Brookhaven National Laboratory
Groundwater Monitoring Improvements Plan
For FY 1998 and 1999

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Groundwater Monitoring Improvements Plan for FY 1998 and FY 1999

Executive Summary

The Groundwater Monitoring Improvements Plan identifies active research and support facilities that have the potential to impact groundwater quality, and establish a basis for an expanded groundwater monitoring program. The evaluation process focused on facilities which have inventories of hazardous or radioactive materials which could create groundwater contamination problems if there were leaks in piping systems or tanks, or whose operations create the potential for groundwater contamination by the direct activation of soils.

Areas Requiring Improved Groundwater Monitoring Programs

The Groundwater Monitoring Improvements Plan provides: 1) an overview of the operational history of each facility requiring improvements in its groundwater monitoring program; 2) the identification of potential contaminant source areas (i.e., underground storage tanks, beam stop areas, etc.); 3) a review of the historical and current groundwater monitoring program and available groundwater data; 4) recommendations for necessary groundwater monitoring upgrades or improvements at each facility; and, 5) a prioritized schedule for the installation of new wells.

The facilities that require improvements to their groundwater monitoring programs include: the Alternating Gradient Synchrotron complex; Relativistic Heavy Ion Collider; Brookhaven LINAC Isotope Producer; Medical Research Reactor, Sewage Treatment Plant; Building 830; Biology Department Greenhouses; Rifle and Shotgun Ranges; Major Petroleum Facility; Site Maintenance and Motor Pool area; and the on-site Gasoline Service Station. The present plan calls for the installation of 81 new groundwater monitoring wells during the remainder of CY 1998 and early CY 1999. This report identifies the screen intervals and depths for the wells, as well as the sampling frequency and analyses to be performed.

Alternating Gradient Synchrotron Complex: Secondary particles created near AGS beam targets and stops have the potential to activate soils surrounding the accelerator tunnels or soils underlying target and beam dump areas in the experimental hall areas. The radionuclides of primary concern because of their potential to impact groundwater quality are tritium and sodium-22. Once present in the soils, these radionuclides can be leached downward into groundwater by means of rainwater percolation. Identified areas where soil activation could be occurring are: Building 912 (main experiment hall); AGS Booster Beam Scraper; E-20 Beam Catcher; Building 914 (transfer tunnel); g-2 Beam Target and Dump; J-10 Beam Dump; and the former U-Line Target area. Low level tritium (up to 5,000 pCi/l) and sodium-22 (up to 25 pCi/l) have been detected in current AGS area wells. A total of 34 new monitoring wells will be installed to provide improved surveillance of these potential soil activation areas.

Brookhaven LINAC Isotope Producer: Secondary particles created near the BLIP target vessel are likely to cause significant activation of soils within a four to five foot radius of the vessel. Tritium (up to 54,000 pCi/l) and sodium-22 (up to 151 pCi/l) have recently been detected in groundwater samples collected directly downgradient of BLIP. A total of six new monitoring wells will be installed to evaluate the effectiveness of recent and proposed remedial measures, and provide improved long-term surveillance of the BLIP facility.

Relativistic Heavy Ion Collider: Secondary particles that will be created at the RHIC beam stop and collimator areas are expected to produce tritium and sodium-22 in soils immediately surrounding those areas. Although the potential radionuclide concentrations in soil pore water are predicted to be well below drinking water standards, landfill-type geomembrane caps will be constructed over the collimator and beam stop areas as an added measure of groundwater protection. As a means of verifying that these engineering controls are effective, a total of 12 new monitoring wells will be installed at the RHIC collimator and beam stop areas.

Brookhaven Medical Research Reactor: The BMRR's primary cooling water system consists of a recirculation piping system that contains 2,550 gallons of water. The tritium concentration in the primary water is currently 465 µCi/L. Historical discharges of primary water to a floor drain system located in the basement of the BMRR has resulted in the creation of a low-level tritium plume with a maximum concentration of 11,800 pCi/l. To prevent future releases, the Reactor Division has implemented new operating procedures and the floor drains will be abandoned. To supplement the existing monitoring well network, two additional wells will be installed. The wells will be used to verify that proposed operational and engineering controls are effective in preventing future environmental releases.

Sewage Treatment Plant: Review of the current groundwater surveillance network for the Sewage Treatment Plant revealed that additional wells are required in two areas of the plant: 1) the sand filter bed area; and 2) the emergency holding pond area. Approximately 15% of the water released to the STP's filter beds is either lost to evaporation or to direct groundwater recharge. Two new monitoring wells will be installed to supplement the existing groundwater surveillance well network at the filter bed area.

Two emergency hold-up ponds are located to the east of the sand filter bed area, and are used for the emergency storage of sanitary waste when the influent flow exceeds the STP's capacity or when the influent contains contaminants in concentrations exceeding BNL administrative limits and/or SPDES permit effluent release criteria. Although the hold-up ponds are equipped with fabric reinforced (hypalon) plastic liners with heat welded seams, the system lacks secondary containment or leak detection devices. Four new monitoring wells will be installed in the holding pond area to verify that groundwater quality has not been impacted from past use, and to provide a means of long-term surveillance once a planned upgrade to the liner system has been implemented.

Building 830: Building 830 contains a water filled inground cobalt-60 source pool that currently contains approximately 35,000 Ci (total) of cobalt-60 sources, and two inactive hot cells and associated transfer canal. Soil and groundwater contamination issues related to historical operations of the hot cells, transfer canal and associated D-Waste systems are currently being evaluated as part of the Environmental Restoration Program. Because Building 830 is located within the defined groundwater source area for BNL potable supply wells 11 and 12, the current network of three monitoring wells will be supplemented with four new wells. The new wells will act as "sentinel" wells for potable supply wells 11 and 12, and will be positioned between Building 830 and the supply wells.

Biology Department Greenhouses: Pesticides, such as Endosulphan II, and fertilizers have been routinely used in the Biology Department greenhouses. Records also indicate that copper sulfate was also applied to the dirt floors of some greenhouses on an annual basis up to 15 years ago. High levels of Endosulphan II have been detected in soil samples collected from a dry well located within Greenhouse 10. To evaluate whether greenhouse operations have impacted groundwater quality, two monitoring wells will be installed downgradient of the greenhouses.

Rifle/Pistol and Shotgun Ranges: BNL currently operates two outdoor target ranges. The BNL "Live-Fire Range" is located immediately to the north of the BNL Sewage Treatment Plant and is used by the BNL Police Group for rifle and pistol practice. The eastern half of the Live-Fire Range is within 200 feet of the Peconic River. The shotgun range is located in an isolated, wooded area north of the new Waste Management Facility and is utilized by the Brookhaven Employees Recreation Association.

To reduce the potential impact to the environment, BNL uses predominantly copper jacketed or Teflon® coated bullets at the Live-Fire Range, and the bermed area is screened annually to remove spent bullets. At the Shotgun range, however, it is estimated that several thousand pounds of lead shot is deposited on the surface of the range annually. There is a potential that residual lead bullets at the BNL Live-Fire Range and lead shot deposited at the Shotgun range could cause soil contamination and potentially impact groundwater quality. To evaluate groundwater quality, two new monitoring wells will be installed downgradient of the Live-Fire range, and two wells will be installed downgradient of the Shotgun Range.

Major Petroleum Facility: The Major Petroleum Facility 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. As part of the NYSDEC licensing requirements for the Major Petroleum Facility, BNL established a groundwater surveillance program in 1989 that was designed to detect both free product and dissolved hydrocarbon products. Evaluation of the current program indicates that three new monitoring wells are required to supplement the existing monitoring well network.

Site Maintenance and Motor Pool Area: The Motor Pool (Building 423) and Site Maintenance facility (Building 326) are attached structures located along West Princeton Avenue. Potential environmental concerns at the Motor Pool include the historical use of underground storage tanks for the storage of gasoline and waste oil, hydraulic fluids used for lift stations, and the use of solvents for parts cleaning. In 1996, two wells were installed downgradient of the gasoline underground storage tanks and pump island area to provide a means of verifying groundwater quality. During CY 1997, low concentrations of 1,1,1-trichloroethane and methyl tertiary butyl ether (MTBE) were detected. Furthermore, in February 1998 it was discovered that soils below a lift station were contaminated with hydraulic oil.

The only environmental concern associated with the Site Maintenance facility (Building 326) is the 1996 discovery of a historic oil spill directly south of the building. Temporary Geoprobe™ wells were installed both upgradient and downgradient of the Building 326 spill area. Although no hydrocarbon breakdown products were detected in the groundwater sample, 1,1,1-trichloroethane was detected at a concentration of 65 µg/l in one downgradient Geoprobe™ well.

Currently, there are no permanent groundwater monitoring wells located directly downgradient of either the hydraulic oil leak in Building 423 or the fuel oil spill area south of Building 326. In an effort to improve BNL's ability to monitor groundwater quality in at the Motor Pool and Site Maintenance Facility, and in response to a NYSDEC request to monitor the spill sites, one upgradient and four downgradient monitoring wells will be installed.

On-site Gasoline Service Station: Potential environmental concerns at the Service Station include the historical use of underground storage tanks for the storage of gasoline and waste oil, hydraulic fluids used for lift stations, and the use of solvents for parts cleaning. In 1996, two wells were installed downgradient of the gasoline underground storage tank area and pump islands to provide a means of verifying groundwater quality. During CY 1997, low levels of tetrachloroethylene, carbon tetrachloride and MTBE were detected in these wells. In an effort to improve BNL's ability to monitor groundwater quality near the service station's underground storage tank area, one upgradient and two downgradient wells will be installed.

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Groundwater Monitoring Improvements Plan for FY 1998 and FY 1999
List of Acronyms

AGS	Alternating Gradient Synchrotron
ALARA	As Low As Reasonably Achievable
AOC	Area of Concern
ASL	Analytical Services Laboratory
BAT	Best Available Technology
BERA	Brookhaven Employees Recreation Association
BGRR	Brookhaven Graphite Research Reactor
BLIP	Brookhaven LINAC Isotope Producer
BMRR	Brookhaven Medical Research Reactor
BNL	Brookhaven National Laboratory
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CY	Calendar Year
DCA	1,1-dichloroethane
DCG	Derived Concentration Guide
DOE	U.S. Department of Energy
EA	Environmental Assessment
ES&H	Environment, Safety and Health
EM	Environmental Monitoring
EPA	U.S. Environmental Protection Agency
ER	Environmental Restoration
FY	Fiscal Year
HFBR	High Flux Beam Reactor
IAG	Interagency Agreement
LINAC	Linear Accelerator
mg/kg	Milligrams per Kilogram
MPF	Major Petroleum Facility
MTBE	Methyl Tertiary Butyl Ether
NPL	National Priorities List
NYSAWQS	New York State Ambient Water Quality Standard
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
NYSDWS	New York State Drinking Water Standard
OU	Operable Unit
PA/SI	Preliminary Assessment/Site Investigation
PCE	Tetrachloroethylene
pCi/l	PicoCuries per Liter
RCRA	Resource Conservation and Recovery Act
RI/FS	Remedial Investigation/Feasibility Study
SAR	Safety Analysis Report
SER	Site Environmental Report
SCDHS	Suffolk County Department of Health Services
SPDES	State Pollution Discharge Elimination System
STP	Sewage Treatment Plant
TCA	1,1,1-trichloroethane

TCE	Trichloroethylene
µg/l	Micrograms per Liter
UST	Underground Storage Tank
VOC	Volatile Organic Compounds
WCF	Waste Concentration Facility

1.0 Introduction

The recent experience involving the detection of tritium in groundwater from a facility previously believed to be free of any environmental impacts has highlighted the need for increased monitoring of operational facilities at the Brookhaven National Laboratory (BNL). The purpose of this report is to identify currently active facilities that have the potential to impact groundwater quality, and establish a basis for an expanded groundwater monitoring program. The evaluation process focused on facilities which have inventories of hazardous or radioactive materials which could create groundwater contamination problems if there were leaks in piping systems or tanks, or whose operations create the potential for groundwater contamination by the direct activation of soils.

One of the early lessons-learned from the High Flux Beam Reactor (HFBR) tritium release was the need to re-examine historical groundwater data to identify potential contaminant source areas that may have been overlooked or given a low priority due to apparently low levels of contamination. In order to identify facilities that require improved groundwater monitoring, historical groundwater data were evaluated to identify potential source areas that may not have been previously discovered, characterized or monitored. The review of historical groundwater data was performed concurrently with the Facility Review Project. Information on historical groundwater quality near certain facilities was used by the facility review teams to assist them in identifying potential contaminant sources.

This report provides a summary review of: the operational history of each facility requiring improvements in its groundwater monitoring program; the identification of potential contaminant source areas (i.e., underground storage tanks, beam stop areas, etc.); review of the historical and current groundwater monitoring program and available groundwater data; recommendations for necessary groundwater monitoring upgrades or improvements at each facility; and, a prioritized schedule for the installation of new wells.

2.0 BNL Groundwater Protection Program

It is the policy of BNL to operate and maintain its facilities in compliance with applicable federal, state and local regulations and DOE Orders. Groundwater quality at BNL is being protected through programs designed to minimize future releases of environmental pollutants, and through site remediation carried out under the Inter Agency Agreement (IAG) between the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), and New York State Department of Environmental Conservation (NYSDEC). The

IAG provides a framework for remediating contaminated soils and groundwater at BNL.

The strategy for protecting groundwater at the BNL site has the following elements:

1. Reviewing engineering designs and conducting environmental assessments for new and existing facilities to ensure that potential environmental impacts are fully evaluated and reduced to acceptable levels;

2. Upgrading existing facilities to reduce the risk of accidental release of contaminants to the environment (i.e., upgrading underground storage tanks, replacing of deteriorated sewer lines, constructing new waste management facilities using best available environmental prevention technologies);

3. Responding promptly and remediating spills to prevent contaminants migrating to surface waters and groundwater;

4. Conducting groundwater and surface water monitoring programs at active facilities that have the potential to impact the environment, so that potential accidental contaminant releases are detected quickly;

5. Conducting groundwater monitoring programs at inactive chemical and radioactive materials storage and disposal sites and spill areas to assess the distribution and movement of existing groundwater contamination;

6. Conducting environmental restoration in areas where soils and groundwater were contaminated by chemicals and radionuclides by past accidental spills, storage, and disposal;

7. Developing waste minimization practices to reduce the volume and toxicity of all wastes, and using best management practices to manage and properly dispose of generated wastes; and,

8. Developing a Pollution Prevention Awareness Program to ensure that employees are cognizant of their responsibilities for the proper storage, use, and disposal of chemicals in the work place.

A number of BNL facilities and processes that could impact groundwater quality are operated under regulatory permit or license. These permits and licenses include provisions that are designed to be protective of environmental resources. Current BNL permits and licenses include: a State Pollutant Discharge Elimination System (SPDES) permit for ten sanitary, process or storm water discharge outfalls; two Resource Conservation and Recovery Act (RCRA) permits (one for the old Hazardous Waste Management Facility and one for the new Waste Management Facility); a license to operate the BNL Major Petroleum Facility (which includes requirements for groundwater monitoring and development of a Spill Prevention, Control and Countermeasures Plan); a certificate from the NYSDEC registering tanks storing bulk quantities of hazardous substances, and the registration of BNL storage facilities (e.g., underground and above ground storage tanks and piping systems) with the SCDHS.

2.1 Comprehensive Environmental Response, Compensation and Liability Act

On December 21, 1989, the BNL site was included as a Superfund site on the National Priorities List (NPL). The DOE, EPA, and NYSDEC have integrated DOE's response obligations under the Comprehensive, Environmental Response, Compensation, and Liability Act (CERCLA), the Resource Conservation and Recovery Act (RCRA), and NY State hazardous waste regulations into a comprehensive Federal Facilities Agreement (FFA). This Interagency Agreement (IAG) was finalized and signed by these parties in May 1992. The BNL Environmental Restoration (ER) Division (formerly the Office of Environmental Restoration) was created in 1991 to oversee the Laboratory's CERCLA activities. The BNL Site Baseline Report (SAIC, 1992, and subsequent revisions), Response Strategy Document (SAIC, 1992) and annual Schedules Documents outline the procedural framework and schedule for developing, implementing, and monitoring appropriate response actions at the site in accordance with CERCLA guidance and policies.

Using historical and current environmental monitoring data, 29 Areas of Concern (AOCs) have been identified at the BNL site (Figure 1). The characteristics of each AOC has been documented in the BNL Site Baseline Report (SAIC, 1992; and subsequent revisions). These 29 AOCs have been grouped into six Operable Units (OUs) based upon relative proximity of AOCs, similarity of contamination problems, similar geology and hydrology, and similar phases of remedial action to be performed. Under the IAG, Remedial Investigation/Feasibility Studies (RI/FSs) have been conducted for each OU. All of the OUs contain source areas that are known to have affected groundwater quality at the site. These sites have been excluded from the scope of this report with the exception of the Sewage Treatment Plant and Building 830.

2.2 BNL Groundwater Surveillance Program

Responsibilities for the BNL groundwater monitoring program at the site are shared between the Environment, Safety and Health (ES&H) Services Division and the ER Division. The ES&H Services Division (formerly the Safety and Environmental Protection Division) maintains the routine Environmental Monitoring (EM) Program for the site. The EM Program includes the monitoring of facility effluents, soils, surface waters, groundwater, and air as required under DOE Order 5400.1, DOE Order 5400.5 or state permits. The ER Division is responsible for overall management of the site ER Program conducted under the IAG. The ER Program monitors groundwater quality at each of the defined AOCs / OUs. Historically, the ES&H Services Division has maintained a baseline monitoring program at each OU or AOC until the active phase of each RI/FS. During the RI/FS, the ER Division is responsible for assessing the full extent of groundwater contamination and developing, when appropriate, remedial alternatives for the control of contaminant source areas and the restoration of groundwater quality. Following the Remedial Investigation (RI) phase at each OU, the ES&H Services Division usually resumed the responsibility for groundwater monitoring until a decision had been made by the IAG parties regarding remedial actions and long-term, post-closure groundwater monitoring requirements. All long-term CERCLA groundwater monitoring will be conducted by the ER Division, and the ES&H Services Division's groundwater monitoring program will be focused primarily on the surveillance of active research and support facilities that have the potential to impact groundwater quality.

As required by DOE Order 5400.1, BNL prepares an annual Environmental Monitoring Plan which documents the Laboratory's environmental surveillance programs (see Naidu *et al.*, 1997). The combined EM and ER groundwater monitoring program is outlined in the annual Environmental Monitoring Plan. The ER Division's CERCLA groundwater monitoring program is also presented in an annual Groundwater Sampling Program Plan. Changes to the sampling schedule that occur throughout the year are documented in monthly Environmental Monitoring Schedules. Results from this monitoring program are published in OU-specific reports required under the IAG and in the annual BNL Site Environmental Report (see Naidu *et al.*, 1996; Schroeder *et al*. 1998). The BNL groundwater monitoring program is revised at least annually to reflect changes in monitoring requirements, or for the incorporation of new surveillance wells.

3.0 General Hydrogeology of the BNL Site and Groundwater Quality

The BNL site is underlain by approximately 1,300 feet of unconsolidated Pleistocene and Cretaceous sediments overlying Precambrian bedrock (Table 1). The unconsolidated sediments, subdivided from youngest to oldest, are as follows:

- Upper Pleistocene deposits (Upper Glacial aquifer),
- Gardiners Clay (confining unit),
- Magothy Formation (Magothy aquifer), and
- Raritan Formation (Raritan Clay confining unit and Lloyd aquifer)

A description of the geologic and hydraulic properties of the Upper Pleistocene deposits are provided below. New monitoring wells required for improved facility monitoring under this Groundwater Monitoring Improvements Plan will installed within the shallow sections of the Upper Glacial aquifer. Detailed discussions on Gardiners Clay, Magothy and Raritan formations can be found in deLaguna (1963), Faust, 1963, Warren *et al.* (1968), and the BNL Regional Groundwater Model Report (Geraghty and Miller, 1996). A generalized hydrogeologic cross section for the BNL site is presented in Figure 2.

3.1 Upper Pleistocene (Glacial) Deposits

The Upper Pleistocene deposits on Long Island were deposited during two Wisconsin glaciation events (Lubke, 1964). At BNL, the glacial deposits range from 130 to 200 feet in thickness, and can be divided into three distinctive units. From oldest to youngest, the units are: the basal "Unidentified Unit"; sand and gravel outwash and moraine deposits; and near surface silt and clay deposits.

<u>Basal Unidentified Unit</u>: The basal "Unidentified Unit" (first described by deLaguna, 1963), is between 25 to 50 feet thick, and appears to be restricted to the central and southern portions of the site. This unit is characterized by light green, fine to medium-grained sand and sandy clay (with 5 to 10% glauconitic clay). The Unidentified Unit is generally less permeable than the overlying coarse-grained glacial moraine and outwash deposits.

<u>Outwash and Moraine Deposits</u>: The Upper Pleistocene deposits at BNL primarily consist of 130 to 200 feet of broadly stratified glacio-fluvial outwash deposits composed of silica-rich medium to coarse-grained sand and gravel. Thin layers of silt and clay have been observed within the outwash deposits, but do not represent significant barriers to groundwater flow. Along the southwest border of BNL, the Ronkonkoma terminal moraine is recognized as a series of discontinuous hills which reach a maximum elevation of 130 feet above sea level (Figures 2 and 3).

<u>Near Surface Silt and Clay</u>: Near surface silt and clay deposits are located along the lowlands of the Peconic River watershed. Although the full areal extent of these deposits has not been determined, their presence is inferred beneath marshes and areas of ponded water, which are wide-spread in the eastern portion of the site (see Warren *et al.*, 1968). Recent drilling within the BNL Sewage Treatment Plant (STP) area and the Relativistic Heavy Ion Collider (RHIC) area has revealed that fine sand, silt and clay deposits occur within 30 feet of land surface. These low permeability deposits retard groundwater recharge, and are responsible for creating perched or semi-perched water table conditions. In the STP area, a broad groundwater mound has formed below the plant's filter beds, where it is estimated that up to 0.1 MGD of STP effluent is recharged directly to Upper Glacial aquifer (Figure 4).

3.2 Upper Glacial Aquifer

The Upper Glacial aquifer is widely used on Long Island for both private and public water supply. Drinking water and process water supplies at BNL are obtained exclusively from the Upper Glacial aquifer. The Laboratory currently operates six potable water supply wells that can be pumped at rates of 1,200 gpm, and five process supply wells that can be pumped at rates between 50 and 1,200 gpm. During maximum water usage at BNL, up to 6 MGD are pumped from the Upper Glacial aquifer. Most of this water is returned to the aquifer by way of recharge basins or discharge of STP effluent to the Peconic River. Groundwater in the Upper Glacial aquifer beneath BNL generally exists under unconfined conditions. However, in the areas along the Peconic River where low permeability near surface silt and clay deposits exist, semi-confined conditions may occur. Depth to groundwater varies from several feet below land surface within the lowlands near the Peconic River, to as much as 75 feet in the higher elevation areas located in the central and western portions of the site.

A main east-west trending regional groundwater divide is located approximately 0.5 miles north of BNL (Figure 5). A second groundwater divide, which transects portions of the BNL site during periods of high water table position (i.e., during periods of inflow from the aquifer to the stream bed), defines the southern boundary of the area contributing groundwater to the Peconic River watershed (Scorca *et al*., 1996, Scorca *et al*., 1997). Shallow groundwater flow directions across the BNL site are influenced by natural drainage systems, varying between being eastward along the Peconic River, southeastward toward the Forge River, and southward toward the Carmans River (Figures 6 and 7). Additionally, pumping and recharge induced stresses on the aquifer system are considerable in the central area of the site. Due to variable supply well pumping schedules and rates, considerable variations in groundwater flow directions and velocities occur (compare Figures 6 and 7). Groundwater flow directions in the southwest corner of the site are also influenced by pumpage at the Suffolk County Water Authority well field located on the west side of the William Floyd Parkway.

Aquifer pumping tests conducted at BNL indicate that the horizontal hydraulic conductivity of the Upper Glacial aquifer is approximately 1,300 gpd/ft^2 (or 175 ft/d based upon an aquifer thickness of 145 feet) and a specific yield (effective porosity) of 0.24 (Warren *et al*., 1968; H2M/Roux Associates, 1985; CDM, 1995; P.W. Grosser, P.C., 1997). Total porosity value for the Upper Glacial is estimated to be 0.33 (Warren *et al*., 1968). Data from aquifer pumping tests and infiltration tests conducted at BNL by the USGS indicate that the vertical to horizontal anisotropy within the Upper Glacial aquifer is between 1:4 to 1:18 (Warren *et al*., 1968). The average vertical to horizontal anisotropy within the Upper Glacial aquifer on Long Island has been estimated to be 1:10 (Smolensky *et al*., 1989). The hydraulic properties of the basal Unidentified Unit cannot be determined with any degree of certainty using the current well network. Since the Unidentified Unit contains significant clay and silt, it is expected that these deposits are less permeable than the overlying glacial outwash and morainal sand and gravel.

The horizontal hydraulic gradient at BNL is typically 0.001 feet per foot (ft/ft). However, in recharge and pumping areas, the hydraulic gradient can steepen to 0.0024 ft/ft or greater. In most areas of the site, the natural groundwater flow velocity is estimated to be approximately 0.75 feet per day (ft/d). However, flow velocities in recharge areas may be as high as 1.45 ft/d, while velocities up to 28 ft/d have been calculated for areas near BNL potable and process supply wells (Woodward-Clyde Consultants, 1993). Water-level measurements taken from paired water table and deep Upper Glacial wells located along the northern site boundary (near the regional groundwater divide) indicate significant deep-flow recharge conditions, with downward vertical hydraulic gradients of up to 0.006 ft/ft. Head differences become negligible in paired wells located in the central and southern areas of the site, indicating that groundwater flow within the Upper Glacial aquifer is predominantly horizontal in these areas. The BNL site is, however, located within a SCDHS designated deep-flow recharge area (Hydrogeologic Zone III) for the Magothy and Lloyd aquifers (Koppleman, 1978; SCDHS, 1987). Comparison of water level measurements from Glacial aquifer and Magothy aquifer wells indicate significant downward flow across the BNL site.

3.3 Groundwater Quality and Classification

In Nassau and Suffolk Counties of Long Island, New York, 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 Long Island aquifer system has been designated by the U.S. EPA as a Sole Source Aquifer System, pursuant to Section 1424(e) of the Safe Drinking Water Act. Groundwater in the sole source aquifers underlying the BNL site is classified as "Class GA Fresh Groundwater" by the State of New York (6NYCRR Parts 700-705). The best usage of Class GA groundwater is as a source of potable water supply. As such, federal drinking water standards, NYS Drinking Water Standards (NYS DWS), and NYS Ambient Water Quality Standards (NYS AWQS) for Class GA groundwater are used as groundwater protection and remediation goals.

For drinking water supplies, the federal maximum contaminant levels (MCLs) set forth in 40 CFR 141 (primary MCLs) and 40 CFR 143 (secondary MCLs) apply. The Laboratory maintains six wells and two water-storage tanks for supplying potable water to Laboratory community. In NYS, the SDWA requirements pertaining to the distribution and monitoring of public water supplies are promulgated under Part 5 of the NYS Sanitary Code, which is enforced by the SCDHS as an agent for the NYS Department of Health. These regulations are applicable to any water supply which has at least five service connections or regularly serves at least 25 individuals. The Laboratory supplies water to a population of approximately 3,500 employees and visitors and must, therefore, comply with these regulations. In addition, DOE Order 5400.5, Radiation Protection of the Public and Environment, establishes Derived Concentration Guides (DCGs) for radionuclides not covered by existing federal or state regulations.

The BNL groundwater surveillance program uses wells (which are not utilized for drinking water supply) that are designed to monitor research and support facilities where there is a potential for environmental impact, or in areas where past waste handling practices or accidental spills have already degraded groundwater quality. BNL evaluates the potential impact of radiological and non-radiological levels of contamination by comparing analytical results to NYS and DOE reference levels. Non-radiological data from groundwater samples collected from surveillance wells are usually compared to NYS Ambient Water Quality Standards (6 NYCRR 703.5). Radiological data are compared to the NYS DWS (for tritium, strontium-90 and gross beta), NYS AWQS (for gross alpha and radium-226/228) and 40 CFR 141/DOE DCGs (for determining the 4 mrem/yr dose for other beta/gamma-emitting radionuclides).

4.0 Facility and Historical Groundwater Data Review

One of the early lessons-learned from the High Flux Beam Reactor (HFBR) tritium release was the need to perform a comprehensive review of all site facilities to identify any past or current activities that have the potential to degrade the environment. Concurrently, historical groundwater data were also reviewed to identify potential contaminant source areas that may have been overlooked or given a low priority due to apparently low levels of contamination.

4.1 Facility Review

In the early 1990's, an extensive Historical Site Review was conducted as part of the ER Program (ITC, 1993). The review was conducted to identify potential areas of interest (AOIs) where environmental impacts may have occurred. The Historical Site Review consisted of interviews with nearly 100 active and retired BNL employees, and the review of approximately 2,400 files, drawings and areal photographs available through BNL, the USDOE, the US Army Corps of Engineers, the NYSDEC, and the SCDHS. The types of concerns targeted during this review included identification of historical discharge areas, cesspools, drywells, septic tanks, floor drains, leach fields, disposal areas, transformer areas, areas where handling or storage of hazardous materials took place, and underground storage tanks. As a result of this review, 21 significant AOIs were identified, and were later evaluated under the ER Division's Preliminary Assessment/Site Investigation (PA/SI) Program (ITC, 1993). However, following the discovery of the HFBR tritium plume, it was clear that a more comprehensive, facility-by-facility evaluation was required to identify all potential environmental vulnerabilities resulting from past and current BNL operations.

In April 1997, BNL began a comprehensive examination of all site facilities to identify any past or current activities that have the potential to degrade the environment. The operational history of each building, including demolished structures, were reviewed to identify potential environmental vulnerabilities. All buildings were characterized as either a Priority One Facility or a Priority Two Facility. This grouping was based primarily upon on the operation and age of each facility. Because of concerns regarding the historical use and control of radioactive material, facilities which used or generated significant quantities of radioactive material during the 1950s and 1960s were selected for Priority One evaluation. This early time period of BNL operations was selected because most of the more stringent environmental regulations and standards were not developed until the 1970s. All other Laboratory buildings were considered Priority Two facilities.

The Laboratory summarized all significant Facility Review findings in two reports. The Interim Report on Priority One Facilities was released on September 9, 1997, and identified 21 significant findings (BNL, 1997a). The Interim Report on Priority Two Facilities was released on December 3, 1997, and identified 14 significant findings (BNL, 1997b). Follow up groundwater investigations have been conducted at 17 facilities (see Section 4.3 below). The final report is scheduled to be published in early September 1998.

4.2 Groundwater Review

The Groundwater Review focused on active research and support facilities that have the potential for impacting groundwater quality. Known or suspected contaminant source areas that have been or are currently being studied, closed or remediated under the IAG were not be part of this review. These areas include the (old) Hazardous Waste Management Facility, the Current Landfill, the Former Landfill, the Biology Department's gamma agricultural fields, and the Upland Recharge/Meadow Marsh experimental areas. The Sewage Treatment Plant area, which was extensively studied as part of the Operable Unit V RI, was evaluated for vulnerabilities of current operations, and possible need for groundwater monitoring improvements.

Phase I - The first phase of the Groundwater Review consisted of the evaluation of all pertinent groundwater data which have been acquired as part of the BNL EM and ER programs. The Groundwater Review was conducted concurrently with the Facility Review Project, and consisted of facility-specific reviews including the following elements:

1. Identification of all present and former groundwater monitoring wells located directly upgradient of the facility, wells located within the facility boundaries, and wells located downgradient of the facility.

2. Evaluation of groundwater flow patterns near and downgradient of each facility. This effort included the review of available water table maps from 1990 through 1997.

3. Review of all available historical groundwater chemistry data collected as part of the EM and ER programs. For each monitoring well and supply well, the ES&H Services Division's EM database (1985 through 1996) and the ER Divisions restoration program database (1991 through 1996) were queried for all detectable levels of radiologic and chemical contamination. The review also consisted of the examination of hard copy reports, the data from which may not presently be incorporated into the electronic databases (i.e., monitoring data collected prior to 1985 and more recent RI reports).

Phase II - The second phase of the Groundwater Review consisted of the integration of historical groundwater data with the evaluation of potential source areas identified by the Facility Review Project. The integration of the Groundwater and Facility reviews consisted of the following elements:

1. Provided Facility Review teams with information on historical groundwater quality near specific facilities in an effort to help identify potential environmental release points or processes.

2. Review of Facility reports to identify areas within the facilities that have the potential to impact groundwater quality.

3. To identify potential groundwater vulnerabilities, and recommend necessary follow-up groundwater investigations and/or long-term improvements to groundwater monitoring programs at key facilities.

4.3 Follow-up Groundwater Investigations

As a follow-up to the Facility Review Project, BNL has been actively evaluating whether potential contaminant release sites identified during the Facility Review Project have impacted groundwater quality (BNL, 1997a; 1997b; 1997c; Paquette, 1997; Grosser, 1998). Ten Priority I and seven Priority II facilities were evaluated by the ER Division as part of the FY 1998 PA/SI activities (Table 2). Groundwater quality near the former Brookhaven Graphite Research Reactor (BGRR), Pile Fan Sump, and the Building 830 area were evaluated as supplemental investigations for the OU III RI (see Section 5.5). Additionally, groundwater quality near the Brookhaven Medical Research Reactor (BMRR) was evaluated during the summer of 1997 as part of the Facility Review process (see Section 5.3). Over 350 groundwater and 35 soil samples were collected during these investigations. Of the facilities investigated, strontium-90 was detected above drinking water standards in wells installed in the BGRR and Pile Fan Sump areas, and the volatile organic compound (VOC) 1,1,1-trichloroethane (TCA) detected at concentrations above drinking water standards in wells located downgradient of the AGS complex, and in the Building 206 (Supply and Material) area. The need for additional characterization and potential remedial actions in these areas will be evaluated as part of the OU III RI/FS.

In addition to active field investigations, the capture zones (or zone of contribution) for each potable and process supply well are currently being evaluated using the Regional Groundwater Model developed as part of the ER Program. As part of a future well head protection program, facilities that fall within the capture zone/zone of influence shall be identified and cross matched with the facilities that may potentially impact groundwater quality.

5.0 Proposed Groundwater Monitoring Improvements

The requirements for groundwater monitoring at active Priority I and Priority II facilities that have the potential to impact groundwater quality have been evaluated. The following sections provide a summary review of: the operational history of each facility; the identification of potential contaminant source areas (i.e., underground storage tanks, beam stop areas, etc.); review of the historical and current groundwater monitoring program and available groundwater data; recommendations for any necessary groundwater monitoring upgrades or improvements at each facility; and, a prioritized schedule for the installation of new wells.

5.1 Alternating Gradient Synchrotron (AGS) Complex

The AGS complex is located near the northern portion of the developed area of the BNL site (Figures 8 and 9). The AGS began operations in the early 1960's. High energy physics investigations of target collision products produced at the AGS complex have sought to improve scientific understanding of the basic structure and interactions of subatomic particles. The AGS accelerator and experimental system are made up of four basic units: the particle injection source; the booster accelerating ring; the main accelerating ring; and experimental target areas. All AGS tunnel structures are of square concrete construction. For radiation shielding, the tunnel areas are first covered with a ten foot layer of native silica-rich sand and gravel, followed by a one foot layer of compressible styrofoam, a five foot layer of a special concrete/soil mixture (soil-crete), then finally a six to 15 foot layer of compacted sand and gravel. This shielding combination is expected to significantly reduce the ability of surface water (precipitation) to infiltrate through the soils immediately surrounding the AGS tunnel.

The main AGS Ring is used to accelerate heavy ions or protons and has a circumference of approximately 2,625 feet (800 meters). Adjacent to the northwest side of the AGS Ring is the Booster Ring with a circumference of approximately 660 feet (200 meters). The Booster is a smaller rapid cycling synchrotron that accelerates heavy ions or protons and serves as an injector into the AGS. Also located to the northwest of the AGS Ring is the Linear Accelerator (LINAC) and the Brookhaven LINAC Isotopes Producer (BLIP). The LINAC is approximately 450 feet (140 meters) long and serves as a proton injector into the AGS Ring and into the BLIP. The particles that are accelerated in the AGS complex are extracted into and stopped in a number of experimental detectors, beam targets and beam dump areas.

Secondary particles are created near beam loss points, beam targets and dumps, and have the potential to escape into the soils surrounding the accelerator tunnels or into the soils underlying target and beam dump areas in the experimental hall areas (such as Building 912). Beam dumps are the sinks used to absorb the energy and associated radiation from beams which have completed their utility. The dumps are typically made up of ilmenite loaded concrete or iron. The length and dimensions of the beam dumps are designed to assure that the radiation generated is attenuated to the greatest extent practicable. Although considerable effort is taken to design appropriate shielding and other engineering controls into these systems, many secondary particles will still interact with soils surrounding the tunnels and underlying floors. In the soils, these secondary particles interact with the Si and O atoms which make up most of the quartz-rich sands and gravels that are native to the BNL site. The types of radionuclides created include tritium, beryllium-7, carbon-11, nitrogen-13, oxygen-15, and sodium-22 (Beavis et al., 1993). Estimates on the concentration of radionuclides produced in soils were made by using the computer code CASIM. Once present in the soils, these radionuclides can be leached downward into groundwater by means of rainwater percolation. These leaching processes are usually quite slow and, therefore, only radionuclides with long half-lives such as tritium ($t_{1/2}$ = 12.3 years) and sodium-22 ($t_{1/2}$ = 2.6 years) are likely to be detected in the groundwater below the AGS. The production of these radionuclides has been measured in experiments using soils native to BNL that were exposed to the AGS beam line (Gollon et al., 1989). Leaching tests on these soils showed the tritium to be 100% leachable whereas sodium-22 is 7.5% leachable.

The AGS Safety Analysis Report (Beavis *et al*., 1993) determined the acceptable levels of radionuclide production in soil by comparing predicted concentrations at a potential source to five times the DOE Order 5400.5 Derived Concentration Guides (DCGs). (The DCG for a radionuclide is the concentration in water, which if ingested at a rate of two liters per day for one year, would result in a committed effective dose equivalent to 100 mrem per year. Drinking water standards are based upon a dose of 4 mrem per year.) DOE Order 5400.5 requires that liquid effluents from DOE activities shall not cause private or public drinking water systems located downstream of facility discharges to exceed the drinking water radiological limits promulgated in 40 CFR Part 141, National Primary Drinking Water Standards. The Order indicates that the 5 DCG value is to be used to evaluate the need to apply Best Available Technology (BAT) to a liquid effluent. This assessment method was used by the AGS Department since existing Orders (e.g., DOE Order 5400.5) are designed to address the more common problem of controlling radioactive liquid effluent releases to surface waters (e.g., BNL sanitary discharge), and do not account for the direct activation of soils.

As part of its environmental impact assessment, the AGS Department used compliance with drinking water standards at the site boundary as the design goal for limiting soil activation (AGS, 1993). By using this method, the only requirement that needs to be satisfied in order to demonstrate environmental compliance is to guarantee that any radionuclides which are produced in soils are reduced to concentration levels which would meet the 4 mrem/yr criteria at the point of ingestion (both on and off-site). Using the best available groundwater flow information at that time, the AGS assessment determined that a potential contaminant plume originating from the AGS area would not be intercepted by current BNL potable water supply wells. This determination resulted in an AGS design goal which allowed for the production of radionuclide concentrations up to 5 DCGs at the source. Based upon the calculations presented in the AGS SAR, the predicted radionuclide concentrations in groundwater would be either below drinking water standards or non-detectable following dilution and decay in transit to the BNL site boundary. (Please note that it is now known that the capture zone for potable supply well 10 extends into the AGS area, and the well could intercept a potential contaminant plume originating from the former U-Line Target area and portions of the Building 912 area.)

Although intended for application to liquid effluents, environmental ALARA considerations should include the assessment of: 1) alternative operating methods and engineering techniques; 2) radiological doses under each alternative; the cost of implementing each alternative; and 4) societal and environmental impacts. To address local stakeholders' desire that the greatest possible effort be made to eliminate intentional releases of radionuclides to the environment, the Laboratory has been taking steps to either reduce the amount of radioactivity produced in soils (by means of additional shielding or modifying operating procedures) or to prevent the leaching of these materials to groundwater. In areas such as the AGS Booster, the Laboratory has installed a plastic liner over the Booster's beam dump as a means of preventing rainwater from leaching through the soils directly outside of the tunnel. In the early 1990s, the AGS ring was also covered by a dense soil-crete mixture for shielding purposes. It is likely that the soil-crete acts as a partial barrier to rainwater infiltration. In similar efforts to prevent rainwater infiltration, in June 1998 cement caps were placed over the beam dump at AGS's g-2 experimental area and at the Brookhaven Linear Isotope Producer (BLIP) facility. Furthermore, the soils underlying other target/beam loss areas such as the main experimental hall in Building 912 are (at least partially) protected from rainwater infiltration by means of the building structures. Whereas most of this radioactivity will decay in place, remediation of any residual activated soils would have to be addressed as a part of any future decommissioning and decontamination (D&D) program for these facilities.

Another potential source of groundwater contamination is the inadvertent release of activated water from the AGS's primary cooling water systems. Several dedicated primary cooling water systems are distributed throughout the AGS facility supplying water to the magnets and radio frequency caves. Because of secondary radiation generated near the beam lines, radionuclides (primarily tritium) are produced in the cooling water. The largest system is the AGS's main magnet cooling water system, which holds approximately 8,000 gallons of water that has a tritium concentration of nearly 280,000 pCi/l. Historically, accidental spills of activated water were routed into floor drains which were originally connected to the storm drain system (BNL 1997a). Water entering the AGS area storm drain systems is presently discharged to either Basin HN located approximately 1,200 feet north of the AGS complex, or to Basin HT located directly north of the LINAC. In the 1960's and 1970's, however, storm water was routed to two former recharge basins located just to the north of the AGS complex. One basin was located directly north of Building 912, and the second was located in the present location of Building 1006 (BNL 1997a; BNL 1997b; Grosser, 1998). Groundwater quality downgradient of these former recharge basin areas was evaluated as part of the 1997 Facility Review Project (Grosser 1998). The most recent example of a release to the storm water system was the release of 100 gallons of primary cooling water from a heat exchanger located at one of the AGS evaporative coolers. Due to considerable dilution, however, the tritium concentration measured at the Basin HN discharge point was less than 350 pCi/l.

In the early 1990's, BNL initiated a program to connect all floor drains within the AGS Complex to the BNL sanitary system. As discussed in Section 5.6, the BNL sanitary system is routinely monitored for radionuclides, and emergency holding ponds are available if radionuclide or chemical concentrations exceed BNL's effluent release criteria. All floor drains within Building 912 have been connected to sanitary. A project to connect all remaining AGS floor drains is proceeding. Furthermore, BNL is currently working with the SCDHS to redesign the cooling water systems to bring them into compliance with Suffolk County Article 12.

5.1.1 *Building 912*

Building 912 consists of five interconnected structures forming approximately five indoor acres of AGS experimental floor (Figure 10). The equipment in the building include 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.

Potential Groundwater Vulnerability

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 (Beavis *et al*., 1993; BNL, 1993). If the activated soils below the B-Line target were subjected to regular rainwater infiltration, a conservative estimate of possible tritium and sodium-22 concentrations in soil pore water can be made by assuming that approximately half of the annual average precipitation (55 cm of the total of 122 cm annual average) leaches through the most activated soils. (The remainder of the precipitation is lost due to evaporation or evapotranspiration.) Under this scenario, the annual average tritium and sodium-22 concentrations in soil-pore water may be as high as 100,000 pCi/l and 10,000 pCi/l, respectively (Beavis *et al*., 1993; BNL, 1993). However, the volume of water having these high concentrations would likely be less than 300 gallons annually (Lessard, 1998b), and there would be significant dilution of this water within a short distance upon entering the aquifer system.

The present target design includes shielding which is likely to significantly reduce the production of additional soil activation. During the earlier years of AGS operation, less shielding was used directly below the target areas (i.e., essentially it consisted of the 1.5 foot thick floor slab). Although the water used to cool these target stations becomes highly activated, the water is contained within a closed loop water system. 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 thought that most of the potentially activated soils underlying the beam targets and dumps are protected from surface water infiltration. However, additional evaluation is needed to ensure that floor drains or other sub-floor water handling systems are not located near these activated areas, and that they are not leaking.

General Hydrogeology

The predominant groundwater flow direction in the Building 912 area is to the south-southeast (Figures, 6, 7, and 11). Groundwater flow directions in this area can be impacted by the operations of potable supply well 10 which is located approximately 800 feet to the east. During periods of continuous use, pumpage from supply well 10 can result in a more easterly groundwater flow direction. The depth to groundwater in the Building 912 area is approximately 30 feet below land surface. Available geologic logs from wells installed in the nearby WCF area suggest that the Building 912 area is underlain by predominantly fine to medium-grained sands and fine gravel.

Current Groundwater Monitoring Program

At the present time, there are no groundwater monitoring wells located directly downgradient of the Building 912 area. However, historical data from wells currently utilized to monitor the Waste Concentration Facility (WCF), which is located approximately 250 feet downgradient of Building 912, may provide insight on the impact of the activation of soils underlying Building 912. The groundwater surveillance well network at the WCF currently consists of six shallow Upper Glacial aquifer wells and two middle to deep glacial wells (Figure 11). Since 1993, both tritium and sodium-22 have been routinely detected in facility's upgradient well 65-06, and in downgradient wells 65-02, 65-03, 65-04 and 65-05. In well 65-06, the maximum observed concentration of tritium has been 5,080 pCi/l and 23 pCi/l for sodium-22. Similarly, both tritium and sodium-22 have been routinely detected in downgradient wells 65-02, 65-03, 65-04 and 65-05, with maximum observed concentrations of 5,990 pCi/l and 30 pCi/l, respectively. The WCF wells have well screens positioned ten to fifteen feet below the water table. Based upon the detection of tritium and sodium-22 in the upgradient well and the deep screen zone positions of these wells, the contamination is likely to be the result of soil activation due to beam target interaction at Building 912, or possibly contamination resulting from the former U-Line target area located to the northwest of Building 912. In addition to radionuclides, TCA is routinely detected in the WCF wells at concentration above the NYS AWQS of 5 µg/l. During 1996, TCA was detected in well 65-02 at a maximum concentration of 97 µg/l. As with the tritium and sodium-22 detected in these wells, the TCA is also likely to have originated from source areas within the AGS complex. Historically, TCA has also been detected in potable supply well 10 at concentrations exceeding the NYS Drinking Water Standard (which is also 5 µg/l). This supply well has been fitted with an granular activated carbon filter system. Radionuclides such as tritium and sodium-22 have not been detected in samples collected from supply well 10.

Proposed Groundwater Monitoring Upgrades

During FY 1998, a series of shallow Upper Glacial aquifer wells will be installed both upgradient and downgradient of Building 912 (Figure 11, Table 3). The shallow wells will be screened from five feet above to ten feet below the water table. This screen position is required because the wells will be installed very close to suspected tritium source areas, and will allow for the sampling of uppermost few feet of the aquifer following seasonal fluctuations in water table position. The recent detection of high levels of tritium within the uppermost three to four feet of the aquifer downgradient of the HFBR and BLIP facilities has underscored the need to perform routine monitoring of groundwater quality at the water table.

Four shallow wells (MW-AGS-10, -11, -12, and -13) will be installed directly upgradient of Building 912 to allow for the identification of contamination originating from potential upgradient sources, such as possible historical waste water discharges to a former recharge basin that was located to the north of the building (see BNL, 1997b), and possible soil activation at the former AGS U-Line target area located to the northwest of Building 912 (Figure 11). Nine shallow wells (MW-AGS-16 through 24) will be installed directly downgradient of Building 912. These wells will be focused on areas downgradient of significant beam target and dump areas located within Building 912 (Figures 10 and 11). Five deeper wells (MW-AGS-25, -26, -27, -28, and -29), with screen zones positioned between 15 to 25 feet below the water table, will be installed downgradient of Building 912 during FY 1999 (Figure 11, Table 4). If contamination is detected in the shallow wells, the deeper wells will be used to evaluate the vertical distribution of the contamination. The final position for some of these wells may be adjusted following the review of initial analytical results of the new shallow wells (i.e., used to better define the vertical extent of potential contamination). Furthermore, additional shallow water table wells may be installed in the Building 912 area to fill in any data gaps identified following the initial sampling and re-evaluation of groundwater flow directions using the new wells proposed above.

Once installed, the wells will be monitored four times per year by the ES&H Services Division as part of the EM Program for the AGS facility (Table 5). Samples will be collected quarterly for tritium and gamma analyses, and semiannually for gross alpha/beta, metals, and VOCs.

5.1.2 *AGS Booster*

The AGS Booster is a circular accelerator with a circumference of nearly 660 feet (200 meters), and is connected to the northwest portion of the main AGS ring and the LINAC (Figure 8). The 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 (Figure 12). The beam scraper consists of a one meter long cylinder surrounding the beam pipe. It has a radial thickness of 19 cm, and is shielded by an additional 20 cm of iron in order to reduce the activation of nearby soil outside the tunnel enclosure (Lessard, 1991). In FY 1999, BNL will construct a new Booster Applications Facility (BAF) which will be used by NASA and the DOE to conduct space radiation research (BNL, 1998). The BAF will consist of a new beam tunnel that will branch from the 11 o'clock position of the AGS Booster ring, a target room and beam stop, and a number of associated support buildings (BNL, 1997f).

Potential Groundwater Vulnerability

The AGS Booster beam scraper is an area where the interaction of secondary particles and soil surrounding the Booster tunnel may result in production of tritium and sodium-22 (Lessard, 1991). In addition to internal shielding, the Booster tunnel was first covered with sand derived from the BNL site, followed by a soil-crete mixture. Although the internal shielding around the beam scraper was designed to keep radiation levels in soils below DOE ALARA guidelines (discussed previously), a liner was constructed over the scraper region to provide an extra margin of protection. The cap, constructed of 15 mil plastic, was designed to extend 15 feet upstream and 45 feet downstream of the beam scraper and is covered a soil crete mixture (Figure 12). Although Rohrig (1990) initially raised concerns as to whether the cap was placed in the optimal position to effectively divert water from the most activated soils, the AGS Department re-confirmed that the cap was properly positioned (Lessard, 1991).

If the cap was not in place over the Booster beam scraper region and approximately one-half the annual total precipitation (55 cm) was able to percolate through the soils overlying the beam scraper region, the predicted annual average tritium and sodium-22 concentrations in soil pore water immediately below the Booster beam scraper would be 100,000 pCi/l and 50,000 pCi/l, respectively (Lessard, 1991). If the cap, in concert with the overlying soil-crete cover, is effective at preventing water from leaching through the activated soils, the radioactivity will be confined to the region outside the Booster tunnel, allowing for the radioactivity to decay in place. However, it is important to note that if water is able to infiltrate the activated soils as a result of a cap failure, the volume of water having high tritium and sodium-22 concentrations would likely be less than 400 gallons annually (Lessard, 1998b), and there would be significant dilution of this contaminated water upon entering the aquifer system.

Potential soil activation issues related to the proposed BAF are discussed by Paquette (1998). At the BAF, there is a potential to activate soils surrounding the beam stop and portions of the target room. Assuming that water was able to leach through the activated soils, the predicted annual average tritium and sodium-22 concentrations in soil pore water immediately below the BAF target and beam stop area would be 100 pCi/l and 307 pCi/l, respectively. However, a landfill-type geomembrane cover will be installed over the target room and adjacent beam stop to prevent the infiltration of water through these soils.

General Hydrogeology

The predominant groundwater flow direction in the AGS Booster area is to the south-southeast (Figures 6, 7 and 11). However, groundwater flow directions in this area can be influenced by the operations of AGS process supply wells 101, 102, and 103, which are located 1,200 to 2,000 feet to the west of the Booster. During periods of continuous use, pumpage totaling nearly 1,200 gpm of water results in a more southerly groundwater flow direction in the Booster area. The depth to groundwater in the Booster area is approximately 40 to 50 feet below land surface. Available geologic data collected during the installation of nearby wells, indicates that the Booster area is underlain by predominantly medium to coarse-grained sand and fine gravel.

Current Groundwater Monitoring Program

The AGS Booster area is currently monitored by one upgradient (54-08) and two downgradient (64-02 and 64-03) surveillance wells (Figure 11). The three wells were installed in August 1993, and are screened within the upper 20 feet of the Upper Glacial aquifer. Due to the complex network of underground utilities and structures in the Booster area, wells were not installed directly downgradient of the Booster beam scraper region. This resulted in well 64-02 being installed approximately 750 feet downgradient of the Booster facility, whereas well 64-03 was installed approximately 500 feet downgradient of the facility. Tritium and sodium-22 have been routinely detected in downgradient well 64-02 since its installation in August 1993 (prior to the start of beam operations at the Booster). The tritium concentrations have been well below the NYS DWS of 20,000 pCi/l, with concentrations generally <1,400 pCi/l. Likewise, sodium-22 concentrations have been <25 pCi/l, well below the 4% DCG guideline of 400 pCi/l. However, analytical results from samples collected in February 1998 indicated elevated tritium concentrations of 14,100 pCi/l and 44 pCi/l for sodium-22. Although, the solvent TCA has been routinely detected above the NYS AWQS of 5 µg/l in well 64-03, with a maximum observed concentration of 62 µg/l, only trace amounts of tritium (up to 452 pCi/l) and sodium-22 (up to 2.8 pCi/l) have been detected.

Because initial beam operations within the Booster did not occur until almost one-half year after the installation of well 64-02, the detection of tritium and sodium-22 in groundwater suggests that these contaminants originated from another nearby source. In an effort to determine the source of the tritium contamination, BNL recently conducted a groundwater investigation that focussed on the Brookhaven LINAC Isotope Producer (BLIP) located upgradient of well 6-02. Operations at the BLIP were predicted to result in the activation of soils outside of the BLIP's target vessel (Mausner, 1985; Alessi *et al*., 1998). During this investigation, tritium and sodium-22 were detected in the shallow groundwater (i.e., within five feet of the water table) directly downgradient of the BLIP facility. In temporary Geoprobe™ wells installed approximately 50 feet downgradient of the BLIP target vessel, tritium was detected at a maximum concentration of 52,000 pCi/l and sodium-22 was detected up to 151 pCi/l. Neither tritium or sodium-22 were detected in a Geoprobe™ well (temporary well 64-24) installed approximately 250 feet downgradient of the Booster beam scraper area.

Proposed Groundwater Monitoring Upgrades

The current groundwater monitoring network is inadequate to properly monitor Booster operations. Therefore, two new downgradient groundwater monitoring wells (MW-AGS-02 and -03) will be installed south of the Booster beam dump, and southeast of the BLIP facility (Figure 11, Table 3). BNL will try to install the wells during FY 1998. However, because the area is designated as a high radiation area during AGS operation, the wells may have to be installed in January 1999, when the AGS is scheduled for a brief shut-down. Given the complexities of underground utilities and tunnel structures, the closest available locations are approximately 250 feet downgradient of the beam dump. Well MW-AGS-02 will be installed at the same location as the recent Geoprobe™ well 64-24 (discussed above). Compared to existing downgradient well 64-02, the new downgradient wells will provide monitoring points that are closer to the beam dump and outside of the potential flow pathway for contaminants originating from the BLIP facility. The wells will be screened from five feet above to ten feet below the water table. Three to four additional wells will also be installed at the proposed BAF (see Paquette, 1998).

Once installed, the wells will be monitored four times per year by the ES&H Services Division as part of the EM Program for the AGS facility (Table 5). Samples will be collected quarterly for tritium and gamma analyses, and semiannually for gross alpha/beta, metals, and VOCs.

5.1.3 E-20 Catcher

The E-20 beam catcher is a beam dump located at the 5 o'clock position of the AGS ring (Figure 11). The E-20 catcher is a minimum aperture area of the AGS ring, and is used to pick up or "scrape" protons that wobble out of acceptable pathways. The E-20 catcher is subject to injection, transition, ejection and studies losses, and picks up about 80 to 90 percent of all of these losses (Lessard, 1998a).

Potential Groundwater Vulnerability

Like other beam loss areas within the AGS complex, the E-20 Catcher is an area where the soils surrounding the AGS tunnel may have become activated by the interaction with secondary particles. The ability of rainwater to infiltrate the activated soils surrounding the E-20 Catcher is likely to be significantly reduced since the AGS tunnel has been covered by layers of sand, styrofoam and soil-crete. A conservative estimate for potential tritium and sodium concentrations in soil pore water near the E-20 can be obtained by assuming that this covering material is not an effective barrier, and assume that approximately one-half the annual total precipitation (55 cm) was able to percolate through the potentially activated soils. The resulting annual average tritium and sodium-22 concentrations in soil pore water immediately below the E-20 region of the tunnel could reach 25,000 pCi/l, and 2,600 pCi/l, respectively (Beavis *et al*., 1993; BNL, 1993). However, the volume of water having these high concentrations would likely be less than 300 gallons annually (Lessard, 1998b), and there would be significant dilution of this water within a short distance upon entering the aquifer system.

General Hydrogeology

The predominant groundwater flow direction in the E-20 catcher area is to the south-southeast (Figures 6, 7 and 11). The depth to groundwater is approximately 30 feet below land surface, and the area is underlain by predominantly fine to coarse-grained sand and fine gravel.

Current Groundwater Monitoring Program

Although there are no permanent groundwater monitoring wells located directly downgradient of the E-20 catcher, four temporary Geoprobe™ wells were installed approximately 500 feet downgradient of the E-20 area as part of the December 1997 Facility Review & PA/SI work performed by the ER Division (Grosser, 1998). Data from one of these wells (913 GP-06) indicate low levels of both tritium (up to 559 pCi/l) and sodium-22 (up to 23.5 pCi/l). Both tritium and sodium-22 were non-detectable in samples from the other wells. TCA was also detected in well 913 GP-06 at a concentration of 14 µg/l, which exceeds the NYS AWQS of 5 µg/l.

Proposed Groundwater Monitoring Upgrades

During FY 1998, two downgradient wells (MW-AGS-14 and -15) will be installed to the south-southeast of the E-20 catcher area of AGS (Figure 11, Table 3). The wells will be screened from five feet above to ten feet below the water table. Once installed, the wells will be monitored four times per year by the ES&H Services Division as part of the EM Program for the AGS facility (Table 5). Samples will be collected quarterly for tritium and gamma analyses, and semiannually for gross alpha/beta, metals, and VOCs.

5.1.4 Building 914

Building 914 houses the transfer line between the main AGS Ring and the Booster (Figure 12).

Potential Groundwater Vulnerability

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. Formal assessments of the possible concentration of radionuclides in soils using the CASIM model have not been conducted to date. 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.

General Hydrogeology

The predominant groundwater flow direction in the Building 914 transfer line area is to the south-southeast (Figures 6, 7, and 11). Depth to groundwater is approximately 40 feet below land surface, and the area is underlain by predominantly fine to coarse-grained sands and fine gravel.

Current Groundwater Monitoring Program

Groundwater monitoring well 64-03 which was installed in 1993 in an effort to monitor the AGS Booster facility, is located approximately 200 feet downgradient of the Building 914 transfer line area. Monitoring data from well 64-03 indicates the presence of trace amounts of tritium (up to 452 pCi/l) and sodium-22 (up to 2.8 pCi/l). However, it cannot be conclusively proven at this time that the Building 914 Transfer line is the source of these radionuclides. 1,1,1-TCA has also been routinely detected in samples from well 64-03, and is likely to have originated from the historical discharge of solvents to several sanitary cesspools located in the northwest, in the Building 919 area. These areas were recently evaluated as part of the OU III RI.

Proposed Groundwater Monitoring Upgrades

During FY 1998, two downgradient wells (MW-AGS-04 and -05) will be installed to the southeast of the Building 914 transfer line area to ensure adequate monitoring coverage for this portion of the AGS facility (Figure 11, Table 3). The wells will be screened from five feet above to ten feet below the water table. Once installed, the wells will be monitored four times per year by the ES&H Services Division as part of the EM Program for the AGS facility (Table 5). Samples will be collected quarterly for tritium and gamma analyses, and semiannually for gross alpha/beta, metals, and VOCs.

5.1.5 g-2 Beam Target and Dump

The g-2 experiment runs off of the AGS V-Line, and includes a target building and beam dump located north of the 1 o'clock region of the AGS Ring (Figure 13). Although the g-2 beam dump is made of iron, which is expected to absorb most of the beam energy, some activation of the soil overlying the dump is expected to occur. The beam target building and beam dump were built upon a concrete pad which extends over several acres in the V-Line target area. During the summer of 1998, the g-2 experiment is expected to run for a period of one month.

Potential Groundwater Vulnerability

Activation products will be produced in the soils surrounding the g-2 beam dump and, potentially, some of the soils underlying the beam target and dump. It has been estimated that the first few centimeters of soil surrounding the beam dump will become activated with tritium and sodium-22 (Lowenstein, 1998). Although the beam dump was designed to keep soil activation levels below DOE ALARA guidelines, a concrete cap was constructed over the dump in June 1998 to provide an extra margin of protection against rainwater infiltration. The cap, constructed of gunnite cement coated with a reinforced emulsion waterproofing, was designed to extend over the entire beam dump. If the cap were not in place and precipitation was able to percolate through the activated soils surrounding the beam dump, then water containing both tritium and sodium-22 could drain to the underlying concrete pad, and ultimately drain to the storm water collection system. Based upon a one month run time for the g-2 experiment, and assuming that approximately one-half of the annual average precipitation (55 cm) was able to leach through the most activated soils located within the few centimeters of the beam stop, the predicted maximum tritium and sodium-22 concentrations in soil pore water could be as much as 6,000 pCi/l and 10,000 pCi/l, respectively (Lowenstien, 1998). However, the resulting volume of activated water would be approximately 1,000 gallons (Lessard, 1998b), and significant dilution would occur upon reaching the aquifer or storm water handling system.

General Hydrogeology

The predominant groundwater flow direction in the g-2 beam target and dump area is to the south-southeast (Figures 6, 7, and 11), although the flow may be slightly more easterly during periods of extended operation of potable supply well 10. The depth to groundwater in the g-2 area is approximately 25 feet below land surface, and the geology consists predominantly of fine to medium grained quartz sand and some gravel.

Current Groundwater Monitoring Program

Groundwater monitoring well 54-07 is located approximately 200 feet downgradient of the g-2 beam dump. The well is screened within the upper 10 to 15 feet of the Upper Glacial aquifer, and has been monitored routinely since 1992. When the well was sampled for the first time in September 1992, tritium and sodium-22 were detected at concentrations of 2,310 pCi/l and 150 pCi/l, respectively. Since that time, however, tritium and sodium-22 concentrations have been significantly lower, with observed low level tritium concentrations of less than 600 pCi/l and sodium-22 concentrations of less than 3 pCi/l. Based upon groundwater flow pathways, the tritium and sodium-22 are likely to have originated from the former U-Line target area, located approximately 600 feet to the north (upgradient) of the present g-2 area. Furthermore, TCA has been routinely detected in samples from well 54-07, with a maximum historical concentration of 471 µg/L, observed during CY 1997. The TCA is likely to have originated from the historical discharge of solvents to nearby cesspools or spills in the former Bubble Chamber area (OU III, AOC-14).

Proposed Groundwater Monitoring Upgrades

Due to the complex network of underground utilities and structures in the g-2 area, it will not be possible to install new wells directly downgradient of the target building or beam dump. Furthermore, it is anticipated that the g-2 cap will provide an effective barrier to rainwater infiltration and that any activated soil below the target and beam dump will be protected from water infiltration by the concrete slab that extends throughout the area. In order to verify, to the extent practicable, that these engineering controls are effective, BNL will continue to monitor existing well 54-07 and several of the proposed new upgradient wells for the Building 912 area. As noted earlier, two wells (MW-AGS-10 and -11) will be installed to the east of Building 912A to serve as upgradient monitoring points for the Building 912 experimental hall (Figure 11, Table 3). During periods of more easterly groundwater flow conditions (i.e., when supply well 10 is active for extended periods of time), these wells may be useful in assessing groundwater quality downgradient of the g-2 target and beam dump area. The wells will be screened from five feet above to ten feet below the water table. In order to detect possible tritium and sodium-22 contamination originating from upgradient sources (such as the former U-Line target area), two additional wells (MW-AGS-08 and -09) will be installed immediately upgradient of the g-2 area (Figure 11, Table 3).

Once installed, the wells will be monitored four times per year by the ES&H Services Division as part of the EM Program for the AGS facility (Table 5). Samples will be collected quarterly for tritium and gamma analyses, and semiannually for gross alpha/beta, metals, and VOCs.

In the unlikely event that the cap were to fail and precipitation was able to percolate through the activated soils surrounding the beam dump, water containing both tritium and sodium-22 could potentially drain to the underlying concrete pad, and ultimately drain to the storm water collection system. As the result of dilution, it is likely that tritium and sodium-22 levels in this storm water will be significantly less than the predicted values noted above. All storm water runoff from the paved areas surrounding the g-2 area is directed to either the HN and HT Recharge Basins (SPDES permitted Outfalls 002 and 006). As a supplement to the SPDES required monitoring program which consists of monthly testing for pH, oil and grease, metals, and VOCs, surface water samples are also analyzed for radiological parameters such as tritium and gamma spectroscopy (see Schroeder *et al*., 1998).

5.1.6 Proposed J-10 Beam Dump

The AGS Department is planning on establishing a new beam dump at the J-10 (12 o'clock) region of the AGS during CY 1998 (Figure 11). The J-10 beam dump will serve as the preferred repository for any beam that might be lost in the AGS ring.

Potential Groundwater Vulnerability

Activation products are likely to be produced in the soils surrounding the tunnel adjacent to J-10 beam dump. The J-10 beam dump will be subject to the same injection, transition, ejection and studies losses presently occurring at the 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, the AGS Department constructed a gunnite cap over exposed soil areas overlying the J-10 region (E.T. Lessard, personal communication). A conservative estimate of radionuclide leaching would be to assume that this covering material is not an effective barrier, and that approximately one-half the annual total precipitation (55 cm) is able to percolate through the soils overlying E-20 area. The resulting annual average tritium and sodium-22 concentrations in soil pore water immediately below the J-10 region of the tunnel could reach 25,000 pCi/l, and 2,600 pCi/l, respectively (see Beavis *et al*., 1993). However, the volume of water having these high concentrations would likely be less than 300 gallons annually (Lessard, 1998b), and there would be significant dilution of this water within a short distance upon entering the aquifer system.

General Hydrogeology

The predominant groundwater flow direction in the proposed J-10 beam dump area is to the south-southeast (Figures 6, 7, and 11), although the flow may be slightly more easterly during extended periods of operation of Potable Supply Well 10. Although detailed borings have not been conducted in the J-10 area, this portion of the AGS facility is likely to be underlain by predominantly fine to coarse-grained quartz sand and fine gravel.

Current Groundwater Monitoring Program

Presently, there are no groundwater monitoring wells located directly upgradient or downgradient of the proposed J-10 beam dump.

Proposed Groundwater Monitoring Upgrades

During FY 1998, one upgradient (MW-AGS-01) to the north of the proposed J-10 beam dump area, and two downgradient wells (MW-AGS-06 and 07) will be installed to the south-southeast of the dump (Figure 11, Table 3). The wells will be screened from five feet above to ten feet below the water table. Once installed, the wells will be monitored four times per year by the ES&H Services Division as part of the EM Program for the AGS facility (Table 5). Samples will be collected quarterly for tritium and gamma analyses, and semiannually for gross alpha/beta, metals, and VOCs.

5.1.7 Brookhaven LINAC Isotope Producer (BLIP)

The Brookhaven LINAC Isotope Producer facility is located at the southern end of the AGS's Linear Accelerator (LINAC) (Figures 11 and 14). The facility has been operated by the Medical Department since its construction in 1972. When the BLIP is operating, the LINAC delivers a 200 MeV beam of protons which impinge on a series of eight targets located within the BLIP target vessel. The radionuclides produced during this interaction, are later processed for pharmaceutical applications.

Potential Groundwater Vulnerability

The BLIP targets are located at the bottom of a 30 foot underground tank (Figure 15). Within this tank, the targets rest inside a water-filled 18-inch diameter shaft which runs the length of the tank. The targets 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 is expected to occur due to the creation of secondary particles produced at the target (Susskind *et al*., 1972; Mausner, 1985; BNL, 1996a; Alessi *et al*., 1998). Prior to 1985, the BLIP target was equipped with a secondary water system that acted as a beam stop which absorbed most of these high energy secondary particles. In 1985, this secondary water system was drained due to concerns of potential leakage of water into the LINAC tunnel in case of a beam window failure. As a result of removing the water, most of the secondary particles produced in the target area now pass through the air gap between the primary system and the outer wall of the vessel, and are stopped in the soils surrounding the BLIP vessel. As part of the 1985 redesign, leak detection devices were installed, and this open space is now used as secondary containment system for the primary vessel.

The direct activation of soil surrounding the target area has been evaluated by Suskind *et al*. (1972), Mausner (1985), and Alessi *et al*. (1998). According to these evaluations, significantly activated soils will be produced within a four to five foot radius of the vessel, with most activation occurring in the forward direction of the beam (i.e., south side of the vessel). Calculated activation products after twelve years of irradiation suggest that the present inventory of radionuclides in soils surrounding the BLIP vessel may contain as much as 4.5 Ci of tritium and 12 Ci of sodium-22 (Alessi *et al*., 1998). The most highly activated soils located near the target area are situated approximately 30 feet above the water table. Although the BLIP building (931) is likely to prevent most precipitation from infiltrating these activated soils, the recent detection of tritium and sodium-22 in groundwater collected downgradient of BLIP indicates that the current storm water management system is not effective (see below). Recent initiatives to improve surface water management at BLIP have included the connection of the building's downspouts to the storm water sewer and the installation of a gunnite surface cap around the building. In an effort to minimize the amount of activity produced in the soils surrounding the BLIP vessel (in a manner that is consistent with environmental ALARA principles), the Laboratory is considering limiting the amount of time and energy of the beam entering the BLIP facility.

In addition to activated soils near the BLIP target, records also indicate that from February through May 1988 approximately 100 to 150 gallons of water leaked from the BLIP's primary cooling water circulation pump which is located within a sealed concrete sump (Miltenberger and Naidu, 1989). The leak occurred as the result of a pump seal failure, and was observed at the time of discovery to be leaking as a fine mist (L. Mausner, personal communication). Once the leak was detected, the sump was inspected and found to have a series of cracks which would have allowed some of the lost water to drain to the soil below the pit. Because the leak was in the form of a fine mist and the sump cover did not form a tight seal to the floor, some amount of this water may have escaped into the atmosphere of the building in the form of water vapor. Miltenberger and Naidu (1989) estimated that as much as 0.69 Ci of beryllium-7 was released. Furthermore, analytical records indicate that the primary water had a tritium concentration of nearly 74 million pCi/l. The total tritium loss would be in the range of 0.03 to 0.04 Ci. Sodium-22 was not detected in the primary cooling water. Because beryllium-7 has a half-life of only 60 days, measurable quantities of this material is not expected to be present in soils below the sump, and has not been detected in groundwater samples.

Since 1988, no unaccounted for water losses from the primary cooling system have been observed. The circulator pump has been replaced and the sump has been sealed to prevent leakage in case of a future spill or leak. BNL is currently working with the SCDHS to determine whether the BLIP target vessel system meets Suffolk County Article 12 requirements. 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 meets all Article 12 requirements, and is registered with the SCDHS. 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 ER Program.

General Hydrogeology

The predominant direction of groundwater flow in the BLIP facility area is to the south-southeast (Figures 6, 7, and 11). During periods of extended use of the AGS supply wells located over one thousand feet to the west of the BLIP, groundwater flow can be more southerly. The depth to groundwater in the BLIP area varies between 20 and 55 feet below land surface. Data from available geologic logs indicate that the facility is underlain by predominantly fine to coarse grained quartz sand. The BLIP building was constructed upon an artificial mound, formed by the covering of the target vessel and associated beam transfer tunnel from the LINAC.

Current Groundwater Monitoring Program

As discussed previously, the BLIP facility is currently monitored by downgradient surveillance well 64-02 (Figure 11). This shallow upper Glacial aquifer well was installed in 1993. It was intended to monitor the AGS Booster facility which is located to the northeast of BLIP. The well is screened within the upper 20 feet of the Upper Glacial aquifer, and is located approximately 450 feet downgradient of the BLIP. Tritium and sodium-22 have been routinely detected in well 64-02 since its installation, with concentrations in the range of <1,400 pCi/l and <25 pCi/l, respectively. However, samples collected in February 1998 indicated elevated tritium concentrations of 14,100 pCi/l and 44 pCi/l for sodium-22. The presence of both tritium and sodium-22 in groundwater samples from well 64-02 suggests that these contaminants are the result accelerator produced activation of soils. In the area upgradient of well 64-02, only two facilities are likely source areas for both tritium and sodium-22, the BLIP and the AGS Booster.

Although secondary particles created at the Booster beam scraper are expected to produce tritium and sodium-22 in the surrounding soils, beam operations at the Booster did not begin until 1994, almost one-half year after the installation of well 64-02. A more likely source for the contamination is the BLIP, which is also located upgradient of this well. The identification of BLIP as the source for this contamination is further supported by the detection of tritium and sodium-22 in a Geoprobe™ well 64-41 recently installed approximately 50 feet downgradient of the BLIP target vessel. Groundwater samples collected within four feet of the water table in Geoprobe™ well 64-41 had tritium and sodium-22 concentrations of 52,000 pCi/l and 151 pCi/l, respectively. Elevated levels of tritium (11,400 pCi/l) and sodium-22 (at 38 pCi/l) were also detected in shallow groundwater samples collected within 5 feet of the water table from Geoprobe™ well 64-20, recently installed 150 feet downgradient of the BLIP (Figure 16). Additional Geoprobe™ wells were installed directly upgradient and downgradient (within 50 feet) of the BLIP building in early June 1998. These results have confirmed that BLIP was the source for the radionuclides detected in well 64-02

Proposed Groundwater Monitoring Upgrades

During FY 1998, two upgradient wells (MW-BLIP-01 and 02) and four downgradient wells (MW-BLIP-03, -04, -05 and -06) will be installed to monitor the BLIP facility (Figure 11, Table 3). The wells will be screened from five feet above to ten feet below the water table. Once installed, the wells will be monitored four times per year by the ES&H Services Division as part of the EM Program for the AGS facility (Table 5). Samples will be collected quarterly for tritium and gamma analyses, and semiannually for gross alpha/beta and VOCs.

5.1.8 Former U-Line Target Area

The U-Line target area was used by the AGS Department from 1974 through 1986 (Figure 13). 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 (Gollon *et al.*, 1989). Secondary particles desired for research would be focused by the horns, and other particles would either strike the collimators or be defocussed 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 (Figure 17). Although the U-Line target has not been in operation since 1986, the associated tunnel, shielding and overlying soils remain in place.

Potential Groundwater Vulnerability

The former U-Line target and horns are areas where the interaction of secondary particles with soil surrounding the tunnel resulted in production of tritium and sodium-22 (Gollon *et al.*, 1989). Gollon *et al.* (1989) predicted that during the first ten years of operations (1974 - 1983), approximately 2.9 Ci of sodium-22 and 1.2 Ci of tritium would have been produced in the soils surrounding the target station and horns. Gollon *et al*. (1989) detected both tritium (up to 0.14 nCi/g) and sodium-22 (up to 0.28 nCi/g) in soils samples obtained beneath the original target location. (Please note that the authors believed the measured tritium concentration to be below its probable *in situ* (or true) value due to the loss of tritium in the soil sample by evaporation prior to sample processing and analysis.) Because the tunnel was not covered by an impermeable cap, the activated soils above and on the sides of the tunnel structure would have been exposed to rainwater.

The target station and horn assembly was modified in 1984, and operations continued until 1986. The re-designed target station of 1984 was built just to the south of the original station (Figure 13). The new target station (referred to as the "Blockhouse") had additional internal shielding consisting of stacked concrete and steel above and to the sides of the target area, and a thicker steel and concrete floor (Gollon *et al*., 1989). Gollon et al. (1989) predicted that most of the soil activation would occur below the floor where the shielding was thinnest. Lessard (1998c) estimated that an additional 0.36 Ci of tritium would have been produced during the 1984 through 1986 operations period.

Because this facility has not been used since 1986, the tritium and sodium-22 that either remains as residual soil contamination or that was leached to groundwater would have decayed by one and five half-lives, respectively.

General Hydrogeology

The predominant groundwater flow direction in the former U-Line target area is to the south-southeast (Figures 6, 7, and 11), although the flow may be slightly more easterly during periods of extended operation of potable supply well 10 (see Figure 11). The depth to groundwater in the U-Line target area is approximately 25 feet below land surface, and the geology consists predominantly of fine to medium-grained quartz sand and some gravel.

Current Groundwater Monitoring Program

Existing groundwater monitoring well 54-01 was installed in the mid-1980s to evaluate the potential impact of soil activation at the U-Line target area (Gollon *et al*., 1989). However, groundwater samples collected soon after the well was installed were non-detectable for both tritium and sodium-22 (Gollon *et al*., 1989). Although the well has been frequently sampled since 1992, only trace amounts of sodium-22 (up to 3 pCi/l) have been detected. A review of available well construction data indicates that the well may be screened five to ten feet below the water table, which is too deep to effectively monitor a nearby source such as the U-Line target area. The solvent TCA has been routinely detected in well 54-01 with a maximum concentration of 50 µg/l observed during CY 1992. The TCA is likely to have originated from the historical discharge of solvents to nearby cesspools or spills in the former Bubble Chamber area located to the north-northwest of the former U-Line target area (OU III, AOC-14). A second monitoring well, well 54-07, is located approximately 200 feet downgradient of the g-2 beam dump and 600 feet south of the former U-Line target area. The well is screened within the upper 10 to 15 feet of the Upper Glacial aquifer, and has been monitored routinely since 1992. When the well was sampled for the first time in September 1992, tritium and sodium-22 were detected at concentrations of 2,310 pCi/l and 150 pCi/l, respectively. Since that time, however, tritium and sodium-22 concentrations have been significantly lower, with observed tritium concentrations of <600 pCi/l and sodium-22 concentrations of <3 pCi/l. Based upon groundwater flow pathways, the tritium and sodium-22 are likely to have originated from the former U-Line target area. Furthermore, TCA has been routinely detected in samples from well 54-07, with a maximum historical concentration of 471 µg/L, observed during CY 1997. As with the TCA detected in well 54-01, the TCA detected in well 54-07 is likely to have originated from the former Bubble Chamber area located to the north-northwest of the former U-Line target area.

Proposed Groundwater Monitoring Program

During FY 1999, one upgradient (MW-AGS-30) three downgradient wells (MW-AGS-31, -32, and -33) will be installed in the former U-Line target area (Figure 11, Table 4). One downgradient well will be installed close to existing well 54-01. The wells will be screened from five feet above to ten feet below the water table. Once installed, the wells will be monitored four times per year by the ES&H Services Division as part of the EM Program for the AGS facility (Table 5). Samples will be collected quarterly for tritium and gamma analyses, and semiannually for gross alpha/beta, metals, and VOCs. Data from new wells MW-AGS-08 and MW-AGS-09 which will be installed directly upgradient of the g-2 beam target and dump (see Section 5.1.5) will also be used to evaluate potential releases from the former U-Line target area.

5.2 Relativistic Heavy Ion Collider (RHIC) Project

The RHIC facility consists of a the Collider ring which is 12,578 feet in circumference, the beam injection system (consisting of the W-, X- and Y-Lines), six experimental halls, and a number of support buildings (Figure 8). The RHIC tunnel was constructed at grade and is covered by earthen shielding which is elevated approximately 30 feet above the grade of Ring Road. A portion of the headwaters for the Peconic River enter and exit the ring by means of culverts located in the northwest and east sections of the RHIC ring.

Within the RHIC facility, there are two areas where radionuclides may be produced in the soils outside of the Collider tunnel from beam loss during operational periods. The first area contains the beam stops which are located at the 10 o'clock portion of the ring, and the second contains the collimators which are located at the 8 o'clock region. Secondary particles created at the internal beam stop and collimator areas have the potential to escape into the soils immediately surrounding those areas. Although considerable effort is taken to design appropriate shielding and other engineering controls into these systems, secondary particles will interact with the Si and O atoms which make up most of the quartz-rich sands and gravels (quartz is predominantly SiO_2) that are native to the BNL site. The types of radionuclides created from interacting secondaries include tritium, beryllium-7, carbon-11, nitrogen-13, oxygen-15, and sodium-22 (Stevens, 1987; BNL, 1991a). Once present in the soils, these radionuclides can be leached downward into groundwater by means of rainwater percolation. These leaching processes are usually quite slow and, therefore, only radionuclides with long half-lives such as tritium ($t_{1/2}$ = 12.3 years) and sodium-22 ($t_{1/2}$ = 2.6 years) are likely to be detected in the groundwater immediately below the zones of production. The production of these isotopes has been measured in experiments using soils native to BNL that were exposed to the AGS beam line (Gollon *et al*., 1989). Leaching tests conducted on these soils showed the tritium to be 100% leachable whereas sodium-22 is 7.5% leachable.

Similar to the evaluations conducted for radionuclide production in soils at the AGS, Stevens (1987, 1998a, 1998b) provided estimates on radionuclide production in soil near the RHIC beam stops and collimator areas using the computer code CASIM (see Sections 5.2.1 and 5.2.2 below). As discussed previously, the AGS SAR (Beavis *et al*., 1993) determined the acceptability of radionuclide production in soils by comparing predicted concentrations at a potential source to five times the Design Concentration Guide (DCG) in DOE Order 5400.5. The DCG for a radionuclide is the concentration in water, which if ingested at a rate of two liters per day for one year, would result in a committed effective dose equivalent (CEDE) of 100 mrem. DOE Order 5400.5 requires that liquid effluents from DOE activities shall not cause private or public drinking water systems located downstream of facility discharges to exceed the drinking water radiological limits promulgated in 40 CFR Part 141, National Primary Drinking Water Standards. The drinking water standards set by EPA are based upon a dose of 4 mrem CEDE per year. The DOE Order indicates that the 5 times the DCG value is to be used to evaluate the need to apply Best Available Technology (BAT) to that liquid effluent. This assessment method was used by the RHIC Project and AGS Departments because existing Orders and regulations are designed to address the more common problem of controlling radioactive liquid effluent releases to surface waters (e.g., BNL sanitary discharges), and they do not address the direct activation of soils and resulting contamination of groundwater. By using this method, the only requirement that needs to be satisfied in order to demonstrate environmental compliance is to guarantee that any radionuclides which are produced in soils are reduced to concentration levels which would meet the 4 mrem/yr criteria at the point of ingestion (both on and off-site). Although detailed groundwater modeling has not been performed, it is likely that radionuclides leached from soils near the RHIC beam stops and collimator areas would undergo significant dilution upon entering the water table, and would be further reduced to concentrations either below drinking water standards or non-detectable following dilution and decay in transit to the nearest BNL drinking water supply well, well 10 (BNL, 1991b; Paquette and Schroeder, 1996). The distance between the collimator area and supply well 10 is approximately 3,500 feet or a groundwater travel time of almost 12 years.

Although intended for application to liquid effluents, environmental ALARA considerations should include the assessment of: 1) alternative operating methods and engineering controls; 2) radiological doses under each alternative; 3) the benefits and cost of implementing each alternative; and 4) societal and environmental impacts. To address local stakeholders' desire that the greatest possible effort be made to eliminate intentional releases of radionuclides to the environment, the Laboratory will be taking all reasonable steps to prevent the leaching of these materials to groundwater. Prior to the start of operations with beam at RHIC, the Laboratory will install geomembrane covers over the beam stop and collimator areas as a means of preventing rainwater from leaching through the soils at the source of radionuclide production (Paquette and Schroeder, 1996; Davis, 1996; Stevens 1996b; Stevens, 1997b). With the installation of the caps, it is anticipated that most of the radioactivity produced at the RHIC beam stops and collimators will decay in place. The remediation of any residual activated soils would have to be addressed as a part of any future decommissioning and decontamination (D&D) program for these facilities.

5.2.1 *Beam Stop Area*

Potential Groundwater Vulnerability

The RHIC beam stops are located at the 10 o'clock intersection region of the Collider (Building 1010), and are the place where the vast majority (~85%) of the beam energy will end up (Stevens, 1996a). Consequently, there is concern that direct activation of soils surrounding the RHIC tunnel may impact groundwater quality in areas surrounding the beam stops. The beam stops are located approximately 200 feet to the north and south of the centerline of Building 1010 (Figures 8 and 18). The southern beam stop is located approximately 200 feet north of the culvert that conveys the Peconic River below the RHIC ring.

In an effort to predict radionuclide production at the beam stops, Stevens (1996a, 1998a) evaluated possible tritium and sodium-22 concentrations in soils directly outside the Collider tunnel. Based upon these evaluations, the maximum predicted annual production of tritium and sodium-22 in soils within 40 cm of the tunnel walls and floor is 220 pCi/cc of soil and 270 pCi/cc of soil, respectively. This production rate is obtained assuming four times the design intensity of RHIC, which was considered as the safety envelop limit for the evaluation. Assuming that the geomembrane cap was not installed, a conservative prediction of the possible concentration of tritium and sodium-22 can be made by assuming that approximately half of the total amount of annual precipitation (55 cm of the total of 122 cm annual average) leaches through the most activated of these soils. (The remainder of the precipitation is lost due to evaporation or evapotranspiration.) Under this scenario, the annual average tritium and sodium-22 concentrations in soil pore water directly below the beam dump areas may be as high as 170,000 pCi/l and 20,300 pCi/l, respectively (Stevens, 1998a). However, the volume of water having these high concentrations at each beam stop would likely to be less than 40 gallons annually (Stevens, 1998b), and there would be significant dilution of this water within a short distance upon entering the aquifer system.

To limit the potential impact that the RHIC Project may have on groundwater quality, landfill-type caps (using geomembrane fabric) will be installed over the two beam stop areas prior to the scheduled CY 1999 start operations with beam at RHIC (see Davis, 1996; Stevens, 1996b; Stevens, 1997c). The design goal for these caps is to prevent the infiltration of precipitation through the most highly activated soils surrounding the tunnel, and thereby prevent the leaching of radionuclides to groundwater. By preventing rainwater infiltration through the most significantly impacted soils, Stevens (1998a) predicted that the tritium and sodium-22 pore water concentrations will be reduced by a factor of at least 100, to concentrations in the range of 1,700 pCi/l and 200 pCi/l, respectively.

General Hydrogeology

The predominant groundwater flow direction in the RHIC beam stop area is to the southeast (Figures 6, 7 and 19). The RHIC beam stop area was built in the low lying portion of the Peconic River drainage system. The depth to groundwater below the tunnel floor is approximately 15 feet, whereas in low lying areas off the RHIC berm, near the Peconic River, the depth to groundwater can be as little as five feet or less. Furthermore, recently installed borings at the 9 o'clock portion of RHIC indicate portions of the tunnel may have been constructed over low permeability fine sands, silts and clays that are indicative of stream deposition. These low permeability deposits may retard the percolation of rainwater, which may result in perched or semi-perched water table conditions.

Current Groundwater Monitoring Program

Presently, there are no groundwater monitoring wells located directly upgradient or downgradient of the beam stops. Wells that could be used to assess background conditions within the Upper Glacial aquifer are located approximately 1,400 feet upgradient of the beam stop area, at the BNL northern site boundary (e.g., Wells 17-01, 17-02, and 17-03). These wells are used for assessing background (ambient) radionuclide concentrations within the Upper Glacial aquifer. To date, tritium values for these wells have been either non-detectable or slightly above detection limits (which is consistent with world-wide fallout values), and sodium-22 has never been detected.

Proposed Groundwater Monitoring Upgrades

As a means of verifying that the operation of the RHIC beam stops will not impact groundwater quality, BNL will establish a routine groundwater monitoring program for the area. During FY 1998, a total of six new wells will be installed in the beam stop area (Figure 19, Table 3). Two shallow Upper Glacial aquifer wells will be installed directly downgradient of each beam stop (wells MW-RHIC-03 through -06), and one well will also be installed directly upgradient of each beam stop (wells MW-RHIC-01 and -02). The upgradient wells will be installed on top of the bermed area overlying the RHIC tunnel, as close as possible to the upgradient side of each beam stop (within 10 feet). The wells will be screened from five feet above to ten feet below the water table. If perched water table conditions are found in the beam stop area, additional wells will be installed in the perched water table.

The new wells will be monitored by the ES&H Services Division as part of the EM Program (Table 5). Samples will be collected quarterly for gamma spectroscopy and tritium analyses, and semiannually for gross alpha/beta and metals. Furthermore, because the southern beam stop is located within 200 feet of the culvert for the Peconic River, surface water samples will be collected to verify that potentially activated groundwater is not being discharged to the stream bed during high transient water table conditions. When surface water is present, water samples will be collected at a sample location near the Ring Road on a quarterly basis for tritium analysis and gamma spectroscopy. Data from the new wells near the beam stops will be compared to results from existing well 17-01, a shallow BNL site perimeter well which is currently monitored quarterly as part of the ER Program. The monitoring program will begin prior to the start-up of the RHIC in order to fulfill DOE pre-operational environmental surveillance requirements.

5.2.2 Collimator Areas

Potential Groundwater Vulnerability

The RHIC limiting aperture collimators are identified areas of beam loss, and are therefore of concern with regard to potential activation of soils. The collimator areas are located at the 8 o'clock region of the RHIC (Figures 8 and 20). In these areas, tritium and sodium-22 may be produced in the soils directly outside the Collider tunnel (Stevens, 1997a; Stevens, 1997b; Stevens, 1998a). In the collimator area, the maximum tritium and sodium-22 concentrations are expected to be approximately five times less than those predicted for the RHIC beam stop area. In soils within 40 cm of the tunnel walls and floors near the collimators, Stevens (1997a, 1997b, 1998a) estimated that tritium and sodium-22 concentrations will be 50 pCi/cc of soil and 61 pCi/cc of soil, respectively. Assuming that the gromembrane cap was not installed, a conservative prediction of the possible concentrations of tritium and sodium-22 in leachate can be made by assuming that approximately half of the total amount of annual precipitation (55 cm of the total of 122 cm annual average) leaches through the most activated soils. Under this scenario, the annual average tritium and sodium-22 concentrations in pore water directly below the collimator areas may be as high as 39,000 pCi/l and 4,600 pCi/l, respectively (Stevens 1998a). It should be noted that the volume of water having these high concentrations would be less than 120 gallons annually along the length of the collimator area (Stevens, 1998b), and that there would be significant dilution of this water within a short distance upon entering the aquifer system.

In an effort to reduce the potential impact that the RHIC Project may have on groundwater quality, a landfill-type cap (using geomembrane liners) will be constructed over the collimator areas prior to the scheduled CY 1999 start of beam operations at RHIC (see Davis, 1996; Stevens, 1996b; Stevens 1997a; Stevens 1997c). The caps will prevent the infiltration of precipitation through the most highly activated soils surrounding the tunnel, and thereby limiting the leaching of radionuclides to groundwater. By preventing surface water from infiltration through the most heavily impacted soils, it is predicted that the tritium and sodium-22 concentrations in soil pore water will be reduced by a factor of at least 100, with concentrations on the order of 400 pCi/l and 46 pCi/l, respectively (Stevens, 1998a).

General Hydrogeology

The predominant groundwater flow direction in the RHIC collimator area is to the southeast, which is parallel to the RHIC tunnel in this region (Figures 6, 7, and 19). The depth to groundwater below the tunnel floor is approximately 15 feet. In areas off the main RHIC berm, the depth to groundwater ranges between 10 to 20 feet. Current information indicates that the collimator area is underlain by predominantly medium to coarse grained sands and gravel.

Current Groundwater Monitoring Program

Presently, there are no groundwater monitoring wells located directly downgradient of the RHIC collimator areas. Wells are located upgradient of the RHIC, at the BNL northern site boundary (e.g., Wells 17-01, 17-02, 17-03 and 25-01). These wells are used for assessing background (ambient) radionuclide concentrations within the Upper Glacial aquifer. To date, tritium values for these wells have been either non-detectable or slightly above detection limits (which is consistent with world-wide fall-out levels), and sodium-22 has never been detected.

Proposed Groundwater Monitoring Upgrades

As a means of verifying that the operations at the RHIC collimator areas will not impact groundwater quality, BNL will establish a routine groundwater monitoring program during FY 1998. The groundwater monitoring program will require a minimum of six new monitoring wells (Figure 19, Table 3). Four wells (MW-RHIC-09 through -12) will be installed directly downgradient of the collimator portion of the tunnel. Because the direction of groundwater flow is nearly parallel with this portion of the RHIC tunnel, the wells will be installed close to the tunnel on both the east and west sides. The downgradient wells will be installed as couplets, with shallow wells screened from five feet above to ten feet below the water table, and deeper wells screened from 15 to 25 feet below the water table. In an effort to establish a more direct means of evaluating groundwater quality close to the potentially activated soils, two wells (MW-RHIC-07 and -08) will be installed along the top of the RHIC tunnel, approximately 150 feet to the north and south of beam crossing point located within Building 1008. The wells will be positioned adjacent to the front edge of the collimators, where the predicted highest levels of soil activity will occur (Stevens, 1997a).

The wells will be monitored on a quarterly basis by the ES&H Services Division as part of the EM Program for facility surveillance (Table 5). Groundwater samples will collected on a quarterly basis for tritium and gamma spectroscopy, and semiannually for gross alpha/beta and metals. Assessment of background radionuclide concentrations will be accomplished utilizing existing Upper Glacial aquifer wells 17-01 and 25-01. Well 17-01 is presently monitored quarterly as part of the ER Program, and the monitoring of well 25-01 will be conducted as part of the EM Program. The monitoring program will begin prior to the start-up of the RHIC in order to fulfill DOE pre-operational environmental surveillance requirements.

5.3 Brookhaven Medical Research Reactor (BMRR)

The BMRR is a 3 MW light water reactor used for biomedical research, most notably of which is Boron Neutron Capture Therapy for brain tumor treatment. The BMRR's primary cooling water system consists of a recirculation piping system that contains 2,550 gallons of water. The tritium concentration in the primary water is currently 465 µCi/L, for a total tritium content of 4.5 Ci. 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. Excess heat is transferred by means of heat exchangers with once through (secondary) cooling water which is obtained from process supply well 105 or the BNL Chilled Water System. This secondary water is discharged to recharge basin HP located 800 feet to the south of the Medical Department complex (Figure 21).

Potential Groundwater Vulnerability

Potential environmental vulnerabilities at the BMRR were initially evaluated during the High Flux Beam Reactor (HFBR) Tritium Remediation Project, and later as part of the BNL's Facility Review Project (BNL, 1997a; Paquette, 1997). Low-level tritium (2,450 pCi/l) was detected in a groundwater sample collected in January 1997 from a shallow Upper Glacial aquifer monitoring well located 400 feet south of the BNL's Brookhaven Medical Research Reactor (BMRR). Following the initial detection of tritium, BNL installed two shallow monitoring wells directly downgradient of the BMRR. Subsequent sampling of the new wells indicated tritium concentrations of up to 11,400 pCi/l. Twenty-five temporary Geoprobe™ wells were then installed to identify the source and determine the extent of the tritium contamination (Paquette, 1997). The highest tritium levels were detected in temporary wells installed within 50 feet of the BMRR, where a maximum concentration of 11,800 pCi/l was detected. The tritium plume was traced from the BMRR to approximately 400 feet south (downgradient), where a maximum concentration of 3,800 pCi/l was detected (Figure 22).

Review of systems and operations within the BMRR facility has identified two potential sources for the tritium detected in the groundwater: 1) a former above ground storage tank that was used to temporally store radioactive liquids; and 2) a floor drain system and associated sump which had received primary cooling water on a number of occasions (Figure 23). Although small volume releases did occur while transferring liquids to the tank on several occasions, the most likely source for the tritium detected in the groundwater is the floor drain system and associated unlined 150 gallon capacity SU-2 sump located in the basement of the BMRR. Records indicate a total of 16 spills or discharges totaling nearly 800 gallons of primary water to the floor drains or directly to the SU-2 sump. The last such discharge occurred in January 1987. Although most of the primary water that was discharged was properly disposed of, recent qualitative leak-rate testing indicates that the sump and/or floor drain piping system is not entirely leak tight and some amount of radioactive water may have leaked to the underlying soils. Furthermore, throughout the history of the BMRR, secondary (non-radioactive) coolant water was routinely discharged to the SU-2 sump and floor drain system. Leakage of secondary water could have provided sufficient water volume to drive the tritium through the unsaturated zone and into the groundwater below the reactor building.

To prevent future release of radioactive materials to the soils and groundwater below the BMRR, the floor drain system will be abandoned in a manner that is acceptable to the SCDHS. Although the last documented discharge of primary water to the SU-2 sump and floor drain system occurred in January 1987, continued use of the sump and floor drain system is likely to leach any residual contamination from the unsaturated zone and into the groundwater. BNL will also seal the SU-2 sump with a SCDHS approved material, and a plastic container will be placed in the sump pit. A liquid sensor was recently installed in the sump, and will be used to detect any liquids outside the plastic container. The plastic container will be used to collect water that is discharged from secondary cooling systems. Alternative approved storage containers will be used when maintenance requires the draining of primary water systems.

General Hydrogeology

The BMRR is underlain by weakly stratified coarse-grained sands of the Upper Glacial aquifer. Depth to groundwater from land surface immediately south of the reactor is approximately 57 feet. Depth to groundwater from the basement floor of the BMRR is approximately 42 feet. The direction of groundwater flow in the area of the Medical Research Facility is generally to the south southeast (Figures 6, 7, 21 and 24). However, due to extraction of groundwater from nearby BMRR cooling water supply well 105 and the recharge of water at Basin HP, groundwater flow in the BMRR area can change to a more south-southwest direction.

Current Groundwater Monitoring Program

The current groundwater monitoring well network at the BMRR consists of three shallow Upper Glacial aquifer wells. During January 1997, low-level tritium (2,450 pCi/l) was detected in a sample collected from shallow Upper Glacial aquifer monitoring well 94-01 located 400 feet south of the BMRR. Following the initial detection of tritium, BNL installed shallow monitoring wells 84-12 and 84-13 directly downgradient of the BMRR. Initial samples from the new wells indicated tritium concentrations of up to 11,400 pCi/l. As noted above, twenty-five temporary Geoprobe™ wells were then installed to characterize the source and extent of the tritium contamination. The highest tritium levels were detected in temporary wells installed within 50 feet of the BMRR, where a maximum concentration of 11,800 pCi/l was detected. As a result of this investigation, a low-level tritium plume was traced from the BMRR to approximately 400 feet south (downgradient), where a maximum concentration of 3,800 pCi/l was detected. Only trace amounts of other reactor-related radionuclides were detected in the groundwater near the BMRR.

Proposed Groundwater Monitoring Upgrades

During FY 1998, two new monitoring wells will be installed to supplement existing downgradient wells 84-12, 84-13 and 94-01 (Figure 24, Table 3). Well MW-BMRR-1 will be installed directly upgradient of the BMRR, and the second well MW-BMRR-2 will be installed immediately downgradient of the BMRR's Receiving Room.

The monitoring wells will be used to evaluate the effectiveness of the new engineering controls noted above, and will focus on groundwater quality directly downgradient of the BMRR. The five wells will be sampled on a quarterly basis by the ES&H Services Division as part of the EM Program (Table 5). Groundwater will be tested for tritium, gross alpha/beta, gamma spectroscopy and, as required, for strontium-90.

5.4 Waste Concentration Facility (WCF)

The Waste Concentration Facility (Building 811) was constructed in 1954, and has been the central facility for the receipt, processing and volume reduction of aqueous radioactive waste (Figure 11). From 1954 to early 1990s, liquid wastes were stored in a series of underground and above ground storage tanks, blending tanks, evaporator/concentration apparatus, and underground pipelines. Past waste processing operations included the distillation of the liquid waste. The resulting solids were collected in the evaporator as a sludge which were later solidified for off-site disposal. The distillate, which contained tritium, was discharged to the sanitary sewer system. The processing of liquid radioactive waste by distillation methods and the discharge to sanitary of the distillates containing tritiated water were stopped in the late 1980's. To date, three 100,000 gallon-capacity above ground (D-Waste) storage tanks have been removed as part of the ER Program (D-Tank Removal Project), and six 8,000 gallon-capacity underground storage tanks are scheduled for removal during FY 1999.

Currently, the WCF is used primarily as a collection facility for BNL's radioactive liquid waste stream. From 1993 to 1997, radioactive liquid waste were processed by a contractor employing a mobile microfiltration/reverse osmosis (MF/RO) processing technology. The treated water was then transferred to the Building 802 Tritiated Water Evaporator where it is discharged to the atmosphere in vapor form. Starting in 1998, raw liquid wastes are now shipped directly to an off-site treatment facility. Building 811 receives most of its liquid waste through an underground transfer pipe that is connected to Building 801. The pipe line has SCDHS approved secondary containment and leak detection. All liquids are currently stored in four 25,000 gallon capacity above ground storage tanks. The tanks, and associated transfer lines have SCDHS approved secondary containment and leak detection devices, and the tanks also have high level alarms. Two of these tanks are currently used to store the tritiated water from the HFBR spent fuel pool.

Potential Groundwater Vulnerability

Past operations at the WCF has resulted in the contamination of the soils and groundwater. Radionuclides such as strontium-90 and cesium-137 have been detected in the soils, and tritium and strontium-90 have been detected in the groundwater directly downgradient of the facility (see below). The soil and groundwater contamination issues are currently being assessed as part of the ongoing ER Program (OU I and OU III, respectively).

All current liquid waste transfer piping and storage tanks have SCDHS approved secondary containment, leak detection, and high level alarms. Furthermore, in an effort to protect soil and groundwater from potential accidental spills in the future, BNL is currently designing a new liquid transfer building for the WCF. Although these systems will be routinely tested to ensure their long-term integrity, there remains a possibility of undetected small-scale leakage.

General Hydrogeology

Groundwater flow in the WCF areas is predominantly to the southeast (Figures 6, 7, and 11). However, during extended operation of potable supply well 10 located approximately 900 feet to the northeast, groundwater flow in the northern portion of the facility may be more to the north northeast. The facility is underlain by predominantly fine to coarse-grained sand, and the depth to groundwater is approximately 40 feet below land surface.

Current Groundwater Monitoring Program

The current groundwater surveillance well network at the WCF consists of six shallow Upper Glacial aquifer wells and two middle to deep glacial wells (Figure 11). Evaluation of the well construction details for the WCF's upgradient well (65-06) and four of its downgradient wells (65-02, 65-03, 65-04 and 65-05) indicates that the wells are screened approximately 10 to 15 feet below the water table, which is too deep to properly monitor the facility. Furthermore, these wells were installed in the mid-1980s to primarily monitor the former D-waste tanks area of the WCF, and are not properly positioned to be downgradient of the active portions of the facility.

Since 1993, both tritium and sodium-22 have been routinely detected in facility's upgradient well 65-06, and in downgradient wells 65-02, 65-03, 65-04 and 65-05. In well 65-06, the maximum observed concentration of tritium has been 5,080 pCi/l and 23 pCi/l for sodium-22. Similarly, both tritium and sodium-22 have been routinely detected in downgradient wells 65-02, 65-03, 65-04 and 65-05, with maximum observed concentrations of 5,990 pCi/l and 30 pCi/l, respectively. Based upon the detection of tritium and sodium-22 in the upgradient well and the deep screen zone positions of these wells, the contamination is likely to be the result of accelerator produced soil activation at Building 912, or possibly from the former U-Line target area located to the northwest of Building 912.

In addition to tritium and sodium-22, strontium-90 has also been detected in several of the existing wells, and groundwater samples collected near the water table from recently installed OU III RI Geoprobe™ and permanent wells. As the result of past waste handling practices and accidental spills, strontium-90 and cesium-137 can be detected in the soils within the WCF. The strontium-90 and cesium-137 contamination is the result of the historical processing of waste from the Brookhaven Graphite Research Reactor which operated from 1950 to 1968, and is not associated with any AGS Department operations. In one OU III Geoprobe well installed downgradient of the WCF, strontium-90 was detected at a concentration of 146 pCi/l, well above the drinking water standard of 8 pCi/l. The full extent of the Sr-90 contamination is currently being evaluated as part of the OU III project. In addition to radionuclides, chemical contaminants such as TCA and DCA, are routinely detected in the WCF wells, including upgradient well 65-06. During 1996, TCA was detected in all six shallow Glacial aquifer wells at concentrations up to 97 µg/l, and 1,1-DCA was detected in several wells up to 10 µg/l. The VOCs are likely to have originated from source areas located within the AGS complex.

Proposed Groundwater Monitoring Upgrades

As noted above, five of the existing WCF groundwater monitoring wells have screens that are too deep and not properly positioned to monitor current WCF operations. New wells should be installed with wells screens positioned to monitor the uppermost ten feet of the aquifer. Potential remedial alternatives for the strontium-90 contaminant plume are currently being evaluated as part of the Operable Unit III Feasibility Study. The need for additional groundwater monitoring wells both upgradient and downgradient of the WCF is currently being evaluated as part of the OU III FS. It is anticipated that the future long-term monitoring well network established as part of the ER Program will also adequately monitor active processes within the WCF area. However, if the future ER monitoring program is found to be inadequate to properly monitor the active operations of the WCF, then additional monitoring wells may be installed as part of this Groundwater Monitoring Improvements Plan in FY 1999.

5.5 Building 830

Building 830 is currently occupied by the Environmental and Waste Technology Center. The building includes analytical and electron microscopy labs, office and administrative spaces. This facility also houses an inactive Gamma Irradiation Facility (GIF) currently containing approximately 35,000 Ci (total) of cobalt-60 sources, and two inactive hot cells and associated transfer canal (Figure 25).

Operations within Building 830 commenced 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. Records indicate that the hot cells were used to repair leaking cobalt-60 sources obtained from a variety of on-site and off-site facilities. The cells have also been used for the cutting, milling and evaluation of radioactively contaminated and activated materials and components, mainly from commercial nuclear power plants (Cowgill, 1997). In 1970, the Low Dosimetry Facility (currently known as the GIF) was added to the northeast end of the building. This facility included a gamma irradiation pool and a machine shop.

Potential Groundwater Vulnerability

Three systems associated with former operations are known or potential sources for soil and groundwater contamination:

Cobalt-60 Source Pool: The cobalt-60 sources are stored in a water filled, in-ground storage tank that is lined with stainless steel. The pool is 8 feet by 10 feet by 13 feet deep, and has a capacity of nearly 7,700 gallons. The cobalt-60 source pool does not contain secondary containment or leak detection devices, and does not comply with Suffolk County Article 12 requirements for storage tanks. However, the pool is fitted with an automatic fill valve which would activate if the water level in the pool drops below a pre-determined level (see Bari, 1997). Furthermore, a water meter was installed two years ago as a means of detecting water losses, and meter readings are recorded weekly. Except for small additions of water resulting from testing the refill valve, the meter readings have not changed appreciably during the two year period. Therefore, it appears that the pool is not leaking.

The cobalt-60 sources maintained in the GIF consist of cobalt metal encapsulated in stainless steel jackets. Although it is possible that a low rate, low volume leak could go undetected, the water in the source pool presently contains only trace amounts of cobalt-60 (5.8 pCi/l) and cesium-137 (3.4 pCi/l). It is not known whether the low level of cobalt-60 is caused by a leaking source. However, the presence of cesium-137 suggests that the contamination may be due to external contamination of the cobalt-60 sources prior to their placement in the pool (Bowerman, 1997).

Hot Cells and Transfer Canal: Hot Cell 1 (“Preparation Cell”) was used to fabricate high intensity cobalt-60 sources for food irradiation programs. These sources were then transferred to Hot Cell 2 (Irradiation Cell) by means of a water filled transfer canal. In Hot

Cell 2, the sources were stored in a twenty-one foot deep water-filled pool until needed. Items to be irradiated were moved in and out of Cell 2 by means of two transfer tunnels located underneath and extending east from the cell. The transfer canal is approximately six feet wide by sixteen feet deep by 16 feet long and is lined with stainless steel. During a recent physical inspection of the transfer canal, it was noted that the stainless steel liner joints were covered with an epoxy-like substance (Cowgill, 1997). It is unclear whether the epoxy coating was part of the original design. Records indicate that make-up water was being added to the transfer canal at a rate of approximately 300 gallons per month (Romano and Bowerman, 1997). Whereas some of this water is likely to be lost due to evaporation, recent detailed leak-rate testing conducted with the canal covered to minimize evaporative losses, revealed that the canal may have been leaking at rate of nearly 4.45 gallons per day (Romano and Bowerman, 1997). The Cell 2 pool and the transfer canal were completely drained and the walls were cleaned in 1997-1998. The water drained from the canal showed low levels of tritium at concentrations of <800 pCi/l, cobalt-60 at concentrations of <3 pCi/l, and cesium-137 up to 25 pCi/l (see Romano and Bowerman, 1997; Schroeder, 1997).

D-Waste Transfer Line and USTs: Soil and groundwater contamination has resulted from a 1984-1986 release of approximately 900 gallons of low-level radioactive waste from the Building 830 liquid waste handling system (Miltenberger *et al*., 1989). The D-waste line which ran from Building 830 to two USTs located to the east, contained cobalt-60, cesium-137, plutonium-239, americium-241, and tritium (SAIC, 1992). Investigations have revealed that the underground transfer line leading from the building to two underground waste holding tanks (located to the east of the facility), had developed leaks as a result of interior corrosion of the pipes. The soil in the vicinity of the identified leak areas was removed in 1988 (see SAIC, 1992). The lines, valve pit, USTs, and soil contaminated above soil cleanup guidelines are being removed during the summer of 1998 as part of the ER Program.

General Hydrogeology

The depth to groundwater in the Building 830 area is approximately 45 feet below land surface. Available geologic data collected during the installation of nearby wells, indicates that the Building is underlain by predominantly medium to coarse-grained sand and fine gravel.

Hydraulic stresses caused by recharge basin HO and potable supply wells 11 and 12 result in significant changes in groundwater flow directions in the Building 830 area. Depending upon pumping and recharge patterns, groundwater flow in the Building 830 area can vary between southeast and northeast (Figures 6 and 7). During certain periods of sustained pumpage of supply well 11, the groundwater flow direction in parts of the Building 830 area may even swing to the north. Supply well 11 is approximately 900 feet from Building 830, and supply well 12 is approximately 1,300 feet to the northeast. Both wells have pumping rates of nearly 1,200 gpm. Water table measurements from wells located in the Building 830 area suggest that the capture zone for supply well 11 may extend close to this facility, resulting in the formation of a pumping induced groundwater divide located close to Building 830. When supply well 12 is in operation by itself, groundwater flow can be in a more easterly direction.

Current Groundwater Monitoring Program

The surveillance well network near Building 830 currently consists of three shallow Upper Glacial aquifer wells (Figure 25). These wells (66-07, 66-08, and 66-09) were installed in 1989 to evaluate the 1984-1986 release of approximately 900 gallons of low-level radioactive waste from the Building 830 liquid waste handling system (Miltenberger *et al*., 1989). Groundwater samples are currently collected on a quarterly basis from wells 66-08 and 66-09 as part of the ER Program, and well 66-07 is monitored as part of the EM Program for the new Waste Management Facility on a quarterly basis. Historically, groundwater samples from the three wells have shown only trace amounts of radioactivity attributable to transfer line leak, with gross alpha typically at <1 pCi/l, gross beta up to 4 pCi/l, tritium up to 2,440 pCi/l, and only trace amounts of cobalt-60 (<1 pCi/l). However, higher levels of cobalt-60 were recently detected in Geoprobe™ wells installed south (nominally downgradient) of the transfer line and USTs. In a Geoprobe™ well located directly downgradient of the UST, cobalt-60 was detected at a concentration of 242 pCi/l which is above the 200 pCi/l drinking water standard (i.e., 4% of the DOE DCG). Low level cobalt-60 was also detected in four of the other downgradient wells, with concentrations ranging between 5.3 pCi/l to 28 pCi/l. Cobalt-60 was not detected in four Geoprobe™ wells installed north of Building 830, used to assess the possible migration of contaminants to the north resulting from the operation of supply wells 11 and 12. However, trace quantities of cobalt-60 have been detected in supply well 11 (<1 pCi/l) and in a shallow Upper Glacial aquifer well 56-21 (4.4 pCi/l) located between supply well 11 and Building 830. At this time it is uncertain whether the cobalt-60 detected in these wells originates from the Building 830 facility or from minor leakage from the main sanitary line that runs through the area between supply well 11 and Building 830. The water supply wells are monitored monthly to verify that the radionuclide concentrations remain well below drinking water standards.

Proposed Groundwater Monitoring Upgrades

Additional monitoring wells are required to maintain surveillance on existing groundwater contamination which resulted from past leaks, and to ensure that a potential leak from the cobalt-60 source pool is detected. Tracking groundwater quality in the Building 830 is important because the facility appears to be within or close to the capture zones of potable supply wells 11 and 12, and the existing monitoring wells are not optimally positioned to monitor the cobalt-60 source pool or to act as sentinel wells for the supply wells. During CY 1999, four new wells will be installed closer to Building 830 (Figure 25, Table 4). Two wells (MW-830-01 and -02) will be installed immediately to the north of Building 830, and two wells (MW-830-03 and -04) will be installed to the east of the building (Figure 25). Well MW-830-02 will be installed immediately adjacent to the cobalt-60 source pool.

Once installed, the wells will be monitored four times per year by the ES&H Services Division as part of the EM Program for the AGS facility (Table 5). Samples will be collected quarterly for gamma spectroscopy for the detection of Co-60, and semiannually for tritium and gross alpha/beta. The sampling frequency would be increased in the event of any sudden water losses from the pool or with the detection of increased cobalt-60 concentration in the source pool water.

5.6 Sewage Treatment Plant (STP)

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 (Hazen and Sawyer, 1993). 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. This discharge is regulated under a NYSDEC SPDES permit (NY-0005835).

5.6.1 Sand Filter Bed Area

Waste water from the STP's clarifier is released to the sand filter beds, where the water percolates through five 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) (Figure 26). 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. The capacity of the filter bed system is 2.3 mgd, which is the current SPDES discharge volume limit.

Potential Groundwater Vulnerability

Because of the known historic, and potential future accidental radiological and chemical releases to the sanitary system, it is necessary to monitor groundwater quality within the STP filter bed area. Due to past chemical and radiological releases to the sanitary system, the filter bed sands have been shown to be contaminated with radionuclides and heavy metals. For example, the filter bed sands were contaminated with low levels of cesium-137 and strontium-90 in 1988 as the result of a release of radioactive water from the WCF to the sanitary system. Although the most heavily contaminated soils were remediated, soil sampling conducted during the OU V RI revealed that low levels of cesium-137 remain. Analysis of the filter bed sand also indicates that heavy metals such as mercury, silver chromium and lead are also present in the filter bed sands (ITC and G&M, 1998). These radionuclides and heavy metals continue to leach from the sand filter beds at a slow rate

(Schroerder *et al*., 1998). Because as much as 15% of the water released to the filter beds is subject to direct groundwater recharge, it is necessary to conduct long-term monitoring of the groundwater within the filter bed area.

General Hydrogeology

Recent drilling within STP area has revealed that fine sand, silt and clay deposits occur within 30 feet of land surface (Figure 4). These low permeability deposits retard groundwater recharge, and are responsible for creating perched or semi-perched water table conditions. In the STP area, a broad groundwater mound has formed below the plant's filter beds, where it is estimated that up to 0.1 MGD of STP effluent may be recharged directly to groundwater (Figures 4, 6, and 7). Shallow groundwater in the filter bed area generally flows in a radial pattern due to these mounding effects. The depth to groundwater in the STP area is approximately 12 feet below ground surface, but can be as little as three to five feet below the filter beds.

Current Groundwater Monitoring Program

The groundwater surveillance network at the STP filter bed area currently consists of six shallow Upper Glacial aquifer wells that were installed in 1993 (Figure 26). Tritium, cesium-137 and strontium-90 have been detected in the filter bed area wells. Tritium, which is the result of on going discharges to the sanitary system, is generally detected in the range of 1,000 to 3,000 pCi/l. Low level cesium-137 (typically <5 pCi/l) and strontium-90 (typically <2 pCi/l) have been routinely detected in the filter bed area wells. Trace amounts of both cesium-137 and strontium-90 are detected in STP effluent at the Peconic River outfall. Comparisons of cesium-137 and strontium-90 concentrations in STP influent and STP effluent, suggest that their presence in STP effluent and groundwater is likely to be the result of leaching of previously contaminated filter bed sands (BNL, 1998). Over the past six years, trace amounts (<1 µg/l) of VOCs have occasionally been detected in wells near the filter beds. However, a low level TCE plume (<20 µg/l) has been detected east of the STP. The TCE plume has been found to extend from the BNL east boundary area to approximately 3,000 feet downgradient of the site (ITC/G&M, 1997, BNL, 1998). This TCE plume is the result of historical discharges of VOCs to the BNL sanitary system.

Proposed Groundwater Monitoring Upgrades

In order to adequately monitor groundwater quality near the filter bed area, two additional shallow Upper Glacial aquifer wells (MW-STP-01 and MW-STP-02) will be installed in the Filter Bed 3 and 4 areas during FY 1999 (Figure 26, Table 4). Depending upon local geology, the wells will be screened from the top of the water table to ten feet below the water table. If perched water table conditions are present due to the occurrence of shallow clay deposits, the wells will be screened within the perched water table. Once installed, the wells will be monitored quarterly by the ES&H Services Division as part of the EM Program for the STP (Table 5). The groundwater samples will be analyzed for water quality, VOCs, tritium, gamma spectroscopy and, as required, for strontium-90. Long-term monitoring under the ER Program will focus on monitoring the TCE plume located to the east of STP.

5.6.2 Emergency Hold-up Ponds

Two emergency hold-up ponds are located to the east of the sand filter bed area (Figure 26). The hold-up ponds are used for the emergency storage of sanitary waste when the influent flow exceeds the STP's capacity or when 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 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 eight days.

To ensure that an accidental contaminant release is detected prior to reaching the STP and ultimately the Peconic River, real-time monitoring of the STP influent for radioactivity (gamma emitting radionuclides), pH and conductivity, takes place at two locations: 1) within the sanitary line at a point about 1.8 km upstream of the STP (Manhole 192); and 2) as the influent is about to enter the STP's clarifier. The upstream station provides about one-half hour of advanced warning that liquid effluents which may exceed BNL effluent release criteria or SPDES limits have entered the system. At the clarifier, an oil monitor examines STP influent for the presence of oil. Effluent leaving the clarifier is monitored a third time for radioactivity. Effluent that does not meet BNL and/or SPDES permit effluent release criteria are diverted to one of the two lined holding ponds, until the effluent meets the release criteria. The effluent diverted to the holding pond is evaluated for treatment and is later released when the addition of this material will not result in exceeding SPDES permit limitations or the BNL administrative release criteria (BNL ES&H Services Division SOP RP-08).

Potential Groundwater Vulnerability

The lined emergency holding ponds lack secondary containment and leak detection devices. Although the Laboratory performs routine maintenance on these ponds, the possibility exists that at undetected leaks could occur in the liners. Because the holding ponds have been and could be used to temporarily store water that is contaminated with either chemical or radioactive materials at concentrations well above drinking water standards, the Laboratory is currently seeking funding to install new liners in the ponds. The liner upgrade project includes a plan to use the existing liners as secondary containment barriers, and for the installation of leak detection devices between the old and new liners.

General Hydrogeology

The predominant groundwater flow direction in the emergency hold-up pond area is to the east (Figures 6, 7, and 26). Depth to groundwater is approximately 10 below land surface. Based upon available boring logs, the near surface geology of the hold-up pond area consists predominantly of fine to medium-grained quartz sand.

Current Groundwater Monitoring Program

There are no groundwater monitoring wells located directly downgradient of the emergency hold-up ponds. Whereas well 39-05 is located immediately north (side-gradient) of the ponds, the closest groundwater downgradient monitoring wells are located approximately 300 feet to the east. Downgradient wells 39-03 and 39-09 are screened within the uppermost 10 of the Upper Glacial aquifer. Well 39-03 is an older well constructed of carbon steel. Because of its deteriorating condition, the well is no longer sampled to assess water quality, and is only used for depth to water measurements. Historically, monitoring results from these wells indicate low to non-detectable levels of radionuclides. Furthermore, metals concentrations have been below the applicable NYS AWQS, and no VOCs have been detected in these wells.

Proposed Groundwater Monitoring Upgrades

During FY 1999, BNL will establish a routine groundwater monitoring program to provide a means of verifying that the operations at the emergency hold-up ponds do not impact groundwater quality. To establish this program, four new monitoring wells will be installed (Figure 25, Table 4). One well will be installed upgradient of the hold-up ponds (MW-STP-03), and three wells will be installed downgradient of the ponds (MW-STP-04, -05, and -06). The wells will be screened from five feet above to ten feet below the water table.

Once installed, the wells will be monitored on a quarterly basis by the ES&H Services Division as part of the EM Program (Table 5). The groundwater samples will be analyzed for water quality, VOCs, tritium, gross alpha, gross beta, gamma spectroscopy and, as required, for strontium-90.

5.7 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 (SAR, November 1988). The range is also occasionally used by federal law enforcement agencies and the Brookhaven Employees Recreation Association (BERA).

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 (Figure 26). BNL utilized this same location as a practice range from 1963 until the present facility was constructed in 1986. Prior to 1963, the Police Group trained at a former Army (Camp Upton era) rifle range located north of Route 25. The small arms and grenade ranges are co-located, side-by-side, and have a combined area of 87,516 square feet (Figure 27). The bullet stop (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 (BNL, 1997c - Live-fire Range Report). The soil of the rear berm is, therefore, 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.

Potential Groundwater Vulnerability

There is a potential that the use of lead bullets at the BNL Live-Fire Range could cause soil contamination and potentially impact groundwater quality. Although the berm is screened for spent bullets on an annual basis, some amount of the bullets may be missed. Lead could leach into the soils as it is exposed to rain water that is typically slightly acidic. Lead can also be imparted directly onto soils as bullets impact with sand grains (typically silica sands). However, most bullets used at the range in recent years were either teflon© coated or copper jacketed, which reduces potential direct contamination or leaching of lead from the spent rounds. Furthermore, the use of CS grenades are thought to have a low probability to impact groundwater. The grenades are infrequently used, and while there is some residual chemical noticed on the soils, the active component, otho-chlorobenzalmalononitrile ($C_{10}H_5ClN_2$) has a low solubility in water.

General Hydrogeology

The predominant groundwater flow direction in the Live Fire and Grenade Range area is to the east (Figures 6, 7, and 26). The depth to groundwater in the range area is generally less than 10 feet below land surface. Information from recent borings in the Live Fire Range and STP area indicates that the near surface geology is highly variable. It is possible that portions of the range may be underlain by low permeability deposits consisting of fine sand, silt and clay, while other sections are underlain by more permeable fine to medium sands.

Current Groundwater Monitoring Program

Presently, there are no groundwater monitoring wells located directly downgradient of the Live Fire and Grenade Range. Existing monitoring well 39-05, located approximately 500 feet to the east of the range, is the closest downgradient monitoring well (Figure 26). Although metals analyses conducted since 1990 do not indicate elevated lead levels, well 39-05 is not properly positioned to monitor potential effects of the range.

Proposed Groundwater Monitoring Upgrades

The installation of monitoring wells downgradient of the Live Fire and Grenade Range would provide a means of verifying that the facility is not impacting groundwater quality. Since the shallow aquifer system can supply water to the Peconic River during periods of high water table levels, verification of groundwater quality near the Live Fire Range is important. During FY 1999, two shallow Upper Glacial aquifer wells (MW-LFR-01 and MW-LFR-02) will be installed directly downgradient of the range (Figure 26, Table 4). Depending upon the depth to groundwater and geology, the wells will be installed close to the water table, and completed with either five foot or ten foot screens.

Once installed, the wells will be monitored by the ES&H Services Division as part of the EM Program (Table 5). For the first year, the wells will be sampled on a quarterly basis. The samples will be analyzed for metals. Metals data from wells located near the STP sand filter beds will be used to provide information on background (upgradient) metals concentrations. If the initial samples indicate low or non-detectable levels of lead, the sampling frequency may be reduced to twice per year.

5.8 Shotgun Range

The BNL shotgun range is utilized for (clay) trap and skeet target shooting by the BERA (Figure 28). 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. Clay targets are thrown south from the trap house into an open field that is approximately 205 feet east-west by 410 feet north-south (Figure 29). 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. The type of shotgun shells used at the facility typically contain lead pellets with 2 to 3 percent antimony. It is estimated that as many as 30,000 shotgun rounds per year have been used at the range (BNL, 1992). At an average of 1.125 oz. per round, as much as 2,100 pounds of lead may be deposited on the surface of the range annually.

Potential Groundwater Vulnerability

Nationally, the use of lead shot for hunting game and its use at skeet ranges has resulted in soil and sediment contamination, and in some cases has affected groundwater quality. Similarly, the use of lead shot at the BNL shotgun range has resulted in the deposition of considerable amounts of lead, which has the potential to impact groundwater quality. In an effort to determine the potential impact to soils, a composite soil sample was collected from 17 sites within the target area of the shotgun range (Lee, 1997a; Lee, 1997c). The soil samples contained lead at a concentration of 96 mg/kg. While the lead content was well below the SCDHS cleanup criteria of 400 mg/kg, the sample was a composite and there may be areas with higher individual lead concentrations. Also of significant importance is the fact that the BNL shotgun range area is likely to be within the source water zone contribution for BNL potable supply well 12.

General Hydrogeology

The predominant groundwater flow direction in the shotgun range area is to the south-southeast (Figure 28). However, flow directions downgradient of the range can be influenced by the operation of potable supply wells 11 and 12, and flow can be more to the south during certain periods of operation. The depth to groundwater in the shotgun range areas is approximately 50 feet below land surface, and the area is underlain by predominantly fine to medium-grained sands and fine gravel.

Current Groundwater Monitoring Program

The current groundwater surveillance well network at the BNL shotgun range consists of two shallow Upper Glacial aquifer wells (Figure 28). One well (46-01) is located upgradient of the shotgun range, and the second well (56-06) is located to the south (nominally downgradient) of the range. Although initially intended to examine variations in groundwater flow patterns related to supply well pumping, the ES&H Services Division began sampling the wells in 1997 to determine lead levels in the groundwater. However, because groundwater flow is predominantly to the south-southeast, well 56-06 is not optimally positioned to properly monitor the shotgun range. Metals analyses performed on samples from the monitoring wells as well as from potable supply wells 11 and 12 have not indicated detectable levels of lead.

Proposed Groundwater Monitoring Upgrades

During FY 1999, two shallow Upper Glacial aquifer wells (MW-SGR-01 and MW-SGR-02) will be installed at the downgradient margin of the shotgun range (Figure 28, Table 4). The wells will be installed with fifteen foot screens that are positioned from five feet above to ten feet below the water table. Once installed, the two new wells and existing upgradient well 46-01 will be monitored by the ES&H Services Division as part of the EM Program (Table 5). For the first year, the wells will be sampled on a quarterly basis, and the samples will be analyzed for metals. If the initial samples indicate low or non-detectable levels of lead, the sampling frequency for the Shotgun Range wells may be reduced to twice per year.

5.9 Major Petroleum Facility (MPF)

The Major Petroleum Facility (MPF) is the holding area for fuels used at the Central Steam Facility (Figure 30). Fuel oil for the CSF 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 1.7 million gallons of #6 fuel oil and 660,000 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 a NYSDEC permit (Permit #1-1700), and as required by law, a Spill Prevention Control and Countermeasures Plan has been developed for the facility (BNL, 1997d).

Potential Groundwater Vulnerability

Presently, 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 which requires monthly sampling for free product, as well as semi-annual sampling for volatile organic compounds.

Most spills of consequence are likely to occur within the bermed containment areas. The clay liners within the containment berms are designed to prevent petroleum product from entering the soils. However, the underside of the tanks are supported by concrete ringwalls and are not lined with clay. Outside of a complete dislodgement of the tank from its foundation, however, leakage through the containment system would primarily be limited to the liner-ring wall interface or leakage from the base of a tank. If sizable, these types of leaks would be evident through noticeably rapid changes in product level in the tank. Otherwise, minor leakage might continue unabated until aquifer impacts were realized in the groundwater monitoring wells. Since antecedent moisture in the vadose zone beneath the tanks is constrained to a large extent by the liner system, a certain volume from these minor leaks would be stored in the unsaturated soils, until field capacity is reached.

General Hydrogeology

The predominant groundwater flow direction in the MPF area is to the south (Figures 6, 7, and 30). However, groundwater flow in the area can be more to the southwest during periods of recharge of AGS secondary cooling water at Basin HO (located 1,500 feet to the northeast) and the recharge of air stripper or granular activated carbon treated water at the RA V Recharge Basin (located 1,000 feet to the east). Furthermore, the operation of the OU IV Air Sparging/Soil Vapor Extraction System may cause additional small-scale effects on groundwater flow in the eastern portion of the MPF area. The depth to groundwater in the MPF area is approximately 40 feet below land surface, and the area is underlain by predominantly medium to coarse-grained quartz sand.

Current Groundwater Monitoring Program

The present surveillance well network at the MPF consists of one upgradient and four downgradient wells that are screened across the water table (Figure 30). The downgradient wells were installed in 1989 as part of the original NYSDEC licensing requirements for this facility. The southerly direction of groundwater flow at the MPF serves as the basis for the placement of the present array of groundwater monitoring wells: Wells 76-16 and 76-17 generally monitor tank batteries on the west side of the facility, whereas Wells 76-18 and 76-19 monitor the more easterly group of tanks (see Figure 30). Well 76-25 functions as the upgradient observation point for ambient water quality.

The five MPF wells are routinely monitored by the ES&H Services Division for both floating and dissolved product. The monitoring program includes sampling the wells two times a year for dissolved phase product. The samples are analyzed by an independent New York State certified laboratory using EPA Method 625. Split samples are also analyzed by the ES&H Services Division's ASL for VOCs, metals and water quality. The MPF wells, which are screened across the water table, are also monitored for floating petroleum products on a monthly basis. Groundwater surveillance conducted to date has indicated no floating product or dissolved contamination that is attributable to the MPF.

Proposed Groundwater Monitoring Upgrades

During FY 1999, the present surveillance well network will be supplemented with three additional shallow Upper Glacial aquifer wells (MW-MPF-01, MW-MPF-02, and MW-MPF-03). These wells, will fill in several of the present monitoring gaps in areas downgradient of the bulk storage tanks (Figure 30, Table 4). The wells will be screened from five feet above to ten feet below the water table, to allow for the detection of floating petroleum products. Once installed, the network of eight wells will be monitored by the ES&H Services Division two times a year for dissolved phase product, with the samples being analyzed by an independent New York State certified laboratory using EPA Method 625 (Table 5). Split samples will also be analyzed by the ES&H Services Division's ASL for VOCs. The wells will also be monitored for floating petroleum products on a monthly basis.

5.10 Biology Department Greenhouses

The Biology Department facility (Building 463) includes 11 greenhouses where various types of plants are grown for biological research (Figure 31). Eight of the greenhouses have dirt floors and three presently have concrete floors.

Potential Groundwater Vulnerability

Pesticides, such as Endosulphan II, and fertilizers have been routinely used in the greenhouses. Records also indicate that copper sulfate was also applied to the dirt floors on an annual basis up to 15 years ago (BNL, 1997c). High levels of Endosulphan II has been detected in soil samples collected from a dry well located within Greenhouse 10. A comprehensive sampling of the soils in the greenhouses has not been conducted, and it is likely that other pesticides have been used over the operational history of the facility.

General Hydrogeology

The predominant groundwater flow direction in the Biology Department greenhouse area is to the southeast (Figures 6, 7, and 31). The depth to groundwater in the greenhouse area is approximately 50 feet below land surface, and the area is underlain by predominantly medium to coarse-grained quartz sand.

Current Groundwater Monitoring Program

There are no groundwater monitoring wells located directly downgradient of the Biology Department Greenhouses. Existing wells located south of the greenhouses are either located too far away or not in the proper groundwater flow pathway to adequately monitor this facility. Process well 9 is located at the southern end of Greenhouse area (Figure 31). The well, which is used by the Biology Department for filling fish tanks, is screened 65 to 70 feet below the water table. Although TCA is routinely detected in water samples from supply well 9, it is likely to have originated from identified TCA source areas located upgradient of the Biology Department such as spill sites located in the Alternating Gradient Synchrotron (AGS) research and support areas and former Building T-111 (Naidu *et al.*, 1996; Schroeder *et al.*, 1998). Although water samples from well 9 have not been analyzed for pesticides, it is unlikely that potential contaminants from the green houses would be detected because the well is screened 65 feet below the water table and is pumped at very low rate.

Proposed Groundwater Monitoring Upgrades

During FY 1999, two shallow Upper Glacial aquifer wells (MW-BIO-01 and MW-BIO-02) will be installed at the downgradient of the greenhouse area, with one well located directly downgradient of the drywell located in Greenhouse 10 (Figure 31). The wells will be installed with fifteen foot screens that are positioned from five feet above to ten feet below the water table (Table 4). Once installed, the two new wells will be monitored by the ES&H Services Division as part of the EM Program (Table 5). For the first year, the wells will be sampled on a quarterly basis. The samples will be analyzed by a NYS DOH certified contractor laboratory for pesticides using EPA Method 608, and by the ES&H Services ASL for metals and water quality parameters. If the initial samples indicate low or non-detectable levels of pesticides and metals, the sampling frequency for the greenhouse area wells may be reduced to once or twice per year.

5.11 Motor Pool and Site Maintenance Area

The Motor Pool (Building 423) and Site Maintenance facility (Building 326) are attached structures located along West Princeton Avenue (Figure 32). The BNL 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 lunch room facilities for custodial, grounds and heavy equipment personnel. Both facilities have been used continuously since 1947.

Potential Groundwater Vulnerability

Potential environmental concerns at the Motor Pool include the historical use of USTs for the storage of gasoline and waste oil, hydraulic fluids used for lift stations, and the use of solvents for parts cleaning. In August 1989, the USTs, pump islands and associated piping were upgraded to 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 (BNL, 1997e). The present tank inventory includes two 8,000 gallon-capacity USTs used for the storage of unleaded gasoline, one 260 gallon-capacity AST used for waste oil, and one 3,000 gallon-capacity UST for Number 2 fuel oil. The facility also has five vehicle lift stations. The hydraulic fluid reservoirs for the lifts are located above ground and have secondary containment. However 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 found to be contaminated with hydraulic oil. Approximately 50 cubic yards of what appeared to the most contaminated soils were removed (DeBobes, 1998). Although analysis of post excavation soil samples confirmed the presence of residual contamination (810 µg/kg of unspecified lubricating oil), hydraulic oil products were not detected in groundwater samples collected from a Geoprobe™ well located approximately 10 feet downgradient of the lift area (DeBobes, 1998).

The only environmental concern associated with the Site Maintenance facility (Building 326) is the discovery of a historic oil spill directly south of the building (Figure 32). During the removal of an underground propane tank in December 1996, the surrounding soils were noticed to have clear petroleum staining and smell (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 (Lee, 1997b; Casey, 1998, DeBobes, 1998). In an effort to investigate the extent of residual contamination, five Geoprobe™ wells were installed to collect soil samples, and three of the wells were also used to collect groundwater samples (see below).

General Hydrogeology

The predominant groundwater flow direction in the Motor Pool area is to the south (Figures 6, 7 and 32). The depth to groundwater is approximately 50 feet below land surface, and the area is underlain by predominantly medium to coarse-grained quartz sand.

Current Groundwater Monitoring Program

In 1996, two wells (102-05 and 102-06) were installed downgradient of the gasoline UST and pump island area to provide a means of verifying groundwater quality (Figure 32). During CY 1997, TCA was detected in UST area well 102-06 at concentrations slightly exceeding the NYS AWQS of 5 µg/l, with a maximum observed concentration of 8 µg/l. Methyl tertiary butyl ether (MTBE) was also detected in well 102-06 at a maximum concentration of 7.4 µg/l. The NYS AWQS for MTBE is 50 µg/l. The TCA probably originated from the historical use of degreasers as part of vehicle repair operations. MTBE is currently widely used as an additive for unleaded gasoline as an antiknock agent.. It was first introduced as a gasoline additive in 1977 (Stout *et al*., 1998). Therefore, the MTBE detected in samples from well 102-06 may have originated from minor gasoline releases prior to the 1989 upgrade of the USTs. No other gasoline breakdown products have been detected (i.e., benzene, xylenes, ethylbenzene, and toluene). Both wells are also checked for the presence of floating product. No floating products have been observed.

There are no permanent groundwater monitoring wells located directly downgradient of either the hydraulic oil leak in Building 423 or the fuel oil spill area south of Building 326. At Building 423, one Geoprobe™ well was installed directly downgradient of the vehicle lift station. No hydrocarbon breakdown products were detected in the groundwater sample (DeBobes, 1998). Geoprobe™ wells were also installed both upgradient and downgradient of the Building 326 spill area. Although no hydrocarbon breakdown products were detected in the groundwater sample, the solvent TCA was detected at a concentration of 65 µg/l in one of two downgradient Geoprobe wells. TCA was not detected in soils collected at the spill area.

Proposed Groundwater Monitoring Upgrades

In an effort to better improve BNL's ability to monitor groundwater quality in at the Motor Pool and Site Maintenance Facility, one upgradient (MW-MTP-01) and four downgradient wells (MW-MTP-02 through 05) will be installed during FY 1998 (Figure 32, Table 3). The wells will be installed with fifteen foot screens that are positioned from five feet above to ten feet below the water table. In response to a NYSDEC request, one well (MW-MTP-02) will be installed directly downgradient of the Building 423 vehicle lift station, and well MW-MTP-04 will be installed directly downgradient of the fuel oil spill site, at the same location of the previously installed Geoprobe™ well in which TCA was detected at 65 µg/l (DeBobes, 1998; Acampora, 1998). Once installed, the new wells will be monitored on a quarterly basis by the ES&H Services Division as part of the EM Program (Table 5). The wells will be monitored quarterly for VOCs and semi-volatile organic compounds, semiannually for metals, and monthly for floating product.

5.12 Service Station

Building 630 is a commercial automobile service station which is privately operated under a contract with BNL (Figure 33). The station, which was built in 1966, is used for automobile repair and gasoline sales.

Potential Groundwater Vulnerability

Potential environmental concerns at the Service Station include the historical use of USTs for the storage of gasoline and waste oil, hydraulic fluids used for lift stations, and the use of solvents for parts cleaning. 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 may leaked from one of the USTs (ITC, 1993). There are no records of remedial actions other than replacement of the tank.

In August 1989, the 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 (BNL, 1997e). 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. The hydraulic fluid reservoirs for the lifts are located above ground and have secondary containment.

General Hydrogeology

The predominant groundwater flow direction in the Motor Pool area is to the south (Figures 6, 7 and 33). The depth to groundwater is approximately 40 feet below land surface, and the area is underlain by predominantly medium to coarse-grained quartz sand.

Current Groundwater Monitoring Program

In 1996, two wells (85-16 and 85-17) were installed downgradient of the gasoline UST and pump island area to provide a means of verifying groundwater quality (Figure 33). During CY 1997, tetrachloroethylene (PCE) was detected in both wells at concentrations exceeding the NYS AWQS of 5 µg/l, with a maximum observed concentration of 12 µg/l. Carbon tetrachloride and MTBE were also detected in well 85-17 at a maximum concentrations of 6.5 µg/l and 18.6 µg/l, respectively. The NYS AWQS for carbon tetrachloride is 5 µg/l, whereas MTBE is 50 µg/l. Well 85-17 is located approximately 100 feet downgradient of the UST area. The PCE probably originated from the historical use of degreasers as part of vehicle repair operations. MTBE is currently widely used as an additive for unleaded gasoline as an antiknock agent. It was first introduced as a gasoline additive in the late 1977 (Stout *et al.*, 1998). Therefore, the MTBE detected in samples from well 86-17 may have originated from gasoline releases prior to the 1989 upgrade of the USTs. No other gasoline breakdown products have been detected (i.e., benzene, xylenes, ethylbenzene, and toluene). Both wells are also checked for the presence of floating product. No floating product has been observed.

Proposed Groundwater Monitoring Upgrades

In an effort to better improve BNL's ability to monitor groundwater quality near the service station's UST area, one upgradient (MW-630-01) and two downgradient wells (MW-630-02 and MW-630-03) will be installed during FY 1999 (Figure 33, Table 4). The wells will be installed with fifteen foot screens that are positioned from five feet above to ten feet below the water table, to allow for the detection of floating petroleum products. Once installed, the new wells together with the existing wells, will be monitored on a quarterly basis by the ES&H Services Division as part of the EM Program (Table 5). The wells will be monitored for on a quarterly basis for VOCs, semi-VOCs, metals, and floating product.

6.0 Well Installation Methods and Schedule

The groundwater monitoring wells installed as part of this plan shall be constructed in accordance with the BNL "Technical Guide for the Installation of Monitoring Wells and Piezometers" (BNL, 1996b). This specification is consistent with the well installation guidelines required by the USEPA and the NYSDEC for both CERCLA and RCRA groundwater investigations. Since most of the wells installed under this plan will be located in close proximity to suspected source areas, the wells will be screened across the water table. In hydrocarbon storage areas, wells must be screened across the water table to allow for the monitoring of floating product as water table positions fluctuate during the year. Additionally, recent data collected during detailed tritium plume investigations at the HFBR and BLIP facilities indicate that the highest tritium levels will occur close to the water table in wells located directly downgradient of the source area. The small distance traveled and lack of density differences between tritium and fresh water are the likely cause. Therefore, wells in other suspected source areas (e.g., the AGS and RHIC facilities) will also be screened across the water table.

Once installed the wells will be surveyed by a N.Y. State licensed surveyor from the BNL Plant Engineering Division to determine their correct vertical and horizontal positions. All new wells will be surveyed, using the BNL bench mark control system, to a horizontal accuracy of 0.50 feet and to a vertical accuracy of 0.01 feet.

The proposed monitoring well installation schedule is presented in Tables 3 and 4. It is anticipated that the first phase of monitoring well installations, using FY 1998 funding and consisting of 49 new wells, will begin by mid October 1998. The second phase of well installations, using FY 1999 funding and consisting of 32 new wells, should begin by December 1999. Additional wells may be added to the FY 1999 schedule as a third phase of this project following: 1) the evaluation of the initial sample results and identification of gaps in the monitoring program; 2) the identification of potential groundwater vulnerabilities at other active BNL facilities; and 3) at the request of regulatory agencies.

7.0 EM Groundwater Sampling Schedule for CY 1998 and 1999

The proposed monitoring well sampling schedule for the EM Program is presented in Table 5. This schedule includes both new wells installed as part of this Plan and existing wells. It is anticipated that sampling of some of the new wells (in the AGS Complex) will begin by late-October 1998.

8.0 Sample Collection and Analysis

All permanent groundwater monitoring wells installed for the EM program will be sampled by the ES&H Services Division using Standard Operating Procedure EM-SOP-25. Each new well will be completed with a new dedicated Geoguard® bladder purge pump (Master-Flo Model 57200M - constructed of NSF rated PVC and Teflon®). Dedicated pumping systems eliminate the need to decontaminate pumps between well sampling events, and prevent potential cross contamination problems if the same pump is used in multiple wells.

The wells will be sampled in accordance with the schedule presented in Table 5. Typically, all VOC (EPA Method 624), gross alpha and beta (Method 900), gamma spectroscopy (Method 901.1), and tritium (Method 906), metals (EPA 200 series) and water quality analyses (EPA Method 300) are performed by the ES&H Services Division's Analytical Services Laboratory (ASL). Other analyses such as strontium-90 (Method 905) and pesticides/PCBs (Method 608) will be performed by NYS DOH certified contractor laboratories.

The ASL is certified by the New York State Department of Health Services for each of the analyses performed. The ASL also participates in the DOE Environmental Measurements Laboratory (EML) QA Program and the EPA National Exposure Research Laboratory Performance Evaluation Study. All contractor labs used for groundwater analyses are also NYSDOH certified. The BNL ASL and contractor labs have established standard operating procedures to calibrate instruments, analyze samples, and check quality control. Depending upon the analytical method, quality control checks include the analysis of blanks or background concentrations, use of Amersham or National Institute for Standards and Technology (NIST) traceable standards, and analysis of reference standards, spiked samples, and duplicate samples. All analytical results are reviewed by BNL ASL supervisors for completeness and accuracy. Quality assurance procedures for the EM Program are described in detail by Schroeder *et al*. (1998).

8.1 Data Quality Objectives

Data Quality Objectives (DQOs) are the statements specifying the quality of data needed to support decisions relative to various stages of environmental surveillance or remedial actions. They are based upon the concept that different data uses require different levels of data quality with respect to the precision, accuracy, and completeness of the data. DQOs must be in place to ensure that the data obtained from the groundwater monitoring program are of sufficient quality, are scientifically defensible, and have the requisite levels of precision and accuracy to support any decisions regarding the assessment of potential impacts of facility operations on groundwater quality. The US EPA (1994) developed a six step DQO evaluation process which is intended to clarify monitoring program objectives, define data needs, and determine data precision and tolerance levels to support decision making. The seven steps are: 1) describe the problem to be studied; 2) identify the decision by determining questions to be answered and actions that may result; 3) identify the data inputs to the decision; 4) define study boundaries; 5) develop a decision rule that describes the logical basis for choosing alternative actions; 6) specify tolerable limits on decision errors; and 7) optimize the data collection process design by evaluating information gathered during steps 1 through 6. Although the information and proposed groundwater monitoring improvements provided in Section 5.0 of this plan satisfy a number of these DQO steps, a more rigorous facility-by-facility review must be performed to establish appropriate decision rules and decision errors for the BNL groundwater surveillance program.

As noted in Section 8.0, all analyses are performed using standardized US EPA methods, and all data generated as part of the EM Program have full quality control documentation and data validation conducted by BNL and/or contractor personnel using standardized USEPA protocols. Quality assurance procedures for the EM Program are described in detail by Schroeder *et al*. (1998).

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