western South Boundary extraction wells will be tested for 1,4-dioxane.

3.11 PFAS SOURCE AREAS AND GROUNDWATER PLUMES

Per- and Polyfluoroalkyl Substances (PFAS) are emerging contaminants of concern across the United States. In 2017, the BNL potable water supply wells were sampled for PFAS compounds for the first time. The samples were collected by the Suffolk County Department of Health Services and were analyzed for 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 (**Figure 3.11-1**). 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 located along the southern site boundary (BNL 2019a). The addendum also called for the installation of 11 temporary wells in the southern and southeastern boundary areas. The Phase 3 addendum sampling includes testing groundwater samples for both PFAS and 1,4-dioxane.

3.11.1 PFAS Groundwater Monitoring

Well Network

During 2018, a total of 37 temporary groundwater monitoring wells were installed at the eight areas where firefighting foam was known to have been released. PFAS data were also collected from: 1) four temporary wells installed as part of the BGRR Sr-90 monitoring program; 2) five permanent monitoring wells located downgradient of the Former Landfill and Current Landfill areas; and 3) five wells located downgradient of the STP. To further evaluate the extent of PFAS contamination in areas downgradient of the source areas, water samples were collected from 42 on-site groundwater extraction (treatment) wells and from 33 existing permanent monitoring wells positioned along the BNL southern boundary.

Sampling Frequency and Analysis

During 2018 and early 2019, approximately 500 groundwater samples were collected from the well network described above. The groundwater samples were analyzed by EPA Method 537 for 21 PFAS compounds.

3.11.2 Foam Release Area Monitoring Well Results

The groundwater sample locations at the eight defined firefighting foam release areas are depicted on **Figures 3.11-2 to 3.11-9**. Analytical results for all temporary well samples are shown in **Tables 3.11-1 through 3.11-42**. A summary of the monitoring results is provided below. During the installation of the temporary wells, groundwater samples were collected at multiple depths below the water table. Sample results for individual samples that had the highest combined concentrations of PFAS compounds perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) are compared to the current EPA Lifetime Health Advisory Level (HAL) of 70 ng/L. The highest individual PFOS and PFOA concentrations detected in each temporary well, regardless of sample depth, are also described.

3.11.2.1 Current Firehouse Area

The current firehouse has been in operation since 1986. Firefighting foam that contained PFAS were released at the current firehouse from 1986 to 2008 during training exercises and equipment maintenance. During 2018, seven temporary wells were installed to evaluate the distribution of PFAS contamination in the firehouse area (**Figure 3.11-2**). The monitoring results indicate:

- Combined PFOS/PFOA concentrations significantly above the 70 ng/L HAL are present in groundwater downgradient of the current firehouse area (**Tables 3.11-1 through 3.11-8**). All seven temporary wells had combined PFOS/PFOA concentrations in individual samples greater than the 70 ng/L HAL, with a maximum combined concentration of 12,440 ng/L detected in PFC-GP-38 at a depth of 52-56 feet below ground surface (BGS).
- The maximum PFOS and PFOA concentrations were detected in PFC-GP-38 at 12,200 ng/L and 240 ng/L, respectively.
- Several other PFAS compounds were detected at high concentration. For example, PFHxS was detected at concentrations up to 3,710 ng/L, and PFBS, PFPeA, PFPeS and PFOSA were detected at concentrations above 100 ng/L.
- The maximum combined PFOS/PFOA concentration in PFC-GP-01, installed approximately 1,600 feet downgradient of the firehouse, was 124 ng/L.

3.11.2.2 Former Firehouse Area

The former firehouse was in operation from 1947 through 1985. Firefighting foam that contained PFAS was released from 1966 to 1985 during training exercises and equipment maintenance. During 2018, twelve temporary wells were installed to evaluate the distribution of PFAS contamination in the firehouse area (**Figure 3.11-3**). The monitoring results indicate:

- Combined PFOS/PFOA concentrations significantly above the 70 ng/L HAL are present in groundwater downgradient of the former firehouse area (**Tables 3.11-9 through 3.11-20**). Seven of the 12 temporary wells had combined PFOS/PFOA concentrations that exceed the 70 ng/L HAL. The maximum combined concentration was 5,371 ng/L in PFC-GP-21.
- The maximum PFOS concentration was detected in PFC-GP-21 at 5,210 ng/L and the maximum PFOA concentration was detected in PFC-GP-22 at 736 ng/L.
- Several other PFAS were also detected at high concentrations. For example, PFHxS was detected at concentrations up to 3,480 ng/L, and PFPeA, PFPeS PFHxA, and PFOSA were detected at concentrations above 100 ng/L.

3.11.2.3 Former Bubble Chamber Source Area

On three occasions, twice in 1973 and once in 1980, firefighting foam was released to the ground from a fire suppression system that was located at this former Bubble Chamber research facility. During 2018, six temporary wells were installed to evaluate the distribution of PFAS contamination downgradient of this facility, which is within the source water contributing area for BNL's eastern drinking water supply wells 10 and 11 (**Figure 3.11-4**). The monitoring results indicate:

- Combined PFOS/PFOA at concentrations above the 70 ng/L HAL were detected in temporary well PFC-GP-17, with a combined concentration of 128 ng/L **(Tables 3.11-21 through 3.11-26**). The other six wells had combined PFOS/PFOA concentrations of less than 20 ng/L.

- The maximum PFOS concentration was detected in PFC-GP-17 at 125 ng/L and the maximum PFOA concentration was detected in PFC-GP-16 at 13.7 ng/L.
- Several other PFAS were also detected. For example, PFBA and PFNA were detected at concentrations above 100 ng/L.
- The likely sources of the PFAS detected in potable supply wells 10 and 11 are the foam releases that occurred at the former Bubble Chamber experiment area and near Building 924 (discussed below).

3.11.2.4 Building 924 Source Area

Records indicate that on one occasion in 1970, high expansion firefighting foam was released inside of a work trailer and onto the surrounding ground during the testing of a fire suppression system. In 2018, two temporary wells were installed to characterize PFAS contamination downgradient of the release area, which is located within the source water contributing area for the eastern drinking water supply wells 10 and 11 (**Figure 3.11-5**). The monitoring results indicate:

- Combined PFOS/PFOA concentrations in both temporary wells were less than the 70 ng/L HAL. The maximum combined PFOS/PFOA concentration was detected in PFC-GP-11 at 17.7 ng/L (**Tables 3.11-27 and 3.11-28**).
- The maximum PFOS concentration was detected in PFC-GP-11 at 16.3 ng/L and the maximum PFOA concentration was detected in PFC-GP-5 at 7.2 ng/L.

3.11.2.5 Building 902 Source Area

On one occasion in 1970, firefighting foam was released to the ground during the testing of a fire suppression system. In 2018, two temporary wells were installed to characterize PFAS contamination downgradient of the release area (**Figure 3.11-6**). The monitoring results indicate:

- Combined PFOS/PFOA concentrations in both temporary wells were above the 70 ng/L HAL. The maximum combined PFOS/PFOA concentration was detected in PFC-GP-18 at 102 ng/L **(Tables 3.11-29 and 3.11-30**). The highest PFAS concentrations were detected in the deepest sample intervals, which suggests that another source of PFAS may be located upgradient of this release area.
- The maximum PFOS concentration was detected in PFC-GP-18 at 92.4 ng/L and the maximum PFOA concentration was detected in PFC-GP-19 at 10.5 ng/L.

3.11.2.6 Building 526 Source Area

During the 1970's and 1980's, a fire suppression system was in operation at Building 526. Although there are no records to indicate firefighting foam was released to the ground, it is possible that some foam may have been released during system testing. Two temporary wells were installed to evaluate PFAS contamination downgradient of this facility (**Figure 3.11-7**). The monitoring results indicate:

- PFOS/PFOA at concentrations in both temporary wells were below the 70 ng/L HAL, with a maximum combined PFOS/PFOA concentration of 46 ng/L in temporary well PFC-GP-29 (**Tables 3.11-31 and 3.11-32**).
- The maximum PFOS and PFOA concentrations were detected in PFC-GP-29 at 11.3 ng/L and 41.7 ng/L, respectively.

3.11.2.7 Major Petroleum Facility Source Area

Records indicate that on one occasion in 1986, the BNL fire department conducted a training exercise at the Major Petroleum Facility where the Laboratory stores large volumes of heating fuel in a series of above ground storage tanks. Firefighting foam was used during this training event. Two temporary wells were installed to evaluate PFAS contamination downgradient of the release area (**Figure 3.11-8**). The monitoring results indicate:

- Combined PFOS/PFOA concentrations in both temporary wells were below the 70 ng/L HAL, with a maximum combined PFOS/PFOA concentration of 46.5 ng/L in temporary well PFC-GP-27 (**Tables 3.11-33 and 3.11-34**).
- The maximum PFOS concentration was detected in PFC-GP-27 at 34 ng/L and the maximum PFOA concentration was detected in PFC-GP-28 at 15.9 ng/L.

3.11.2.8 Recreation Facility Source Area

Records indicate that on at least two occasions, in 1978 and 1980, high expansion foam was released to a paved area and a grass field adjacent to the BNL Recreation Center. The paved area has a storm water collection system that discharges to a nearby drainage area. Six temporary wells were installed downgradient of the foam release areas and two wells were installed downgradient of the stormwater discharge area (**Figure 3.11-9**). The monitoring results indicate:

- Combined PFOS/PFOA concentrations in all eight temporary wells were less than the 70 ng/L HAL (**Tables 3.11-35 through 3.11-42**).
- In the foam release areas, the maximum combined PFOS/PFOA concentration was 17.7 ng/L detected in PFC-GP-32.
- In the stormwater recharge area, combined PFOS/PFOA concentrations in both temporary wells were less than the 70 ng/L HAL, with a maximum combined concentration of 31.2 ng/L detected in PFC-GP-33.
- The maximum PFOS concentration was detected in PFC-GP-32 at 12.8 ng/L and the maximum PFOA concentration was detected in PFC-GP-33 at 28 ng/L.

3.11.3 Landfill and STP Area Monitoring Well Results

To evaluate whether PFAS-containing material had been disposed in the landfill areas or whether firefighting foam had been released to the sanitary system, 10 existing monitoring wells were sampled (**Figure 3.11-10**).

3.11.3.1 Former Landfill Area

- Only low to trace levels of PFAS compounds were detected in the two Former Landfill area wells. PFOS was not detected in either monitoring well, whereas PFOA was detected in both wells, with a maximum concentration of 3.3 ng/L in well 106-30 (**Table 3.11-43**).

3.11.3.2 Current Landfill Area

- The combined PFOS/PFOA concentrations in the three wells were less than the 70 ng/L HAL, with a maximum combined concentration of 16 ng/L in well 087-11 (**Table 3.11-43**).
- The maximum PFOS concentration was detected in well 88-109 at 4.7 ng/L and the maximum PFOA concentration was detected in well 087-11 at 16 ng/L.

3.11.3.3 Sewage Treatment Plant and Downgradient Areas

- Combined PFOS/PFOA concentrations in two of the five wells sampled exceeded the 70 ng/L HAL. The maximum combined concentration of 338.6 ng/L was detected in well 039-08 (screened from 17-27 feet BGS) which is located at the STP facility (Table 3.11-43). The maximum individual PFOS and PFOA concentrations were detected in well 039-08 at 261 ng/L and 77.6 ng/L, respectively.

- Well 061-05 (screened from 195-205 feet BGS), located close to the BNL eastern boundary, had a combined PFOS/PFOA concentration of 122.9 ng/L. The individual PFOS and PFOA concentrations were 102 ng/L and 20.9 ng/L, respectively.
- Off-site monitoring well 000-122 (screened from 240-260 feet BGS) had a combined PFOS/PFOA concentration of 29.2 ng/L. The individual PFOS and PFOA concentrations were 19.5 ng/L and 9.7 ng/L, respectively.
- Several other PFAS were also detected at high levels in the monitoring wells. For example, in well 039-08 PFHxS was detected at concentration of 1,410 ng/L, and PFBS, PFPeS and PFHxA were detected at concentrations above 100 ng/L.

3.11.4 William Floyd Well Field Area Monitoring Well Results

The Suffolk County Water Authority operates the William Floyd Parkway Well Field located west of the BNL site. The well field currently contains three water supply wells that are screened in the Upper Glacial aquifer. Because the source water contributing area for this well field extends into the BNL property, during 2018 well field sentinel wells 109-03 and 109-04 were sampled for PFAS (**Figure 3.11-10**).

During December 2018 and January 2019, samples were collected from wells 109-03 and 109-04 using the existing sample pumps and discharge lines that contained Teflon® components and a second time using newly installed Teflon®-free sample pumps and discharge lines (**Table 3.11-44**). (See discussion at the end of Section 3.0 on the issue of possible cross contamination of samples by Teflon-containing sampling equipment.)

- In the December 2018 samples, the two primary PFAS of concern, PFOS and PFOA, were not detected. However, trace levels of PFAS compounds PFBS and PFHxS were detected in the sample from well 109-03 that was collected using the Teflon®-containing sampling equipment. Similar trace levels of PFBS and PFHxS were also detected in the field reagent blank submitted with the samples collected in January 2019. It is unclear whether these detections are due to sample cross contamination in the field during collection or during the analysis of the samples.
- There were no PFAS compounds detected in the January 2019 samples collected with the Teflon®-free equipment. However, as noted above trace levels of PFBS and PFHxS were detected in the field reagent blank.

3.11.5 Groundwater Treatment Systems

To evaluate the extent of PFAS contamination downgradient of the firefighting foam release areas, 43 on-site extraction wells were sampled (**Figure 3.11-10**).

3.11.5.1 OU III Western South Boundary

- PFOS was detected in three of the six Western South Boundary extraction wells and PFOA was detected in two of the wells (**Table 3.11-45**). The maximum PFOS and PFOA concentrations were detected in extraction well WSB-1 at 5.7 ng/L and 3.2 ng/L, respectively.
- The maximum combined PFOS/PFOA concentration in the six extraction wells was 8.9 ng/L in WSB-1.
- The combined PFOS/PFOA concentrations in the WSB treatment system influent was 3.5 ng/L, whereas PFOS/PFOA concentrations in the combined Western South Boundary, Middle Road and OU III South Boundary treatment system effluent was 11.7 ng/L.

3.11.5.2 OU III Middle Road

- PFAS compounds were detected in all seven Middle Road extraction wells (**Table 3.11-46**). The maximum PFOS and PFOA concentrations were detected in extraction well RW-2 at 11.2 ng/L and 10.9 ng/L, respectively.
- The maximum combined PFOS/PFOA concentration in the seven extraction wells was 22.1 ng/L detected in extraction well RW-2.
- The combined PFOS/PFOA concentrations in the Middle Road influent to the treatment system was 12.9 ng/L. As noted above, the PFOS/PFOA concentration in the combined Western South Boundary, Middle Road and OU III South Boundary treatment system effluent was 11.7 ng/L.

3.11.5.3 OU III South Boundary

- PFAS compounds were detected in all seven OU III South Boundary extraction wells (**Table 3.11-47**). The maximum PFOS concentration was detected in extraction well EW-5 at 18.9 ng/L, and the highest PFOA concentration was detected in extraction well EW-7 at 16.4 ng/L.
- The maximum combined PFOS/PFOA concentration in the seven OU III South Boundary extraction wells was 31.1 ng/L in EW-5.
- The combined PFOS/PFOA concentration in the South Boundary influent to the treatment system was 24.7 ng/L. As noted above, the combined Western South Boundary, Middle Road and OU III South Boundary treatment system effluent was 11.7 ng/L.

3.11.5.4 OU I South Boundary

- PFAS compounds were detected in both extraction wells (**Table 3.11-48**). The maximum PFOS concentration was detected in extraction well EW-2 at 7.3 ng/L, and the highest PFOA concentration was detected in extraction well EW-1 at 5.1 ng/L.
- The maximum combined PFOS/PFOA concentrations detected in the OU I South Boundary extraction wells was 10.7 ng/L in EW-1.

3.11.5.5 Chemical Holes

- PFAS compounds were detected in all three extraction wells (**Table 3.11-49**). The maximum PFOS and PFOA concentrations were detected in extraction well SR90 EW-1 at 2.3 ng/L and 8.8 ng/L, respectively.
- The maximum combined PFOS/PFOA concentrations detected in the Chemical Holes extraction wells was 11.1 ng/L in SR90 EW-1.

3.11.5.6 HFBR

- PFAS compounds were detected in all four extraction wells (**Table 3.11-48**). The maximum PFOS and PFOA concentrations were detected in extraction well EW-9 at 13.1 ng/L and 7.1 ng/L, respectively.
- The maximum combined PFOS/PFOA concentrations detected in the HFBR extraction wells was 20.2 ng/L in EW-9.

3.11.5.7 Building 96 and Building 452

- PFAS compounds were detected in all five extraction wells (**Table 3.11-49**). The maximum PFOS and PFOA concentrations were detected in Building 96 extraction well RTW-4 at 40 ng/L and 13.8 ng/L, respectively.

- The combined PFOS/PFOA concentration detected in the Building 452 extraction well EW-18 was 29.5 ng/L.
- The maximum combined PFOS/PFOA concentrations detected in the Building 96 extraction wells was 53.8 ng/L in RTW-4.
- Effluent samples were collected for the two Building 96 extraction wells that were in active operation during 2018. Combined PFOS/PFOA effluent concentration for RTW-1 was 21.3 ng/L, while the combined PFOS/PFOA effluent concentration for RTW-2 was 11.9 ng/L.

3.11.5.8 BGRR

- PFAS compounds were detected in all nine extraction wells (**Table 3.11-50**). The maximum PFOS concentration was detected in extraction well SR-6 at 12.3 ng/L, and the highest PFOA concentration was detected in extraction well SR-3 at 6.2 ng/L.
- The maximum combined PFOS/PFOA concentration in the nine BGRR extraction wells was 16.4 ng/L in extraction well SR-6.
- The combined PFOS/PFOA concentration in the BGRR treatment system influent was 10.3 ng/L, whereas the effluent concentration was 7.9 ng/L.

3.11.6 South Boundary Monitoring Wells

To evaluate PFAS and 1,4-dioxane concentrations at the BNL southern boundary, 33 previously installed groundwater monitoring wells associated with the Western South Boundary and OU III South Boundary treatment systems were sampled in January 2019. While most of the wells are screened in the middle to deep portions of the Upper Glacial aquifer, four wells are screened in the upper portion of the Magothy aquifer. During the spring of 2019, eleven temporary monitoring wells were installed to characterize the shallower sections of the aquifer along the south boundary. The locations of the wells are presented on **Figure 3.11-11**. PFAS analytical results for the 33 monitoring wells are presented in **Table 3.11-51**. PFAS analytical results for the 11 temporary wells are presented in **Tables 3.11-52** through **3.11-62.** The analytical results are also posted on hydrogeologic cross section **Figures 3.11-12** and **3.11-13**. 1,4-Dioxane analytical results for the 33 monitoring wells and 11 temporary wells are presented in **Section 3.10**.

- The maximum PFOS concentration was detected in OU III South Boundary monitoring well 122-10 at 65.6 ng/L, and the highest PFOA concentration was detected in well 122-31 at 24 ng/L.
- The maximum combined PFOS/PFOA concentrations detected in the South Boundary monitoring wells was 69.2 ng/L in well 122-10.

3.11.7 PFAS Groundwater Monitoring Program Evaluation

The 2018 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. In four of the eight sites, combined PFOS and PFOA concentrations exceed the 70 ng/L HAL that has been established for drinking water (**Figure 3.11-14**). 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.

3.11.8 PFAS Monitoring Recommendations

The following are recommended for the PFAS monitoring program for 2019:

- During 2019, BNL completed the installation of eleven temporary monitoring wells along the BNL south boundary to characterize the extent of 1,4-dioxane and PFAS (described in **Section 3.11.6**).
- Continue to evaluate whether the use of existing groundwater sampling equipment that contains Teflon® components (e.g., bladder pumps, discharge tubing, valves on extraction well system sample ports) results in cross contamination of the samples.

4.0 FACILITY MONITORING PROGRAM SUMMARY

During 2018, 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 2018, 77 groundwater monitoring wells were sampled during 104 sampling events for facility surveillance required by state operating permits and DOE Orders. An additional 36 facility monitoring wells were sampled during 56 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 2018 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 the activated soils by rainwater and does not bind to soil particles. When 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 many of the activated soil shielding areas. 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. 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 the AGS complex: the 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 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 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 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**).

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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 (i.e., 1,000 pCi/L) or 25 percent of the drinking water standard for sodium-22 (i.e., 100 pCi/L).

Sampling Frequency and Analysis

During 2018, 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 2018, 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 7,420 pCi/L detected in a sample collected from well 065-323. 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 2018 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 indicate 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 2019, 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

During 2018, the Booster area wells were sampled one time, and 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 (**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.

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

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 near the Booster 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 2019, 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 2018, the NSRL monitoring wells were sampled one time. The samples were analyzed for tritium (**Table 1-6**).

4.1.3.2 NSRL Monitoring Well Results

During 2018, tritium was not detected in the NSRL monitoring wells.

4.1.3.3 NSRL Groundwater Monitoring Program Evaluation

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

[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.

<u>1. Is there a continuing source of contamination? If present, has the source been remediated or controlled?</u>
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 2019, 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 2018, 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 2018, tritium was detected only in well 064-80, at a concentration of 266 pCi/L (**Figure 4.1-3**).

4.1.4.3 Former AGS E-20 Catcher Groundwater Monitoring Program Evaluation

The 2018 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>
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 2019, 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 2018, 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 2018, 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 2018 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>

The lack of detectable levels of tritium since 2008 indicates that the building structure and associated stormwater controls are effectively preventing significant 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 2019, 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 2018, 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 2018, tritium was not detected in any of the wells.

4.1.6.3 Former g-2 Beam Stop Groundwater Monitoring Program Evaluation

The 2018 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>

Overall monitoring results for the past fifteen 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 2019, 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 2018, 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

Tritium has not been detected in the J-10 area wells since 2010 (**Figure 4.1-5**).

4.1.7.3 AGS J-10 Beam Stop Monitoring Program Evaluation

The 2018 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>

Groundwater monitoring results indicate that the engineered controls in place at J-10 are preventing significant rainwater infiltration into the activated soil shielding. However, the occasional detection of low levels of tritium (up to 1,000 pCi/L) prior to 2010 indicates some water was periodically infiltrating through 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 2019, 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 2018, 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 2018, 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 2018 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>

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 2019, the former U-Line area wells will continue to be monitored for tritium on an annual basis.

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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 2018, 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). Surface water sample are collected at location HV annually and are analyzed for tritium.

4.2.2 RHIC Monitoring Well Results

During 2018, tritium was not detected in any of the RHIC monitoring wells. Furthermore, tritium was not detected in the surface water sample collected from downstream location HV.

4.2.3 RHIC Groundwater Monitoring Program Evaluation

The 2018 monitoring data were evaluated using the following Data Quality Objective statement.

1. Has the source of potential contamination been controlled?

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 2019, 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 2016. The groundwater samples were analyzed for tritium (**Table 1-6**). No samples were collected during 2017.

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**). During 2018, tritium was not detected in any of the samples. Previous analyses for gamma, gross alpha, and gross beta did not indicated 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 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 waste water 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 2018. As required by the permit, the samples are analyzed for the following metals: copper, iron, lead, nickel, silver, zinc and mercury.

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 four of the STP recharge basin wells, with a maximum concentration of 79 mg/L in well 039-88.

4.4.3 STP Groundwater Monitoring Program Evaluation

The 2018 monitoring data were evaluated using the following Data Quality Objective statement.

1. Are STP operations impacting groundwater quality?

Monitoring results for 2018 continue to indicate that 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 2019, 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 Motor Pool facility's groundwater monitoring program for the UST area is used to confirm that the current engineered and institutional controls are effective in preventing contamination of the aquifer. Two 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 four wells (102-10, 102-11, 102-12, and 102-13).

Sampling Frequency and Analysis

During 2018, the two UST area wells were monitored annually, and the samples were analyzed for VOCs (**Table 1-6**). The remaining wells were not sampled during 2018. The wells were also checked for the presence of floating petroleum hydrocarbons.

4.5.2 Motor Pool Monitoring Well Results

Underground Storage Tank Area

During 2018, chloroform was detected in both wells, with a maximum concentration of 2.3 µg/L in well 102-05. As in previous years, no floating product was detected in the wells.

4.5.3 Motor Pool Groundwater Monitoring Program Evaluation

The 2018 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?

During 2018, there were no reported gasoline or motor oil losses or spills 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 2019:

- 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 removed and removed from the site for proper disposal.

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 2018.

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, with was below the NYS AWQS of 5 µg/L. **Figure 4.6-2** provides a summary of VOC concentrations in the Service Station wells from 1999 through 2017.

4.6.3 Service Station Groundwater Monitoring Program Evaluation

Monitoring data collected to date 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>

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 tank, 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.

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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 Special License Conditions for the MPF requires semiannual sampling for VOCs and SVOCs and monthly monitoring for floating petroleum (**Table 1-6**).

4.7.2 MPF Monitoring Well Results

During 2018, 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 a number of VOCs (e.g., chloroform, tetrachloroethylene and acetone) 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 was detected in upgradient well 076-25 at a concentration up to 2.5 µg/L. 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 2018 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 2019, 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.

4.8.1 WMF Groundwater Monitoring

Well Network

Groundwater quality at the WMF is monitored using six shallow Upper Glacial aquifer wells. Two wells (055-03 and 055-10) are used to monitor background water quality, and four wells monitor groundwater quality downgradient of the two main waste handling and storage facilities. Wells 066-220 and 066-221 are located downgradient of the RCRA Building, and wells 066-222 and 066-223 are located downgradient of the Reclamation Building. 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 2018, 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 *2018 Groundwater Monitoring Report for the Waste Management Facility* (BNL 2019).

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 2018, cobalt-60 (Co-60) was detected in monitoring well 066-222 at a concentration of 9.2+/-4.2 pCi/L, which is approximately 5% of the 200 pCi/L DWS. During 2017, Co-60 was also detected in well 066-222 at a concentration of 6.3+/-3.5 pCi/L. Based upon documented waste management operations and results of groundwater monitoring over the past 20 years, the WMF is not a likely source for Co-60.

As reported for the 2016 and 2017 monitoring periods, low levels of strontium-90 (Sr-90) continued to be detected in a number of the upgradient and downgradient monitoring wells. The maximum Sr-90 concentration was detected in well 066-220 at 0.43+/-0.15 pCi/L (MDL = 0.19 pCi/L), which is approximately 5% 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 NYS AWQS in both upgradient wells (055-03 and 055-10) at concentrations up to 120 mg/L, and in all four downgradient wells (066-220, 066-221, 066-222 and 066-223) at concentrations up to 93 mg/L. The elevated sodium concentrations are likely the result of road salting operations. Although trace levels of several VOCs (primarily chloroform) continue to be detected in a number of the WMF's upgradient and downgradient wells, all concentrations were below the NYS AWQS.

4.8.3 WMF Groundwater Monitoring Program Evaluation

The 2018 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 2018 continued to show that WMF operations are not affecting groundwater quality. Furthermore, there were no outdoor or indoor spills at the facility during 2018 that could have affected soil or groundwater quality.

4.8.4 WMF Recommendation

The following are recommended for 2019:

- 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 2018, 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 2018.

4.9.3 NSLS-II Groundwater Monitoring Program Evaluation

The 2018 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 2018 indicate that NSLS-II beam line operations conducted to date have not affected groundwater quality.

4.9.4 NSLS-II Recommendations

For 2019, 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 all of the recommendations included in **Sections 3** and **4**. The recommendations are sequenced as they appear 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

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

- Based on the lack of significant rebound in VOC concentrations since system shutdown in 2013 and very low remaining VOC concentrations in area monitoring wells, submit a petition for closure of the OU I South Boundary Treatment System in 2019.
- Maintain the VOC groundwater monitoring program of an annual sample collection from plume core wells: 107-40, 107-41, 115-13, 115-16, and 115-51. Maintain quarterly sampling of well 098-99.
- Install three shallow monitoring wells at the locations of GP-30, GP-40 and GP-42 to provide permanent monitoring points where the highest Sr-90 concentrations were observed at locations in and adjacent to the former source at the FHWMF. Install temporary wells as needed to fill monitoring data gaps and characterize extent of Sr-90 plume.
- Discontinue Sr-90 sampling for monitoring wells 099-04, 107-10, 107-24, 107-26, 107-40, 115-03, 115-13, 115-14, 115-15, 115-16, 115-28, 115-29, 115-30, and 115-31. Sr-90 concentrations have been either non-detect or barely detectable for at least five years in these wells. In addition, several of the wells are located significantly to the west of the plume location or are significantly deeper than the observed plume depth.

5.2 Building 96 Treatment System

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

- Maintain full time operation of treatment wells RTW-1 and RTW-2. Maintain a monthly sampling frequency of the influent and effluent. Continue operating RTW-2 based on influent TVOC concentrations and concentrations observed in upgradient well 095-159.
- Increase monitoring frequency of well 095-159 to monthly to evaluate the influence of increased pumping rate of RTW-1 and westward expansion of capture zone.
- 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.
- Install a monitoring well at the location of B96-GP02-2019 and screen from 15 to 25 feet mean sea level (ft. msl.)

5.3 452 Freon-11 Source Area and Groundwater Plume

The following are recommendations for the Building 452 Freon-11 remediation system and monitoring program:

- Maintain the Building 452 Treatment System in standby mode. If there isn't a significant rebound in Freon-11 concentrations, with concentrations exceeding 50 µg/L, prepare a petition for closure by mid-2019. It is anticipated that the Building 96 treatment well RTW-1 will remain in full-time operation for several more years. The Freon-11 tray air stripper is being repurposed to treat some of the water extracted from RTW-1.

- Following regulatory agency review and approval of the petition for closure, discontinue the Building 452 monitoring program. Select monitoring wells located downgradient of extraction well EW-18 may be incorporated into the Building 96 program. Furthermore, any decisions to abandon extraction well EW-18 and the monitoring wells will be made after the PFAS plume originating from the former firehouse area has been fully characterized (see **Section 3.11).**

5.4 Middle Road Treatment System

The following recommendations are made for the Middle Road Pump and Treat 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.

5.5 OU III South Boundary Treatment System

The following are recommendations for the OU III South Boundary Pump and Treat 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. 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.
- Maintain the current routine O&M monitoring frequency.

5.6 Western South Boundary Treatment System

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 core monitoring wells, extraction well WSB-2 may be put into full time operation.
- Begin operation of the four new extraction wells in March 2019. 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

The following are recommendations for the Industrial Park In-Well Air Stripping 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.
- Due to individual VOC concentrations remaining below AWQS since 2017 in IP-EW-8 and IP-EW-9, place wells on standby in July 2019 and continue to monitor for rebound of VOCs.

5.8 Industrial Park East Treatment System

The following is recommended for the Industrial Park East Treatment System and groundwater monitoring program.

- 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 is discontinued.

5.9 North Street Treatment System

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

- Extraction wells NS-1 and NS-2 will remain in standby. If TVOC concentrations in any core monitoring wells increase to over the 50 µg/L capture goal, the extraction well(s) may be restarted.
- Submit a petition for closure in 2019 as this system has met its cleanup goals.

5.10 North Street East Treatment System

The following recommendations are made for the North Street East Treatment System and groundwater monitoring program:

- Maintain the existing treatment system in standby mode. The extraction wells will continue to be sampled on a quarterly basis for VOCs, EDB, and tritium. 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.
- Based on the EDB vertical profile characterization performed and the fate and transport model recommendation, begin the design for modification of the treatment system for two additional extraction wells. Submit a design modification to the regulators.
- Sample the five new monitoring wells on a quarterly basis using EDB Method 504.
- 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, add this well to the NSE monitoring program and perform quarterly sampling for EDB using Method 504.

5.11 LIPA/Airport Treatment System

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

- Continue the Airport extraction wells pulsed pumping schedule of pumping one week per month for wells RTW-2A and RTW-3A and 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.
- No changes to the current monitoring schedule is recommended at this time for the LIPA and Airport Systems.

5.12 Magothy Monitoring

The following are recommendations for the Magothy groundwater monitoring program:

- Continue the current monitoring schedule for the Magothy monitoring program.
- Continue pumping the Magothy extraction wells at Middle Road, South Boundary, Airport and the two IP wells. The two IP extraction wells will be 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

No changes are recommended for the OU III South Boundary Radionuclide Groundwater Monitoring Program.

5.15 BGRR/WCF Strontium-90 Treatment System

The following are recommendations for the BGRR/WCF Groundwater Treatment System and monitoring program:

- Maintain SR-8 in pulsed pumping mode (one month on and one month off) based on low, but slightly increasing, Sr-90 concentrations.
- Maintain a source area monitoring frequency of monthly for BGRR source area wells 075-664 and 075-701.
- Continue operating wells SR-1, SR-2, SR-3 and SR-9 in full time mode. Maintain wells SR-4, SR-5, and SR-6, and SR-7 in standby mode.
- Install a temporary well downgradient of 085-403 to re-establish the location of the leading edge of the plume.
- Reduce sampling frequency of WCF well 065-160 to annual following re-start of SR-1 and decline of Sr-90 concentrations in 2018. Discontinue sampling of wells 065-03, 065-04, and 065-161 due to lack of significant detections in these wells since late 1990s.
- Install up to 15 temporary wells to fill in monitoring network data gaps north of the HFBR and just south of the WCF.
- Maintain well 065-175 semi-annual sampling frequency to monitor for Sr-90 migrating south from the WCF yard.

5.16 Chemical/Animal Holes Strontium-90 Treatment System

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 is identified, these extraction wells may be restarted.
- Maintain the annual monitoring well sampling frequency (standby phase), except for wells 097-313, 097-314, 097-315, which will remain at a semi-annual.

5.17 HFBR Tritium Pump and Recharge System

The following are recommendations for the HFBR AOC 29 Tritium Pump and Recharge System and monitoring program:

- Monitor the source area with a combination of the seven new monitoring wells and three existing wells listed in **Section 3.2.17.2**. The monitoring data will continue to be documented in the annual Groundwater Status Reports.

5.18 Building 650 (Sump Outfall) Strontium-90 Monitoring

The following is recommended for the Building 650 and Sump Outfall Strontium-90 Monitoring Program:

- Continue the current monitoring frequency stated in **Table 1-5**, except for the following:
    - Increase sampling frequency to semi-annual for well 076-25 in response to Sr-90 concentration increases in this well during 2018.
    - Decrease well 076-13 from quarterly to semi-annually
- Install up to eight temporary wells to verify whether there has been any southeast shift of the plume due to changes in groundwater flow direction in the area. Temporary wells will be located southeast of monitoring wells 076-168, 076-24, 076-415, and south of Brookhaven Avenue (leading edge of plume).

5.19 Operable Unit VI EDB Treatment System

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.
- Update the groundwater model based on the analytical results from the two vertical profiles installed in December 2018 to better refine the remaining time required to remediate the EDB plume to below the DWS.

5.20 Site Background Monitoring

- Discontinue sampling well 063-09 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.

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.

5.23 g-2 Tritium Source Area and Groundwater Plume

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 Building 912.

5.24 Brookhaven Linac Isotope Producer (BLIP) Facility

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.

5.25 1,4-Dioxane Sampling

- Complete installation of the 11 temporary monitoring wells outlined in the Addendum to the Phase 3 Work Plan (BNL 2019a). This work was completed during April-May 2019, and the results are described in **Section 3.10**. During the third quarter of 2019, samples from the newly installed Western South Boundary extraction wells will also be tested for 1,4-dioxane.

5.26 PFAS Source Areas and Groundwater Plumes

- Complete installation of the 11 temporary monitoring wells outlined in the Addendum to the Phase 3 Work Plan (BNL 2019a). This work was completed during April-May 2019, and the results are presented in **Section 3.11**.

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

The groundwater monitoring program is adequate at this time, and no changes are required.

5.29 Brookhaven Medical Research Reactor (BMRR) Facility

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.

5.30 Sewage Treatment Plant (STP) Facility

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.

5.31 Motor Pool Area

The following is recommended for the Motor Pool monitoring program:

- 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.

5.33 Major Petroleum Facility (MPF) Area

For 2019, 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 2019, the four NSLS-II and two MPF (background) monitoring wells will continue to be monitored annually for tritium.

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