2001 BNL GROUNDWATER STATUS REPORT

June 13, 2002

Environmental Services Division
Environmental Restoration

Brookhaven National Laboratory
Operated by
Brookhaven Science Associates
Upton, NY 11973

BROOKHAVEN NATIONAL LABORATORY

Under Contract with the United States Department of Energy
Contract No. DE-AC02-98CH10886

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LIST OF ACRONYMS

2001 BNL Groundwater Status Report

µg/L	Micrograms per Liter	DCE	1,1-dichloroethylene
AGS	Alternating Gradient Synchrotron	DCG	Derived Concentration Guide
AOC	Area of Concern	DDT	Dichlorodiphenyltrichloroethane
AS	Air Sparging	DG	Deep Glacial
AS/SVE	Air Sparge/Soil Vapor Extraction	DMR	Discharge Monitoring Report
ASL	Analytical Services Laboratory	DOE	U.S. Department of Energy
ASTM	American Society for Testing and Materials	DQO	Data Quality Objective
AWQS	Ambient Water Quality Standards	DTW	Depth to Water
BERA	Brookhaven Employees Recreation Association	DWS	Drinking Water Standard
BGRR	Brookhaven Graphite Research Reactor	EDB	Ethylene Dibromide
BLIP	Brookhaven LINAC Isotope Producer	EDD	Electronic Data Deliverable
BMRR	Brookhaven Medical Research Reactor	EE/CA	Engineering Evaluation/Cost Analysis
BNL	Brookhaven National Laboratory	EIMS	Environmental Information Management System
CERCLA	Comprehensive Environmental Response Compensation and Liability	EM	Environmental Management
CFR	Code of Federal Regulations	EPA	United States Environmental Protection Agency
CLP-SOW	Contract Laboratory Program-Statement of Work	ER	Environmental Restoration
COC	Chain of Custody	ERP	Emissions rate potential
CSF	Central Steam Facility	ES	Environmental Surveillance
CT	Carbon Tetrachloride	ESD	Environmental Services Division
CY	Calendar Year	fbg	feet below grade
DCA	1,1-dichloroethane	FFA	Federal Facility Agreement

LIST OF ACRONYMS

2001 BNL Groundwater Status Report

FS	Feasibility Study	NPL	National Priorities List
ft msl	feet above mean sea level	NYCRR	New York Code of Rules and Regulations
FY	Fiscal Year	NYS	New York State
GAC	Granular Activated Carbon	NYSDEC	New York State Department of Environmental Conservation
gal/hr	Gallons per hour	NYSDOH	New York State Department of Health
GPM	Gallons per minute	O&M	Operation and Maintenance
HFBR	High Flux Beam Reactor	OU	Operable Unit
HWMF	Hazardous Waste Management Facility	P&T	Pump and Treat
IAG	Inter Agency Agreement	PCBs	Polychlorinated Biphenyls
ID	Identification	PCE	Tetrachloroethylene
lb/gal	Pounds per gallon	pCi/L	pico Curies per Liter
lbs	Pounds	PE	Plant Engineering
LIE	Long Island Expressway	PLC	programmable logic controller
LIPA	Long Island Power Authority	ppb	parts per billion
MAG	Magothy	QA/QC	Quality Assurance and Quality Control
MCL	Maximum Contaminant Level	QAPP	Quality Assurance Project Plan
MDL	Minimum Detection Limit	RA	Removal Action
MeV	Mega electron volt	RCRA	Resource Conservation and Recovery Act
MGD	Millions of Gallons per Day	RHIC	Relativistic Heavy Ion Collider
MPF	Major Petroleum Facility	RI	Remedial Investigation
MS/MSD	Matrix Spike/Matrix Spike Duplicate	RI/FS	Remedial Investigation/Feasibility Study
msl	Mean Sea Level	ROD	Record of Decision
MTBE	Methyl tertiary Butyl Ether	SCDHS	Suffolk County Department of Health Services

LIST OF ACRONYMS

2001 BNL Groundwater Status Report

SCGs	Standards, Criteria and Guidances	TVOC	Total Volatile Organic Compounds
SCWA	Suffolk County Water Authority	USGS	U.S. Geological Survey
SDG	Sample Delivery Group	UST	Underground Storage Tank
SDWA	Safe Drinking Water Act	VOC	Volatile Organic Compound
SG	Shallow Glacial	WCF	Waste Concentration Facility
SOP	Standard Operating Procedure	WMF	Waste Management Facility
SOW	Statement of Work	WTP	Water Treatment Plant
SPCC	Spill Prevention Control and Countermeasures		
SPDES	State Pollution Discharge Elimination System		
Sr-90	Strontium-90		
STP	Sewage Treatment Plant		
SVE	Soil Vapor Extraction		
SVOC	Semi-Volatile Organic Compound		
TAL	Target Analyte List		
TCA	1,1,1- Trichloroethane		
TCE	Trichloroethylene		
TOC	Total Organic Carbon		
TSG	Technical Support Group		

2001 BROOKHAVEN NATIONAL LABORATORY GROUNDWATER STATUS REPORT

EXECUTIVE SUMMARY

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

- Pollution prevention – preventing the potential pollution of groundwater at the source.
- Monitoring - monitoring the effectiveness of pollution-prevention efforts, as well as progress in restoring the quality of degraded groundwater.
- Restoration - restoring groundwater quality that BNL has impacted.
- Communication - communicating the findings and the results of the program to regulators and other stakeholders.

The 2001 BNL Groundwater Status Report is a comprehensive summary of groundwater data collected in calendar year 2001. It provides an interpretive technical summary of data on the performance of BNL's Groundwater Protection Program. This is the fifth annual groundwater status report issued by BNL. This document is unique in that it examines the performance of the program on a project-by-project (facility-by-facility) basis, as well as comprehensively in a "watershed-like" analysis.

HOW TO USE THIS DOCUMENT- This detailed technical document includes summaries of laboratory data, as well as data that have been interpreted by BNL's groundwater group. It is intended for internal BNL users, regulators, and other technically oriented stakeholders. Less technical summaries of this information can be obtained through the BNL website, BNL Community Affairs office, as well as BNL's annual Site Environmental Report.

Data are presented in five key subject areas:

- Improvements to the understanding of the hydrogeologic environment beneath BNL and surrounding areas,
- Identification of any new impacts on groundwater quality due to BNL's active operations,
- Progress in cleaning up the legacy contamination of groundwater,
- Performance of individual groundwater remediation systems, and
- Recommended changes to the groundwater protection program.

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

Section 1 summarizes the drivers of the data collection work in 2001, the site's groundwater classification, and the objectives of the groundwater monitoring efforts. Section 2 discusses improvements to our understanding of the hydrogeologic environment at BNL and its surrounding area. It also summarizes the dynamics of the groundwater flow system in 2001. Section 3 summarizes the groundwater cleanup data, progress towards achieving the site's cleanup goal and recommended modifications to the remediation systems or monitoring programs. Section 4 summarizes the groundwater surveillance data used to verify that operational and engineering controls are preventing further contamination from the site's active experimental and support facilities and recommended changes to the groundwater protection program. The recommended changes to the Groundwater Protection Program are summarized in Section 5.

Hydrogeologic Data

The following were important hydrogeologic findings in 2001:

- Groundwater flow directions were relatively stable during 2001in part due to the efforts of the BNL Groundwater Pump and Recharge Committee. Supply pumping was relegated primarily to the western supply well field during the year. The Operable Unit (OU) III Middle Road Pump and Treat System, located on-site and immediately south of the Laboratory, came on line in 2001. The system was designed such that treated water could be recharged to both the OU III and RA V basins. This helped to maintain an overall balance of recharged treatment system water in the central portion of the site and minimized changes to groundwater flow direction.

- Total annual precipitation in 2001 was recorded as 45.5 inches, below the average for the period of record of 48.5 inches per year. In an average year, approximately 24 inches of rainfall recharge the Upper Glacial aquifer. Taking into account seasonal variations in evapotranspiration, the recharge rate for 2001 was estimated as approximately 23 inches.

- A number of vertical profile borings were drilled in areas south of the site during 2001 as part of remediation system pre-design groundwater characterization efforts. Geologic information gathered from these deep borings refined the interpretation of the extent of the Magothy Brown Clay and Gardiners Clay units in these off-site areas. These are important confining units that govern the flow of groundwater form the Upper Glacial aquifer to the Magothy aquifer.

Progress in Groundwater Restoration

594 wells were sampled as part of the Environmental Restoration (ER) Groundwater Monitoring Program in 2001 comprising a total of 2,389 sampling events. BNL continued to make significant progress in characterizing and restoring groundwater quality at the site in 2001. Six groundwater remediation systems were in operation by the end of 2001 with the addition of the OU III Middle Road system. Eight of the seventeen planned groundwater treatment plants have been constructed. Two systems remained in standby mode in 2001 as they substantially met their goal; they were the OU IV Air Sparging/Soil Vapor Extraction (AS/SVE) system, and the HFBR Pump & Recharge System. An additional extraction well was constructed for the OU III Carbon Tetrachloride pump and treat system and was operational in December 2001.The total groundwater cleanup treatment capacity was increased from 1,945 gpm to 2,575 gpm. Ultimately, the total groundwater cleanup capacity will be on the order of 4,500 gpm. Extensive groundwater characterization work was performed as part of the pre-design work for several off-site groundwater treatment systems. The data obtained from these investigations refined our understanding of the BNL contaminant plumes, particularly in off-site areas. The progress of the groundwater restoration program is summarized in Table E-2. Other progress highlights include:

- A Five-Year Review Report was submitted for the Current Landfill in 2001 and recommended a reduction in sampling parameters and frequency.
- A report was drafted for the Former Landfill and will be finalized in 2002.
- A petition was submitted for the shutdown of the OU IV AS/SVE system in January 2001.
- Data Quality Objectives (DQOs) were developed for sixteen of the nineteen Environmental Restoration (ER) monitoring programs in 2001, and the resulting recommendations are being implemented in 2002.
- The OU III High Flux Beam Reactor (HFBR) program for low-flow groundwater extraction and off-site disposal, which was implemented for the HFBR tritium plume in 2000, continued into 2001 with a total of 95,000 gallons of tritiated water removed from the aquifer and sent off-site for disposal.
- Strontium-90 was detected during groundwater characterization work in the Brookhaven Graphite

Research Reactor (BGRR) area (south of the below ground ducts) at concentrations up to 540 pico Curies per liter (pCi/L). Additional monitoring wells will be installed to address this as part of the pre-design work for the BGRR strontium-90 contamination in 2003.

- Characterization of the strontium-90 plume south of the former Hazardous Waste Management Area in OU I was completed in 2001. Sentinel wells will be added to complete the monitoring well network in the spring of 2002.

Table E-1 summarizes the status and progress of groundwater cleanup at BNL. In 2001, 609 pounds (lbs) of volatile organic compounds (VOCs) were removed from the aquifer by BNL treatment systems. To date, approximately 2,950 or about 10% of the estimated 25,000 to 30,000 lbs of VOCs in the aquifer have been removed by BNL. This estimate has been revised downward from 50,000 lbs as a result of groundwater characterization data obtained in 2000 and 2001.

Table E-1. BNL Groundwater Remediation System Treatment Summary for 1997 through 2001.

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

Notes:

[a] Treatment system not installed/operational until 1999.

[b] System was shut down and placed in standby mode on September 29, 2000.

[c] Air Sparging/Soil Vapor Extraction system performance measured by pounds of VOC removed per cubic feet of air treated.

[d] Values rounded to the nearest whole number.

Groundwater remediation is expected to take up to 10 years of aquifer treatment before noticeable and wide spread improvements in groundwater quality at BNL is clear. Even so, some noticeable improvements in groundwater quality are evident in OU IV, the OU III South Boundary area, and the OU I South Boundary area. Groundwater remediation activities are expected to continue until approximately 2025 to meet the ultimate cleanup objective.

Figures **E-1** and **E-2** summarize the extent of the primary VOC and radionuclide plumes at BNL as of December 2001, respectively.

Environmental Surveillance Monitoring Results

During 2001, the Environmental Surveillance program monitored groundwater quality near 14 active research and support facilities. Groundwater samples were collected from 120 wells during approximately 350 individual sampling events.

No new impacts to groundwater quality were discovered during 2001. Results of the surveillance program do indicate that groundwater quality improved at two of the activated soil shielding areas at the Alternating Gradient Synchrotron (AGS) facility, with tritium concentrations dropping to well below the 20,000 pCi/L standard at the former U-Line beam stop and the former E-20 Catcher. The reduction in tritium concentrations suggests that the impermeable caps that were constructed over these soil shielding areas have been effective in preventing rainwater infiltration, and leaching of tritium to the groundwater. Tritium concentrations also declined at the Brookhaven LINAC Isotope Producer (BLIP). In wells located immediately downgradient of BLIP, tritium concentrations were well below the 20,000 pCi/L standard during the entire year, and tritium declined to close to the standard in a well located approximately 150 feet downgradient of the facility. The pattern of decreasing tritium concentrations indicate that the short-termed tritium release resulting from the May-June 2000 soil grouting process is dissipating in the aquifer. Furthermore, VOC contamination detected during 2000 near Building 830 dropped to nearly non-detectable levels by early 2001.

Groundwater quality continues to be impacted at three facilities: continued high levels of tritium at the g-2/VQ12 area of the AGS facility; VOCs at the Motor Pool/Facility Maintenance area; and VOCs at the Service Station.

In the g-2/VQ12 area, tritium was detected at concentrations up to 1,800,000 pCi/L in late 2001. Because these concentrations were higher than expected following the capping of the source area, the design of the cap was re-evaluated to ensure that it met design specifications, and the cap itself was thoroughly inspected. The cap was found to be constructed as planned and to be in excellent condition. It is likely that the continued presence of high levels of tritium in groundwater directly downgradient of the source area is due to the release of residual tritium from the vadose zone following a natural rise in water table position that occurred during 2000. BNL and the regulatory agencies determined that additional monitoring of the permanent wells would be required before completing the g-2 tritium plume Engineering Evaluation/Cost Analysis (EE/CA) and Action Memorandum.

At the Motor Pool/Facility Maintenance area, the solvents 1,1,1-trichloroethane (TCA) and 1,1-dichloroethane (DCA) were detected at concentrations greater than the New York State (NYS) Ambient Water Quality Standards (AWQS) of 5 µg/L. TCA was detected at concentrations up to 77.3 µg/L, and DCA was detected at concentrations up to 14.5 µg/L. The gasoline additive methyl tertiary butyl ether (MTBE) was also detected, with a maximum observed concentration of 73.8 µg/L. The NYS standard for MTBE is 10µg/L. No floating petroleum was detected in the monitoring wells. At the Service Station, MTBE levels in groundwater increased from approximately 5 µg/L in 2000, to a maximum concentration of 64 µg/L in 2001. Low levels of tetrachloroethylene (up to 9.8 µg/L) were also detected. No floating petroleum was detected in the monitoring wells. Monitoring of the leak detection systems at both vehicle maintenance facilities indicate that the gasoline storage tanks and associated distribution lines are not leaking. Furthermore, evaluation of current vehicle maintenance operations indicates that all waste oils and used solvents are being properly stored and recycled. Therefore, it is believed that the solvents and MTBE detected in groundwater originate from historical vehicle maintenance activities at the Motor Pool, and are not related to current operations.

Proposed Changes to the Groundwater Protection Program

The data summarized in this report are the basis for several significant operational changes to the groundwater protection and cleanup programs. A summary of those significant changes follows.

- Proposed reduction in groundwater monitoring for the OU I Current Landfill Program
- Proposed reduction in groundwater monitoring for the OU I South Boundary Program. Installation of four sentinel monitoring wells to address former Hazardous Waste Management Facility

(HWMF) strontium-90 contamination. Update groundwater model for OU I South Boundary and perform engineering evaluation for persistent high total volatile organic compound (TVOC) spots.

- Shut down OU III Carbon Tetrachloride System well EW-13. Develop characterization work plan for deep carbon tetrachloride contamination. Perform groundwater modeling optimization analysis on system.
- Addition of three monitoring wells and five geoprobes to the OU III Building 96 Program to verify contaminant concentrations and monitor for any plume spreading.
- Installation of one additional OU III South Boundary Program bypass monitoring well to verify capture of high concentrations near EW-4.
- Installation of two additional bypass monitoring wells to verify the capture of contamination by the OU III Industrial Park system.
- Proposed reduction in groundwater monitoring for the OU III Former Landfill Program.
- Installation of five geoprobes to track the high concentration portion of the OU III HFBR Tritium plume. Installation of up to five vertical profiles and monitoring wells to define the tritium plume.
- Installation of four sentinel monitoring wells for the OU III BGRR strontium-90 plume.
- Installation of one sentinel monitoring well downgradient of the strontium-90 plume south of the Former Landfill.
- Petition for closure of the OU IV Area of Concern (AOC) 5 AS/SVE system.
- Installation of one sentinel monitoring well for the OU IV AOC 6 Building 650 Sump Program. This is due to a potential westward shift to the strontium-90 plume resulting from changes to groundwater flow conditions in the area.

Table E-2
Groundwater Restoration Progress

Operable Unit	Project	Target	Mode	Treatment Type	Treatment Progress	Years of Operation	Groundwater Quality Highlights
OU I							
	OU I South Boundary (RA V)	VOCs	Operational	Pump and Treat (P&T)	254 lbs of VOC treated to date	5 of 7-14	The decline in VOCs leveled off. The mean total VOC concentration in the monitoring wells decreased from approximately 25 µg/L in 1999 to 15 µg/L in 2001. Several persistent areas of contamination exist near the former HWMF (i.e., five monitoring wells still exceeded 50 µg/L TVOC.
	Current Landfill	VOCs tritium	Long-term Stewardship	Landfill capping	See Groundwater Quality Highlights.	6 of 30	VOCs and tritium stable or slightly decreasing.
	Former Landfill	VOCs Strontium -90 (Sr-90) tritium	Long-term Stewardship	Landfill capping	See Groundwater Quality Highlights.	5 of 30	Continued decline in Sr-90. VOCs have declined below New York State Ambient Water Quality Standards (NYS AWQS).
	Former HWMF	Sr-90	Long-term Stewardship	Monitoring	NA	NA	Sr-90 plume downgradient form former HWMF was characterized in 2001 and 2002. Sentinel monitoring wells to be installed in 2002.
OU III	Chemical/Animal Holes	VOCs Sr-90	Completed pre-design groundwater characterization.	P&T with ion exchange	Construction of Pilot Study remediation system to begin in May 2002	NA	Characterized Sr-90 plume, including leading edge, in 2001. Highest concentrations between Animal Pits and Princeton Ave. firebreak road. Highest concentration to date was 2,540 pCi/L in well 106-16 in 1999.
	Carbon Tetrachloride source control	VOCs (carbon tetra-chloride)	Operational	P&T, carbon adsorption	236 lbs of VOC treated to date	2 of 5	Additional characterization was performed to characterize the downgradient extent of high concentrations. A third extraction well was constructed and operational in December 2001.

Table E-2
Groundwater Restoration Progress

Operable Unit	Project	Target	Mode	Treatment Type	Treatment Progress	Years of Operation	Groundwater Quality Highlights
	Building 96 source control	VOCs	Operational	Recirculation with air stripping	35 lbs of VOC treated to date	1+	System is in operation. Significant reduction in VOCs has been observed in system influent and monitoring wells.
	South Boundary	VOCs	Operational	P&T with air-stripping	1709 lbs of VOC treated to date	4 of 10	Continued decline in monitoring well VOC concentrations at the site boundary.
	Middle Road	VOCs	Operational	P&T with air-stripping	39 lbs of VOC treated to date	<1	System startup in October 2001.
	Western South Boundary	VOCs	Construction	P&T	NA	NA	System construction completed. Monitoring well installation to be completed in June 2002 and system start-up in May 2002
	Industrial Park	VOCs	Operational	In-well stripping	448 lbs. of VOCs treated to date.	2 of 7	VOC high concentrations began decreasing in western portion of system, a slight increase was observed to the east. The duration of treatment has not been long enough to ascertain a trend in the groundwater quality of the area.
	Industrial Park East	VOCs	Design	NA	NA	NA	Began pre-design groundwater characterization work.
	North Street	VOCs	Design	P&T with carbon treatment	NA	NA	Pre-design groundwater characterization work was completed in 2001.
	North Street East	VOCs	Design	P&T	NA	NA	Pre-design groundwater characterization work began in May 2001 and will be completed in 2002.
	Long Island Power Authority	VOCs	Design	Recirculation wells with carbon	NA	NA	Pre-design groundwater characterization work was completed in 2001.

Table E-2
Groundwater Restoration Progress

Operable Unit	Project	Target	Mode	Treatment Type	Treatment Progress	Years of Operation	Groundwater Quality Highlights
	(LIPA) Right of Way			treatment			
	Airport	VOCs	Design	Recirculation wells with carbon treatment	NA	NA	Completed pre-design groundwater characterization. Defined leading edge of VOC plume (>5 micrograms per liter [µg/L]) in vicinity of Flower Hill Dr.
	Magothy	VOCs	TBD	NA	NA	NA	The Magothy characterization project, which started in 2000, is ongoing and continues to define the extent of contamination that was previously characterized. Characterization will be completed in 2002.
	HFBR tritium	Tritium	Low flow pumping of high concentration area was completed; the downgradient pump & recharge system placed in standby mode in September 2000.	Monitoring	0.2 Curies removed for off-site disposal.		30,000 gallons of high- activity groundwater were pumped from the plume and disposed of off-site during 2001 for a total of 95,000 gallons removed via low flow pumping. The extent of the plume has not expanded and activity is attenuating. The peak concentration observed in 2001 was 0.93 million pCi/L compared to 2.09 million (M) pCi/L in 2000. The pump and recharge system continued in standby mode.
	BGRR/Waste Concentratio n Facility (WCF)	Sr-90	Planned fall 2003	P&T with Ion Exchange	NA	NA	Groundwater characterization work for the Below Ground Ducts detected Sr-90 up to 540 pCi/L.
OU IV							

Table E-2
Groundwater Restoration Progress

Operable Unit	Project	Target	Mode	Treatment Type	Treatment Progress	Years of Operation	Groundwater Quality Highlights
	AS/SVE system	VOCs	Stand-by (as of January 2001)	Air sparging/ soil vapor extraction	47 lbs. of VOCs were treated to date.	4 of 4	ORC treatment was utilized for well 76-04. VOC concentrations <DWS during the last 2 quarters of 2001. Petition submitted for system shutdown.
	AOC 6/650 sump outfall	Sr-90	MNA	Monitoring	Plume slowly migrating to south within monitoring-well network.	NA	Sr-90 concentrations remained relatively stable in monitoring wells.
OU V	STP	VOCs tritium	Long term stewardship monitoring	MNA	NA	NA	VOC plume concentrations remained stable during 2001. Tritium was detected in two wells above the detection limits but well below NYS AWQS and continued to slowly decline.
OU VI	Ethylene Dibromide (EDB)	EDB	Design	P&T with carbon treatment	NA	NA	Pre-design groundwater characterization was completed in 2001.

1.0 Introduction and Objectives

The mission of Brookhaven National Laboratory's Groundwater Protection Program is to protect and restore the aquifer system at BNL. The program is summarized in the *BNL Groundwater Protection Management Program Description* [Paquette *et al*. 1998].

The program is built on four key elements:

- Pollution prevention – preventing the potential pollution of groundwater at the source.
- Restoration - restoring groundwater that BNL has impacted.
- Monitoring - monitoring the effectiveness of pollution-prevention efforts, as well progress in restoring the quality of affected groundwater.
- Communication - communicating the findings and results of the program to regulators and stakeholders.

The BNL Calendar Year (CY) 2001 Groundwater Status Report is a comprehensive summary of groundwater data collected in 2001 that provides an interpretation of information on the performance of the Groundwater Protection Program. This is the fifth annual groundwater status report issued by the Laboratory. This document is unique in that it examines performance of the program on a project-by-project (facility-by-facility) basis, as well as comprehensively in a "watershed-like" analysis.

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 group. This technical document is intended for internal users, regulators, and other technically oriented stakeholders. Generalized summaries of this information can be obtained through BNL's website, the Community Affairs office, as well as the annual Site Environmental Report.

Data are presented in five key subject areas:

- Improvements to the understanding of the hydrogeologic environment and surrounding areas,
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- Progress in cleaning up legacy contamination of groundwater,
- Performance of groundwater remediation systems, and
- Proposed changes to the groundwater protection program.

This document satisfies Brookhaven's requirement to report groundwater data under the Interagency Agreement (IAG) 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 drivers of the data collection work in 2001, the site's groundwater classification, and the objectives of groundwater monitoring. Section 2 discusses improvements to our understanding of the hydrogeologic environment at BNL and its surrounding area. It also summarizes the dynamics of the groundwater flow system in 2001. The groundwater cleanup data and progress towards achieving the site's cleanup goal are described in Section 3. Section 4 outlines the groundwater surveillance data used to verify that operational and engineering controls are preventing further contamination from the site's active experimental and support facilities.

Appendices **C** and **D** contain the analytical results for each sample obtained under the Environmental Restoration (ER) and Environmental Surveillance (ES) Groundwater Monitoring Programs, respectively. Due to the volume of these data, all of the report appendices are included on a CD ROM; which significantly reduces the size of the hardcopy of this report. The CD ROM 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. A hardcopy of the results can be printed from the CD ROM. The groundwater results are arranged by specific monitoring project and analytical group (VOCs, SVOCs, metals, chemistry, pesticides/ PCBs, and radionuclides). The data are organized further by well ID and the date of collection 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 shown. Results exceeding the corresponding groundwater standard or guidance criteria (see Section 1.1.2 [Groundwater Quality and Classification]) are identified by shading. By including the complete results, the reader can analyze the data in detail.

1.1 Groundwater Monitoring Program

1.1.1 Regulatory Drivers

Comprehensive Environmental Response, Compensation and Liability Act (CERCLA): On December 21, 1989, the BNL site was included as a Superfund Site on the National Priorities List (NPL). The U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), and New York State Department of Environmental Conservation (NYSDEC) integrated the DOE's response obligations under the Comprehensive, Environmental Response, Compensation, and Liability Act (CERCLA), the Resource Conservation and Recovery Act (RCRA), and New York State (NYS) hazardous waste regulations into a comprehensive Federal Facilities Agreement (FFA). This Interagency Agreement (IAG) was finalized and signed by these parties in May 1992 (EPA 1992). The Environmental Restoration (ER) program's groundwater monitoring program is conducted in accordance with the IAG-approved plans for sampling and analysis.

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 (O&M) requirements specified in 6 NYCRR (New York Code of Rules and Regulations) Part 360, "Solid Waste Management Facilities." These monitoring programs are being conducted as part of the ER program.

BNL's Major Petroleum Facility (MPF) is operated under NYSDEC 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 engineering controls and monitoring program for the MPF are described in the BNL Spill Prevention, Control and Countermeasures (SPCC) Plan.

The BNL's Waste Management Facility (WMF) is a NYSDEC permitted hazardous waste storage facility (NYSDEC Permit No. 1-422-00032/00102-0). BNL voluntarily developed a groundwater monitoring program for the WMF. Although it was not specifically required under RCRA regulations for this type of facility, this monitoring program was started because of the WMF's close proximity to two of BNL's potable water supply wells (see initial groundwater assessment, in Paquette, 1994). This program is specifically designed as a secondary means of verifying the effectiveness of the facility's administrative and engineered controls.

DOE Orders: DOE Order 5400.1, Chapter IV - *Environmental Monitoring Requirements* states that "Groundwater that is or could be affected by DOE activities shall be monitored to determine the effects of operations on groundwater quality and quantity and to demonstrate compliance with DOE requirements and applicable federal, state and local laws and regulations" (DOE 1988).

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). The EPA designated the Long Island aquifer system as a Sole-Source aquifer system, 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, the Laboratory adopted federal drinking water standards, NYS Drinking Water Standards (NYSDWS), and NYS Ambient Water Quality Standards (NYS AWQS) for Class GA groundwater as the goals for protecting and remediating groundwater.

For drinking water supplies, the applicable federal maximum contaminant levels (MCLs) are set forth in 40 CFR (Code of Federal Regulations) 141 (primary MCLs) and 40 CFR 143 (secondary MCLs). In NYS, the SDWA requirements on the distribution and monitoring of public water supplies are promulgated under the NYS Sanitary Code [10 NYCRR Part 5], that is enforced by the Suffolk County Department of Health Services (SCDHS) as an agent for the NYS Department of Health (NYSDOH). These regulations apply to any water supply that has at least five service connections, or regularly serves at least 25 individuals. BNL supplies water to approximately 3,500 employees and visitors, and therefore, must comply with these regulations. In addition, DOE Order 5400.5, *Radiation Protection of the Public and Environment* (DOE 1990), establishes Derived Concentration Guides (DCGs) for radionuclides not covered by existing federal or state regulations.

BNL evaluates the potential impact of radiological and nonradiological levels of contamination by comparing analytical results to NYS's and DOE's 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 NYS AWQS (for tritium, Strontium-90 (Sr-90), and gross beta), NYS AWQS (for gross alpha, radium-226, and radium-228), and 40 CFR 141/DOE DCGs (for determining the 4 mrem/yr dose for other beta-/gamma-emitting radionuclides).

Tables 1-1, 1-2, 1-3, and **1-4** show the regulatory and the 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 Order, best management practice, and our commitment to environmental stewardship. BNL monitors its groundwater resources for the following reasons:

<u>Groundwater Resource Management:</u>

- Refine the conceptual hydrogeologic model of the site and maintain a current assessment of the dynamic patterns of groundwater flow and water table fluctuations to support initiatives in protecting, managing, and remediating groundwater;

- Determine the natural background concentrations for comparative purposes. The site's background wells provide information on the chemical and radiological composition of groundwater that has not been affected by BNL's activities. These data are a valuable reference for comparison with those on groundwater quality from affected areas. This network of wells also can warn us of any contaminants originating from potential sources that may be located upgradient of the BNL site; and,

- Ensure that potable water supplies meet all regulatory requirements.

<u>Groundwater Surveillance:</u>

- Verify that operational- and engineered-controls effectively prevent groundwater contamination.
- Trigger early action and communication should the unexpected happen (e.g. control failure).
- Determine the efficacy of the operational and engineered control measures designed to protect the groundwater;
- Demonstrate compliance with applicable requirements for protecting and remediating groundwater.

<u>Groundwater Restoration</u>

- Track a dynamic groundwater cleanup problem when designing and constructing treatment systems;

- Measure the performance of the groundwater remediation efforts in achieving cleanup goals;
- Protect public health and the environment during the cleanup period;
- Define the extent and degree of groundwater contamination; and,
- Provide early warning of the arrival of a leading edge of a plume thereby triggering contingency remedies to protect public health and the environment.

Detailed information on each source area is found in the BNL Environmental Monitoring Plan (BNL 2000a, 2002). The Environmental Monitoring Plan includes: a description of the source area: description of groundwater quality; criteria for selecting locations for groundwater monitoring; and, and frequency of sampling and analysis. **Figure 1-1** highlights BNL, Operable Unit locations designated as part of the CERCLA program, and significant known or potential source areas of groundwater contamination. Details on the screen depths, sampling parameters, frequency and analysis by well are listed in **Tables 1-5** through **1-8**. Figure **1-2** shows the locations of wells monitored as part of The Laboratory's groundwater protection program.

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

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2.0 HYDROGEOLOGY

This section briefly describes the improvements to our understanding of the hydrogeologic environment at BNL and the surrounding area. It also summarizes the dynamics of the groundwater flow system in 2001 along with on-site pumping rates and rainfall recharge.

The following short overview of the hydrogeologic framework centers on those portions of the aquifer system that are the focus of the BNL's Groundwater Protection Program. More detailed descriptions, including the lithology and the geometry of the aquifer underlying BNL and its surrounding areas, are given in previous reports generated under the CERCLA process and other investigations. They include reports of the United States Geologic Survey (USGS) by Scorca et al. (1999) *Stratigraphy and Hydrologic Conditions at the Brookhaven National Lab and Vicinity, Suffolk County, New York, 1994-97,* and by Wallace deLaguna (1963) *Geology of Brookhaven National Laboratory and Vicinity, Suffolk County New York.* The stratigraphy underneath BNL consists of approximately 1,300 feet of unconsolidated deposits overlying bedrock. Among these unconsolidated deposits, the Groundwater Monitoring Program currently focuses on the Upper Pleistocene deposits, the Gardiners Clay, and the upper portions of the Matawan Group-Magothy Formation.

The Upper Pleistocene deposits, generally from 100 to 200 feet thick, are divided into two primary hydrogeologic units that comprise the Upper Glacial aquifer: An undifferentiated sand and gravel outwash and moraine deposit; and, the finer-grained, more poorly sorted stratigraphic Upton Unit, discussed by Scorca et al. (1999) and deLaguna (1963). The Upton Unit typically is encountered within the lower portion of the Upper Glacial aquifer beneath various areas of the site. It generally consists of fine- to medium-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 upper portion of the Upper Glacial aquifer (near the Sewage Treatment Plant [STP]) and reworked Magothy deposits (a transitional interval between the Magothy and Upper Glacial aquifer generally located within the lower portion of the latter). The Gardiners Clay is a regionally defined geologic unit that is discontinuous beneath parts of BNL and areas to the south. Typically, it is characterized by variable amounts of massive 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 contaminants between the Upper Glacial aquifer and the underlying Magothy aquifer.

The Magothy aquifer is composed of the continental deltaic deposits of the Cretaceous Age, that unconformably underlie the Upper Glacial aquifer and Gardiners Clay. 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 deposits consituting the Upper Glacial aquifer. Massive grey-brown to yellow-brown clay layers exist at varying depths within the Magothy aquifer, reflecting its high stratification. Of particular importance, underlying BNL is a massive, locally continuous, grey-brown clay layer within the upper portion of the Magothy aquifer (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 contaminants between the Upper Glacial and Magothy aquifers.

Regional patterns of groundwater flow near BNL are influenced by natural and artificial factors. Under natural conditions, recharge to the regional aquifer system is derived solely from precipitation and enters the saturated groundwater system at the water table; **Figure 2-1** illustrates the trends in annual precipitation at BNL. A regional groundwater divide exists immediately to our north near Route 25. It is oriented roughly east-west, and appears to coincide with the regional recharge area. Groundwater to the north of this divide flows north, ultimately discharging to the Long Island Sound. Shallow groundwater in the vicinity of BNL generally flows south and east, ultimately to the Great South Bay and Atlantic Ocean, and towards major local surface-water bodies, such as the Peconic River and Carmans River. Vertical flow is predominantly downward near areas of recharge, becoming essentially horizontal as groundwater moves towards regional discharge boundaries, and ultimately moving upward toward them (e.g., Carmans River and Great South Bay). Superimposed on the natural regional field of groundwater flow are the artificial influences, due to pumping and recharging. Close to the pumping centers, the water table is locally depressed; near recharging areas, it is locally mounded.

Groundwater flow through the aquifer system underlying BNL, and ultimately, the migration of contaminants within it, in large part are controlled by the hydrogeologic framework and these natural and artificial factors.

2.1 Hydrogeologic Data

Various hydrogeologic data collection and summary activities were undertaken as part of our 2001 Groundwater Monitoring Program to provide the requisite information to comprehensively evaluate groundwater flow patterns and conditions. This work, and the information obtained, is described in the following sections and includes the results of groundwater elevation monitoring, information on pumping and recharging activities on and off-site, and precipitation data.

2.1.1 Groundwater Elevation Monitoring

The ER sitewide groundwater elevation monitoring program consists of measuring synoptic water levels quarterly from a network of on-site and off-site wells screened at various depths within the Upper Glacial aquifer and upper portions of the Magothy aquifer. The data are used to adequately characterize the groundwater flow-field (direction and rate) and to evaluate seasonal and artificial variations in its flow patterns. These water level data are the bases for subsequent comprehensive analyses of groundwater flow discussed in Section 2.2 (Groundwater Flow).

The network of groundwater monitoring wells includes those installed and maintained by BNL, located on the BNL property and off-site areas. The remainder of BNL's wells is off-site in surrounding areas; they adequately cover the area to characterize flow, particularly to the south and east in the direction of regional downgradient flow. Most wells are screened within the shallow glacial and deep glacial zones of the Upper Glacial aquifer; the rest are screened within the mid glacial zone and the upper portion of the Magothy aquifer. Several wells were completed in clusters (e.g., midglacial wells installed close to shallow glacial and/or deep glacial wells). In addition, water level data from the USGS off-site wells supplemented our data.

During 2001, Dvirka & Bartilucci Consulting Engineers, an EM contractor , collected water level data from the BNL network from March 18 to 21, June 18 to 20, September 17 to 19, and December 17 to 20, measuring 837 to 901 wells each period Water levels were measured with electronic water level indicators following BNL's Standard Operating Procedure (SOP) EM-SOP-300. **Appendix A** (located on the enclosed CD-ROM) has the depth-to-water (DTW) measurements and the calculated groundwater elevations for these quarterly synoptic measurements. As more wells were installed during 2001 under specific EM and ES projects, we evaluated their possible incorporation into subsequent synoptic events.

Other water level data beyond those described above include historic values for select USGS wells, and quarterly data for certain BNL wells, collected in 2001, that were used to develop the long-term and short-term hydrographs discussed in Section 2.2 (Groundwater Flow).

2.1.2 Summary of Data on Pumpage of Onsite Supply/Process/Remediation Wells

Groundwater at BNL is withdrawn by pumping from the aquifer system at various locations to supply potable and process water and to hydraulically contain and remediate contaminated groundwater. Water usage data were obtained for the various potable water supply wells, process water supply wells, and remediation wells that were in service during 2001. These data were used to interpret groundwater flow, particularly the degree of localized influences that the pumping wells exert on its patterns (i.e., locally depressing the water table). **Figures 2-2** and **2-3** show the pumping wells' locations, and their effects are discussed in Section 2.2 (Groundwater Flow).

Table 2-1 is a water usage report summarizing the monthly and total water usage for 2001 for the six on-site potable supply wells (4, 6, 7, 10, 11, and 12). It includes information on the wells' screened intervals and the pumps' capacities. These wells primarily withdraw groundwater from the mid glacial zone of the Upper Glacial aquifer. The variation in monthly pumpage primarily reflects demand, and the well's maintenance schedules. The western potable well field includes wells 4, 6, and 7; the eastern field contains wells 10, 11 and 12. To closely control the effects of all the groundwater pumping on-site and minimize the effects of changing groundwater flow direction in the core of the site, the BNL Pump and Recharge Committee decided to utilize the western well field as the primary supply for most of the potable water on-site. As shown in **Table 2-1**, potable water well 7 (western well field lead well) contributed most of BNL's supply during 2001. During 2000, wells 7 and 12 provided the majority of the supply. The annual pumpage from well 12 decreased slightly from 2000 to 2001, while that from well 7 increased by approximately 130%. These changes are the result of continuing to increase pumpage from the western potable well field and decreasing the overall pumpage from the eastern field, in response to the recommendation of the Groundwater Pump and Recharge Committee. The change in pumping patterns increased the overall contribution of water from the western field from 17% overall in 1999; to 66% overall in 2000; to 73% overall in 2001, meanwhile, the overall supply from the eastern field declined from 83% in 1999 to 34% in 2000 and; to 27% in 2001. Overall, BNL's pumping of potable water decreased approximately 8% from 1999 to 2000, and increased approximately 8% from 2000 to 2001.

Table 2-2 summarizes the monthly and total water usage for 2001 by the five-on-site process supply wells (101, 102, 103, 105, and 9). These wells primarily withdraw groundwater from the mid Upper Glacial aquifer, and the variation in monthly pumpage depends upon demand (e.g., experiment run times) and maintenance schedules. As **Table 2-2** shows, well 105 contributed most of the process water during 2001, although this was approximately 2.5% of the 2000 pumpage. Overall, the pumpage of process water was reduced significantly; 2001 pumpage totals were approximately 4% of the 2000 totals. This reduction generally is due to water conservation measures throughout The Laboratory.

Additional information on water usage was obtained from EM projects that specifically monitor and report on the operation of each groundwater remediation system. **Table 2-3** summarizes the monthly and total water usage for 2001 by the four operating pump and treat systems.

The OU I South Boundary groundwater remediation system (formerly known as RA V) consists of two extraction wells (EW-1 and EW-2) located on-site at the southern boundary. These wells, which began operating in December 1996, provide hydraulic containment at the southern boundary and extract contaminated groundwater from the mid glacial and deep glacial zones. This water is pumped to an air-stripper tower, and the treated water is recharged at the RA V basin on-site. Total pumpage for 2001 increased approximately 25% above 2000, mainly due to the decreased downtime of the system wells in 2001, and better performance from the pumps.

The HFBR Tritium Pump and Recharge System, located on-site along Princeton Avenue, consists of three extraction wells (EW-9, EW-10, and EW-11) that began operating in May 1997. It was installed to hydraulically contain the potential downgradient migration of tritium originating from the HFBR's spent-fuel pool. Groundwater was extracted from the midglacial zone, passed through activated carbon to remove commingled volatile organic compounds, and recharged at the RA V basin. The system was placed in stand-by mode and shut off at the end of September 2000, in accordance with the criteria specified in the OU III Record of Decision (ROD) (BNL 2000d). Consequently, there was no pumpage for 2001 because of the placing of the wells on stand-by in 2000.

The OU III Pump and Treat System consists of seven extraction wells (EW-3, EW-4, EW-5, EW-6, EW-7, EW-8, and EW-12) located on-site along the southern boundary. EW-12 was installed in 1999 and pumping started late in December 1999. This system, which began operating in May 1997, provides hydraulic containment along the southern boundary; contaminated groundwater is extracted primarily from the deep glacial zone, treated (via air stripping), and recharged on-site. Before September 2001 water was recharged to the OU III basin; afterwards, it was recharged to the OU III and RAV basins at equal rates. Total pumpage for 2001 decreased approximately 12% below 2000 levels, mainly attributable to slightly increased downtime and well maintenance.

The OU III Carbon Tetrachloride pump and treat system consists of two extraction wells (EW-13 and EW-14) located near the on-site Service Station, and a newly installed extraction well (EW-

15) southeast of the on-site Service Station. EW-15 was installed during the fourth quarter of 2001 and was activated on December 20, 2001. This system was established in response to a contaminant release that occurred when an underground storage tank was removed. Operation began in October 1999, providing hydraulic containment along the main axis of the carbon tetrachloride plume. The contaminated groundwater is extracted primarily from the shallow glacial zone (EW-13 and EW-14), and EW-15 pumps water from the mid Upper Glacial aquifer, which is treated (via carbon adsorption), and recharged on-site at basin HS. The total pumpage for 2001 was approximately 9% of the total OU III pumpage.

The OU III Middle Road Groundwater remediation system includes six newly installed extraction wells, RW 1 through 6, located on Middle Road intersecting the deep glacial, high concentration portion of the OU III TVOC plume. Groundwater is pumped from the deep zone of the upper glacial aquifer at RW 2 through 6 (-170 to –288 feet below mean sea level) and pumped from the mid glacial zone at RW-1 (-90 to –130 feet below mean sea level). The water is treated by air stripping and recharged at equal rates to the RAV and OU III basins.

2.1.3 Offsite Water Supply Wells

Several Suffolk County Water Authority SCWA well-fields are located in areas surrounding BNL, generally in the southerly direction of regional downgradient flow. They are discussed in this section because they are considered as potential sensitive receptors to groundwater contamination attributable to BNL, and also because they influence local patterns of groundwater flow. Currently, there are two SCWA potable well-fields within the general area covered by BNL's Groundwater Monitoring Program: Parr Village Well Field, and Country Club Drive Well Field (see **Figures 2-2** and **2-3** for locations of the SCWA well fields). Other SCWA well fields (e.g., Lambert Avenue and Main Street-Mastic Well Fields) are sited south of Sunrise Highway. Although they are viewed as potential sensitive receptors, they are considerably beyond the area of groundwater contamination attributable to BNL.

Parr Village Well Field, located along William Floyd Parkway to the west/southwest of BNL, consists of three water supply wells that withdraw groundwater from the mid Upper Glacial aquifer and the upper portion of the Magothy aquifer. Country Club Drive Well Field, lying south/southeast of BNL, consists of two water supply wells that withdraw groundwater from the mid Upper Glacial aquifer. Information for 1989 through 2001, evaluated as part of BNL's regional modeling, shows they typically operate yearlong, with Parr Village Well Field and County Club Drive Well Field producing, on average, approximately 324, and 280 millions of gallons per year, respectively. In 2001, the Parr Village and Country Club Drive Well Fields produced 343 and 564 millions of gallons per year, respectively.

2.1.4 Summary of Onsite Recharge and Precipitation Data

Onsite recharge and precipitation data for 2001 provides information on recharge to the aquifer system underlying BNL. Components of this recharge include sources of artificial recharge (i.e., on-site recharge basins) and precipitation, the natural origin of recharge to the groundwater via infiltration.

Table 2-4 summarizes the monthly and total flow of water through the eight primary on-site recharge basins; their locations are shown on **Figures 2-2** and **2-3**. Section 2.2 (Groundwater Flow) discusses the effects associated with recharge. Six of the basins (HN, HO, HP, HS, HT, and HX) receive water originally withdrawn by BNL's potable and process supply wells that is not consumed or is lost via evaporation. The ES Program monitors the monthly flow into these basins. Generally, the amount of water recharging to the groundwater system via these basins primarily reflects supply well pumpage. Annual water supply flow diagrams show the general relationships between recharge basins and the supply wells and are published in the annual Site Environmental Reports. In addition, the volume of water recharged at several basins includes stormwater runoff. The flow discharging to recharge basin HO is approximately 73,520 cubic feet per day (CFD), yearly average. Historically, this basin has been the main contributor of recharge water to the aquifer system, principally due to the large amount it received from the AGS process supply wells, 101, 102, or 103. Due to water conservation measures and upgrades to the cooling system in 1998, the AGS now uses significantly less water; overall recharge water to basin HO now is 60% less.

The remaining two recharge basins, summarized in **Table 2-4**, were constructed for 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 located adjacent to recharge basin HP along Princeton Avenue. After September 2001, groundwater from that system and the OU III Middle Road Pump and Treat System was discharged equally to the OU III and RAV basins. Treated groundwater from the OU I South Boundary also is discharged to the RA V basin. **Table 2-4** gives estimates of flow to these basins based on monthly pumpage for the corresponding remediation systems' extraction wells. The discharge to these recharge basins for 2001 (119,974 and 173,653 CFD yearly average for the OU III and RA V basins, respectively) is significantly greater than that from other individual on-site basins.

Other important sources of artificial recharge, not included in **Table 2-4**, include a storm-water retention basin referred to as HW (on Weaver Drive), and the sand filter beds at the STP. Basin HW causes localized mounding of the water table and is near several contaminant plumes. At the sand filter beds, approximately 20 percent of the treated effluent (or 50 million gallons annually) seeps directly to the underlying water table via leaks in the underlying tile-drain collection system. The remaining treated effluent (approximately 290 million gallons annually) ultimately is discharged from the STP to the Peconic River. Most of it recharges the water table, except during times of seasonally high water levels, such as the spring.

Table 2-5 summarizes the data on monthly and annual precipitation from 1949 to 2001 collected on-site by the BNL Meteorology Group, Department of Applied Science, with the maximum, minimum, average monthly, and average values. Variations in the rises and falls in the water table generally can be correlated with the amount of precipitation. As **Table 2-5** shows, total annual precipitation in 2001 was 45.55 inches, below the yearly average of 48.47, and significantly less than the total annual precipitation in 2000, which was 54.37 inches. Monthly precipitation for 2001 varied from 0.74 inches (November) to 10.37 inches (March).

Precipitation provides the majority of recharge to the groundwater system at BNL. In an average year, approximately 24 inches per year of rainfall recharges the Upper Glacial aquifer. 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 soils and recharges the ground water system (Aronson and Seaburn, 1974; Franke and McClymonds, 1972). In 2001, it is estimated that the recharge rate at BNL was approximately 23 inches.

2.2 Groundwater Flow

This evaluation includes the following: a presentation of groundwater flow patterns within the Upper Glacial aquifer (on contour maps for shallow-glacial and deep-glacial zones); an evaluation of the magnitude of the three-dimensional components of flow (by horizontal, and vertical hydraulic gradients); and, an assessment of long-term and short-term seasonal fluctuations of water levels (through well hydrographs and trends in precipitation).

2.2.1 Water Table Contour Maps

Figure 2-2 shows groundwater elevation contour maps of the shallow glacial zone representing the configuration of the water table for March, June, September, and December 2001. The contours were generated from the water level data collected during each synoptic round from shallow glacial wells, assisted by a computer-aided contouring package (SURFER and Quick SURF). 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 [Hydrogeologic Data]). Nearby surface water readings taken by the USGS from the Carmans River and Peconic River were included when available. For clarity, some data collected in certain areas (primarily in the central portion of the site) were omitted in contouring because the coverage was more than sufficient to generate representative flow patterns.

Groundwater flow in the shallow Upper Glacial aquifer in 2001 generally was characterized by a southeasterly component in the site's northern portion, with a gradual transition to a more southerly direction at the southern boundary and beyond. Flow directions in the east portion of BNL are predominately to the east and southeast (**Figure 2-2**). This pattern is consistent with comparable historical data published by the Suffolk County Department of Health Services (SCDHS) and USGS.

The highest water table elevations on-site occurred in the northwestern section, (nearest the groundwater divide), varying from a high of approximately 51 feet above mean sea level (msl) in June and September, to a low of approximately 48 feet above msl in March. The lowest elevations were along the southern boundary, with a high of approximately 35 feet above msl in June, and a low of approximately 33 feet above msl in March. This quarterly variation, wherein the water table was higher in June/September 2001 and lower in March/December 2001, does not correspond with the typical seasonal fluctuations in water level; it may be attributable to the higher than average precipitation during the summer months, coupled with low precipitation during the Fall of 2001(discussed further in Section 2.2.4, Well Hydrographs).

Localized hydrogeologic disturbances are evident on the quarterly contour maps, resulting from active pumping wells, on-site recharge basins, and other artificial recharges. Influences from the pumping wells can be seen as cones of depressions, most notably near potable supply wells 7 and 12, near process supply well BNL-105, and in the vicinity of the extraction wells along the southern boundary (when operating).

Influences from recharging activities can be observed as localized mounding of the water table, particularly around the recharge basin HO and the RA V basin (in the central site), and also near the HP/OU III basins and the STP. The degree of mounding is generally consistent with the monthly flows to recharge basins summarized in Section 2.1 (Hydrogeologic Data). However, mounding also reflects the ability of the underlying deposits to transmit water, which varies. For example, the volume of recharged water at the STP sand filter beds typically is not as great as that at recharge basin HO or the RA V basin. Near-surface clay layers underlying portions of the STP, in conjunction with the recharging water at the STP sand filter beds, causes mounding near the STP apparently as great as that at basin HO.

Other quarterly variations in these localized cones of depression and mounding largely are attributed to the monthly variations in rates of groundwater pumping and/or recharge. For example, during December, 2001 potable supply well 12 was used heavily. Accordingly, those contours showed a significant cone of depression in the well's vicinity that was not observed on the corresponding March 2001 contours when the pumpage was much less.

Other noteworthy features are the influence that surface water bodies have on the water. **Figure 2-2** shows groundwater flowing towards the Carmans River in areas south/southwest of BNL. This pattern is consistent with typical surface water/groundwater interactions expected regionally (i.e., Carmans River as a groundwater discharge boundary). To a lesser extent, such interactions have been inferred along the on-site portion of the Peconic River. During March (i.e., during an apparently higher seasonal water table), the Peconic River probably is a gaining stream. During other periods (e.g., September, apparently lower seasonal water table), it generally is inferred to be a losing stream, primarily reflecting the recharging of water discharged from the STP to the aquifer. There are gaining and losing segments of the river at any time, regardless of the season; the transition point between them fluctuates seasonally.

2.2.2 Deep Glacial Contour Maps

Figure 2-3 shows groundwater elevation contour maps of the deep glacial zone representing the configuration of the potentiometric surface contours for March, June, September, and December 2001. The contours were generated in the same manner as the water table contours, but using water level data from wells screened only within the deep glacial zone.

The patterns for groundwater flow in the deep glacial zone for 2001 are similar to those in the shallow glacial zone. They are characterized by a southeasterly component in the northern portion of the site, with a gradual transition to a more southerly flow at the southern site boundary and beyond. In areas to the south/southwest of BNL, the deep glacial contour maps also suggest flow towards the Carmans River. Water level elevations in this zone also were typically higher in September 2001, and lower in March 2001. The localized influences of pumping on the potentiometric surface configurations are evident as cones of depression. As with the water table configurations, variations in these localized hydrogeologic effects are attributed to the monthly variations in pumpage and to the initial operation of the extraction wells/remediation systems.

Although the localized influences of recharging on the potentiometric surface configurations are evident as areas of inferred mounding, they are not as pronounced as at the water table because such hydrogeologic effects generally decrease with depth in the saturated aquifer zone. Furthermore, mounding is not inferred beneath the STP sand filter beds because there it is also controlled by shallow, near-surface clay layers. Finally, the surface water/groundwater interactions along the Peconic River are not thought to influence the deep glacial zone.

2.2.3 Horizontal and Vertical Hydraulic Gradients

Horizontal and vertical hydraulic gradients were calculated to evaluate spatial variation in the magnitude of the horizontal component of groundwater flow, and in the magnitude and direction of its vertical component. Hydraulic gradients provide information on the driving force behind groundwater flow, and can be used with estimates of aquifer parameters (such as hydraulic conductivity and porosity) to assess the velocities of flow.

Horizontal hydraulic gradients were estimated for 2001 both on and off-site using the data on groundwater elevation for the shallow and deep glacial zones. **Table 2-6** summarizes representative, average, horizontal hydraulic gradients for different portions of the site and for off-site areas of interest. Generally, the gradients across the site and immediately off-site in areas not influenced by localized recharging (or pumping) varied by a factor of 2 to 3 (ranging from 0.0007 to 0.0019 feet/foot). The central, northern, and eastern on-site areas and southeastern off-site areas usually are characterized by lower horizontal hydraulic gradients, typically less than 0.001 feet/foot. The southern portions of the site and areas immediately downgradient of site (in North Shirley) have relatively moderate gradients (generally between 0.0008 and 0.0019 feet/foot). Areas with higher gradients include localized areas immediately downgradient of the recharge basins (seasonally ranging from 0.0015 [March 2001] to 0.0022 feet/foot [December 2001]), and off-site near the Carmans River (approximately 0.0044 feet/foot).

Vertical hydraulic gradients were calculated for 16 well clusters across the site and off-site for March, June, September, and December 2001, based on water level data from BNL's monitoring of groundwater elevation. **Appendix A** has the values for each quarter. **Table 2-7** summarizes the magnitude and direction of vertical hydraulic gradients in 2001 for these well clusters within the Upper Glacial aquifer and between the Upper Glacial and Magothy aquifers. **Figure 2-4** depicts the directions of vertical flow within well clusters for each quarter, and shows the chosen site of the well clusters that ensure a reasonable areal coverage to assess spatial variations in the flow's vertical component. Their selection also was based on the number of screened intervals (e.g., shallow, mid and deep glacial) to allow a meaningful evaluation of vertical flow within the Upper Glacial aquifer.

Vertical groundwater flow is downward in 2001 for most of the on-site and off-site well clusters, especially between the Upper Glacial and Deep Glacial aquifers. Downward vertical hydraulic gradients ranged from 0 to 0.0132 feet/foot within the Upper Glacial aquifer to Mid Glacial zones (**Table 2-7**), and from 0 to 0.0068 feet/foot within the Upper Glacial aquifer to Deep Glacial zones. In several on-site and off-site well clusters, groundwater flow within the Upper Glacial aquifer was almost horizontal (i.e., no measurable vertical gradient). As expected, at two of the well clusters close to the Carmans River and Peconic River (natural groundwater-discharge boundaries), vertical gradients and flow were consistently upward (cluster 800-23/-22/-21 and 600-18/-16/15). In addition, upward flow between the Upper Glacial and Magothy aquifers at these locations also is likely to be influenced by the presence of the Gardiners Clay and/or Magothy Brown Clay, confining the water level in the Magothy aquifer.

Generally, calculations of the vertical gradients for 2001 indicate that vertical flow on-site and immediately off-site is predominantly downward, becoming almost horizontal in some southern areas downgradient from the groundwater divide/regional recharge area. Ultimately, flow moves upward closer to natural groundwater discharge boundaries (e.g., the Carmans River). These directions are consistent with, and supported by, numerous regional investigations, regional groundwater modeling studies, and the widely accepted conceptualized model of the Long Island groundwater system.

2.2.4 Well Hydrographs

Long-term (typically 1950-2002) and short term (1997 through 2001) well hydrographs were constructed from water level data obtained for select USGS and BNL wells, respectively, located both on and off site. These hydrographs track fluctuations in water level over time. Precipitation data also were used to evaluate natural fluctuations in water levels. **Appendix B** contains the well hydrographs and precipitation- trend graphs, together with a map depicting the locations of these wells.

Seven long-term hydrographs were constructed from historical data on water level elevation obtained from wells installed and maintained by the USGS (2001 data was not available for well S-74289 due to problems with access). These wells provide reasonable areal coverage for historical trends in areas both on-site and surrounding The Laboratory (just south of the southern boundary). Changes in water level elevations indicate a long-term variability, with fluctuations from 8 to 14 feet. The maximum variation, 14 feet, reflects the fact that the period of record began in the early 1950s and subsequently encompassed the regional drought of the 1960s. The minimum variation of 8 feet is more indicative of the change in water level elevations since the late 1970s and early 1980s. These fluctuations correlate reasonably with long-term precipitation trends for a similar period.

Quarterly data on water levels collected during 2001 were used to construct nine short-term hydrographs corresponding to wells that are part of three well cluster (or triplets). Well cluster 75-39/-40/-41, located near the HFBR, consists of wells screened at varying depths within the Upper Glacial aquifer. Well cluster 105-05/-07/-024, along Princeton Avenue immediately downgradient of the Former Landfill also consists of wells similarly screened. Well cluster 122-01/-04/-05, sited along the southern boundary near the OU III Pump and Treat System, contains wells screened at varying depths within the Upper Glacial and Magothy aquifers. The short-term hydrographs indicate that annual water level fluctuations are consistent within various zones of the Upper Glacial aquifer and within the Magothy aquifer. Such changes from 1997 to 2001 were approximately 5.0 feet at the 122-well cluster, to slightly less than 9 feet at the 75 well cluster, and 6 feet for the 105 well cluster. Generally, the highest groundwater elevations can be expected during March, based on long-term averages. They fell to the expected seasonally low elevations during the winter (e.g., primarily in December 2001). This seasonal fluctuation, while out of phase with historical trends, generally correlates to the short-term trends in precipitation given in **Appendix B**.

A New York State drought warning was issued for Long Island in January 2002. Drought extremes were not observed at BNL based on the hydrograph data.

2.3 Site Geology

Geological investigations of the BNL area have been conducted by the USGS since the 1940s. The defined geological framework has been used as the technical basis for groundwater modeling work. The main documentation of the site geology include reports of the United States Geologic Survey (USGS) by Scorca et al. (1999) *Stratigraphy and Hydrologic Conditions at the Brookhaven National Lab and Vicinity, Suffolk County, New York, 1994-97,* and by Wallace deLaguna (1963) *Geology of Brookhaven National Laboratory and Vicinity, Suffolk County New York.*

In 2001, 42 temporary wells were drilled south of the BNL site to support the design of the off-site groundwater treatment systems. The primary purpose of this pre-design characterization was to better define the contamination targeted for treatment. This effort also confirmed and refined our understanding of the off-site geology. This work provided additional information on the Gardiners Clay and the Magothy Brown Clay. These two important confining units govern the flow of groundwater from the Upper Glacial aquifer to the Magothy aquifer.

These data were used to revise the interpretation and mapping of these units. The changes have been incorporated into the BNL groundwater flow model.

The main geologic updates during 2001 include minor yet noteworthy changes to the Magothy Brown Clay, **Figure 2-5** and the Gardiners Clay, **Figure 2-6**. In each figure, three interpretations are presented:

- The 1997 USGS interpretation (Scorca et al, 1999). These interpretations are based on lithology rather than hydrogeologic criteria. Their data is based upon data available through 1997.

- The 1999 BNL regional groundwater model update interpretation (AG&M, 1999). This interpretation built on the framework of the original groundwater model (G&M, 1996) and was updated with borehole data through 1998. This interpretation is hydrogeologic based and includes groundwater flow model calibration input. The USGS report was not yet published; hence it was not a significant source of information for this interpretation.

- The 2001 BNL regional groundwater model update interpretation (unpublished). This interpretation considered the 1999 regional groundwater model interpretation, the USGS lithologic interpretation, and off-site borehole data collected in 2001. Therefore, this interpretation is both lithologic and hydrogeologic based, and includes groundwater flow model calibration input.

The 2001 BNL regional groundwater model update interpretation is considered the most accurate for groundwater management purposes.

The USGS interpretation of the Magothy Brown Clay includes a small area of discontinuous clay in the erosional valley south of the site and north of Brookhaven airport. Based on new stratigraphic data obtained from boring logs and gamma logs, this area was incorporated into BNL's regional model update. Also, the Magothy Brown Clay now is thought to be mainly continuous on site, with the exception of an erosional valley feature in the south-central portion of the site.

The main body of the Gardiners Clay on-site, as recently interpreted by the USGS, is largely continuous, with the mid to southern central parts not present due to an erosional valley. The main update to the regional model connects the two lobes of Gardiners Clay in the east portion of the site and connects a formerly isolated area of clay just south of the site (**Figure 2-6**).

3.0 Environmental Restoration Groundwater Monitoring and Remediation

This section gives an overview of groundwater monitoring and remediation efforts work at Brookhaven during 2001. Topics include the results of groundwater monitoring, including recent groundwater characterization, and the performance, operation, evaluation and recommendations for groundwater remediation systems. The section is organized first by Operable Unit, and then by the specific groundwater remediation and/or monitoring program. The time covered is from January 1 to December 31, 2001. **Figure 1-2** shows the locations of monitoring wells throughout the site and, through colors and symbols, depicts the association of the well to either the ER or ES program and the particular groundwater program grouping. Monitoring well location maps specific to particular monitoring programs are included throughout Chapter 3.

Appendices **C** and **D** contain the analytical results for each sample. Due to the large volume of data, these appendices are included on a CD ROM; this significantly reduces the size of the hardcopy of this report. The CD ROM 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. Users can print a hardcopy of the results from the CD ROM. The groundwater results are arranged by specific monitoring project and then by analytical group (VOCs, SVOCs, metals, chemistry, pesticides/ PCBs, and radionuclides). The data are organized further by well ID and the date of collection 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 shown. Results exceeding the corresponding groundwater standard or guidance criteria (see Section 1.1.1 [Regulatory Drivers]) are shaded. Inclusion of the complete results allows the reader to analyze them in detail. In addition, the entire report is included on the CD-ROM with active links to tables and figures.

Contaminant plumes are represented by maps depicting the areal extent and magnitude of contamination; they were developed by contouring the highest contaminant concentration for a particular well cluster. This method presents the significant plumes in a manner consistent with the objectives of this report. VOC plumes are simplified somewhat by using the TVOC values for drawing the contours, except for those consisting almost exclusively of one chemical (i.e., OU III Carbon Tetrachloride, OU VI EDB).

There have been significant changes in the distribution of contaminant plumes since the ER Groundwater Monitoring Program started in 1997 that can be attributed to the following effects:

- The beneficial effects of active remediation systems,
- Various source removal actions,
- The impacts of BNL pumping and recharge on the groundwater flow system,
- Radioactive decay, biological degradation, and natural attenuation,
- The addition of permanent monitoring wells to enhance the existing networks and,
- Newly acquired data from groundwater characterization filling gaps in the data.

Changes in the distribution of the primary plumes over the past four years also are shown. Ranges of contaminant concentrations are displayed in color so readers can compare the changes in both the plumes' extent and distribution within these ranges. Cross-sectional transects show the vertical distribution/extent of contamination, as well as the hydrogeology, along a transect line oriented through the most highly contaminated sector of the plume. These transects are identified on the corresponding plume distribution map. The plume distribution maps and cross-sections color-code the monitoring wells by project as in **Figure 1-2**; this simplifies interpretation of the figures and also aids in finding the data in Appendices **C** and **D** for a particular well. The color-coding denotes that monitoring well data from more than one ER Monitoring Project may have been used to determine the distribution and extent of a particular plume.

The data were used in the hydrogeological cross-sections to depict the stratigraphy at The Laboratory. In any instance, this stratigraphy may be based on additional data points not shown on that particular cross-section; incorporating them would have greatly complicated the presentation of the information that is our primary goal.

The extent of contamination for a given plume was determined primarily using CY 2001 data from permanent monitoring wells. Several pre-remedial design groundwater characterization efforts were undertaken in 2001. These data were used to define the various contaminant plumes both on and off-site. In some cases data from early 2002 was utilized. This is noted on the specific figures.

The extent of plumes containing VOC contamination was contoured to represent the typical NYS AWQS of 5 µg/L (there is no standard for TVOCs that incorporates all the VOCs analyzed by EPA Method 524.2); similarly, individual radiochemical plumes were contoured to their appropriate MCL. The exception to this is the HFBR Tritium Plume that is contoured to 1,000 pCi/L, reflecting both the elevated sensitivity to this plume historically, and the fact it has shifted over time due to artificial hydraulic stresses. This necessitated tracking this plume to a level of detail greater than the NYS AWQS of 20,000 pCi/L.

A single representative round of monitoring data was chosen for each plume, typically, the last of the year because it includes the most comprehensive network of wells and recent data. This report also serves as the fourth quarter report for remediation systems. Plots incorporating all the historical data were made of trends in concentration for the key wells in each plume to identify any changes; they are shown on maps depicting the plumes' extent to assist the reader in interpreting the information. Several new monitoring wells along with numerous temporary wells, were added to the various programs during the 2001 remedial pre-design and design characterization; this effort afforded a more detailed depiction of contaminant plumes, particularly in off-site and source areas. Data from monitoring wells sampled under BNL's ES Monitoring Program also supplement some ER data, and define the plumes more completely.

3.0.1 ER Groundwater Remediation Program: An Overview

Groundwater remediation systems have operated at Brookhaven since 1997, beginning with the OU I South Boundary pump and treat system. The goal of groundwater remediation as defined by the OU III ROD, is to prevent or minimize plume growth and achieve MCLs in the Upper Glacial aquifer in 30 years or less.

There are presently six groundwater remediation systems in operation at BNL, two in stand-by mode and nine planned. **Figure 3.0-1** shows the locations. This figure also delineates the groundwater capture zones for each of the systems. In addition to the groundwater treatment systems, two landfills were capped (Current and Former), which minimizes them as sources of groundwater contamination.

In general, Brookhaven uses two types of groundwater remediation systems to treat VOC contamination, pump and treat and recirculation with in-well 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. The two types of treatment utilized at BNL are air stripping and granular activated carbon. Treated water then is introduced back into the aquifer via recharge basins, injection wells or dry wells. Pump and treat is a standard environmental cleanup industry technology and particularly lends itself to on-site applications at BNL where recharge to groundwater is not an issue.

Recirculation wells with either in-well air stripping or carbon treatment are an innovative groundwater remediation technology and are particularly attractive to BNL as an alternative in off-site areas. Here, the recharge of treated water and the noise generated by air stripper towers are important factors. This technology is based on a remediation well with two hydraulically isolated screen zones set some distance apart. Contaminated water is pumped up from the deeper zone in the contaminant plume, and treated either below the ground surface with a shallow tray air stripper or through carbon filtration. The treated water then is returned to the aquifer via the shallow recharge screen. Off gas generated by the air stripping process is passed through granular activated carbon and is sent back to the in well air strippers for reuse. **Table 3.0-1** summarizes both the operating and planned remediation systems.

Table 3.0-1 Summary of Groundwater Remediation Systems at BNL

Operable Unit	System Status	Project	System Type	Recharge Method
OU I	Operational	South Boundary	Pump and Treat	Basin
OU III	Planned	North Street East	Pump and treat	Dry Wells
	Operational	Carbon Tetrachloride	Pump and treat	Basin
	Operational	Bldg. 96	Recirculation	In-well
	Operational	Middle Rd.	Pump and treat	Basin
	Planned	W. South Boundary	Pump and treat	Basin
	Operational	Industrial Park	Recirculation	In-well
	Planned	LIPA	Pump and treat	In-well
	Planned	North Street	Pump and treat	Recharge Wells
	Planned	Industrial Park East	Carbon treatment	Recharge Wells
	Planned	Airport	Recirculation	In-well
	Planned	BGRR Sr-90	Pump and treat	TBD
	Planned	Chemical Holes Sr-90	Pump and treat	Dry wells
	Operational	South Boundary	Pump and treat	Basin
	Stand-by	HFBR Tritium	Pump and recharge	Basin
OU IV	Stand-by	1977 Spill	AS/SVE	In-well
OU VI	Planned	EDB	Pump and treat	Diffusion wells

Soil and groundwater contaminated by the 1977 fuel oil/solvent spill were treated utilizing an air sparge/soil vapor extraction (AS/SVE) system; 48 air AS and 23 SVE wells were installed. Air is introduced into the AS wells (screened below the water table) via a two-staged rotary lobe blower thereby liberating VOCs which then are removed from the unsaturated zone by the SVE wells. The off-gas is then passed through granular activated carbon and released to the atmosphere.

The remediation of radiologically contaminated groundwater was begun for the HFBR tritium plume and is planned for several strontium-90 plumes. A pump and recharge system was employed for the tritium plume beginning in 1997, that pumped groundwater from the mid Upper Glacial aquifer at Princeton Avenue and recharged it back to the RA V recharge basin. The goal was to prevent the plume from moving south of Princeton Avenue. The system was placed on stand-by in September 2000 as tritium was not detected south of Weaver Drive, and the southern extent of the plume was adequately delineated. During 2000 and early 2001, low flow extraction of highly contaminated groundwater from the HFBR tritium plume was undertaken to reach the OU III ROD goals. A total of 91,000 gallons of groundwater were pumped from ten wells in twenty-one separate pumping events. The water was transported off-site for treatment and disposal at an EPA approved facility.

Remediation of strontium-90 contaminated groundwater is planned for both the BGRR/WCF and Chemical/Animal Holes areas. A pilot study scheduled for 2002 at the Chemical/Animal Holes will test the feasibility of remediating groundwater containing high concentrations of strontium-90 water by extracting it, treating it with zeolite adsorption, and recharging to the aquifer via dry-wells. If the pilot study is successful this technology will be used for strontium-90 contaminated water in the BGRR/WCF area.

The location of pump and recharge systems near BNL's supply and process wells has required detailed coordination within ER and with the rest of the facility. A BNL Groundwater Pump and Recharge Committee formed in 2000 and consisting of key personnel from the EM Directorate, Environmental Services Division, Plant Engineering, DOE, and other facilities, meets regularly to discuss groundwater management at Brookhaven. An example of this coordination is the shifting of supply well pumping during 2000 to the western well field to stabilize groundwater flow in the central portion of the site where many of the contaminant plumes reside. Another example is the design of the OU III Middle Road Pump and Treat System to allow for treated water to be recharge back to the aquifer at both the OU III and RA V basins in various ratios depending on groundwater flow conditions.

An assessment of the BNL groundwater pump and treat system performance modeling is provided in Section 3.0.2. The purpose of this assessment is to determine whether the cleanup is progressing as forecasted in technical documents supporting the OU III ROD. **Table 3.0-2** summarizes the schedules for the planned BNL groundwater treatment systems.

Table 3.0-2 Schedule for Future BNL Groundwater Remediation

Operable Unit	System	Construction	Start-Up Date
OU III	Western South Boundary	Complete	May 2002
	North Street East	February to August 2003	September 2003
	LIPA	August 2003 to February 2004	February 2004
	North Street	May to October 2003	October 2003
	Airport	January to August 2003	September 2003
	BGRR Sr-90	August 2004 to March 2005	March 2005
	Chemical Holes Sr-90	May to October 2002	November 2002
	Industrial Park East	May to December 2003	December 2003
OU VI	EDB	November 2002 to March 2003	March 2003

3.0.2 Assessment of BNL Groundwater Pump and Treat System Model Performance

3.0.2.1 Purpose

Seventeen groundwater treatment systems with a total treatment capacity of about 4500 gpm, in combination with natural attenuation, are expected to restore the Upper Glacial aquifer to drinking water standards within 30 years (the cleanup goal). Fourteen of these systems are designed to treat VOCs; the others treat or control radionuclides. It is important to assess whether the cleanup is progressing as planned.

The selection of this cleanup strategy is documented in the OU III and OU VI RODs (BNL 2000b). The chosen strategy was simulated using groundwater flow and solute transport models to illustrate that it could achieve the cleanup goals. Comparing the changes in the data on groundwater quality with the model predictions is a useful analytical approach to index groundwater cleanup performance.

The purpose of this assessment is to determine whether the cleanup is progressing as forecasted in technical documents supporting the OU III ROD. Numerous sub-models were developed since then to support the design of the individual systems. However, the model originally established to support the OU III Feasability Study (FS) and select the alternative is again used in this "watershed" view of the cleanup performance. This assessment will focus on VOCs in OU III. Future assessments will expand into OU I, OU V, and OU VI.

3.0.2.2 Assessment Approach

The approach to this assessment for Brookhaven's 2001 Annual Groundwater Status Report is as follows:

- Compare predicted vs. actual cumulative mass removal of VOCs with time by treatment system.

- Compare FS model predictions for OU III VOCs for year three (2001) with the plume as mapped with 2001 data.

3.0.2.3 Discussion of Results

The BNL groundwater remediation program is in its early stages of cleanup. This is illustrated in **Figure 3.0-2**, which graphs the VOC cumulative mass removal for the program over time. The figure also shows mass removal predicted by groundwater modeling. A total of 2,950 pounds of VOCs have been removed from the aquifer to date. The rate of cleanup will accelerate over the next year as additional systems become operational.

A comparison of the measured cumulative VOC mass removed with time with a 2000 prediction (which is predominately based on the OU III Remedial Investigation/Feasability Study (RI/FS) characterization data and predictions, the RA V EE/CA, and early design prediction) and a revised 2002 prediction (which is based on pre-design characterization data and design predictions) is shown in **Figure 3.0-3**. Several observations and interpretations drawn from these comparisons are:

- The 2002 forecast of cumulative mass removed is significantly less than the 2000 forecast because of more detailed pre-design characterization data collected in 2000 and 2001 that delineates the contamination in more detail. The 2000 forecast relied more on data interpolation and interpretation and was apparently conservative.

- The updated 2002 forecast is based on compiling of more detailed sub-models used during the design process, that have more detailed finite-difference grids. This fact, combined with better characterization data, significantly improved the estimates.

- The actual mass removed matches the prediction through 2001 reasonably well, but better corresponds to the updated 2002 forecast.

- The updated 2002 forecast includes a more up to date startup schedule for each of the 14 VOC treatment systems. The construction schedule for the treatment systems was revised in 2001. In general, construction was extended out to 2005 from 2004. Even with the construction schedule extension, the forecasted "knee of the curve" in cumulative mass removal, or the point at which mass removal begins to level off with time, still occurs at approximately 2012.

- The minor delay in the construction schedule is compensated by better than expected VOC removal performance in several systems. These include, the Carbon Tetrachloride project and the HFBR pump & recharge system. When the HFBR pump and recharge system was operating it captured and treated a significant quantity of VOCs.

- The single greatest change between the 2000 and 2002 forecasts is in the performance of the Middle Road treatment system. Modeling done during the FS assumed very high VOC concentrations in this area. Pre-design characterization data collected in that area in 2000 significantly reduced the estimates of VOCs in that area.

Figure 3.0-4 compares the 2001 OU III VOC groundwater quality data to the model predictions of VOCs for 2001. Several interpretations are drawn from these comparisons:

- The travel paths and extent of contamination are similar for the measured and the modeled OU III VOC plume.

- Because the duration of treatment has been relatively short and not all the systems are operational, clear trends still are difficult to discern. The early indications are than the cleanup goals can be achieved and that cleanup progress is going as planned.

- The model projects that a large, clean area of the aquifer emerges in the vicinity of Princeton Avenue and the OU III recharge basin. This is caused by the recharge of clean water to the OU III basin. The data do not reflect this most likely because there are few monitoring wells in that area.

- The FS model projections of the extent of the VOC contamination in 2001 are greater than what was actually observed. This suggests that the FS model predictions were conservative from a "watershed view".

- A number of new "hot spots" appear in the 2001 data that are not captured in the OU III VOC simulations. For example, the contributions of the Carbon Tetrachloride and Building 96 plumes was not fully characterized in the FS model runs used to support the OU III ROD.

- The model predicts some progress in reducing contamination around the North Street and LIPA groundwater treatment systems. However, these systems still were in the design stages in 2001. The systems were assumed to be operating during 2001 for the FS model runs. This is a limitation of this assessment approach.

- The OU III South Boundary treatment system seems to be removing more mass than was predicted.

We conclude that since signing the OU III ROD, pre-design characterization work has continued, but several systems have been designed and constructed on a schedule, which varied from the assumptions used in the OU III FS. Some of the designs utilized new sub-models to address very site-specific design issues. The introduction of new sub-models, new plume data, additional systems not contemplated during the OU III FS modeling (e.g., Carbon Tetrachloride, Building 96, Western South Boundary) and variation in assumed start-up times for certain treatment systems greatly complicates a "simple" comparison of changing groundwater quality data to model predictions.

This is the first time this type of assessment has been presented in the BNL Annual Groundwater Status report. Because the treatment system has been operating for a relatively short time, clear trends at the OU III or "watershed" scale are difficult to discern and considerable uncertainty remains. The early indications are that the cleanup goals can be achieved. With time, more recognizable improvements will dominate the picture and the limitations to the assessment approach are expected to become less significant. Limitations in the remediation strategy and individual treatment system performance will likely become more visible with time. Therefore, this type of assessment is expected to become more valuable with time.

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3.1 Operable Unit I

The major sources of groundwater contamination in OU I were the former HWMF and the Current Landfill. The former HWMF was BNL's central RCRA receiving facility for processing, neutralizing, and storing hazardous and radioactive wastes before off-site disposal until 1997, when a new WMF was constructed along East Fifth Avenue. Several hazardous materials spills were documented at this former location. This facility has been characterized and soil remediation is scheduled to begin in 2002.

The Current Landfill operated from 1967 through 1990, but was permanently closed in 1995 under the ER program. It was used to dispose of putrescible waste, sludge containing precipitated iron from the Water Treatment Plant (WTP), and anaerobic digester sludge from the Sewage Treatment Plant (STP). The latter contained low concentrations of radionuclides, and possibly metals and organic compounds. BNL also disposed of limited quantities of laboratory wastes containing radioactive and chemical material at the landfill.

The Current Landfill and former HWMF plumes become commingled south of the HWMF, partially caused by the pumping and recharge effects of the former Spray Aeration System, which operated from 1985 to 1990, and was designed to treat VOC contaminated groundwater originating from the former HWMF. The VOC plume is depicted in **Figures 3.1-1** (plan view) and **3.1-2** (cross sectional view). The plume extends off-site, approximately 3,300 feet south of the site property boundary. The Current Landfill/former HWMF plume is being remediated by a groundwater pump and treat system consisting of two wells screened in the deep portion of the Upper Glacial aquifer at the site property boundary (Removal Action (RA) V Treatment System). The extracted groundwater is treated for VOCs by air-stripping and recharged to the ground in the RA V basin, located to the northwest of the Current Landfill (**Figure 3.1-1**).

A second system is being planned to treat the off-site portion of the plume. Groundwater pre-design characterization work was performed during 2001 as part of the planned North Street East groundwater remediation system. The purpose of this work was to define the leading edge of the plume and the extent of the higher VOC concentrations in this area. Eleven temporary vertical profile wells were installed and sampled as part of this effort, the locations of which are shown in **Figure 3.1-1**. The construction of the off-site groundwater remediation system is scheduled for 2003 with system start-up in early 2004.

Tritium is detected below the 20,000 pCi/L NYS AWQS in several monitoring wells in the Current Landfill/OU I South Boundary/North Street East program. Strontium-90 (Sr-90) is detected in on-site wells, several of which exceed the 8 pCi/L NYS AWQS.

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3.1.1 Current Landfill Monitoring

Data obtained from the Current Landfill groundwater monitoring program are presented in this section along with conclusions and recommendations for future monitoring. A Five-Year Evaluation Report (P.W. Grosser, January 2001) was prepared and submitted as per the requirements of 6 NYCRR Part 360 Section 2.1.5, Solid Waste Management Facilities (effective December 31, 1988). This report summarized the status of groundwater quality in the vicinity of the Current Landfill, giving conclusions and recommendations about the effectiveness of the cap and future monitoring efforts. This section reiterates those conclusions and recommendations.

3.1.1.1 Landfill History and Cap Description

The Current Landfill operated from 1967 to 1990. for the disposal of putrescible waste, sludge containing precipitated iron from the BNL Water Treatment Plant, and anaerobic digester sludge from the Sewage Treatment Plant. The latter contained low concentrations of radionuclides, and possibly metals and organic compounds. Limited quantities of laboratory wastes containing radioactive and chemical material were disposed of at the landfill. During its operating life, this landfill was unlined and did not have a leachate control system.

The current Landfill was capped in the fall of 1995 in accordance with 6 NYCRR Part 360. This cap consists of a geotextile fabric overlain by a 12-inch gas-venting layer followed by a 40-millimeter double-sided textured geomembrane topped with a 24-inch thick protection layer and 6 inches of topsoil. The *Construction Certification Report for the Former Landfill* (CDM 1995a) has more information on the landfill's construction and maintenance.

3.1.1.2 Groundwater Monitoring

Well Network: The Current Landfill monitoring program, a network of eleven monitoring wells located immediately adjacent to the landfill, was designed for post-closure monitoring following the NYSDEC requirements (**Figure 3.1-3**). These wells are used to determine the cap's effectiveness in preventing the continued leaching of contaminants from the landfill, and to document the anticipated long-term improvements to groundwater quality.

Sampling Frequency and Analysis: The Current Landfill wells are sampled quarterly. The samples are analyzed for VOCs, metals, cyanide, gross alpha/beta, gamma spectroscopy, tritium, and Sr-90 (**Table 1-6**).

3.1.1.3 Monitoring Well Data Results

The primary VOCs that have been consistently detected in Current Landfill Monitoring Program wells are chloroethane and benzene. The complete results for the eleven Current Landfill monitoring wells can be found in **Appendix C**. The highest TVOC value during 2001 was 87 µg/L in well 88-109 (primarily chloroethane) which is located immediately east and adjacent to the landfill. This sample was obtained in the fourth quarter following three previous quarters of levels below 10 µg/L. **Figure 3.1-4** plots the historical trend in concentrations of VOCs for this and several other monitoring wells. VOC trends in other Current Landfill wells were stable or slightly decreased in 2001.

Tritium and strontium-90 were detected several times at concentrations well below the NYS AWQS in 2001. They occurred in wells that have a previous history of low-level tritium and/or strontium-90 contamination. Americium-241 was detected at 18 pCi/L in well 88-23 however, a review of data usability deemed that there was an interference problem with the analysis, and that the concentration was not distinguishable from background. **Appendix G** has this data usability report.

Conventional landfill leachate parameters were below applicable NYS AWQS except for ammonia. This is the only leachate parameter that has been detected historically at concentrations exceeding the NYS AWQS of 2 mg/L. The highest concentration in 2001 was 7 mg/L inI well 88-109. Ammonia is a common landfill contaminant and is generated by the degradation of organic material.

Iron and magnesium were the only metals detected above NYS AWQS in 2001. Their concentrations will fall relatively slowly due to their sorption to aquifer materials, thereby reducing their mobility.

3.1.1.4 Groundwater Monitoring Program Evaluation

These data are used to support the following site-specific decision developed from the DQO process.

1. Are the controls effectively eliminating further discharges to soils and groundwater below the landfill?

Data show that, in general, contaminant concentrations have been decreasing following the capping of the landfill in 1995. Studies by Oweis and Biswas (1993) suggest that a period of two to ten years may be required before groundwater quality improvements are observed, depending on the underlying hydrogeology. The predominant direction of groundwater flow at the Current landfill is to the south, and does not vary significantly during the year (**Figure 2-2**). The velocity of groundwater flow in the vicinity of the Current Landfill is approximately 0.75 feet/day. Considering that the landfill is approximately 750 feet wide in the direction of flow, it is estimated to take two to three years for leachate on the upgradient side of the landfill to pass through the downgradient side. Therefore, improvements to groundwater quality are not expected to be observed in the monitoring wells on the edge of the landfill (87-11, 88-109, 88-110) for at lest three years following capping. The furthest downgradient wells (87-27, 87-26, 87-24, 87-23, 88-22, and 88-23) would not be expected to see groundwater quality improvement for at east four years following capping. The time of travel from the landfill to the OU I South Boundary pump and treat system is approximately 10-15 years. The trend in the data suggests that the cap is effective in mitigating contamination. Additional groundwater quality improvement is expected.

3.1.1.5 Recommendations

The sampling program was modified in 2002 following the recommendations of the Five-Year review report:

- Eliminate SVOC's, pesticides and EDB from the monitoring program.
- Continue sampling for VOCs, leachate parameters, metals and radionuclides at the established frequencies (quarterly) for an additional year.
- Undertake a second evaluation, if warranted, after completing the additional year of monitoring.

An additional recommendation in the draft report was to reduce the frequency of VOC sampling from quarterly to semi-annually. After discussions with NYSDEC it was agreed to maintain the quarterly frequency for another year and evaluate the data at that point. Based on the stability of the VOC data, it is recommended that the frequency of VOC analysis is reduced to semi-annually for all wells except 88-109. This well exhibited a significant spike in chloroethane concentrations during the fourth quarter of 2001.

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3.1.2 South Boundary Pump and Treat System

This section summarizes the operational data for 2001 from the OU I South Boundary groundwater pump and treat system, and presents conclusions and recommendations for its future operation. This system began operating in December 1996 to provide hydraulic control at the site boundary by removing VOCs from the groundwater.

Quarterly reports were prepared with the operational data from January 1 through September 30, 2001. A monthly Discharge Monitoring Report (DMR) is submitted to EPA and NYSDEC for treated effluent water from the air-stripping tower. This section summarizes the 2001 operations, including fourth quarter results, and gives a detailed evaluation of monitoring well analytical data.

3.1.2.1 System Description

Two groundwater extraction wells, EW-1 and EW-2, provide hydraulic control of the VOC plume. Groundwater is extracted at a total maximum flow rate of 700 gallons per minute (gpm). The actual rates vary during the extraction system's life, according to operational monitoring data. **Table 3-1** shows the depths of the extraction wells and pump settings.

Table 3-1. OU I Extraction Well Construction Data

Well	Screen Interval (Feet below grade)	Pump Setting (Feet)
(EW-1, 115-27)	150-190	170
(EW-2, 115-43)	100-140	120

Each wellhead is enclosed in a reinforced concrete vault with the top slab at grade. The vaults are located along the southern boundary of the site. Piping within the vaults is schedule 80 PVC, transitioning to Blue Brute PVC Class water pipe before exiting through the vault's wall. The pipes are 4-inch (EW-1) and 6-inch (EW-2) diameter, increasing to 8- inches in the vault, and join an 8-inch diameter pipe, at the start of the common force-main to the treatment facility.

The groundwater treatment facility consists of a treatment control building and an air-stripping tower located north of Brookhaven Avenue between Fifth and Sixth Streets. The treatment facility is designed for limited automatic operation, defined as automatic equipment shutdown with manual restart. Any alarm condition will signal a common trouble alarm at BNL's Central Chilled Water Facility requiring physical inspection of the main control panel to determine the source of the alarm.

The stripping tower is 6 feet in diameter and 48 feet tall, and is equipped with a minimum of 20 feet of 2-inch plastic packing. The latter is based on the requirements to remove 1,1-DCA. One of two centrifugal blowers supplies air to the tower at a normal flow rate of 6,550 cfm, providing an air/water ratio of 70:1 at the maximum water flow rate of 700 gpm.

The water discharged from the air-stripping tower flows by gravity to the adjacent recharge basin to the east. The basin can receive a continuous flow of 1,500 gpm that includes a sufficient factor of safety to account for OU I discharge, variations in subsurface soil, and fouling of the basin over time. The OU III (HFBR Tritium Pump and Recharge System) also discharged to this same basin until September 29, 2000. The OU III Middle Road System began partially discharging to this basin in October 2001.

3.1.2.2 Groundwater Monitoring

Well Network: The OU I South Boundary monitoring program uses a network of 62 monitoring wells (15 of which also are used for the Current Landfill and OU III North Street monitoring programs) located downgradient of the Current Landfill and former HWMF. The network was organized into core, perimeter and bypass wells as part of the groundwater DQO process. The well's designations/locations are shown in **Figure 3.1-5**. They are designated as follows:

- Background – background water quality results will be utilized to determine whether a contaminant slug is traveling toward the remediation system
- 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 Detection – data used to determine whether plume capture performance is being met.

Sampling Frequency and Analysis: The wells are monitored four times per year and analyzed quarterly for VOCs, tritium, and strontium-90, and annually for gross alpha/beta and gamma spectroscopy (**Table 1-6**).

3.1.2.3 Monitoring Well/Vertical Profile Well VOC Data Results

The Current Landfill and former HWMF are considered source areas for the VOC plume. A discussion of monitoring well data specific to the Current Landfill source area is provided in Section 3.1.1. Distributions of TVOC concentrations for this plume were derived from sampling in the fourth quarter round (October/November 2001). Supplemental data were obtained from monitoring wells sampled under the Current Landfill Post Closure Monitoring Program during October 2001. **Figure 3.1-1** shows the areal extent of TVOC contamination from the Current Landfill/former HWMF area.

The primary VOCs on-site in this plume include chloroethane and DCA, the signature contaminants for the Current Landfill. TCA, 1,1-dichloroethene (DCE), trichloroethene (TCE), and chloroethane are prevalent in the plumes' off-site segment. The OU I South Boundary/North Street East plume (defined by TVOC concentrations greater than 5 µg/L) extends south from the Current Landfill to an area approximately 2,250 feet south of North Street (approximately 7,300 feet long as measured from the Current Landfill). Its maximum width is about 1,300 feet at the southern site boundary. The plume segments with higher concentrations (greater than 50 µg/L) are approximately 300 feet wide. The areas of the plume displaying the highest VOC concentrations (greater than 100 µg/L) are located approximately 500 feet downgradient of the former HWMF (well 98-59), and off-site, south of well 000-124.

Eleven vertical profile wells were installed during 2001 to detail the extent of the TVOC plume greater than 50 µg/L in the area south of North Street near well 000-124. These data were used to map the 2001 plume. Gamma logs were obtained from each of the temporary well locations. The maximum TVOC concentration detected was 165 µg/L in a temporary well located approximately 600 feet south of well 000-124. The leading edge of the plume, defined by the 5 µg/L isocontour, is approximately 1,400 feet south of this well. Complete groundwater characterization data will be given in the *OU III North Street East Groundwater Treatment System 90% Design Report*, which is scheduled for completion in July 2002.

Figure 3.1-2 shows the vertical distribution of VOCs. The transect line for cross-section A-A' is shown on **Figure 3.1-1**. DCA and chloroethane are primarily detected in the Shallow Glacial aquifer near the source areas, and in the deep Upper Glacial aquifer at the site's boundary and off-site. TCA, DCE, TCE, chloroethane and chloroform are found in the mid to deep Upper Glacial aquifer off-site south of North Street.

The Gardiners Clay and the Upton Unit underlie the deep Upper Glacial aquifer from the source areas to the Princeton Avenue firebreak, but are absent south of this area. There, the Magothy Brown Clay unit lies immediately below the Upper Glacial aquifer and extends some distance to the south of North Street.

Data obtained from plume perimeter wells (**Figure 3.1-5**) indicates that the VOC plume did not shift during 2001 and remains bounded by the current network of wells. **Figure 3.1-4** gives the historical trends in VOC concentration for key plume core and bypass wells along the Current Landfill/HWMF Plume. **Table 3-2** summarizes VOC detections in monitoring wells exceeding the NYS AWQS during 2001. **Appendix C** has the complete 2001 analytical results from the monitoring of the 62 OU I South Boundary Program wells.

- Plume core well 98-59 (**Figure 3.1-5**) has remained relatively stable over the past several years with TVOC concentrations generally above 200 µg/L. This well is screened in the deep Upper Glacial aquifer immediately above the Gardiners Clay.

- Plume core well 115-36, situated between the fire break road and the extraction wells, continued to show a declining trend in VOCs established in 1999. TVOCs ranged from 12 to 19 µg/L during 2001, well down from concentrations greater than 100 µg/L before 1999.

- TVOC concentrations in plume core wells 115-14 and 115-31, both located adjacent to the extraction wells, remained relatively stable during 2001 ranging from 10 to 45 µg/L.

- TVOC concentrations in bypass wells 115-42 and 000-138 showed slight decreases or remained stable.

- Plume core well 000-124 continued to display a decreasing trend in TVOCs, begun in 1998, as concentrations dropped below 100 µg/L.

Groundwater characterization work performed in 2001 indicates that the core of the high concentration slug of contamination previously observed at the location of well 000-124 continues to migrate south and decrease in concentration. The south boundary pump and treat system appears to have created a break in the plume that is characterized by a region of low level TVOCs from south of the extraction wells to just south of the Long Island Expressway (LIE).

There were no detections of VOCs above NYS AWQS in upgradient perimeter wells during 2001.

3.1.2.4 Radionuclide Monitoring Results

The on-site monitoring wells are analyzed for tritium and strontium-90 quarterly, and gross alpha/beta and gamma spectroscopy annually in addition to the quarterly VOC monitoring. Offsite wells are analyzed for tritium at a quarterly frequency and gross alpha/beta, gamma spectroscopy and strontium-90 annually. **Table 3-3** summarizes radionuclide detections in monitoring wells above detectable levels during 2001. The complete radionuclide results for these wells is provided in **Appendix C**.

Tritium has historically been detected in OU I South Boundary Monitoring Program wells below the NYS AWQS of 20,0000 pCi/L. The maximum detection during 2001 was 11,400 pCi/L in well 98-30 during the fourth quarter. A plot of historical tritium results for this well is shown in **Figure 3.1-6**. Tritium in this well has been steadily increasing since 2000 but remains well below the NYS AWQS. Well 98-30 is the only on-site well that continues to show increasing tritium concentrations. Stable or decreasing tritium trends are observed for the remainder of the wells. Results from the fourth quarter 2001 sampling round are posted on **Figure 3.1-7**. Concentration trends for select monitoring wells in which tritium has been observed are indicated in **Figure 3.1-6**.

Strontium-90 has historically been detected in two wells located within and downgradient of the former HWMF (88-26 and 98-21) at concentrations above the NYS AWQS of 8 pCi/L. In 2001, additional groundwater characterization work was performed and groundwater samples were collected at thirteen locations downgradient of the former HWMF using Geoprobe ™ sampling technology (**Figure 3.1-8**). Samples were collected from ten foot depth intervals at each location beginning at the water table and utilizing a four foot long well screen. The strontium-90 detections were observed at two distinct depth intervals. The mixing of the strontium-90 vertically within the aquifer is probably the result of the hydraulic effects of the former spray aeration system pumping and recharge. The extent of strontium-90 concentrations greater than the NYS AWQS of 8 pCi/L is shown in **Figure 3.1-8**. The leading edge of this plume was defined as being north of locations 108-38 and 108-42. Sentinel monitoring wells are planned for installation in 2002 downgradient of the leading edge of the plume. Historical trends for monitoring wells in this area in which strontium-90 has been detected are provided in **Figure 3.1-9**.

3.1.2.5 Systems Operations

The extraction wells are currently sampled every two months. The influent and effluent of the air-stripper tower are sampled once per month. All samples are analyzed for volatile organic compounds. In addition, the influent and effluent samples are analyzed for pH weekly, and iron and manganese monthly. **Table 3-4** provides the effluent limitations for meeting the requirements of the State Pollution Discharge Elimination System (SPDES) equivalency permit. Furthermore, the effluent is sampled for metals, pesticides, PCBs, strontium-90 and gross alpha/beta annually, although the permit does not require this. In addition, they are analyzed for tritium each sampling event. In September 2001 the original equivalency permit form 1996 expired. Reissue of the equivalency permit was requested from the NYSDEC in October 2001.

Table 3-4. SPDES Parameter Effluent Concentrations for 2001

Parameter	Threshold Value* (mg/L)	Maximum Measured Value
pH	9.0	
Benzene	0.8	<MDL**
Chloroform	7.0	<MDL
Chloroethane	5.0	<MDL
1,2-Dichloroethane	5.0	<MDL
1,1-Dichloroethene	5.0	<MDL
1,1,1-Trichloroethane	5.0	<MDL
Carbon Tetrachloride	5.0	<MDL
1,2-Dichloropropane	5.0	<MDL
Methylene Chloride	5.0	0.98B
Trichloroethylene	5.0	<MDL
Vinyl Chloride	2.0	<MDL
1,2-Xylene	5.0	<MDL

* Maximum effluent concentration (µg/L) allowed – Equivalent to a SPDES Permit.

** Minimum Detection Limit (MDL) = 0.5 µg/L

The following is a month-by-month summary of the OU I operations for 2001. BNL's Plant Engineering Division (PE) performed routine maintenance checks on this system daily, in addition to their routine and non-routine maintenance. BNL's Environmental Services Division (ESD) collected the samples. Full details are recorded in the system's operation and maintenance log. The daily operations and maintenance inspection logs are available in the project files and the treatment facility.

January-September 2001:

The system operated normally, with only two interruptions. The first occurred in February with EW-1 and EW-2 off for 10 days due to well maintenance and repairs. The second occurred in June when the entire system was shut down for 6 days due to work on a nearby electrical main. All effluent samples met equivalency permit requirements. A total of 299,135,000 gallons of groundwater was pumped and treated between January and September 2001.

October 2001:

The system operated normally, with no interruption. A total of 37,324,000 gallons were pumped and treated. The extraction wells were not sampled this month, but the air-stripper influent and effluent were sampled. All effluent discharges met the equivalency permit requirements.

November 2001:

The system operated normally, without interruption. A total of 36,852,000 gallons were pumped and treated. The extraction wells, influent, and effluent were sampled in November 2001. All effluent samples met the equivalency permit's requirements.

December 2001:

The system operated normally, without interruptions. A total of 38,088,000 gallons were pumped and treated. The air-stripper influent and effluent were sampled December 18. All effluent samples met equivalency permit requirements.

3.1.2.6 Systems Operations Data

Extraction Wells

During 2001, 411,399,000 gallons were pumped and treated by the OU I system, with an average flow rate of 631 gpm. **Table 2-3** gives monthly pumping data for the two extraction wells. VOC and tritium concentrations for EW-1 (115-43) and EW-2 (115-27) are provided in **Table F-1** in **Appendix F** (located on the enclosed CD-ROM). TVOC levels in both wells continued to show a slight decreasing trend with time (**Figure 3.1-10)**. Year-end tritium levels were below detection limits in both wells.

System Influent and Effluent

VOC and tritium concentrations in 2001 for the air-stripper influent and effluent are summarized in **Tables F-2** and **F-3** in **Appendix F**. Radiological (gross alpha/beta and gamma spectroscopy), pesticide, and metals data for the effluent are shown in **Table F-4**. TCA, DCA, DCE, chloroethane, chloroform, and TCE influent concentrations to the air stripper tower versus time are illustrated in **Figure 3.1-7**. The concentrations of TCA and DCA steadily decreased over the three years of OU I operation; there was little change in other compounds, however.

The air-stripper system effectively removed all elevated contaminants from the influent groundwater. All effluent data were below the analytical method's detection limit and below the regulatory limit specified in the permit equivalency conditions.

Cumulative Mass Removal

The mass of TVOCs removed from the aquifer by the OU I treatment system was calculated. Average flow rates for each monthly monitoring period were used, in combination with the TVOC concentration in the air-stripper's influent to calculate the pounds per month removed. The cumulative mass of TVOCs removed by the treatment system vs. time was then plotted (**Figure 3.1-12**). It shows that 24.6 pounds of TVOCs were removed during 2001; cumulatively, 256.8 pounds have been removed since the system started. (Note: The 1996 RA V Design modeling estimated that the system would remove 260 to 300 pounds by 2006 to 2011). The data for this figure is summarized in **Table F-6**.

Air Discharge

Table 3-5 below presents the VOC air emission data for the year 2001 and compares the values to levels stipulated in NYSDEC Air Guide 1 regulations. Emission rates are calculated through mass balance for all water treated during operation. The concentration of each constituent of the air-stripper's influent was averaged for the period. That value was converted from µg/L to pounds per gallon (lb/gal), which was multiplied by the average pumping rate (gallons per hour (gal/hr)) to compare with the regulatory value. All VOC air emissions were well below allowable levels.

Table 3-5. OU I South Boundary System Air Stripper VOC Air Emissions Data for 2001*

Parameter	Allowable ERP**	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
Carbon Tetrachloride	0.016	<0.0002	<0.0002	<0.0002	<0.0002
Chloroform	0.0086	0.00023	0.00027	0.00031	0.00038
1,1 - Dichloroethane	10***	0.00133	0.00142	0.00152	0.00132
1,2 - Dichloroethane	0.011	<0.0002	<0.0002	<0.0002	<0.0002
1,1 - Dichloroethene	0.194	0.00009	0.00012	0.00011	0.00011
Chloroethane	10***	0.00057	0.00056	0.00067	0.00058
1,1,1 - Trichloroethane	10***	0.00028	0.00033	0.00031	0.00031
Trichloroethene	0.119	<0.0002	<0.0002	<0.0002	<0.0002

* Actual Emission Rate reported as the average rate (lb/hr) for each quarter.
** Emission Rate Potential (ERP) based on NYSDEC Air Guide 1 Regulations.
***6 NYCRR Part 212 restricts emissions of VOCs to a maximum of 10 pounds per hour without controls.

Table F-5 in Appendix F shows the tritium air emissions for the year 2001, sampled at three sites near the RAV basin. All results were less than the MDL. **Figure 3.1-13** compares the tritium concentrations in the air-stripper's influent and effluent since the system started in 1996. They essentially are identical (within measurement error) indicating that tritium was not transferred to air during the stripping process.

Air monitoring for tritium was suspended in the third quarter of 2001. It will be re-started if tritium levels in the air-stripper effluent rise above 1,000 pCi/L for three consecutive months.

Recharge Basin

There are nine sentinel monitoring wells in the immediate area surrounding the RA V recharge basin that are monitored for tritium as part of the HFBR Tritium monitoring program (**Figure 3.2-53**). Until September 29, 2000, this basin also received approximately 125 gpm of effluent from the OU III HFBR Tritium Pump & Recharge system, which contributed to the total tritium concentration being recharged. These wells are used to monitor water quality and water levels to assess the impact of the recharge basin on the aquifer. **Appendix C** (located on the enclosed CD-ROM) contains the data for these wells. All tritium detections were below 1,000 pCi/L during 2001. The highest detection of tritium was 949 pCi/L in well 76-174. Beginning November 1, 2001 the RAV recharge basin began receiving 650 gpm of treated groundwater from the South Boundary and Middle Road treatment systems. The South Boundary SPDES Equivalency Permit was modified to include the Middle Road treatment system and their outfalls at the OU III and RAV recharge basins.

3.1.2.7 System Evaluation

The pump and treat system continued to establish hydraulic control of contaminants from the Current Landfill and former HWMF and to prevent their further migration across the site's southern boundary. No permit equivalencies have been exceeded and no operating difficulties were experienced beyond normal maintenance. There have been no air emission problems and no observed interference with other BNL operations, such as the recharge to Basin HO or the OU III South Boundary pump and treat system.

The OU I South Boundary Pump and Treat system performance can be evaluated based on the five major decisions identified for this system resulting from applying the DQO process.

1. Was the BNL Contingency Plan Activated?

There were no unusual or unexpected concentrations of VOCs observed in monitoring wells associated with the OU I South Boundary Pump and Treat System.

2. Have the cleanup goals been met?

It was determined that, to meet cleanup goals in the required timeframe (30 years), groundwater extraction should continue until plume core wells show concentrations of TVOCs below 5 µg/L. **Figure 3.1-14** plots the mean concentration of each well computed from measurements over the previous two years. Aquifer cleanup continues to be demonstrated as shown in **Figure 3.1-15**, which compares the TVOC plume from 1997 to 2001. The cleanup goals for this system have not yet been achieved.

3. If not, has the plume been controlled?

Since the cleanup goals have not been met, it must be verified that the plume is not growing. An analysis of the plume perimeter and bypass wells reveals that there have been no significant increases in VOC concentrations during 2001; thus, we conclude that the plume has not grown and continues to be controlled.

Groundwater elevation data is obtained from many of the OU I South Boundary Monitoring program wells in addition to wells located throughout the BNL on-site and off-site areas on a quarterly basis. Groundwater contour maps were generated from these data (**Figures 2-2** and **2-3**). The capture zone for the OU I South Boundary Pump and Treat System is indicated in **Figure 3.0-1**. The capture zone depicted is inclusive of the 50 µg/L isocontour, that is the capture goal of this system.

4. Is the System operating as planned?

The system continued to be effective during 2001 in removing VOCs from the deep Upper Glacial aquifer. **Figure 3.1-16** plots the mass of VOCs (in pounds) removed from the aquifer over time. This plot also shows the mass removal predicted by the groundwater model in the OU I (RA V) Groundwater EE/CA. The actual amount of VOCs removed to date exceeds the predicted value by approximately 75 pounds.

The hydraulic capture performance of the system is operating as planned. However, some portions of the targeted cleanup area appear not to be progressing as quickly as simulated in the groundwater modeling performed during the design of the system. Camp Dresser & McKee (1995, 1996) carried out a series of groundwater model as part of the EE/CA and 30% Design of the system. These simulations focused on the most prevalent and design limiting contaminant 1,1 DCA. The predicted 1,1-DCA concentrations after 5 and 10 years of RA V operation are shown in **Figure 3.1-17**. Only the "hot spots" were simulated in these runs. After 5 years of operation (2001) the early model runs indicated that the 1,1-DCA concentrations in the aquifer would be reduced to about 30 µg/L. The plume map data for 2001 generally support this, with the following exceptions:

- TVOC concentrations at well 98-59 southwest of the former HWMF remain high at 198 µg/L.
- Even though the Current Landfill is capped, it remains a weak source of contaminations. TVOC levels as high as 87 µg/L were detected at its downgradient edge. Concentrations in groundwater are declining in this area; however, it will take several more years to fully flush out the contaminants beneath the landfill cap.

These types of local limitations are not unexpected. Earlier design reports identify some of these risks.

The RAV system operated at an average pumping rate of 631 gpm in 2001; the design rate was 600-700 gpm. This higher rate of pumping may be one reason that the rate of mass removal is greater than planned. Another reason is that there may have been more mass than originally estimated.

The groundwater model for this system has not been updated since 1996. The modeling will be updated and that and engineering evaluation will be performed to consider means to better remediate the two local persistent areas in an effort to optimize and manage the operational life of the system.

5. Have asymptotic conditions been demonstrated?
Asymptotic conditions are demonstrated by analyzing the average trends in VOC concentrations in the plume core wells (**Figure 3.1-14**). These concentrations were fairly stable during 2001, although the Kendall-Mann statistical test shows a continuing decreasing trend. Kendal-Mann is a nonparametric trend analysis (Gilbert, 1987) used to aid in determining the slope in groundwater quality data. It is particularly useful when the residuals from a regression analysis are not normally distributed, or of an unknown distribution. Asymptotic conditions have not yet been achieved, but are expected in the next few years. Asymptotic concentrations of target VOCs in plume core wells can indicate that the practical limits of treatment have been reached.

3.1.2.8 Recommendations

The following are recommendations related to the OU I South Boundary groundwater remediation system and groundwater monitoring programs:

1) The groundwater model will be updated in 2002 in an effort to optimize and manage the operational life of the system. In addition, an engineering evaluation will be performed to consider remediation alternatives for the persistently high TVOC concentrations in an area immediately south of the former HWMF.

2) The former HWMF strontium-90 plume will be evaluated in 2002, particularly with respect to the effects of the extraction wells on it.

3) Four sentinel monitoring wells will be installed in the spring of 2002 for the former HWMF strontium-90 plume. The wells will be located immediately south of the downgradient line of geoprobes installed in 2001 and 2002. These will provide early warning for Sr-90 approaching the south boundary extraction wells.

4) Reduce the frequency of the perimeter monitoring wells from quarterly to semi-annually. The fringes of the OU I South Boundary TVOC plume have not shown evidence of shifting over the past several years of monitoring. In addition, the TVOC concentrations are less than 5 µg/L in these wells. The modification would affect wells 98-21, 98-22, 98-30, 98-33, 98-58, 98-61, 98-62, 99-04, 107-10, 107-23, 107-24, 107-25, 108-08, 108-12, 108-13, 108-14, 108-17, 108-18, 108-30, 115-03, 115-30, 116-05, and 116-06. The modification in sampling frequency will be implemented beginning in the first quarter of 2003.

3.2 Operable Unit III

The OU III plumes, as depicted in **Figure 3.2-1,** are actually multiple commingled plumes originating from several sources defined in the OU III RI/FS, including Building 96, Building 208, the Former Landfill and Animal/Chemical Holes area, the AGS area, and the former Carbon Tetrachloride underground storage tank. One exception to this is the North Street plume, which has sources in OU IV and the Former landfill areas. **Figure 3.2-1** is a simplified representation of the plumes, done for clarity. The eastern portion of **Figure 3.2-1** also includes the OU IV plume and the North Street (OU I/IV) plumes.

The primary chemical contaminants found in OU III groundwater are TCA, tetrachloroethene (PCE), and carbon tetrachloride. The primary OU III VOCs detected in on-site monitoring wells include carbon tetrachloride, TCA, and PCE; carbon tetrachloride and PCE are the main contaminants detected in off-site groundwater.

The OU III VOC plume extends overall from the AGS/WCF area in the northern part of the site, south to the vicinity of Flower Hill Drive off-site (approximately 18,000 feet). The maximum width of its main body is about 1,500 feet, as defined by TVOC concentrations greater than 5 µg/L. The western lobe of the OU III plume is defined by discontinuous VOC contamination less than 50 µg/L. This contamination most likely results from multiple small source areas in the northern and central portions of the site, and its distribution has been complicated by earlier changes in the on-site groundwater flow system due to changes in pumping and recharge. The basis for this representation of the lobe of the plume is the extensive vertical profile characterization conducted under the OU III RI, in addition to data points from several existing monitoring wells.

The two most significant source areas are the Building 96 area, and the former Carbon Tetrachloride underground storage tank. Onsite portions of the plume displaying the highest VOC concentrations during 2001 were south of Building 96 (primarily PCE and lower concentrations of TCA, with TVOCs up to 1,794 µg/L), continuing south to Carleton Drive with TVOC concentrations of greater than 500 µg/L. TVOC levels range up to 9,780 µg/L (primarily carbon tetrachloride and PCE) in the off-site area, from the industrial park to Carleton Drive. Characterization of the Magothy Aquifer was begun in 2000 and 2001 and will be completed in 2002. Vertical profiles have been completed at 16 locations and monitoring wells installed at six locations. Data obtained from these vertical profiles has been used to help draw the various OU III contaminant plume maps.

The transect lines for cross-sections B-B' (**Figure 3.2-2**) and C-C' (**Figure 3.2-3**) are shown on **Figure 3.2-1**. A review of the associated data reveal that, in general, PCE, TCA, and carbon tetrachloride occur in the shallow Upper Glacial aquifer in the central portion of OU III, and in the deep Upper Glacial aquifer at the southern site boundary and off-site. In addition, the results from wells 000-249 and 000-130 suggest that there is significant carbon tetrachloride and PCE contamination off-site in the Upper Magothy aquifer. Magothy aquifer characterization is ongoing in this area. The highest carbon tetrachloride and PCE concentrations occurred in wells 000-253 and 000-130, with maximum TVOC concentrations of 2,161 and 1,142 µg/L, respectively. The levels have been steadily decreasing from peak concentrations in 2000/2001, and in fact, the highest 20001 concentrations occurred during the first quarter sampling. A comparison of the OU III plumes between 1997 and 2001 is provided in **Figure 3.2-4**.

The Gardiners Clay forms the base of the Upper Glacial aquifer in the northernmost area of OU III. The Brown Clay unit discontinuously represents the upper portion of the Magothy aquifer, from the central part of OU III south to areas off-site.

Sections 3.2.1 through 3.2.5 summarize the groundwater monitoring and system operations data for the OU III operational groundwater treatment systems, evaluate the system performance and provides recommendations for modifications. Sections 3.2.6 through 3.2.14 summarize the various OU III groundwater monitoring programs that will either become a part of the monitoring program for planned remediation systems (i.e., North Street, Chemical/Animal Holes etc.), are associated with landfill capping (Former Landfill) or are intended to monitor general areas such as the OU III Central monitoring program. This includes evaluations of the monitoring well data, adequacy of the well network and recommendations for modifications to the monitoring well program.

3.2.1 Carbon Tetrachloride Pump and Treat System

This section summarizes the operational data from the OU IIII Carbon Tetrachloride Pump and Treat System, and offers conclusions and recommendations for the future operation. This system began operating on October 6, 1999. This summary is prepared annually and discusses the operational data from January 1, 2001 through December 31, 2001. In addition, a monthly DMR is submitted to EPA and NYSDEC for treated effluent water from the granular activated carbon units.

As part of BNL's Facility Review in 1997, a 1,000-gallon underground storage tank (UST) that was used in the 1950s for an experiment at the former Chemistry Department complex was unearthed at the southwest corner of Rowland Street and Rochester Street.

After the experiment finished in June 1955, the UST, which contained carbon tetrachloride, was pumped out. Reportedly, it was empty. However, based upon follow-up sampling, it is apparent that some of the carbon tetrachloride remained in it. Access to, and removal of, the tank was difficult because it was buried 20 feet below grade. It was removed on April 10, 1998 by BNL's Plant Engineering (PE) Department and supervised by SCDHS as part of the Facility Review Project. A small hole was found on the side of the tank. The tank contained approximately 15 inches of water contaminated with carbon tetrachloride at levels of 560,000 µg/l.

Carbon tetrachloride in samples from monitoring well 085-98, located approximately 25 feet downgradient of the former UST, have been as high as 179,000 µg/l. Sampling indicated that the contamination was confined to the immediate area surrounding the well and most likely was due to removing the tank.

More detailed findings on the contamination are discussed in the *Summary Report for the Carbon Tetrachloride Investigation*, dated March 1999 (Grosser 1999).

After the April 1998 discovery of groundwater contamination near the former Carbon Tetrachloride tank, a time critical removal action was implemented to pump out the highest concentrations in the groundwater. The major threat to the environment from this source is the further migration of contaminants in the groundwater, designated as a sole-source aquifer under the Federal Safe Drinking Water Act. The basis for the removal action was to remove and treat these high concentrations of carbon tetrachloride from the groundwater to minimize migration. This action is further discussed in the *Final Action Memorandum for the Carbon Tetrachloride Tank Groundwater Removal Action*, dated January 4, 1999 (BNL 1999a).

The Removal Action consisted of pumping and treating groundwater from monitoring well 085-98 for approximately nine days between January 14 - 29, 1999. Samples were taken each day. In this time, 87,300 gallons of groundwater were pumped and treated. The highest concentration of carbon tetrachloride was 183,000 µg/l; it fell to 25,000 µg/l on the final day of pumping. The volume of carbon tetrachloride removed was estimated as 4.6 gallons.

Additional groundwater characterization was performed in 2001 due to the presence of high concentrations of carbon tetrachloride downgradient of the treatment system (beyond the capture zone of the extraction wells) including the installation of new permanent monitoring wells. A third extraction well was constructed in the vicinity of the Weaver Drive recharge basin. Start-up of this well took place in December 2001.

3.2.1.1 System Description

A pump and treat system using liquid-phase granular activated carbon was recommended as a continuation of the Time Critical Removal Action. Installation of the system began in June 1999, and it was started up on October 6, 1999.

The Carbon Tetrachloride Pump & Treat System, consisting of three groundwater-extraction wells, is located in a building (TR-829) at the southwest corner of Rowland Street and Rochester Street. The first well, EW-13, is sited in the source area, adjacent to the building. The second well, EW-14, is further south, on the west side of Rochester Street. In December 2001 a new extraction well (EW-15) was added to the system. EW-15 is located 1,100 feet east south east of the treatment building (**Figure 3.2-5**). This was located to capture the high concentration portion of the plume, which had migrated downgradient of the two existing wells. Each well consists of a submersible pump sending water to three 2,500-pound granular activated carbon filter vessels housed in the treatment shed. Treated groundwater returns to the on-site drainage system via a 4-inch PVC pipe to a catch basin on Rowland Street.

Three groundwater extraction wells, EW-13, EW-14 and EW-15, control the VOC plume hydraulically. Groundwater is treated at a total flow rate of approximately 70 gpm, although the system can operate at rates up to 120 gpm. Operational monitoring data suggests that actual rates vary during the life of the system. Each well is 6-inches in diameter with a 20- foot long, 20- slot, 304 stainless-steel screen and a minimum 3-inch filter pack surrounding it.

The three recovery wells are located in areas where the highest VOC concentrations were identified. Groundwater is recovered using stainless-steel submersible pumps operating on a 208 volt, 3-phase power supply. The pumps have check valves at their discharge. **Table 3-6** shows the extraction well and pump settings.

Table 3-6. Carbon Tetrachloride Extraction Well Construction Data

Well	Screen Interval (Feet below grade)	Pump Setting (Feet)
(EW-13, 085-158)	32-52	42
(EW-14, 085-159)	32-52	42
(EW-15, 095-278)	65-85	75

The groundwater treatment facility consist of the treatment shed set on a concrete slab housing three 2,500-pound granular activated carbon adsorber vessels in series, PVC piping, valves and gauges, including starter and electrical panels, lighting, and space heating.

To evaluate the performance of the system, six sample ports are located in the treatment building. Four locations evaluate the performance of the carbon units, taking samples at the influent point, midpoint 1, midpoint 2, and at the effluent. Two additional sampling points are located on the influent piping from the extraction wells.

The water is discharged via a 4-inch PVC pipe from the treatment building to a catch basin approximately 100 feet west of the intersection of Rochester and Rowland Streets, on the south side of Rowland Street; **Figure 3.2-6** shows its route.

3.2.1.2 Groundwater Monitoring

Well Network: A network of 20 wells was designed to monitor the extent of the plume and the effectiveness of its remediation. The BNL Regional Groundwater Model was used to site the wells. The network was organized into plume core, sentinel and Middle Road Tracking wells as part of the DQO process; well designations/locations are shown in **Figure 3.2-7**. Six new monitoring wells were installed during 2001 and were sampled for the first time during the fourth quarter. The wells are designated as follows:

- Plume Core – utilized to monitor the high concentration or core area of the plume. In addition, plume core wells will be used to provide data for measuring the performance of the source control measure.
- Sentinel – used to monitor the effectiveness of the shallow remediation system.
- Middle Road Tracking –used to determine whether the contamination already downgradient of the groundwater remediation system will be captured by the Middle Road system.

Sampling Frequency and Analysis: The wells are sampled quarterly, and samples are analyzed for VOCs (see **Table 1-6**).

3.2.1.3 Monitoring Well Data Plume Description

Carbon tetrachloride is the primary contaminant in this plume that extends from the former UST (located at the corner of Rowland Street and Rochester Street) southeast to the vicinity of the Weaver Road recharge basin, a distance of approximately 1,300 feet (**Figure 3.2-8**). The width of the plume as defined by the 50 µg/L isocontour is approximately 120 feet. **Table 3-7** summarizes monitoring well VOC results exceeding the NYS AWQS. The complete 2001 analytical results from the monitoring of wells in the Carbon Tetrachloride Program are provided in **Appendix C**.

Based on data from the plume perimeter wells the plume has not shifted outside of the bounds of the current monitoring well network. The plume may have shifted slightly to the west, as evidenced by the declining carbon tetrachloride concentrations in well 95-45 (**Figure 3.2-9**).

Perimeter and sentinel well carbon tetrachloride concentrations were all below the NYS AWQS of 5 µg/L with most remaining below detectable levels during 2001.

- Plume core well 85-98, located just south of the former UST, displayed carbon tetrachloride concentrations greater than 150,000 µg/L in 1999. A decreasing trend in this well, begun in 1999 with the start of groundwater pumping, continued during 2001 with a concentration of 7 µg/L reported during the fourth quarter.

- Plume core well 85-17 is sited next to the BNL service station on Rochester Avenue and downgradient of the source area. It also continued to show declining carbon tetrachloride trends, which dropped from 3,760 µg/L to 409 µg/L in 2001.

- Plume core well 85-161 is located approximately 100 feet downgradient from well 85-98. The declining carbon tetrachloride concentration trend in this well since 1999 continued, with a fourth quarter result of 12 µg/L in 2001.

- Plume core well 95-183 is approximately 450 feet downgradient of EW-13. Carbon tetrachloride concentrations in this well have decreased from greater than 2,000 µg/L in 2000 to less than 1 µg/L during the last two quarters of 2001.

- Plume core wells 95-277 and 95-279 were installed in 2001 after groundwater characterization of the downgradient segment of the plume. They were not sampled until February 2002; however, the data are included in **Figure 3.2-9**.

Carbon tetrachloride was not detected in any of the sentinel wells during 2001.

Six groundwater vertical profiles were performed from April through July 2001 in two phases, the details of which are contained in the OU III Carbon Tetrachloride Plume Pre-Design Characterization Report (BNL, 2001b). The locations of these six vertical profiles are shown in **Figure 3.2-8**. The leading edge of the shallow, high concentration portion of the carbon tetrachloride plume was delineated for purposes of locating an additional groundwater extraction well immediately north of the Weaver Drive recharge basin. The southernmost vertical profile installed along the plume centerline, 95-248, contained carbon tetrachloride at 106 µg/L in the deepest sample interval (79-83 feet bls). The deep carbon tetrachloride contamination in vertical profile 95-248 and concentrations greater than 200 µg/L in well 95-88 (screened from 155-160 feet bls) indicate that the depth of the carbon tetrachloride has not been fully characterized.

3.2.1.4 Systems Operations

Operating Parameters

The influent, midpoints, and effluent of the carbon vessels were sampled twice a month. The extraction wells were sampled monthly. All samples are analyzed for volatile organic compounds (VOCs). In addition, the pH of the influent and effluent samples is measured monthly. The parameters for sampling pH and VOCs adhere to the requirements of the SPDES equivalency permit. All effluent samples during this period of operation were below the permit levels (**Table 3-8**).

Table 3-8. SPDES Equivalency Permit Levels January 1 - December 31, 2001

Parameters	Permit Limit (µg/l)	Max. Observed Value
pH	5.5/6.5** - 8.5	6.1 - 7.4
Bromodichloromethane	50.0	<0.5
Carbon Tetrachloride	5.0	<0.5
Chloroform	7.0	<0.5
Methylene Chloride	5.0	2.8B
Tetrachloroethylene	5.0	<0.5
Toluene	5.0	<0.5
Trichloroethylene	5.0	<0.5
Xylene (o-isomers)	5.0	<.05
Xylene (sum of M&P isomers)	10.0	<0.5

***Maximum effluent allowed by Requirements Equivalent to a SPDES Permit**
****pH value lowered by NYSDEC to 5.5 in September 2000.**
B - Detected in Blank

System Operations

The following summarizes the systems operations for each month of 2001. BNL's PE Division performed daily routine maintenance checks, in addition to sampling and routine and non-routine maintenance work. Details are given in the system's operation and maintenance manual. The daily operations and maintenance inspection logs are available in the project files and the treatment system building (TR-829).

January – September 2001:

The system ran continuously with the exception of four carbon change-outs (system was off for one day for each one), and also from February 21 to February 27 when EW-14 was shut down to replace a pump motor. All effluent samples met the equivalency permit requirements. The extraction wells were sampled once a month. A total of 27,610,000 gallons were pumped and treated. The system's flow rate averaged 73 gpm during this period.

October 2001:

The system was shutdown to perform a carbon change-out on October 30, 2001 and was re-started on October 31, 2001. The extraction wells were sampled on October 1, 2001. All effluent samples met equivalency permit requirements. A total of 3,218,000 gallons were pumped and treated in October. The system flow rate averaged 74.5 gpm during this month.

November 2001:

The system operated continuously this month. All effluent samples met equivalency permit requirements. The extraction wells were sampled on November 1, 2001. A total of 3,507,000 gallons were pumped and treated in November. The system flow rate averaged 70.5 gpm during this month.

December 2001:

The system was shut down for an addition of a new extraction well (EW-15) on December 17, 2001 and was re-started on December 20, 2001. The second system sampling event in December was missed due to the system shutdown. Both extraction wells were sampled on December 4, 2001. All effluent samples met equivalency permit requirements. A total of 3,328,000 gallons were pumped and treated in December. The system flow rate averaged 82.5 gpm during this month. Well EW-15 started operation on December 19 and pumping rates were changed to 50 gpm in EW-15 and EW-14. EW-13 continued to pump at 20 gpm.

3.2.1.5 Systems Operations Data

System Influent and Effluent

All parameters in the permit equivalency conditions were below the regulatory limit specified in the SPDES permit equivalency.

The overall quality of the influent water to the carbon vessels continued to show a decrease in the concentrations of contaminants. The influent carbon tetrachloride concentration at the beginning of system operation in October 1999 was 11,000 µg/l. The concentration was 29 µg/l at the end of December 2001. **Tables F-7** through **F-10** in **Appendix F** (located on the CD-ROM) summarize carbon tetrachloride concentrations in the influent, effluent and Midpoint samples.

Plots of the concentrations of carbon tetrachloride in the extraction wells and in the influent to the carbon vessels against time are shown in **Figure 3.2-10**. Extraction well EW-13 showed a steady decline, with a high of 128 µg/l in January 2001 falling to 33 µg/l in December. The downgradient extraction well, EW-14 also showed a steady decline, from 67 µg/l in January 2001 to 29 µg/l in December 2001, as did the combined influent water quality for 2001. A concentration of 1,010 µg/L was observed in new extraction well EW-15 in the first sampling event on December 26, 2001.

Cumulative Mass Removal

Mass removal was estimated from the results of water collected from the influent and calculations of the volume of water pumped. During 2001, approximately 13,024,000 gallons and 25,348,300 gallons, respectively, were removed and treated from EW-13 and EW-14, for a total of 38,372,300 gallons. **Table 2-3** lists monthly pumpage values for 2001. Groundwater was treated at an average flow rate of 73 gpm, 77gpm, 81 gpm, and 80 gpm for the 1st, 2nd, 3rd and 4th quarters of 2001, respectively. These rates were used in determining mass removal of VOCs.

Average flow rates for each monthly monitoring period were used to determine the pounds removed, in combination with the carbon tetrachloride concentration in the carbon vessels' influent. **Table F-11** in **Appendix F** gives total pounds of mass of carbon tetrachloride removed by the treatment system; **Figure 3.2-11** plots mass removal versus time. Approximately 17.3 pounds (1.32 gallons) of carbon tetrachloride were removed during 2001, with a cumulative total of 219 pounds (18.22 gallons) since the system started.

3.2.1.6 System Evaluation

The pump and treat system continued effectively in 2001, removing high concentrations of carbon tetrachloride from groundwater near the former underground storage tank. No permit equivalencies were exceeded and no operating difficulties were experienced beyond normal maintenance. groundwater characterization work undertaken during 2001 was followed by the installation and operation of a third groundwater extraction well.

The performance of the OU III Carbon Tetrachloride Pump and Treat system can be evaluated based on the six major decisions identified for this system after applying the DQO process.

1. Was the BNL Contingency Plan Triggered?
Groundwater characterization samples collected in 2001 showed carbon tetrachloride concentrations up to 3,760 µg/L downgradient of the capture zone of EW-13 and EW-14. These results triggered an additional round of groundwater characterization further downgradient and demonstrated the need for a third groundwater extraction well. This well will serve to remediate the high carbon tetrachloride concentrations that were downgradient of the capture zones of wells EW-13 and EW-14.

Were the cleanup goals met?
This system was designed as a source control measure that when integrated with the other groundwater treatment systems and natural attenuation, will result in meeting the cleanup goals. Initial model estimates indicate that 90% of the shallow carbon tetrachloride plume will be remediated within 4 years. However, a number of assumptions were required to develop such an estimate. TVOC trends in plume core wells in the vicinity of EW-13 and EW-14 continued to decline during 2001; however significant mass remains in the aquifer. The third extraction well (EW-15) only became operational in December 2001. With this third extraction well, the source control system is complete and is just beginning to perform as needed to control and reduce the

source. **Figure 3.2-12** plots the mean concentration of each plume core well computed from measurements over the previous two years. Any lower level carbon tetrachloride contamination that already has migrated south of the third extraction well is predicted to be captured by the OU III Middle Road Pump and Treat System.

3. If not, has the plume been controlled?

Groundwater monitoring data showed some local plume growth, which triggered a significant modification to the treatment system. Before adding the third extraction well, EW-15, the entire high concentration, shallow carbon tetrachloride plume was not controlled. Because the third well only became operational in December 2001, the 2001 groundwater monitoring data cannot reveal whether the shallow plume is controlled. The 2002 groundwater monitoring data will be utilized to make this determination.

Groundwater elevation data is obtained from most of the OU III Carbon Tetrachloride program wells in addition to wells located throughout the BNL on-site and off-site areas on a quarterly basis. Groundwater contour maps were drawn using this data (**Figures 2-3** and **2-4**). The capture zone for the Carbon Tetrachloride Pump and Treat System is indicated in **Figure 3.0-1**. The capture zone depicted includes the 50 µg/L isocontour, which is the capture goal of this system.

4. Is the System operating as planned?

The system continues to be very effective at removing carbon tetrachloride from the Upper Glacial aquifer. Influent carbon tetrachloride concentrations have continued to steadily decline in EW-13 and EW-14 during 2001. Since the leading edge of the plume was not completely captured. EW-15 was installed to address the high concentration area which has migrated south from the former UST area.

Figure 3.2-13 shows both the actual and predicted mass removals of VOCs versus time. Early indications are that the mass removal rate generally is tracking as planned. Several key model estimate parameters that have significant uncertainty are the partitioning coefficient of carbon tetrachloride, the significance of any historical releases other than the tank spill recently observed, and the rate of desorption (linear or non-linear) of carbon tetrachloride from the aquifer. The modeling predictions will be refined as data collection continues.

5. Have asymptotic conditions been demonstrated?

Average TVOC concentrations for the plume core wells are plotted in **Figure 3.2-12**. Based on the trend demonstrated in that figure, the asymptote has not been reached. Average TVOC concentrations increased during 2001. This increase is a reflection the addition of new plume core wells to the monitoring program.

6. Is an engineering evaluation needed to modify the Middle Road treatment system to ensure the capture and remediation of the carbon tetrachloride plume?

A work plan will be developed for additional characterization of the deep carbon tetrachloride contamination in 2002. An evaluation of the need to modify the Middle Road system will be considered if warranted by the results of the additional characterization.

3.2.1.7 Recommendations

The following are recommendations for the OU III Carbon Tetrachloride groundwater remediation system and monitoring program:

1) Due to the low carbon tetrachloride concentrations in extraction well EW-13 this well will be shut down beginning in the third quarter of 2002. Sampling of both EW-13 and EW-14 will continue on a monthly basis.

2) A groundwater modeling analysis will be performed in late 2002 to review the remediation system optimization and determine whether the upgraded system is performing as planned. A work plan will be developed during 2002 to outline the characterization of deep carbon tetrachloride contamination, which is not currently being addressed by the existing remediation system. This plan will be developed in conjunction with the groundwater modeling and a field investigation implemented during the fall of 2002.

3) The adequacy of the monitoring well network will be re-evaluated in late 2002.

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3.2.2 Building 96 Air Stripping System

This section summarizes the operational data from the OU III Building 96 source control system of recirculation wells with air stripping treatment for 2001, and presents conclusions and recommendations for future operation. The system began operation in February 2001. This summary is prepared annually and presents the operational data from January 1 through December 31, 2001. The analytical information from monitoring wells and characterization work is evaluated in detail.

3.2.2.1 System Description

The Building 96 groundwater treatment system consists of four recirculation treatment wells (RTW-1 through RTW-4) housed in individual treatment sheds. Construction details for the treatment system components are contained in as-built drawings available through Brookhaven. The wells used in the system are referred to as recirculation treatment wells since water is withdrawn from, and recharged to, the aquifer in the same well. Contaminated groundwater is drawn from the aquifer, via a submersible well pump, into a lower well screen, which is set near the base of the contaminant plume. The groundwater then is pumped into a shallow stripping tray adjacent to the well, and recharged back to the shallow portion of the plume through the upper screen after treatment.

An additional feature of the recirculation well technology, and the reason it was chosen for the Building 96 area, is its relatively small, localized impact on aquifer hydraulic heads. Groundwater is returned to the aquifer in the same well, creating a zone of influence around the well without generating a large drawdown that may impact local groundwater flow. Further, since groundwater is returned to the aquifer through the same well just above the point of extraction, there are no large mounding effects that typically occur from discharges to standard recharge basins.

The Building 96 system removes contaminants, from the groundwater (liquid phase) to the vapor phase via air stripping in a low profile stripping tray adjacent to each wellhead inside the treatment sheds. The vapor phase contaminants are then passed through a moisture-knockout drum in each treatment shed, and piped to Treatment Shed No.3 where the contaminated vapor streams from the four treatment sheds are combined in a common pipe manifold. The combined VOC contaminated vapor stream is passed through an electric reheat coil (duct heater) to lower relative humidity, and then through a series of Granular Activated Carbon (GAC) filters to remove VOCs. The clean air is discharged to the atmosphere.

Treatment Well RTW-1 is located in the northern most treatment shed in the area having highest concentrations of VOCs in groundwater. Treatment Wells RTW-2, 3 and 4 are located farther south (hydraulically downgradient), in an east-west line to intercept, capture and treat the groundwater plume moving south from the vicinity of RTW-1.

Recirculation Treatment Wells

The major component of the groundwater treatment system is the four recirculation treatment wells (RTW). RTW-1 is located in the area containing the highest VOC concentrations in the

Building 96 area and the other three wells, RTW-2 through RTW-4 (from west to east), provide hydraulic control of the VOC plume. **Figure 3.2-14** shows the RTW locations.

The groundwater recirculation wells provide hydraulic control and create a re-circulation cell. A portion of the treated groundwater circulates through the cell and back into the extraction screen, while the balance flows to the south in the direction of regional flow. Recirculation is not necessary because MCLs are achieved by the air stripping treatment. The degree of re-circulation and therefore, the extent of the capture zone, is influenced by the well pumping rate, the distance between the extraction and recharge screens and the hydraulic parameters of the aquifer. Of these, only the pumping rate can be controlled during system operation.

Each treatment well is 8-inches in diameter with two separate 10-foot long, 304 stainless steel screens. The wells are constructed with a minimum three-inch filter pack. An inflatable packer separates the two well screens; it is inflated through an airline that runs to the wellhead and is fitted with a pressure gauge. The submersible pump is located below the packer to draw water in from the lower screen.

The groundwater around each treatment well is recirculated using a 1 hp stainless steel submersible pump operating on a 208 volt, 3-phase power supply. Each pump has a rated capacity between 20 and 30 gpm at a total discharge head (TDH) of 80 feet. The flow rate of each water pump can be controlled from the treatment sheds by adjusting the butterfly throttling valves. Each pump and inflatable packer assembly is supported in the well with a stainless steel cable. Discharge piping is 1-1/2 to 2 inches in diameter. **Table 3-9** shows the depths of the recirculation wells and pump settings.

Table 3-9. OU III Building 96 Recirculation Well Construction Data

Well	Well Depth (bls)	Influent Sreen Depth (bls)	Effluent Screen Depth (bls)	Pump Intake Setting (bls)
RTW-1	61	48-58	25-35	52
RTW-2	61	48-58	25-35	52
RTW-3	61	48-58	25-35	52
RTW-4	61	48-58	25-35	52

bls = below land surface.

Air Treatment Facility

Several components comprise the air treatment system. Air lines run below grade from each treatment shed to Treatment Shed No. 3 carrying VOC laden air. Each air line joins to a common pipe header, which is connected to a duct heater. After the air passes through the duct heater it flows through two vapor phase granular activated carbon (GAC) filter vessels, piped in series, before it is released.

The airflow to the stripping tray at each well can be controlled by adjusting the blower effluent damper at the individual treatment sheds, or by adjusting the gear operated butterfly valves in Treatment Shed No. 3. The air pipe and valve configuration enables increased airflow to wells exhibiting higher VOC concentrations, which results in higher removal efficiencies. Airflow meters are located on the influent line to each blower, with a fifth airflow meter located on the discharge line from the GAC filter vessels. After the stripping tray, air piping is connected to a knockout drum inside each treatment shed to collect moisture. After the knockout drum, the air piping runs below grade and travels to Treatment Shed No. 3 where it connects to a common header, before passing through the duct heater.

Condensate may accumulate in the below grade air lines and condensate pumps are employed to remove standing water. The pumps are installed in the air lines prior to the duct heater and are located in Treatment Shed No. 3. This system removes condensate from the air lines, allowing for unobstructed airflow from Treatment Sheds No. 1, 2, and 4. The pumps are operated by an adjustable timer and can also be triggered manually. Condensate removed from the air lines is pumped into the top of the RTW-3 air stripper tray for treatment and subsequent recharge.

The duct heater air dehumidification system is self-controlling. This system lowers the relative humidity by heating the air prior to entering the GAC vessels. This lowering of the relative humidity of the air is necessary to prolong the life of the GAC bed and to minimize the pressure loss through the filters. When the relative humidity of the air “down stream” of the duct heater rises above an adjustable set point, the heater control panel will increase the output of the heating element, so long as the temperature remains below the emergency high temperature setting. The set point should be adjusted to a minimum temperature of approximately 30 degrees above the ambient air temperature for proper dehumidification.

Air leaves the duct heater and travels through two vapor phase GAC filter vessels, piped in series, to remove VOCs from the air stream. Each filter vessel contains 13,600 lbs of GAC. The GAC filters are located outside of Treatment Shed No. 3.

3.2.2.2 Groundwater Monitoring

Well Network: The monitoring network of 17 wells was designed to monitor the PCE plume originating in this source area, and the effectiveness of a groundwater remediation system (**Figure 3.2-13**).

Sampling Frequency and Analysis: The wells are sampled quarterly, and samples are analyzed for VOCs (see **Table 1-6**).

3.2.2.3 Monitoring Well Data Results

The VOC plume in the Building 96 area is currently monitored by 17 permanent wells shown on **Figure 3.2-14**. VOC concentrations exceeding NYS AWQS during 2001 are summarized in

Table 3-10. Additional characterization of the plume, consisting of seven temporary, geoprobe boreholes was conducted in October 2001. This activity is discussed in detail in Section 3.2.2.3.1.

The plume distribution, drawn from the permanent well network data for the fourth quarter of 2001 is shown in **Figure 3.2-15**. The plume contours resulting from the permanent well data combined with the geoprobe data are shown in the third quarter 2001 map in **Figure 3.2-16**. Historical TVOC trends for key wells are shown in **Figure 3.2-17**. Comparing of the plume outlines and concentrations in these figures indicates that after an initial increase in the beginning of the year, the plume is shrinking, and the highest concentrations of VOCs are declining in response to the pumping and treatment of the RTW wells. These conclusions are in line with the mass removal data and the previously projected performance of the system as discussed below.

3.2.2.3.1 Geoprobe Investigation

Based on the rise of TVOC concentrations in perimeter monitoring wells through the third quarter of 2001, and the increase in RTW 2, -3, and –4 (a rise but subsequent decline in RTW-1), a geoprobe investigation of the plume was conducted. The spreading of the plume could have caused the observed declines in concentration, rather than cleanup work, especially in the vicinity of RTW-1 where the silty unit could interfere with the development of the recirculation cell. In addition, the plume may have shifted vertically out of the screened zones of the wells. The geoprobe investigation would verify that cleanup was continuing as planned.

Seven borings were installed at locations shown on **Figure 3.2-16** and sampled for VOCs continuously at four-foot intervals from the water table to a depth of 80 feet bls. The data are presented on **Table F-12** in **Appendix F** (located on the enclosed CD-ROM) and three of the borings are included in the cross section of the plume shown in **Figure 3.2-18**. **Figure 3.2-19** compares the distribution of the plume between 2000 and the fourth quarter of 2001.

Some amount of spreading has occurred on the western side of the plume near RTW-1, as shown in **Figure 3.2-19**. The highest concentration interval of 095-264 (355.6 µg/L) is higher than earlier data from nearby geoprobe locations (95-116 and 95-117). However the concentration contours are similar to the earlier ones and the contaminants are upgradient of RTW wells 2, 3 and 4 at the B96 scrapyard. Also this pattern was predicted after one year of operation by the groundwater modeling in the 90% Design Report. As these contaminants migrate downgradient with the groundwater they will be treated by RTW wells 2, 3 and 4. Additional indication of some contaminant spread can be seen in the initial increase in concentration in upgradient permanent well 095-160 (renamed 085-293 in this report to correct an initial identification grid error). The subsequent concentration decline is evidence that the spread is not significant. However, several additional permanent monitoring wells are recommended in the summary section of this report to track the situation.

Additional information gleaned from the recent geoprobe borings is that the permanent wells are located at the proper depth to monitor the bulk of the plume contoured in cross section in **Figure 3.2-18**. The contaminants shown at depths of approximately 70 feet bls also were detected in the original pre-design characterization. These deeper VOCs are within the capture zones of

Building 96 system recirculation wells. Geoprobes will be installed to periodically monitor changes at depth over time.

Data from geoprobes 95-263 shows that high concentrations of VOCs, up to 4,870 µg/L are present still just at the silt layer upgradient of RTW-1. To monitor this concentration more closely, two new permanent monitoring wells are recommended in the summary section of this report.

3.2.2.4 Systems Operations
Operating Parameters

The influent, midpoint and effluent air samples from the carbon vessels were sampled monthly and analyzed for volatile organic compounds by EPA method TO-14A. These samples monitor the efficiency of the GAC units and demonstrate when a carbon change-out is required. Please note, based on the consistency of the air sampling results in 2001, beginning in April 2002, the air sampling frequency will be changed to quarterly. Air sampling results are included in **Table F-13** in **Appendix F**.

Influent and effluent water samples are collected monthly from each of the four recirculation wells; all samples are analyzed for volatile organic compounds by EPA method 524.2. These samples determine the well's removal efficiency and performance. Based on these results operational adjustments can be made to optimize the system's performance.

System Operations

The following summarizes the system's operations for 2001. BNL's Environmental Services Division performs daily checks on the system and undertakes system sampling. BNL's PE Division carries out routine and non-routine maintenance. Details of these activities are given in the system's operation and maintenance manual. The daily operations and maintenance logs are available in the project files.

January-September 2001:
The Building 96 Groundwater Treatment System underwent a comprehensive 12-week start-up monitoring program beginning February 6, 2001 and ending May 7, 2001. The findings are discussed in the *Building 96 Groundwater Source Removal Treatment Start –Up Report* dated August 2001. On July 13, the flow rate in RTW-1 was reduced from approximately 25 gallons per minute (gpm) to 15 gpm. This was performed as a precaution against potential spreading of the plume until an updated plume map could be prepared from additional geoprobe data. Influent and effluent water and air samples from the treatment system were collected monthly from May through September 2001. The effluent air samples were much lower than the DAR-1 Air Toxics Assessment limits. Effluent water samples were at or lower than one half the drinking water standard or non-detectable. The average flow rate for the system was 70 gpm.

October 2001:
Influent and effluent water and air samples from the treatment system were collected on October 2, 2001. The effluent air samples were much lower than the DAR-1 Air Toxics Assessment

limits. Effluent water samples were at or lower than one half the drinking water standard or non-detectable. The average flow rate for the system was approximately 70 gpm. A geoprobe investigation was conducted to determine whether the recirculation wells were "spreading" the contaminants laterally.

November 2001:
Due to Programmable Logic Controller (PLC) problems, the system experienced intermittent outages during November. In addition, the system was shut down from November 9th through the 12th, to repair the power line. Influent and effluent water and air from the treatment system was sampled on November 1, 2001. Contaminants in the effluent air samples were much lower than the DAR-1 Air Toxics Assessment limits. Effluent water samples were at or lower than one half the drinking water standard or non-detectable. The average flow rate for the system was approximately 70 gpm.

December 2001:
The system experienced intermittent outages during the beginning of December due to a faulty fuse in the duct heater. Samples were collected from the influent and effluent water and air on December 7, 2001. The effluent air samples were much lower than the DAR-1 Air Toxics Assessment limits. Effluent water samples were at or lower than one half the drinking water standard or non-detectable. The average flow rate for the system was approximately 70 gpm.

In 2001, approximately 24,238,000 gallons of groundwater were pumped and treated (**Table 2-3**).

3.2.2.5 Systems Operations Data

Recirculation Well Influent and Effluent

During 2001, we noted a significant overall decrease in TVOC concentrations in the influent of wells RTW-1 and RTW-3. These wells are located in the center of the plume, with RTW-1 at the northern end (upgradient), and RTW-3 in the southern end (downgradient). Influent concentrations in wells RTW-2 and RTW-4, downgradient of the plume center, fluctuated throughout the period but TVOC's remained less than 200 µg/L. **Table F-14** in **Appendix F** lists the influent and effluent TVOC concentrations for each of the four recirculation wells. No tritium was detected in the system influent.

Throughout 2001, effluent concentrations in all recirculation wells were, at or below, one half the drinking water standard, or non-detectable.

Cumulative Mass Removal
Mass-balance calculations were made to determine the mass of VOCs removed from the aquifer by the pumping wells, during this period of operation. For each RTW, we used the gallons of water pumped during each month, in combination with the influent TVOC concentrations to calculate the pounds removed. The pumpage and mass removal data are summarized in **Table F-15** in **Appendix F**. To date, the system removed approximately 35 pounds of VOCs. **Figure 3.2-20** plots the total pounds of TVOCs removed vs. time.

Air Treatment System

Air samples were collected monthly from the GAC vessels before treatment (influent), between the two vessels (mid-point), and after the second vessel (effluent). The findings are utilized to monitor the efficiency of the GAC units and to determine when a carbon change-out is required (**Table F-13**). Airflow rates, measured for each air-stripping unit inside the treatment building, show that they typically range between 250 and 450 cfm for each of the four wells. Assuming a total airflow rate of 1200 cfm, all compounds detected in the carbon effluent during the operating year were much lower than the New York State DAR-1 Air Toxics Assessment limits for the worst-case potential impacts to the public.

Although the concentrations in the GAC air effluent have been well within the DAR-1 Toxics Assessment, the presence in the midpoint and effluent of benzene compounds not present in the influent or the groundwater is a concern. As long as the concentrations remain below the DAR-1 levels the situation only requires monitoring.

Another concern is TCA appearing in the midpoint air samples on November 1 and December 7, 2001. Since this compound also is in the influent and the groundwater, it appears to be breaking through the first carbon filter. Additional monthly samples will be taken in the first and second quarters of 2002. The system was designed such that the carbon would not have to be changed out during its operational life.

3.2.2.6 System Evaluation

The system is operating according to expectations and removed 35 pounds of VOCs during 2001. Discharge concentrations to the aquifer have been non-detected or up to one-half the drinking water standard. Twenty-four million gallons of groundwater were treated during the year.

Based on data from the permanent monitoring well network and the geoprobes installed during October 2001, the plume is behaving as expected with little spreading of the contaminants due to the recharge of treated water. The contaminants continue to be located within the capture zones of the remediation wells. A plot of average plume core monitoring wells over time is shown in **Figure 3.2-21**. Well concentrations declined during 2001. To address the remaining contaminants, the monitoring network will be modified as discussed below.

Figure 3.2-22 shows the actual removal of VOC mass over time versus the model predictions. Source remediation, as measured by mass removal, is continuing as predicted. The change in the plume distribution from 2000 to 2001 is shown in **Figure 3.2-19**.

Concentrations throughout most of the plume have declined significantly since the pre-design characterization. This is attributable to the operation of the system. According to the geoprobe data, a portion of the aquifer upgradient of RTW-1, in the silty layer, continues to show elevated VOC concentrations up to 4,870 µg/L.

3.2.2.7 Recommendations

The following are recommendations for the OU III Building 96 groundwater remediation system and monitoring program:

1) Two new permanent monitoring wells will be installed upgradient (1) and down gradient (1) of the high concentration area after two additional geoprobes are installed to verify the concentrations.

2) One additional permanent monitoring well will be installed southwest of well 095-159 at the GP-2 location to monitor potential westward spread of the contaminants.

3) Contaminants deeper than 70 feet from the land surface will be monitored by the repeated installation of geoprobes GP-2 and GP-6.

4) Air emissions data will continue to be collected monthly at least for the first two quarters of 2002 to track aromatic compounds and TCA concentrations in the midpoint and effluent of the air treatment equipment.

3.2.3 Middle Road Pump and Treat System

This section summarizes the operational data from the Middle Road groundwater pump and treat system for 2001, and presents conclusions and recommendations for future operation. This system began operating on October 23, 2001. The analytical data from the monitoring wells also is evaluated in detail. In addition, a monthly DMR is submitted to EPA and NYSDEC for treated effluent water from the air-stripping tower.

3.2.3.1 System Description

Recovery Wells

Six groundwater extraction wells, RW-1 through RW-6, hydraulically control the VOC plume (**Figure 3.2-23**). Groundwater currently is extracted at an average flow rate of approximately 600 gpm, although rates vary during the system's life, based on operational monitoring data. Each well is 8-inches in diameter with a 30 to 40 foot long, 304 stainless-steel screen, and a minimum 3-in. filter pack surrounding it. The slot sizes for each well screen vary from 10 to 20 slot, based on the results of sieve analyes from the Pre-Design Characterization. The wells vary in depth from 130 to 268 feet.

VOC concentrations in groundwater along BNL's Middle Path are stratified vertically and horizontally. The six recovery wells are screened at the depths showing the highest VOC concentrations. The pipe and valve configuration enables pumping rates to be increased at wells exhibiting higher VOC concentrations, and recovery wells to be added, if required. The extraction wells are sampled monthly.

Groundwater is extracted by stainless-steel submersible pumps operating on a 480 volt, 3-phase power supply. The pumps have check valves at the discharge. The discharge piping is 3-inch carbon steel pipe up to a pitless adapter, and then 4-inch PVC piping to the well house. **Table 3-11** shows the depths of the extraction wells and the pump settings.

Table 3-11. Middle Road Extraction Well Construction Data

Well #, (Site Id)	Screen Interval (Feet below grade)	Pump Setting (Feet)
MRW-1, (113-23)	90-130	110
MRW-2, (113-24)	170-200	185
MRW-3, (113-25)	228-268	248
MRW-4, (113-26)	150-180	165
MRW-5, (113-27)	150-180	165
MRW-6, (106-66)	188-218	205

Well House

The well house is situated along Middle Path in the center of the southern portion of the site to the west of the wells. Each of the six pump discharge lines is reduced from 4-inch to 3-inch diameter just before it enters the well house. Inside the well house, each pump discharge line contains a gate valve to isolate the line, a propeller-type flow meter, a check valve, and a butterfly valve to control flow. High and low-level pressure switches and a sampling port also are located on each line before the gate valve. After the butterfly valve, the piping manifolds into a 10-inch discharge line that conveys the water to the treatment facility.

Treatment Facility

The groundwater treatment facility consists of a treatment control building and an air- stripping tower system, and is located just northwest of Rochester Street and Princeton Avenue. The facility is designed for limited automatic operation, defined as automatic equipment shutdown with manual restart. Any alarm condition will signal a common trouble alarm at BNL's Central Chilled Water Facility requiring a physical inspection of the main control panel to determine the source of the alarm. The treatment building also houses a 150-gallon riser drain tank used to temporarily capture drained water from the tower's influent line if the air-stripping tower is shut down during cold weather. Two re-injection pumps send the drained water back into the stripping tower's influent line when the system is placed back in operation.

Air-Stripping Tower

The packed air-stripping tower removes VOCs from the groundwater to meet the discharge criteria. The stripping tower is 6 feet in diameter and 52 feet tall. It is equipped with a minimum of 39 feet of 2-inch plastic packing, configured in two separate beds. The tower's internals include five influent spray nozzles, water distribution trays for the two media beds, packing support/air distributor for the two media beds, a mist eliminator, screened air exit, and water redistribution rings. The 39-foot height of the packing media is based on the requirements to remove TCA. The efficiency of removing other VOCs of interest is greater than the required minimum, and effluent concentrations are lower than NYSDEC permitted levels. A centrifugal blower supplies air to the tower at an average flow rate of 3,200 cfm, providing an air to water ratio of 34:1 at the maximum water flow rate of 700 gpm.

Recharge Basin

The water discharged from the air-stripping tower flows by gravity through 10-inch diameter PVC piping to either of two recharge basins. A buried house trap in the piping has a 30-inch water seal to prevent air, under pressure in the stripping tower, from discharging through this line. The discharge piping splits to convey the water to either the OU III recharge basin, or to the existing HP recharge basin. A gate valve in the line to each basin controls the flow to the basin.

The OU III basin can receive a continuous flow of greater than 850 gpm; this figure includes a sufficient factor of safety to account for variations in subsurface soil and fouling of the basin over time. The existing HP recharge basin provides backup for the discharge facilities during maintenance of the primary OU III basin.

A new discharge pump station was constructed to distribute the flow of water into both the OU III and RAV recharge basins. The pump station balances the flow between the two basins, therefore managing the flow of groundwater recharge.

3.2.3.2 Groundwater Monitoring

Well Network: The Middle Road Monitoring Program consists of a network of 26 monitoring wells located along the road between the fire break road and the OU III South Boundary Pump and Treat System (**Figure 3.2-24**). Eleven new wells were installed during 2001 to supplement 15 existing wells and complete the current network. The wells are designated as follows:

- Plume Core – utilized to monitor the high concentration or core area of the plume. In addition, plume core wells will be used to provide data for measuring the performance of the system.

- Perimeter – used to define the extent of the plume both horizontally and vertically.

- Bypass Detection –used to determine whether the plume capture performance objective is met.

Sampling Frequency and Analysis: The 26 Middle Road wells are monitored quarterly and the samples are analyzed for VOCs. Several wells that also are part of the OU III HFBR Tritium Monitoring Program are also monitored for tritium (**Table 1-6**).

3.2.3.3 Monitoring Well Data

The complete VOC results are shown in **Appendix C** (located on the enclosed CD-ROM). VOC results exceeding the NYS AWQS are summarized in **Table 3-12**. The monitoring well network was completed in early 2001 a pre-system start-up sampling round was performed for the new wells during June 2001. A second (post start-up) sampling round took place in December 2001.

The highest plume concentrations are found in the vicinity of extraction wells RW-2 and RW-3, based on influent data for these wells and available monitoring well data. TVOC concentrations in monitoring wells east of RW-3 are below 100 µg/L. The highest TVOC concentration detected was in bypass detection well 113-17 at 1,466 µg/L. The VOCs in this bypass well were present prior to the operation of the pump and treat system and will be ultimately captured by the OU III South Boundary System.

Plume core well 105-23 is located approximately 2000 feet upgradient of RW-1 near Princeton Avenue; it contained high concentrations of VOCs up to 1,794 µg/L during 2001. VOC concentrations have steadily risen in this well since early 2000, as shown by the trend plot in **Figure 3.2-5**. This increase correlates with operation of the HFBR Pump and Recharge system located approximately 285 feet east of the well. Initially, high VOC concentrations in this well declined in 1997 following the start-up of the remediation system, and rapidly increased during 2000 after the HFBR Pump and Recharge system was put on on stand-by. TVOC concentrations in plume core wells further to the east along Princeton Avenue are generally below 100 µg/L in 2001, except for well 105-44 in which concentrations ranged as high as 423 µg/L. **Figure 3.2-25** shows the vertical distribution of contamination running along an east-west line through the extraction wells; the location of this cross section is given in **Figure 3.2-1**.

3.2.3.4 Systems Operations

The influent and effluent to the air stripper tower are sampled twice a month. Individual extraction wells currently are sampled monthly. All samples are analyzed for volatile organic compounds. In addition, the pH values of the influent and effluent samples are recorded weekly. The effluent sampling parameters for pH and VOCs follow the requirements of the SPDES equivalency permit. In addition, system influent samples are analyzed for tritium during each system sampling event. Tritium remains below detection limits in all samples. All effluent samples from the treatment system during this period of operation were below equivalency permit levels (**Table 3-13**).

Table 3-13. SPDES Equivalency Permit Levels November 1 - December 31, 2001

Parameters	Permit Limit (µg/l)*	Max. Observed Value (mg/L)
pH (range)	6.5 - 8.5	7.7.
Carbon Tetrachloride	5.0	ND
Chloroform	7.0	ND
1,1-Dichloroethane	5.0	ND
1,2-Dichloroethane	5.0	ND
1,1-Dichloroethene	5.0	ND
cis-1,2-Dichloroethylene	5.0	ND
trans-1,2-Dichloroethylene	5.0	ND
Tetrachloroethylene	5.0	0.25 J
1,1,1-Trichloroethane	5.0	ND
Trichloroethylene	5.0	ND

*** Maximum effluent allowed by Requirements Equivalent to a SPDES Permit.**
ND - Not detected above the method detection limit of 0.50 mg/L
J - Estimated value, below the method detection limit.

System Operations

The following summarizes the systems operations for each month of 2001. The PE Division, in addition to routine and non-routine maintenance work, made routine maintenance checks daily on this system. Details are given in the operation and maintenance manual for this system. The daily operations and maintenance inspection logs are available in the project files and the treatment system buildings.

October 2001:

The Middle Road Groundwater Treatment System began start-up testing in October 2001, and operated for approximately 10 days. The system testing was tested during the beginning of the month, and on October 23, it was started to complete a 7-day pump test. This system pumped and treated 8,871,510 gallons of water in October. The average flow rate for the system was 616 gpm. Influent and effluent waters to the treatment system were sampled six times in October and the effluent met all equivalency permit requirements.

November 2001:

The Middle Road Groundwater Treatment System began its operation and maintenance phase in November 2001. Since this new system operates in conjunction with the South Boundary Groundwater Remediation System, both systems experienced some downtime this month for troubleshooting. The Middle Road system pumped and treated a total of 18,410,710 gallons of water in November. The average flow rate was 426 gpm. Influent and effluent waters to the treatment system were sampled twice in November. All effluent samples met equivalency permit levels.

December 2001:

A total of 28,071,330 gallons of water were pumped and treated in December. The average flow rate was 629 gpm. The influent and effluent waters to the treatment system were sampled twice in December and the effluent met all equivalency permit requirements.

A total of 55,353,550 gallons of water were pumped and treated during the fourth quarter of 2001.

3.2.3.5 Systems Operations Data

System Influent and Effluent

All parameters in the permit equivalency conditions were within the specified ranges during 2001. The effluent data were either below the method detection limit, or below the regulatory limit specified in the permit equivalency conditions.

Figure 3.2-26 plots the concentrations of TVOC, TCA, and PCE in the influent to the system's air-stripper tower vs. time. The influent's overall water quality showed a slight decrease in concentrations over the reporting period. The average concentration of TVOCs in the influent between October 24, 2001 and December 31, 2001 was 123.55 µg/l (see **Table F-16, Appendix F**). The system influent also is sampled twice per month for tritium; it was not detected in any sample during 2001. The results from sampling the influent and effluent are summarized in **Tables F-16** and **F-17**, respectively.

Cumulative Mass Removal

Mass balance was calculated for the period of operation to determine the mass removed from the aquifer by the pumping 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 577 gpm from October 24, 2001 through December 31, 2001 (**Table 2-3,** and **Table F-19**). The cumulative total of TVOCs removed was approximately 38.59 pounds since the system began start-up testing on October 23, 2001. The cumulative total of TVOCs removed vs. time is plotted in **Figure 3.2-27**.

Air Discharge

Table 3-14, below, shows the air-emission data from the system for the operational period, and compares the values to levels stipulated in NYSDEC Air Guide 1 regulations. Emission rates are obtained through mass-balance calculations for all water treated during that time. The concentration of each constituent was averaged for the operation and maintenance period of November1, 2001 through December 31, 2001, and those values were used in determining the emission rate. All air emissions were below allowable levels.

Table 3-14. Air Emission Rates November 1, 2001 - December 31, 2001

Parameter	**Allowable***	**Carbon**
Carbon Tetrachloride	**0.022 lb/hr**	**0.0038 lb/hr**
Chloroform	**0.0031 lb/hr**	**0.0004 lb/hr**
1,1 - Dichloroethane	**10 lb/hr****	**0.0001 lb/hr**
1,2 - Dichloroethane	**0.008 lb/hr**	**0.0001 lb/hr**
1,1 - Dichloroethylene	**0.034 lb/hr**	**0.0005 lb/hr**
cis-1,2-Dichloroethylene	**10 lb/hr****	**0.0003 lb/hr**
Trans-1,2-Dichloroethene	**10 lb/hr****	**0.0000 lb/hr**
Tetrachloroethylene	**0.387 lb/hr**	**0.0235 lb/hr**
1,1,1 - Trichloroethane	**10 lb/hr****	**0.0018 lb/hr**
Trichloroethylene	**0.143 lb/hr**	**0.0006 lb/hr**

*** - Emission Rate Potential (ERP) based upon NYSDEC Air Guide 1 Regulations.**
**** - 6 NYCRR Part 212 restricts emissions of VOCs to a maximum of 10 pounds per hour without controls.**
***** Actual Emission Rate reported as the average rate for November 1 through December 31, 2001.**

Extraction Wells

The six extraction wells are sampled monthly. Decreasing VOC concentrations were observed in five of the six extraction wells over the two months that the system was operating (**Table F-18**, **Appendix F**). RW-6 showed a slight increase in VOC concentrations although, generally, the concentrations in this well were low (less than 17 µg/L TVOC). The highest concentrations have been seen in RW-1 and RW-2. The highest TVOC concentration was 694 µg/L in RW-2 during start-up sampling. In general, the high concentration portion of the plume is in the western portion of the remediation system.

3.2.3.6 System Evaluation

The system has only been in operation since October 24, 2001. Groundwater level mapping indicates that the system is creating a cone of depression, consistent with the design estimates. Hence, it can be inferred that hydraulic control has been achieved. Continued operation time will provide performance data to evaluate other performance indices.

3.2.3.7 Recommendations

No changes to this system are recommended at this time.

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3.2.4 South Boundary Pump and Treat System

This section summarizes the operational data from the OU III South Boundary groundwater pump and treat system for 2001, and gives conclusions and recommendations for future operation. This system began operation June 17, 1997. The analytical information from monitoring wells is evaluated in detail. In addition to this report, a monthly DMR is submitted to the EPA and NYSDEC for treated effluent water from the air-stripping tower.

3.2.4.1 System Description

Recovery Wells

Seven groundwater extraction wells, EW-3 through EW-8 and EW-12, hydraulically control of the VOC plume (**Figure 3.2-28**). EW-12 began operation in December 1999. Groundwater is currently extracted at a total maximum flow rate of about 750 gpm. The actual rates vary during the extraction systems life, based on operational monitoring data. Each well is 8-inches in diameter with a 30 to 40 foot long, 20 slot, 304 stainless-steel screen, and they vary in depth from 190 to 250 feet.

VOC concentrations in groundwater along the site's southern property line are stratified vertically and horizontally. The seven recovery wells are screened at the depths showing the highest VOC concentrations. The pipe and valve configuration will enable pumping rates to be increased at wells exhibiting higher VOC concentrations, and recovery wells to be added, if required in the future. The extraction wells are sampled quarterly.

Groundwater is extracted by stainless-steel submersible pumps operating on a 480 volt, 3-phase power supply. The pumps have check valves at the discharge. The discharge piping is 3-inch carbon steel pipe up to a pitless adapter, and then 4-inch PVC piping to the well house. The depths of the extraction wells, and pump settings, are shown in **Table 3-15**.

Table 3-15 OU III South Boundary System Extraction Well Construction Data

Well #, (Site ID)	Screen Interval (Feet below grade)	Pump Setting (Feet below grade)
EW-3, (121-17)	150-190	170
EW-4, (121-16)	160-180 and 190-200	190
EW-5, (121-15)	160-200	180
EW-6, (122-14)	160-200	180
EW-7, (122-13)	170-210	190
EW-8, (122-12)	190-210 and 230-250	220
EW-12,(122-30)	180-220	200

Well House

The well house is situated along the southern boundary of the site to the west of the wells. Each of the seven pump discharge lines is reduced from 4-inch to 3-inch diameter just before it enters the well house. Inside the well house, each pump discharge line contains a gate valve to isolate the line, a propeller-type flow meter, a swing-type check valve, and a butterfly valve to control flow. High and low-level pressure switches and a sampling port also are located on each line before the gate valve. After the butterfly valve, the piping manifolds into a 10-inch discharge line that conveys the water to the treatment facility.

Treatment Facility

The groundwater treatment facility consists of a treatment control building and an air- stripping tower system, and is located just northwest of Rochester Street and Princeton Avenue. The facility is designed for limited automatic operation, defined as automatic equipment shutdown with manual restart. Any alarm condition will signal a common trouble alarm at BNL's Central Chilled Water Facility requiring physical inspection of the main control panel to determine the source of the alarm. The treatment building also houses a 110-gallon riser drain tank used to temporarily capture drained water from the tower's influent line if the air-stripping tower is shut down during cold weather. Two re-injection pumps send the drained water back into the stripping tower's influent line when the system is placed back in operation.

Air-Stripping Tower

The packed air-stripping tower removes VOCs from the groundwater to meet the discharge criteria. The stripping tower is 6 feet in diameter and 52 feet tall, and equipped with a minimum of 39 feet of 2-inch plastic packing, configured in two separate beds. The tower's internals include five influent spray nozzles, water distribution trays for the two media beds, packing support/air distributor for the two media beds, a mist eliminator, screened air exit, and water redistribution rings. The 39-foot height of the packing media is based on the requirements to remove TCA. The efficiency of removing other VOCs of interest are greater than the required minimum, and effluent concentrations will be lower than NYSDEC permitted levels. A centrifugal blower supplies air to the tower at a normal flow rate of 3,100 cfm, providing an air to water ratio of 27:1 at the maximum water flow rate of 850 gpm, and 31:1 at the more typical rate of 750 gpm.

Recharge Basin

The water discharged from the air-stripping tower flows by gravity through 10-inch diameter PVC piping to either of two recharge basins. A buried house trap in the piping has a 30-inch water seal to prevent air, under pressure in the stripping tower, from discharging through this line. The discharge piping splits to convey the water to either the OU III recharge basin, or to the existing HP recharge basin. A gate valve in the line to each basin controls the flow to the basin.

The OU III basin is sized to receive a continuous flow of more than 850 gpm; this value includes a sufficient factor of safety to account for variations in subsurface soil and fouling of the basin over time. The existing HP recharge basin provides backup discharge facilities during maintenance of the primary OU III basin. Water can now also be diverted to the RA V basin with the addition of the Middle Road system.

3.2.4.2 Groundwater Monitoring

Well Network: The monitoring well network consists of 40 wells and was designed to monitor the VOC plume(s) in this area of the southern site boundary, as well as the efficacy of the groundwater remediation system (**Figure 3.2-29**).

Sampling Frequency and Analysis: The South Boundary wells are sampled and analyzed for VOCs quarterly, except for shallow wells, that are analyzed for VOCs semiannually (details are given in **Table 1-6**).

3.2.4.3 Monitoring Well Data Results

The monitoring well network consisting of 40 wells is sampled quarterly for VOCs. **Appendix C** has complete results (located on the enclosed CD-ROM). **Table 3-16** summarizes VOC results exceeding the NYS AWQS.

The south boundary segment of the OU III VOC plume continued to be bounded by the existing monitoring well network. VOC concentrations in the plume perimeter wells were less than 5 µg/L (**Figure 3.2-30**). VOCs were detected in the deep Upper Glacial aquifer as depicted in **Figure 3.2-2**.

The plume core wells generally continued to show the same trend of decreasing VOC concentrations that was observed following the start-up of the pump and treat system in 1997. The VOC concentration trends for specific key plume core wells are shown in **Figure 3.2-31**.

- Plume core well 114-07 is located just upgradient of EW-12. The original purpose of this well was to monitor VOC concentrations on the eastern plume perimeter, outside the capture zone of EW-8. Increasing VOCs in this well during 1998 prompted the addition of EW-12, which began pumping in December 1999. TVOC concentrations have stabilized to 10 to 20 µg/L during 2000 and 2001.

- Plume core well 122-22 is located just east of EW-8. A sharp drop in TVOC concentrations was observed during 1997 and 1998 from its pre start-up concentration of 1,617 µg/L. They have dropped below 5 µg/L during the last two quarters of 2001.

- Plume core well 122-19 is located directly downgradient of EW-8. TVOC concentrations that were as high as 367 µg/L in 1997 decreased to less than 1 µg/L during the last three quarters of 2001.

- Plume core well 122-04 is between EW-7 and EW-8 and slightly upgradient. TVOC concentrations in this well displayed a dramatic decrease from 1998 to early 2000 during which they dropped to below 5 µg/L for seven consecutive quarters. The increasing trend begun in 2000 continued during 2001 with concentrations rising above 200 µg/L, apparently in response to a slug of higher VOC concentrations reaching the site boundary.

- Plume core well 121-23 is immediately downgradient from EW-5. It generally has shown declining TVOC concentrations since 1997 with the exception of two spikes in 1998 and again in early 2001. Concentrations have been decreasing during the first two quarters of 2001. A concentration of 152 µg/L was observed during the fourth quarter of 2001. The spikes in TVOCs are most likely the result of higher concentration slugs of VOCs arriving at the site boundary.

- Plume core well 121-13 is located immediately upgradient of, and between, EW-4 and EW-5. TVOC concentrations in this well have fluctuated somewhat since 1997, peaking at 1,098 µg/L in 1999. Concentrations stabilized between 30 µg/L and 50 µg/L during the last three quarters of 2001.

- Plume core well 121-10 is situated upgradient of EW-3. TVOC concentrations decreased dramatically in 1998 from a high of 1,458 µg/L and have remained between 1 µg/L and 10 µg/L since the third quarter of 1999.

By-pass detection well 122-35, located south of EW-8, continued to show little to no detectable levels of VOCs in 2001. TVOC concentrations in well 122-34, clustered with 122-34, declined during the four quarters of 2001 from a high of 50 µg/L in February to 10 µg/L in October 2001.

3.2.4.4 Systems Operations

The system influent and effluent to the air stripper tower are sampled twice a month. The individual extraction wells are sampled on a quarterly basis. All samples are analyzed for volatile organic compounds. In addition, the influent and effluent samples are analyzed for pH values on a weekly basis. The effluent sampling parameters of pH and VOCs are done in accordance with SPDES equivalency permit requirements (**Table 3-17**). In addition, samples are analyzed for tritium with each system sampling event. In all samples, tritium continues to remain below detection limits. All effluent samples from the treatment system during this period of operation were below equivalency permit levels.

Table 3-17. SPDES Equivalency Permit Levels January 1 - December 31, 2001

Parameters	Permit Limit (µg/l)*	Max. Observed Value µg/L
pH (range)	6.5 - 8.5	7.7
Carbon Tetrachloride	5.0	ND
Chloroform	7.0	ND
1,1-Dichloroethane	5.0	ND
1,2-Dichloroethane	5.0	0.82
1,1-Dichloroethylene	5.0	ND
cis-1,2-Dichloroethylene	5.0	ND
trans-1,2-Dichloroethylene	5.0	ND
Tetrachloroethylene	5.0	0.3J
1,1,1-Trichloroethane	5.0	ND
Trichloroethylene	5.0	ND
1,2-Xylene	5.0	ND
Sum of 1,3 & 1,4 Xylenes	10.0	ND

***Maximum effluent allowed by Requirements Equivalent to a SPDES Permit.**
J = Estimated Value.
ND = Not detected above method detection limit of 0.50 mg/L.

System Operations

The following summarizes the systems operations for each month of 2001. BNL's PE Division, in addition to system sampling and routine and non-routine maintenance work, made routine maintenance checks daily on this system. Details are given in the operation and maintenance manual for this system. The daily operations and maintenance inspection logs are available in the project files and the treatment system buildings.

January –September 2001:
The individual extraction wells were not sampled during the first two quarters of 2001 due to scheduling errors. The extraction wells were subsequently sampled in July and August of 2001. The pump in EW-5 was not operational for 5 days in March due to electrical problems. On March 29, effluent flow was temporarily diverted to the HP Recharge Basin to perform maintenance work on the OU III Recharge Basin.

The system was shut down June 26-27 for a tie-in connection with the new Middle Road project. On July 13, 2001, a faulty flow meter was replaced at extraction well EW-7. In August 2001, extraction well EW-5 experienced intermittent outages due to electrical problems. In addition, the system was shut down August 21-23, and September 27-28 for tie-in connections with the Middle Road project. The system pumped and treated approximately 29,507,290 gallons during the first three quarters of 2001, and all effluent samples met equivalency permit requirements.

October 2001:
The Middle Road Groundwater Treatment System began start-up testing in October 2001. Since this new system operates in conjunction with the South Boundary Groundwater Remediation System, both systems experienced some downtime this month during the system troubleshooting. The quarterly extraction well sampling was performed on October 1st, however, due to an intermittent outage, EW-5 was sampled on October 15th. On October 22, a faulty flow meter was replaced at well EW-4. The South Boundary System pumped and treated a total of 25,432,100 gallons of water in October. The average flow rate for the system was 570 gpm. Influent and effluent waters to the treatment system were sampled twice in October; the effluent met all equivalency permit requirements.

November 2001:
The Middle Road Groundwater Treatment System began its operation and maintenance phase in November 2001. Since this new system operates in conjunction with the South Boundary Groundwater Remediation System, both systems experienced some downtime this month during system troubleshooting. In addition, due to combining both system's influent waters into a common 10-inch line leading to the air stripping towers, the South Boundary Influent sampling port had to be relocated to the well house. Therefore, the former South Boundary influent sampling port (Site Id # 095-127) has been superseded by a new one (Site Id # 121-41).

On November 15, 2001, extraction Well EW-8 went off-line due to a faulty pump. The South Boundary system pumped and treated 17,023,350 gallons of water in November, at an average flow rate of 394 gpm. Influent and effluent waters to the treatment system were sampled twice in November; all effluent samples met equivalency permit levels.

December 2001:
During December, extraction well EW-8 was re-developed and a new pump and motor were installed. On December 19, extraction well EW-8 was placed back into operation. On December 31, 2001, the flow meter for EW-12 was replaced due to a faulty totalizer. A total of 29,437,960 gallons of water were pumped and treated in December, at an average flow rate of 659 gpm. The influent and effluent waters to the treatment system were sampled twice in December. All effluent samples met equivalency permit requirements.

Approximately 339,408,450 gallons of water were pumped and treated in 2001 by the OU III South Boundary System.

3.2.4.5 Systems Operational Data

System Influent and Effluent

All parameters in the permit equivalency conditions were within the specified ranges during 2001. The effluent data were either below the method's detection limit, or below the regulatory limit specified in the permit equivalency conditions.

Figure 3.2-32 plots the concentrations of TVOC, TCA and PCE in the influent to the systems air-stripper tower vs. time. The overall influent water quality and the individual extraction wells show a general leveling off of concentrations. The average concentration of TVOCs in the influent for this operational period was 100.5 µg/l, a slight decrease compared to 107 µg/l for the same period last year. The system is sampled twice per month for tritium; it was not detected in any sample during 2001. System Influent and Effluent sampling results are summarized in **Tables F-21** and **F-22**, respectively.

Cumulative Mass Removal

Average flow rates for each monthly monitoring period were used, in combination with the TVOC concentration in the air-stripper influent to calculate the mass removed. Flow averaged 651 gpm from January 1, 2001 through December 31, 2001 (see **Tables 2-3** and **Table F-23**). The cumulative total of TVOCs removed by the treatment system vs. time is plotted in **Figure 3.2-33**. The cumulative total was approximately 285.5 pounds during this period of operation; altogether, the system removed approximately 1,717.09 pounds since it was started on June 17, 1997.

Air Discharge

Table 3-18, below, shows the air-emission data from the system for the operational period, and compares the values to levels stipulated in NYSDEC Air Guide 1 regulations. Emission rates are obtained through mass-balance calculations for all water treated during that time (**Table F-20**). The concentration of each constituent was averaged for the period, and that value was used in the calculation. All air emissions were below allowable levels.

Table 3-18. Air Emission Rates January 1, 2001 - December 31, 2001

PARAMETERS	ALLOWABLE ERP*	ACarbon
Carbon Tetrachloride	.022 lb/hr	.0022 lb/hr
Chloroform	.0031 lb/hr	.0005 lb/hr
1,1 - Dichloroethane	10 lb/hr**	.0001 lb/hr
1,2 - Dichloroethane	.008 lb/hr	.0005 lb/hr
1,1 - Dichloroethylene	.034 lb/hr	.0022 lb/hr
cis-1,2-Dichloroethylene	10 lb/hr**	.0001 lb/hr
Trans-1,2-Dichloroethylene	10 lb/hr**	.0000 lb/hr
Tetrachloroethylene	.387 lb/hr	.0205 lb/hr
1,1,1 - Trichloroethane	10 lb/hr**	.0060 lb/hr
Trichloroethylene	.143 lb/hr	.0008 lb/hr

Actual Emission Rate reported as the average rate for the period of operation.
*** -** Emission Rate Potential (ERP) based upon NYSDEC Air Guide 1 Regulations.
** - 6 NYCRR Part 212 restricts emissions of VOCs to a maximum of 10 pounds per hour without controls

Extraction Wells
In general, the extraction wells continued to show slowly decreasing VOC concentrations during 2001. This trend has continued since 1999 (**Figure 3.2-34**). The exception is EW-4, which displayed increasing VOC concentrations from 1999 into 2000 followed by a gradual decline. There was a slight increase in VOCs in this well in the fourth quarter of 2002. PCE is the primary contaminant in this well. **Table F-24, Appendix F** summarizes the data for the extraction wells.

3.2.4.6 System Evaluation

The pump and treat system continued to establish hydraulic control of contaminants originating from source areas in the central portion of the BNL site and continues to prevent further migration across the southern site boundary. Plume core and by-pass wells continued to show stable or decreasing VOC concentrations. The system operated at an average of 651 gpm during 2001 with all seven-extraction wells operational. There were some minor downtime due to electrical problems and the start-up of the OU III Middle Road system. No permit equivalencies were exceeded and no operating difficulties were experienced beyond normal maintenance. There have been no air emission problems.

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

1. Was the BNL Contingency Plan Triggered?
There were no unusual or unexpected VOC concentrations observed in the monitoring wells associated with the OU III South Boundary Pump and Treat System during 2001.

2. Were the cleanup goals met?
It was determined that, in order to meet cleanup goals in the required timeframe (30 years), groundwater extraction should continue until plume core wells show TVOC concentrations below 50 µg/L and this 50 µg/L level has been reached by 2007 to 2012. The TVOC trend in plume core wells slightly increased during 2001. **Figure 3.2-35** is a plot of the mean concentration of the plume core wells with time.

The groundwater cleanup goal index of reaching a mean concentration of less than 50 µg/L TVOC for the plume core wells over two consecutive years has not yet been achieved, although it is close. The next index is the number of plume core monitoring wells exceeding 50 µg/L TVOC. A number of monitoring wells exceed 50 µg/L, so this index was not developed further. System pulsing was not performed in 2001. Therefore, the cleanup goal index of concentration rebound after pulsing was not assessed. This system will probably need to operate several more years before developing and presenting the other groundwater cleanup indices.

3. If not, has the plume been controlled?
Since the cleanup goals have not been met it must be verified that the plume is not growing. An analysis of the plume perimeter and bypass wells reveals that there have been no significant VOC concentration increases in these wells during 2001. In addition, groundwater level measurements indicate the presence of a cone of depression consistent with estimates prepared

during the design. Therefore, we conclude that there has been no plume growth and the plume continues to be controlled.

Groundwater elevation data is obtained quarterly from many of the OU III South Boundary Monitoring program wells, in addition to wells located throughout the BNL on-site and off-site areas on a quarterly basis. Groundwater contour maps are generated using this data (**Figures 2-3** and **2-4**). The capture zone for the OU III South Boundary Pump and Treat System is depicted in **Figure 3.0-1**. The capture zone depicted is inclusive of the 50 µg/L isocontour, which is the capture goal of this system.

4. Is the System operating as planned?

The OU III South Boundary System continues to be effective in removing VOCs from the deep Upper Glacial aquifer. Actual mass removal is within 250 pounds or 13% of what was predicted using the groundwater model (**Figure 3.2-36**). **Figure 3.0-4** compares the OU III plumes as modeled during the FS with the fourth quarter 2001 plume data. The plume data compares favorably with the modeled plume particularly with respect to some of the high concentration segments in the vicinity of the OU III southern site property boundary. If anyting, the FS model predictions seem to be conservative. **Figure 3.2-3** compares the OU III plume from 1997 to 2001. The overall reduction in the high concentration areas of the plume near the south boundary is evident.

The OU III South Boundary system is planned to operate for 10 to 15 years; at the end of 2001, it had operated for approximately 4.5 years. Therefore, it is not expected to be approaching its cleanup goals. The system is removing contamination at the expected rate and hydraulic control of the plume was demonstrated; hence, it is operating as planned. However, the duration of operation could be closer to 15 years rather than 10 years. The duration of operation for the OU III South Boundary system is dependent upon the partition coefficient of the contamination, the rate of desorption (i.e., linear or non-linear) and the start-up and effectiveness of the Middle Road Groundwater Treatment System. The Middle Road system started operation approximately 4.5 years after the OU III South Boundary system. The contaminant travel time from Middle Road to the OU III South Boundary system is about 5-10 years. Therefore, the high concentrations observed at well 113-17 will likely determine the remaining operating period of this system.

The trend in the mean of the TVOC concentrations in the core groundwater monitoring wells is a declining one; however, there is significant variability in the mean from quarter to quarter. This is not indicative of poor performance, but rather, the capture of pulses or slugs of higher concentration contamination. The target contamination in this area is the result of periodic historical releases and not continuous sources of contamination. As a result, the nature of the plume is rather discontinuous and exists as a series of contamination pulses or slugs. This is the likely explanation of the significant variability in the mean from quarter to quarter. This variability makes it difficult to estimate the mass of contamination in the aquifer requiring treatment and the duration that treatment will be required.

5. Have asymptotic conditions been demonstrated?

The average TVOC concentrations of the OU III South Boundary wells showed a general increasing trend in 2001 (**Figure 3.2-35).** Therefore, asymptotic conditions have not been met for the OU III South Boundary Pump and Treat System plume core wells.

3.2.4.7 Recommendations

The recommendation for the OU III South Boundary groundwater remediation system is for one additional downgradient (bypass detection) monitoring well be installed on the south side of the LIE downgradient of EW-4 to verify high levels of contamination in this vicinity are being captured. This work will be planned in October 2002.

3.2.5 Industrial Park In-Well Air Stripping System

This section summarizes the operational data from the OU III Industrial park In-Well Air Stripping System for 2001, and presents conclusions and recommendations for future operation. The system began operation September 27, 1999. This summary is prepared annually and presents the operational data from January 1 through December 31, 2001. The analytical information from monitoring wells is evaluated in detail.

The OU III VOC plumes originate near the south central portion of the BNL site and extend beyond the site's southern boundary. The Industrial Park RA groundwater treatment system represents one of several groundwater remedial systems installed (or proposed for installation) to remediate the OU III plume. A groundwater pump and treat system, consisting of seven extraction wells located along the southern boundary of BNL, was constructed in 1997 to intercept the contaminant plume at the southern property line. It is referred to as the "South Boundary System." Operation of this system since June 1997 has contained the plume at the southern boundary; however, portions of the plume had migrated south of BNL before the southern boundary system started operating in 1997. The OU III Offsite RA was implemented to contain and remediate the portion of the OU III that off-site portion. Specifically, the OU III Industrial Park RA system was designed to contain and remediate the portion of OU III plume existing between BNL's southern boundary and the southern boundary of the Parr Industrial Park. **Figure 3.2-30** illustrates the extent of the OU III contaminant plume in the vicinity of the Industrial Park.

3.2.5.1 System Description

The OU III Industrial Park system includes the operation of a groundwater treatment system consisting 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 screen) 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 screen).

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 granular activated carbon units in series to remove the VOCs. Treated air is then re-circulated back to the wellhead. The carbon units, system blower, and the system control panel are all housed in the one story, masonry treatment building.

The system treatment wells are referred to as "UVB" wells, which is a German abbreviation for vacuum extraction well. A significant feature of the technology is the "in-situ" treatment of groundwater. Groundwater is simultaneously withdrawn, treated and recharged at a single location. Groundwater is treated below grade within a well vault and returned to a contaminated segment of the aquifer (via the same well from which it is withdrawn). Therefore, a NYSDEC SPDES permit equivalent is not required. The simultaneous withdrawal and recharge of groundwater from a single well causes a flow cell to form near the treatment well. This localized change in the aquifer flow field takes the shape of a highly three-dimensional recirculation cell that is the mechanism by which the hydraulic control is achieved.

In addition to hydraulic control, the recirculation cell also efficiently cleans the aquifer. Some of the treated groundwater that is recharged through the upper screen re-circulates 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. The amount of recharged groundwater drawn back into the treatment well relative to the total amount of treated groundwater recharged, is referred to as the "recirculation rate."

The seven groundwater treatment wells are designated from west to east as UVB-1 through UVB-7 (**Figure 3.2-37)**. Collectively, they hydraulically control and treat the off-site portion of the OU III VOC plume between the BNL southern boundary and the Parr Industrial Park. Each of the seven treatment wells are constructed with eight (8) inch diameter steel casing and two (2), 20 foot long, stainless steel screens separated by an inflatable packer. One, three (3) horsepower submersible well pump is installed below the packer in each well to draw water into the well through the lower screen.

Well casing, about 25 feet to 35 feet in length, separates the screen zones in each well. The well screens are strategically placed to intercept and contain the full vertical extent of the contaminant plume. Therefore, screen zone depths differ from well to well based upon the plume configuration at each location. **Table 3-19** summarizes construction information for the recirculation wells.

Table 3-19. OU III Industrial Park System UVB Well Construction Data

Well	Well Depth (fbg)	Grade at Well (ft msl)	Screen Depths Top / Bottom (fbg)	Pump Intake Setting (fbg)
UVB-1	243	83.0	165-185 / 220-240	229
UVB-2	218	79.5	140-160 / 195-215	204
UVB-3	220	74.0	142-162 / 197-217	179
UVB-4	193	72.0	125-145 / 170-190	184
UVB-5	203	71.0	125-145 / 180-200	179
UVB-6	215	82.0	140-160 / 192-212	214
UVB-7	228	82.0	150-170 / 205-225	219

ft bls = feet below grade.
ft msl = feet above mean sea level

The sizing of the groundwater treatment system was based upon a nominal hydraulic capacity of 60 gallons per minute (gpm) for each stripping tray with the capacity to operate at a maximum of 80 gpm. To permit independent flow rate control, variable frequency drives were used for the well pumps. Flow rates for each individual well can be controlled from a programmable logic controller (PLC) located in the treatment and control building.

Air Treatment Facility

The air treatment system is a closed loop system that provides airflow to the UVB wells for the stripping process. The air treatment equipment, which consists of a blower, a dehumidification unit, a duct heater and two 13,800 pound Granular Activated Carbon Units (GAC), are housed in the treatment and control building. Individual air suction and return lines run underground from the building to each UVB well. A single blower provides the airflow for all seven wells. Like the submersible well pumps, the system blower has a variable frequency drive motor that is controlled from the PLC to regulate the output of the blower. The airflow to individual UVB wells can be controlled by adjusting the blast gates on the influent and effluent manifolds within the building, and by adjusting gear operated butterfly valves in the valve vault adjacent to each UVB well.

Contaminated air from the UVB wells is combined in a common header and passed through the dehumidification system and duct heater to remove moisture. Compressors, located on an exterior slab adjacent to the west wall of the building, circulate a chilled water-glycol solution through two banks of coils. As the contaminated air stream passes over the cold coils, moisture condenses out and collects in a drip pan. The drip pan drains via gravity to a sump where a sump pump transfers this condensate to the UVB-4 air-stripping tray for treatment.

Two (2) GAC filter vessels (piped in series) are utilized to remove VOCs from the air stream. After the air leaves the GAC filter units, it is re-circulated to the UVB wells and again used in the air stripping process. A clean air relief port allows removal of clean air from the air-piping loop if necessary.

3.2.5.2 Groundwater Monitoring

Well Network: The monitoring well network consists of 39 wells and is designed to monitor the VOC plume(s) in the vicinity of the industrial park south of the site, and also the effectiveness of the in-well air stripping groundwater treatment system on this part of the high concentration OU III VOC plume(s). The wells are located throughout the industrial park, and on Carleton Drive as shown in **Figure 3.2-38**. The wells were installed as single, doublets and triplets and are constructed of both two and four inch diameter PVC. Screen depths vary to capture contaminant concentrations at multiple levels, and to obtain water quality data above the treatment well effluent depth, at the effluent depth, and at the treatment well influent depth.

Sampling Frequency and Analysis: The wells are sampled quarterly, and the samples are analyzed for VOCs (**Table 1-6**).

3.2.5.3 Monitoring Well Data

The network of 39 wells is sampled quarterly for VOCs. The complete results are included in **Appendix C** (located on the enclosed CD-ROM). **Table 3-20** summarizes VOC detections exceeding the NYS AWQS.

VOC concentrations in the plume perimeter wells monitoring the width of the plume (000-245 and 000-272) continued to remain below NYS AWQS during 2001. Based on this data the plume is effectively bounded by the current well network. **Figure 3.2-30** shows the plume distribution based on fourth quarter 2001 data. The vertical extent of contamination is shown in **Figure 3.2-39**. The location of this cross section is illustrated in **Figure 3.2-1**.

The highest VOC concentrations in the Industrial Park area are observed between remediation wells UVB-1 and UVB-3. The maximum concentration during 2001 was in monitoring well 000-256 at 3,853 µg/L during the first quarter.

- Plume core wells 000-253 (located just east of UVB-1), 000-256 (located between UVB-1 and UVB-2) and 000-259 (located between UVB-2 and UVB-3) all showed stable or decreasing VOC concentrations during 2001 (**Figure 3.2-40**).

- There has been a steady decline in VOC concentrations in plume core well 000-112 (located immediately upgradient of UVB-1 and UVB-2) since 1999. Concentrations have decreased from a historical high of 1,898 µg/L in 1997 to 24 µg/L in October of 2001. The decreases in this well could be due either to inherent variability in the VOC plume distribution or that the trailing edge of the western portion of the plume is approaching the Industrial Park. Monitoring will continue to assess this issue.

- Plume core well 000-262 (located between UVB-4 and UVB-5) displayed slightly increasing VOC concentrations during 2001 (**Figure 3.2-40**), while VOC concentrations in 000-268 (located between UVB-6 and UVB-7) declined during 2001. It is difficult to draw any conclusions from these trends due to the lack of time the system has been operating and well data collected.

- Bypass monitoring wells located near Carleton Avenue showed stable or decreasing VOC concentrations during 2001.

- With one exception, VOC concentrations for individual constituents remained below NYS AWQS (5 µg/L) at each of the shallow wells screened to monitor the adjacent UVB effluent wells. Well 000-246, located west of UVB-1, had concentrations of PCE of 18 µg/L and 8 µg/L during the first and second quarters of 2001. They fell to below 5 µg/L during the third and fourth quarters.

3.2.5.4 Systems Operations

Operating Parameters

The influent and effluent of the carbon vessels are sampled once per quarter (4 times per year) and analyzed for volatile organic compounds. These samples monitor the GAC units for a VOC break-through to determine when a carbon change-out is required. Since the system utilizes a closed-loop air system, no air equivalency permits are required for its operations.

Water samples are obtained monthly from each of the seven wells before air stripping in each UVB tray and after treatment. All samples are analyzed for volatile organic compounds. These samples determine the well’s removal efficiency and performance. Based on these results operational adjustments are made to optimize the system’s performance.

System Operations

The following summarizes the systems operations for each month of 2001. BNL's PE Division carries out routine maintenance checks daily on the system, in addition to routine and non-routine maintenance. The Environmental Services Division collects the samples. Details of these activities are given in the system’s operation and maintenance manual. The daily operations and maintenance inspection logs are available in building OS-1.

January-September 2001:

The recirculation wells were sampled once each month from January to September 2001. A total of 133,472,440 gallons were pumped and treated. The water flow meters for UVB wells 1 through 7 were not operating properly for this period, so the flows were calculated by hand. The system was shut down for a carbon change-out of GAC unit number 1 from June 5 to June 7,

2001. The system also was shut down from July 23 to August 31 2001 for systems repairs on the blower.

October 2001:

The recirculation wells pumped and treated 18,591,840 gallons in October. They were sampled on October 2, 2001. The water flow meters for UVB wells 1 through 7 were not operating properly for this period, so the flows were calculated instead.

November 2001:

The recirculation wells were sampled once on November 8, 2001. A total of 16,812,320 gallons were pumped and treated. The water-flow meters' totalizers for UVB wells 1 through 7 did not operate properly, so their flows were calculated.

December 2001:

The recirculation wells were sampled on December 19, 2001. A total of 18,051,240 gallons were pumped and treated. The water flow meters' totalizers for UVB wells 1 through 7 were not operating properly, so the flows were calculated by hand. Well UVB 7 was off from December 21 to December 27, 2001 for repairs.

In 2001, 186,927,840 gallons of groundwater were pumped and treated.

3.2.5.5 Systems Operational Data

Recirculation Well Influent and Effluent

During 2001, influent TVOC concentrations decreased overall in wells UVB-1 and UVB-2 (**Figure 3.2-41**). The remainder of the wells showed relatively stable TVOC concentrations during 2001 with the exception of UVB-5 and UVB-4. The net overall change in concentration from the beginning to end of 2001 was not significant, however; each well displayed a marked increase during the month of October. The corresponding effluent well concentrations (**Figure 3.2-42**) also showed increasing TVOC concentrations. The effluent concentrations from the remainder of the UVB wells displayed either decreasing or stable trends for the year.

During the fourth quarter of 2001, the average removal efficiency for TVOCs was 92.8% and overall for 2001, it was 93.1% (**Table F-25**, **Appendix F**), a slight increase in efficiency from 93% in the start-up period.

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 to calculate the pounds per month removed. **Table F-26** summarizes this data and is included in Appendix F. Flow averaged 54 to 60 gpm for the wells from January 1, 2001 through December 31, 2001. **Figure 3.2-43** plots the total pounds of TVOCs removed by the treatment system vs. time. Two hundred and nine pounds were removed during this period, and a total of 448.6 pounds since the system started operations.

Air Treatment System

Air samples were collected quarterly from the GAC vessels prior to treatment, between the two vessels, and after the second vessel (effluent). The samples were used to determine when a GAC change-out is needed. In addition, airflow rates were recorded to correlate the flow with efficiency rates in individual recirculation wells.

Airflow rates are measured for each in-well air-stripping unit inside the treatment building. These rates averaged 588 cfm for the seven wells in the fourth quarter, and 597 cfm during 2001 (**Table F-27, Appendix F**).

3.2.5.6 System Evaluation

The Industrial Park In-Well Air system continued to efficiently remove VOCs from the groundwater from January 1, 2001 through December 31, 2001. The GAC vessels were effective in removing VOCs from the air stream. The system treated 186,927,840 gallons of groundwater, and removed 209 pounds of VOCs during 2001. The average efficiency rate was 92.8%. UVB well influent data show that VOC concentrations in the western portion of the system (UVB-1, UVB-2 and UVB-3) have slowly declined. These data, in conjunction with the decreasing concentration trend in well 000-112 (located upgradient of the western portion of the system), indicates that the trailing edge of higher concentration contamination maybe shifting south.

There was an increase in VOC concentrations in the eastern portion of the system during the beginning of the fourth quarter. A slug of higher concentration VOCs is most likely responsible for this.

Effluent monitoring well VOC concentrations exceeded the NYS AWQS for PCE (5 µg/L) in 000-246, located just to the west of UVB-1, during the first and second quarters. Concentrations subsequently dropped to below 5 µg/L during the second half of 2001. There were several detections of VOCs exceeding NYS AWQS in UVB effluent wells during 2001; the highest was 16 µg/L in UVB-2.

Figure 3.2-44 compares actual mass removal with that predicted by the groundwater modeling for the OU III FS. There is reasonably good agreement between the two so far.

Figure 3.2-45 plots the average TVOC concentrations in plume core wells versus time from the OU III Industrial Park System start-up in 1999. A steadily decreasing trend is noted for the first three quarters of 2001, with an upward spike during the fourth quarter. Monitoring well concentrations are in the range given the amount of time the system has been in operation and the initial concentrations in the aquifer.

In 2001, Arcadis Geraghty & Miller (AG&M 2002a) was retained to perform an independent performance evaluation of this system. The results of their various evaluation methods, or lines of evidence, cumulatively support the overall conclusion that the system is effective in meeting its objectives. The following is a summary of their conclusions:

- The contoured water levels indicate a cone of depression around UVB-1 that is consistent with expectations drawn from model simulations.

- In general, a detailed evaluation of water quality data indicate that the system is operating as expected and that the capture along the treatment well line can be inferred over the assessment time frame.

- It is premature to evaluate downgradient groundwater quality to assess if the system is achieving adequate capture. However, there are some limitations to the existing down gradient monitoring well clusters.

- The mass removal rates measured compare favorably with those estimated during the design.

3.2.5.7 Recommendations

The following are recommendations for the OU III Industrial Park groundwater remediation system on monitoring programs:

1) An additional well will be installed at the 000-276 location and screened within the deep horizon at elevations equivalent to the UVB extraction well screen depths.

2) A second additional bypass monitoring well will be installed along Carleton Drive approximately 200 feet west of existing well 000-273. Installation of a second bypass monitoring well at this location will provide adequate downgradient bypass monitoring of the area where the highest concentrations are observed (between UVB-1 and UVB-2). Therefore, this well will be screened in the deep horizon at elevations similar to UVB extraction well screens.

3) The existing remediation wells will continue operation at 60 gpm per well pumping rates.

4) Formal groundwater DQOs will be developed for this system in 2002.

3.2.6 Former Landfill Groundwater Monitoring

Data obtained from the Former Landfill groundwater monitoring program is discussed in this section, along with conclusions and recommendations for future monitoring. A *Five-Year Evaluation Report* (P.W. Grosser) was prepared and submitted in March, 2002 as per the requirements of 6 NYCRR Part 360 Section 2.1.5, Solid Waste Management Facilities (effective December 31, 1988). This report summarized the status of groundwater quality in the vicinity of the Former Landfill and presented conclusions and recommendations on the effectiveness of the cap, and about future monitoring efforts. This annual status report reiterates those conclusions and recommendations.

3.2.6.1 Landfill History and Cap Description

The Former Landfill is an unlined waste disposal area originally used by the United States Army in the 1940's for waste disposal prior to the development of BNL. Disposal activities ceased in 1966, and the landfill was covered with soil. The Interim Landfill is also unlined, and is reported to have been used for approximately one year following the closing of the Former Landfill. The Slit Trench is unlined as well, and believed to have operated during the 1960s.

An estimated three tons per day of waste material were deposited in the Former Landfill, of which a small percentage was radioactive (including tritium) or hazardous waste. Waste materials included laboratory debris, irreclaimable partially decontaminated equipment, contaminated clothing, radioactive animal carcasses, and sanitary wastes. Sewage sludge was also periodically disposed of in the landfill.

The Former Landfill and Slit Trench were capped in November 1996 and the Interim Landfill in October 1997.The Former Landfill cap was constructed in accordance with 6 NYCRR Part 360. The cap consists of a geotextile fabric overlain by a 12-inch gas-venting layer followed by a forty-millimeter double-sided textured geomembrane topped with a twenty-four inch thick protection layer and six inches of topsoil. Additional details regarding the cap construction may be obtained from the Construction Certification Reports for Former Landfill (CDM Federal, 1997) and the Interim Landfill (PW Grosser, 1997).

3.2.6.2 Groundwater Monitoring

Well Network: The monitoring program, consisting of a network of eight monitoring wells sited immediately adjacent to the landfill, was designed to provide post-closure monitoring as per NYSDEC requirements (**Figure 3.2-1**). The program was started after the Former Landfill was capped to verify whether the cap effectively prevents the continued leaching of contaminants from the landfill, and to document anticipated long-term improvements to groundwater quality.

Sampling Frequency and Analysis: These Former Landfill area wells are monitored quarterly. The samples are analyzed for VOCs, EDB, SVOCs, pesticides/PCBs, metals, cyanide, gross alpha/beta, gamma spectroscopy, tritium, and strontium-90 (**Table 1-6**).

3.2.6.3 Monitoring Well Data

The primary VOCs that are consistently detected in the Former Landfill Monitoring Program wells are TCA, 1,1-DCA, and chloroform. **Appendix C** contains the complete 2001 analytical results. A detailed evaluation of VOC, radionuclide, leachate parameters, metals, and pesticides/PCBs is provided in the *Former Landfill Five-Year Evaluation Report* (P.W. Grosser, 2002a). The contaminants of concern for the Former landfill wells are VOCs and strontium-90.

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

Strontium-90 formerly was detected in well 97-64 which is screened at the water table and located less than 100 feet downgradient of the landfill footprint. Strontium-90 concentrations in this well have shown a steadily declining trend since 1998 when it was last detected above the NYS AWQS of 8 pCi/L (at a concentration of 12 pCi/L). The highest concentration in this well during 2001 was 3 pCi/L in January.

3.2.6.4 Groundwater Quality Evaluation

Groundwater DQOs have not yet been formally developed for this groundwater monitoring program the objective of which is to determine whether the controls implemented are effectively improving groundwater quality below and downgradient of the landfill. Based on the declining VOC and strontium-90 concentration trends in downgradient wells it does appear that the landfill cap is performing as planned. VOC concentrations in nearby wells remain below NYS AWQS. The VOC plume emanating form the Former Landfill is now showing the trailing edge of the plume to be south of the monitoring well network (**Figure 3.2-1**). This feature is also illustrated in **Figure 3.2-4**, which compares the plume distribution from 1997 to 2001.

The strontium-90 plume has also shifted south of well 97-64 and the Former Landfill network as shown in **Figure 3.2-64**. The capping of the landfill in conjunction with the passage of time since the landfill was utilized (1966) are contributing factors to the reduction in plume concentrations in the vicinity of the landfill.

3.2.6.5 Recommendations

The following recommendations were outlined in the Former Landfill Five-Year Review Report based on the analysis of data collected over the five-year period (1997-2001):

1) Eliminate SVOCs and EDB from the monitoring program as they were not detected in groundwater during this period.

2) Reduce the analytical frequency from quarterly to annually for VOCs in upgradient wells 86-42, 86-72, and 87-22. Little or no VOCs were detected historically in these upgradient wells, and none exceeded NYS AWQS.

3) Reduce the analytical frequency for radionuclides from quarterly to annually. Tritium has not been detected at concentrations exceeding the NYS AWQS of 20,000 pCi/L. Historically, the highest tritium concentration recorded at the Former Landfill was 746 pCi/L in 106-30 in December 1998. Strontium-90 has not been detected above the NYS AWQS of 8 pCi/L with the exception of well 97-64. A declining trend has been demonstrated for several years in this well with the concentration during the last two rounds of 2001 below 2 pCi/L.

4) Reduce the sampling frequency for metals to semi-annual. Metals were below applicable NYSA AWQS with the exception of iron, manganese, sodium, antimony, and aluminum.

5) Create formal DQOs for this program.

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3.2.7 Offsite Monitoring

The OU III Offsite Groundwater Monitoring Program consists of twenty wells that were installed primarily during the OU III RI. Three of the wells (000-97, 00-98, and 000-99) were installed as part of the Sitewide Hydrogeologic Characterization program. The wells installed during the OU III RI were meant to track the plume core or perimeter in off-site areas or to serve as sentinel wells for the leading edge of the plume. The three wells installed as part of the Sitewide Hydrogeologic Characterization are used as plume perimeter wells. Most of these wells will be folded into the groundwater monitoring programs associated with the planned OU III off-site remediation systems Long Island Power Authority and Brookhaven Airport (LIPA and Airport) as the systems come on line.

3.2.7.1 Groundwater Monitoring

Well Network: The network has 20 wells that monitor the off-site, downgradient extent of the OU III VOC plumes (**Figure 3.2-46**). Some wells downgradient of the leading edge of the plumes serve as sentinel wells. Their locations, which are screened in the deep portions of the Upper Glacial aquifer, were selected using BNL's Regional Groundwater Model. Over the next two years, these wells will be incorporated into monitoring programs planned for the off-site LIPA and Airport groundwater remediation systems.

Sampling Frequency and Analysis: The wells are sampled quarterly, and samples are analyzed quarterly for VOCs, and semiannually for gross alpha/beta, gamma, and tritium (**Table 1-6**). Based on recommendations in the 2000 Groundwater Status Report radionuclide monitoring of these wells was eliminated for 2002, and the sampling frequency for wells 800-21, 800-22, 800-23, 800-51, and 800-53 was reduced to semiannually.

3.2.7.2 Monitoring Well/Vertical Profile Data

The complete results for the wells in this program can be found in **Appendix C**. Pre-design groundwater characterization work was performed in the vicinity of the proposed LIPA Remediation System and consisted of installing five vertical profile wells (**Figure 3.2-1**). These characterization wells were intended to better define the plume extent in this area for purposes of designing a groundwater remediation system. The additional data does not significantly alter the previous plume extent interpretations either in the horizontal (**Figure 3.2-1**) or vertical (**Figure 3.2-2**) dimensions. Plume core well 000-131 continues to show a gradual decrease in TVOC concentrations (**Figure 3.2-31)**.

Eight vertical profile wells were installed along the northern boundary of the Airport as part of the Airport Groundwater Remediation System pre-design characterization. Four of these vertical profiles were sited in the vicinity of monitoring well 800-43 to define the leading edge of the OU III VOC plume. The data obtained verified that maximum TVOC concentrations in this area are in the 5 to 7 µg/L range. Individual VOCs in both wells and vertical profiles are below NYS AWQS. The monitoring well networks for each of these areas will be enhanced during 2003 with additional wells.

Radiological analyses were performed on the samples obtained during the second quarter of 2001. There were several detections of gamma emitters and gross alpha at concentrations near and just above detectable limits. Data usability reports qualified each of these results as potentially false positive. The data qualifiers can be found in the data tables in **Appendix C** and the data usability reports are included in **Appendix G**.

3.2.7.3 Groundwater Monitoring Program Evaluation

There were no unexpected results during 2001 that triggered the BNL Groundwater Contingency plan (BNL 2000c). The plume remained within the boundaries of the perimeter wells currently in place. Sentinel well 800-43 continued to show very low concentrations of VOCs, indicating that leading edge of the plume is in the vicinity of the northern boundary of the Airport. There is good agreement between the off-site segment of the OU III plume (**Figure 3.0-4**) and the FS modeled plume.

The monitoring wells comprising this program will be absorbed into other programs over the next several years as OU III Offsite remediation systems are constructed and begin operation. Thus, monitoring of these wells provides us with data on the off-site OU III plumes in the interim.

3.2.7.4 Recommendations

Development of groundwater DQOs for this project in 2001 resulted in reduced sampling frequency for VOCs in several wells and the transfer of responsibility to another groundwater monitoring project and a reduction in radiological monitoring during 2002. This level of monitoring should be continued until the start-up of the LIPA and Airport Systems, at which time it will be reevaluated.

3.2.8 North Street Monitoring

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

Pre-design groundwater characterization consisted of drilling 15 vertical profile borings and collecting and analyzing groundwater samples and analysis for VOCs and tritium from these temporary wells.

Groundwater treatment will consist of a two-well extraction and four well recharge system operating at a combined pumping rate of 450 gallons per minute (gpm). This will capture the higher concentration portion of the VOC plume (i.e., TVOC concentrations greater than 50 µg/L) in the Upper Glacial aquifer and minimize the potential for migration to the Magothy aquifer. A November 2003 start date is scheduled for the treatment system. Details on the pre-design groundwater characterization and the planned groundwater treatment system can be found in the *North Street Groundwater Remediation System 90% Design Report* (AG&M, 2002b).

The leading edge of the North Street plume extends south to the vicinity of the Airport. A groundwater remediation system (Airport System) is being designed to address the leading edge of this plume (as well as the OU III plume) and satisfy the cleanup objectives defined in the OU III ROD (minimize plume growth and meet MCLs in the Upper Glacial aquifer in 30 years or less). Recirculation wells were selected for this application and three out of the five planned will be sited to address the leading edge of the North Street plume. Details on the proposed remediation system and pre-design characterization activities can be found in the *OU III Aiport Groundwater Treatment System 90% Design Documents* (J.R. Holzmacher, 2002a). Construction of the system is scheduled to begin in January 2003.

Pre-design chacterization to deal with the leading edge of the North Street Plume consisted of the drilling and sampling of four vertical profiles. The results of this work are discussed below.

3.2.8.1 Groundwater Monitoring

Well Network: A network of 25 monitoring wells monitors the downgradient portion of the OU IV, Former Landfill, Animal/Chemical Pits, and Glass Holes VOC plumes and the potential radiological contamination originating in these areas (**Figure 3.2-47**). Additionally, wells sampled under the OU III South Boundary and Industrial Park Programs are utilized for mapping this plume. Additional wells will be installed during 2003 in association with the construction of the groundwater treatment system.

Sampling Frequency and Analysis: The wells are sampled quarterly, and analyzed quarterly for VOCs, and annually for gross alpha/beta, gamma spectroscopy, tritium, and Sr-90 (**Table 1-6**).

3.2.8.2 Monitoring Well Data Results

The primary VOCs associated with this plume are carbon tetrachloride, PCE, and TCA. **Figure 3.2-1** depicts the TVOC plume distribution and includes data from the 24 monitoring wells, along with the 15 associated vertical profile borings drilled and sampled in 2001. The complete groundwater monitoring well data are included in **Appendix C**. Details of the pre-design groundwater characterization data can be found in the *North Street Groundwater Remediation System 90% Design Report* (Arcadis G&M, March 2002) and the *OU III Airport Groundwater Treatment System 90% Design Documents* (J.R. Holzmacher, March 2002). A hydrogeologic cross section running through the spine of the plume is provided in **Figure 3.2-48;** its location is shown on **Figure 3.2-1**. Vertical profile data is given, along with monitoring well data on the figures. This is screening level data and the TVOC concentrations posted are used as a guide in delineating contaminant contours. Toluene was detected ubiquitously at varying concentrations in vertical profile samples. Toluene has not been identified as a contaminant of concern throughout most of the BNL VOC plumes. Its presence throughout vertical profile sampling intervals is suspected to be related to potential field contamination issues, which are taken into consideration in the data contouring process.

The North Street VOC plume continues to be bounded by the existing well network with the exception of the leading edge of the plume. Groundwater sampling results from vertical profiles along the northern boundary of the Airport near Flower Hill Drive contained low concentrations of VOCs with a maximum TVOC value of 7 µg/L at location 800-76 in the deep Upper Glacial Aquifer (see **Figure 3.2-1** and **Figure 3.2-48**). Permanent monitoring wells will be installed in 2003 to monitor the leading edge of this plume.

Monitoring well 000-154 has historically shown the highest VOC concentrations (primarily carbon tetrachloride) in the North Street area. TVOC concentrations greater than 1,000 µg/L were observed in 1997 and 1998 but have steadily declined since as illustrated in **Figure 3.2-49**. This high concentration area appears to have migrated south of 000-154 as evidenced by vertical profile 000-381 which contained 2,020 µg/L of TVOC in the deep Upper Glacial aquifer approximately 700 feet south of well 000-154. The delineation of this plume to 50 µg/L TVOC was achieved by the pre-design characterization as shown in **Figure 3.2-1**.

Tritium has been detected historically in very localized off-site areas roughly corresponding to the area covered by the North Street VOC plume. Potential sources for this tritium as well as other radionuclides are located in the Former Landfill/Chemical/Animal Holes and OU IV Building 650 areas of the site. Tritium detections have been in the in the deep Upper Glacial aquifer at concentrations well below the NYS AWQS of 20,000 pCi/L.

Tritium has been detected historically in well 000-153. The tritium concentration in this well in 2001 was 2,560 pCi/L. Tritium was detected in seven of the fifteen vertical profiles installed in 2001/2002. In six of the seven vertical profiles tritium was detected at concentrations less than 1,000 pCi/L. The highest tritium concentration was detected in 000-337 at 9,130 pCi/L. This location is approximately 300 feet north of well 000-153. There were several detections of gamma-emitters (including Europium-155, americium-241, cesium-137 and beryllium-7) just above detectable concentrations. All of these detections were assessed for data usability and declared to be potential false-positives and/or had interference issues. Data qualifiers are included with the data in **Appendix C**. The data usability reports are provided in **Appendix G**.

3.2.8.3 Groundwater Monitoring Program Evaluation

Construction of the OU III North Street and Airport Remediation Systems and installation of additional monitoring wells is scheduled for 2003. **Figure 3.2-50** compares the TVOC plume from 1997 to 2001. The following significant changes were observed in the plume over this period:

- The trailing edge of the plume migrated south of the Former Landfill, Chemical/Animal Holes Areas.
- The high concentration area has moved south from well 000-154 and, based on the 2001 characterization data, appears to be just north of well 000-153.
- A small area of TVOC greater than 50 µg/L has migrated south of the site boundary and is crossing to the south of North Street. Due to the lack of recent well data the movement of this plume segment was estimated from groundwater modeling. The North Street System will capture this contamination.
- The leading edge of the plume, as defined by TVOC of 5 µg/L, remains in the vicinity of Flower Hill Drive.

Figure 3.0-4 compares the observed plume in 2001 to the plume modeled in the OU III FS. There is good correlation between the observed and predicted plumes.

The OU III North Street Monitoring Program can be evaluated from the four decision rules identified from the groundwater DQO process.

1. Was the BNL Groundwater Contingency Plan triggered?
There were no unusual or unexpected VOC or radionuclide concentrations in the monitoring wells associated with this program during 2001.

2. Does the existing contaminant plume represent a potential risk to downgradient receptors?
There have been no significant increases in the concentrations of contaminants during 2001 in the monitoring wells. The leading edge of the plume was defined at the northern boundary of the Airport at concentrations below the NYS AWQS for individual VOCs. There are no downgradient receptors within the Airport. Homes in the residential area overlying the plume should have been connected to public water.

3. Is the planned remediation system adequate to intercept and treat the existing contamination to prevent impacts to potential downgradient receptors?
The remediation systems are being planned to intercept and treat the contamination as outlined in the OU III ROD. The combined North Street and Airport systems will prevent any impacts to potential downgradient receptors south of the leading edge of the plume, as currently defined.

4. Is there evidence of a mobile radionuclide plume from the Building 650 sump that would trigger additional actions?

Based on both monitoring well data and the extensive pre-design characterization in 2001 radionuclide contamination appears to be relegated to isolated occurrences of tritium, primarily in the Deep Upper Glacial aquifer, at concentrations below the NYS AWQS of 20,000 pCi/L.

3.2.8.4 Recommendations

The monitoring well network will be enhanced during 2003 by establishing monitoring wells associated with both the North Street and Airport Remediation Systems. There are no recommendations for the monitoring well network other than those currently planned as part of these efforts.

3.2.9 Western South Boundary Monitoring

In 2001, the OU III Western South Boundary Monitoring Program consisted of four existing monitoring wells. During late 2001 and early 2002 the installation of an additional 12 wells was started to enhance this network and provide for monitoring of the newly constructed remediation system and recharge basin.

The Western South Boundary pump and treat system was designed to capture the VOCs in the Upper Glacial aquifer along the western portion of the BNL south property boundary. This system will capture and remediate a portion of the OU III VOC plume to reduce future off-site migration of the contamination, and discharge of the VOC plume to the Carmans River.

Construction of the groundwater extraction and treatment system is scheduled for completion in May 2002. The system includes two extraction wells located along the BNL south property boundary. Extracted groundwater will be treated via air stripping and recharged at the western end of the Middle Road upgradient and cross-gradient of the plume. Groundwater flow in this area is toward the south.

3.2.9.1 Groundwater Monitoring

Well Network: A network of four existing wells was used to monitor this portion of the OU III plume in 2001. Twelve wells will be added to the program in 2002. Their locations are shown in **Figure 3.2-51**.

Sampling Frequency and Analysis: The wells are sampled quarterly and analyzed for VOCs. The initial baseline round of sampling for the new wells will include analysis for gamma spectroscopy, tritium, and strontium-90.

3.2.9.2 Monitoring Well Data Results

The primary VOCs associated with this portion of the OU III plume are TCA, TCE, chloroform and dichlorodifluoromethane (freon). VOC contamination in the monitoring wells is located in the mid to deep Upper Glacial aquifer. Maximum TVOC concentrations during 2001 were in well 130-02 at 28 µg/L during the fourth quarter. Fourth quarter well data is posted on **Figure 3.2-1**. The complete results are in **Appendix C**. The wells are included under the OU III South Boundary Section.

3.2.9.3 Groundwater Monitoring Program Evaluation

Start-up testing of the OU III Western South Boundary Pump and Treat System is scheduled to begin in May 2002. No significant changes in contaminant concentrations were observed in monitoring wells during 2001. Twelve additional monitoring wells will be added to the existing network in early 2002, with sampling scheduled for the second quarter.

3.2.9.4 Recommendations

No changes are recommended for the OU III Western South Boundary Monitoring Program for 2002.

3.2.10 Central Monitoring

The OU III Remedial Investigation identified several low-level (less than 100 µg/L) source areas and non-point contaminant sources within the developed central areas of the BNL Site. Since these sources, which include spills within the Alternating Gradient Synchrotron (AGS) Complex, and the storage area for site maintenance equipment (Building 208) and others, are not large enough to warrant a dedicated monitoring program, they are monitored under the OU III Central project. In addition, this project includes wells 109-03 and 109-04, which are located near the BNL site boundary and serve as sentinel wells for the Suffolk County Water Authority (SCWA) William Floyd Parkway well field.

3.2.10.1 Groundwater Monitoring

Well Network: The monitoring well network established to check the relatively low-level VOC contamination in the central areas of the site is comprised of 21 wells (**Figure 3.2-52**). Seven of these wells have shifted into other programs (primarily OU III Middle Road) for 2002. The locations provide data on groundwater quality near the source areas that aid in defining the VOC plumes, which extend downgradient from this area of the site. This network also is supplemented by data from Environmental Surveillance program wells that monitor active research and support facilities (**Table 1-7**).

Sampling Frequency and Analysis: The wells are sampled and analyzed quarterly for VOCs quarterly, and semiannually for gross alpha/beta, gamma spectroscopy, tritium, and Sr-90 (**Table 1-6**).

3.2.10.2 Monitoring Well Data Results

VOC concentrations detected in most of the OU III Central wells are near or below NYS AWQS. The following wells displayed significant changes in VOC concentrations or were otherwise noteworthy:

- Well 65-05 is screened in the shallow Upper Glacial aquifer and is located in the AGS area. TVOCs in well 65-05 increased during 1999 and 2000 peaking at a concentration of 123 µg/L in September 2000. Concentrations continued a decreasing trend in 2001 with a detection of 17 µg/L during the fourth quarter. Based on the occurrence of VOCs in this well, the contamination most likely is traveling as a slug from an unidentified small source to the north.

- Well 66-09 is located southeast of building 830 and screened in the shallow Upper Glacial aquifer. VOC concentrations, primarily TCA, significantly increased during late 2000 and early 2001, peaking at 112 µg/L TVOC in February 2001. A preliminary investigation identified several potential sources in building 830. The collection of groundwater samples during a subsequent geoprobe investigation of the area downgradient of the building during the summer of 2001 revealed little or no VOC contamination (details of this investigation can be found on the ESD website (BNL, 2001c). VOC concentrations during the final three quarters of 2001 dropped to below NYS AWQS.

- Well 83-02 is located near the intersection of Brookhaven Avenue and Upton Road and is screened in the mid to deep Upper Glacial aquifer. This well consistently has contained 10 to 25 µg/L of chloroform since 1997. Potential sources of this contamination may be in the AGS area of the site.

- SCDHS wells 109-03 and 109-04 serve as sentinel wells for the SCWA William Floyd Well Field and are located near the eastern BNL site property boundary. There were no detections of either VOCs or radionuclides in these wells during 2001.

3.2.10.3 Groundwater Monitoring Program Evaluation

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

1. Was the BNL Groundwater Contingency Plan triggered?
No groundwater sampling results triggered the BNL Groundwater Contingency Plan in 2001. However, 2000 Groundwater Contingency Plan actions did spill over into 2001 due to the VOC detection at Building 830. That issue is now closed.

2. Are there potential impacts to the SCWA William Floyd Parkway well field from on-site contamination?
There were no detections of either VOCs or radionuclides in sentinel wells (109-03 and 109-04) of the SCWA William Floyd well field during 2001; therefore Brookhaven's activities are unlikely to have had any impacts on this well field.

3. Are the performance objectives met?
Individual wells continue to contain VOC concentrations exceeding the NYS AWQS; therefore, the OU III ROD objectives have not been met.

4. If not, are observed conditions consistent with the attenuation model?
Figure 3.0-4 compares the observed OU III plume in 2001 with the FS groundwater model predictions for 2001. In the areas of the site where the wells of the OU III Central Monitoring Program are located the observed TVOC concentrations generally are in good agreement with the model predicted concentrations with respect to both the plume extent and contaminant concentrations.

3.2.10.4 Recommendations

The OU III Central Monitoring Program continues to be adequate for addressing minor groundwater contamination areas across the site. Significant or substantial levels of contaminants were not observed in 2001; therefore, additions to the current monitoring well network are not warranted.

3.2.11 HFBR Tritium Monitoring

In late 1996, tritium was detected in wells near the High Flux Beam Reactor (HFBR). The source of the release was traced to the HFBR spent fuel pool. In response, the fuel rods were removed from the pool for off-site disposal, the spent fuel pool was drained and the HFBR was removed from service in 1997. Also, numerous monitoring wells were constructed to characterize the tritium plume downgradient of the HFBR. In May 1997, operation of a three-well groundwater extraction system began. This system was constructed on Princeton Avenue approximately 3,500 feet downgradient of the HFBR to capture any tritium and ensure that the plume would not move off-site. Extracted water was recharged at the RA V recharge basin. Groundwater modeling demonstrated that the tritium plume would naturally attenuate naturally to below drinking water standards before reaching the site boundary. In addition, there have been no detections of tritium in monitoring wells south of Weaver Drive therefore; the extraction system was placed on stand-by status in September 2000.

As described in the OU III ROD, the selected remedy to address the HFBR tritium plume includes implementing monitoring and low-flow extraction programs to prevent or minimize the plume's growth. Through April 2001, six low-flow extraction events were completed which removed a total of 30,000 gallons of tritiated water, that was sent off site for disposal. The trigger level for low flow extraction has not been exceeded since the last shipment. Plume growth is defined as a detection of tritium at an activity above 750,000 pCi/L in any well, above 25,000 pCi/L in wells at the Chilled Water Plant Road, or above 20,000 pCi/L in wells along Weaver Drive. Exceedances of these activities will necessitate implementing the specific actions described in the ROD, including possible reinitiation of low-flow pumping of impacted groundwater or reactivation of the Princeton Avenue pumping system.

As of December 2001, the monitoring well network for the OU III HFBR project includes 141 wells that provide data on groundwater quality in the vicinity of the source area and at on-site downgradient locations. The locations of many of the wells were selected using the BNL Regional Groundwater Flow Model. Well locations are shown in **Figure 3.2-53**. Depending on location wells were sampled biweekly, monthly or quarterly for analysis of tritium, and semi-annually for analysis of VOCs.

Tritium is the contaminant of concern associated with the OU III HFBR wells. The extent of the tritium plume, determined from data collected during the fourth quarter of 2001, is shown on **Figure 3.2-53**.

Groundwater flow locally in the vicinity of the HFBR is variable due to BNL pumping and recharge sources in the area. In general, groundwater flow is toward the south or southeast (**Figures 2-2** and **2-3**). Evaluation of groundwater flow and quality data indicates that the downgradient portion of the tritium plume (south of Brookhaven Avenue) has shifted to the east since 1997 in response to changing flows to the HO recharge basin, the use of the OU III recharge basin, and the pumping of BNL supply wells 10, 11 and 12.

3.2.11.1 Groundwater Monitoring

Well Network: A monitoring well network of 157 wells (including 22 wells installed in 2001) was designed to follow the extent of the plume, the source area, and the effectiveness of the groundwater remediation system (**Figure 3.2-53**). Due to the closeness of the HFBR to artificial pumping and recharge locations, the plume is subjected to changing hydraulic stresses, which have warranted an extensive monitoring network. BNL's Regional Groundwater Model was utilized to assist with the placement of the wells.

Sampling Frequency and Analysis: The wells associated with the high concentration portion of the plume were sampled either biweekly or monthly. The remaining wells were sampled quarterly. Samples are analyzed for tritium quarterly and VOCs semiannually (**Table 1-6**). The *OU III HFBR Downgradient Monitoring Plan* (BNL, 2001d) proposed changes to the sampling program that will be implemented beginning in the first quarter of 2002.

3.2.11.2 Monitoring Well/Vertical Profile Well/Geoprobe Data

Data from the OU III HFBR Tritium Groundwater Monitoring program were supplemented with data obtained from six vertical profiles and 43 geoprobes during 2001. The geoprobes were installed along a series of three east-west transects to track the high concentration segment of the plume (**Figure 3.2-54**). Tritium concentrations in geoprobes greater than 750,000 pCi/L triggered low-flow remediation pumping in wells that subsequently were installed at the geoprobe location. Monitoring wells were sited at many of the geoprobe locations, based on the data, in order to enhance the network of sampling points focusing on the high concentration segment of the plume. These wells were sampled at a higher (biweekly or monthly) frequency than others not associated with this segment.

Six vertical profiles were drilled and sampled to fill data gaps in the downgradient portion of the monitoring network. The data from these vertical profiles were used to site wells monitoring both the plume core and perimeter areas. Ongoing characterization of the plume is necessary to satisfy the requirements of the OU III ROD. Detailed summaries of the characterization data are provided in a series of five quarterly data reports that were submitted to the regulatory agencies during 2001. **Appendix C** has the complete set of monitoring well data.

Figure 3.2-55 shows the high concentration segment of the plume. The highest level observed in a monitoring well during the fourth quarter of 2001 was 447,000 pCi/L in well 75-418, located just to the east of the Light Source facility. Tritium concentration trend plots are shown for key wells located along the spine of the plume in **Figure 3.2-56**. The high concentration core of the plume passed through the vicinity of well 75-296 during the beginning of 2001 then through well 75-418 during the middle to latter part of 2001. The high concentration segment is expected to reach the line of wells along Brookhaven Avenue during 2002. Tritium concentrations have remained below 750,000 pCi/L, the trigger level for low-flow remediation pumping, since April 2001. The vertical extent of contamination is depicted in cross section H-H' (**Figure 3.2-56**).

A small, high concentration slug of tritium was observed immediately downgradient of the HFBR in late 1999 and early 2000 as evidenced by the graph of the trend in tritium concentration for well 75-43 (**Figure 3.2-58)**. This slug migrated to Cornell Avenue in 2001 as can be seen by the increasing trend in well 75-225 which peaks in late 2001. This slug now is migrating past Cornell Avenue and is expected to be in the vicinity of Temple Place during 2002.

The overall fourth quarter 2001 HFBR tritium plume distribution is shown in **Figure 3.2-59**. The leading edge of the 20,000 pCi/L isocontour is just to the north of vertical profile 95-262 in the mid to deep Upper Glacial aquifer (**Figure 3.2-57**). This vertical profile was located to find the leading edge of the 20,000 pCi/L isocontour. The highest concentration in this vertical profile was 18,500 pCi/L. The outer edge of the main body of the plume as defined by the 1,000 pCi/L isocontour is just to the north of Weaver Drive. There were no detections of tritium in excess of 1,000 pCi/L during 2001 south of Weaver Drive.

Well 95-93 is screened in the deep Upper Glacial aquifer along the western portion of Weaver Drive. Tritium concentrations were detected above 1,000 pCi/L beginning in July 2000 and peaked at 5,500 pCi/L in April 2001 (**Figure 3.2-58**). Concentrations have been dropping over the last three quarters of 2001, with 2,460 pCi/L reported in October 2001. This tritium was originally detected in vertical profiles further north as part of the 1997 investigation and appears to be a small slug with concentrations less than 6,000 pCi/L.

Groundwater flow data suggest that the eastward shift of the downgradient segment of the tritium plume has stabilized during 2001 (**Figures 2-2** and **2-3**), along with the absence of tritium in vertical profiles 85-296 and 96-87 which are located just east of the eastern plume perimeter.

3.2.11.3 Groundwater Monitoring Program Evaluation

The OU III HFBR Tritium Monitoring program can be evaluated based on five major decision rules established for this program using the groundwater DQO process.

1. Was the BNL Groundwater Contingency Plan triggered?
The BNL Groundwater Contingency Plan was not triggered during 2001. High tritium concentrations detected in vertical profiles, geoprobes and monitoring wells were all expected, due to our understanding of the HFBR Tritium plume.

2. Is the tritium plume growing?
As described in the OU III ROD, plume growth is defined as a detection of tritium at an activity above 750,000 picoCuries per liter (pCi/L) in any well, above 25,000 pCi/L in wells at the Chilled Water Plant Road or above 20,000 pCi/L in wells along Weaver Drive. None of these criteria were approached during 2001. A comparison of the plume distribution between 1997 and 2001 is shown in **Figure 3.2-60**.

3. Are observed conditions consistent with the attenuation model?
The tritium concentrations detected in monitoring wells, vertical profiles and geoprobes during 2001 were consistent with the HFBR Tritium groundwater model predictions. (*HFBR Tritium Low Flow Pumping Evaluation Report, September 2001[BNL, 2001e]*)

4. Is the tritium plume migrating toward the zone of influence of BNL water supply wells 10, 11 and 12?

Tritium was not detected above 1,000 pCi/L in any of the monitoring wells located upgradient of the HFBR. These wells are sited to serve as sentinel wells for any northward migration of tritium towards the supply wells.

5. Has any segment of the plume migrated beyond the current monitoring network?

There were no detections in plume perimeter wells during 2001 indicating that tritium had moved beyond the current monitoring network. Additional perimeter monitoring wells were installed during 2001 to supplement the existing network.

3.2.11.4 Recommendations

The following are recommendations for the HFBR groundwater monitoring program.

1) Five geoprobes will be installed in 2002 to track the high concentration portion of the plume as per the HFBR Tritium Low Flow Pumping Evaluation Report (BNL 2001).

2) Based on the results of groundwater monitoring well data, up to five addition vertical profiles and monitoring wells will be installed in 2002 in order to define the tritium plume.

3) Re-evaluate the monitoring well network and sampling frequency during 2002.

4) Evaluate operating the HFBR Pump and Recharge wells on Princeton Avenue to remediate the high concentrations in the OU III VOC plume located immediately to the west of the extraction wells.

3.2.12 BGRR/Waste Concentration Facility Strontium-90 Monitoring

The OU III Brookhaven Graphite Research Reactor (BGRR)/Waste Concentration Facility (WCF) project monitors the extent of strontium-90 plumes in groundwater. Some of the wells included in the OU III BGRR/WCF network also are monitored as part of the OU III AOC 29 (High Flux Beam Reactor) program. These wells are sampled concurrently for both programs to avoid duplication of effort.

The analytical results show two separate areas of elevated strontium-90, one emanating from the WCF and extending approximately 1,500 feet south, and the other beginning south of the BGRR and extending south for approximately 600 feet (**Figure 3.2-61**). Variability in groundwater flow directions due to changes in pumping and recharge patterns in the plume vicinity over time have resulted in lateral spreading of the contamination.

Groundwater characterization work was conducted for the Below Ground Ducts (BGD) portion of the BGRR decommissioning in 2001. Geoprobe groundwater samples were obtained from 24 locations as part of the characterization; details on the sample data can be found in the BGRR Below Ground Ducts EE/CA (BNL 2002e). Geoprobe groundwater characterization also was performed during 2001 in the vicinity of the HFBR stack Groundwater samples were obtained from three locations. Additional pre-design characterization of the strontium-90 plumes is planned for calendar year 2003, with design and construction of a groundwater remediation system operation planned for calendar year 2004 and 2005.

3.2.12.1 Groundwater Monitoring

Well Network: A network of 57 monitoring wells was designed to monitor the Sr-90 plumes associated with the BGRR, WCF, and Pile Fan Sump (**Figure 3.2-62**). Fourteen wells monitored under this program also are sampled under the AOC 29 HFBR Tritium program; sampling events are coordinated between the two programs to eliminate any duplication of effort. The 14 wells, which were originally installed as part of the AOC 29 HFBR program, are utilized either as sentinel wells or to bound the Sr-90 plumes to the east.

Sampling Frequency and Analysis: The wells are monitored semiannually, and the samples are analyzed for Sr-90 (**Table 1-6**).

3.2.12.2 Monitoring Well/Geoprobe Data

The BGRR/WCF strontium-90 plumes consist of two distinct lobes. The first extends from just south of building 701 in the area of the BGD to just north of Brookhaven Avenue (**Figure 3.2-61**). Contamination in this lobe migrates from the shallow to mid Upper Glacial aquifer. The southern extent of the plume was delimited based on the apparent significant increase in strontium-90 concentrations in well 75-198 after its installation in 1999 (**Figure 3.2-63**). This interpretation is complicated by the fact that the direction of groundwater flow has varied in this area of the site due to changes in the supply well pumping and recharge to the north and east. Therefore, fluctuations in strontium-90 concentrations in the well also could reflect movement of the plume away from the well. This complication must be considered for contaminant histories for all wells in this general area. **Figure 3.2-63** plots the trends in Strontium-90 for key wells.

There also is the possibility that the strontium-90 contamination is moving in discreet slugs or pulses, and those concentrations in that well may have been higher prior to its installation in 1999.

The second lobe extends from just south of the former “D”tanks area to south of Cornell area. An overall eastward shift to this plume lobe was observed during 2000 and is reflected in the increasing strontium-90 concentrations in former perimeter well 65-39. Strontium-90 was not detected during the first sampling event for this well in 1997, but subsequently concentrations have increased to 35 pCi/L in October 2001.

There are three areas of high strontium-90 concentrations (greater than 50 pCi/L) within the plumes. The first is in the vicinity of the BGD where a geoprobe groundwater sample in August 2001 detected levels at 540 pCi/L. Concentrations greater than 50 pCi/L extend south of this area to well 75-190, which is located just south of Cornell Avenue.

Another area of high strontium-90 concentrations exists immediately south of the former “D” tanks area just west of the WCF and extends southwards by approximately 200 feet. The highest strontium-90 concentration observed in this well during 2001 was 760 pCi/L in December; it has exceeded 800 pCi/L since its installation in 1997 (**Figure 3.2-63**).

A third area of high strontium-90 concentrations is in the vicinity of the HFBR stack and southeast of the Pile Fan Sump (PFS). A geoprobe sampled in 2001 detected 392 pCi/L of strontium-90. There are currently no monitoring wells in this immediate area.

3.2.12.3 Groundwater Monitoring Program Evaluation

The OU III BGRR/WCF Strontium-90 Monitoring program can be evaluated in the context of four basic decisions established for this program using the groundwater DQO process.

1. Was the BNL Groundwater Contingency Plan triggered?
The detection of Sr-90 at 540 pCi/L at geoprobe location 75-530 qualified as a Category Two under the contingency plan. We plan to install additional monitoring wells for this area as part of the overall BGRR groundwater remediation pre-design characterization.

2. Is the extent of the strontium-90 plume still defined by the existing monitoring well network?

There are several areas where the Sr-90 plumes are not defined by the existing monitoring well network.

- The leading edges of the each of the two strontium-90 plume lobes do not have downgradient, “clean” sentinel wells. The installation of four wells immediately south of Brookhaven Avenue is planned for the spring of 2002 to address these issues.
- The former perimeter well on the eastern edge of the WCF strontium-90 plume currently contains strontium-90 at 35 pCi/L. Geoprobes will be installed to address this issue as part of the BGRR groundwater remediation pre-design characterization.

- The extent of the high strontium-90 concentrations detected in the vicinity of the HFBR stack during geoprobe characterization. Additional characterization will be performed during the BGRR groundwater remediation pre-design study.

3. Can strontium-90 contamination impact existing or planned groundwater remediation systems?

The nearest operating groundwater remediation systems are the Carbon Tetrachloride and Building 96 Systems which are located more than 2,000 feet south of this area and will not be affected by strontium-90 contamination in the foreseeable future. Strontium-90 plume impacts would have to be evaluated should the need for additional HFBR tritium remediation occur.

4. Is the strontium-90 plume (s) migrating toward BNL supply wells 10,11, and 12?

Strontium-90 was not detected in the sentinel wells located upgradient of the WCF area. There is no evidence at this time of strontium-90 moving towards the BNL supply wells.

3.2.12.4 Recommendations

The following are recommendations for the BGRR groundwater monitoring program:

1) Two sentinel wells will be installed south of Brookhaven Avenue at two separate locations (total of four wells) to monitor the leading edge of the strontium-90 plumes.
2) The HFBR stack will be evaluated as a potential source for the tritium (detected during HFBR characterization work in 2001) as part of the BGRR pre-design characterization work beginning in the fall of 2003. The groundwater monitoring well network will also be re-evaluated at that time.

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3.2.13 Chemical/Animal Holes Strontium-90 Groundwater Monitoring

Waste, glassware containing chemical and radioactive waste, and animal carcasses containing radioactive tracers were disposed of in shallow pits in an area directly east of the Chemical/Animal Holes area between 1960 and 1966. Used glassware continued to be disposed in shallow pits directly north of this area from 1966 through 1981. Remediation of the Chemical/Animal Holes area, including waste excavation, treatment, and disposal, was completed in September 1997.

Two distinct strontium-90 plumes were identified in this general area during the OU I RI/FS. The larger of the two is associated with the Chemical Holes and the other with the former Landfill. This plume is approximately 650 feet long and 90 feet wide, with a maximum thickness of 15 feet (**Figure 3.2-64**).

The OU III ROD specified the selected remedy for the Chemical Holes area to consist of:

1. Groundwater extraction;
2. Strontium-90 treatment using ion-exchange;
3. Onsite discharge of treated water.

A pilot/treatablity study will be performed to evaluate the effectiveness of extraction and treatment of strontium-90 before implementation of the remedy; it is scheduled to begin construction in May 2002.

Pre-design groundwater characterization was performed for this area in 2001. Groundwater samples were obtained in three phases using the geoprobe from 30 locations around and downgradient of the source areas. Additional details on the pre-design characterization and the planned pilot/treatability study are given in in the *Strontium-90 Pilot Study Work Plan/ 90 Percent Design Report* (IT Corp., November 2001).

3.2.13.1 Groundwater Monitoring

<u>*Well Network*</u>: A network of 24 monitoring wells is positioned to monitor the strontium-90 plume downgradient of the Former Landfill and Chemical/Animal Holes source areas (**Figure 3.2-65**). Additional (sentinel) wells, screened in the middle Upper Glacial aquifer, are sited along Middle Path to signal early warning of the plume's migration. The locations for the sentinel wells were selected with help from BNL's Regional Groundwater Model (Geraghty and Miller 1996).

<u>*Sampling Frequency and Analysis*</u>: The Chemical/Animal Holes area wells are monitored semiannually, and samples are analyzed semiannually for Sr-90, and annually for VOCs (**Table 1-6**). Plume core wells 106-16, 106-17, 106-48 and 106-49 will be sampled quarterly for strontium-90 in 2002, based on the recommendations of the Groundwater DQO Project.

3.2.13.2 Monitoring Well/Pre-Design Characterization Results

Groundwater samples were obtained from 30 locations around and downgradient of the source areas during 2001, in addition to two rounds of sampling of the 24 monitoring wells. Detailed results of the 2001 groundwater characterization can be found in the *Strontium-90 Pilot Study Work Plan/ 90 Percent Design Report* (IT Corp., 2001).

Figure 3.2-64 shows the strontium-90 plume distribution. The plume depiction is derived from fourth quarter monitoring well data and the highest strontium-90 detection from each geoprobe location during 2001. The highest strontium-90 concentration observed during 2001 was 1,770 pCi/L in well 106-16, that is located immediately south of the Animal Pits and historically has shown the highest concentrations in this area (**Figure 3.2-66**). The sharp increase in strontium-90 in this well seems to be correlated with the excavation of the Animal Pits area in 1997.

A high concentration plume segment of greater than 100 pCi/L strontium-90 was delineated during the 2001 groundwater characterization and extends from approximately 75 feet northwest of well 106-16 to approximately 125 feet south of the Princeton Avenue firebreak road (**Figure 3.2-64**). The leading edge of the plume, as defined by the NYS AWQS of 8 pCi/L, is approximately 275 feet south of this firebreak road.

A second, smaller plume occurs south of the Former Landfill (and the Princeton Avenue firebreak road). A concentration of 17 pCi/L was detected in a geoprobe south of the extent of the current monitoring well network.

The monitoring wells in this program also are analyzed annually for VOCs. The data are summarized in section 3.2.9 of this report; the complete results are in **Appendix C**.

3.2.13.3 Groundwater Monitoring Program Evaluation

The OU III Chemical/Animal Holes Strontium-90 Monitoring Program can be evaluated in the context of the three basic decision rules identified for this program after applying the groundwater DQO process.

1. Was the BNL Contingency Plan Triggered?

There were no unexpected strontium-90 concentrations detected during 2001 under the groundwater monitoring program.

2. Are the strontium-90 plumes targeted for monitored natural attenuation attenuating as planned?

Natural attenuation and groundwater monitoring are planned for the strontium-90 plume originating from the Former Landfill area. The leading edge of this plume has not been fully characterized; therefore natural attenuation of this plume cannot be fully assessed.

<u>3. Is the high concentration strontium-90 plume to be addressed by the upcoming pilot study still located in the pilot study area?</u>

Data indicate that the high concentration portion of the plume is still in the pilot study area. The pilot/study will include an extraction well placed in the segment of the plume with the high concentration of strontium-90. Additional wells may be installed for further hydraulic control and to facilitate remediation if necessary. The plume is anticipated to remain within the pilot study area.

3.2.13.4 Recommendations

The following are recommendations for the OU III Chemical/Animal Holes groundwater monitoring program:

1) Monitoring wells will be installed during 2002 as part of the pilot-study groundwater remediation system construction to address the Chemical/Animal Holes strontium-90 plume.

2) The installation of an additional sentinel monitoring wells is recommended to monitor the leading edge of the strontium-90 plume downgradient of the Former Landfill area. This well would be located along Middle Path to the west of existing well 106-62.

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3.2.14 South Boundary Radionuclide Monitoring Program

The South Boundary Radionuclide Monitoring Program was created in late 2001 as a result of developing groundwater DQOs for the OU III South Boundary Remediation System and OU III Western South Boundary Remediation System Programs. The elimination of radionuclides from those monitoring programs was recommended as this was not required as part of monitoring the groundwater remediation systems. However, it was decided that such analyses were warranted to confirm that groundwater impacted by radionuclides is not migrating off-site. Tritium, gamma spectroscopy, and strontium-90 were previously analyzed annually from wells in these programs. The sampling will continue, in conjunction with the South Boundary and Western South Boundary programs, to eliminate additional costs of collecting samples. The south boundary of the eastern portions of the site are monitored for radionuclides as part of the OU I South Boundary, EDB, and OU V Sewage Treatment Plant groundwater monitoring programs.

3.2.14.1 Groundwater Monitoring

Well Network: A network of 31 monitoring wells incorporates wells also sampled under the OU III South Boundary and OU III Western South Boundary programs. Their locations along the southern property boundary are shown in **Figure 3.2-67**.

Sampling Frequency and Analysis: The OU III South Boundary Radionuclide Monitoring Program wells will be sampled annually for tritium, strontium-90, and gamma spectroscopy (**Table 1-6**).

3.2.14.2 Monitoring Well Results

The radionuclide analytical results for the wells can be found in the OU III South Boundary Remediation System section of **Appendix C**. All detections are summarized in **Table 3-21**. There were nine estimated detections of radionuclides in 2001 in eight separate wells at concentrations slightly above detection limits. Data usability reviews performed on each of these analyses applied an N2 qualifier to them. The N2 qualifier means that the data are not usable because the results and the propagated error are indistinguishable from background. The data usability reports are included in **Appendix G**.

3.2.14.3 Groundwater Monitoring Program Evaluation

The OU III South Boundary Radionuclide Monitoring Program can be evaluated based on the 1 decision rule identified for this program resulting from applying the groundwater DQO process.

1. Was the BNL Contingency Plan Triggered?
There were no unexpected results during 2001 that triggered the BNL Groundwater Contingency Plan.

3.2.14.4 Recommendations

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

3.3 Operable Unit IV

3.3.1 Air Sparge/Soil Vapor Extraction (AS/SVE) Remediation System

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

Air sparge with soil vapor extraction was selected as the remedy for soil and groundwater contaminated with VOCs underlying OU IV. Three areas of soil and/or groundwater contamination were addressed in the remedial design.

The AS/SVE system has been operating since November 1997. The performance goals for soil cleanup were achieved in 1998, while those for groundwater were met in August 2000. Subsequently, a formal petition for shutdown was submitted to the EPA and NYSDEC and approval was received in January 2001. The system was shutdown on January 10, 2001. However, following the shutdown, groundwater results were received for well 076-04 showing a rebound in several VOC parameters (indicative of fuel oil). This well is located in the area where the original fuel oil/solvent spill occurred and it had shown VOC levels below MCLs for nearly two years previously. As a result of this finding, pulsing of the AS/SVE system was activated on a weekly basis in February 2001. The system was pulsed for one day (approximately 24 hours) each week and focused on the sparge and extraction well in the vicinity of well 076-04. During the following months, analytical results from the monthly sampling showed a decreasing trend in VOC concentrations.

In addition, the supplemental action recommended in the 2000 BNL Groundwater Status Report was accomplished during July 29 to July 31, 2001. The objective of this action was to further reduce any residual VOCs, primarily ethylbenzene, xylenes and trimethylbenzenes, through enhanced biodegradation processes using an oxygen releasing compound (ORC). A slurry of a mixture of magnesium peroxide powder and water was injected under pressure at seven locations around well 076-04 into the water table. The system was shutdown on August 08, 2001 and further monitoring was continued as per OU IV Remediation Area 1 Proposed Supplemental Remedial Effort - Work Plan, May 2001.

3.3.1.1 Groundwater Monitoring

Well Network: A network of 21 wells was designed to monitor the effectiveness of the groundwater remediation system and extent of the VOC plume associated with the 1977 spill (**Figure 3.3-1**). Locations were selected using BNL's Regional Groundwater Model. During planning for placing the wells, the proximity of the RA V and HO Recharge basins was considered, along with their associated effects on local patterns of groundwater flow. Sixteen of the wells sampled under this program also monitor radionuclide contamination originating from

Building 650's Sump Outfall Area. The two programs coordinate sampling to eliminate any duplication of effort.

Sampling Frequency and Analysis: The wells are sampled quarterly, and samples are analyzed for VOCs and SVOCs (**Table 1-6**). Some wells also are used for the OU IV AOC 6 (Building 650 Sump Outfall) program, and are analyzed semiannually for gross alpha/beta, gamma spectroscopy, Sr-90, and tritium.

3.3.1.2 Monitoring Well Results

The complete groundwater data are given in **Appendix C**. Well 076-04 was sampled twice (third and fourth quarters) since the implementation of the ORC compound. The TVOC concentrations for these two rounds were 4 µg/L and 3µg/L, respectively. The fourth quarter groundwater TVOC results are shown in **Figure 3.3-2**.

VOCs were not detected in the remainder of the wells in the monitoring program except for wells 76-23 and 76-06, that are located outside the area of influence of the AS/SVE system. All VOC detections in 2001 exceeding NYS AWQS are summarized in **Table 3-22**.

Well 76-23 is located to the west of the AS/SVE system and south of the CSF. The VOCs in well 76-23 are primarily cis-1, 2-dichloroethylene. The highest TVOC concentration in this well during 2001 was 45 µg/L during the second quarter.

Well 76-06 is located to the east of the AS/SVE system. TVOC concentrations were greater than 10 µg/L in the first and fourth quarters and below 4 µg/L during the second and third quarters of 2001. the VOCs are primarily BTEX compounds.

3.3.1.3 Remediation System Evaluation

The system can be evaluated based on three decision rules identified during the groundwater DQO process.

1. Was the BNL Contingency Plan Triggered?
There were no unexpected VOC concentrations in groundwater during 2001.

2. Were the cleanup goals met?
VOC concentrations have remained below NYS AWQS since the ORC was implemented in August 2001. If this trend were to continue through the first three months of 2002, the cleanup goal of concentrations remaining below MCLs for six months would be achieved.

3. Are additional enhancements (that is, ORC) necessary or is further operation of the AS/SVE system required?
VOC concentrations have remained below NYS AWQS since the implementation of the ORC in August 2001. Neither the further operation of the AS/SVE system nor additional ORC enhancements is required.

3.3.1.4 Recommendations

The pulsing of the AS/SVE in February 2001 and the injection of ORC around monitoring well 076-04 have accomplished the goal of cleaning up the residual VOCs within the area of concern for the AS/SVE system. Since all the wells have shown TVOC concentrations below MCLs for two consecutive quarters, satisfying the criteria for closure based on the OU IV AS/SVE Operations, Maintenance and Monitoring Plan (BNL, 1999b), a petition for closure will be submitted in Spring 2002 to the regulators for review and approval.

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3.3.2 Building 650 (Sump Outfall) Strontium-90 Monitoring Program

The Building 650 (Sump Outfall) Strontium-90 Monitoring Program monitors a strontium-90 plume emanating from contaminated soil within an area known as the Building 650 Sump Outfall Area. This area is a natural depression at the terminus of a discharge pipe from the building. The pipe conveyed discharges from the decontamination of radioactively contaminated clothing and equipment that was conducted on an outdoor pad at Building 650, beginning in 1959.

Remediation of the soils associated with the Building 650 sump outfall and the pipe leading to the outfall are undergoing excavation and off-site disposal during the Spring 2002.

3.3.2.1 Groundwater Monitoring

Well Network: A monitoring network was designed to clarify the extent of Sr-90 contamination originating from the area of the Building 650 Sump Outfall. The network consists of 29 wells (five of which are used for the OU IV AOC 5 program) located to define the limits of Sr-90 contamination and serve as an early warning system for the downgradient migration of the plume (**Figure 3.3-3**).

Sampling Frequency and Analysis: The wells are monitored semiannually, and the samples analyzed for gross alpha/beta, gamma spectroscopy, tritium, and Sr-90 (**Table 1-6**).

3.3.2.2 Monitoring Well Results

The complete results from radionuclide sampling can be found in **Appendix C**. The annual *OU IV AOC 6 Interim Remedy Monitoring Report* (BNL) was submitted to the regulators in May 2002. The overall extent of the strontium-90 plume originating from the Building 650 sump outfall did not change significantly from 2000 to 2001 (**Figure 3.3-4**). The highest strontium-90 concentrations were detected in well 76-13 at 28 pCi/L in February 2001. In general, the concentrations in wells associated with the Building 650 sump outfall decreased during 2001.

Strontium-90 concentrations in well 76-28 increased to 14 pCi/L during the second round of 2001 after 2 consecutive rounds during which they had decreased (**Figure 3.3-5**). This well is located immediately north of Building 650, adjacent to a former decontamination pad. Strontium-90 in this well had spiked up to 20 pCi/L in 2000 following several years in which it was less than 4 pCi/L. Changes in the water table due to recharge to the RA V basin may be shifting the plume in a west-southwest direction. Tritium from the basin has been detected to the northwest of the basin indicating water table mounding in the area.

3.3.2.3 Groundwater Monitoring Program Evaluation

The system can be evaluated based on the three decision rules identified from the groundwater DQO process.

1. Was the BNL Groundwater Contingency Plan triggered?

There were no unexpected strontium-90 concentrations in groundwater during 2001.

2. Were performance objectives met?

The performance objective for this project is to lower strontium-90 concentrations below the NYS AWQS of 8 pCi/L. Currently, three wells exceed this limit therefore, the performance objectives have yet to be achieved. The removal of contaminated soils in 2002 should help to alleviate some of the source of groundwater contamination.

3. If not, are observed conditions consistent with the attenuation model?

The observed data is consistent with the attenuation model. The recent changes in groundwater flow direction will be evaluated with a new monitoring well installed west of the centerline of the plume.

3.3.2.4 Recommendations

The following are recommendations for the OU IV AOC 6 Strontium-90 monitoring program:

1) Soil remediation is planned for the spring of 2002. It is recommended that groundwater monitoring continue as planned.

2) Well 76-28 should be evaluated for at least one year after the removal of contaminated soils in the vicinity of the Building 650 decontamination pad to determine if further investigation is required to identify the source of the strontium-90 contamination in this well.

3) The addition of recharge water from the OU III Middle Road groundwater remediation system to the RA V recharge basin has resulted in a more westerly component to groundwater flow in the OU IV area. An additional monitoring well will be installed in 2002 to monitor for the potential westerly migration of the plume.

3.4 Operable Unit V

3.4.1 Sewage Treatment Plant Monitoring Program

Historically, Brookhaven's sewage treatment plant (STP) received discharges of contaminants from routine operations. Releases of contaminants, in particular volatile organic compounds (VOCs), metals and radionuclides, to groundwater occurred via the STP sand filter beds and discharges to the Peconic River. In addition, trace levels of pesticides were detected in some wells. The OU V project monitors the identified groundwater contamination in the area of the STP, eastern site boundary, and off-site.

3.4.2 Groundwater Monitoring

<u>*Well Locations*</u>: A monitoring network of 34 wells was designed to follow groundwater contamination in the vicinity of the STP, at the boundary, and off-site (**Figure 3.4-1**). Sentinel wells were installed downgradient of the leading edge of the off-site VOC plume. BNL's Regional Groundwater Model was used to aid in placing these wells.

<u>*Sampling Frequency and Analysis*</u>: Wells are sampled semiannually, and samples are analyzed for VOCs, Pesticides/PCBs, water quality parameters, metals, and tritium (**Table 1-6**).

3.4.3 Monitoring Well Results

The OU V wells were sampled during two rounds in 2001. **Appendix C** contains the complete data. There were no significant changes to the VOC plume in 2001 (**Figure 3.4-2**). The highest TVOC concentration was 28 µg/L in well 61-05 located near the eastern site property boundary. The vertical distribution of VOC contamination is shown in the cross section in **Figure 3.4-3**. In general, decreasing VOC concentrations were observed in the monitoring well. **Figure 3.4-4** plots earlier trends in VOC levels.

Three pesticides were detected in monitoring wells for the OU V program during 2001, 4,4-dichlorodiphenyltrichloroethane (DDT), aldrin and dieldrin. 4,4'-DDT was detected in 5 wells during 2001 at a maximum estimated concentration of 0.12 µg/L. Aldrin and dieldrin were detected in one well, 000-123, at estimated concentrations of 0.016 µg/L and 0.011 µg/L, respectively, during the March sampling event but were not detected during the August sampling event.

Aluminum, antimony, iron, manganese, sodium, and thallium were detected in monitoring wells for the OU V program at concentrations above the applicable NYS AWQS levels. Aluminum was detected in 11 wells above the NYS AWQS of 200 µg/L. The highest concentration was 2,760 µg/L detected in well 061-03 during the March sampling event. Antimony was detected above the NYS AWQS of 3 in one well, 037-04, at 5.82 µg/L during the March sampling event. Iron was detected in 18 wells above the NYS AWQS of 300 µg/L. The highest concentration of iron was 25,900 µg/L detected in well 050-02 during the August sampling event. Manganese was detected in 9 wells above the NYS AWQS of 300 µg/L. The highest concentration of manganese was 1,270 µg/L detected in well 061-04 during the March sampling event. Sodium was detected in 5 wells above the NYS AWQS of 20,000 µg/L. The highest concentration of sodium was 107,000 µg/L detected in well 600-21 during the March sampling event. Thallium was detected in one well (049-05) at a concentration of 4.76 µg/L which exceeds the NYS AWQS of 0.5 µg/L.

Hexavalent chromium was detected in six monitoring wells at concentrations ranging from 5 µg/L to 58 µg/L. However, total chromium was reported in these wells at concentrations ranging from non-detect to 2.46 µg/L, all of which were significantly below the associated hexavalent chromium levels. The hexavalent chromium methodology is subject to interferences which cause false positive results. The total chromium methodology is not subject to many of these interferences and is, therefore, a more accurate measure of the chromium present in the groundwater. Since the concentration of total chromium reported in these samples is below the hexavalent chromium values and well below the 50 µg/L NYS AWQS value, hexavalent chromium is not deemed to be an issue in these wells.

Tritium has historically been detected at low concentrations in monitoring wells 50-02 and 61-05 (**Figure 3.4-5**). Historical trends for tritium in these wells are plotted in **Figure 3.4-6**. Tritium concentrations were barely above detectable levels in well 61-05, and below 2,500 pCi/L in well 50-02; this is almost ten times lower than the NYS AWQS of 20,00 pCi/L.

Radionuclides were found in 2001 in several monitoring wells at concentrations slightly above detection limits. Data usability reviews were performed on each of these analyses and an N2 qualifier applied to the data. The N2 qualifier means that the data are not usable because the results and the propagated error are indistinguishable from background. The data usability reports are included in **Appendix G**.

3.4.4 Groundwater Monitoring Program Evaluation

1. Was the BNL Groundwater Contingency Plan Triggered?
There were no unexpected VOC concentrations in groundwater during 2001.

2. Were the performance objectives met?
The performance objective for this program is to attain drinking water standards in groundwater in the Upper Glacial aquifer within 30 years. These standards continue to be exceeded in two of the monitoring wells. **Figure 3.4-7** compares the plume distribution between 1997 and 2001. The segment of the plume greater than 20 µg/L plume has shifted southeast, and the leading edge of the plume is located between the LIE and South Street.

3. Is the extent of the plume still defined by the existing monitoring well network?

The leading edge of the plume is located to the southeast of well 000-122 (south of the LIE). Currently, two well clusters serve as sentinel wells for this plume along North Street and Wading River Road.

3.4.5 Recommendations

Although presently there are sentinel wells south of the leading edge of the VOC plume, additional wells are recommended because the plume is narrow and there is potential for it to bypass the existing wells. A hydrogeologic evaluation, including some updated modeling, is recommended to re-evaluate the monitoring network with respect to the recently signed ROD requirements. This will determine whether any modifications to the monitoring well network are warranted.

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3.5 Operable Unit VI

3.5.1 EDB Monitoring Program

The OU VI EDB Program monitors the extent of an EDB plume in groundwater. EDB was used during the 1970s as a fumigant for the BNL Biology Department's agricultural fields in the southeastern portion of the site. 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. A groundwater remediation system to address the off-site EDB plume is being designed, and system construction is planned in November 2002.

Pre-design groundwater characterization work was performed in 2001 and consisted of installing five vertical profiles. There is detailed information and data obtained during this investigation in the *OU VI EDB Plume Groundwater Remediation System 90 Percent Design Documents* (J.R. Holzmacher, 2002b).

3.5.2 Groundwater Monitoring

Well Locations: A network of 27 wells monitor the EDB plume from the source area in the Biology Department's agricultural fields to locations on private property south of North Street (**Figure 3.5-1**). Additional monitoring wells will be installed as part of the construction of the pump and treat system in 2003.

Sampling Frequency and Analysis: The wells are monitored quarterly, and samples analyzed for EDB, VOCs, total organic carbon, tritium and gross alpha/beta (**Table 1-6**).

3.5.3 Monitoring Well/Characterization Results

Appendix C contains the complete results of the quarterly sampling program. Data obtained during pre-design groundwater characterization work are given in the *OU VI EDB Plume Groundwater Remediation System 90 Percent Design Documents* (J.R. Holzmacher, May 2002). The distribution of the EDB plume is shown for the fourth quarter 2001 in **Figure 3.5-2**. This map also incorporates the highest EDB concentrations from each of the five pre-design vertical profile wells. The leading edge of the plume appears to be in the vicinity of vertical profile wells 000-383 and 000-385. The plume is located in the deep Upper Glacial aquifer and is generally moving horizontally as depicted in **Figure 3.5-3**. The highest EDB concentration observed during 2001 was 7.6 µg/L in well 000-283. The Federal Drinking Water Standard for EDB is 0.05 µg/L. A summary of all EDB detections exceeding the Federal Drinking Water Standard in 2001 is located in **Table 3-23**.

The southward migration of the plume can be observed by analyzing the trends in Figure **3.5-4**. EDB shows decreased trends for wells north of the current plume's core position. In contrast, EDB has increasing in the wells in the plume core area. Comparing the plume's distribution from 1997 to 2001 in **Figure 3.5-5** also illustrates plume movement.

The wells are sampled annually for VOCs in addition to EDB. There were several detections above detection limits but none exceeded NYS AWQS in any of the wells (**Appendix C**).

The wells are sampled annually for radionuclides. There were no detections observed in 2001.

3.5.4 Monitoring Program Evaluation

The plume is migrating as predicted by groundwater modeling. Installing new monitoring wells during system construction in 2003 will address the current gap in the data at the leading edge of the plume. The groundwater remediation system will be constructed in late 2002 and is scheduled to be operational in March 2003.

3.5.5 Recommendations

The EDB Monitoring Program will be enhanced with additional wells in 2003 to more precisely monitor the high concentration area of the EDB plume and sentinel wells downgradient of the plume edge. No additional modifications to the monitoring program are warranted at this time.

3.6 Site Background Monitoring

Background water quality has been monitored since 1996. Historically, low levels of VOCs were routinely detected in several background wells that are screened in the deeper portions of the Upper Glacial aquifer.

3.6.1 Groundwater Monitoring

Well Network: The 2001 program included thirteen wells located in the northwestern portion of the BNL property and adjacent off-site areas (**Figure 3.6-1**). The groundwater DQO process identified three wells (000-118, 000-119, and 000-120) for elimination from the program in 2002 as they are not positioned hydraulically upgradient of the site. Background quality is defined as the quality of groundwater that is completely unaffected by BNL's operations.

Sampling Frequency and Analysis: Analytical parameters for groundwater samples include the Contaminants of Concern that were identified through the characterization work undertaken during various remedial investigations and removal actions (**Table 1-6**). Samples were analyzed for VOCs, gross alpha/beta, gamma spectroscopy, tritium, and strontium-90. Due to the extensive database for these wells, sampling will be reduced to annually in 2002. Since historic sampling detected low levels of VOCs, and the extensive database established ambient concentrations of naturally occurring constituents (metals and radionuclides), the well samples will be analyzed only for VOCs in 2002.

3.6.2 Monitoring Well Results

The complete groundwater data is provided in **Appendix C**. There were no significant detections of VOCs in the site background wells. The highest concentration detected was chloroform at 1.4 μg/L in well 000-120.

There were no significant detections of radionuclides in the site background wells; there were several slightly above detection limits. Data usability reviews were performed on each of these analyses and an N2 qualifier applied to the data. The N2 qualifier means that the data are not usable because the results and the propagated error are indistinguishable from background. The data usability reports are included in **Appendix G**. **Table 3-24** summarizes the range of radionuclide values detected in background wells from 1996 through 2001.

3.6.3 Monitoring Program Evaluation

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

1. Is groundwater quality at BNL being impacted by off-site, upgradient source(s) of contamination?

There were no contaminants detected in site background wells above NYS AWQS during 2001. Based on these results there has not been any impact to BNL groundwater quality from upgradient contaminant source(s).

3.6.4 Recommendations

No further modifications are recommended to this monitoring program other than those being implemented in 2002 from the groundwater DQO process.

4.0 ENVIRONMENTAL SURVEILLANCE PROGRAM SUMMARY

BNL's Environmental Surveillance (ES) Program monitors the groundwater quality at 13 active research and support facilities. New York State operating permits require groundwater monitoring at three support facilities (the Major Petroleum Facility, Waste Management Facility, and the Water Treatment Plant); the remaining ten research and support facilities are monitored in accordance with DOE Order 5400.1. This Order requires BNL to establish environmental monitoring programs at facilities that potentially might impact environmental quality, and to demonstrate compliance with DOE requirements and the applicable federal, state and local laws and regulations. BNL is implementing this part of the Environmental Management System to collect information on groundwater quality, and will use the data to determine whether current engineering and administrative controls effectively protect groundwater quality, and whether additional corrective actions are needed.

During 2001, 120 groundwater surveillance wells were monitored in approximately 350 individual samplings. Potential threats to groundwater quality at each of the monitored research and support facilities are described below. **Table 1-7** summarizes ES Groundwater Monitoring Program's wells by project. The monitoring wells' screened depths and specific analytical requirements are provided in **Table 1-8**. Analytical results from groundwater samples collected in 2001 can be found in **Appendix D** located on the accompanying CD-ROM.

4.1 Alternating Gradient Synchrotron (AGS) Complex

Activated soils have been created near a number of AGS experimental areas as the result of secondary particles (primarily neutrons) produced at beam targets and beam stops. Radionuclides, such as tritium and sodium-22, have been produced by the interaction of these secondary particles with the soils that surround these experimental areas. To prevent rainwater from leaching these radionuclides from the soils and transporting them to the groundwater, impermeable caps have been constructed over these soil activation areas.[1] Between January 1999 and December 2001, BNL installed 42 permanent and nearly 50 temporary groundwater monitoring wells to evaluate the impact of current and historical operations at the AGS's beam stop and target areas. The locations of permanent monitoring wells are shown on **Figure 4-1**.

During 2001, 44 monitoring wells were used to evaluate groundwater quality near areas of potential soil activation within the AGS Complex (e.g., Building 912, AGS Booster Beam Stop, 914 Transfer Tunnel, g-2 experimental area, E-20 Catcher, former U-Line Target, and the J-10 Beam Stop). Since 1999, BNL's improved monitoring program has detected three tritium plumes that originated from activated soil shielding. These plumes originated from the g-2/VQ12 experimental area, the former U-Line beam stop, and the former E-20 Catcher. The subsequent installation of impermeable caps over these soil activation areas has resulted in a reduction of tritium levels to less than the 20,000 pCi/L drinking water standard in the Former U-Line and E-20 Catcher areas. As discussed below, tritium concentrations well above 20,000

[1] Assessment and design criteria for potential soil activation areas are described in the SBMS Accelerator Safety Subject Area.

pCi/L continue to be detected downgradient of the g-2/VQ12 soil activation area (see Section 4.1.5).

Historical surface spills and discharges of solvents to cesspools and recharge basins near the AGS have contaminated soils and groundwater with volatile organic compounds (VOCs). VOC contamination is monitored under the ER OU III Central Groundwater Monitoring Program (see **Section 3.2.10**).

4.1.1 AGS Building 912

Building 912 (Experimental Area Group) consists of five interconnected structures. The equipment in the building includes the beam lines (A, B, C, and D Lines) with magnets, instrumentation, high voltage electrostatic devices, beam targets, radiation shielding, cooling water systems and experimental detectors. A typical beam line contains bending and focusing electro-magnets along with their associated electrical power supplies, cooling water systems and vacuum pipes.

Beam loss and production of secondary particles at proton target areas results in the activation of adjacent equipment, floors, and probably the soils beneath the building's floor. The highest levels of soil contamination beneath Building 912 are expected at the B-Line target cave. Stormwater infiltration around the building is controlled by paving and stormwater drainage systems that direct most of the water to recharge basins located to the north of the AGS complex. Therefore, it is believed that the potentially activated soils underlying the beam targets and stops are adequately protected from surface water infiltration.

4.1.1.1 Groundwater Monitoring

Well Network: Seventeen shallow Upper Glacial aquifer wells have been installed upgradient and downgradient of Building 912 (**Figure 4-1**). Upgradient wells are positioned to monitor potential tritium contamination from sources such as the g-2 area and the former U-Line experimental areas. The downgradient wells are positioned to be directly downgradient of significant beam stop and target areas within Building 912.

Sampling Frequency and Analysis: During 2001, Building 912 wells that were used to help track the g-2/VQ-12 tritium plume were sampled quarterly, whereas the remainder of the wells were sampled semiannually. The groundwater samples were analyzed for tritium and sodium-22 (**Table 1-7**).

4.1.1.2 Monitoring Well Results

Other than tritium and sodium-22 contamination that is traceable to several upgradient sources (such as the g-2/VQ12 magnet source area and the former U-Line target and beam stop areas described below), groundwater surveillance data for 2001 do not indicate that appreciable levels of tritium or sodium-22 are being released from potentially activated soils located beneath the experimental floor of Building 912. The g-2 tritium plume has been tracked from the VQ-12 magnet source, beneath a portion of Building 912, to an area located just to the southwest of the

Waste Concentration Facility (**Figure 4-1**). Elevated levels of tritium from this plume have been detected in several downgradient wells (especially wells 065-121, 065-122, 065-123 and 065-124). Furthermore, low levels of tritium that are traceable to the former U-Line target and stop area have been detected in upgradient wells 054-67, 054-68, 054-69 and 055-14, and in downgradient well 055-32. In areas not impacted by the g-2 tritium plume or former U-Line experimental areas, tritium and sodium-22 was either non-detectable or were only observed at trace levels. As described in Section 4.1.5, BNL is preparing an Engineering Evaluation/Cost Analysis (EE/CA) for the g-2 Tritium Plume to evaluate the adequacy of the corrective actions taken to date, and the need for further actions. During 2001, BNL conducted additional characterization work designed to obtain the necessary plume concentration and position data required to prepare the EE/CA.

4.1.1.3 Groundwater Monitoring Program Evaluation

As noted above, in areas not impacted by the g-2 tritium plume or former U-Line experimental areas, tritium and sodium-22 was either non-detectable or were only observed at trace levels. These results indicate that the building and associated stormwater management operations are effectively preventing rainwater from infiltrating activated soils located below the experimental hall.

4.1.2 AGS Booster

The AGS Booster is a circular accelerator with a circumference of nearly 660 feet, and is connected to the northwest portion of the main AGS ring and the LINAC. The AGS Booster, which has been in operation since 1994, receives either a proton beam from the LINAC or heavy ions from the Tandem Van de Graaff. The Booster accelerates protons and heavy ions prior to injection into the main AGS ring. In order to dispose of the beam during studies, a beam scraper system consisting of a beam kicker and an absorber block was constructed at the 10/11 o'clock portion of the Booster.

The AGS Booster beam scraper is an area where the interaction of secondary particles and soil surrounding the Booster tunnel will result in production of tritium and sodium-22. Although internal shielding around the beam scraper was designed to keep secondary particle interactions with the soil to very low levels, a landfill-type geomembrane cap was constructed over the scraper region to provide an extra margin of protection.

4.1.2.1 Groundwater Monitoring

Well Network: Two shallow Upper Glacial aquifer monitoring wells (064-51 and 064-52) are located approximately 250 feet downgradient of the beam stop (**Figure 4-1**). Two nearby upgradient wells (054-61 and 054-61) are used to provide data on background radionuclide concentrations.

Sampling Frequency and Analysis: During 2001, the Booster area wells were monitored semiannually. Samples were analyzed for tritium and sodium-22 (**Table 1-7**).

4.1.2.2 Monitoring Well Results

During 2001, low levels of tritium and sodium-22 were detected in well 064-52. The highest tritium and sodium-22 levels were detected in the November sample, at concentrations of 1,340 pCi/L at 12.5 pCi/L, respectively.

4.1.2.3 Groundwater Monitoring Program Evaluation

The low-levels of tritium and sodium-22 detected during 2001 may be related to a short-term uncovering of activated soil shielding near the Booster Beam Stop during the construction of the tunnel leading from the Booster to the new Booster Applications Facility. This work, which began in September 1999 and was completed by October 1999, may have allowed rainwater to infiltrate the low-level activated soil shielding. (Note: Before construction of the BAF tunnel commenced, soil samples were collected by drilling through the tunnel wall near the Booster beam stop to verify that the tritium and sodium-22 levels were within acceptable limits for worker safety and environmental protection.)

4.1.3 E-20 Catcher

The E-20 beam catcher was used from 1984 to 1999. It is located at the 5 o'clock position of the AGS ring (**Figure 4-1**). The E-20 Catcher is a minimum aperture area of the AGS ring, and is used to pick up or "scrape" protons that move out of acceptable pathways. The E-20 Catcher was subject to injection, transition, ejection, and losses studies, and picked up about 80 to 90 percent of all of these losses.

Like other beam loss areas within the AGS complex, the E-20 Catcher is an area where the soils surrounding the AGS tunnel became activated by the interaction with secondary particles. In late 1999, tritium and sodium-22 were detected in two wells located approximately 100 feet downgradient of the former E-20 Catcher. The highest levels of tritium and sodium-22 were 5,800 pCi/L and 219 pCi/L, respectively. To further evaluate the extent of contamination, four Geoprobe wells were installed in January 2000. Tritium and sodium-22 levels in the temporary wells were found to exceed the drinking water standards, with concentrations of 40,400 pCi/L and 704 pCi/L, respectively. In April 2000, a temporary impermeable cap was installed over the E-20 Catcher soil activation area to prevent rainwater infiltration and the continued leaching the radionuclides out of the soils and into groundwater. A permanent cap was constructed by October 2000, and an additional downgradient well was installed to allow for improved long-term monitoring.

4.1.3.1 Groundwater Monitoring

Well Network: The effectiveness of the impermeable cap over the E-20 Catcher area is monitored by shallow Upper Glacial aquifer wells 064-55, 064-56 and 064-80. These wells are located approximately 100 feet downgradient of the source area (**Figure 4-1**).

Sampling Frequency and Analysis: During 2001, the E-20 Catcher wells were monitored quarterly. The samples are analyzed for tritium and sodium-22 (**Table 1-7**).

4.1.3.2 Monitoring Well Results

During 2001, all tritium and sodium-22 concentrations were found to be below applicable drinking water standards, with a maximum tritium concentration of 2,070 pCi/L, and a maximum sodium-22 concentration of 163 pCi/L.

4.1.3.3 Groundwater Monitoring Program Evaluation

The reduction in tritium and sodium-22 concentrations since the impermeable cap was constructed over the E-20 Catcher area in 2000, indicates that the cap has been effective in preventing additional rainwater infiltration into the activated soils that surround that portion of the AGS tunnel.

4.1.4 Building 914

Building 914 houses the transfer line between the main AGS Ring and the Booster. Due to beam loss near the extraction (kicker) magnet, the extraction area of Building 914 is heavily shielded with iron. Since the extraction area is housed in a large building structure, soil activation is likely to be limited to the areas below the floor of the building. As with other beam loss areas within the AGS complex, soil activation could result in the introduction of tritium and sodium-22 to the groundwater below the facility. Water infiltration through potentially activated soils is likely to be minor, because the soils are isolated beneath the floor of the building, and portions of the transfer tunnel are covered with a soil-crete mixture.

4.1.4.1 Groundwater Monitoring

Well Network: Groundwater quality in the Building 914 transfer line area is monitored by five shallow Upper Glacial aquifer wells; two upgradient wells, and three downgradient wells (**Figure 4-1**).

Sampling Frequency and Analysis: During 2001, the Building 914 area wells were monitored semiannually. Samples were analyzed for tritium and sodium-22 (**Table 1-7**).

4.1.4.2 Monitoring Well Results

Low levels of tritium (616 pCi/L) were detected in one sample from downgradient well 064-53. Low levels of sodium-22 (up to 20.6 pCi/L) were detected in all three downgradient wells (064-03, 064-53 and 064-54).

4.1.4.3 Groundwater Monitoring Program Evaluation

The detection of only low levels of tritium and sodium-22 in the groundwater downgradient of Building 914 indicates that the building structure and associated stormwater controls are effectively preventing significant rainwater infiltration into activated soils located below the building.

4.1.5 g-2 Beam Stop and VQ-12 Magnet Area

The g-2 experiment started operations in 1997. The beam line has a beam stop that is composed of iron. The iron beam stop is covered by soil. Like other beam loss areas within the AGS complex, the g-2 Beam Stop is an area where the soils surrounding the stop may become activated by the interaction with secondary particles. To prevent rainwater from infiltrating the soils surrounding the beam stop, BNL installed a gunnite cap over the stop area prior to the start of beam line operations.

In November 1999, monitoring wells located approximately 250 feet downgradient of the g-2 experimental area detected the presence of tritium and sodium-22 in the groundwater. A sample from Well 054-067 collected in October 1999 had a tritium concentration of 41,700 pCi/L (approximately twice the drinking water standard of 20,000 pCi/L). A groundwater investigation conducted during November-December 1999 revealed a narrow plume of approximately 20-30 feet wide and 250-300 feet long. The maximum radionuclide concentrations were detected in temporary Well 054-116, located approximately 70 feet downgradient of the g-2 beam line, with a tritium concentration of 1,800,000 pCi/L and sodium-22 concentration of 60 pCi/L (or 15% of the 400 pCi/L drinking water standard).

Following the discovery, an investigation into the source of the contamination revealed that the tritium originated from activated soil shielding located adjacent to the g-2 experiment's VQ-12 Magnet. In December 1999, an impermeable cap was installed over the VQ12 soil activation area to prevent rainwater infiltration and the continued leaching the radionuclides out of the soils and into groundwater. In September 2000, the activated soil shielding and the associated tritium plume were designated as new sub-Area of Concern 16T. Following this designation, DOE agreed to prepare an Engineering Evaluation/Cost Analysis (EE/CA) to evaluate the adequacy of the corrective actions taken to date, and the need for further actions. During 2001, BNL conducted additional characterization work designed to obtain the necessary plume concentration and position data required to prepare the EE/CA.

4.1.5.1 Groundwater Monitoring

Well Network: A total of 20 wells are used to monitor the g-2 Beam Stop and the tritium plume that originates from the VQ12 magnet area (**Figure 4-1**). The monitoring program consists of two upgradient and 18 downgradient wells. Groundwater quality downgradient of the g-2 Beam Stop is monitored using four wells. The tritium plume is monitored using 16 downgradient wells. Three of these wells were installed in late 2001 as part of the g-2 Tritium Plume EE/CA. Additionally, seventeen temporary Geoprobe wells were installed as part of the EE/CA in an effort to better characterize the plume and determine the effectiveness of the cap.

Sampling Frequency and Analysis: During 2001, the g-2 beam stop and tritium plume wells were monitored quarterly, and the samples were analyzed for tritium and sodium-22 (**Table 1-7**).

4.1.5.2 Monitoring Well Results

g-2 Tritium Plume: In February 2001, BNL installed eight temporary Geoprobe wells. The effort focused on two main areas, the area just west of Building 912A and the area just east of Building 912. The results from the temporary well samples taken west of Building 912A indicated tritium concentrations up to 170,000 pCi/L. During this same period, the tritium concentration in nearby well 054-07 was 77,100 pCi/L. The results from the temporary well samples collected east of Building 912 indicated tritium concentrations up to 67,500 pCi/L at location GP8. Based upon these results, the leading edge of the g-2 tritium plume was found to be situated to the east of Building 912, and positioned entirely within the shallow portion of the Upper Glacial aquifer. In anticipation that higher levels of tritium would eventually migrate to the east of Building 912, BNL obtained regulatory agency concurrence that an additional year of monitoring was required before the EE/CA could be finalized.

In November 2001, BNL installed nine additional Geoprobe wells. The effort again focused on two main areas, the area just west of Building 912A and the area just east of Building 912. The results from the temporary well samples taken west of Building 912A indicated tritium concentrations up to 1,820,000 pCi/L. The results from the temporary well samples collected east of Building 912 indicated that the leading edge of the g-2 tritium plume was now located approximately 100 feet to the southwest of the Waste Concentration Facility, a distance of approximately 1,000 feet from the VQ-12 source area (**Figure 4-1**). Tritium concentrations up to 79,500 pCi/L were observed at Geoprobe location G2-GP-11 located directly to the east of Building 912, and tritium concentrations up to 25,500 pCi/L were detected in G2-GP-16 located approximately 100 feet to the southwest of the Waste Concentration Facility.   Based upon these findings, BNL installed three additional permanent monitoring wells near Building 912A to allow for improved long-term monitoring of the source area.

g-2 Beam Stop: Low levels of tritium and sodium-22 (up to 725 pCi/L and 3.3 pCi/L, respectively) were occasionally detected in downgradient wells 064-67 and 064-68. Based upon a slightly more south-southeasterly groundwater flow direction observed during 2001, it is likely that these wells are intercepting contamination that originates from activated soils at the former U-Line target area.

4.1.5.3 Groundwater Monitoring Program Evaluation

Following the late 2001 detection of tritium concentrations up to 1,820,000 pCi/L in temporary wells located immediately downgradient of the VQ-12 soil shielding area; questions arose as to the integrity of the cap. The design of the cap was re-evaluated to ensure that it met design specifications, and the cap itself was thoroughly inspected. The cap was found to be in excellent condition. It is likely that the continued presence of high levels of tritium in groundwater directly downgradient of the source area is due to the release of residual tritium from the vadose zone following a natural rise in water table position that occurred during 2000. BNL and the regulatory agencies determined that additional monitoring of the permanent wells would be required before completing the g-2 tritium plume EE/CA and Action Memorandum.

Although trace levels of tritium and sodium-22 were detected in tow of the wells used to monitor the g-2 beam stop, it is likely that this contamination is from the former U-Line stop area, and that the g-2 beam stop cap is effective in preventing rainwater from infiltrating the soils.

4.1.6 J-10 Catcher

In 1998, BNL established a new beam stop at the J-10 (12 o'clock) section of the AGS Ring (**Figure 4-1**). The J-10 stop serves as the preferred repository for any beam that might be lost in the AGS Ring. Activation products are likely to be produced in the soils surrounding the tunnel adjacent to J-10 beam stop. The J-10 beam stop is subject to the same injection, transition, ejection and studies losses that occurred at the former E-20 Catcher discussed above. The ability of rainwater to infiltrate potentially activated soils surrounding the J-20 is likely to be significantly reduced because the AGS tunnel has been covered by layers of sand, Styrofoam and soil-crete. In an effort to further reduce the potential for surface water to infiltrate activated soils, BNL constructed a gunnite cap over remaining exposed soil areas overlying the J-10 region prior to its operation.

4.1.6.1 Groundwater Monitoring

Well Network: The monitoring well network for the J-10 beam stop consists of one upgradient (054-62) and two downgradient wells (054-63 and 054-64).

Sampling Frequency and Analysis: During 2001, the three J-10 beam stop wells were monitored semiannually, and the samples analyzed for tritium and sodium-22.

4.1.6.2 Monitoring Well Results

As in past years, low levels of tritium and sodium-22 were detected in wells located downgradient of the J-10 area. The maximum tritium and sodium-22 concentrations were 450 pCi/L and 5.6 pCi/L, respectively.

4.1.6.3 Groundwater Monitoring Program Evaluation

Available data suggests that the engineered controls in place at J-10 are providing effective control in preventing rainwater infiltration into the activated soil shielding. Low levels of sodium-22 have been detected in this area of the AGS Ring even before beam-scraping activities at J-10 began in December 1999. Therefore, the low-levels of tritium and sodium-22 may be related to historical low-level activation of soils along this section of the beam line.

4.1.7 Former U-Line Target and Beam Stop Area

The U-Line target area was in operation from 1974 through 1986. During its operation, a 28 GeV proton beam from the AGS would first strike a target and the resulting secondary particles would be selected by an arrangement of two magnetic "horns" and collimators immediately downstream of the target. Secondary particles desired for research would be focused by the horns, and other particles would either strike the collimators or be de-focused and enter the surrounding shielding. The entire assembly was located in a ground-level tunnel covered with an earthen berm. Internal shielding was stacked around the horns. Although the U-Line target has not been in operation since 1986, the associated tunnel, shielding and overlying soils remain in place. The former U-Line target, horns and beam stop are areas where the interaction of secondary particles with soil surrounding the tunnel resulted in production of tritium and sodium-22.

In 1999, BNL installed new monitoring wells downgradient of the target area to evaluate whether residual activated soil shielding was impacting groundwater quality. Subsequent monitoring found low levels of tritium and sodium-22, but at concentrations well below the applicable drinking water standards. In early 2000, BNL installed four Geoprobe wells downgradient of the former U-Line beam stop, which is located approximately 200 feet north of the target area. Tritium was detected at concentrations up to 71,600 pCi/L. Sodium-22 was not detected in any of the samples. In May 2000, a temporary impermeable cap was installed over the U-Line stop soil activation area to prevent additional rainwater infiltration and the continued leaching the radionuclides out of the soils and into groundwater. By October 2000, a permanent cap was constructed over the U-Line stop area, and two additional permanent wells were installed to provide improved long-term monitoring of this source area.

4.1.7.1 Groundwater Monitoring

Well Network: The former U-Line area is monitored by one upgradient and seven downgradient wells; with three downgradient wells monitoring the target area, whereas the beam stop is monitored using four downgradient wells (**Figure 4-1**).

Sampling Frequency and Analysis: During 2001, the former U-Line area wells were monitored quarterly, and the samples were analyzed for tritium and sodium-22 (**Table 1-7**).

4.1.7.2 Monitoring Well Results

U-Line Target Area: Low levels of tritium and sodium-22 continue to be detected in wells located downgradient of the former U-Line target. The tritium and sodium-22 concentrations are well below the applicable drinking water standards. The highest tritium concentration during 2001 was 3,960 pCi/L in well 054-129 located approximately 200 feet downgradient of the target area. The highest sodium-22 concentration was 26.6 pCi/L in well 054-69 located approximately 550 feet downgradient of the target area. Low-level contamination from the former U-Line area can be traced to well 055-32, located approximately 1,000 feet downgradient of the target area. The maximum tritium and sodium-22 concentrations detected in this well was 3,820 pCi/L and 7.5 pCi/L, respectively. As noted earlier, the low levels of tritium and sodium-22 detected in two of the nearby g-2 beam stop monitoring wells (054-67 and 054-68) are likely to have originated from the former U-Line target area.

U-Line Beam Stop Area: During 2001, the maximum tritium and sodium-22 concentrations observed were in downgradient well 054-128, with concentrations of 3,960 pCi/L and 1.9 pCi/L, respectively.

4.1.7.3 Groundwater Monitoring Program Evaluation

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

4.2 Brookhaven LINAC Isotope Producer (BLIP) Area

When the BLIP is operating, the LINAC delivers a 200 MeV beam of protons that impinge on a series of eight targets located within the BLIP target vessel. During irradiation, the BLIP targets are located 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 500 gallon closed loop primary cooling system. During irradiation, several radionuclides are produced in the cooling water, and activation of the soils immediately outside of the tank occurs due to the creation of secondary particles produced at the target.

As part of a 1985 redesign of the vessel, leak detection devices were installed, and the open space between the water filled shaft and vessel's outer wall is used as secondary containment system for the primary vessel. The BLIP target vessel system conforms to Suffolk County Article 12 requirements, and is registered with SCDHS. The BLIP facility also has a 500 gallon-capacity UST used for liquid radioactive waste (change out water from the BLIP primary system). The waste tank and its associated piping system conform to Article 12 requirements, and are registered with SCDHS.

In 1998, BNL conducted an extensive evaluation of groundwater quality near the BLIP facility. Tritium concentrations of 52,000 pCi/L and sodium-22 up to 151 pCi/L, were detected in a temporary well installed approximately 50 feet downgradient of the BLIP target vessel. Elevated levels of tritium (11,400 pCi/L) and sodium-22 (at 38 pCi/L) were also detected in shallow groundwater samples collected from a temporary well that was installed 150 feet downgradient of the BLIP. Due to the activation of soils and the detection of tritium and sodium-22 in groundwater, the BLIP facility has been designated as AOC 16K under the Environmental Restoration program.

Starting in 1998, BNL made improvements to the stormwater management program at BLIP in an effort to prevent rainwater infiltration of the activated soils below the building. The BLIP building's roof drains were redirected away from the building, paved areas were resealed, and an extensive gunnite (cement) cap was installed on three sides of the building. In May-June 2000, BNL undertook additional protective measures by injecting a colloidal silica grout into the activated soils. The grout reduces the permeability of the soils, thus further reducing the potential of rainwater leaching radionuclides out of the soil and into groundwater.

4.2.1 Groundwater Monitoring

Well Network: The monitoring well network for the BLIP facility consists of two upgradient and five downgradient wells. These wells were installed as a means of verifying that the engineered and administrative controls described above are effective in protecting groundwater quality (**Figure 4-1**).

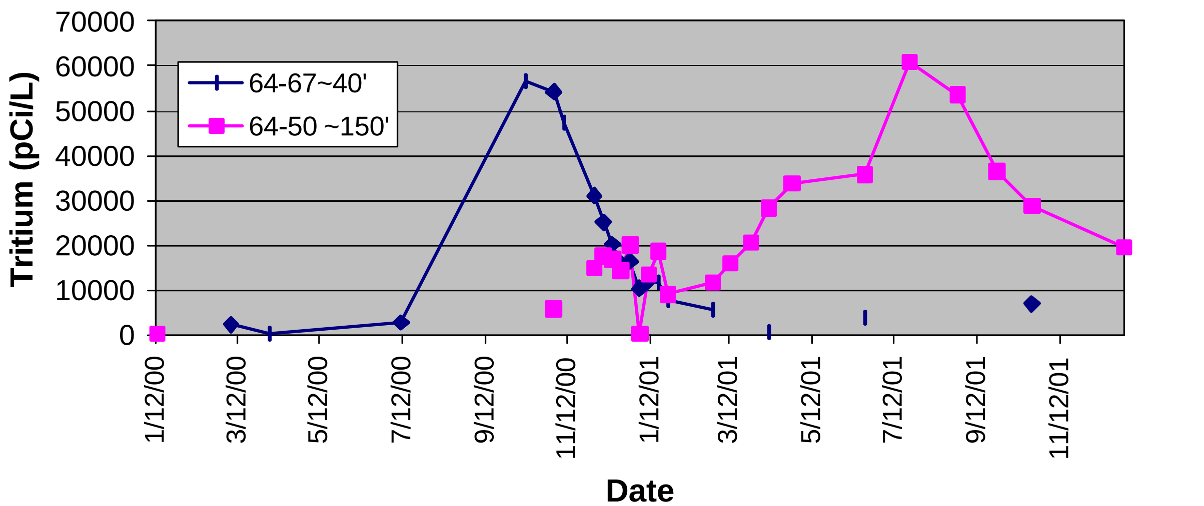
Sampling Frequency and Analysis: During 2001, most of the BLIP area wells were monitored quarterly, and samples were analyzed for tritium and sodium-22 (**Table 1-7**)

4.2.2 Monitoring Well Results

As noted in the *2000 Groundwater Status Report* (BNL, 2001f), monitoring data collected from January 1999 to July 2000 indicated that the corrective actions taken during 1998 were highly effective in preventing the release of tritium and sodium-22 from the activated soils surrounding the BLIP target vessel. Prior to May 2000, tritium and sodium-22 concentrations in wells located directly downgradient of BLIP were <3,000 pCi/L and <5 pCi/L, respectively. However, significant increases in tritium and sodium-22 concentrations were observed in groundwater samples collected after the silica grout injection process in late May-early June 2000. Samples collected in early July indicated tritium and sodium-22 concentrations of 5,700 pCi/L and 57 pCi/L, respectively. By early October, indicated tritium concentrations increased to a maximum of 56,500 pCi/L in samples from monitoring well 064-67, located approximately 40 feet downgradient of the BLIP vessel. In accordance with the BNL Groundwater Contingency Plan, BNL and DOE notified the regulatory agencies of this situation and increased the groundwater sampling frequency to bi-weekly. At the request of the agencies, the well sampling frequency was increased to weekly starting December 1, 2000. The maximum sodium-22 concentration was 299 pCi/L detected in well 064-67 on December 1, 2000. By December 21, 2000, tritium concentrations dropped to below the 20,000 pCi/L drinking water standard in wells located approximately 40 feet downgradient of BLIP, and weekly sampling of the wells was discontinued by the end of January 2001.

During 2001, tritium concentrations in wells located 40 feet downgradient of BLIP did not exceed 7,000 pCi/L. As the slug of tritium continued to migrate downgradient of BLIP, concentrations in well 064-50 increased to 20,000 pCi/L by December 28, 2000. Well 064-50 is located approximately 150 feet downgradient of BLIP. Well 064-50 was sampled monthly during 2001. Tritium concentrations in well 064-50 reached a maximum of 60,800 pCi/L in July 2001, and then declined to less than 20,000 pCi/L by November 2001 (**Figure 4-2**).

Figure 4-2
Tritium Activity in Groundwater Downgradient of BLIP
2000-2001



4.2.3 Groundwater Monitoring Program Evaluation

Following the detection of elevated tritium concentrations in October 2000, BNL conducted a review of the grouting process. Findings of this review suggested that that grout displaced residual vadose zone soil pore water that was contaminated with tritium. The pattern of decreasing tritium concentrations in wells directly downgradient of BLIP indicate a short-term (pulsed) tritium release and that the plume has dissipated quickly in the aquifer. There was good correlation between modeled and observed tritium concentrations in well 064-50 during 2001, and it is expected that peak tritium concentrations in the plume will drop below the drinking water standard at all locations by September 2002.

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

4.3 Relativistic Heavy Ion Collider (RHIC)

Beam line interaction with the RHIC collimators and beam stops will produce secondary particles that will interact with some of the soils surrounding the 8 o'clock and 10 o'clock portions of the RHIC tunnel, and the W-Line stop. These interactions will result in the production of tritium and sodium-22, which could be leached out of the soils by rainwater. Prior to the start of RHIC operations, BNL installed impermeable caps over these beam loss areas to reduce the potential impact to environmental quality.

4.3.1 Groundwater Monitoring

Well Network: During 1999-2000, thirteen wells were installed to provide a means of verifying that the engineered (i.e., impermeable caps) and operational controls implemented at the RHIC beam stops and collimators are effective in protecting groundwater quality. Six monitoring wells were installed in the beam stop area, six wells in the collimator area, and one well near the W-Line Beam Stop (**Figure 4-3**). As an extension to the groundwater monitoring program, surface water samples are also collected from the Peconic River both upstream and downstream of the beam stop area to ensure that potentially activated groundwater is not being discharged into the Peconic River stream bed during high water table conditions.

Sampling Frequency and Analysis: During 2001, groundwater samples were collected from the thirteen RHIC monitoring wells on a semiannual schedule, and the samples were analyzed for tritium and sodium-22 (**Table 1-7**). Surface water samples were also collected semiannually, and analyzed for tritium and sodium-22.

4.3.2 Monitoring Well Results

As in past years, no tritium or sodium-22 was detected in any of the groundwater samples. Furthermore, no tritium or sodium-22 was detected in the surface water samples collected from the Peconic River both upstream and downstream of the beam stop area.

4.3.3 Groundwater Monitoring Program Evaluation

Groundwater monitoring data continue to demonstrate that the impermeable caps that were constructed over the RHIC beam stop and collimator areas have been effective in preventing rainwater infiltration into potentially activated soils.

4.4 Brookhaven Medical Research Reactor

The BMRR is a 3 MW light water reactor that was used for biomedical research. Research operations at the BMRR stopped in December 2000, and BNL is preparing plans to permanently decommission the facility.[2]

[2] All spent fuel is scheduled to be removed from the BMRR by the fall of 2002. Drainage of the primary cooling water will be completed sometime following fuel removal.

The BMRR's primary cooling water system consists of a recirculation piping system that contains 2,550 gallons of water containing high levels of tritium (tritium concentration in 1997 was 465 ìCi/L). Unlike the High Flux Beam Reactor, the BMRR does not have a spent fuel storage canal or pressurized imbedded piping systems that contain radioactive liquids. Historically, fuel elements that required storage are either stored within the reactor vessel, or were transferred to the HFBR spent fuel canal. The primary system's piping is fully exposed within the containment structure, and is accessible for routine visual inspections. When the BMRR was operational, excess heat was transferred by means of heat exchangers with once through (secondary) cooling water which was obtained from process supply well 105 or the BNL Chilled Water System. This secondary water was discharged to recharge basin HP located 800 feet to the south of the Medical Department complex, and was monitored as part of the State Pollutant Discharge Elimination System (SPDES) program.

In 1997, tritium was detected in wells installed 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 drinking water standard of 20,000 pCi/L. The tritium 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 soils surrounding the floor drain piping system to the groundwater. The floor drains were permanently sealed in 1998 to prevent any accidental future releases to the underlying soils.

4.4.1 Groundwater Monitoring

Well Network: The monitoring well network for the BMRR facility consists of one upgradient and three downgradient wells (**Figure 4-4**).

Sampling Frequency and Analysis: During 2001, the BMRR wells were monitored semiannually, and the samples were analyzed for tritium, gamma spectroscopy, gross alpha and gross beta (**Table 1-7**). Samples collected from four groundwater monitoring wells are used to verify that the engineered and administrative controls described above are effective in preventing additional impacts to groundwater quality.

4.4.2 Monitoring Well Results

Monitoring results for sampling conducted during 2001 indicates that tritium concentrations continued to be well below the drinking water standard of 20,000 pCi/L. Detectable levels of tritium were observed in all three downgradient wells, with the maximum value of 1,550 pCi/L in Well 084-27. As in past years, no other reactor-related radionuclides were detected in the groundwater.

4.4.3 Groundwater Monitoring Program Evaluation

Compared to the initial monitoring results from 1997, tritium concentrations in groundwater have shown a steady decline. Discontinuing the use of the BMRR's floor drains has apparently helped to reduce the movement of residual tritium from the soils surrounding the floor drain piping system to the groundwater.

4.5 Sewage Treatment Plant

The STP processes sanitary sewage for BNL facilities. The STP processes an average of 0.72 million gallons per day (MGD) during non-summer months and approximately 1.25 MGD during the summer months. Treatment of the sanitary waste stream includes: primary clarification to remove settleable solids and floatable materials; aerobic oxidation for secondary removal of the biological matter and nitrification of ammonia; secondary clarification; sand filtration for final effluent polishing; and, ultraviolet disinfection for bacterial control prior to discharge into the Peconic River. By regulating the oxygen levels during the treatment process, nitrogen can be biologically removed by using nitrate bound oxygen for respiration. This discharge is regulated under a NYSDEC SPDES permit (NY-0005835).

Wastewater from the STP's clarifier is released to the sand filter beds, where the water percolates through three feet of sand before being recovered by an underlying clay tile drain system, which transports the water to the discharge point at the Peconic River (SPDES Outfall 001). Approximately 15% of the water released to the filter beds is either lost to evaporation or to direct groundwater recharge. At the present time, six sand filter beds are used in rotation.

Two emergency hold-up ponds are located to the east of the sand filter bed area. The hold-up ponds are used for the emergency storage of sanitary waste in the event of an upset condition or if the influent contains contaminants in concentrations exceeding BNL administrative limits and/or SPDES permit effluent release criteria. The hold-up ponds are equipped with fabric reinforced (hypalon) plastic liners that are heat-welded along all seams. The first lined hold-up pond was constructed in 1978, and has a capacity of approximately four million gallons. A second four million gallon capacity lined pond was constructed in 1989, for a combined capacity of nearly eight million gallons. The combined capacity of the hold-up ponds provides the Laboratory with the ability to divert all sanitary system effluent for approximately twelve days. As part of the Phase III Sewage Treatment Plant Upgrades project in 2001, the liners were enhanced by the addition of new primary liners and a leak detection system. The older liners are now used as secondary containment.

4.5.1 Groundwater Monitoring

Well Network: The STP's groundwater monitoring program is designed to provide a secondary means of verifying that STP operations are not impacting environmental quality. Six wells are used to monitor groundwater quality in the filter bed area and three wells are monitored in the holding pond area (**Figure 4-5**).

Sampling Frequency and Analysis: During 2001, the nine STP wells were monitored semiannually, and samples were analyzed for VOCs, anions, metals, tritium, gross alpha, gross beta, and gamma emitting radionuclides (**Table 1-7**).

4.5.2 Monitoring Well Results

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

Non-radiological Analyses: During 2001, all water quality and most metals concentrations were below the applicable New York State Ambient Water Quality (NYS AWQS). Sodium was detected at concentrations slightly above the NYS AWQS of 20 mg/L in three filter bed area wells. Wells 039-07, 039-08 and 039-86 had maximum sodium concentrations of 28.5 mg/L, 29.3 mg/L and 30.5 mg/L, respectively. One sample from well 039-07 had a silver concentration slightly above the 0.1 mg/L standard. Nitrates were detected in most STP area wells, with a maximum concentration of 6.5 mg/L detected in filter bed area monitoring well 039-08. The NYS AWQS for nitrate is 10 mg/L. No volatile organic compounds were detected in any of the monitoring wells.

4.5.3 Groundwater Monitoring Program Evaluation

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

4.6 BNL Shotgun Range

The BNL shotgun range is utilized for (clay) trap and skeet target shooting by the Brookhaven Employees Recreation Association (BERA). The shotgun range is located in an isolated, wooded area north of the new Waste Management Facility. The range was established by the BERA in 1974. Although most of the shot falls within the cleared range, shooting from several of the trap line positions results in the deposition of some of the shot into the nearby wooded areas.

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

4.6.1 Groundwater Monitoring

Well Network: The monitoring well network for the Shotgun Range consists of one upgradient and two downgradient wells (**Figure 4-6**).

Sampling Frequency and Analysis: During 2001, the Shotgun Range wells were monitored one time, and the samples were analyzed for metals (**Table 1-7**).

4.6.2 Monitoring Well Results

During 2001, the groundwater monitoring wells at the Shotgun Range were sampled in March. All metals concentrations were below the applicable NYS AWQS, and were consistent with established background levels.

4.6.3 Groundwater Monitoring Program Evaluation

Groundwater monitoring data continue to indicate that Shotgun Range operations have not impacted groundwater quality. If monitoring results for 2002 continue to show that the range is not impacting groundwater quality, BNL will likely reduce the sampling frequency for these wells to once every two years starting in 2003.

4.7 BNL Live Fire Range

The BNL Live-Fire Range consists of a six-position, 100-yard, bermed outdoor small arms and grenade range. The primary use of the current facility is to allow members of the BNL Police Group to practice and qualify in the use of firearms and to gain experience in the use of smoke and CS gas grenades. Federal law enforcement agencies and the Brookhaven Employees Recreation Association (BERA) also occasionally use the range.

The present BNL Live-Fire Range was constructed in 1986, and is located immediately to the north of the BNL Sewage Treatment Plant. The eastern half of the range is located within 200 feet of the Peconic River. BNL utilized this same location as a practice range from 1963 until the present facility was constructed in 1986. The small arms and grenade ranges are co-located, side-by-side, and have a combined area of 87,516 square feet. The bullet stop (i.e., rear berm) of the live fire range is an earthen berm, and is screened for lead on an annual basis. The bullets are known to have a typical penetration depth of approximately two to three inches into the berm. The soil of the rear berm is screened to a depth of approximately one foot. The lead shot recovered during the screening process and the spent brass cartridges are disposed of off-site via a commercial waste handler as scrap metal. The grenade range is essentially an open field surrounded by earthen berms.

4.7.1 Groundwater Monitoring

Well Network: Groundwater quality at the Live-Fire Range is evaluated using two downgradient wells (**Figure 4-5**).

Sampling Frequency and Analysis: During 2001, the Live-Fire Range wells were monitored one time, and samples analyzed for metals (**Table 1-7**).

4.7.2 Monitoring Well Results

During 2001, all metals concentrations were below the applicable NYS AWQS and are consistent with established background levels.

4.7.3 Groundwater Monitoring Program Evaluation

Groundwater monitoring data continue to indicate that range operations have not impacted groundwater quality.

4.8 Water Treatment Plant (WTP) Area

The BNL Water Treatment Plant (WTP) is designed to remove naturally occurring iron from groundwater pumped from drinking water supply wells 4, 6 and 7. The WTP uses a conventional lime softening process for iron removal with air stripping for volatile organic compound removal. Precipitated iron is removed using multi-media (sand and anthracite coal) filters, which require routine backwashing. When the plant is in full operation, the filters are backwashed one to two times a day. The effluent from this backwash process is discharged into Recharge Basin HX, located adjacent to the plant. (Note Basin HX is divided into east and west sections that are separated by a sand berm.) The majority of the water percolates through the sand below the basin, but an iron residue is left at the bottom of the basins. Typically over several years of use, the iron residue builds up to an extent that prevents proper percolation of the backwash water, and creating a potential overflow condition. To restore proper percolation, the iron residue is periodically scraped off the basin floors.

Until February 2002, discharges of the STP backwash water to the basins were monitored as part of BNL's State Pollutant Discharge Elimination System (SPDES) program (SPDES Outfall 007). Because the discharges typically have iron concentrations in excess of the State discharge limit to groundwater of 0.6 mg/L, the NYSDEC had also required BNL to determine whether the backwash effluent has a detrimental effect on groundwater quality before a variance could be issued. In 1992, BNL installed five monitoring wells. These wells have been routinely monitored since that time. Additionally, the SPDES permit had required that samples of the backwash water be collected monthly, and analyzed for soluble and insoluble iron

4.8.1 Groundwater Monitoring

Well Network: The monitoring well network for the Water Treatment Plant recharge basins consists of two upgradient and three downgradient wells (**Figure 4-7**).

Sampling Frequency and Analysis: During 2001, the three downgradient wells were sampled one time, and the samples were analyzed for metals and anions (**Table 1-7**). The upgradient monitoring wells were not sampled during 2002 because previous sampling had already established background iron concentrations for the WTP area (<0.075 mg/L).

4.8.2 Monitoring Well Results

The groundwater monitoring wells in the WTP's recharge basin area were sampled in June 2001. Analytical results indicate that anions and metals (including iron) concentrations were below the applicable NYS AWQS, and were consistent with established background levels for Long Island.

4.8.3 Groundwater Monitoring Program Evaluation

Since the beginning of the WTP groundwater monitoring program in 1992, iron has rarely been detected above the typical detection limit of 0.075 mg/L in groundwater near Basin HX, and has never exceeded the 0.3 mg/L water quality standard. Following anticipated 2002 changes to BNL's SPDES permit, BNL will discontinue monitoring iron levels in WTP discharges to Basin HX. Concurrent with this change in SPDES permit requirements, BNL will discontinue the collection of groundwater samples from wells located near the basin. BNL will maintain the wells for the collection of water level measurements and for potential future collection of water samples to periodically verify water quality.

4.9 Motor Pool and Facility Maintenance Area

The Motor Pool (Building 423) and Site Maintenance facility (Building 326) are attached structures located along West Princeton Avenue (**Figure 4-8**). The Motor Pool area consists of a five bay automotive repair shop, which includes office and storage spaces. The Site Maintenance facility provides office space, supply storage, locker room and lunchroom facilities for custodial, grounds and heavy equipment personnel. Both facilities have been used continuously since 1947.

Potential environmental concerns at the Motor Pool include the historical use of underground storage tanks (USTs) for the storage of gasoline, diesel fuel and waste oil, hydraulic fluids used for lift stations, and the use of solvents for parts cleaning. In August 1989, the gasoline and waste oil USTs, pump islands and associated piping were upgraded to comply with Suffolk County Article 12 requirements for secondary containment, leak detection devices and overfill alarms. Following the removal of the old USTs, there were no obvious signs of soil contamination. The present tank inventory includes two 8,000 gallon-capacity USTs used for the storage of unleaded gasoline, one 260 gallon-capacity above ground storage tank used for waste oil, and one 3,000 gallon-capacity UST for Number 2 fuel oil. An inactive 275 gallon-capacity UST that was used for diesel fuel is scheduled for removal in early 2002.

The Motor Pool facility has five vehicle lift stations. The hydraulic fluid reservoirs for the lifts are located above ground. In February 1998, it was discovered that hydraulic fluid was leaking from one of the lift stations (BNL Spill Number 98-14). The lift was excavated and soils below the lift were contaminated with hydraulic oil. Approximately 50 cubic yards of the most contaminated soils were removed. In response to a NYSDEC request to evaluate whether the spill affected groundwater quality, BNL installed a monitoring well (102-09) inside the building, directly downgradient of the spill area. Hydraulic oil products were not detected in groundwater samples collected during 1999. Based upon these findings, the hydraulic fluid spill was removed from the NYSDEC's Active Spill List.

The only known environmental concern associated with the Site Maintenance facility (Building 326) was the December 1996 discovery of a historic oil spill directly south of the building. During the removal of an underground propane tank, the surrounding soils were contaminated with petroleum hydrocarbons (BNL Spill Number 96-54). The site was excavated to the extent that the footings of the building were almost undermined. Although approximately 60 cubic yards of contaminated soil were removed, there was clear evidence that contaminated soils remained. In an effort to investigate the potential impact to groundwater quality, four wells were installed. Although groundwater monitoring detected the presence of the solvent TCA at concentrations above NYS AWQS, petroleum hydrocarbons were not detected in groundwater downgradient of the spill site. Based upon these findings, the oil spill was removed from the NYSDEC's Active Spill List.

4.9.1 Groundwater Monitoring

Well Network: The Motor Pool facility's groundwater monitoring program for the underground storage tank area is designed to confirm that the engineered and institutional controls in place are effective in preventing contamination of the aquifer. Two wells (102-05 and 102-06) are used to monitor for potential contaminant releases from the UST area (**Figure 4-8**).

Groundwater quality downgradient of Building 423 and Building 326 is monitored using four wells (102-10, 102-11, 102-12, and 102-13). The program is designed to periodically assess existing solvent contamination that resulted from historical vehicle maintenance operations, and to confirm that the current engineered and institutional controls are effective in preventing additional contamination of the aquifer.

Sampling Frequency and Analysis: During 2001, the UST area wells were monitored semiannually, and the samples were analyzed for VOCs, including MTBE. The wells were also checked for the presence of floating petroleum hydrocarbons on a semiannual basis (**Table 1-7**). The Building 423/326 area wells were monitored semiannually, and the samples were analyzed for VOCs, including MTBE

4.9.2 Monitoring Well Results

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

Building 423/326 Area: During CY 2001, TCA was detected in all four wells at concentrations ranging from 6.0 µg/L to 77.3 µg/L. 1,1-dichloroethane (DCA) was detected in Well 102-12 at concentrations up to 14.5 µg/L. The NYS AWQS for TCA and DCA is 5 µg/L. The gasoline additive MTBE was detected in all four wells, with a maximum observed concentration of 73.8 µg/L. The NYS standard for MTBE is 10µg/L. The extent of VOC contamination in the Motor Pool area is depicted on **Figure 3.2-1**. It is believed that the TCA and DCA originate from historical vehicle maintenance/part degreasing operations. MTBE has been used as a gasoline additive since 1977. This compound has been detected at low levels in the Motor Pool wells since the monitoring program began in 1996.

4.9.3 Groundwater Monitoring Program Evaluation

Analysis of groundwater samples collected at the Motor Pool facility during calendar year 2001 indicates that releases from historical operations have impacted groundwater quality. Monitoring of the leak detection systems and the wells located downgradient of the Motor Pool's underground storage tank area indicate that the tanks and associated distribution lines are not leaking. Furthermore, evaluation of current vehicle maintenance operations indicates that all waste oils and used solvents are being properly stored and recycled. Therefore, it is believed that the solvents detected in groundwater originate from historical vehicle maintenance activities at the Motor Pool, and are not related to current operations.

4.10 On-Site Service Station

Building 630 is a commercial automobile service station, which is privately operated under a contract with BNL. The station, which was built in 1966, is used for automobile repair and gasoline sales.

Potential environmental concerns at the Service Station include the historical use of underground storage tanks (USTs) for the storage of gasoline and waste oil, hydraulic fluids used for lift stations, and the use of solvents for parts cleaning. When the service station was built in 1966, the UST inventory consisted of two 8,000 gallon-capacity and one 6,000 gallon-capacity tanks for the storage of gasoline, and one 500 gallon-capacity tank for used motor oil. An inventory discrepancy discovered in 1967, suggested that up to 8,000 gallons of gasoline might have leaked from one of the USTs. There are no records of remedial actions other than the replacement of the tank, and the loss of 8,000 gallons of gasoline has never been confirmed. 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. During the removal of the old USTs, there were no obvious signs of soil contamination.

The present tank inventory includes three 8,000 gallon-capacity USTs used for the storage of unleaded gasoline, and one 500 gallon-capacity UST used for waste oil. The facility also has three vehicle lift stations.

Groundwater quality in the Service Station area has been impacted by historical small-scale spills of oils, gasoline, and solvents, and by carbon tetrachloride contamination associated with a nearby underground storage tank that was used as part of an experiment conducted in the 1950s. In April 1998, BNL removed an underground storage tank from an area located approximately 200 feet to the northwest (upgradient) of the Service Station. Although there are indications that the tank was releasing small quantities of carbon tetrachloride prior to the tank removal, the detection of a significant increase in carbon tetrachloride concentrations in groundwater suggests that additional amounts of this chemical were inadvertently released during the excavation and removal process. BNL started to remediate the carbon tetrachloride plume in October 1999.

4.10.1 Groundwater Monitoring

Well Network: The Service Station's groundwater monitoring program is designed to confirm that the engineered and institutional controls in place are effective in preventing contamination of the aquifer. Five wells are used to monitor for potential contaminant releases (**Figure 4-9**).

Sampling Frequency and Analysis: During 2001, the Service Station facility wells were monitored semiannually, and samples were analyzed for VOCs, including MTBE (**Table 1-7**). The wells were also checked for the presence of floating petroleum hydrocarbons on a semiannual basis.

4.10.2 Monitoring Well Results

During 2001, carbon tetrachloride continued to be observed in Service Station monitoring wells (see **Section 3.2.1**; **Figure 3.2-9**). The maximum carbon tetrachloride concentration was 1,621 μg/L observed in well 085-16. These concentrations are less than those observed in CY 2000, when carbon tetrachloride concentrations in Service Station area wells approached 4,400 μg/L. The NYS AWQS for carbon tetrachloride is 5 μg/L.

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

Service Station area wells, and it is probably related to historical degreasing operations. No floating petroleum was detected in the monitoring wells.

4.10.3 Groundwater Monitoring Program Evaluation

In addition to the release of carbon tetrachloride from an upgradient source, operations at the Service Station have impacted groundwater quality. Available information indicates that the Service Station's underground storage tanks and associated distribution lines are not leaking and that all waste oils and used solvents are being properly stored and recycled. Therefore, it is believed that the petroleum hydrocarbon related compounds and solvents detected in groundwater originate from historical vehicle maintenance and fuel dispensing operations prior to improved chemical storage and handling controls implemented in 1989.

4.11 Major Petroleum Facility (MPF) Area

The Major Petroleum Facility (MPF) is the holding area for fuels used at the Central Steam Facility. Fuel oil for the Central Steam Facility is held in a network of seven above ground storage tanks, two of which are currently inactive. The tanks, which have a combined capacity to contain up to 2.3 million gallons of #6 fuel oil and 60,000 gallons of #2 fuel oil, are connected to the CSF by above ground pipelines that have secondary containment and leak detection devises. All fuel storage tanks are located in bermed containment areas that have a capacity to hold >110% of the volume of the largest tank located within each bermed area. The bermed areas have bentonite clay liners consisting of either Environmat (consisting of bentonite clay sandwiched between geotextile material) or bentonite clay mixed into the native soils to form an impervious soil/clay layer. As of December 1996, all fuel unloading operations were consolidated in one 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 Plan and a Facility Response Plan have been developed for the facility.

4.11.1 Groundwater Monitoring

Well Network: The MPF's groundwater monitoring program is designed to confirm that the engineered and institutional controls in place are effective in preventing contamination of the aquifer. In April 2000, five wells (076-16, 076-17, 076-18, 076-19 and 076-25) were used to monitor for potential contaminant releases (**Figure 4-10**). By October 2000, BNL incorporated three new wells (076-378, 076-379 and 076-380) into the MPF monitoring program.

Sampling Frequency and Analysis: The MPF stores primarily No. 2 and No. 6 fuel oil. Groundwater contaminants from these products can travel both as free product and in dissolved form with advective groundwater flow. The need to monitor for both forms of transport is reflected in the MPF groundwater monitoring plan. In accordance with the Special License Conditions, groundwater samples are analyzed semiannually for the Polynuclear Aromatic and Base Neutral Compounds contained in USEPA test method 625. The wells are also monitored for the presence of floating petroleum hydrocarbons on a monthly basis (**Table 1-7**).

4.11.2 Monitoring Well Results

During 2001, none of the target compounds were detected. The MPF wells were tested monthly for the presence of floating petroleum hydrocarbons. As in previous years, no floating product was observed.

4.11.3 Groundwater Monitoring Program Evaluation

Analysis of samples collected at the MPF during 2001 indicates that fuel storage and transfer operations are not impacting groundwater quality. No fuel related chemicals were detected in the groundwater. Following anticipated changes to the MPF monitoring requirements in 2002, BNL will expand the groundwater monitoring program to include analyses for VOCs, including MTBE.

4.12 New Waste Management Facility (WMF)

BNL has established a groundwater monitoring program at WMF to evaluate potential impacts to environmental quality and to demonstrate compliance with DOE requirements and applicable federal, state and local laws, regulations and permits. Groundwater monitoring is a requirement of the RCRA Part B permit issued for WMF operations. The WMF is located adjacent to BNL Potable Supply Wells 11 and 12, which are located south of East Fifth Avenue and just north of the WMF site (**Figure 4-11**). Because of the close proximity of the WMF to Potable Wells 11 and 12, it is imperative that the engineered and institutional controls discussed above are effective in ensuring that waste handling operations at the WMF do not degrade the quality of the soils and groundwater in this area. 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 WMF.

4.12.1 Groundwater Monitoring

Well Network: Eight wells are used to monitor for potential contaminant releases from the three main waste handling and storage buildings (**Figure 4-11**). Four wells are used to assess background water quality, whereas four are positioned downgradient of the three waste handling and storage buildings.

Sampling Frequency and Analysis: During 2001, the WMF wells were monitored quarterly, and the samples were analyzed for VOCs, metals, anions, tritium, gamma spectroscopy, gross alpha, and gross beta (**Table 1-7**).

4.12.2 Monitoring Well Results

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

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

During 2000, TCA and DCE were detected in upgradient Well 066-07 at concentrations up to 153 µg/L and 35 µg/L. During 2001 TCA concentrations in this well dropped to a maximum of 2.6 µg/L, and DCE was not detected in any of the samples. It is believed that the TCA and DCE contamination originated from historical releases from Building 830. In December 2000, BNL conducted an investigation into current and historical operations at Building 830, which included the installation of temporary wells (see **Section 4.14**). Although TCA had been used during metal cleaning operations, BNL could not identify a continuing source for the contamination. It is unlikely that contamination from this facility will significantly impact groundwater quality in the WMF area.

4.12.3 Groundwater Monitoring Program Evaluation

Groundwater monitoring results for 2001 are consistent with previous monitoring, and continue to show that WMF operations are not impacting groundwater quality. Groundwater analyses indicate that metals, anions and radionuclides are at concentrations that are consistent with established background levels. Although low levels of several volatile organic compounds (1,1,1-trichloroethane and MTBE) have been detected in several WMF area wells, it is not believed that these contaminants are related to WMF operations.

In 2002, BNL will petition the NYSDEC to modify the RCRA Part B Permit groundwater monitoring requirements. With NYSDEC concurrence, BNL will reduce monitoring frequency to semiannual, and analyze samples for gross alpha, gross beta, gamma, and VOCs. Monitoring requirements for metals and anions will be removed.

4.13 Biology Department Greenhouse Area

The Biology Department facility (Building 463) includes 11 greenhouses where various types of plants are grown for biological research. Eight of the greenhouses have dirt floors and three have concrete floors. Pesticides and fertilizers have been routinely used in the greenhouses. Records also indicate that copper sulfate was applied to the dirt floors on an annual basis until the mid-1980's. During the 1997 Facility Review Project, the pesticide Endosulphan II was detected in soil samples collected from a dry well located within Greenhouse 10. In accordance with DOE Order 5400.1, BNL established a groundwater monitoring program at the greenhouse area to evaluate potential impacts to environmental quality.

4.13.1 Groundwater Monitoring

Well Network: Two downgradient wells are used to monitor groundwater quality in the greenhouse area (**Figure 4-12**).

Sampling Frequency and Analysis: During 2001, the two greenhouse area wells were monitored one time, and samples analyzed for pesticides, metals and anions (**Table 1-7**).

4.13.2 Monitoring Well Results

The greenhouse area wells were sampled in September 2001, and tested for pesticides, metals, and anions. Groundwater monitoring results indicate that greenhouse operations are not impacting groundwater quality. Pesticides were not detected, and all water quality and most metals concentrations were below the applicable NYS AWQS. Sodium was detected at a concentration slightly above the NYS AWQS of 20 mg/L in well 084-36. The detection of low levels of sodium is not uncommon in wells located within the developed area of the site, and could be related to road salting operations.

4.13.3 Groundwater Monitoring Program Evaluation

Analysis of groundwater samples collected to date does not indicate that greenhouse operations have impacted groundwater quality. No pesticides have been detected, and metals and nitrate levels are at concentrations that are consistent with established background levels. If no contaminants are detected during 2002, BNL will reduce the sampling frequency to once every two years starting in CY 2003.

4.14 Building 830

During CY 2000, BNL's groundwater monitoring program for the Waste Management Facility (see Section 4.12 above) detected the presence of the volatile organic compounds TCA and DCE at concentrations that exceed NYS AWQS in background well 066-07, which is located near Building 830. TCA and DCE were detected at concentrations as high as 154 µg/L and 34 µg/L, respectively. These findings were considered unusual which triggered implementation of the BNL Groundwater Protection Contingency Plan and subsequent notification of BNL management and regulatory agency stakeholders.

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

Based upon an evaluation of current and historical operations in the Building 830 area, the TCA and DCE appear to have originated from historical metal cleaning activities at Building 830.

Previous analysis of liquids that were contained in two former underground radioactive liquid waste storage tanks near Building 830 indicated the presence of high levels of both TCA and DCE. The waste lines that lead from Building 830 to the tanks are known to have leaked. While the tank, exterior piping and contaminated soils were removed, portions of the piping still remain beneath the building.

4.14.1 Groundwater Monitoring

Well Network: Two downgradient wells are used to monitor groundwater quality in the greenhouse area (**Figure 4-11**). In June 2001, BNL installed six temporary Geoprobe wells to verify that the source of the contamination is Building 830, and evaluate contaminant concentrations close to the source. Two groundwater samples for VOCs will be collected from each geoprobe. One sample will be collected 2 feet below the water table. The second sample from the geoprobes will be collected from 10 feet below the water table.

Sampling Frequency and Analysis: During 2001, well 066-07 was monitored on a quarterly basis as part of the WMF monitoring program, and samples analyzed for VOCs, metals, gross alpha/beta, tritium and gamma (**Table 1-7**). Following the discovery of high levels of VOCs in well 066-07, nearby well 066-08 was monitored several times, and samples were analyzed for VOCs. Groundwater samples collected from the Geoprobe wells installed in June 2001 were analyzed for VOCs

4.14.2 Monitoring Well Results

During July 2001, six geoprobe points were installed in the vicinity of Building 830 as recommended in the Preliminary Investigation Report (Paquette *et al*, 2001). The Geoprobe wells were located with respect to potential source areas and the predominant local groundwater flow direction. The six Geoprobe locations essentially surround Building 830. Two groundwater samples were collected from each geoprobe point, one sample at the approximate location of the water table and the second sample at approximately 10 feet below the water table. No VOCs were detected in the Geoprobe samples at concentrations greater than the NYS AWQS of 5 µg/L (see BNL, 2001). TCA and DCE concentrations were <5 µg/L in samples collected from wells 066-07 and 066-08 during 2001. In February 2001, TCA and DCE concentrations in well 066-09 increased to nearly 80 µg/L and 25 µg/L, respectively. VOC concentrations in all wells dropped to <5 µg/L for the remainder of 2001.

4.14.3 Groundwater Monitoring Program Evaluation

The groundwater investigation conducted during 2000-2001 concluded that Building 830 is not a significant or a continuing source of groundwater contamination (see *Building 830 Groundwater Investigation Report, September 2001*). This conclusion is consistent with the earlier findings of the OU III Remedial Investigation. It is probable that historic, low-level VOCs releases from Building 830 have been contaminating the groundwater for many years. TCA has been detected in the nearby potable water supply wells 11 and 12 since the late 1980s. Because Building 830 area lies within the capture zones (or zones of contribution) for these supply wells, it is probable that TCA released from this facility was a contributing source of this contamination. Therefore, it is believed that the initial detection of VOCs in Wells 066-07 and 066-09 during 2000 was the result of recent changes in groundwater flow directions, and is not indicative of a new release from Building 830.

One scenario for the source of the contamination that is indirectly supported by this investigation is that some soil contamination went undetected during the exterior pipeline and D-tank removal projects. In 1998, the pavement covering the area where the leaking D-waste pipes were removed in and was left exposed for several heavy rain events. This may have caused leaching of any residual soil contamination.

Groundwater monitoring in the Building 830 area will continue. This monitoring is integrated into the OU III Central and WMF groundwater monitoring programs. In the event that unusual or off-normal groundwater monitoring results are found again for this area, BNL will re-implement its Groundwater Protection Contingency Plan which calls for confirmation, notification of BNL management, DOE and stakeholders, as well as near and long-term follow-up actions. The Facility Use Agreement for Building 830 has also been updated to account for potential environmental issues when the facility is significantly modified or taken out of service and demolished.

5.0 SUMMARY OF RECOMMENDATIONS

The following section is a summary of all of the recommendations from sections three and four and is provided for a quick reference. The recommendations are ordered under the categories Remediation System Programs and Groundwater Monitoring Programs.

5.1 Remediation System Programs

5.1.1 OU I South Boundary Pump and Treat System

The following are recommendations related to the OU I South Boundary groundwater remediation system and groundwater monitoring programs:

1) The groundwater model will be updated in 2002 in an effort to optimize and manage the operational life of the system. In addition, an engineering evaluation will be performed to consider remediation alternatives for the persistently high TVOC concentrations in an area immediately south of the former HWMF.

2) The former HWMF strontium-90 plume will be evaluated in 2002, particularly with respect to the effects of the extraction wells on it.

3) Four sentinel monitoring wells will be installed in the spring of 2002 for the former HWMF strontium-90 plume. The wells will be located immediately south of the downgradient line of geoprobes installed in 2001 and 2002. These will provide early warning for Sr-90 approaching the south boundary extraction wells.

4) Reduce the frequency of the perimeter monitoring wells from quarterly to semi-annually. The fringes of the OU I South Boundary TVOC plume have not shown evidence of shifting over the past several years of monitoring. In addition, the TVOC concentrations are less than 5 µg/L in these wells. The modification would affect wells 98-21, 98-22, 98-30, 98-33, 98-58, 98-61, 98-62, 99-04, 107-10, 107-23, 107-24, 107-25, 108-08, 108-12, 108-13, 108-14, 108-17, 108-18, 108-30, 115-03, 115-30, 116-05, and 116-06. The modification in sampling frequency will be implemented beginning in the first quarter of 2003.

5.1.2 OU III Carbon Tetrachloride Pump and Treat System

The following are recommendations for the OU III Carbon Tetrachloride groundwater remediation system and monitoring program:

1) Due to the low carbon tetrachloride concentrations in extraction well EW-13 this well will be shut down beginning in the third quarter of 2002. Sampling of both EW-13 and EW-14 will continue on a monthly basis.

2) A groundwater modeling analysis will be performed in late 2002 to review the remediation system optimization and determine whether the upgraded system is performing as planned. A work plan will be developed during 2002 to outline the characterization of deep carbon tetrachloride contamination, which is not currently being addressed by the existing remediation system. This plan will be developed in conjunction with the groundwater modeling and a field investigation implemented during the fall of 2002.

3) The adequacy of the monitoring well network will be re-evaluated in late 2002.

5.1.3 OU III Building 96 Air-Stripping System

The following are recommendations for the OU III Building 96 groundwater remediation system and monitoring program:

1) Two new permanent monitoring wells will be installed upgradient (1) and down gradient (1) of the high concentration area after two additional geoprobes are installed to verify the concentrations.

2) One additional permanent monitoring well will be installed southwest of well 095-159 at the GP-2 location to monitor potential westward spread of the contaminants.

3) Contaminants deeper than 70 feet from the land surface will be monitored by the repeated installation of geoprobes GP-2 and GP-6.

4) Air emissions data will continue to be collected monthly at least for the first two quarters of 2002 to track aromatic compounds and TCA concentrations in the midpoint and effluent of the air treatment equipment.

5.1.4 OU III Middle Road Pump and Treat System

No changes to this system are recommended at this time.

5.1.5 OU III South Boundary Pump and Treat System

The recommendation for the OU III South Boundary groundwater remediation system is for one additional downgradient (bypass detection) monitoring well be installed on the south side of the LIE downgradient of EW-4 to verify high levels of contamination in this vicinity are being captured. This work will be planned in October 2002.

5.1.6 OU III Industrial Park In-Well Air Stripping System

The following are recommendations for the OU III Industrial Park groundwater remediation system on monitoring programs:

1) An additional well will be installed at the 000-276 location and screened within the deep horizon at elevations equivalent to the UVB extraction well screen depths.

2) A second additional bypass monitoring well will be installed along Carleton Drive approximately 200 feet west of existing well 000-273. Installation of a second bypass monitoring well at this location will provide adequate downgradient bypass monitoring of the area where the highest concentrations are observed (between UVB-1 and UVB-2). Therefore, this well will be screened in the deep horizon at elevations similar to UVB extraction well screens.

3) The existing remediation wells will continue operation at 60 gpm per well pumping rates.

4) Formal groundwater DQOs will be developed for this system in 2002.

5.2 Groundwater Monitoring Programs

5.2.1 Current Landfill Groundwater Monitoring Program

A recommendation in the Five Year Review Report (BNL 2001) was to reduce the frequency of VOC sampling from quarterly to semi-annually. After discussions with NYSDEC it was agreed to maintain the quarterly frequency for another year and evaluate the data at that point. Based on the stability of the VOC data, it is recommended that the frequency of VOC analysis is reduced to semi-annually for all wells except 88-109. This well exhibited a significant spike in chloroethane concentrations during the fourth quarter of 2001.

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5.2.2 Former Landfill Groundwater Monitoring Program

The following recommendations were outlined in the Former Landfill Five-Year Review Report based on the analysis of data collected over the five-year period (1997-2001):

1) Eliminate SVOCs and EDB from the monitoring program as they were not detected in groundwater during this period.

2) Reduce the analytical frequency from quarterly to annually for VOCs in upgradient wells 86-42, 86-72, and 87-22. Little or no VOCs were detected historically in these upgradient wells, and none exceeded NYS AWQS.

3) Reduce the analytical frequency for radionuclides from quarterly to annually. Tritium has not been detected at concentrations exceeding the NYS AWQS of 20,000 pCi/L. Historically, the highest tritium concentration recorded at the Former Landfill was 746 pCi/L in 106-30 in December 1998. Strontium-90 has not been detected above the NYS AWQS of 8 pCi/L with the exception of well 97-64. A declining trend has been demonstrated for several years in this well with the concentration during the last two rounds of 2001 below 2 pCi/L.

4) Reduce the sampling frequency for metals to semi-annual. Metals were below applicable NYS AWQS with the exception of iron, manganese,, sodium, antimony, and aluminum.

5) Create formal DQOs for this program.

5.2.3 OU III Offsite Groundwater Monitoring Program

Development of groundwater DQOs for this project in 2001 resulted in reduced sampling frequency for VOCs in several wells and the transfer of responsibility to another groundwater monitoring project and a reduction in radiological monitoring during 2002. This level of monitoring should be continued until the start-up of the LIPA and Airport Systems, at which time it will be reevaluated.

5.2.4 OU III North Street Groundwater Monitoring Program

The monitoring well network will be enhanced during 2003 by establishing monitoring wells associated with both the North Street and Airport Remediation Systems. There are no recommendations for the monitoring well network other than those currently planned as part of these efforts.

5.2.5 OU III Western South Boundary Monitoring Program

No changes are recommended for the OU III Western South Boundary Monitoring Program for 2002.

5.2.6 OU III Central Monitoring Program

The OU III Central Monitoring Program continues to be adequate for addressing minor groundwater contamination areas across the site. Significant or substantial levels of contaminants were not observed in 2001; therefore, additions to the current monitoring well network are not warranted.

5.2.7 OU III HFBR (AOC 29) Tritium Monitoring Program

The following are recommendations for the HFBR groundwater monitoring program.

1) Five geoprobes will be installed in 2002 to track the high concentration portion of the plume as per the HFBR Tritium Low Flow Pumping Evaluation Report (BNL 2001).

2) Based on the results of groundwater monitoring well data, up to five addition vertical profiles and monitoring wells will be installed in 2002 in order to define the tritium plume.

3) Re-evaluate the monitoring well network and sampling frequency during 2002.

4) Evaluate operating the HFBR Pump and Recharge wells on Princeton Avenue to remediate the high concentrations in the OU III VOC plume located immediately to the west of the extraction wells.

5.2.8 BGRR /WCF Strontium-90 Monitoring Program

The following are recommendations for the BGRR groundwater monitoring program:

1) Two sentinel wells will be installed south of Brookhaven Avenue at two separate locations (total of four wells) to monitor the leading edge of the strontium-90 plumes.
2) The HFBR stack will be evaluated as a potential source for the strontium-90 (detected during HFBR characterization work in 2001) as part of the BGRR pre-design characterization work beginning in the fall of 2003. The groundwater monitoring well network will also be re-evaluated at that time.

5.2.9 Chemical/Animal Holes Strontium-90

The following are recommendations for the OU III Chemical/Animal Holes groundwater monitoring program:

1) Monitoring wells will be installed during 2002 as part of the pilot/study groundwater remediation system construction to address the Chemical/Animal Holes strontium-90 plume.

2) The installation of an additional sentinel monitoring well is recommended to monitor the leading edge of the strontium-90 plume downgradient of the Former Landfill area. This well would be located along Middle Path to the west of existing well 106-62.

5.2.10 OU III South Boundary Radionuclide Monitoring Program

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

5.2.11 OU IV AOC 5 Monitoring Program

The pulsing of the AS/SVE in February 2001 and the injection of ORC around monitoring well 076-04 have accomplished the goal of cleaning up the residual VOCs within the area of concern for the AS/SVE system. Since all the wells have shown TVOC concentrations below MCLs for two consecutive quarters, satisfying the criteria for closure based on the OU IV AS/SVE Operations, Maintenance and Monitoring Plan (BNL, 1999b), a petition for closure will be submitted in Spring 2002 to the regulators for review and approval.

5.2.12 OU IV Building 650 Sump Outfall Monitoring Program

The following are recommendations for the OU IV AOC 6 Strontium-90 monitoring program:

1) Soil remediation is planned for the spring of 2002. It is recommended that groundwater monitoring continue as planned.

2) Well 76-28 should be evaluated for at least one year after the removal of contaminated soils in the vicinity of the Building 650 decontamination pad to determine if further investigation is required to identify the source of the strontium-90 contamination in this well.

3) The addition of recharge water from the OU III Middle Road groundwater remediation system to the RA V recharge basin has resulted in a more westerly component to groundwater flow in the OU IV area. An additional monitoring well will be installed in 2002 to monitor for the potential westerly migration of the plume.

5.2.13 OU V STP Monitoring Program

Although there presently are sentinel wells south of the leading edge of the VOC plume, additional wells are recommended because the plume is narrow and there is potential for it to bypass the existing wells. A hydrogeologic evaluation, including some updated modeling, is recommended to re-evaluate the monitoring network with respect to the recently signed ROD requirements. This will determine whether any modifications to the monitoring well network are warranted.

5.2.14 OU VI EDB Monitoring Program

The EDB Monitoring Program will be enhanced with additional wells in 2003 to more precisely monitor the high concentration area of the EDB plume and sentinel wells downgradient of the plume edge. No additional modifications to the monitoring program are warranted at this time.

5.2.15 Site Background Monitoring Program

No further modifications are recommended to this monitoring program other than those being implemented in 2002 from the groundwater DQO process.

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