ATSDR
AGENCY FOR TOXIC SUBSTANCES
AND DISEASE REGISTRY

Public Health Assessment for

BROOKHAVEN NATIONAL LABORATORY
UPTON, SUFFOLK COUNTY, NEW YORK
EPA FACILITY ID: NY7890008975
SEPTEMBER 30, 2005

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
Agency for Toxic Substances and Disease Registry

Comment Period Ends:

NOVEMBER 15, 2005

THE ATSDR PUBLIC HEALTH ASSESSMENT: A NOTE OF EXPLANATION

This Public Health Assessment-Public Comment Release was prepared by ATSDR pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6), and in accordance with our implementing regulations (42 C.F.R. Part 90). In preparing this document, ATSDR has collected relevant health data, environmental data, and community health concerns from the Environmental Protection Agency (EPA), state and local health and environmental agencies, the community, and potentially responsible parties, where appropriate. This document represents the agency's best efforts, based on currently available information, to fulfill the statutory criteria set out in CERCLA section 104 (i)(6) within a limited time frame. To the extent possible, it presents an assessment of potential risks to human health. Actions authorized by CERCLA section 104 (i)(11), or otherwise authorized by CERCLA, may be undertaken to prevent or mitigate human exposure or risks to human health. In addition, ATSDR will utilize this document to determine if follow-up health actions are appropriate at this time.

This document has previously been provided to EPA and the affected state in an initial release, as required by CERCLA section 104 (i) (6) (H) for their information and review. Where necessary, it has been revised in response to comments or additional relevant information provided by them to ATSDR. This revised document has now been released for a 30-day public comment period. Subsequent to the public comment period, ATSDR will address all public comments and revise or append the document as appropriate. The public health assessment will then be reissued. This will conclude the public health assessment process for this site, unless additional information is obtained by ATSDR which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.

Agency for Toxic Substances and Disease Registry	Julie L. Gerberding, M.D., M.P.H., Administrator Howard Frumkin, M.D., Dr.P.H., Director
Division of Health Assessment and Consultation	William Cibulas, Jr., Ph.D., Director Sharon Williams-Fleetwood, Ph.D., Deputy Director
Health Promotion and Community Involvement Branch	Lisa Calhoun Hayes, P.E, DEE, Acting Chief
Exposure Investigations and Consultation Branch	Susan M. Moore, Ph.D., Chief
Federal Facilities Assessment Branch	Sandra G. Isaacs, B.S., Chief
Superfund and Program Assessment Branch	Richard E. Gillig, M.C.P., Chief

Please address comments regarding this report to:

Agency for Toxic Substances and Disease Registry
Attn: Division of Health Assessment and Consultation (E-60)
1600 Clifton Road, N.E., Atlanta, Georgia 30333

You May Contact ATSDR TOLL FREE at
1-888-42ATSDR or
Visit our Home Page at: http://www.atsdr.cdc.gov

ATSDR and the Public Health Assessment Process at Department of Energy Facilities

The Agency for Toxic Substances and Disease Registry (ATSDR) is part of the U.S. Public Health Service. ATSDR's mission is to prevent or mitigate adverse human health effects and diminished quality of life resulting from exposure to hazardous substances in the environment. ATSDR has no regulatory authority; it does, however, recommend public health actions that address potential adverse health effects resulting from environmental releases from hazardous waste sites.

The public health assessment is the principal means by which ATSDR addresses public health issues. The document discusses available information about site-related hazardous substances and evaluates whether exposure to them — in the past, present, or future — might cause adverse health effects in members of the community.

ATSDR is responsible for preparing public health assessments, according to the Comprehensive Environmental Response, Compensation, and Liability Act, as amended, (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6). As mandated by that law, ATSDR conducts public health assessments of hazardous waste sites listed or proposed for listing on the U.S. Environmental Protection Agency's (USEPA) National Priorities List (NPL). ATSDR also responds to requests (petitions) to conduct public health assessments.

Three primary sources of information are used in a public health assessment: environmental data, community health concerns, and health outcome data. ATSDR does not routinely perform environmental sampling. The environmental data used in public health assessments are provided by the Department of Energy (DOE) component involved; by the USEPA, by state and local environmental and health agencies, and by other groups or individuals. In addition, ATSDR health assessors conduct site visits to observe firsthand current conditions at the site, land use, public accessibility, and demographic characteristics of the nearby community.

Other sources of community health concerns are records from the installation's Public Affairs Office, USEPA’s community relations representative, and state and local health and environmental agencies.

Health outcome databases document health effects that occur in populations. Those data, which come from sources such as state tumor registry databases, birth defects databases, vital statistics records, or other records, might provide information about the general health of the community living near a site. Other, more specific records, such as hospital and medical records and records from site-specific health studies, might also be used. Analysts use demographic data that provide information on population characteristics (e.g., age, sex, and socioeconomic status) when they analyze health outcome data.

ATSDR representatives identify actual and perceived site-related health effects and the level of public health hazard posed by the site. ATSDR staff members then make recommendations to the appropriate DOE components, to USEPA, and to relevant state and local agencies on

PUBLIC HEALTH ASSESSMENT

BROOKHAVEN NATIONAL LABORATORY
UPTON, SUFFOLK COUNTY, NEW YORK
EPA FACILITY ID: NY7890008975

Prepared by:

Energy Facilities Section
Federal Facilities Assessment Branch
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry

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preventing or alleviating human exposures to site-related contaminants. When circumstances warrant, ATSDR identifies a need for any follow-up health activities, such as epidemiologic studies, registries, or community health education. Finally, ATSDR provides a mechanism to re-evaluate health issues as site conditions change (e.g., after site remediation or changes in land use) or when new data or information are available.

The public health assessment includes a public health action plan (PHAP). The PHAP contains a description of actions ATSDR and other parties will take at and in the vicinity of the site. The purpose of the PHAP is to provide a plan of action for preventing and mitigating adverse human health effects resulting from exposure to hazardous substances in the environment. ATSDR monitors the implementation of the plan annually. Public health actions might include, but are not limited to, restricting site access, sampling, surveillance, registries, health studies, environmental health education, and applied substance-specific research.

Public health assessments are distributed in three phases: an initial release (red cover), a public comment release (brown cover), and a final release (blue cover). The initial release document, which is prepared as part of the process of gathering, analyzing, and drawing conclusions and recommendations from the vast amount of information evaluated in a public health assessment, is provided for review and comment to the DOE component involved, to USEPA, and to state and local environmental and health agencies. The red cover release gives agencies the opportunity to comment on the completeness of information they have provided and the clarity of the presentation. The initial release comment period lasts 45 days. Following the initial release, ATSDR prepares the document for distribution to the general public.

The public is notified of the document's availability at repositories (e.g., libraries and city halls) in the site area through advertisements and public notices in newspapers. The comment period lasts 30 days. ATSDR addresses all public comments and revises or appends the document as appropriate. The final public health assessment is then released; that document includes written responses to all public comments.

A public health assessment is an ongoing process. ATSDR revises final documents if new information about the environment, community health concerns, and health outcome data becomes available and is found to modify previous conclusions and recommendations. For more information about the ATSDR public health assessment process and related programs, please write to the following address:

Director

Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry
1600 Clifton Road (E-32)
Atlanta, Georgia 30333

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Document Notes

This public health assessment addresses potential off-site exposures to radioactive and non-radioactive substances released from the Brookhaven National Laboratory (BNL). With the exception of on-site potable wells, the assessment does not address on-site exposures of BNL workers to radioactive or hazardous materials. Workers may be expected to be exposed at higher levels than the general public to radioactive and hazardous materials that have been used at the site. Workers should be trained in the use and safe handling of hazardous materials, and their exposures should be monitored. Current DOE internal regulations require all DOE facilities to meet worker safety and health standards developed by the Department of Labor, Occupational Safety and Health Administration (OSHA).

During the 1940s and the 1950s air monitoring of the reactor emission stacks was not performed with the sophistication that improved instrumentation allowed for during the 1960s, 1970s, and through the present day. BNL representatives retrieved old log books and estimated the amount of radioactive material released as a result of the 28 fuel ruptures that occurred during this time frame. The document entitled “Radiological Emissions and Environmental Monitoring for Brookhaven National Laboratory, 1948-1961” was the result of their efforts. Similar ruptures had occurred at the Oak Ridge Reservation, and an attempt was made to correlate the two.

Also, this public health assessment does not explicitly address exposures to hazardous materials of visitors to the Brookhaven National Laboratory. ATSDR does not think that visitors have been, or will be, exposed to hazardous or radioactive materials at levels of health concern.

At the end of this document ATSDR has included a glossary of terms frequently used by public health officials. Not all the terms in the glossary are used in this public health assessment. The glossary was prepared by ATSDR for many purposes. It is included in this document to help readers become familiar with the terminology used.

Summary

The Brookhaven National Laboratory (BNL), located on Long Island, New York, is a Department of Energy (DOE) facility that has been in operation since 1947. Activities at BNL include research in the fields of physics, chemistry, biology, materials science, and medicine. The disposal of waste from some of these operations was not always done by today’s standards and, as a result, various environmental media (soil, water, air, and biota) were contaminated. The contamination led in December 1989 to the USEPA listing the site on the National Priorities List (NPL).

Soil

As the result of accidental spills, leaking sewer lines, and the disposal of radioactive and chemical materials into unlined pits and landfills, soil contamination has occurred in many areas on site. Soil contamination has not occurred in off-site areas. Many of the areas that were contaminated have been remediated. The Former and Current Landfills have been capped. The remaining areas of contamination are fenced or are buried deep below the surface, as is the case

with the Brookhaven Graphite Research Reactor (BGRR). Thus only workers remediating the soils have the potential of being exposed to the contaminants. Remediation workers are expected to wear protective gear and are expected to be trained in the removal of contaminated soil as documented in the worker health and safety plan for the site. Adverse health effects resulting from their limited exposure to contaminated soils are not expected.

Groundwater

Many of the materials disposed of in unlined pits and landfills have traveled through the soil and reached the groundwater beneath BNL. In addition, the groundwater is contaminated as a result of past storage practices and spills from the Former Hazardous Waste Management Facility, from spills at the Central Steam Facility, from discharges to cesspools, from the use of a pesticide in the Biology Fields, and from a leak from the spent fuel pool at the High Flux Beam Reactor. Monitoring by the DOE and the Suffolk County Department of Health Services (SCDHS) has indicated the presence of multiple contaminant plumes on site, five of which (two plumes commingled) have flowed off site, and two that originated off site. Both plumes that originated off site contaminated area residential wells. One of the plumes that originated off site was attributed to an industry in the Brookhaven R & D Industrial Park, the other to a gasoline station located at the intersection of Moriches Middle Island Road and William Floyd Parkway.

The groundwater monitoring data that have been collected indicate that the highest contaminant concentrations at on-site locations are between depths of 30 to 50 meters (m), with maximum concentrations at about 50 m below ground level (bgl) at the site boundary (BNL/ERD 1998). Monitoring was completed for approximately 675 residential wells in the areas of North Shirley, Shirley, East Yaphank, and Manorville. Monitoring results indicated that some of the wells contained levels of volatile organic compounds (VOCs) and a pesticide above the federal and New York State drinking water standards. The radionuclides strontium-90, radium-226, and tritium have also exceeded drinking water standards in on-site monitoring wells, but not in any of the off-site monitoring or residential wells. DOE offered residents in the potentially affected areas the option of connecting residences to the public water supply. DOE, in conjunction with the Suffolk County Water Authority, connected approximately 1,500 residences and commercial properties to the public water supply. Seven residents declined the hookup and continue to use their private wells (BNL, August 2004). These private wells have not been affected by the contaminant plumes and DOE has offered free testing on an annual basis to ensure that they have not been affected.

The levels of trichloroethylene, carbon tetrachloride, perchloroethylene, strontium-90, tritium, and 1,1,1-trichloroethane in some of the monitoring wells could cause adverse health effects if someone was exposed. These wells are not, however, used for potable (i.e., suitable for drinking) purposes. The levels detected in residential wells are much lower and are not expected to cause adverse health effects.

High concentration pulses have migrated down gradient for several plumes. Although these pulses present the potential for historical contaminant concentrations that exceed recently measured values, monitoring data and the results of our analysis indicate that the high concentration zones are deeper than typical residential well depths. The public water supply is being monitored and has not been affected by the plumes.

Air

Throughout the history of BNL, several reactors have been in operation. Routine air emissions associated with the operation of BNL from 1948 through 1961 were mainly from the Brookhaven Graphite Research Reactor (BGRR). The reactor operated on the use of natural uranium fuel from 1951 to 1957. During this time, 28 ruptures of the fuel cartridges were reported. Each rupture released noble gases, particulates, and radioiodines into the reactor-cooling air stream. ATSDR used computer models to estimate the radiological dose an individual might have received during specific periods of time. ATSDR determined that the combined estimated doses for the years with the highest releases are less than the lifetime dose recommendation of the agency and are not expected to cause any observable or detectable adverse health effects. Current emissions from today’s laboratory facilities are in compliance with their permitted releases and do not pose a health hazard.

Surface Water and Sediments

Although individual samples of the Peconic River had elevated inorganic contaminants (e.g., arsenic, cadmium, lead, manganese, mercury, and thallium), the average annual concentrations were below health screening values. The maximum concentrations detected for organic compounds (toluene 3ppb; total xylenes 3ppb) were below health screening values. Tritium was detected at a maximum concentration of 5,800 picocuries per liter (pCi/L). Any exposure(s) to contaminants in surface water at these levels would not be expected to cause adverse health effects.

The areas of elevated levels of mercury and polychlorinated biphenyls in the sediments of the Peconic River on site and just off site have been removed, and restoration is complete (BNL 2005).

Biota

Fish sampling was conducted since the 1970s, but most samples were only analyzed for radionuclide contamination. Although strontium-90 and cesium-137 levels were elevated compared with background levels, the radiation doses to individuals consuming fish were not at levels that would pose a public health concern. Inorganics, pesticides, and PCBs were only analyzed from 1996-2003. Fish from on-site and off-site Peconic River locations contained elevated levels of PCBs and mercury. Contaminant levels are higher in the fish samples collected from on site and decrease in downstream samples. The Peconic River is an intermittent stream on site and edible-size fish are not likely to be present throughout the year.

The New York State Department of Health (NYSDOH) has issued a fish advisory for fresh waters of Long Island. The advisory states that no one should eat more than one meal of fish per week from any of the state’s fresh waters. Currently, if people adhere to the fish advisory, adverse health effects would not be expected to occur.

Deer sampling confirmed the presence of potassium-40 (a naturally occurring radionuclide), strontium-90, and cesium-137. The NYSDOH estimated the effective dose equivalent (EDE) from consuming contaminated deer meat to be 7.1 millirem (mrem) — lower than the national average EDE (10 mrem) from eating foods containing naturally occurring radionuclides. Therefore, the consumption of deer meat would not result in adverse health effects.

ATSDR believes the site does not currently pose a health hazard because no current, completed exposure pathway(s) to chemicals or radionuclides at levels of public health concern exist. Past airborne radionuclide releases from the various reactors appear to have been large, but the radiological doses are relatively small. The reason for the low doses is based upon the properties of the respective radionuclides that were released. The properties of the radionuclides that were released are either low energy emitters (tritium) or are not absorbed to a great extent in the body (argon-41). Past exposures to groundwater contaminants do not appear to have been at levels that would result in adverse health effects. ATSDR modeled the groundwater contaminant plumes to determine the likelihood of the wells being contaminated prior to them being sampled. Our modeling of the groundwater plumes indicated that the levels of contaminants in the residential wells would not have been above those detected at the time of sampling.

Health Outcome Data

The high incidence of breast cancer on the eastern end of Long Island is a major health concern of residents living near the Brookhaven National Laboratory. In response to their concern, ATSDR reviewed health outcome data pertaining to studies being conducted on breast cancer and the incidence rates of breast cancer and other forms of cancer.

ATSDR staff reviewed several studies of breast cancer in the northeastern United States. A study conducted by the National Cancer Institute (NCI) looked at demographic data and age-specific breast cancer mortality rates for women in 11 northeastern states and the District of Columbia for 1988-1992. Results indicated that the increased breast cancer mortality on Long Island was statistically significant and that the increase was not confined to this area but extended into parts of New Jersey and Philadelphia. The New York City-Philadelphia metropolitan area had a 7.4 percent excess compared with the rest of the Northeast, which in turn had a 12.4 percent excess compared with the rest of the country (NCI 1997). The risk factors analyzed in this study included age at first birth, age at menopause, breastfeeding, genetic mutations, and environmental factors.

The Long Island Breast Cancer Study Project (LIBCSP) — the result of Public Law 103-43 — was done to determine whether certain environmental contaminants increased the risk of breast cancer among women in Nassau and Suffolk counties on Long Island. Researchers from the LIBCSP concentrated their research on organochlorine compounds, including the pesticide DDT, its metabolite DDE, and polychlorinated biphenyls (PCBs). This study is one of the largest and most comprehensive environmental epidemiologic studies ever done for breast cancer. Results from the study project indicated no increased rate of breast cancer among women who may have been exposed to organochlorine compounds or PCBs (Gammon 2002).

ATSDR also looked at the following cancers in the health outcome data: liver, prostate, brain and other nervous system, thyroid, Non-Hodgkin’s lymphomas, multiple myelomas, leukemias. ATSDR found that none of these cancers were elevated in Suffolk County compared to the neighboring Nassau County or to the state of New York.

Background

Site Description and History

The Brookhaven National Laboratory (BNL) is a DOE research laboratory that opened in 1947 on the site of the United States Army's former Camp Upton. BNL is located on Long Island, New York, in the geographic center of Suffolk County. The main mission of BNL is basic and applied research in the fields of physics, chemistry, biology, materials science, and medicine. The disposal of wastes from the various research projects was not always done by today's standards. Research conducted at BNL resulted in both chemical and radioactive contamination.

Several reactors have been used throughout the history of BNL operations. The history of BNL reactors began in 1950 with the operation of the Brookhaven Graphite Research Reactor (BGRR). The BGRR was the main source of emissions in the early years of operation (1950–1968). During the operation of the BGRR, 28 ruptures of the fuel cartridges were reported. In 1952, the Cosmotron became operational, and in 1960 the Alternating Gradient Synchrotron (AGS) came on line. The AGS was built to surpass the capabilities of the Cosmotron. In 1970, the Tandem Van de Graaff accelerator became operational.

The High Flux Beam Reactor (HFBR) began operating in 1965 and operated until 1989 when it was shut down to analyze the potential for loss of coolant. It was restarted in 1991 and operated until 1997. In 1997, BNL officials shut the reactor down because of a leak in the spent fuel pool. The HFBR was permanently shut down in 1999. The Laboratory's last operating reactor, the Medical Research Reactor (MRR) was permanently shutdown in 2000.

Many areas of soil, sediment, surface water, groundwater, air, and biota were contaminated on BNL property. As a result, BNL was included on the USEPA's National Priority List on December 21,1989. BNL is required to remediate those areas that are contaminated. To characterize the site and determine which areas have specific problems associated with them, BNL representatives grouped the areas into six operable units (OUs). Figure 1 in Appendix B shows the locations of the OUs on BNL property.

Site Visits

ATSDR staff made several visits to BNL. The initial site visit was conducted in July 1996. During the initial site visit, ATSDR staff viewed the areas of contamination on laboratory property. ATSDR staff made additional visits to view specific areas of the site and to meet with site personnel who are familiar with the various areas of contamination. ATSDR staff returned to BNL in November 1996 to attend a community work group health symposium at the local high school in Yaphank. The staff presented an overview of ATSDR and described its mission regarding the site. Staff members also provided community members with an introduction to radiation and the health effects associated with it.

ATSDR met with residents of the community to gather their concerns regarding contamination at BNL. The community requested that ATSDR prepare health consultations on the groundwater and air pathways and determine if individuals had been, are currently, or could be exposed in the future to any of the contaminants in these media. Health consultations are not as comprehensive as a public health assessment; health consultations are a means of providing advice on a specific public health issue related to real or possible human exposure to toxic material.

ATSDR completed the initial release of the groundwater consultation (October 1997) and recommended that individuals living south of the laboratory who had a private well accept the offer from the Department of Energy to be connected to the public water supply. ATSDR staff presented the final results of the groundwater consultation to the Brookhaven Executive Roundtable on August 24, 1999.

When ATSDR staff began to write the health consultation for the air pathway, they identified a data gap for emissions from the late 1940s until 1961. Without this information, ATSDR could not evaluate exposures to airborne emissions. In response to ATSDR's request for data, BNL staff reviewed old archives (laboratory log books) and interviewed individuals who worked at the site during that time. BNL staff identified what records were available and what materials were used. A final DOE document regarding historical air emissions for the Brookhaven Graphite Research Reactor was completed in May 2001.

The most recent ATSDR site visit, conducted in August 2004, involved ATSDR staff viewing the stretches of the Peconic River that are on site and in the Peconic River County Park just south of BNL boundary. Surface water and sediments are contaminated in the Peconic River on site with metals, organic chemicals, and radionuclides. ATSDR viewed different stretches of the Peconic River to determine the river=s accessibility and flow and to determine the likelihood of exposure to off-site residents. At this time, most of the on-site portion of the Peconic River had been remediated, and the remaining on-site areas were being remediated. Since our last visit, remediation and restoration both on site and off site have been completed.

Demographics, Land Use, and Natural Resources Use

Approximately one-third of the 1.36 million people who reside in Suffolk County live in the Brookhaven Township where BNL is located (LIPA 1998). Eight thousand of these people live within 1 mile of BNL boundary. Figure 9 in Appendix B details the demographics and specific age group statistics within 1 mile of the site (Bureau of Census 2000). Approximately 250–300 people reside in apartments and cottages on site (BNL 2000). The apartments and cottages are located in the western portion of the site. Residence in these on-site facilities is generally short in duration — usually less than 3 months — and rarely more than a year.

BNL comprises 5,263 acres, and approximately one-third of the site is developed. The developed portion of the site is located near the center of the property. Much of the land within 10 miles of the site is either undeveloped or cultivated; however, recent trends have shown an increase in residential housing, and those trends are expected to continue.

The soil on Long Island is very porous; as a result, there is little surface runoff. BNL is part of the upper drainage area of the Peconic River, which is the principal drainage feature of the Manorville drainage basin. The surface drainage is poor in the Manorville drainage basin, and much of the land near the river is swampy. Six wetland areas are on site.

The Peconic River enters BNL property northwest of the Sewage Treatment Plant (STP) outfall and exits the property to the southeast. The discharge from the STP accounts for approximately 90% of the water flow in the Peconic during the spring and almost 100% during the late summer and fall. When the water table is below the bottom of the riverbed the effluent from the STP flows into the Peconic River and into the surrounding aquifer. In the general vicinity of the STP outfall, the Peconic is a gaining stream because it receives groundwater seepage from the surrounding aquifer. The situation reverses as the downstream distance from the STP outfall increases.

Many factors influence groundwater flow beneath BNL. Groundwater in the northeast and northwest sections of the site flows toward the Peconic River. On the western portion of the site, groundwater flow is to the south, and along the southern and southeastern portions of the site, the flow tends to be towards the south to southeast. South of the southwestern boundary, the groundwater flow is southwest because of the influence of the Carmans River. In the southeastern portion of the site, the Peconic River influences the groundwater to flow to the southeast. Figure 4 in Appendix B details the hydrogeologic cross section and groundwater flow directions in the vicinity of BNL (BNL 1997b). Groundwater from BNL site flows predominately southward in the unconfined to semi-confined Upper Glacial aquifer. Although net groundwater transport from BNL is southward, BNL facility overlies a deep flow recharge zone such that initial groundwater flow is downward (ITC 1998b).

Hydrogeologic evaluations of BNL site indicate that near the surface, groundwater flows vertically downward. But as depths increase, groundwater flows in a lateral southerly direction. To determine the vertical extent of the contamination, BNL defined three sampling zones within the Upper Glacial Aquifer and one within the Magothy Aquifer. The Upper Glacial Aquifer zones are (1) the water table from 0 to 50 feet above mean sea level (msl), (2) the mid glacial zone from 0 to 60 feet below msl, and (3) the deep glacial zone from 60 to 150 feet below msl. The Magothy Aquifer sampling zone extends from 150 to 250 feet below msl. A detailed description of the hydrogeology underlying BNL facility and the methods used in the modeling of the plumes is included in Appendix D.

In the Upper Glacial aquifer, the upper boundary of the saturated groundwater system is defined by the water table, which is 16 feet or less below ground surface. Water table elevations are significantly affected by recharge from settling basins and by discharges to streams and pumping wells (ITC 1998b). Although the Magothy aquifer is in direct contact with the Upper Glacial aquifer over most of BNL site, groundwater flow occurs preferentially in the Upper Glacial aquifer as a result of much higher permeabilities (ITC 1998b). The Upper Glacial aquifer is partially separated from the underlying Magothy aquifer by the Gardiners Clay or Cretaceous-age clays of the Monmouth Group (ITC 1998). The Upper Glacial aquifer is predominately sandy to gravelly permeable glacial outwash deposits, with some finer-grained glacial lake deposits and near-surface silts and clays (CDM Federal Programs 1996a).

Precipitation averages about 122 cm/year, with about 58 cm/year recharge to the aquifer system. The remaining precipitation is lost as evapo-transpiration or surface runoff (CDM Federal Programs 1996a). Surface streams are controlled by groundwater discharge from the Upper Glacial aquifer, which constitutes about 95 percent of the base flow. Upper reaches of the

Peconic River and other area streams have intermittent flow and often go dry when the water table is lower than the stream channels (ITC 1998a).

Fifteen mammal species are native to the site. During the early 1990s, white-tailed deer populations were estimated to be at least 100 per square mile (Thomlinson 1993). More recent surveys conducted between November and December 2000 estimated the deer population at 236 deer per square mile (BNL 2000). The increase in deer population has left BNL officials with the task of determining the best method for controlling it. Although hunting is prohibited on BNL property, hunting does take place off site. Several endangered species inhabit BNL property, including the tiger salamander, the banded sunfish, and the swamp darter.

Many industrial facilities other than BNL are located in Suffolk County as well as in nearby Nassau County. According to the USEPA's Toxic Chemical Release Inventory (TRI) database, 24 facilities in Suffolk County reported releasing one or more of the following into the environment in 1999: dichloromethane, toluene, trichloroethene, tetrachloroethene, ethylbenzene, n-hexane, xylenes, methyl ethyl ketone (MEK), and methyl tert-butyl ether (USEPA 2000). Facilities are required to report releases to the environment on a yearly basis. Releases represent nonradioactive air emissions, surface water discharges, underground injections, and releases to land. The TRI is a publicly available database that contains an inventory of chemical releases and other waste management activities reported annually by certain industry groups as well as by federal facilities.

Environmental Contamination and Other Hazards

This section presents the contaminants of concern in each environmental medium (surface soils, subsurface soils, surface water, sediments, air, groundwater, vegetation, and biota). Each environmental medium has been tested for a large number of chemicals and radionuclides. The following sections address whether individuals have been exposed or could be exposed to the contaminants and whether those exposures are of public health significance.

ATSDR selects and discusses contaminants by using criteria such as concentrations and locations of contaminants on site and off site, field data quality, laboratory data quality, frequency of detection, and comparison of concentrations of contaminants to comparison values (CVs) for cancerous and noncancerous health effects.

ATSDR and other agencies have developed CVs to provide guidelines for identifying levels of contaminants in environmental media that might pose public health hazards. These values include Cancer Risk Evaluation Guidelines (CREGS), Environmental Media Evaluation Guidelines (EMEGs), USEPA's Reference Doses (RfDs), Reference Concentrations (RfCs), Risk-Based Concentrations (RBCs), and Lifetime Health Advisories (LTHAs).

ATSDR derives CREGs from USEPA=s cancer slope factor, which predicts no more than one excess cancer in a million persons exposed over a lifetime (70 years). Standard body weights and daily ingestion rates for both adults and children are assumed in the derivation of these values. EMEGs are concentrations in water, air, or soil that should not cause adverse noncancerous effects, even if exposure occurred daily. EMEGs are calculated from ATSDR=s Minimal Risk Levels (MRLs). Both MRLs and RfDs are estimates of the daily exposure to contaminants that are unlikely to cause adverse noncarcinogenic health effects over a lifetime. USEPA=s LTHAs are concentrations at which adverse noncancerous health effects are not expected to occur. USEPA also has maximum contaminant levels (MCLs), which are enforceable drinking water regulations that are protective of human health to the "extent feasible" over a lifetime.

On-Site Contamination

Contamination at BNL has been grouped into six operable units. Appendix F contains a description of the type of contamination found in the soil and groundwater associated with each operable unit. Contamination in surface water, sediments, biota, air, and vegetation are discussed on a site-wide basis rather than for each operable unit. Figure 1 in Appendix B shows the operable unit locations. Contamination associated with the Brookhaven Graphite Research Reactor (BGRR) is discussed in the air emissions section.

Potable Water Well Contamination

Figure 7 in Appendix B shows the locations of the potable and supply wells at BNL. Potable well water at BNL is currently tested on a quarterly basis for radionuclides, volatile organic compounds (VOCs), metals, pH, temperature, dissolved solids, conductivity, phosphorous, nitrate-nitrogen, and dissolved oxygen. Sampling for VOCs, specifically 1,1,1-TCA, TCE, chloroform, and PCE, however, did not occur until 1984. Because VOCs were detected in 1984 in potable water wells, the wells were sampled monthly in 1985; but the samples were analyzed by BNL, which at the time was not certified to do the analysis. In 1985, VOC samples were only analyzed once by a certified laboratory.

An important note is that the majority of the samples from the wells were collected prior to the water going through the water filtration/treatment plant. Therefore, these concentrations were not at the tap, (i.e., where people would actually be drinking the water). Only a very limited number of samples were taken at the tap. Because laboratory certified sampling data were available for only 1 month in 1985, ATSDR also used the data from the uncertified laboratory as an indication of concentrations at various times throughout the year. Because of quality assurance and quality control, ATSDR prefers to use certified laboratory data as opposed to non-certified laboratory data methods and procedures. The data from the non-certified laboratory was used only to compare with the limited amount of data from the certified laboratory.

For the years 1984 through 1989, very limited tap sampling data exist. The maximum 1,1,1-TCA concentration detected at the tap was 45 ppb, collected in September 1986 in Building 901A, room 102. The tap was resampled the next month, October 1986. The original laboratory detected 1.5 ppb, and a different laboratory found 15 ppb of 1,1,1-TCA from the same tap.

Potable water wells 1, 2, 4, 6, 7, 10, 11 and 12 have had 1,1,1-trichloroethane (1,1,1-TCA) contamination problems in the past. The New York State Department of Health (NYSDOH) advisory guideline for 1,1,1-TCA was 50 ppb until 1989. In 1989, NYSDOH established a drinking water standard at 5 ppb for 1,1,1-TCA.

The periods of operation for the wells were:

- Well # 1 1941BSeptember 1986
- Well # 2 1942BAugust 1985
- Well # 3 1948BDecember 1986
- Well # 4 1960BOctober 1990 (back in service January 1991)
- Well # 6 1960BPresent
- Well # 7 1964BPresent
- Well # 10 1980BAugust 1989 (back in service September 1992)
- Well # 11 1981BOctober 1989 (back in service March 1992)
- Well # l2 l986BPresent.

Concentrations of 1,1,1-TCA in well #1 ranged from non-detectable (ND) to 11 ppb in 1984. These levels were below the New York state advisory guideline. In 1985, the average 1,1,1-TCA concentration in well #1 was 12 ppb. Between 1985 and 1986, 1,1,1-TCA concentrations in well #1 increased. In 1986, concentrations ranged from 60 ppb to 390 ppb, with an average of 137 ppb. Well #1 was removed from service in September 1986 because of the 1,1,1-TCA contamination (BNL 1987). The maximum concentration detected (390 ppb) was found in the well during October 1986, after the well had been shut down.

In 1984, 1,1,1-TCA concentrations ranged from ND to 4 ppb in well #2. Both chloroform and TCE were also detected in the well at a maximum concentration of 9 ppb (BNL 1985). Twenty-one samples were collected from well #2 in 1985, and the average 1,1,1-TCA concentration was 86 ppb (BNL 1986). The maximum concentration (212 ppb) was found in May 1985. This analytical result was from a non-certified laboratory. In August 1985, samples were analyzed by both BNL and a certified laboratory. The maximum concentration detected by the certified laboratory was 142 ppb. BNL analysis was almost identical at 134 ppb. Well #2 was removed from service in August 1985. Wells #1 and #2 were sealed in 2002.

Low concentrations of chloroform (3 ppb) and 1,1,1-TCA (1 ppb) were detected in well #3 from 1984 through 1985. Chloroform was not detected in well #3 during 1986. 1,1,1-TCA was detected (14 ppb) in September 1986. Well #3 was removed from service in November 1986 because it had the potential to draw contamination from the 1977 fuel oil/solvent spill at the Central Steam Facility. For a description of the contamination related to this spill, see the Operable Unit IV contamination section in Appendix F. Well #3 was sealed in 2002.

Chloroform was detected in well #4 from 1984 through 1990 at concentrations ranging from 3 ppb to 17 ppb. 1,1,1-TCA was also present in well #4 in 1984 at a maximum concentration of 4 ppb. In 1985, the average concentration was 4 ppb. 1,1,1-TCA was not detected in the well from 1986 through 1988. The average concentration in 1989 was 1.1 ppb, and in 1990 the average concentration was 4.8 ppb. In October 1990, well #4 was removed from service because 1,1,1-TCA was detected at 7.5 ppb, a level above the new drinking water standard (5 ppb).

Water from potable wells #4, #6 and #7 is treated at BNL Water Treatment Plant for the removal of naturally occurring iron. BNL conducted a testing program for the purpose of evaluating the ability of the existing aeration processes at BNL Water Treatment Plant to remove organic compounds. On the basis of the results of the testing program, the SCDHS granted authorization to return potable well #4 to service in February l991 (BNL 1992b). Aeration of the water during the treatment process has reduced the 1,1,1-TCA concentrations in well #4 to levels below the detection limit.

1,1,1-TCA concentrations were detected in well #6 at a maximum concentration of 4 ppb in 1984 and at an average concentration of 3 ppb in 1985. It was not detected in the well during 1986 and 1987. From 1988 through 1990, concentrations averaged 1 to 2 ppb. During 1991, chloroform was detected in well #6 at a maximum concentration of 17 ppb and an average of 11 ppb. These concentrations are below the drinking water standard of 100 ppb. 1,1,1-TCA was detected in well #7 at an average concentration of 2 ppb in 1985, but it was not detected in the well thereafter.

In 1985, concentrations of 1,1,1-TCA averaged 15 ppb and 9 ppb in wells #10 and #11, respectively. In 1986, 1,1,1-TCA averaged 8 ppb in both wells. 1,1,1-TCA was not detected in well #10 during 1987, but in well #11 1,1,1-TCA concentrations averaged 12 ppb, with a maximum of 14 ppb. In 1988, wells #10 and #11 had average concentrations of 7 ppb and 13 ppb, respectively (BNL 1989). In 1989, wells #10 and #11 had average concentrations of 1,1,1-TCA of 5.8 ppb and 7 ppb, respectively (BNL 1990). Wells #10 and #11 were shut down in August and October 1989, respectively.

Wells #10 and #11 remained out of service during 1991, and carbon filtration systems were installed on both wells during 1992, and they were returned to service (BNL 1996b). Low 1,1,1-TCA concentrations (7−8 ppb) have been detected in well #11 in recent years, but these concentrations are in samples taken from the wellhead. The carbon absorption treatment devices installed in 1992 have reduced the concentrations of TCA to non-detectable levels in the potable water prior to it being used at the tap.

Water in well #12 contained 1,1,1-TCA concentrations just below the MCL of 5 ppb. BNL has installed a granular activated carbon filter on well #12 to remove the 1,1,1-TCA, and this well is currently in service (BNL 1996b).

The SCDHS inspected BNL drinking water supply system August 18, 1994, and again September 13, 1995. Analysis of water samples showed all analytical parameters met the New York State drinking water standards (BNL 1995; BNL 1996b). Six potable water wells (4,6,7,10,11, and 12) are currently operating at BNL (BNL 1994b). Potable wells #4, #6, and #7 were not used for potable purposes during 1996 because of construction activities at the Water Treatment Plant (WTP). The SCDHS inspected the potable water supply in November 1996 and found that all water samples met the New York State drinking water standards. After construction activities were completed at the WTP in 1997, potable wells #4, #6, and #7 were used on a limited basis.

Sampling of BNL potable water supply was conducted in April and June 2001, and all biological and chemical constituents were within the applicable drinking water standards set forth by the NYSDOH (BNL 2002).

BNL has installed an air stripper tower at the Water Treatment Plant to ensure complete removal of VOCs prior to distributing the water to its various facilities. The system is inspected on an annual basis by the SCDHS and has been in compliance with the necessary requirements.

Surface Water

Surface waters located on site include recharge basins, wetlands, and the Peconic River. Wetlands and marsh areas on the northern portion of the site form part of the headwaters of the Peconic River (BNL 2000); wetlands also exist in other parts of the site. The Peconic River is an intermittent stream at on-site locations, with flows greatest during periods of sustained precipitation, usually in the spring. Water flow in the Peconic River varies greatly with seasonal fluctuations in precipitation. During dry periods, the Peconic River at on-site locations is essentially dry, with the discharge from the STP gradually flowing into groundwater. Evidence of this dryness is indicated by the fact that BNL could not collect surface water samples at the site boundary many times during its history because the Peconic River at this location had no flowing, or even standing, water (ITC 1998b). During wet periods, however, water may be present throughout the on-site portions of the Peconic River. For example, in May 1997, enough water was flowing in the on-site portions of the Peconic River for fish samples to be collected at the site boundary (ITC 1998a).The highest concentrations of several inorganic compounds, gross alpha radiation, gross beta radiation, tritium, and thorium-234 all exceeded corresponding screening values.

Data for on-site recharge basins and wetlands

The highest concentrations of organic compounds in the recharge basin sampling data provided by NYSDEC are as follows: hydroxyethylidene diphosphonic acid, 2,150 ppb; bromodichloromethane, 6 ppb; chloroform, 7 ppb; and tolytriazole, 500 ppb.

Data for On-Site Sections of the Peconic River

The site environmental reports document nearly 25 years of sampling the Peconic River, with a focus on two locations: the former site perimeter (roughly 0.5 mile downstream of the STP outfall) and the current site boundary (more than 1.5 miles downstream of the STP outfall). Samples were collected at these two locations as often as three times per week, as flow permitted. Some analytes (e.g., gross alpha, gross beta, and tritium) were analyzed in every sample collected, while other analytes were analyzed in only a subset of the samples.

BNL has collected samples from additional on-site locations, but such sampling is conducted far less frequently. These additional sampling locations include three locations upstream of the STP outfall and an on-site tributary to the Peconic River not impacted by the STP discharges. Also, two remedial investigation studies included samples at on-site locations along the Peconic River from the STP outfall to the current site boundary.

Only a small subset of the contaminants had maximum concentrations greater than corresponding screening values for toxicity — and no contaminant concentration was more than two orders of magnitude higher than the screening value.

Very limited information is available for organic sampling in the Peconic River on site. The limited data — primarily documented in the 1991 and 1993 Site Environmental Reports — indicate the following: (1) very few organics were detected in the surface water (i.e., toluene, trichloroethane, dichloroethane); (2) the detections are infrequent; and (3) the detections are at levels marginally higher than detection limits. For the following three reasons, ATSDR does not view the lack of extensive surface water sampling data for organics in the on-site Peconic River as an important data gap: (1) no site report evidence suggests that BNL processes large volumes of organic chemicals that are discharged to surface waters; (2) the site=s discharge monitoring data is generally in compliance with the limited sampling requirements for organics; and (3) exposure to on-site surface water is believed to be extremely infrequent.

Sediments

Sediments are found on site at many locations, including the Peconic River, wetlands, recharge basins, and other areas (e.g., at the on-site fields used for various agricultural experiments). Sediments were sampled for organic and inorganic compounds, pesticides, and radionuclides. The following contaminants were in concentrations greater than corresponding health-based comparison values: sodium-22, potassium-40, strontium-90, cesium-137, lead-210, radium-226, arsenic, cadmium, mercury, benzo(a)pyrene, benzo(b)fluoranthene, and two different mixtures of PCBs (Aroclor 1254 and 1260).

BNL representatives collected sediment samples from more than 20 on-site locations along the Peconic River during the various remedial investigations. Of the 19 inorganic contaminants listed in Table SD1, only three — arsenic, cadmium, and mercury — were at concentrations higher than the corresponding ATSDR comparison values. The highest arsenic levels measured (9.7 ppm) are comparable to those measured at off-site control locations (see Table SD2). The highest cadmium concentration (18.8 ppm) is within the same order of magnitude as the corresponding ATSDR comparison value (10 ppm), which is based on chronic exposure assumptions. Later sampling confirmed mercury levels as high as 39.7 ppm.

Of all the analytes sampled for, three exceeded their respective health-based comparison values, all by very small margins: the highest concentration of benzo(a)pyrene was 0.46 ppm, compared with the CREG value of 0.1 ppm; the highest detection of benzo(b)fluoranthene was 1.2 ppm, compared with the risk-based concentration of 0.87 ppm; and the highest concentration of Aroclor-1254 was 1.5 ppm, compared with the EMEG of 1.0 ppm.

Data for Sediments in On-Site Recharge Basins, Wetlands, and Agricultural Fields

Two rounds of sampling, one in 1989 and another in 1994, examined levels of sediment contamination at on-site locations other than the Peconic River. The sampling results indicate that numerous contaminants were in sediments at these on-site locations — a result that is not surprising, given that some of these locations (e.g., the recharge basins) receive BNL=s wastewater. Sodium-22, potassium-40, strontium-90, cesium-137, and lead-210 concentrations were higher than the National Council on Radiation Protection (NCRP) soil screening limits.

Arsenic and three organic compounds (benzo(a)pyrene, benzo(b)fluoranthene, and Aroclor-1260) had at least one surface sediment concentration higher than their corresponding health-based comparison values. The highest arsenic concentration (9 ppm) in these on-site sediments is consistent with the level measured in the on-site sections of the Peconic River and at off-site control locations, suggesting that the level detected might be naturally occurring. The three organic compounds that exceeded comparison values all did so by less than an order of magnitude.

Off-Site Contamination

In May 1988, the SCDHS detected 1,1,1-TCA concentrations as high as 1,200 ppb in a leaching pool on the east side of the Precision Concepts building in the Brookhaven R & D Industrial Park. From May through October 1990, the SCDHS installed and sampled groundwater monitoring wells in the industrial park to isolate the source of the contamination. Monitoring wells were also installed between BNL and the industrial park to determine if contaminants were moving off BNL property. Samples collected from the monitoring wells between BNL and the industrial park contained contaminants in the middle and deep portions of the Upper Glacial aquifer (30 to 110 feet below the water table). 1,1,1-TCA was found at a maximum of 15 ppb, while trichloroethylene (TCE) and 1,1-DCE ranged from non-detection (ND) to 6 ppb, and PCE ranged from 2 ppb to 5 ppb.

Higher levels of 1,1,1-TCA appeared in profile wells just south of the Precision Concepts building in the industrial park. The 1,1,1-TCA was 30 to 40 feet below the water table, and concentrations ranged from ND to 9,300 ppb. Other solvents were also in the same wells, including 95 ppb of 1,1-DCA, 290 ppb of PCE, and 430 ppb of 1,1-dichloroethylene (1,1-DCE) (SCDHS 1990). The contaminant plume was approximately 3,100 feet long, and it was determined that Precision Concepts was the source of that plume. Lower concentrations of TCE and 1,1-DCE (37 ppb) were deeper in the aquifer, at 80 to 100 feet below the water table. This contamination probably originated from BNL.

Residential (Private) Well Sampling

The SCDHS conducted private well sampling in areas south and east of BNL in 1979 and repeated the sampling in 1981 and 1983. SCDHS tested the samples for radionuclide contamination. In 1985, quarterly sampling of private wells from 16 different locations located north, south, and east of BNL was conducted, and samples were analyzed for volatile organic compounds (VOC) and radionuclide contamination. Sampling continued through 1995, and approximately 732 samples were collected (SCDHS 1996). Private well sampling data collected from the North Shirley area in the 1980s indicated l, l, l-TCA and trichloroethylene (TCE) contamination. This contamination was attributed to homeowner solvent use within the area.

Residential wells downgradient of BNL have also been contaminated from other sources. For example, in July 1982, elevated levels of benzene, toluene, and xylenes (BTX) were detected in a residential well on William Floyd Parkway in North Shirley. In January 1985, three additional residential wells were found to be contaminated with BTX. Two of the wells are located on Auburn Avenue, and the third well is on Belmont Drive. In the latter part of 1987, two more wells had elevated concentrations of BTX. These wells are located on Belmont Drive and Patton Drive. After mapping the locations of the contaminated wells, investigators were able to trace the contamination back to a source upgradient of the first contaminated well. The source of the contamination was a leaking underground storage tank at a gasoline station located at the corner of Moriches Middle Island Road and William Floyd Parkway (SCDHS 1990).

In March 1990, BNL informed the SCDHS that 1,1,1-TCA and dichloroethane (DCA) were detected in monitoring wells near the southern boundary of the site at concentrations of 11 ppb and 4 ppb, respectively (SCDHS 1990). From March through June 1990, the SCDHS sampled 90 private wells in an area of North Shirley, town of Brookhaven, New York, bounded by Carleton Drive East, Wellwood Drive, Crestwood Drive, and William Floyd Parkway. Five private wells were found to be contaminated with 1,1,1-TCA and l, l-dichloroethene (l,1-DCE). The 1,1,1-TCA concentrations ranged from 41 ppb to 340 ppb, and 1,1-DCE ranged between 2 ppb and 20 ppb. The contamination was at 40 to 60 feet below the water table. Owners of the wells were provided with carbon filters to remove the contaminants.

BNL requested the SCDHS to perform a private well survey in October 1995 to determine whether known contamination at the site was reaching residential wells in the communities of North Shirley, Shirley, East Yaphank, and Manorville. From October 1995 through March 1996, SCDHS officials sampled 528 private wells, and the samples were analyzed for VOC and tritium contamination (SCDHS 1996). They sampled a total of 404 wells in North Shirley-East Yaphank and 124 in Manorville. Monitoring results indicated 10 wells with VOCs above the maximum contaminant level (MCL): 7 in North Shirley, and 3 in Manorville. In North Shirley-East Yaphank, five wells contained 1,1,1-TCA concentrations ranging from 5–180 parts per billion (ppb), and two wells contained Freon compounds ranging from 6–10 ppb. Table 1 below summarizes the contaminants found in residential wells.

The source of the 1,1,1-TCA contamination was attributed to a business, Precision Concepts, in the industrial park southwest of BNL, and the Freon contamination was attributed to homeowner use. The Freon contamination is not listed in the table because it was an isolated incident and Freon is not a contaminant of concern at BNL unlike the TCA that was from multiple sources. In Manorville, one well contained ethylene dibromide at 0.16 ppb, and one well contained TCE at 8 ppb. The source of contamination in these two wells was attributed to BNL, and a third well contained xylene at 33 ppb, which was attributed to a gasoline spill. Sampling continued in both areas through November 1996.

Table 1. Contaminants in Residential Wells**

Chemical	*Concentration Range (ppb)*	*Comparison Value (ppb)*	*# of wells with contaminants equal to or exceeding the comparison value*

Chloroform	NDB10	6 (CREG) 100 (USEPA MCL [p])	1
1,1-Dichloroethylene (1,1-DCE)	NDB20	0.06 (CREG) 7 (USEPA MCL)	8
Ethylene Dibromide (EDB)	NDB1.2	0.0004 (CREG) 0.05 (USEPA MCL)	2
Perchloroethylene (PCE)	NDB10	0.7 (CREG) 5 (USEPA MCL)	14
1,1,1-Trichloroethane (1,1,1-TCA)	NDB340	5 (NYS MCL) 200 (USEPA MCL)	19
Trichloroethylene (TCE)	NDB8	3 (CREG) 5 (USEPA MCL)	3
Strontium-90*	NDB1.25	8 (USEPA MCL)	0
Tritium*	NDB7,238	20,000 (USEPA MCL)	0

* Strontium-90 and tritium concentrations are in picocuries per liter (pCi/L)

ppb: parts per billion

USEPA MCL: Environmental Protection Agency Maximum Contaminant Level

NYS MCL: New York State Maximum Contaminant Level

CREG: Cancer Risk Evaluation Guide

ND: Non-detection

** Summary of contaminants found in wells between 1981–1996

Radiological analysis of private well water has been performed since 1979. The SCDHS submitted split samples to the NYSDOH to confirm the results of BNL's analyses. Sampling results have indicated detectable concentrations of tritium in 18 private wells. The maximum concentration of tritium was detected in September 1993 at 7,238 picocuries per liter (pCi/L), which is approximately one-third of the MCL (SCDHS 1996). Sampling data from May 22, 1996 indicated tritium contamination in six wells on North Street, with concentrations ranging from 393 to 3,930 pCi/L (SCDHS 1996). ATSDR scientists believe that the levels of tritium in private wells, well below the MCL, would not be expected to cause adverse health effects. Tritium has not been detected above background levels in any of the Suffolk County public water supply wells.

Strontium-90 was also detected in some residential wells, but the levels were far below the MCL of 8 pCi/L. The maximum strontium-90 concentration in residential wells (1.25 pCi/L) was in a well on Weeks Avenue (USDOE 1996a). ATSDR believes that this level would not cause adverse health effects.

ATSDR-s Modeling of the Groundwater Plumes

DOE and its contractors have conducted several groundwater modeling analyses to define aquifer properties and to predict the response of the groundwater system to remedial actions (CDM 1995; CDM 1996d; ITC 1998e). These models are good representations of the hydrogeological system and they provide valuable information about hydrogeological parameters. They do not, however, address the early progression of the contaminant plumes after contaminant introduction but before detection in off-site monitoring or residential wells.

Sampling of residential wells near BNL before 1985 was limited to approximately 50 wells, and these were sampled for radionuclide contamination only. To determine if residential wells were affected by the contaminant plumes prior to their being sampled, ATSDR staff conducted groundwater modeling for the seven on-site plumes and the one plume emanating from the industrial park off site. ATSDR first wanted to determine if it was feasible that any of the contaminant plumes affected any of the off-site residential wells prior to their being sampled in 1985. Also, ATSDR staff wanted to determine if any of the contaminant concentrations were higher than what was found during the 1985–1995sampling period.

Although uncertainty surrounds assigning a specific time and location of origin to individual plumes, of most of the sources have been sufficiently characterized to estimate durations of plume migration and distances of source origins to residential well locations. Ongoing monitoring has also characterized the current distribution of the contaminant plumes.

The contaminant transport evaluation was based on one dimensional (1-D) and three dimensional (3-D) groundwater flow equations. The 1-D model was used to evaluate vertical transport, and the 3-D model was used for lateral transport. Analysis indicated that downward vertical flow predominates at the ground surface to about 35 m, and southward flow at depths from 35 m to 80 m.

The plume durations listed in Table 2 represent a maximum duration and an estimate of contaminant migration that is very protective of public health.

Table 2. Groundwater Plume Durations

Plumes or Sources	*Contaminants*	*Plume Duration*	*Source to Fence Length*	*Source to Off-Site Wells Length*	*Total Plume Length*
1) Precision Concepts	TCA	10B12 years	Off site source	500 m Carleton Dr.	1150 m
2) OU-III Multiple Sources a) Bldgs. 96, 208	PCE, TCA, Ctet, TCE	53 years	1400 m	2400 m Carleton Dr.	3900 m
b) Unknown	CCl-4	53 years	3100 m	3900 m	4400 m
3) OU-IV Waste Solvent Spill	TCA, TCE, PCE, DCE, BTEX	20 years	1500 m	2000 m Carleton Dr.	2000 m
4) Former Landfill	TCA, TCE, PCE, DCE,	50 years	1300 m	1600 m North St.	2100 m
5) Haz. Waste Mgmt. Area	TCA, Tritium	>35 years	1300 m	1600 m North St.	2100 m
6) Current Landfill Area	TCA	28 years	1300 m	1600 m North St.	2100 m
7) Biology Fields	EDB, TCA, Tritium	Unknown (25 years)	800 m	1200 m North St.	1500 m
8) Sewage Treatment Plant	TCE, TCA	Unknown	400 m	1600 m	1900 m

Table 2 distances and durations of eight groundwater contaminant plumes at or adjacent to BNL.

Distances are measured to areas of closest residences for each plume by use of the ARC/VIEW measurement tool.

Durations are from several source characterization references (CDM 1995; CDM 1996b; ITC 1998).

The shortest flow paths and longest plume duration present the greatest potential for contaminant exposure. From Table 2, the critical flow paths are plume 2 (OU-III), with a path length of 2400 m and a potential duration of greater than 50 years; plume 4, with a path length of 1600 m and a duration of 45 years; and, plume 5, with a path length of 1600 m and a potential duration of more than 35 years. Contaminant concentrations were estimated for path lengths of 1500 m, 2000 m, and 2500 m for 10-year time intervals.

Initial transport of contaminants from BNL sources is downward. One-dimensional vertical modeling indicates that it took about 4 years for contaminants to migrate downward to 50 m depth. The 1-D vertical flow model indicates that it takes about 10 years for maximum contaminant concentrations to migrate to a 50 m depth in the aquifer. Including time for vertical transport, contaminants have been migrating southward at a rate of 100 to 125 m/yr. Horizontal contaminant transport is occurring predominantly within the zones of higher hydraulic conductivity.

For the contaminant plume to travel 1500 m downgradient of the source takes about 10 years. After 20 years, contamination concentrations level off at the 1500 m location, and after 30 years for the 2000 m and 2500 m locations. At the 2000 m location (40 m depth), appreciable contaminant concentrations occur after 20 years and reach an asymptotic maximum of 450 Cg/l after 30 years. Maximum concentrations for the 2000 m location (30 m depth) reach about 250 Cg/l after 30 years. At the 2500 m location, contamination is present after 20 years, and it increases rapidly to about 300 Cg/l for the 40 m depth and 200 Cg/l for the 30 m depth after 30 years.

Most of the measured contaminant values are lower than the modeled values with the exception of carbon tetrachloride in wells 000-112, 000-130, 000-154, and 000-161. All these higher measured values are attributed to the OU-III (a; bldg. 96) plume except the 000-154 samples, which are attributed to the Former Landfill plume. The samples with high carbon tetrachloride concentrations (>800 μg/l) are all taken from depths greater than 50 m.

Contaminant concentrations from plume 2, assuming a constant source release, were never higher than measured values. In the constant source release scenario, the modeled values increase to an asymptotic maximum and were never higher than monitored values. A declining source concentration scenario (e.g., a contaminant spill event such as the OU-IV waste solvent spill), however, creates a high concentration pulse that migrates downgradient. As the pulse migrates past a point, contaminant concentrations increase and then decrease. This type of source scenario is likely for only two of the eight BNL plumes.

The contaminant concentrations derived by use of the analytical transport equation at a 40 m depth are generally higher than those detected in either residential or monitor wells. Modeled concentrations at a 30 m depth are comparable to measured values in residential and monitor wells (ATSDR 1999). Although knowledge of the depth of residential wells is limited, the data available indicate that most residential wells are relatively shallow, with depths between 30 and 37 m, while the zones of maximum contamination have migrated to depths of 50 m or more (BNL/ERD 1998).

For the five contaminant plumes that match the constant release scenario, contaminant concentrations have probably never been higher than 1985–1987 values, and exposure at those locations was not likely before 1987. For two plumes that fit the declining source release scenario (OU-IV waste solvent spill and OU-I former landfill plume), contaminant concentrations at specific locations first increase and then decrease as the high concentration pulses migrate past those locations. Contamination has been present in limited off-site areas since about 1980. Because, however, the high concentration contaminant zones occur at depths below most residential wells, it is unlikely that contaminant concentrations in residential wells have ever been significantly higher than levels reported by the SCDHS.

For five of the eight plumes illustrated in Figure 5 (plumes 3, 5, 6, 7, and 8), most of the results in this analysis indicate that it is unlikely that groundwater contaminants had migrated to areas of potential off-site exposure prior to 1987. According to the results of this analysis, portions of plume 2 and plume 3 had reached areas of potential exposure between 1977 and 1980. The source of contamination from the Precision Concepts plume (plume 1) is only about 500 m from residential wells, and contaminants from that source probably reached residential wells less than 5 years after source introduction into the aquifer.

Air Emissions

Many sources of air emissions are located on BNL property. BNL has 66 permitted air sources that include, for example, the Central Steam Facility (CSF), the pathological incinerator, several boilers, and two gas stations. BNL has several emission sources that are subject to state or federal regulatory requirements that do not mandate emissions monitoring. The CSF is the only BNL emission source required to monitor nonradiological emissions (BNL 2000). Figure 8 in Appendix B shows the air monitoring station locations at BNL.

Emissions from the CSF include particulates, carbon monoxide, carbon dioxide, nitrogen oxides, sulfur dioxides, and volatile organic compounds (VOCs). In 1997, natural gas replaced residual oil (#6) as the main source of fuel for operating the four boilers in the CSF. The use of natural gas has reduced the annual particulate, nitrogen oxide, and sulfur dioxide emissions (BNL 2000). The use of natural gas, however, produces greater emissions of VOCs compared to the use of residual oil. Levels of VOC emissions have increased since 1997. VOC emission levels are reported as tons of total VOCs released; a level is not reported for each VOC.

Air releases of radioactive material have occurred throughout the operational history of BNL. These release points are currently under control of the National Emission Standards for Hazardous Air Pollutants (NESHAPS) and the Clean Air Act. Under these environmental laws, BNL is regulated by the NESHAPS part H, which, in part states that “emissions of radionuclides to the ambient air from Department of Energy facilities shall not exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent of 10 mrem/yr.” Radiological emission sources include the High Flux Beam Reactor (HFBR), the Brookhaven Medical Research Reactor (BMRR), the Brookhaven LINAC Isotope Production facility (BLIP), the Alternating Gradient Synchrotron (AGS), the Relativistic Heavy Ion Collider (RHIC) Accelerator, Building 801, and the Tritium Evaporator, which is used to evaporate the tritium from the heavy water.

Past Emissions

ATSDR reviewed historical site environmental reports covering the time frame of 1948 through 1998 and the 2003 site environmental report. ATSDR believes that generally, environmental reports do not contain sufficient information to perform a complete historical dose reconstruction. However, there usually is sufficient data to evaluate in terms of public health impacts. For the most part, this is the case at BNL. Of interest is the omission of H-3 (tritium) releases from the 2000 report on radiological emissions between 1948 and 1961 from the BGRR (BNL 2001). In this report, the major focus was on Ar-41 and fuel ruptures during operations of the BGRR and these fuel ruptures could have released tritium as well as the radionuclides covered in the report.

Routine air emissions from BNL from 1948 to 1961 mainly were from the BGRR with contributions from other sources such as the BMRR, a hot cell, and accelerators operating on site. These reactors were air-cooled so that air flowed through the system and the neutrons released from the operations were absorbed by naturally occurring argon. This argon was converted to Ar-41 with a radioactive half-life of about 1.8 hours. BNL estimates the total emissions of Ar-41 during this time was about 30 million curies and I-131, produced during nuclear fission and having a radiological half-life of 8 days, totaled about 12 curies (BNL 2001).

The Brookhaven Graphite Research Reactor (BGRR) was completed in 1950. The BGRR was designed as an air-cooled, graphite-moderated and reflected reactor, originally fueled with aluminum-canned natural uranium elements. The BGRR was in operation from 1950–1969; it served as the primary source of routine air emissions during this time frame. Argon 41 was the main radionuclide released during the BGRR operational history. Argon 41 is a short-lived radionuclide with a half-life of 1.83 hours.

From 1950 until 1957, a natural-uranium fuel was used in the BGRR. During the operation of the BGRR, the fuel elements were subject to stress-related failures. During this time frame, a total of 28 malfunctions (fuel ruptures) of the BGRR resulted in the emission of radioiodines, noble gases, and particles. The ruptures lasted from a few minutes to several hours. Some of the ruptures occurred when the prevailing winds were blowing in the direction of dairy farms that existed at the time. The fuel element failures resulted in the oxidation of the uranium metal, causing dispersion of the uranium/fission product/plutonium oxide particles to the graphite channels, the air ducts, and the air filters. Fission products were also released as the result of leaks in the fuel element claddings or of fissioning of uranium contamination on the outer surfaces of elements. Larger releases occurred when there were actual breaks in the cladding.

The primary contaminants within the vicinity of BGRR were the result of spreading oxidized uranium particles; the contaminants included fission products such as cesium-137 and strontium-90 and the activation product cobalt-60 (BNL 1997f). Several areas within or surrounding the BGRR are known to have or are suspected of having contamination present. The Reactor Building (Building 701) contains the Reactor Pile (Building 702), and portions of the Reactor Building were contaminated during operations. Accessible areas within the Reactor Building were surveyed and decontaminated where necessary following the shutdown of the BGRR. Reactor experiments stopped in June 1968. The presence of contamination in areas that are inaccessible in the building, such as drains, sewers, trenches, is currently being determined during the decommissioning of the building.

Radioactive contamination, primarily cesium-137 (Cs-137) and strontium-90 (Sr-90), has been detected in the secondary liner and surrounding soils in the below-ground areas of Building 701.

Soil in the pipe trench that traverses the north end of the building and all of the drains are also contaminated with Cs-137 and Sr-90 in the first few feet of soil. At the base of the north duct air plenum significant quantities of radionuclides including plutonium-238, plutonium 239/240, uranium 233/234, uranium 235, cobalt-60, Cs-137 and strontium-90 were detected (BNL 2003).

Dose rates within the fuel channels of the Reactor Pile were as high as 10 Roentgen per hour. The highest doses measured were at the center and bottom of the pile. Graphite samples contained the full ranges of fission products and transuranics with carbon-14 and tritium being the predominant radionuclides (BNL 2003).

At BNL, the release points in the past and the present, included the Medical Research Reactor (BMRR), the Graphite Research Reactor (BGRR), the High Flux Beam Reactor (HFBR), LINAC Isotope Production Facility (BLIP) and associated operations including a 3 MeV Van De Graaff Accelerator (VDGG), Tritium Evaporator Facility, and a waste incinerator. The HFBR, BGRR, Bldg. 801 and Bldg. 802 all shared a common stack noted as Bldg. 705). The radioactive materials released from these sources enter the atmosphere through stacks on site. Other potential release points include emergency waste water hold-up ponds from which evaporation may occur. These ponds are used to prevent releases of radiological materials to the Peconic River in the event of an accidental discharge. Table 3 lists the release points, stack height and operations associated with that release point.

Table 3. BNL stack atmospheric release points*

RELEASE POINT	STACK HEIGHT (METERS)	ASSOCIATED FACILITIES
Building 931	10	BLIP
Building 705	100	HFBR, BGRR, Bld. 801 Hot Lab and Bld. 802 (tritium evaporator)
Building 491	46	BMRR
Building 444	10	Incinerator
Building 555†	16	Chemistry Roof

*(BNL1995), (BNL1990).

For these release points, the BNL environmental monitoring sections evaluated the releases by means of stack monitors, calculated release rates from reactor operations, and air monitoring stations. The locations of air monitoring stations were on the grounds of BNL, the perimeter of the laboratory, and off-site locations. During the data review, ATSDR found that the number of perimeter and off-site locations changed over time. Furthermore, the station identifiers changed as well. Some examples of these changes include the following. In 1955 there were ten off-site (O-1 to O-10) and 9 on-site monitoring stations (E-1 to E-9) that were established as part of the original monitoring program for the Brookhaven Graphite Research Reactor. (Ref BNL-1955, “Area Survey Manual”, BNL-344, 1955.) In the 1963 Environmental MMonitoring Report, BNL listed 3 on-site locations (E-10, E-11, and E-12), 4 sites at the perimeter (E-2, E-4, E-7 and E-9), and 2 off-site locations (O-1, O-6), one almost due north 6 miles from the site and the other 4 miles to the south (BNL 1963). In 1965, the E stations were renamed as P stations and by 1971 monitoring at the original O stations ceased. The E/P-2, 4, 7 and 9 Stations were perimeter stations and were monitored continuously from the first days of BGRR operations. In 1981 21 new Thermoluminescent Dosimeters (TLDs) were placed at offsite locations and in 1982 an additional 15 off-site TLDs were added (BNL 1982). In 2003 there were 18 off-site TLDs and 56 on-site TLDs used for measuring radiation dose to the public and the on-site employee. Table 4 gives the distance to several perimeter monitoring locations from the central stack associated with the BGRR which was shut down in 1970 (BNL 1998 b).

Table 4. Distances from the BGRR stack

Station	*Degrees*	*Distance from Stack*
O-6 background	167	8700 meters
E-9 perimeter	217	2750
E-7 perimeter	321	2500
O-1 background	352 (due south?)	6000
E-3 perimeter	32	1800
E-5	243	1700
E-4	65	2200

Determination of radioactive background during routine operation of an air-cooled nuclear reactor (no date given) by IA Singer, M. Smith, R Bartlett and C Nagle. Meteorology Group BNL.

The majority of the radioactive materials released from these release points over their operational history have been either of two radioactive elements. These are hydrogen-3 (H-3; tritium) and argon-41 (Ar-41). Tritium can be produced in various ways from cosmic ray interactions in the atmosphere, nuclear weapons testing, and nuclear interactions associated with nuclear reactors. At BNL, the tritium produced is from the reactor operations associated with nuclear fission and neutron interactions with non-radioactive water or other testing materials. The radiological half-life of tritium is 12.3 years and decays to stable helium. When in the body, the biological half-life is approximately 10 days (ICRP 1994).

Similarly, Ar-41 production is from the naturally occurring argon in the atmosphere. As outside air for cooling flowed through the BGRR and the BMRR, this argon absorbed neutrons from the reactors and was transmutated to Ar-41. Argon is an inert gas and has a radiological half-life of 110 minutes and decays to stable potassium. Argon is not absorbed in the body nor does it attach to dust in the air; therefore, exposure to Ar-41 does not result in an internal radiation dose. Submersion in a cloud of Ar-41, however, does result in an external radiation dose to both the skin and the whole body (USEPA 1993).

Evaluation of Historical Tritium, Argon-41, and Iodine-131 Releases

Via public meetings and information received by ATSDR, a major concern of the community around BNL is the release of tritium from the facilities, especially the HFBR. Tritium from the HFBR can be released in two forms-elemental tritium and as tritiated water vapor (HTO). The elemental forms of tritium can be converted to tritiated water vapor. Beginning in 1967, BNL was in the process of developing monitoring methods for HTO so no measurements exist prior to 1974 (BNL 1998b).

To evaluate the impact of releases from BNL (either routine or accidental), ATSDR randomly evaluated selected annual environmental reports. Although ATSDR realized that emission would be variable, initial review of reports from 1970 to the present showed that releases were usually in the same order of magnitude.

Tritium data from 1975 to the present are readily available and show great variability in the amounts released from the HFBR and the 3 MeV Van De Graaff system (Figure 1). These data show that the most tritium as either elemental or HTO was released not from the HFBR but from the VDGG operations when a total of 1365 Ci were released and 1263 Ci or 92.5% were from the VDGG. The HFBR maximum tritium release occurred in 1973 when it released 775 Ci to the environment. Over the last 20 years, the amount of tritium released from the HFBR has decreased as shown in Figure 2 and Figure 3.

Releases of the radionuclide Ar-41 also occurred and in many cases, these releases exceeded the releases of tritium. As previously stated, Ar-41 exposures result in a submersion dose because of the cloud formed during its release. Figure 4 shows the relationship between the releases of Ar-41 from the BMRR and the total tritium released from all stack locations.

Figure 1. Tritium releases from BNL operations.

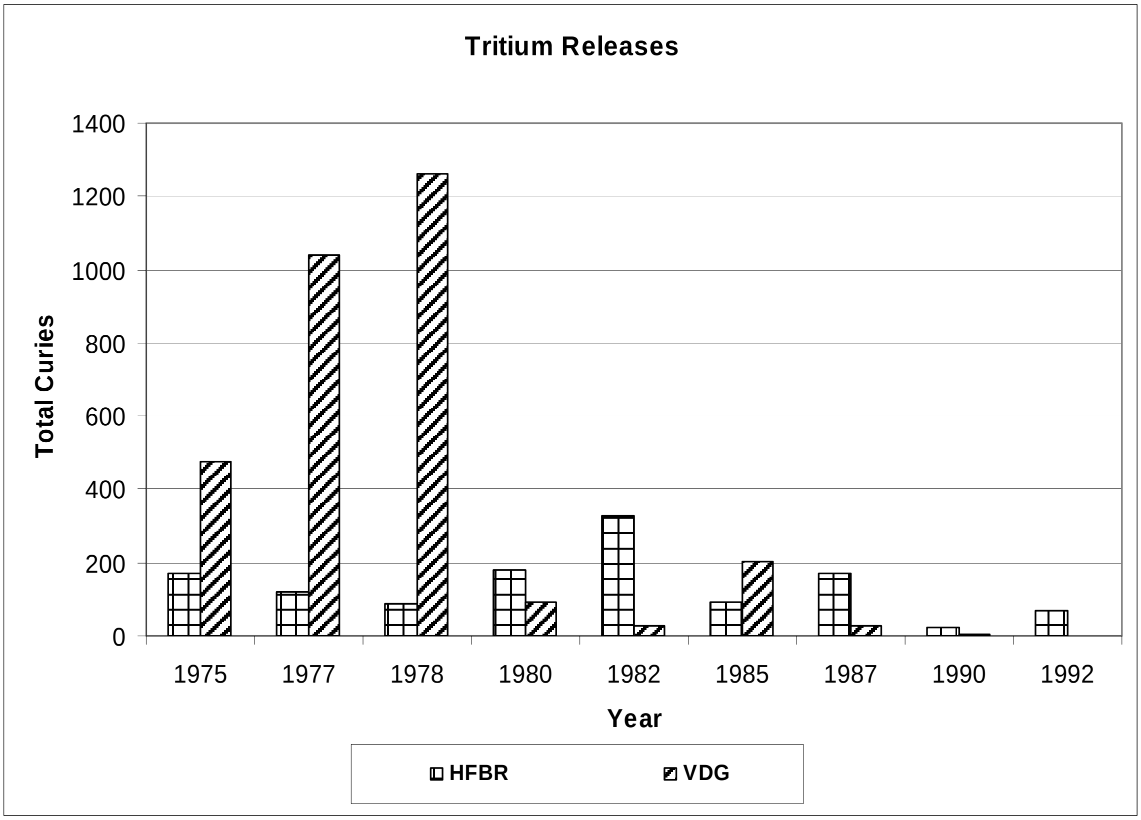


Figure 2. Ten year trend in tritium releases from HFBR

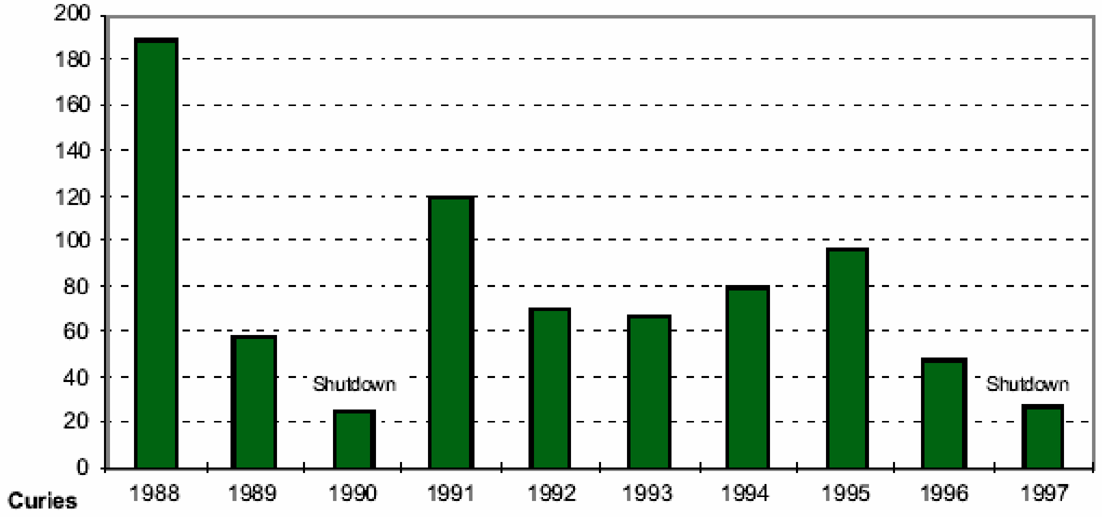
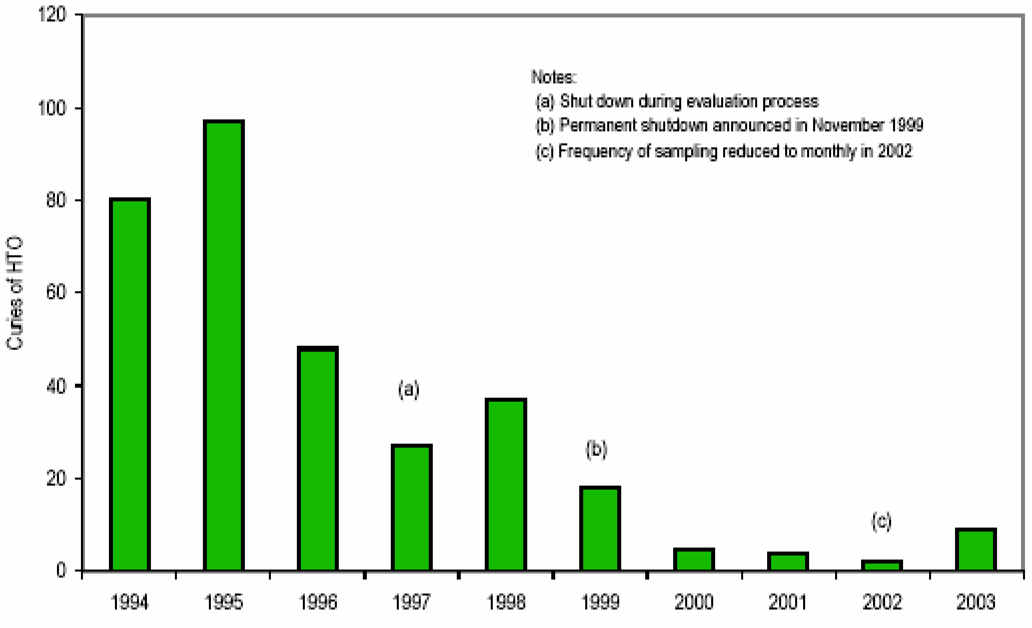


Figure 5-2. HFBR Airborne Tritium Emissions, 10 Year Trend

BNL 1999a. Available on-line at http://www.bnl.gov/esd/SER_1997.asp

Figure 3. Ten year tritium releases from HFBR

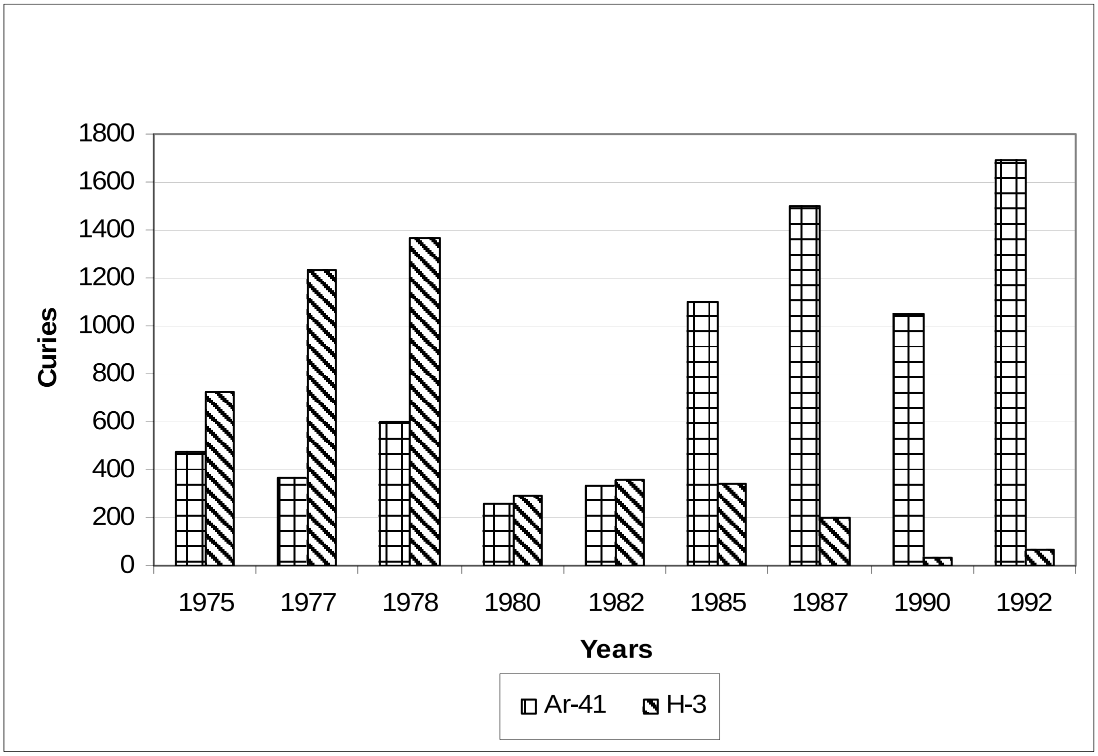


Notes:
(a) Shut down during evaluation process
(b) Permanent shutdown announced in November 1999
(c) Frequency of sampling reduced to monthly in 2002

Figure 4-2. High Flux Beam Reactor Tritium Emissions, Ten-Year Trend (1994 – 2003).

BNL 2005

Figure 4. Argon-41 and Tritium Releases



Radioiodines released during the 12 year period from 1950 to 1961 averaged about 1 Ci of iodine per year. However, during this time frame, 28 accidents were reported, all related to fuel failure, ruptures in the cladding surrounding the fuel. Although the accidental releases included other fission products, the iodines released can be considered having the potential for greatest impact on public health. The most iodine released among these accidents occurred on April 11, 1954, when about 155 Ci of I-131 were released. Calculations by BNL indicate the greatest potential for deposition was toward the north-northeast of the facility 2.5 kilometers (1.55 miles) from the release point but still on BNL property. Computer modeling also indicated that the concentration of I-131 deposited on the ground was on the order of 0.7 microcuries per square meter.

Radiological dose assessment

To perform this part of the assessment, ATSDR relied on computer models to estimate the radiological dose an individual might have received during specific periods of time. The model used for the assessment of routine releases is the CAP-88PC program which, in general, was developed under the NESHAPS for monitoring emissions and compliance procedures for Department of Energy (DOE) facilities (40 CFR 61.93 (a)) require the use of CAP-88 or AIRDOS-PC computer models, or other approved procedures, to calculate effective dose equivalents to members of the public.

ATSDR evaluated the potential radiation dose for the two specific time frames: 1982 when the highest amount of tritium was released from the HFBR and 1962 when the greatest amount of Ar-41 was released from the BGRR (BNL 1963). In both cases, the doses for both radionuclides were included to give the combined radiological dose. The following tables show the results of these computer runs.

Table 5. Maximum radiological dose and cancer estimates

Year	Tritium dose	Argon 41 dose	Total Dose (mrem/y)	Percent of the ATSDR Comparison Value (100 mrem/y)
1982	8.28E-07	4.39E-02	4.39E-02	0.04%
1962	--	185	185*	185

*The computer program estimated the maximum dose to be 750 meters (0.15 miles) north of the release point. As shown in Table 4, this maximum exposure point is well within the boundaries of BNL. Therefore, the public would not be exposed to the maximum dose.

Table 6. Directional Dose from 1962 Ar-41 releases.

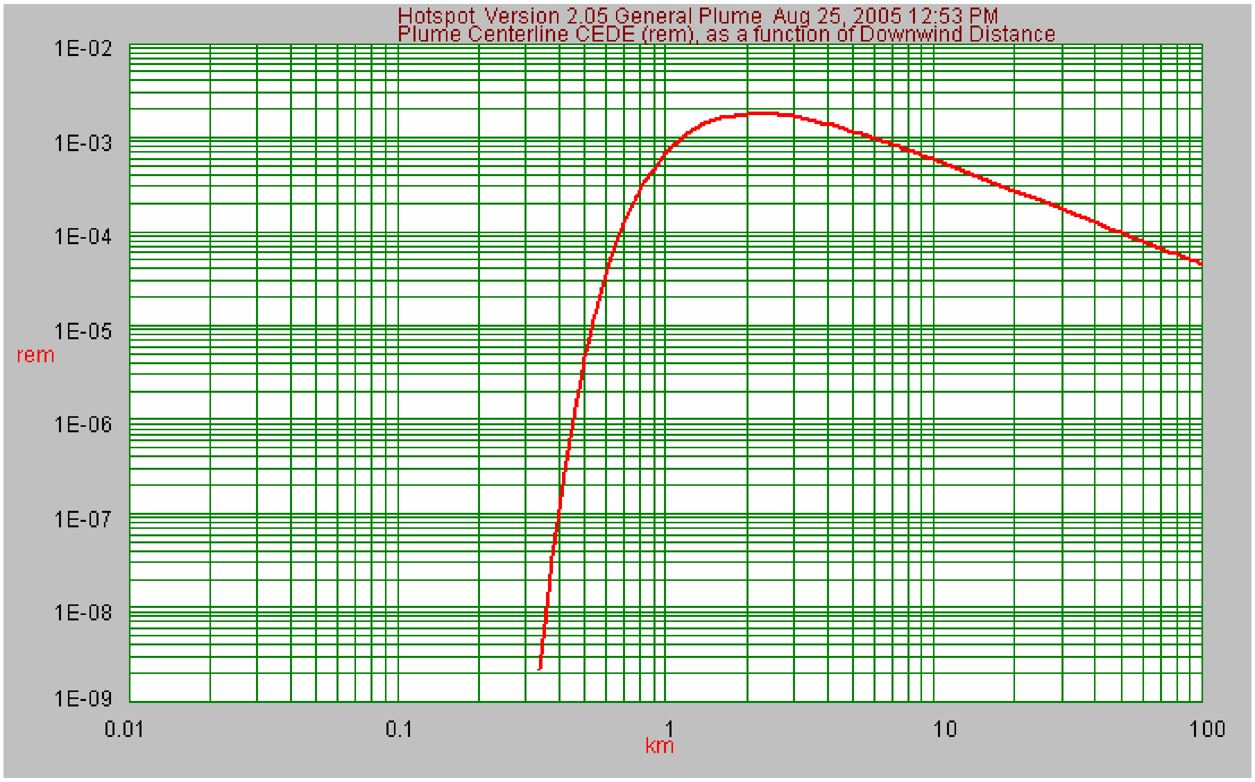
Distance and direction from Stack	*Concentration*	*Estimated radiological dose*	*Computer Generated lifetime cancer risk for an individual*
750 meters/0.5 mile north	25,800 pCi/m^3	185 millirem/y	0.005
2500 /1.5 north	20,600	150	0.0041
4500 /2.7 northeast	14,600	100	0.0029

The results between the 1962 annual report and the computer model appear to be in relative agreement with the dose assessment as reported in the 1962 environmental report. In that year, the average radiological dose from Ar-41 releases as measured in the northeast (perimeter sample E-9) was 1.08 milliroentgen per week or an annual dose of about 56 millirem/y, about 30% of the maximum dose calculated by CAP 88-PC. The difference can be explained by the distance of the air sampler (perimeter) in relation to the release point and computer generated maximum location. The annualized Ar-41 dose resulting from releases in July 1962, about 120 millirem, would be within the uncertainty range of the annual dose estimates.

For releases of iodine-131 as result of the accidental releases, ATSDR using the HOTSPOT computer code. The Hotspot code was created to provide emergency response personnel and emergency planners with a fast, field-portable set of software tools for evaluating incidents involving radioactive material. The Hotspot codes are designed for short-term (less than a few hours) release durations.

Using the release estimates as published in (BNL 2001), the maximum dose to the whole body would be about 2 millirem (Figure 5). Because the critical organ for radiological effects resulting from the intake of I-131 is the thyroid, ATSDR also estimated a 40 millirem thyroid dose using the tissue weighting factor of 0.05.

Figure 5. Whole body dose as the result of a 155 Ci I-131 release.



Comparison to Regulatory Limits

Throughout operation history of the Department of Energy and its predecessors, regulatory limits have been changed. In the early days of operation, dose limits were in place to protect workers with little apparent concern for off-site radiation doses. Early worker dose limits were 500 millirem per year. In 1959, the US Department of Commerce published maximum limits for many radionuclides. These limits were both for a 40 hour work week and a continuous exposure of 168 hours (continuous, weekly exposure). In the case of air immersion, the tritium limits were 400,000 pCi/m^3, and for Ar-41, the limit was 400 pCi/m^3 (USDOC 1959). Department of Energy sites currently are required to meet the National Emission Standards for Radionuclides released to ambient air. The standards require that DOE shall not exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent (dose to the whole body) of 10 mrem/yr (**10 CFR 40.61 Subpart H).**

Historical releases from BNL met the dose limitations in existence at those times and current releases meet current regulatory dose limits. However, computer modeling of the 1962 Ar-41 releases indicated an annual dose at the perimeter of 120 millirem. This dose estimate is above the current standard of 100 millirem (the standard in 1962 was 500 millirem).

Surface Water Contamination

The Peconic River=s headwaters are located west of BNL site. The river flows east as it enters the site, picks up discharge from the Sewage Treatment Plant (STP) outfall midway through the site, then flows southeast through the property before leaving through the eastern site boundary. Throughout its history BNL has handled wastewater in two ways. Some wastewater is pooled on site in basins that gradually evaporate or recharge the underlying groundwater aquifer. Other wastewater is treated at the STP and then discharged to the Peconic River. The STP has been in operation for the site=s entire history, though the type and efficiency of treatment operations has changed over the years. Currently, BNL has hold-up tanks in many of its facilities to prevent the discharge of untreated wastewater to the Peconic River, but these hold-up tanks were not always present. As a result, earlier in its history, BNL discharged untreated wastewater to the Peconic River.

In addition to direct discharges of wastewater, contaminants from BNL enter local surface water by other processes. Contaminants in sediments can be an ongoing source of releases to surface water. A specific example of sediments that caused surface water contamination at BNL is the leaching of cesium-137 from sand filter beds at the treatment plant (BNL 2000). Groundwater contamination can flow into surface waters, particularly during times with above-normal precipitation, leading to the discharge of groundwater into the Peconic River and its tributaries. Air emissions from BNL can be washed into local surface water during rainstorms.

BNL discharges process and non-process related wastewater at several on-site locations. NYSDEC has permitted all of these discharges under the State Pollutant Discharge Elimination System (SPDES). The SPDES permit requires BNL to measure levels of contamination in the discharges and ensure that these levels are lower than permitted thresholds. BNL currently has 10 permitted outfalls. The discharge from the STP (outfall 001) flows directly into the Peconic River. The discharges from the other outfalls are primarily cooling water and storm water, and they flow into various on-site recharge basins. The monitoring requirements vary from one outfall to the next, with the most extensive monitoring required at outfall 001.

This section summarizes two sets of discharge measurements: those from the STP and those from all other discharge measurements. This distinction is made because only the STP discharge flows directly into the Peconic River (where exposures at downstream locations can potentially occur), while all other discharges flow into on-site recharge basins (where exposures are expected to occur infrequently, if at all).

Two sets of sampling data were available for outfall 001. First, BNL routinely collects samples from the outfall and analyzes them for constituents specified in the facility=s wastewater discharge permit. Second, as part of the facility=s ongoing environmental surveillance efforts, BNL analyzes samples for numerous radionuclides to characterize releases of contaminants that NYSDEC does not require BNL to measure.

As Table SW 1 indicates, several non-radiological contaminants have been detected in BNL=s effluent to the Peconic River. The discharge monitoring data indicate, however, that contaminant levels either rarely or never exceeded corresponding health-based comparison values during the 1990s — the time frame of sampling data that NYSDEC provided. The following non-radiological contaminants had at least one measured concentration higher than its corresponding comparison value: bis (2-ethylhexyl) phthalate, chromium, copper, lead, mercury, methylene chloride, nickel, and silver.

Table SW 2 shows the radionuclide concentrations greater than screening levels, including short-term peak levels of gross beta (94.2 pCi/L) and tritium (67,300 pCi/L). Annual average concentrations for these and all other contaminants were below the screening levels.

Discharges to On-Site Recharge Basins

In addition to releasing wastewater to the Peconic River, BNL releases certain wastewater (primarily storm water and cooling water) into on-site recharge basins. The water released to these basins either evaporates or gradually recharges the local groundwater. The amount of water released to the recharge basins varies from day to day and from year to year, though recent estimates have shown that daily flow into the recharge basins is less than 2 million gallons per day.

Many different types of surface water (e.g., creeks, rivers, ponds) are located off site. Most site documents split these surface waters into two categories: the Peconic River and background locations. The background locations include all surface waters not directly affected by wastewater discharges from BNL, though they may still be contaminated by laboratory operations as a result of atmospheric deposition or air releases.

Since 1970, both BNL and NYSDOH have conducted extensive water quality monitoring in the Peconic River. Most of the samples were collected at four locations along the Peconic River:

- At Schultz Road, approximately 1.5 miles downstream from BNL site boundary
- At Wading River, approximately 2.8 miles downstream from the site boundary
- In the town of Manorville,[1] approximately 5 miles downstream from the site boundary
- In the town of Riverhead, at the mouth of the Peconic River, approximately 10 miles downstream from the site boundary

Of these four locations, samples were collected most frequently at Manorville and Riverhead, and surface water contamination at the other locations is not as well characterized. At all locations, the sampling studies evaluated primarily concentrations of radiological contaminants.

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[1] Both BNL and NYSDOH collect samples from a location designated as AManorville.@ The sampling documentation indicates that NYSDOH=s Manorville sampling station is *upstream* of BNL=s Schultz Road sampling station, while BNL=s Manorville sampling station is *downstream* from the Schultz Road station.

Specifically, concentrations of gross alpha radiation, gross beta radiation, and tritium were measured in most samples collected; concentrations of certain isotopes (e.g., strontium-90 and cesium-137) were detected more frequently than others. Sampling for inorganic contaminants has also been conducted routinely, but to a lesser extent than for the radiological contaminants. The inorganic analytes measured have varied from year to year. For instance, analysis of cadmium and lead concentrations has taken place since at least 1977, but analysis of manganese levels was not documented in the Site Environmental Reports until 1991, and later still for other analytes (e.g., cobalt, molybdenum, and thallium).

Inorganic contaminants

Arsenic, cadmium, lead, manganese, and thallium were occasionally found at concentrations higher than their corresponding lowest health-based comparison values. Closer examination of the sampling data reveals, however, that the average concentrations of these contaminants (e.g., annual average levels) are lower than the listed comparison values.

Radiological contaminants

In some off-site surface water samples, gross alpha radiation, gross beta radiation, and tritium were detected at levels higher than their corresponding health-based comparison values. To characterize realistic long-term exposure scenarios, the 30-year record of sampling data compiled by NYSDOH was examined to determine average, rather than peak, levels of contamination. The NYSDOH data reveal that gross alpha radiation was not detectable in most samples, the highest annual average concentration of gross beta radiation was 15 pCi/L, and the highest annual average concentration of tritium was 5,800 pCi/L.

Organic compounds

Toluene (3 ppb) and total xylenes (3 ppb) were detected in off-site Peconic River waters. Both of these detections are at levels lower than corresponding health-based comparison values.

Data for “control locations” (i.e., off-site surface waters other than the Peconic River) Although the Peconic River is the only surface water that directly receives wastewater discharges from BNL, many other surface water bodies are located in the vicinity of the site. These surface water bodies include small tributaries to the Peconic River, the Carmans River, the Connetquot River, and several lakes and ponds (e.g., Artist Lake, Lake Panomoka, Sandy Pond, Swan Pond). Because they are not directly affected by liquid effluents from BNL, these surface waters have not been extensively tested. Site-related contamination in these waters, if any, must originate from atmospheric deposition of air pollution. All these locations appear to be accessible to the public; thus, the potential for exposure does exist.

Sampling of these waters occurred in fewer locations and with less frequency than in the areas described above. The sampling results, which considered 21 inorganic analytes and 19 radiological contaminants, indicate that most analytes were never detected. Lead was the only analyte detected at concentrations higher than its corresponding health-based comparison value. Elevated lead concentrations were found in samples from the Carmans River with a maximum of 119.4 ppb and an average of 31 ppb; and four in Artist Lake (62.3 ppb, 57 ppb, 30 ppb, and 16 ppb). The source of the lead is not known. That atmospheric deposition from BNL would account for all of the lead contamination in just these control locations is, however unlikely, given that comparable levels of lead were not observed in other nearby surface waters.

Four rounds of sampling were conducted in the Peconic River during 2003 to determine what the levels of total mercury, methylmercury, and PCBs were in various sections of the Peconic River. Total mercury concentrations decreased with distance downstream of the STP during all sampling rounds by a factor of three to four times between the stations just downstream of the STP (37 to 80 nanograms(ng)/L) and the one at Schultz Road (11 to 21ng/L)(QEA 2003). Methylmercury concentrations differed somewhat because the concentrations between BNL=s property line and Schultz Road were consistently higher than those on BNL property. Sample results from further downstream at Donahue=s Pond indicate that both total mercury and methylmercury concentrations are consistent with background levels. Total PCB concentrations were consistent with background levels.

Off-Site Sediment Contamination

Some of the contaminants detected in surface waters have also been detected in sediments. This is especially true for hydrophobic compounds (e.g., PCBs) and compounds with an affinity for soils (e.g., metals). Many radionuclides are known to accumulate in sediments because of their chemical and physical properties, such as relative insolubility and lack of biodegradability, and having a high affinity for soil. Though most site-related contaminants entered surface waters at on-site locations, these contaminants have gradually been transported to downstream locations in runoff or under the force of river flow. Therefore, site-related contaminants are present not only in sediments near BNL=s wastewater discharges, but also in downstream locations.

Sediments at many off-site locations have been sampled to identify contamination that might be related to BNL=s operations. Contaminated sediments are located in various rivers, lakes, and ponds, but most of the available data characterize levels of contamination in the Peconic River. The contaminants originate from many sources, including BNL, runoff from roads and farms, municipal and industrial discharges, and atmospheric fallout.

Exposure to off-site sediments is believed to occur more often than exposure to on-site sediments, because off-site surface waters (e.g., the Peconic River, lakes and ponds) are accessible to anyone wishing to swim or fish in them. In the case of the Peconic River, people probably do not come into contact with submerged sediments often, but many upstream portions of the Peconic River periodically have little or no flow, with the result that potentially contaminated sediments are directly accessible to anyone walking or otherwise using the dry riverbed. Many BNL sampling efforts have confirmed that the Peconic River is often dry near, and downstream from, the site boundary.

Throughout the Peconic River basin, exposure to contaminants in sediments can occur via various pathways, including

- incidental ingestion of sediments,
- dermal contact with sediments,

- inhalation of dusts created during low water conditions when contaminated sediments may be dried and exposed, and
- external radiation from sediments with radiological contamination.

In general, residents who live near BNL and off-site surface waters and children who play in these areas could potentially be exposed to contaminated sediments.

Several studies conducted by BNL, NYSDOH, and SCDHS have documented contamination in off-site sediments, with the measured contaminants originating from multiple sources, and not strictly from BNL. These studies include BNL=s Remedial Investigations, environmental sampling data collected by NYSDOH, and a sampling effort coordinated by SCDHS and involving BNL, SCDHS, and Fish Unlimited.[2] Overall, the studies document levels of sediment contamination throughout the Peconic River basin and beyond. Specifically, sampling has been conducted along the entire Peconic River, Flanders Bay, Northport Bay, Peconic Bay, Donahues Pond, and Peconic Lake (also known as Forge Pond).

Samples were also taken at "control locations," or locations not directly affected by BNL=s wastewater discharges. These locations included the Peconic River upstream of BNL site boundary, Carmans River, Connetquot River, Lloyd Harbor, Yaphank Lake, Sandy Pond, and Swan Pond. Sandy Pond and Swan Pond feed into but do not receive water from the Peconic River.

Table SD2 summarizes the sediment sampling results reported for off-site locations. To put the levels of contamination into context, the sediment sampling results for off-site locations were split into two categories: samples collected along off-site portions of the Peconic River and samples collected at the control locations.

Data for Off-Site Sections of the Peconic River

Sediment data was obtained primarily from BNL=s Site Environmental Reports, BNL=s Remedial Investigation studies (including the follow-up 2000 plutonium contamination characterization study), NYSDOH=s 1996 report on radioactive contamination in the Peconic River (NYSDOH 1996), and SCDHS=s 1998 study on the same topic (SCDHS 1998). Table SD2 in Appendix C presents the maximum sediment concentrations measured across these studies for three groups of contaminants: radionuclides, pesticides and PCBs, and inorganics.

As Table SD2 shows, five radionuclides—strontium-90, cesium-137, radium-226, thorium-232, and uranium-233/234—had at least one concentration in off-site Peconic River sediments greater than the corresponding lowest NCRP soil screening limit. Of these, radium-226 levels exceeded the screening limit by the greatest margin, a factor of 20. For the remaining 19 radiological

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[2] According to the SCDHS report, Athe Independent Group (Fish Unlimited) did not continue to participate in this study following sample collection and distribution to each group. The [Memorandum of Understanding] required all participants to share their analytical data for the purposes of writing of this report. The Independent Group failed to provide adequate information regarding their analytical results. . . . Therefore this report includes only SCDHS and BNL/DOE analytical results@ (SCDHS 1998).

contaminants listed in Table SD2, one of the following is true: the contaminant was not detected (“ND”); the contaminant was not analyzed for in the samples that were collected (“NM”); the contaminant does not have an NCRP soil screening limit (“NA”), or the highest concentration is lower than the corresponding NCRP soil screening limit. The NCRP soil screening limits used in this analysis are based on land uses (e.g., farming) that realistically will not take place in the off-site Peconic River sediments. The comparisons shown in Table SD2 should be interpreted accordingly.

The SCDHS expressed concern over detections of americium-241 in the Peconic River sediments, because this radionuclide is a decay product of plutonium (SCDHS 1998). It is not clear, however, whether the americium in the sediments resulted from discharges of americium or from discharges of plutonium that later decayed to americium. Plutonium has been detected in the Peconic River sediments.

Of the 18 inorganic analytes listed in Table SD2, only arsenic had a sediment concentration higher than its corresponding health-based comparison value. Because this concentration (24.2 ppm) was measured far downstream from BNL site, near the town of Riverhead, whether the arsenic detected can be attributed to BNL operations is questionable. Moreover, the comparison value for arsenic used is a CREG, which is derived under the assumption of lifetime exposure to the contaminant. The probability that an individual would be exposed to sediments near Riverhead over such durations is low.

When compared with the on-site sediments, the off-site sediments had fewer contaminants at levels exceeding health-based comparison values. The contaminants that did exceed comparison values were strontium-90, cesium-137, radium-226, thorium-232, uranium-233/234, and arsenic. None of the PCBs and pesticides that were detected in the Peconic River sediments was found at concentrations higher than their corresponding ATSDR health-based comparison value.

The sampling that was conducted in the Peconic River during 2003 indicated that sediments between BNL boundary and Shultz Road had higher concentrations of methylmercury compared to the concentrations in sediments upstream on BNL property. It appears that the mercury contaminated sediments on site have migrated downstream and are pooling just off site. Mercury levels between Shultz Road and Donahue=s Pond decline and are consistent with background levels at Donahue=s Pond.

Data for Control Locations (i.e., Off-Site Sediments Other Than Those in the Peconic River)

To assess the extent to which sediment contaminants can be attributed to BNL operations, various agencies have compared levels of contamination in the Peconic River to off-site control locations. These locations do not receive waters from the Peconic River and therefore are not downstream from BNL=s wastewater discharges. It is possible that BNL operations have introduced some contaminants to surface waters and sediments in the control locations by way of atmospheric deposition of the site=s air emissions.

Sediment sampling of control locations was noted in many documents, including BNL=s Remedial Investigation reports and the SCDHS cooperative sediment sampling program. The results of these and other studies are shown in Table SD2. Of all the contaminants listed in the table, three — radium-226, uranium-233/234, and arsenic — were at levels greater than their corresponding health-based comparison values. The levels of the two radionuclides exceed the comparison values by relatively small margins (not greater than 12), and the comparison is a very conservative screen for toxicity, given that sediments at the control locations probably will never be used for the land uses for which NCRP derived its screening limits. In the case of arsenic, the peak concentration (9.1 ppm) appears to be a level indicative of naturally occurring contamination, and the public health implications of this contamination are expected to be minimal, given that residents probably come into contact with the off-site sediments only sporadically.

Biota Contamination

Various researchers have sampled biota in the area surrounding BNL, including BNL Analytical Services Laboratory (ASL), Suffolk County Department of Health Services (SCDHS), New York State Department of Health (NYSDOH), and New York State Department of Environmental Conservation (NYSDEC). International Technology Corporation (ITC) and Camp Dresser and McKee Corporation (CDM), are contractors for BNL. Much of the data from these sampling efforts are used in this summary.

This section reviews the results of biota sampling studies performed between 1973 and 1999. The five general categories of biota that were sampled and included in this review are fish, shellfish, wildlife (deer), vegetation (plants), and milk. The species and contaminants selected for sampling and the laboratory analytical methods varied from one sampling program to the next.

The combination of these factors makes comparing the monitoring data across years quite difficult. Some of the factors considered in the interpretation of the biota sampling data are as follows:

Sampling Locations

Levels of soil, sediment, and surface water contamination vary from location to location near BNL site. Thus, one would expect concentrations in vegetation and wildlife to vary with location as well. This is particularly true for vegetation and species that forage in a limited area.

Sampling and Analytical Methods

The sampling studies date from the early 1970s to the present — a time frame over which laboratory analytical methods for many contaminants improved greatly. Therefore, comparing results across different studies is difficult because analytical laboratories used many different methods (and some studies did not document the methods used). Moreover, the various studies sampled different tissues from biota (and some did not document which tissues were sampled), further complicating data interpretations, given that people tend to eat only certain parts of the biota.

Other Concerns

Other factors must be considered when one is interpreting data. For example, the age, size, or sex of the sample may have an impact. Depending on species, older or larger specimens may have higher concentrations of pollutants. Different types of contaminants accumulate in different parts of the body. PCBs tend to be stored in the fatty tissues of fish and mammals. Metallic mercury will accumulate in the kidneys and can enter the brain of mammals. For some mammals, the female forages in a smaller area and could be more affected by a contaminated on-site area than the male, which typically forages in a large area likely to encompass both on- and off-site territory.

Fish

Fish sampling studies conducted by BNL and the NYSDOH from 1973 through 1999 were included in the following documents: BNL=s Environmental Monitoring Reports, Site Environmental Reports, and the Remedial Investigation Studies (including the 2000 Plutonium Contamination Characterization and Radiological Dose and Risk Assessment Report), and NYSDOH=s 1996 Radioactive Contamination in the Peconic River. The sampling studies investigated fish living in the Peconic River not only on site and off site, but also in off-site background locations. All together, 763 samples were collected. The NYSDOH studies were conducted between 1973 and 1999 in off-site Peconic River locations and in control locations.

Laboratory analysis of fish samples differed among the different laboratories for the sample study time frame (1973–1999). Segregated analysis of fish (i.e., analyzing flesh and skin, viscera and bones, and whole fish separately) allows for more realistic dose calculations, because different radionuclides may become localized in different tissues (BNL 2000). Separating the analyses allows for the localization of radionuclide contamination within the fish. For example, strontium-90 mimics calcium within an organism and localizes in the bone. Because bones are not typically eaten, the potential dose from consumption is reduced. The following summary notes the type of sample used if the information was available.

The amount of sampling that was conducted depleted the number of larger fish in the Peconic River and as a result BNL suspended most on-site sampling beginning in 2001 (BNL 2002). In order to allow the fish populations to rebound to the numbers that were present in past years, BNL decided to suspend on-site sampling for three years. Sampling of fish from the Peconic River occurred only in off-site areas in 2001 and 2002.

On-site Fish Sampling

On-site fish sampling locations included the Peconic River at the former site perimeter (0.8 km downstream of the STP outfall), the current site boundary (2.6 km downstream), and the STP outfall itself. All together, 122 samples were taken on site. Samples were analyzed for radionuclides, specifically potassium-40, strontium-90, and cesium-137. Inorganics, pesticides, and polychlorinated biphenyls (PCBs) were analyzed in on-site fish samples only from 1996 – 1999. Data were usually presented as wet weight, although data in dry weight were occasionally provided.

The maximum potassium-40 concentrations (wet weight) were found in pumpkinseed (20.212 pCi/g), chain pickerel bone/viscera (7.536 pCi/g), and brown bullhead (6.625 pCi/g). Maximum strontium-90 concentrations (wet weight) were found in largemouth bass (5.447 pCi/g), brown bullhead (4.786 pCi/g), and pumpkinseed (4.752 pCi/g). Maximum cesium-137 concentrations were found in pumpkinseed (25.0 pCi/g), sunfish flesh (11.016 pCi/g), chain pickerel bone/viscera (9.312 pCi/g), and brown bullhead (8.0 pCi/g).

Mercury was the only inorganic detected at concentrations above comparison values. The maximum concentrations were found in chain pickerel (1.6 mg/kg) and pumpkinseed (1.2 mg/kg). Mercury levels in fish increased in 2000 to 3.01 mg/kg in brown bullhead catfish and 3.72 mg/kg in chain pickerel. Both of these samples were whole body composites composed of several small fish. The comparison value for fish consumption (0.14 mg/kg, RBC) is based on an assumption of residents consuming nearly 1 pound of locally caught fish per week over a 30-year period. Refer to Section 3.2.3 for further information on likely fish ingestion rates and NYSDOH=s advisory for eating fish caught from the state=s fresh waters.

Off-site Fish Sampling

The off-site portion of the Peconic River flows for 16.75 kilometers from BNL site perimeter through Donahue=s Pond and Forge Pond (currently known as Peconic Lake) before emptying into Peconic Bay at Riverhead. Sampling occurred most often in Donahue=s Pond and Forge Pond.

Samples were analyzed primarily for the radionuclides potassium-40, strontium-90, and cesium-137. Inorganics, pesticides, and PCBs were analyzed only from 1996B1999. All together, 363 samples were taken from the Peconic River off site.

Highest wet weight concentrations of potassium-40 (see Table B9) were found in pumpkinseed bone/viscera (6.49 ± 5.32 pCi/g), bluegill flesh/skin (6.40 ± 2.15 pCi/g), and chain pickerel flesh/skin (5.03 ± 1.45 pCi/g), although the levels for all fish species sampled were in the same order of magnitude.

Highest wet weight concentrations for strontium-90 (see Table B10) were found in the bone of an unspecified Atop feeder@ (7.90 ± 0.474 pCi/g), brown bullhead (3.328 pCi/g), and golden shiner (2.597 pCi/g). The highest levels for strontium-90 were recorded between the mid-1970s and the mid-1980s.

For cesium-137, the highest wet weight concentrations (see Table B11) were found in the flesh of an unspecified Atop feeder@ (2.8 ± 0.56 pCi/g), another unspecified so-called top feeder (2.59 ± 0.13 pCi/g), and the flesh of an unspecified s-called bottom feeder (2.33 ± 0.193 pCi/g). All three samples were recorded by NYSDOH during the mid-1970s. The highest concentration of cesium-137 for a more recent sample was for an unspecified fish caught in 1997 (1.66 pCi/g).

Mercury and arsenic exceeded health-based comparison values (see Table B14) in at least one sample. Almost all samples exceeded USEPA=s RBC for mercury, with the highest wet weight levels for largemouth bass (0.914 mg/kg), chain pickerel (0.645 mg/kg), and pumpkinseed (0.418, mg/kg). Fish sampling data for 2001 indicated mercury levels at 1.3 mg/kg and in 2002 mercury levels were below 1.0 mg/kg in all fish sampled off site. Arsenic was highest (wet weight) in the flesh of largemouth bass (0.91 mg/kg). As noted previously, NYSDOH has issued a fish consumption advisory for all fresh waters in the state.

Control Fish Sampling

Samples were taken at control locations off site to determine background levels of contaminants. Control locations included Carmans River, Connetquot River, Meadow Lake, Hempstead Lake, Lake Panamoka, Lake Ronkonkoma, Smith Pond, Fresh Pond, Massapequa Pond, Upper Twin Pond, Searington Pond, Willow Pond, Kahler=s Pond, Artist Lake, Sandy Pond, and Swan Pond. None of these locations receive waters from the Peconic River. Sandy Pond and Swan Pond both feed into the Peconic River, while the other locations are not connected to the Peconic River.

Samples were analyzed for the following radionuclides: potassium-40, strontium-90, and cesium-137. Inorganics, pesticides, and PCBs were analyzed only in 1997. All together, 278 samples were taken in off-site background locations. Tables B16 through B21 list the contaminants that were found in background samples.

The highest wet weight concentrations for potassium-40 were found in black crappie (12.91 ± 4.48 pCi/g), gizzard shad flesh/skin (7.15 ± 2.05 pCi/g), and carp (6.89 pCi/g). Other fish species had similar potassium-40 levels.

Strontium-90 maximum wet weight concentrations were found in an unspecified species (4.31 pCi/g), a bluegill (1.78 ± 0.08 pCi/g), and a brown bullhead bone/viscera (1.10 ± 0.06 pCi/g). The highest levels were recorded in the late 1990s.

Highest wet weight concentrations for cesium-137 were found in an unspecified bottom feeder (1.77 ± 0.071 pCi/g), a brown bullhead (1.687 pCi/g), and an unspecified mixed feeder (1.20 ± 0.020 pCi/g).

Fish collected from off-site control locations had detectable levels of two pesticides (DDD and DDE), and both pesticides were found at concentrations in some samples higher than their respective comparison value. Mercury was the only inorganic that exceeded health-based comparison values in the control samples, with the highest wet weight level found in a largemouth bass (0.364 mg/kg, wet). These detections at control locations suggest that the chemicals originate from sources other than BNL, such as pesticide applications in nearby farming or residential areas.

Shellfish

Off-site shellfish sampling locations included Flanders Bay, Indian Point, and Peconic Bay. Shellfish samples were analyzed for radionuclides, including potassium-40, strontium-90, and cesium-137, and for inorganic metals. Concentrations of potassium-40 in shellfish ranged from non-detectable to 9.21 pCi/g, wet weight, with the maximum concentration found in 1999. Cesium-137 concentrations ranged from non-detectable to 0.510 pCi/g, wet weight (maximum concentration found in 1976), and strontium-90 was found in concentrations ranging from non-detectable to 1.390 pCi/g, wet weight (maximum concentration found in 1980).

Maximum wet weight shellfish concentrations recorded by NYSDOH were lower than concentrations recorded by BNL for potassium-40 (2.50 pCi/g and 9.21 pCi/g, respectively). NYSDOH detected higher concentrations for cesium-137 and strontium-90 (0.510 pCi/g and 1.390 pCi/g by NYSDOH, 0.14 pCi/g and 0.053 pCi/g by BNL), though concentrations were the same order of magnitude.

Shellfish samples exceeded health-based comparison values for arsenic. Highest wet weight concentrations of arsenic were found in off-site control samples (2.61 and 2.12 mg/kg). All samples were contaminated with arsenic levels above the USEPA RBC. The RBC is based upon the assumption that residents eat approximately 1 pound per week of locally harvested shellfish over a 30-year period. Refer to Section 3.2.3 for a more detailed evaluation of the public health significance of the detected shellfish contamination.

Control samples were collected to determine background levels of radionuclides and chemicals in the environment that are not affected by BNL. The control locations where samples were collected were Seaford, NY and Raritan Bay. It should be noted that Raritan Bay is located in an industrial area.

Deer

A 1996 site environmental report released by BNL in 1998 documented cesium-137 concentrations in deer meat samples taken on and off site. A local group of citizens known as Standing for Truth About Radiation (STAR) felt that the concentrations could be harmful to people who hunt and consume deer in the vicinity of BNL. STAR petitioned the NYSDEC to implement a formal hunting ban on BNL property and issue a consumption advisory for deer from the area around BNL. In response, the NYSDEC conducted biota sampling on deer from an area adjacent to BNL between August 18 and October 12, 1998 to determine the levels of radiological contaminants contained in the deer tissues. Because only a few samples were collected, data were compiled for meat samples from deer killed on site and in the vicinity of the site between 1992 and 1999. Samples from a total of 32 deer were analyzed.

The NYSDOH estimated the effective dose equivalent (EDE) from exclusive consumption of local deer meat to be 7.1 millirem (mrem). Because the average EDE from eating foods containing naturally occurring radionuclides is 10 mrem per year, NYSDOH did not impose any restrictions on consuming locally grazing deer (NYSDOH 1999).

On-site Deer Populations

On-site deer samples were taken at several locations, including the South and Main Gates, the West Boundary, AGS, the Observatory, and Buildings 1001 and 830. Samples were analyzed for radionuclides, including potassium-40, strontium-90, and cesium-137. The levels detected are listed in Tables B23, B24, and B25, respectively.

The maximum potassium-40 concentration detected was 7.72 pCi/g found in deer flesh.

The highest concentration of cesium-137 was found in deer liver, measuring 14.59 ± 2.88 pCi/g. Concentrations in other tissues and samples also had levels at the same order of magnitude, though concentrations ranged from undetectable to the maximum of 14.59 pCi/g.

The maximum strontium-90 concentration detected was in deer flesh at 0.04 ± 0.10 pCi/g. Strontium-90 was undetectable in the majority of samples.

Off-site Deer Populations

Off-site deer samples were taken at several locations, ranging from 0.25 miles (Wm Floyd Parkway) to 38 miles (East Hampton, NY) from BNL. Locations included the Brookhaven State Park, Camp Wawepea, Bridgehampton, Yaphank, Hubbard Park, Mattituck, Watermill, and Shelter Island. The levels found are in Tables B26 through B28 in Appendix C.

The maximum potassium-40 concentration detected in an off-site sample was 21.23 ± 18.14 pCi/g, taken from a thyroid gland. This concentration was much higher than the maximum concentrations found in flesh and liver (6.32 ± 1.46 and 4.44 ± 1.22 pCi/g, respectively).

The maximum cesium-137 concentration was found in a deer flesh sample, at 4.71 ± 0.80 pCi/g. Similar to the range of samples taken on site, the cesium-137 concentration in off-site samples was from undetectable amounts to 4.71 ± 0.80 pCi/g.

Strontium-90 was not detected in off-site samples, though it may have been present at less than the detection limit of 0.04 pCi/g.

Small Mammals

BNL representatives conducted sampling studies of small mammals living on and off site. The mammals sampled included cats, raccoons, foxes, and opossums. All together, at least 14 samples were taken (the 1993 sampling study did not report the number of samples — only a minimum and maximum concentration). Tables B30 and B31 show the levels found in small mammals on site and off site, respectively.

Samples were analyzed for cesium-137 and potassium-40. Cesium-137 concentrations (wet weight) ranged from 0.132 to 8.17 pCi/g. Small mammal species caught off site showed reductions in cesium-137, with a range of 0.010 to 0.262 pCi/g, wet weight. In general, cesium-137 concentrations were 2 to 6 times greater in flesh than in liver tissues. Potassium-40 concentrations (wet weight) ranged from to 1.36 to 3.38 pCi/g.

Even though the small mammal species sampled by BNL might not be eaten by local residents, contamination levels might be similar to those of other small mammal species that might be eaten.

Vegetation

ATSDR reviewed vegetation sampling studies conducted by BNL and the SCDHS from 1973 through 1999. The sampling studies investigated edible vegetation grown on farms in close proximity to BNL and inedible vegetation, such as grass and tree leaves, growing on site.

Grass and tree leaves were monitored at BNL from 1985 to 1995 at various locations on site. Concentrations of potassium-40, cesium-137, beryllium-7, thorium-228, and radium-226 were found. A 1992 analysis of tree leaves in the vicinity of Building # 830 was performed in response to a leak in the facility. Maximum concentrations of cesium-137, potassium-40, thorium-232, and cobalt-60 in leaves were 1300, 7.45, 18.60, and 0.23 pCi/g, respectively. Both cobalt-60 and cesium-137 were present in the liquid spill (BNL 1993).

Local farms surrounding BNL were sampled for potassium-40, cesium-137, beryllium-7, and strontium-90. Samples were analyzed by BNL analytical services laboratory, with some analyses performed cooperatively with SCDHS. BNL and SCDHS concluded that the radionuclides detected were naturally occurring and at levels typical of global fallout. No radionuclides attributable to BNL operations were observed.

Though the available sampling data do not characterize levels of radionuclide contamination in all plant species at all locations near BNL, they do provide useful insights into levels of contamination at several nearby farms. More specifically, maximum concentrations of potassium-40 in edible vegetation were found in carrot leaves (6.59 pCi/g, wet weight) and Italian hot peppers (6.0 ± 1.5 pCi/g, wet weight). Maximum concentrations of cesium-137 and strontium-90 in edible vegetation were found in strawberries (cesium-137, 2.22 pCi/g, wet weight) and carrot leaves (strontium-90, 0.040 ± 0.008 pCi/g, wet weight).

Pathways Analysis

A release of a chemical or a radionuclide into the environment does not always result in human exposure. When these substances are present in environmental media such as air, drinking water, surface water, or soil, people can be exposed by eating, breathing, or contacting them. Unlike chemicals, radionuclides at high enough concentrations in the environment can result in external (or direct) radiation exposures to persons who are close to the material.

To determine whether nearby residents have been or currently are exposed to contaminants on site or off site, respectively, ATSDR evaluated the environmental and human components that could lead to an exposure. A pathway consists of the following five elements:

1. a source of contamination,
2. transport through an environmental medium,
3. a point of exposure,
4. a route of human exposure, and
5. an exposed individual or a population.

ATSDR characterizes an exposure pathway as completed or potential if it cannot be eliminated.

Completed pathways occur when all five elements are present and there are indications that exposure to a contaminant has occurred in the past, is currently happening, or will occur in the future. A potential exposure pathway exists when evidence of one or more of the five elements is missing, but the missing elements are plausible. Potential pathways indicate that exposure to a contaminant could have occurred in the past, could be occurring now, or could happen in the future. An exposure pathway can be eliminated if at least one of the five elements is missing and is not likely to be present. Exposure is defined by ATSDR as "contact at a boundary between a human being and the environment with a contaminant of a specific concentration for an interval of time."

An example of an exposure pathway scenario might include chemicals or radionuclides being released from a facility onto the ground (soil) during routine operations or an accident (the contaminant source). These substances may then dissolve in rainwater that percolates down through the soil to the underlying groundwater (the environmental media). If the contaminated groundwater is being used as a drinking water source (the point of exposure and exposed population), then people may be drinking or bathing (the routes of exposure) in water that contains these contaminants. All elements of the pathway must be present before the pathway is complete.

The focus of the ATSDR public health assessment is on current and past exposure to chemicals and to radioactive materials from the site. ATSDR scientists also evaluated potential future exposure to chemical and radioactive materials released from the site to the environment, when such an exposure was applicable.

The "Exposure Pathways Analyses" section describes the first tier of a multi-tiered approach to evaluate public health hazards in the public health assessment. This first tier, the exposure pathways analysis, is essentially a screening step to enable rapid identification of which pathways and contaminants are unlikely to cause adverse health effects and therefore require no further evaluation. Using conservative assumptions about exposure, ATSDR scientists estimated exposure doses for chemicals and radioactive materials in completed or potential exposure pathways. For chemicals, the estimated exposure doses are compared to a variety of health-based guidelines. The health-based guidelines are used to identify whether contaminant exposure merits further evaluation, not to quantify health risk. When the estimated chemical exposure dose exceeds an appropriate health guideline, a second tier of analysis involving a more in-depth, weight-of-evidence approach is used to evaluate any health hazard. The weight-of-evidence approach involves a thorough evaluation of the quality and relevance of scientific information that is the basis of health guidelines, considering various factors. The weight-of-evidence evaluation also considers whether human exposure will occur under hypothetical but realistic conditions of exposure. For radioactive contaminants, ATSDR scientists evaluate all site exposure pathways that contribute to radiological doses (committed effective doses and equivalent doses to the target organ).

Many uncertainties exist regarding the different exposure scenarios that could occur in the Peconic River. The upstream (on site) portions of the Peconic River are inaccessible in many areas, is either dry or has very little flow during parts the year, and the number and size of the fish vary compared to other areas of the river. These uncertainties can have an effect on the exposure rates. If there is little or no flow in the Peconic River during parts of the year then the amount of fish that a person consumes will be affected. Sampling results have indicated that downstream (off site) locations have lower contaminant concentrations in the water and sediment than those in the upstream (on site) locations. Where the fish was collected during the sampling could have an effect on the amount of contaminants the fish has accumulated.

Other uncertainties include what portion of the fish was sampled (whole fish or only edible portions of the fish). Extrapolating concentrations found in whole fish to only parts of the fish that are edible can be difficult because some contaminants concentrate in the bone or fatty tissues, which are generally not consumed. Concentrations may be overestimated or underestimated based upon where the contaminant concentrates in the fish. Additional factors that complicate efforts to evaluating exposures due to fish ingestion include different consumption patterns (e.g., some people eat only fillets and some people use all fish body parts when preparing meals) and preparation methods (e.g., pan fried, grilled, boiled).

Child Health Considerations

Women and children may sometimes be affected differently from the general population by contaminants in the environment. Both are physically smaller than the population average and are affected by smaller quantities of the contaminants. The effect of hormonal variations, pregnancy, and lactation can change the way a woman's body responds to some substances. Exposure during pregnancy and lactation can expose the fetus or infant if contaminants cross the placenta or get into the mother's milk. Depending upon the stage of pregnancy, exposure of the fetus could result in death (miscarriage or stillbirth) or birth defects. If the mother is exposed during lactation, her milk may concentrate certain contaminants, increasing the exposure of her infant.

ATSDR recognizes that a developing young person, whether fetus, infant, or child, has unique vulnerabilities. For example, some exposures would affect children more than adults because of children=s lower body weight and higher ingestion rate, with the result of an increased dose or amount taken into the body compared to their body weight. Because children are shorter, their breathing zones are closer to the ground, and thus closer to soil contaminants and low-lying layers in the air. Different behavioral characteristics include more hand-to-mouth behavior, increasing the ingestion of soil or dust contaminants.

Furthermore, children's metabolic pathways are less developed than those of adults, especially in the first months after birth. In some instances, children are better able to deal with environmental toxins, but in others, they are more vulnerable. Some chemicals that are not toxic to adults are highly toxic to infants.

Children grow and develop rapidly in their first months and years of life. Some organ systems, especially the nervous and respiratory systems, may experience permanent damage if exposed to high concentrations of certain contaminants during this period. Because of rapid growth and development, a child's genetic material (deoxyribonucleic acid, or DNA) is more likely to be exposed than later in life, making it more vulnerable to damage. Children have more future years than adults, giving more time for the development of illnesses that require many years to progress from the earliest initiation to the manifestation of the disease. Finally, young children have less ability to avoid hazards because of their lack of knowledge and their dependence on adults for decisions that may affect children but not adults.

The Exposure Pathways Analyses section indicates whether women and children were, are, or could be exposed to chemical and radioactive contaminants of concern in the completed and potential exposure pathways for the site. In the following section, “Public Health Implications,” this report discusses the public health hazard from exposures via these pathways.

Completed Exposure Pathways

Past Completed

Residential well sampling done by the SCDHS indicated that some of the wells contained contaminants at levels above current drinking water standards. ATSDR staff conducted different modeling scenarios for the contamination that exists in on- and off-site groundwater. When the model was run with a constant source concentration (at 50m depth), concentrations at residential wells were never significantly higher than the values measured in the late 1980s and 1990s.

For a single spill or for a very short-term type of contaminant release, off-site contaminant concentrations could have been higher prior to 1985. According to source and other on-site monitoring, this scenario is likely for only two plumes (the OU-IV waste solvent plume and the OU-I former landfill plume). ATSDR estimated the rate of contaminant migration and the estimated concentrations at specific locations and times.

Although several different contaminants have been detected, most of these are VOCs with similar physical properties such that behavior of the different plumes will be very similar. Because all the plumes are adjacent, it is further assumed that hydrogeological properties for the different plume areas are similar. Differences in the plumes are based on distance from plume origin to area of potential exposure and duration of plume migration (based on time of contaminant release at source). Distances of plume migration to areas of potential exposure range from 500 to 3900 m, and migration times from 12 to 53 years.

Depending on the specific plume and residential well location, exposure to several plumes could have occurred 5 to 7 years before initial detection in 1985. Limited data on depths of residential wells indicate, however, that the zones of highest contaminant concentration are below the screened well depths, so that actual exposures are much lower than potential exposures that are based on the assumption of lateral plume migration. Contaminant concentrations estimated for a depth of 30 m are very close to values measured in off-site residential and monitoring wells. Retardation and attenuation of contaminants within the groundwater flow system has reduced the concentrations of potential exposures relative to conservatively modeled concentrations.

Potential Exposure Pathways

Air

Throughout the history of BNL, several reactors have been in operation. Routine air emissions associated with the operation of BNL from 1948 through 1961 were mainly from the Brookhaven Graphite Research Reactor (BGRR). The reactor operated on the use of natural uranium fuel from 1951 to 1957. During this time, 28 ruptures of the fuel cartridges were reported. Each rupture released noble gases, particulates, and radioiodines into the air stream that cooled the reactor. Air monitoring was conducted during this time frame, but not with the sophistication of today's instrumentation standards.

Radiological releases from operations at the Brookhaven National Laboratory have resulted in atmospheric releases. Although these releases on the surface appear to be quite large, the radiological doses are relatively small with respect to doses known to cause observable adverse health effects. The reasoning for these low doses is based on the properties of the respective atoms. Tritium is a very low energy beta emitter that is uniformly distributed throughout the human body and is rapidly removed from the body. Argon-41, the largest contributor to the radiologic dose, is an inert gas, is not absorbed to a great extent in the body, and delivers the greatest amount of its radiologic dose to the skin surface.

With respect to the radiological dose to the thyroid, results from the Chernobyl accident suggest that adverse health effects would not be expected at doses less than 5 rem. The maximum estimated thyroid dose at BNL, 40 millirem, is about 12.5 times lower than the 5 rem dose limit. Therefore, we do not expect any observable adverse health effect that can be tied to these releases.

ATSDR has established a comparison value for the evaluation of radiogenic cancers (ATSDR 2004. Public Health Assessment Y-12 Uranium Releases Oak Ridge Reservation (USDOE) Oak Ridge, Anderson County, Tennessee. Atlanta: ATSDR.). This value is 100 millirem per year (mrem/y) and a lifetime dose not to exceed 7000 millirem above nominal background. The combined estimated doses for the years with the highest releases from BNL are all less than the lifetime dose recommendation of the agency and are not expected to cause any observable or detectable adverse effects.

Surface Water

Contamination in Wastewater Discharges

Sampling of BNL=s various wastewater discharges confirms that the laboratory releases trace levels of contaminants into local surface waters. Inorganic and radiological contaminants were detected most frequently — but only a small subset of these contaminants had at least one concentration higher than corresponding health-based comparison values. Direct exposure to BNL=s wastewater discharges is not likely, and any such exposure would be infrequent.

Contamination in On-Site Surface Water

BNL has routinely sampled its on-site recharge basins, the wetlands, and the Peconic River, finding that several inorganic and radiological contaminants periodically exceed corresponding health-based comparison values. No contaminants, however, routinely exceeded these values. Because exposure is limited, the contamination in the on-site surface waters is not believed to be a public health hazard. Factors limiting exposure include the restricted access to the site and the limited flow in the Peconic River.

Contamination in Off-Site Surface Water

Exposures to off-site surface waters appear to be limited to dermal contact, which may be frequent for some individuals (e.g., anglers), and to occasional ingestion (e.g., accidental ingestion when swimming or canoeing/kayaking in the Peconic River). At downstream locations, human exposure to the Peconic River waters clearly occurs, particularly via the dermal exposure route. In these locations, the Peconic River is accessible to anyone wishing to swim, boat, or observe wildlife. BNL and NYSDOH have collected samples from the Peconic River and other nearby bodies of water. Occasionally, inorganic contaminants (arsenic, cadmium, lead, manganese, and thallium) and radiological contaminants (gross alpha radiation, gross beta radiation, and tritium) were found at levels higher than health-based comparison values.

Biota

Biota are considered a potential human exposure pathway for residents near BNL. Site-related contaminants can be taken up from water, sediment, and food by aquatic organisms and by terrestrial animals through the food chain or by ingestion of sediment and soil. For example, some of the heavy metals and radionuclides that have been detected in the sediment, groundwater, and surface water can accumulate and concentrate in aquatic biota (e.g., fish and mussel). The Peconic River has several species of edible fish, including bluegill, perch, largemouth bass, crappie, and pumpkinseed.

Hunting on BNL property is prohibited, but it is allowed in areas surrounding BNL. The deer study conducted by the NYSDEC and analyzed by the NYSDOH indicates that on-site deer have elevated levels of cesium-137 compared with deer in areas far enough away from BNL as to not be affected by BNL contaminants. Although the levels of cesium-137 are elevated, they are not elevated to the point that they would cause adverse health effects if someone were to eat the deer. Estimated exposure doses fall between 5 mrem and 9 mrem for 1 year of intake. This exposure dose is below the 10 mrem/year limit, and therefore hunting restrictions relating to the consumption of deer meat were not warranted.

Local anglers in the area have access to areas on site and off site along the Peconic River as well as residents who live off site along the Peconic River. The on-site portion of the Peconic River during parts of the year is either dry or has very little flow — too little to support thriving fish populations. Sampling results have indicated that fish from the on-site portion (upstream) of the Peconic tend to be smaller in size than those in off-site locations. Fish sampling conducted in the on-site portion of the Peconic has indicated that most samples are of insufficient size to eat, and the sampling results have been reported for whole-body contaminant loads. Extrapolating sampling results from whole body contaminant measures as opposed to concentration measures in the edible portions adds uncertainty regarding those contaminants to which an individual might be exposed.

Fish consumption rates for populations who live near and fish from the Peconic River are not known. The national average fish consumption rate by the general population is 6.5 grams/day and 17.5 grams/day for the recreational or sports fishermen (USEPA 1998).

The majority of the samples were analyzed for radionuclides. Inorganics, pesticides, and PCBs were only analyzed from 1996 – 1999, 2003. Mercury and PCB concentrations have been detected at levels above comparison values in several species (largemouth bass, chain pickerel, creek chub sucker, and pumpkinseed) mainly in on-site portions of the Peconic River and in a few off-site locations. The maximum mercury concentration detected in fish on site was 3.72 mg/kg, and off site the maximum concentration was 0.914 mg/kg. A maximum concentration of mercury (0.364 mg/kg) was detected in fish from control or background locations. Although the level is lower than that found near the site, it is a clear indication of multiple sources of contamination in areas surrounding BNL. Average mercury concentrations in edible fish tissue samples outside BNL property were 0.62 ppm and 0.02 ppm PCBs. Fish on BNL property were analyzed as whole body samples. The average concentrations for the on-site samples were 0.68 ppm mercury and 1.77 ppm PCB.

The New York State Department of Health has issued a health advisory for the fresh waters of Long Island regarding fish consumption. The advisory states that no one should eat more than one meal of fish per week from any of the state=s fresh waters (NYSDOH 2003). If residents and anglers follow the recommendations in the advisory, adverse health effects are not expected. If residents and anglers were to subsist from fish in the on-site portion of the Peconic River, adverse health effects from PCBs and mercury may be expected. The maximum concentrations of mercury found in fish on site are above the action level of 1 ppm for methylmercury in fish (FDA 1996). FDA also recommends that the regular consumption of fish with methylmercury levels around 1 ppm be limited to approximately 7 ounces per week; for fish with levels averaging 0.5 ppm, the limit is about 14 ounces per week.

ATSDR performed a screening dose assessment to determine if a more in-depth dose assessment would be necessary. For the screening, ATSDR did not select the various species analyzed, but rather chose the biota sample with the highest concentration of the radionuclide. For fish, the whole sample (flesh and bone) was evaluated. In the case of deer, only the flesh was evaluated. For shellfish, the species evaluated was not given.

For ingestion rates, ATSDR used values for deer derived from a previous BNL assessment, which assumed that a hunter would consume 29 kilograms (64 pounds) of a deer a year. In the case of fish, shellfish, and edible vegetables, ATSDR used values derived from the USEPA Exposure Factors Handbook. In the evaluation of the radiation dose, dose coefficients derived from Federal Guidance 13 were used.

The following tables present the results of ATSDR=s dose analysis. Because some radionuclides concentrate in specific organs, delivering a higher dose to those organs, ATSDR evaluated doses both to the whole body and to the critical organ. Table 7 shows the radiological dose to the whole body.

Table 7. Radiation Dose (mrem/year) to the Whole Body Following Ingestion of Listed Foods*

	Cs-137	*Sr-90*	*U-234*	*U-238*	*Total DoseH*
Fish (maximum concentration found)	1.66	1.06	0.0268	0.00108	2.75
Shellfish	0.0226	0.124			0.1147
Deer	17.2	0.118			17.3
Vegetables	7.63	0.28			7.91
Off-site Fish	0.186				0.186
Control Fish	0.0372	0.121	0.000629	0.000412	0.159
Off-site Deer	6.90				6.90

* the listed value for a food does not necessarily mean the same sample had all the listed radionuclides

H dose is expressed in millirems per year

An individual would receive the highest dose from consuming deer obtained from on-site locations. Nonetheless, the estimated dose of 17 millirems per year is not considered by ATSDR as a public health hazard. Furthermore, if a hunter consumed both deer and vegetables from off-site locations, the total dose would be approximately 15 millirems, a dose that is also not considered a public health hazard.

Table 8 lists the estimated radiological dose to the critical organ. The critical organs are the lower large intestinal (LLI) wall for Cs-137 and the bone surfaces for Sr-90, U-234, and U-238. The radionuclides of greatest concern in this analysis are Cs-137 and Sr-90. As with the radiation dose to the whole body, these doses are not a public health concern.

Table 8. Radiation Dose (mrem/year) to the Critical Organ Body Following Ingestion of the Listed Foods*

	Cs-137	*Sr-90*	*U-234*	*U-235*
Fish (maximum	2.03	15.7	0.426	0.0173

	Cs-137	*Sr-90*	*U-234*	*U-235*
concentration found)				
Shellfish	0.0277	1.84		
Deer	21.1	1.75		
Vegetables	9.35	4.15		
Off-site Fish	0.228			
Control Fish	0.0456	1.79	0.010	0.00657
Off-site Deer	8.45			
Critical Organ	LLI Wall	Bone Surface	Bone Surface	Bone Surface

* the listed value for a food does not necessarily mean the same sample had all the listed radionuclides

H doses are expressed in millirems per year

Cesium-137 and strontium-90 are byproducts of nuclear reactors and nuclear weapons; until nuclear weapons testing, they were not found in nature. There are few regulatory restrictions limiting the public to exposures to these radionuclides specifically. internal dose limits have, however, been codified in the Code of Federal Regulations by both the Nuclear Regulatory Commission (NRC) and the Department of Energy (DOE). These agencies= dose limits vary, but they are much higher than the doses ATSDR calculated. For example, the NRC limits for internal **and** external dose to individual members of the public from its licensees and their operations do not exceed 100 millirems in a year (10 CFR 20.1301).

The DOE has no regulations in effect that protect the public from internal doses resulting from the intake of radiological materials. Still, DOE regulations that limit the occupational doses do exist. These limits are not to exceed 5000 millirems per year for general employees (10 CFR 835.202), 500 millirems to the fetus considered from conception to birth (10 CFR 835.206), and 100 millirems per year to a minor (10 CFR 835.207) or a member of the public during direct on-site access at a DOE site or facility (10 CFR 835.208).

ATSDR has recently developed draft toxicological profiles for cesium and strontium. These documents summarize the science associated with the health effects of these elements in their stable and radioactive forms. In general, health effects are not observed with any radioactive material until the dose exceeds 5,000 to 10,000 millirem levels. These levels are much higher than those estimated by ATSDR for ingestion of foods around BNL. A summary of the health effects associated with cesium (stable or radioactive) indicates there are no immunological effects at doses less than 100 rad (similar to 100,000 millirems), and no reproductive effects at doses less than 300,000 millirems.

ATSDR’s toxicological profile for strontium states that the data for adverse health effects of stable strontium in humans are sparse. An epidemiological study found no positive association between strontium ingestion and certain kinds of heart disease. Strontium chloride had no adverse effect on the function of stored human sperm in in-vitro fertility assays. However, numerous animal studies demonstrated adverse effects of excess stable strontium on skeletal development following oral ingestion.

Because absorbed Sr-90 is a bone-seeking radionuclide, it is preferentially retained in bone, and internal exposures will lead to chronic internal exposure to ionizing radiation. Consequently, the most significant effects of exposure to absorbed radioactive strontium are necrosis and cancers of bone and tissues adjacent to bone. Persons with Paget=s disease (osteitis deformans) may be vulnerable to radioactive strontium because of their higher than normal rates of retention in focal sites of bone deposition.

Soil

OU I

The highest concentrations of contaminants detected in soils were at various locations in and around the Hazardous Waste Management Facility (HWMF). Workers were probably exposed to these soils, but their exposure was infrequent and of short duration. The HWMF is fenced and access to the facility is controlled, thereby restricting access to the public or trespassers. This site is unlikely to be visited by anyone other than the workers.

OU III

The highest concentrations of contaminants that exceeded CVs or RBCs and were detected in soils were found in samples taken from the Recharge Basins HP (arsenic and iron) and the TCE Spill Area (benzo(a)pyrene). Mercury-contaminated soils from Building 464 were removed and are no longer present. OU III is not completely fenced in, and occasional trespassers could enter these areas (ITC 1998d).

Residential areas in OU III are located southwest of the Recharge Basin HP, but residents are not expected to enter this area because the Recharge Basin HP is not easily accessible via roadways. Contaminant levels are not high enough to result in adverse health effects in the unlikely event an occasional visitor comes into contact with contaminated soil. Exposure to these contaminants is probably infrequent, if at all.

OU IV

The highest concentrations of contaminants detected in soils are mostly located at the Sump Outfall of Building 650. OU IV is located near the center of BNL property, and on-site residential areas are located to the southwest, some distance from OU IV. Contaminated areas of OU IV are unlikely to be visited by anyone other than the workers.

OU V

The highest concentrations of contaminants detected in soils in OU V are at various locations in and around the Sewage Treatment Plant (STP). Because the STP is in a remote area of BNL, it is unlikely to be visited by anyone other than workers. Exposure to these contaminants is probably infrequent, if at all. Contaminated areas in OU V are some distance from on-site residential areas.

OU VI

BNL personnel are not expected to be working regularly in any of the three areas of concern in OU VI. The highest concentrations of contaminants detected in soils were at various locations throughout the upland recharge/meadow marsh area. Anyone temporarily working in these areas is presumed to wear appropriate protective clothing. These areas are in a remote area of BNL, and they are unlikely to be visited by anyone other than BNL personnel.

Public Health Implications

Toxicologic Evaluation

The evaluation of toxicological properties of contaminants and their effects on human health takes a variety of factors into account. First, a person must be exposed to a chemical by coming in contact with it. The routes of exposure can include breathing, drinking, eating, or dermal contact with a substance that contains the contaminant. Second, the type and severity of adverse health effects resulting from an exposure to a contaminant depend on the concentration of the chemical, the frequency and duration of exposure, the route of exposure, whether the exposure was to a single contaminant or a mixture of contaminants, and whether there were multiple exposures.

The following is a listing of the comparison values used in ATSDR=s analysis and a description of what they measure:

Minimal Risk Level (MRL)—An estimate of daily exposure of a human being to a chemical (in milligrams per kilogram per day [mg/kg/day]) that is likely to be without an appreciable risk of deleterious effects (noncarcinogenic) over a specified duration of exposure. MRLs are based on human and animal studies and are reported for acute (less than or equal to 14 days), intermediate (15–364 days), and chronic (greater than or equal to 365 days) durations (ATSDR 1992b).

MRLs have been derived from animal data for both short- and long-term exposure and used to provide a basis for hazard estimates in humans, based upon all known experimental data on the chemical of concern. Because the method for deriving MRLs does not use any information about cancer, an MRL does not imply anything about the presence, absence, or level of risk of cancer. For carcinogenic substances, USEPA has established the Cancer Slope Factor (CSF) as a health guideline. The CSF is used to determine the number of excess cancers expected from exposure to a carcinogenic contaminant.

Lowest-Observed-Adverse-Effect-Level (LOAEL)—The lowest exposure dose in a dose-response experiment at which there is a biologically or statistically significant increase in frequency or severity of adverse effects between the exposed population and its appropriate control. It is the level at which adverse health effects first appear.

No-Observed-Adverse-Effect-Level (NOAEL)—The dose of chemical at which there were no statistically or biologically significant increases in frequency or severity of adverse effects seen in the exposed population above its appropriate control. Effects may be produced at this dose, but they are not considered to be adverse. It is the highest exposure level at which no harmful effects were seen in the organ system(s) studied.

The following formula is used in determining an exposure dose:

$$ED = \frac{(C \times IR \times EF)}{BW}$$

where

ED = exposure dose (mg/kg/day),

C = contaminant concentration,

IR = intake rate,

EF = exposure factor, and

BW = body weight.

Standard intake rates are used for the ingestion of soil and water. A conservative estimate of 0.5 liter per day for incidental surface water ingestion was used in the calculation of an estimated exposure dose. Standard body weights used in the calculations are 16 kg for children and 70 kg for adults.

The maximum concentration for a contaminant is used to calculate an exposure dose most protective of public health. Exposures might vary — different groups of the population will be exposed at different frequencies. An exposure factor is used in certain situations, because exposures can be intermittent and not continuous.

ATSDR staff used the following variables in calculating the estimated exposure doses by various pathways for the different exposure scenarios:

1. Ingestion Rate (drinking water): Adults = two liters per day, Children = one liter per day
2. Exposure Factor: Adults and Children assumed to be exposed daily
3. Body Weight: Adults = 70 kilograms (kg); Children = 16 kg for ages 1 though 6; and 10 kg for an infant.

ATSDR compares data collected from animal testing and human epidemiological studies, as well as occupational studies, with estimated exposure doses calculated from known or potential exposures at hazardous waste sites. On comparison, ATSDR can evaluate the likelihood of adverse noncancerous health effects and cancerous effects or cancer risk. Very few epidemiological studies, however, have been carried out on low-level exposure to VOCs, thus making production of reliable cancer estimates difficult. In this public health assessment, ATSDR has evaluated exposures on an individual contaminant basis because of the limited amount of toxicological information on mixtures. Most occupational studies involve subjects who were exposed to high concentrations (in the parts per million range) for short periods of time (8 hours or less) to the undiluted chemical.

Trichloroethylene (TCE)

Trichloroethylene (TCE) is a nonflammable, colorless liquid at room temperature with a sweet odor and a sweet, burning taste. TCE is used mainly as a solvent to remove grease from metal parts and to formulate other chemicals. TCE is also a degradation (breakdown) product of tetrachloroethylene (PCE).

The intermediate MRL for ingestion of TCE that was used as a comparison value in the groundwater consultation has since been withdrawn because of a lack of adequately designed studies examining suitable end points. A chronic MRL for oral exposure has not been derived either. No health guideline is available for chronic TCE exposure (greater than 1 year duration) for either inhalation or ingestion.

In the past, TCE was used as an anesthetic. Studies involving TCE exposures in humans indicate that the central nervous system is the primary system affected. Effects include headache, vertigo, fatigue, short-term memory loss, impaired word associations, central nervous system depression, and anesthesia.

The highest concentration of TCE detected in residential wells surrounding BNL was 8 ppb at an unknown depth. Other concentrations of TCE detected in residential wells were at or just below the MCL of 5 ppb. The only oral (ingestion) MRL that exists for TCE is for acute exposure (14 days or less). That MRL is equal to 0.2 mg/kg/day (ATSDR 1997b). The MRL was based on a study in which mouse pups between the ages of 10 and 16 days were dosed by gavage with 0, 50, or 290 mg/kg/day TCE in a 20% peanut oil emulsion (Fredricksson et al 1993). ATSDR estimated exposure doses for children and adults by using the highest level found in residential wells. The estimated adult dose is equal to 0.00023 mg/kg/day, and the dose for children is 0.0008 mg/kg/day. The estimated doses are below the acute MRL of 0.2 mg/kg/day, and they are not expected to produce adverse health effects.

A MRL for acute inhalation exposure to TCE is equal to 2 ppm. The MRL was based on a study in which volunteers were exposed to 200 ppm TCE for 5 days, 7 hours per day. A LOAEL was observed for mild neurological effects, such as fatigue and drowsiness. The MRL for intermediate inhalation exposures to TCE is 0.1 ppm, based on a study of rats showing an increase in sleep-apneic episodes and cardiac arrhythmias after the rats' exposure to TCE. Indoor air monitoring for TCE was not conducted.

Occupational studies have shown that workers who have had dermal contact with pure or concentrated TCE have had adverse effects including skin rashes and dermatitis; potential effects of low levels of TCE exposure on the skin are however, unknown (ATSDR 1997b).

Both the USEPA and the International Agency for Research on Cancer (IARC) consider TCE to be a probable carcinogen in humans (ATSDR 1997b). USEPA expresses toxicity values for carcinogenic effects as slope factors. The maximum TCE concentration detected in residential wells (8 ppb) was used to determine a lifetime excess cancer risk for children and adults. ATSDR assumed an exposure duration of 20 years in the calculation of excess cancer risk; the site has not been in operation for 70 years, and the modeling conducted indicates that the earliest any of the plumes would have reached the residential wells was 1977. At this concentration, neither children nor adults would be expected to develop cancer.

A study of a Tucson, Arizona population evaluated exposure to TCE (6 to 239 ppb) and other contaminants (1,1-dichloroethylene [1,1-DCE] and chromium) in the drinking water from certain wells. The study showed an association between the elevated levels of TCE in drinking water and congenital heart disease in children whose mothers were exposed during the month before conception and during the first trimester of pregnancy (Goldberg et al 1990). A limitation of this study is the exposures to other well contaminants besides TCE. 1,1-DCE was also found in some of the residential wells around BNL, but chromium was not. None of the residential wells around BNL contained both TCE and 1,1-DCE above their respective drinking water standard.

1,1-Dichloroethylene (1,1-DCE)

1,1-Dichloroethylene is a man-made chemical used for certain plastics (such as packaging materials and flexible films such as Saran Wrap®) and flame-retardant coatings for fiber and carpet backing. It is a colorless liquid that evaporates quickly at room temperature. Also, 1,1-DCE is a breakdown product of 1,1,1-trichloroethane (1,1,1-TCA).

Evidence from animal studies indicates that 1,1-DCE toxicity is mediated by metabolism to reactive intermediates that act at the cellular level and ultimately compromise the viability of the target tissues (ATSDR 1994b). Therefore, the toxicity in humans would most likely depend on the extent to which 1,1-DCE is metabolized and the concentration of intermediates formed. Animal studies have indicated that animals are much less tolerant of continuous exposure (23B24 hours per day) to 1,1-DCE than of intermittent exposure. For example, there was no evidence of toxicity in beagle dogs exposed to 100 ppm of 1,1-DCE via the inhalation route for 8 hours/day, 5 days/week for 42 days, but continuous exposure to 48 ppm of 1,1-DCE for 90 days caused marked liver damage (ATSDR 1994b).

The highest concentration of 1,1-DCE detected in residential wells was found in 1990 by the SCDHS Bureau of Drinking Water in an area of North Shirley at a concentration of 20 ppb (SCDHS 1990). The SCDHS was investigating contamination from the Precision Concepts business in the Brookhaven Industrial Park. It was determined that the source of the 1,1-DCE in this particular residential well was from Precision Concepts. Because similar concentrations were found off site, ATSDR has used the maximum concentration found in residential wells to determine the likelihood of adverse health effects.

ATSDR staff used the maximum detected concentration of 1,1-DCE (20 ppb) in residential wells to estimate a daily exposure dose via ingestion for adults and children. The estimated exposure doses from ingestion are 0.0006 mg/kg/day for adults and 0.0013 mg/kg/day for children. A chronic exposure MRL equal to 0.009 mg/kg/day was derived for the ingestion route (ATSDR 1994b). There is no intermediate ingestion MRL for 1,1-DCE, but it can be assumed that the level would be greater than the chronic MRL. Therefore, there is no expectation that adverse health effects would occur for people ingesting this level of 1,1-DCE.

The liver, the kidneys, and possibly the lungs can be considered target organs when individuals are exposed to1,1-DCE through ingestion (oral) and/or inhalation (ATSDR 1994b). 1,1-DCE is associated with liver and kidney toxicity in humans after repeated, low-level exposure (ATSDR 1994b). The actual level that caused the toxic effects was not reported in the study.

The intermediate inhalation MRL for l, l-DCE is 0.02 ppm (ATSDR 1994b). The MRL is based on a no-observed-adverse-effect-level (NOAEL) of 5 ppm for hepatic effects in guinea pigs continuously exposed to l, l-DCE. Assuming that the inhalation exposure dose(s) is (are) similar to the estimated ingestion dose(s), based upon the 20 ppb concentration, the likelihood of adverse health effects would be low.

Other off-site detections were at levels below the 20 ppb concentration. The concentrations of 1,1-DCE in residential wells are not at levels at which adverse health effects would be expected. No information is available concerning the human organs that are targets of dermal exposure to 1,1-DCE, and no studies regarding l, l-DCE dermal absorption were located. 1,1-DCE has a high vapor pressure (greater than 500 torr at room temperature), and as a result, the rate of evaporation would be rapid, leaving little time for skin penetration.

Evidence of carcinogenicity in animals is limited. Animal studies involving the ingestion of 1,1-DCE have not shown statistically significant increases in the incidence of cancer when the exposed animals are compared with the control (non-exposed) animals. The USEPA has determined that 1,1-DCE is a possible human carcinogen and has derived an oral cancer slope factor of 0.6 mg/kg/day. The IARC has determined that 1,1-DCE is not classifiable as to its carcinogenicity in humans. No relationship has been demonstrated between the occurrence of cancer in humans and occupational exposure (primarily chronic inhalation exposure) (ATSDR 1994b). No studies have been located regarding cancer in humans after oral or dermal exposure to l, l-DCE (ATSDR 1994b).

The likelihood that residents were drinking this level (20 ppb) of 1, 1-DCE for more than 20 years is very low, because the maximum concentration was from the Precision Concepts plume, which had a duration of 10B12 years. ATSDR=s modeling indicates that it would have taken approximately 5 years after introduction of 1, 1-DCE to the aquifer before it reached the residential wells. Assuming this scenario, a residential well may have had the contamination for 5B7 years. The excess cancer risk based on this scenario would be very low.

The extensive residential well sampling conducted in 1995B1996 did not indicate 1,1-DCE contamination above the drinking water standard of 5 ppb.

Chloroform

Chloroform is a colorless liquid with a nonirritating odor and a slightly sweet taste. It is found in waste water from sewage treatment plants, and small amounts are formed as an unwanted product during the process of chlorinating water. Exposure to chloroform via ingestion of drinking water is expected to be extensive because most U.S. community drinking-water supplies are chlorinated. Typical levels in drinking water range from 2 to 68 ppb (Brass et al 1977; USEPA/AMWA 1989; Furlong et al 1986; Kasso et al 1981; Krasner et al; 1989 Rogers et al 1987).

The chronic oral (ingestion) MRL and the chronic-duration oral reference dose (RfD), both derived from the LOAEL of 15 mg/kg/day in dogs, are equal to 0.01 mg/kg/day (ATSDR 1997a). The dose was adjusted for intermittent exposure and divided by an uncertainty factor of 1,000 (10 for extrapolation from animals to humans, 10 for the use of a LOAEL, and 10 for human variability). A NOAEL of 2.46 mg/kg/day for liver and kidney effects was determined in humans who used a mouthwash containing 0.43% chloroform for 1B5 years (Desalva et al 1975). The maximum chloroform concentration detected in residential wells was 10 ppb. This level is one-eighth of the drinking water standard. Estimated exposure doses were calculated by use of this concentration. The resulting doses were equal to 0.0003 mg/kg/day for adults and 0.0006 mg/kg/day for children. These doses are two orders of magnitude below the chronic MRL, and adverse health effects would not be expected.

Many incidents of occupational exposure to chloroform via inhalation are documented. LOAELs are available for both intermediate and chronic duration. Workers exposed for 1 to 6 months experienced vomiting and nausea at concentrations of 14 ppm and 22 ppm, respectively (Phoon, Goh, Lee, et al. 1983). Workers also experienced toxic hepatitis and jaundice when exposed to 14B400 ppm for 1 to 6 months (Phoon, Goh, Lee, et al. 1983). Similar conditions have been reported for workers exposed chronically. An MRL of 0.02 ppm has been derived for chronic-duration inhalation exposure to chloroform (ATSDR 1997a). The MRL was based on a LOAEL of 2 ppm in workers exposed to concentrations of chloroform ranging from 2 to 205 ppm for 1B4 years (Bomski 1967).

These levels are in the part-per-million range, and the maximum concentration in the wells was in the part-per-billion range. The levels detected in the wells are one thousand times lower than the MRL. ATSDR does not believe that these levels are sufficient to cause adverse health effects. There was no clinical evidence of liver injury in workers exposed to chloroform at levels as high as 71 and 237 ppm chloroform for intermediate and chronic durations, respectively (Challen et al 1958). No other studies indicated any observed adverse effects in individuals exposed to chloroform concentrations below the part-per-million level. No studies were located regarding systemic effects in humans after dermal exposure to chloroform. Chloroform has been found to be carcinogenic in animals after oral exposure. However, the data are not sufficient to support any conclusion regarding the carcinogenic potential in humans exposed to chloroform by the inhalation, oral, or dermal routes.

1,1,1-Trichloroethane (1,1,1-TCA)

1, l, l-TCA is a synthetic colorless liquid that has a sweet, sharp odor. The liquid evaporates quickly and becomes a vapor in the air. It is often used as a solvent to dissolve other substances, such as glues and paints. In industry, it is widely used to remove oil or grease from manufactured metal parts. The maximum concentration of l, l, l-TCA detected in residential wells was 340 ppb at an unknown depth. ATSDR calculated estimated daily exposure doses for children and adults. At 340 ppb, a child's ingestion exposure dose would be 0.0213 mg/kg/day. The estimated ingestion exposure dose for adults at this concentration would be 0.0097 mg/kg/day.

MRLs for the ingestion pathway for acute, intermediate, and chronic exposures do not exist. Unpublished studies, which were considered as potential candidates for deriving acute-, intermediate-, and chronic-duration oral MRLs, were peer-reviewed and found to be of inadequate design. The only available exposure data for the ingestion of l, l, l-TCA in humans were from two acute exposures in which the people had ingested 600 mg/kg/day (ATSDR 1995). This level is much greater than the levels associated with the groundwater contamination around BNL. Studies performed with rats that received doses of up to 3 mg/kg/day indicated no observed adverse effects. No documented studies of animals and humans demonstrate adverse health effects for exposure to concentrations below 3 mg/kg/day (ATSDR 1995).

An intermediate MRL of 0.7 ppm exists for the inhalation pathway of 1,1,1-TCA (ATSDR 1995). Assuming that the inhalation dose is similar to the ingestion dose, the estimated inhalation exposure doses for 1,1,1-TCA-contaminated well water were 340 ppb (0.340 ppm) for adults and approximately half the intermediate MRL for children. A chronic MRL for the inhalation pathway does not exist. Nevertheless, two occupational studies of workers who had been exposed for 6 years and 6.7 years to concentrations of 150 and 200 ppm, respectively, did not identify adverse effects (ATSDR 1995). These levels are much greater than those found in the residential wells, and ATSDR does not believe that exposures to 1,1,1-TCA in well water at this site are sufficient to cause adverse effects.

There is no documented information available on the extent and speed of skin absorption of 1,1,1-TCA from aqueous (mixed in water) solutions (ATSDR 1995). Because of l, l, l-TCA's high volatility, exposure doses of less than 1 mg/kg/day — the likely scenario around BNL — would produce no dermal reactions. Occupational exposures to undiluted (pure) l, l, l-TCA have produced a mild burning and a mild erythema to exposed areas of the skin (ATSDR 1995). But the effects were reversible after the exposure ended.

No studies were located regarding cancer in humans exposed to l, l, l-TCA through the inhalation and dermal routes. A study performed by Isacson et al in 1985 involved the relationship between the presence of organic chemicals, including l, l, l-TCA, in drinking water and the incidence of cancer in Iowa residents (Isacson et al 1985). The authors found no difference in the incidence of bladder, colon, lung, rectal, breast, or prostrate cancer in people over age 55 (Isacson et al 1985). No other studies regarding the risks of cancer in humans after oral exposure to l, l, l-TCA were located. Neither a cancer slope factor nor a CREG has been derived for l, l, l-TCA.

Ethylene Dibromide (EDB)

Ethylene dibromide (EDB), also referred to as 1,2-dibromoethane, is a pesticide. In the past, it was used as a leaded gasoline additive to produce better fuel efficiency. In the 1970s and early 1980s, it was used in soil to kill insects and worms that were destroying fruits, vegetables, and grain crops. The maximum concentration detected in residential wells around BNL was 1.2 ppb, approximately one-third of the maximum detected in off-site monitoring wells. Detections of EDB in two residential wells on Weeks Avenue indicate that the levels of EDB are decreasing (from 1.2 ppb to 0.12 ppb and from 0.2 ppb to no detection) over time. The decreasing concentrations might be the result of EDB’s high water solubility or of differing sensitivities in monitoring equipment.

Most of the available information on the effects of EDB in humans comes from cases of acute poisoning following accidental or intentional ingestion and from occupational exposures in agricultural industries (ATSDR 1992a). Acute exposures (less than or equal to 14 days) have caused depression and collapse because of neurologic effects and erythema and necrosis of tissue at the point of contact (e.g., oral and pharyngeal ulcers for ingestion, skin blisters and peeling for dermal exposure) (ATSDR 1992a). Except for occupational exposures, which have caused adverse reproductive effects in men, there have been no documented chronic effects of EDB exposure in humans (ATSDR 1992a). Studies have led researchers to determine that the liver and the kidneys are the target organs following human dermal and oral exposure to EDB (ATSDR 1992a).

ATSDR staff used the highest concentration detected in residential wells (1.2 ppb) to determine estimated ingestion doses of 0.00003 mg/kg/day for adults and 0.00012 mg/kg/day for children. Because of a lack of quantitative exposure data, no MRLs for EDB are available. Animal studies showed the LOAELs in bulls given 4 mg/kg/day for 20 days (Amir 1975; Amir et al. 1977). The study indicated that the bulls had transient sperm anomalies. This concentration is much greater (10,000 times) than the estimated exposure doses people might experience around BNL, and it was the lowest concentration at which adverse effects were noted. ATSDR merely used the LOAEL to indicate what adverse effects might be experienced at such low concentrations. It is important to note that using a brief duration (20 days) of EDB exposure in adult animals is difficult to compare to chronic exposure in humans.

The respiratory tract, particularly the nasal cavity, is the point-of-contact organ affected by inhalation of EDB (ATSDR 1992a). A study by Nitschke in 1981 indicated a NOAEL in rats through inhalation at 2 ppm (Nitschke et al 1981). This determination was based on studies of rats and mice exposed to 3 ppm EDB for 13 weeks, 5 days/week, 6 hours/day (Nitschke et al. 1981). In the scientific literature, no adverse health effects have been documented in animals or humans exposed at concentrations below 1 ppm. The estimated inhalation doses at BNL are well below the 1 ppm level; therefore, there is no expectation of adverse health effects.

ATSDR staff reviewed two epidemiological studies regarding workers exposed occupationally to EDB, primarily through respiration (ATSDR 1992a). Neither study indicated an increased risk of cancer in people occupationally exposed to EDB through inhalation. USEPA has classified EDB as a B2 carcinogen. A B2 classification indicates that evidence for carcinogenicity is inadequate or nonexistent according to human studies but is sufficient according to animal studies. The IARC has classified EDB as a 2A carcinogen. The class 2A carcinogen classification recognizes limited evidence of carcinogenicity from human studies, indicating that a causal relationship is credible but not conclusive. Subsequent sampling has indicated that the concentrations of EDB in the wells are decreasing over time to very low to no levels of EDB.

Perchloroethylene (PCE)

Perchloroethylene (PCE), also known as tetrachloroethylene, is a synthetic chemical widely used for dry cleaning and metal-degreasing operations. It is also used as a starting material for making other chemicals and as a component of some consumer products. PCE evaporates easily into the air and has a sharp, sweet odor. The highest concentration of PCE detected in residential wells was found at 10 ppb in 1985 on Avondale Drive; the depth of the well was not provided. The residence was connected to the public water supply in August 1991.

ATSDR calculated estimated exposure doses for the maximum concentration (10 ppb) found off site in residential wells. The acute (14 days or less) oral MRL for PCE is 0.05 mg/kg/day (ATSDR 1997c). Intermediate-- and chronic-duration oral MRLs have not been derived. The estimated ingestion doses based on the maximum concentration detected in residential wells are 0.0003 mg/kg/day for adults and 0.0006 mg/kg/day for children. Both doses are below the acute MRL. The acute oral MRL is not very appropriate because it is for exposures of 14 days or less. Wells have been contaminated longer than this, and exposures are assumed to have been also longer. A chronic reference dose (RfD), which is appropriate for chronic exposures, calculated by the USEPA is equal to 0.01 mg/kg/day. The estimated exposure doses are two orders of magnitude lower than the RfD and as a result, adverse health effects would not be expected.

LOAELs in humans for intermediate and chronic exposure also do not exist. NOAELs and LOAELs have been determined in animal studies for intermediate and chronic exposures. For intermediate exposures, a study of Sprague-Dawley rats showed increased kidney/body weight ratios when the rats were exposed to concentrations of PCE at 400mg/kg/day for 90 days (Hayes 1986). No effects on the kidneys were observed at a dose of 14 mg/kg/day (NOAEL). Chronic-duration oral studies in animals have not identified NOAELs or less serious LOAELs at doses below those causing decreased survival of rats and mice (NCI 1977).

ATSDR calculated estimated inhalation exposure doses for adults and children by using the 10 ppb concentration. An intermediate duration inhalation MRL has not been derived because of inadequate data. The chronic-duration inhalation MRL for PCE is equal to 0.04 ppm (ATSDR 1997c). This level is four times greater than that found in the residential wells, and adverse health effects would not be expected to occur.

The MRL was derived from a study in which women were exposed to PCE at an average concentration of 15 ppm for an average period of 10 years (Ferroni et al 1992). Significantly prolonged reaction times were observed in the women. Another study did not reveal any effects on neurological function among fourteen persons who lived above or next to dry cleaning facilities for 1B30 years. Median air concentrations of 0.2 ppm were detected in the apartments of the exposed individuals. This was the lowest concentration at which adverse health effects were not noted. Consequently, the 0.2 ppm concentration is considered a NOAEL. The LOAEL in humans exposed to PCE occurred in an occupational setting where the worker had been exposed to 10 ppm for 14 years (Franchini et al 1983). The worker experienced increased urinary levels of lysozyme and beta-glucuronidase, suggestive of mild renal tubular damage (Franchini et al 1983).

Very little information is available regarding human dermal exposure to PCE. The information that is available indicates that adverse dermal/ocular effects can occur in humans exposed to moderate concentrations. In a study by Wayne and Orcutt, volunteers were exposed to vapors of PCE at 5 or 20 ppm, and no appreciable eye irritation resulted from the exposure (Wayne 1960). Intense ocular irritation has been reported in humans after acute exposure to PCE vapor at concentrations greater than 1,000 ppm (Carpenter 1937; Rowe et al 1952). The concentrations in these studies are in the ppm range, whereas the contaminant levels in wells around BNL are in the ppb range (1000 times lower).

No studies were located regarding cancer in humans after oral and dermal exposure to PCE. No documentation has been found of carcinogenic effects in exposed workers. A number of epidemiology studies have been conducted of dry cleaning and laundry workers exposed to PCE via inhalation. Many of these studies are complicated by potential exposure to other petroleum products. The only investigation of dry cleaning workers with no known exposure to petroleum solvents was a retrospective mortality study of a sub-cohort of workers employed in shops where PCE was the primary solvent (Brown 1987). Excess risk for cancer at any site was not identified in this sub-cohort. Other studies were inconclusive because workers were also exposed to petroleum solvents and other dry cleaning agents, and factors such as smoking and alcohol consumption were not considered in the analyses.

1,1-Dichloroethane (1,1-DCA)

l, l-DCA is a colorless, oily, man-made liquid. It can also be found in the environment as a breakdown product of 1, l, l-TCA in landfills where oxygen does not come in contact with the 1,1,1-TCA. 1,1-DCA is used to dissolve other substances, such as paint, varnish and finish removers, and to remove grease. In 1989, 1,1-DCA was detected in a residential well on Carleton Drive at 8 ppb. No other residential wells contained l, l-DCA above the MCL of 5 ppb.

Very little information is available on the health effects of l, l-DCA in animals or humans. The limited available animal data indicate it is less toxic than its isomer, 1,2-dichloroethane (Bruckner 1989). Studies of animals (mice) that ingested l, l-DCA on a chronic basis indicated that adverse effects did not appear at doses lower than 475 mg/kg/day (NCI 1977). One study indicated body weight depression during a sub-chronic exposure scenario. Other studies have not provided any conclusive evidence of adverse toxic effects associated with oral exposure to 1,1-DCA.

No studies were found regarding humans exposed to 1,1-DCA through ingestion or inhalation. Because of the limited information on the ingestion or inhalation of 1,1-DCA, no MRLs have been derived for these routes of exposure. A study performed with cats exposed to 1,1-DCA at 500 ppm for 13 weeks, 6 hours/day, for 5 days/week showed no adverse effects in the hematological, hepatic, or renal systems. In the same study, a decreased body weight was noted at the 1,000 ppm level. No studies were identified regarding adverse health effects in animals or humans after dermal exposure to 1,1-DCA. In the past, it was used as an anesthetic, but it was discontinued after the discovery that it induced cardiac arrhythmias in humans at doses of 26,000 ppm. These levels are much greater than the estimated exposure doses calculated for people exposed to the maximum concentration detected off site.

Evidence concerning 1,1-DCA carcinogenicity in humans is inconclusive. The USEPA has classified 1,1-DCA as a Class C chemical, a possible human carcinogen (IRIS 1990). USEPA has not derived an oral slope factor for 1,1-DCA. There have been no documented cases of individuals developing cancer when exposed to levels of 1,1-DCA similar to those found in private wells around BNL.

Carbon Tetrachloride

Carbon tetrachloride is a clear liquid that evaporates very rapidly. In the past, carbon tetrachloride was widely used as a cleaning fluid. Dry cleaning establishments and industries used it as a degreasing agent, and in households it was used as a spot remover for clothing, furniture, and carpeting. Most of these uses discontinued in the mid-1960s. It was used as a pesticide until 1986 (ATSDR 1994a). Carbon tetrachloride has not been detected in residential wells. Modeling has indicated that the maximum concentrations of carbon tetrachloride are at depths of 50 meters or more, which is thought to be much deeper than the residential wells.

The intermediate MRL was calculated by use of a NOAEL of 1 mg/kg/day, based on the absence of detected adverse hepatic effects in rats (Bruckner 1986). Slightly elevated blood levels of sorbitol dehydrogenase and centrilobular vacuolation of the liver were observed at a LOAEL of 10 mg/kg/day, but not at 1 mg/kg/day. No adverse health effects have been documented in humans exposed orally to levels of carbon tetrachloride below 40 mg/kg/day (ATSDR 1994a).

Acute and intermediate MRLs have been derived for inhalation exposure to carbon tetrachloride. The acute MRL is equal to 0.2 ppm, and the intermediate MRL is 0.05 ppm (ATSDR 1994a). The intermediate MRL was calculated by use of a NOAEL of 5 ppm, based on the absence of liver effects in rats (Adams 1952). Fatty degeneration was evident at concentrations of 10 ppm, and cirrhosis occurred at 50 ppm. A NOAEL of 10 ppm for acute exposures in humans based on a LOAEL of 50 ppm exists (ATSDR 1994a). For intermediate exposures, a LOAEL of 20 ppm exists. Both the NOAEL and the LOAEL for intermediate exposure are greater than the estimated exposure dose(s) of less than 1 ppm.

Very little information exists for dermal exposure in animals, and as a consequence no MRLs have been derived for dermal exposure in humans. The available information on human dermal exposure to carbon tetrachloride is not sufficient to determine the adverse health effects people might encounter if exposed to the levels found around BNL. Again, carbon tetrachloride was not detected in any of the residential wells.

IARC has classified carbon tetrachloride as possibly carcinogenic to humans, and USEPA has determined that it is a probable human carcinogen. Two studies located reported the occurrence of liver cancer in humans exposed to carbon tetrachloride fumes; however, the evidence was not strong enough to establish a cause-and-effect relationship. No studies were identified regarding carcinogenic effects in humans following oral or dermal exposure to carbon tetrachloride.

Mercury

Mercury occurs naturally in the environment and can exist in various forms depending on the conditions of the environment. The most common organic compound that microorganisms and natural processes generate from other forms is methylmercury. Methylmercury is of particular concern because it can bioaccumulate (i.e., build up) in certain edible freshwater and saltwater fish and marine mammals to levels that are many times greater than levels in the surrounding water. Mercury is deposited primarily in the muscle tissue of fish, rather than in fatty tissue. Thus unlike PCBs, dioxins, and other organochlorine pesticides, trimming and skinning of mercury contaminated fish does not reduce the mercury content of the fillet (Armbuster et al 1988; Gutenmann and Lisk 1991).

The maximum mercury concentration was found in the chain pickerel on site at 3.72 mg/kg. Concentrations were lower in fish sampled off site. The maximum concentration found in fish off site was in a large mouth bass at 0.914 mg/kg. The Food and Drug Administration (FDA) recommends that regular consumption of fish species with methylmercury levels around 1 ppm be limited to approximately 7 ounces per week; for fish with levels averaging 0.5 ppm, the limit is about 14 ounces per week (FDA 1996).

As stated, fishing on BNL property is not permitted, and sampling has indicated the fish on site are too small to be legally kept for consumption. Fish are able to migrate on site and off site easily, but there are times throughout the year that the river goes dry. During these periods the on-site fish are confined to the on-site portion of the river. On-site fish populations have declined considerably the past few years because of drought conditions and over-sampling. Off-site sampling has indicated that the mercury levels are right at or below the action level of 1 ppm. Where fishing is allowed, the levels of mercury in off-site fish are not at levels that would cause adverse health effects.

Health Outcome Data Evaluation

A major concern among residents of Long Island, New York is the elevated rates of breast cancer in New York compared with other states in the northeastern United States and with the country as a whole. Breast cancer is the most common type of cancer diagnosed among women nationally (National Cancer Institute (NCI)), as well as in New York State (New York State Cancer Registry). According to the American Cancer Society, aging and having a family history of breast cancer account for only about a quarter of breast cancer cases. A number of other factors may be associated with the other 75% of breast cancer cases. These include age at menarche, age at first child birth, age at menopause, the practice of breast-feeding, country of birth, alcohol consumption, access to health care, and various environmental factors.

ATSDR staff reviewed several studies regarding breast cancer in the northeastern United States. A study conducted by the NCI looked at demographic data and age-specific breast cancer mortality rates for women in 11 northeastern states and the District of Columbia for 1988B1992. Results indicated that the increased breast cancer mortality on Long Island was statistically significant and that the increase was not confined to this area but extended into parts of New Jersey and Philadelphia. The New York City-Philadelphia metropolitan area had a 7.4 percent excess compared with the rest of the Northeast, which in turn had a 12.4 percent excess compared to the rest of the country (Kulldorff et al 1997).

Increased age at menarche, decreased age at menopause, the practice of breast feeding, and younger age at first full-term pregnancy have been shown to reduce the risk of breast cancer (John, Kelsey 1993). Researchers in this study did not have information regarding local variation within the Northeast to determine if these factors contributed to the elevated rates in the Northeast. Other studies have indicated that age at first full-term pregnancy is greater in the Northeast than in the rest of the country and that this may affect the elevated mortality rates, but researchers did not have a more local distribution, which might explain some of the excess in the New York-Philadelphia area (Blot et al 1977).

Approximately 0.5% of U.S. women have a genetic mutation that increases their risk of developing breast cancer and results in 5 percent of all cases (Baker and Freedman 1995). The occurrence of one of the mutations has been observed mostly in Ashkenazi Jews, who reside in significant numbers in and around New York City (Struewing et al 1995). This may account for some of the increase in breast cancer cases.

Exposure to environmental contaminants has also been suggested as a potential factor in increased rates. A case-control study was conducted in Connecticut from 1994 to 1997 to investigate the relationship between exposure to the organochlorinated compounds dichlorodiphenyldichloroethane (DDE) and dichlorodiphenyltrichloroethane (DDT) and the incidence of breast cancer (Zheng et al 1999). Adipose tissue was collected from the cases (women who had breast cancer) as well as the controls (women who did not have breast cancer) to determine if the levels of DDE and DDT in the tissues were significantly different. The age-adjusted geometric mean tissue levels of DDE and DDT were similar between the two groups. A study conducted in Europe revealed a significant inverse association between the adipose tissue level of DDE and breast cancer risk (van=t Veer et al 1997). This study indicated that as DDE levels increased, the risk of breast cancer decreased.

Intense concern among residents led to federal legislation under which the National Cancer Institute initiated a group of epidemiological studies known as The Long Island Breast Cancer Study Project (LIBCSP). The LIBCSP, the result of Public Law 103-43, was to determine whether certain environmental contaminants increased the risk of breast cancer among women in Nassau and Suffolk counties on Long Island. Researchers from the LIBCSP concentrated their research on organochlorine compounds, including the pesticide DDT, its metabolite DDE, and polychlorinated biphenyls (PCBs). This study is one of the largest and most comprehensive environmental epidemiologic studies ever done for breast cancer. Results from the study project indicated no increased rate of breast cancer among women who may have been exposed to organochlorine compounds or PCBs (Gammon 2002).

ATSDR looked at health outcome data for cancers of the liver, prostate, brain and other nervous system, and thyroid, as well as for Non-Hodgkin=s lymphomas, multiple myelomas, and leukemias, and found that none of them were elevated in Suffolk County compared with the neighboring Nassau County or the state of New York. ATSDR used the age-adjusted rates with 95% confidence intervals provided by the New York State Cancer Registry within the New York State Department of Health (NYSDOH 1999). Other studies have incorporated a 15-mile radius around BNL to compare rates and similar findings, but these studies have shown no increase in cancer levels within the 15-mile radius compared with outside the 15 miles. Correlations between plume and wind directions with cancer incident cases were investigated, but no correlations were noted.

Worker Study

At the request of the Department of Energy, a study was conducted by the New York State Cancer Registry in 1999–2000. The study compared cancer rates among former and current BNL workers with those of residents of New York State. Cancer cases diagnosed from 1979B1996 were used in the analysis. This time period was used because cancer cases that were diagnosed prior to 1979 were no longer on the active Cancer Registry database, and the reporting of cancer cases diagnosed after 1996 was incomplete. To control for possible regional variations in the distribution of cancer, the New York State Cancer Registry used three separate comparison populations in the analysis: New York State exclusive of New York City, Nassau County, and Suffolk County.

The study revealed a proportionate deficit of respiratory cancers among BNL employees compared to what would be expected. The study population (cohort) was mainly composed of men (73%), and as a result the majority of the observed cancers occurred in men. The overall distribution of cancers in this cohort did not deviate significantly from what was expected. Also, radiosensitive solid cancers were not proportionately elevated compared to the same cancers in the control population (Schymura 2001).

Community Health Concerns and Evaluation

Evaluation of community health concerns assists in determining whether people who live or work near BNL are experiencing specific health effects. Information from the public also helps ATSDR determine how people might have been or might be exposed to hazardous substances in the environment. Throughout the public health assessment process, ATSDR staff members talk with people living or working at or near the site about their site-related health concerns. The community that surrounds BNL includes the townships of East Yaphank, Manorville, and Yaphank. The health-related concerns that these communities have expressed regarding BNL include adverse health effects such as cancer or non-cancerous effects. Other concerns are also discussed below.

Members of the community surrounding BNL are concerned that emissions from the lab could result in exposures that may lead to someone developing a disease or cancer. A major concern is the high rate of breast cancer on the eastern end of Long Island. Several research projects, including the Long Island Breast Cancer Study Project, have been undertaken by various universities to determine what the cause(s) of the high rates are associated with. Because the concern for breast cancer is so great, ATSDR has reviewed the research and presented the results in this health assessment.

Breast Cancer

Although most breast cancers are diagnosed in women, breast cancer does occur very rarely in men. However, the following discussion pertains only to female breast cancer, because there is limited information on risk factors for male breast cancer. Breast cancer is the most common cancer diagnosed in women, the second leading cause of cancer deaths in women, and the leading cause of death in women between 40 and 55 years of age. The number of newly diagnosed breast cancer cases rose by 4% per year during the 1980s, but the increase has since leveled off. Although a variety of factors have been associated with an increased risk for breast cancer, it is important to note that some people who get breast cancer do not have any of these risk factors (ACS 1999). Also, some people who have some or all of these risk factors do not get cancer.

Sex can be considered a risk factor, because women are 100 times more likely to develop breast cancer than men. The risk of developing breast cancer increases with age. Whites tend to develop breast cancer at a higher rate than African-Americans, but African-American women are more likely to die from the disease. Asian and Hispanic women have lower rates of this disease than do African-American women. Other risk factors are a family history of breast cancer, therapeutic irradiation of the chest area, and alcohol abuse. Factors associated with a slightly increased risk are early age of first menstruation or late age of menopause, use of oral contraceptives, late age (more than 30 years of age) of first childbirth or not having children, and estrogen replacement therapy. Genetics is thought to play a role in an estimated 5% to 10% of breast cancer cases (ACS 1999). Numerous inconclusive studies have evaluated the association between breast cancer and various other risk factors, such as having a child but not breast-feeding, consuming a diet high in animal fat, obesity, and a low level of physical activity.

Whether an association exists between exposure to certain environmental contaminants, called endocrine disruptors, and breast cancer is a subject of much controversy in the scientific community. Endocrine disruptors are so named because of their ability to behave like hormones and other substances that occur naturally in the body and in some foods. Once taken into the body, these chemicals alter the function (e.g., by increasing or decreasing the response) of the endocrine system, and they may cause adverse effects on an organism or its offspring (NIOSH 1998). Within the category of endocrine disruptors, much attention has been given to two widely spread contaminants, polychlorinated biphenyls (PCBs) and the banned insecticide DDT and its metabolite, DDE. Some scientists believe that these chemicals contribute to the development of breast cancer in humans, because they have been found to mimic the activity of the hormone estrogen in laboratory experiments (Feigelson et al. 1996; Rudel 1997). In these experiments, the contaminants bind to the estrogen receptors of breast cells grown in vitro (in a test tube), causing the cells to divide and grow continuously, a common feature of cancerous cells. Other scientists point to evidence of endocrine disruption in certain wildlife populations exposed to these chemicals in the environment (Soto 1998). Still other scientists, not convinced that these chemicals contribute significantly to breast cancer development in humans, point out that human health studies have failed to show a definite association between occupational or environmental exposure to endocrine disruptors and an increase in the risk of developing breast cancer (Davidson 1998; Datson et al. 1997; Safe 1997). Almost all scientists, however, agree that more studies are needed on how diet (Schildkraut et al. 1999; Verma et al. 1998), genetics (Moysich et al. 1998), and environmental exposures may together affect an individual's risk for this disease.

USEPA's Office of Prevention, Pesticides and Toxic Substances chairs an Endocrine Disruptor Screening and Testing Advisory Committee (EDSTAC) that focuses on chemical substances in drinking water and food that may be endocrine disruptors. Additional information about chemicals that may be classified as endocrine disruptors and methods for screening and testing for these substances in water and food can be obtained by accessing USEPA's home page (http://www.USEPA.gov) (USEPA 2000).

Other concerns expressed by the community include the following:

- If the water is not contaminated, why are they (BNL) offering residents to be hooked up to the public water supply?

The levels of contamination in residential wells are not at levels that are known to cause adverse health effects in humans. The extent of some of the plumes and the depths of residential wells is uncertain. Because of this uncertainty, ATSDR believes that in the interest of public health it is safer to obtain water from a source area that has not been affected by the contamination from BNL or other facilities and that is monitored regularly. Because on-site remedial actions will take years to get groundwater contaminants below drinking water standards, and because off-site remedial actions have only recently been initiated, ATSDR believes that it is “safer” to provide to the residents a source area of water that is known not to have been contaminated from BNL or from other facilities in the area, rather than assume that all wells that could be affected already have been. Also, wells that have not been contaminated could potentially become so in the future.

- If you are using BNL=s data, how do you know it is reliable?

In preparing this public health assessment, ATSDR relied on the information provided in the referenced documents. The agency assumes that adequate quality assurance and quality control measures were followed with regard to chain-of-custody, laboratory procedures, and data reporting. The validity of analyses and conclusions drawn for this public health assessment depends on the completeness and reliability of the referenced information.

Quality assurance and quality control procedures are available in the different operable unit remedial investigation reports. Various field quality control samples such as trip blanks, field blanks, and field duplicates were collected from the different media (soil, surface water, groundwater) sampled. The data collected are validated and checked for accuracy, sensitivity, precision, representative quality, and completeness. Screening concentrations for inorganic compounds, organic compounds, pesticides and polychlorinated biphenyls, and radiologicals are used for each type of media sampled. The screening criteria are based on applicable requirements that are promulgated under federal or state laws that specifically address a hazardous substance, a remedial action, or other circumstance at a hazardous waste site. Others are based upon relevant and appropriate requirements that are also promulgated under federal or state law not applicable to a hazardous substance, a remedial action, or other circumstance at a hazardous waste site, but that address situations similar to those encountered and that are well suited for use at the hazardous waste site.

In the past, BNL has had problems with some of the work and analyses provided by some of its contractors. BNL used several contractors within a short time frame during 1984B1986 to analyze sample media. Also, some of the data that were generated in the past were not developed by a certified laboratory. For example, in 1985, potable well water samples were analyzed only once by a certified laboratory. BNL was analyzing some of the samples, but at the time BNL was not certified to do the analysis on the potable well water samples. ATSDR had only one round of potable well water sample results from 1985 completed by a certified laboratory on which to base any conclusions. The results from BNL were used only to do a comparison with the certified results. Because those results did not significantly differ from those from the certified laboratory. ATSDR used all the results.

In June 1996, radium-226 was found at concentrations above 3 pCi/L in 6 of the 83 on-site monitoring wells, and a maximum concentration of 130 pCi/L was found in an off-site monitoring well (ITC 1997). The range of radium-226 in on-site monitoring wells was 17.9 pCi/L-77.3 pCi/L (ITC 1997). In ATSDR's groundwater health consultation, dated September 29, 1997, ATSDR recommended resampling the well containing the 130 pCi/L level. BNL sampled the monitoring well to confirm the 130 pCi/L level by a more specific analytical method. ATSDR received the resampling results and wrote an addendum to the September 29, 1997 version. The original result appears to have been an anomaly or interference from another radionuclide. ATSDR has recommended that BNL use more specific methods to analyze its samples. For example, ATSDR recommends that the radon emanation method be used in conjunction with the gamma spectroscopy scan when elevated or inconsistent gamma levels are detected.

- What made you question the elevated radium-226 reading?

The elevated reading was questioned because no other readings off site were consistent with this reading, and the highest concentration on site was about half the off-site reading. The rest of the groundwater contaminants were much higher on site than they were off site. That the elevated radium-226 reading was off site caught ATSDR=s attention. After a more specific method was used for analyzing the sample, it was evident that the first reading was an anomaly or the result of interference from another radionuclide.

- Are there multiple contaminants in the wells that have been found to be contaminated?

Yes. None of the wells, however, contained all the chemical contaminants. The monitoring results from the residential wells indicated that none of the wells had more than one contaminant above their respective drinking water standard, except for two of the wells that were affected by the leaking underground storage tank at a nearby gasoline station, which was not BNL-related. The people using these wells were provided with a filter to place on their taps (one resident) or they were provided an alternate source of water (bottled water). The residents were then offered hookups to the public water supply.

- How do we know the wells were not contaminated prior to the sampling?

ATSDR used groundwater models to reconstruct expected levels prior to sampling. Modeling of the various plumes indicates that five of the eight plumes had not reached areas of potential off-site exposure before 1987. Two plumes had reached areas of potential off-site exposure between 1977 and 1980. The Precision Concepts plume reached the residential wells within 5 years after source introduction into the aquifer. For further clarification, please see the section “ATSDR=s modeling of the groundwater plumes.”

The majority of BNL potable well water samples were collected at the well head prior to the water going to the water filtration/treatment plant. At the water treatment plant, the water was being treated for elevated levels of iron. Very few samples were collected from the tap, which is where employees would have been exposed to the contaminated water. Most likely, because the water was being treated prior to being distributed to the tap (point of exposure), the concentrations of VOCs would have been much lower than the concentrations in the samples taken at the well head. In the few tap samples collected, the concentrations of contaminants were not at levels that would cause adverse health effects.

- Is the evaporation from the recharge basin hazardous?

The levels of tritium in the recharged water have been below the MCL. Air was monitored for tritium at the HFBR tritium pump and recharge system basin. The level of tritium evaporated would not be high enough to cause adverse effects unless someone lived within a few feet of the recharge basin.

Community members were concerned about the air emissions from the lab and requested ATSDR to write a consultation regarding the emissions. ATSDR began writing the health consultation and found a large data gap for emissions from the reactors from the time the lab started operation (1947) through 1961. In addition there was a gap from 1967 through 1970. Apparently monitoring had been done, but an environmental report was not published for those years.

BNL staff went back through old log books and compiled emissions monitoring results for the different reactors. The reports "Radiological Emissions and Environmental Monitoring for Brookhaven National Laboratory, 1948 – 1961" and " Radiological Environmental Monitoring Report for Brookhaven National Laboratory 1967-1970 " were the result of their efforts.

ATSDR has analyzed the monitoring results and addressed the concerns of the community in section 3.2.1.

Conclusions

ATSDR categorized off-site exposure to the different environmental media as follows:

1. Soil No health hazard

2.	Groundwater	No apparent health hazard (contamination, but no health effect expected)
3.	Air	No apparent health hazard (contamination, but no health effect expected)
4.	Surface Water	No apparent health hazard (contamination, but no health effects expected)
5.	Biota	No apparent health hazard (contamination, but no health effects expected)
6.	Sediment	No apparent health hazard (contamination, but no health effects expected)

On-site soils are contaminated in several areas, and those areas are currently undergoing remediation or already have been remediated. Those areas that are undergoing remediation are either fenced off, or the contaminants are buried beneath the surface of the soil, as is the case with the Brookhaven Graphite Research Reactor (BGRR). With the exception of the workers removing the contaminated soils, no one is expected to be exposed to the contaminated soil. Workers are aware of the contamination and are trained in removing the contaminated soil. Adequate protective clothing is required during the removal of the contaminated soil.

Sampling results of residential wells in the areas of North Shirley, Shirley, East Yaphank, and Manorville showed that in some of the wells, levels of VOCs and a pesticide were above federal and New York state drinking water standards. Owners of the wells with contaminants above regulatory standards were either provided an alternate water supply (bottled water) or a carbon filter to remove the contaminants. The Department of Energy, as a precautionary measure, offered approximately 1,500 residents living south of the laboratory the option of public water at no cost. Only seven residents declined the offer. DOE offered these residents free annual testing of their water for VOCs and tritium by the SCDHS.

Levels of the radionuclides strontium-90 and tritium that were detected in residential wells are below their respective drinking water standards and present no apparent health hazard.

Depending on the specific plume and residential well location, exposure to several plumes could have occurred 5 to 7 years before initial detection in 1985. However, limited data on depths of residential wells indicate that the zones of highest contaminant concentration are below the screened well depths, so that actual exposures are much lower than potential exposures based on lateral plume migration. Although the concentrations are above regulatory standards, ATSDR determined that there was no apparent health hazard.

Residents were offered public water in March 1997. The potential for future exposures to BNL contaminant plumes has been eliminated for those residents who elected public water. Monitoring wells located between the contaminant plumes and the public water supply are checked routinely to ensure that the plumes are not impacting the public water supply. The public water supply is routinely sampled, and it has not been affected by BNL contamination.

Brookhaven National Laboratory (BNL) supply wells with 1,l,1-trichloroethane (1,l, l-TCA) contamination in the past have been taken off line or have had activated carbon filters installed to remove the 1,1, l-TCA. The concentrations of VOCs detected in the limited samples collected from the tap, before the wells were taken off line, presented no apparent health hazard.

ATSDR categorized past air releases as no apparent health hazard. Although the releases appear to be quite large, the resulting doses are relatively small with respect to doses known to cause observable adverse health effects. The combined estimated doses for the years with the highest releases from BNL are all less than the lifetime dose recommendation and are not expected to cause any observable or detectable adverse health effects.

The Peconic River is contaminated with arsenic, cadmium, lead, manganese, thallium, mercury, and PCBs. Contaminant concentrations are higher in on-site portions of the Peconic River compared to off-site locations. Mercury concentrations in some of the on-site fish are above the FDA action level; however on-site fishing is not permitted and the river runs dry periodically throughout the year. Off-site fish samples have mercury concentrations below the action level.

Residents should read and follow the fish advisory instituted by the NYSDOH for fresh waters of Long Island. Contaminated sediments in the on-site portion and off-site portion of the Peconic River were removed in the summer and fall of 2004. Sampling to confirm the removal of contaminants has been completed, and the areas are currently being restored with native plants.

Deer sampling confirmed the presence of potassium-40, strontium-90, and cesium-137. The estimated effective dose equivalent (EDE) from consuming contaminated deer meat is 7.1 millirems (mrem). This is lower than the national average EDE (10 mrem) from eating foods containing naturally occurring radionuclides. Adverse health effects would not be expected from the consumption of deer meat.

Recommendations

DOE should continue to sample the wells of the seven residents who declined the public water hookup to determine whether the contaminant plumes are affecting the wells in these areas.

If any of the seven wells are found to contain contaminants at levels above drinking water standards in the future, Suffolk County Department of Health Services should restrict the use of those wells until remedial actions are complete. For any of these wells with concentrations above drinking water standards DOE should provide alternative water sources to those individuals using the well(s) until remedial actions are completed. If remediation is not feasible and depending on the levels of volatile organic compounds (VOCs) and/or radionuclides in the water, restrict use of the water to non-potable purposes, such as irrigation, or abandon the well.

Advise residents who have recently moved into the East Yaphank, Shirley, and Manorville townships and future residents of the potential for private well contamination and advise them not to use the well(s) until the water has been tested for VOC and radionuclide contamination. Restrict use of all new private supply wells in these areas if the wells have known contamination levels above drinking water standards.

DOE should continue to sample sediments in on-site and off-site portions of the Peconic River to ensure that recent remedial actions have removed the contaminants.

Suffolk County Department of Health services should post signs along the Peconic River alerting residents and anglers of the fish advisory that is in effect. Anglers and residents who fish in the Peconic are encouraged to follow the fish advisory by limiting their intake to one meal per week.

Public Health Action Plan

The Public Health Action Plan (PHAP) for the Brookhaven National Laboratory (BNL) site contains a description of actions taken and those to be taken by ATSDR, the Suffolk County Department of Health Services, the U.S. Environmental Protection Agency, and the New York Department of Environmental Conservation at and in the vicinity of the site after the completion of this PHA. The purpose of the PHAP is to ensure that this PHA not only identifies public health hazards, but also provides a plan of action designed to mitigate and prevent adverse human health effects resulting from exposure to hazardous substances in the environment. The public health actions that are completed, being implemented, or planned are as follows:

Completed Actions

Because several off-site private wells contained levels of volatile organic compounds above the federal and state regulatory limits and because of the uncertainty of the depths of many of the private wells, the Department of Energy (DOE), as a precautionary measure, offered connections to the public water supply to well owners living in a defined area. The area is bounded to the south by Sunrise Highway, to the north by Carleton Drive and North Street, to the east by Wading River Road, and to the west by River Road (BNL 1996d). Figure 3 in Appendix B details the hookup areas. Because ethylene dibromide (EDB) was detected on and off site, the DOE and the Suffolk County Water Authority also offered to provide public water to private well owners on South Street between Rosewood Drive and North Street, on the northern portion of Woodland Avenue, on North Street north of the Long Island Expressway to the Long Island Railroad tracks, on North Weeks Avenue, on Weeks Avenue from North Street to just south of Victoria Lane, and on Douglas Lane and Calendar Road off Weeks Avenue (BNL 1996e).

The closest downgradient public water supply well field providing water to these areas is approximately two miles southeast of the contaminant plumes and has not been impacted by the contaminant plumes. Monitoring wells are north of the water supply well field and will detect any potential contamination before it reaches the well field. DOE offered the free public water hookups and the Suffolk County Water Authority connected approximately 1,500 residences and commercial properties to the public water supply.

A large network of groundwater monitoring wells is in place both on and off site. Characterization of the plumes is complete. A groundwater extraction and treatment system was implemented for the HWMF and Current Landfill contaminant plumes in December 1996. In addition, a hydraulic containment and treatment system was installed to prevent additional off-site migration and to remove the volatile organic compounds to levels below drinking water standards. Currently there are seven monitoring wells adjacent to the Former Landfill in up-gradient and down-gradient locations, and these are monitored on a quarterly basis. Similarly, a network of eleven monitoring wells surrounds the Current Landfill, and these are also monitored on a quarterly basis.

DOE has conducted several soil monitoring events to characterize the nature and extent of contamination in soil at the site and in the vicinity. The Current Landfill was capped in 1995, and the Former Landfill was capped in 1996. Capping of the landfills will help to prevent water from percolating into the contaminated soil and prevent further migration of contaminants into the groundwater. The Chemical/Glass Holes and the Animal Pits were remediated during the summer of 1997. The soil and debris were removed and shipped off site to a licensed hazardous waste facility.

Remedial actions to remove contaminated sediments have recently been completed in the off-site portions of the Peconic River. On-site areas A-D of the Peconic River have been excavated, regraded, and restored as of September 2004. Area E restoration was completed in April 2005 (BNL 2005b).

Ongoing Actions

Remedial actions have been ongoing for a number of years. Currently, the Brookhaven Graphite Research Reactor is being decommissioned. Surface structures and soils are being removed and all remaining soil samples (both surface and deep) obtained have concentrations of Cs-137 and Sr-90 below the cleanup goals of 23 picoCuries per gram (pCi/g) and 15 pCi/g, respectively.

At the end of 2004, 15 groundwater remediation systems were in operation to remove the VOCs from the groundwater both on site and off site. There are seven in -well air strippers in the Brookhaven Industrial Park and eight extraction wells at the southern boundary of the laboratory. The eight extraction wells are pump-and-treat type wells. Continued monitoring will allow for a better delineation of the plumes and will help determine whether contaminant concentrations are increasing, decreasing, or leveling off.

Contributors

The Brookhaven National Laboratory Public Health Assessment was prepared with input from many individuals. The contributors have different expertise that includes hydrogeology, toxicology, health physics, engineering, and environmental health science. The ATSDR scientists and engineers who contributed to the public health assessment include:

Arthur Block
Health Scientist

Paul Charp, PhD
Health Physicist

Andy Dudley
Environmental Health Scientist

Mark Evans, PhD
Hydrogeologist

Rita Ford, MBA
Supervisory Engineer

Jo Ann Freedman, PhD, DABT
Toxicologist

Ernie Martin
Writer-Editor

John Wilhelmi
Environmental Engineer

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Appendix A. Glossary of Environmental Health Terms

Absorption

The process of taking in. For a person or animal, absorption is the process of a substance getting into the body through the eyes, skin, stomach, intestines, or lungs.

Acute

Occurring over a short time [compare with chronic].

Acute exposure

Contact with a substance that occurs once or for only a short time (up to 14 days) [compare with intermediate duration exposure and chronic exposure].

Additive effect

A biologic response to exposure to multiple substances that equals the sum of responses of all the individual substances added together [compare with antagonistic effect and synergistic effect].

Adverse health effect

A change in body function or cell structure that might lead to disease or health problems.

Aerobic

Requiring oxygen [compare with anaerobic].

Ambient

Surrounding (for example, ambient air).

Anaerobic

Requiring the absence of oxygen [compare with aerobic].

Analyte

A substance measured in the laboratory. A chemical for which a sample (such as water, air, or blood) is tested in a laboratory. For example, if the analyte is mercury, the laboratory test will determine the amount of mercury in the sample.

Analytic epidemiologic study

A study that evaluates the association between exposure to hazardous substances and disease by testing scientific hypotheses.

Antagonistic effect

A biologic response to exposure to multiple substances that is less than would be expected if the known effects of the individual substances were added together [compare with additive effect and synergistic effect].

Background level

An average or expected amount of a substance or radioactive material in a specific environment, or typical amounts of substances that occur naturally in an environment.

Biodegradation

Decomposition or breakdown of a substance through the action of microorganisms (such as bacteria or fungi) or other natural physical processes (such as sunlight).

Biologic indicators of exposure study

A study that uses (a) biomedical testing or (b) the measurement of a substance [an analyte], its metabolite, or another marker of exposure in human body fluids or tissues to confirm human exposure to a hazardous substance [also see exposure investigation].

Biologic monitoring

Measuring hazardous substances in biologic materials (such as blood, hair, urine, or breath) to determine whether exposure has occurred. A blood test for lead is an example of biologic monitoring.

Biologic uptake

The transfer of substances from the environment to plants, animals, and humans.

Biomedical testing

Testing of persons to find out whether a change in a body function might have occurred because of exposure to a hazardous substance.

Biota

Plants and animals in an environment. Some of these plants and animals might be sources of food, clothing, or medicines for people.

Body burden

The total amount of a substance in the body. Some substances build up in the body because they are stored in fat or bone or because they leave the body very slowly.

CAP

See Community Assistance Panel.

Cancer

Any one of a group of diseases that occurs when cells in the body become abnormal and grow or multiply out of control.

Cancer risk

A theoretical risk of for getting cancer if exposed to a substance every day for 70 years (a lifetime exposure). The true risk might be lower.

Carcinogen

A substance that causes cancer.

Case study

A medical or epidemiologic evaluation of one person or a small group of people to gather information about specific health conditions and past exposures.

Case-control study

A study that compares exposures of people who have a disease or condition (cases) with people who do not have the disease or condition (controls). Exposures that are more common among the cases may be considered as possible risk factors for the disease.

CAS registry number

A unique number assigned to a substance or mixture by the American Chemical Society Abstracts Service.

Central nervous system

The part of the nervous system that consists of the brain and the spinal cord.

CERCLA [see Comprehensive Environmental Response, Compensation, and Liability Act of 1980]

Chronic

Occurring over a long time (more than 1 year) [compare with acute].

Chronic exposure

Contact with a substance that occurs over a long time (more than 1 year) [compare with acute exposure and intermediate duration exposure].

Cluster investigation

A review of an unusual number, real or perceived, of health events (for example, reports of cancer) grouped together in time and location. Cluster investigations are designed to confirm case reports; determine whether they represent an unusual disease occurrence; and, if possible, explore possible causes and contributing environmental factors.

Community Assistance Panel (CAP)

A group of people, from a community and from health and environmental agencies, who work with ATSDR to resolve issues and problems related to hazardous substances in the community. CAP members work with ATSDR to gather and review community health concerns, provide information on how people might have been or might now be exposed to hazardous substances, and inform ATSDR on ways to involve the community in its activities.

Comparison value (CV)

Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the public health assessment process.

Completed exposure pathway [see exposure pathway].

Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)

CERCLA, also known as Superfund, is the federal law that concerns the removal or cleanup of hazardous substances in the environment and at hazardous waste sites. ATSDR, which was created by CERCLA, is responsible for assessing health issues and supporting public health activities related to hazardous waste sites or other environmental releases of hazardous substances.

Concentration

The amount of a substance present in a certain amount of soil, water, air, food, blood, hair, urine, breath, or any other media.

Contaminant

A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.

Delayed health effect

A disease or injury that happens as a result of exposures that might have occurred in the past.

Dermal

Referring to the skin. For example, dermal absorption means passing through the skin.

Dermal contact

Contact with (touching) the skin [see route of exposure].

Descriptive epidemiology

The study of the amount and distribution of a disease in a specified population by person, place, and time.

Detection limit

The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.

Disease prevention

Measures used to prevent a disease or reduce its severity.

Disease registry

A system of ongoing registration of all cases of a particular disease or health condition in a defined population.

DOD

United States Department of Defense.

DOE

United States Department of Energy.

Dose (for chemicals that are not radioactive)

The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An Aexposure dose@ is how much of a substance is encountered in the environment. An Aabsorbed dose@ is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.

Dose (for radioactive chemicals)

The radiation dose is the amount of energy from radiation that is actually absorbed by the body. This is not the same as measurements of the amount of radiation in the environment.

Dose-response relationship

The relationship between the amount of exposure [dose] to a substance and the resulting changes in body function or health (response).

Environmental media

Soil, water, air, biota (plants and animals), or any other parts of the environment that can contain contaminants.

Environmental media and transport mechanism

Environmental media include water, air, soil, and biota (plants and animals). Transport mechanisms move contaminants from the source to points where human exposure can occur. The environmental media and transport mechanism is the second part of an exposure pathway.

USEPA

United States Environmental Protection Agency.

Epidemiologic surveillance

The ongoing, systematic collection, analysis, and interpretation of health data. This activity also involves timely dissemination of the data and use for public health programs.

Epidemiology

The study of the distribution and determinants of disease or health status in a population; the study of the occurrence and causes of health effects in humans.

Exposure

Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [acute exposure], of intermediate duration, or long-term [chronic exposure].

Exposure assessment

The process of finding out how people come into contact with a hazardous substance, how often and for how long they are in contact with the substance, and how much of the substance they are in contact with.

Exposure-dose reconstruction

A method of estimating the amount of people's past exposure to hazardous substances. Computer and approximation methods are used when past information is limited, not available, or missing.

Exposure investigation

The collection and analysis of site-specific information and biologic tests (when appropriate) to determine whether people have been exposed to hazardous substances.

Exposure pathway

The route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed to) it. An exposure pathway has five parts: a source of contamination (such as an abandoned business); an environmental media and transport mechanism (such as movement through groundwater); a point of exposure (such as a private well); a route of exposure (eating, drinking, breathing, or touching), and a receptor population (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a completed exposure pathway.

Exposure registry

A system of ongoing followup of people who have had documented environmental exposures.

Feasibility study

A study by USEPA to determine the best way to clean up environmental contamination. A number of factors are considered, including health risk, costs, and what methods will work well.

Geographic information system (GIS)

A mapping system that uses computers to collect, store, manipulate, analyze, and display data. For example, GIS can show the concentration of a contaminant within a community in relation to points of reference such as streets and homes.

Grand rounds

Training sessions for physicians and other health care providers about health topics.

Groundwater

Water beneath the earth's surface in the spaces between soil particles and between rock surfaces [compare with surface water].

Half-life (t2)

The time it takes for half the original amount of a substance to disappear. In the environment, the half-life is the time it takes for half the original amount of a substance to disappear when it is changed to another chemical by bacteria, fungi, sunlight, or other chemical processes. In the human body, the half-life is the time it takes for half the original amount of the substance to disappear, either by being changed to another substance or by leaving the body. In the case of radioactive material, the half life is the amount of time necessary for one half the initial number of radioactive atoms to change or transform into another atom (that is normally not radioactive). After two half lives, 25% of the original number of radioactive atoms remain.

Hazard

A source of potential harm from past, current, or future exposures.

Hazardous Substance Release and Health Effects Database (HazDat)

The scientific and administrative database system developed by ATSDR to manage data collection, retrieval, and analysis of site-specific information on hazardous substances, community health concerns, and public health activities.

Hazardous waste

Potentially harmful substances that have been released or discarded into the environment.

Health consultation

A review of available information or collection of new data to respond to a specific health question or request for information about a potential environmental hazard. Health consultations are focused on a specific exposure issue. Health consultations are therefore more limited than a public health assessment, which reviews the exposure potential of each pathway and chemical [compare with public health assessment].

Health education

Programs designed with a community to help it know about health risks and how to reduce these risks.

Health investigation

The collection and evaluation of information about the health of community residents. This information is used to describe or count the occurrence of a disease, symptom, or clinical measure and to estimate the possible association between the occurrence and exposure to hazardous substances.

Health promotion

The process of enabling people to increase control over, and to improve, their health.

Health statistics review

The analysis of existing health information (i.e., from death certificates, birth defects registries, and cancer registries) to determine if there is excess disease in a specific population, geographic area, and time period. A health statistics review is a descriptive epidemiologic study.

Indeterminate public health hazard

The category used in ATSDR=s public health assessment documents when a professional judgment about the level of health hazard cannot be made because information critical to such a decision is lacking.

Incidence

The number of new cases of disease in a defined population over a specific time period [contrast with prevalence].

Ingestion

The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see route of exposure].

Inhalation

The act of breathing. A hazardous substance can enter the body this way [see route of exposure].

Intermediate duration exposure

Contact with a substance that occurs for more than 14 days and less than a year [compare with acute exposure and chronic exposure].

In vitro

In an artificial environment outside a living organism or body. For example, some toxicity testing is done on cell cultures or slices of tissue grown in the laboratory, rather than on a living animal [compare with in vivo].

In vivo

Within a living organism or body. For example, some toxicity testing is done on whole animals, such as rats or mice [compare with in vitro].

Lowest-observed-adverse-effect level (LOAEL)

The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.

Medical monitoring

A set of medical tests and physical exams specifically designed to evaluate whether an individual=s exposure could negatively affect that person=s health.

Metabolism

The conversion or breakdown of a substance from one form to another by a living organism.

Metabolite

Any product of metabolism.

mg/kg

Milligram per kilogram.

mg/cm2

Milligram per square centimeter (of a surface).

mg/m3

Milligram per cubic meter; a measure of the concentration of a chemical in a known volume (a cubic meter) of air, soil, or water.

Migration

Moving from one location to another.

Minimal risk level (MRL)

An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects [see reference dose].

Morbidity

State of being ill or diseased. Morbidity is the occurrence of a disease or condition that alters health and quality of life.

Mortality

Death. Usually the cause (a specific disease, condition, or injury) is stated.

Mutagen

A substance that causes mutations (genetic damage).

Mutation

A change (damage) to the DNA, genes, or chromosomes of living organisms.

National Priorities List for Uncontrolled Hazardous Waste Sites (National Priorities List or NPL)

USEPA=s list of the most serious uncontrolled or abandoned hazardous waste sites in the United States. The NPL is updated on a regular basis.

No apparent public health hazard

A category used in ATSDR=s public health assessments for sites where human exposure to contaminated media might be occurring, might have occurred in the past, or might occur in the future, but where the exposure is not expected to cause any harmful health effects.

No-observed-adverse-effect level (NOAEL)

The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.

No public health hazard

A category used in ATSDR=s public health assessment documents for sites where people have never and will never come into contact with harmful amounts of site-related substances.

NPL [see National Priorities List for Uncontrolled Hazardous Waste Sites]

Physiologically based pharmacokinetic model (PBPK model)

A computer model that describes what happens to a chemical in the body. This model describes how the chemical gets into the body, where it goes in the body, how it is changed by the body, and how it leaves the body.

Pica

A craving to eat nonfood items, such as dirt, paint chips, and clay. Some children exhibit pica-related behavior.

Plume

A volume of a substance that moves from its source to places farther away from the source. Plumes can be described by the volume of air or water they occupy and the direction they move. For example, a plume can be a column of smoke from a chimney or a substance moving with groundwater.

Point of exposure

The place where someone can come into contact with a substance present in the environment [see exposure pathway].

Population

A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age).

Potentially responsible party (PRP)

A company, government, or person legally responsible for cleaning up the pollution at a hazardous waste site under Superfund. There may be more than one PRP for a particular site.

ppb

Parts per billion.

ppm

Parts per million.

Prevalence

The number of existing disease cases in a defined population during a specific time period [contrast with incidence].

Prevalence survey

The measure of the current level of disease(s) or symptoms and exposures through a questionnaire that collects self-reported information from a defined population.

Prevention

Actions that reduce exposure or other risks, keep people from getting sick, or keep disease from getting worse.

Public comment period

An opportunity for the public to comment on agency findings or proposed activities contained in draft reports or documents. The public comment period is a limited time period during which comments will be accepted.

Public availability session

An informal, drop-by meeting at which community members can meet one-on-one with ATSDR staff members to discuss health and site-related concerns.

Public health action

A list of steps to protect public health.

Public health advisory

A statement made by ATSDR to USEPA or a state regulatory agency that a release of hazardous substances poses an immediate threat to human health. The advisory includes recommended measures to reduce exposure and reduce the threat to human health.

Public health assessment (PHA)

An ATSDR document that examines hazardous substances, health outcomes, and community concerns at a hazardous waste site to determine whether people could be harmed from coming into contact with those substances. The PHA also lists actions that need to be taken to protect public health [compare with health consultation].

Public health hazard

A category used in ATSDR=s public health assessments for sites that pose a public health hazard because of long-term exposures (greater than 1 year) to sufficiently high levels of hazardous substances or radionuclides that could result in harmful health effects.

Public health hazard categories

Public health hazard categories are statements about whether people could be harmed by conditions present at the site in the past, present, or future. One or more hazard categories might be appropriate for each site. The five public health hazard categories are no public health hazard, no apparent public health hazard, indeterminate public health hazard, public health hazard, and urgent public health hazard.

Public health statement

The first chapter of an ATSDR toxicological profile. The public health statement is a summary written in words that are easy to understand. The public health statement explains how people might be exposed to a specific substance and describes the known health effects of that substance.

Public meeting

A public forum with community members for communication about a site.

Radioisotope

An unstable or radioactive isotope (form) of an element that can change into another element by giving off radiation.

Radionuclide

Any radioactive isotope (form) of any element.

RCRA [See Resource Conservation and Recovery Act (1976, 1984)]

Receptor population

People who could come into contact with hazardous substances [see exposure pathway].

Reference dose (RfD)

An USEPA estimate, with uncertainty or safety factors built in, of the daily lifetime dose of a substance that is unlikely to cause harm in humans.

Registry

A systematic collection of information on persons exposed to a specific substance or having specific diseases [see exposure registry and disease registry].

Remedial Investigation

The CERCLA process of determining the type and extent of hazardous material contamination at a site.

Resource Conservation and Recovery Act (1976, 1984) (RCRA)

This Act regulates management and disposal of hazardous wastes currently generated, treated, stored, disposed of, or distributed.

RFA

RCRA Facility Assessment. An assessment required by RCRA to identify potential and actual releases of hazardous chemicals.

RfD

See reference dose.

Risk

The probability that something will cause injury or harm.

Risk reduction

Actions that can decrease the likelihood that individuals, groups, or communities will experience disease or other health conditions.

Risk communication

The exchange of information to increase understanding of health risks.

Route of exposure

The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin [dermal contact].

Safety factor [see uncertainty factor]

SARA [see Superfund Amendments and Reauthorization Act]

Sample

A portion or piece of a whole. A selected subset of a population or subset of whatever is being studied. For example, in a study of people the sample is a number of people chosen from a larger population [see population]. An environmental sample (for example, a small amount of soil or water) might be collected to measure contamination in the environment at a specific location.

Sample size

The number of units chosen from a population or environment.

Solvent

A liquid capable of dissolving or dispersing another substance (for example, acetone or mineral spirits).

Source of contamination

The place where a hazardous substance comes from, such as a landfill, waste pond, incinerator, storage tank, or drum. A source of contamination is the first part of an exposure pathway.

Special populations

People who might be more sensitive or susceptible to exposure to hazardous substances because of factors such as age, occupation, sex, or behaviors (for example, cigarette smoking). Children, pregnant women, and older people are often considered special populations.

Stakeholder

A person, group, or community who has an interest in activities at a hazardous waste site.

Statistics

A branch of mathematics that deals with collecting, reviewing, summarizing, and interpreting data or information. Statistics are used to determine whether differences between study groups are meaningful.

Substance

A chemical.

Substance-specific applied research

A program of research designed to fill important data needs for specific hazardous substances identified in ATSDR's toxicological profiles. Filling these data needs would allow more accurate assessment of human risks from specific substances contaminating the environment. This research might include human studies or laboratory experiments to determine health effects resulting from exposure to a given hazardous substance.

Superfund Amendments and Reauthorization Act (SARA)

In 1986, SARA amended CERCLA and expanded the health-related responsibilities of ATSDR. CERCLA and SARA direct ATSDR to look into the health effects from substance exposures at hazardous waste sites and to perform activities including health education, health studies, surveillance, health consultations, and toxicological profiles.

Surface water

Water on the surface of the earth, such as in lakes, rivers, streams, ponds, and springs [compare with groundwater].

Surveillance [see epidemiologic surveillance]

Survey

A systematic collection of information or data. A survey can be conducted to collect information from a group of people or from the environment. Surveys of a group of people can be conducted by telephone, by mail, or in person. Some surveys are done by interviewing a group of people [see prevalence survey].

Synergistic effect

A biologic response to multiple substances where one substance worsens the effect of another substance. The combined effect of the substances acting together is greater than the sum of the effects of the substances acting by themselves [see additive effect and antagonistic effect].

Teratogen

A substance that causes defects in development between conception and birth. A teratogen is a substance that causes a structural or functional birth defect.

Toxic agent

Chemical or physical (for example, radiation, heat, cold, microwaves) agents which, under certain circumstances of exposure, can cause harmful effects to living organisms.

Toxicological profile

An ATSDR document that examines, summarizes, and interprets information about a hazardous substance to determine harmful levels of exposure and associated health effects. A toxicological profile also identifies significant gaps in knowledge on the substance and describes areas where further research is needed.

Toxicology

The study of the harmful effects of substances on humans or animals.

Tumor

An abnormal mass of tissue that results from excessive cell division that is uncontrolled and progressive. Tumors perform no useful body function. Tumors can be either benign (not cancer) or malignant (cancer).

Uncertainty factor

Mathematical adjustments for reasons of safety when knowledge is incomplete. For example, factors used in the calculation of doses that are not harmful (adverse) to people. These factors are applied to the lowest-observed-adverse-effect-level (LOAEL) or the no-observed-adverse-effect-level (NOAEL) to derive a minimal risk level (MRL). Uncertainty factors are used to account for variations in people=s sensitivity, for differences between animals and humans, and for differences between a LOAEL and a NOAEL. Scientists use uncertainty factors when they have some, but not all, the information from animal or human studies to decide whether an exposure will cause harm to people [also sometimes called a safety factor].

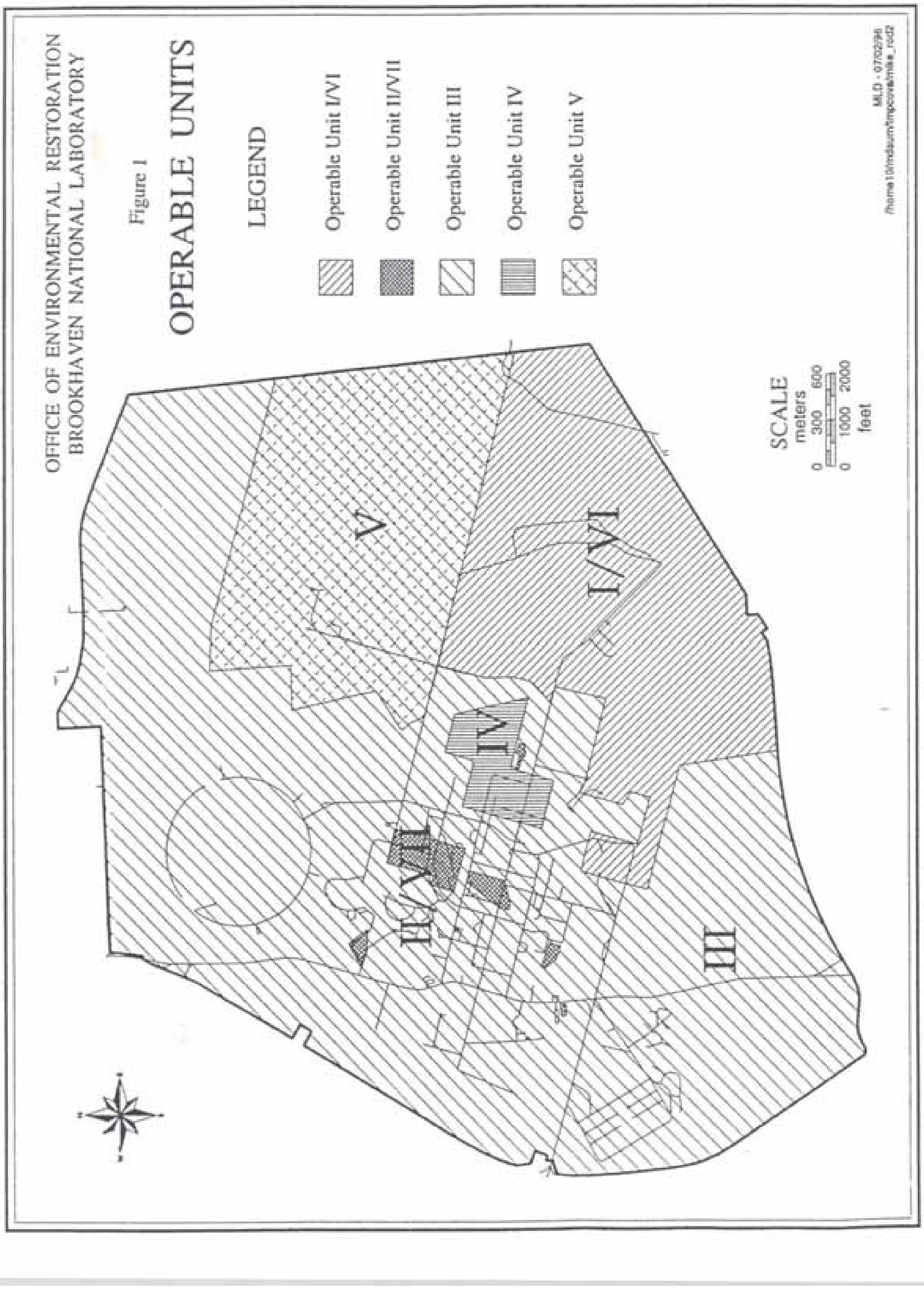
Urgent public health hazard

A category used in ATSDR=s public health assessments for sites where short-term exposures (less than 1 year) to hazardous substances or conditions could result in harmful health effects that require rapid intervention.

Volatile organic compounds (VOCs)

Organic compounds that evaporate readily into the air. VOCs include substances such as benzene, toluene, methylene chloride, and methyl chloroform.

Appendix B. Figures


OFFICE OF ENVIRONMENTAL RESTORATION
BROOKHAVEN NATIONAL LABORATORY
Figure 1
OPERABLE UNITS
LEGEND
Operable Unit I/VI
Operable Unit II/VII
Operable Unit III
Operable Unit IV
Operable Unit V
SCALE
meters
0 300 600
0 1000 2000
feet
MLD - 07/02/96
V
I/VI
IV
II/VII
III

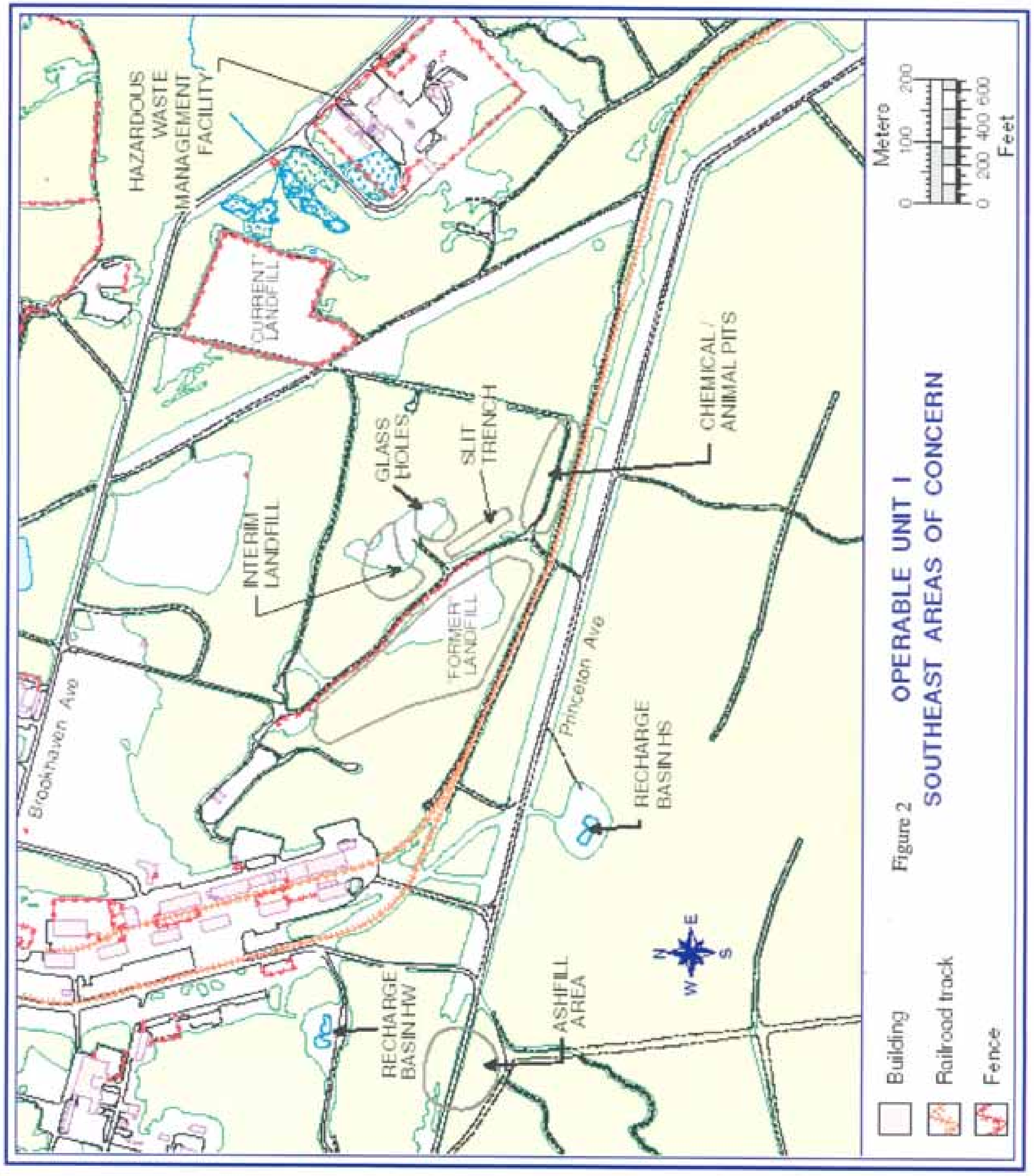
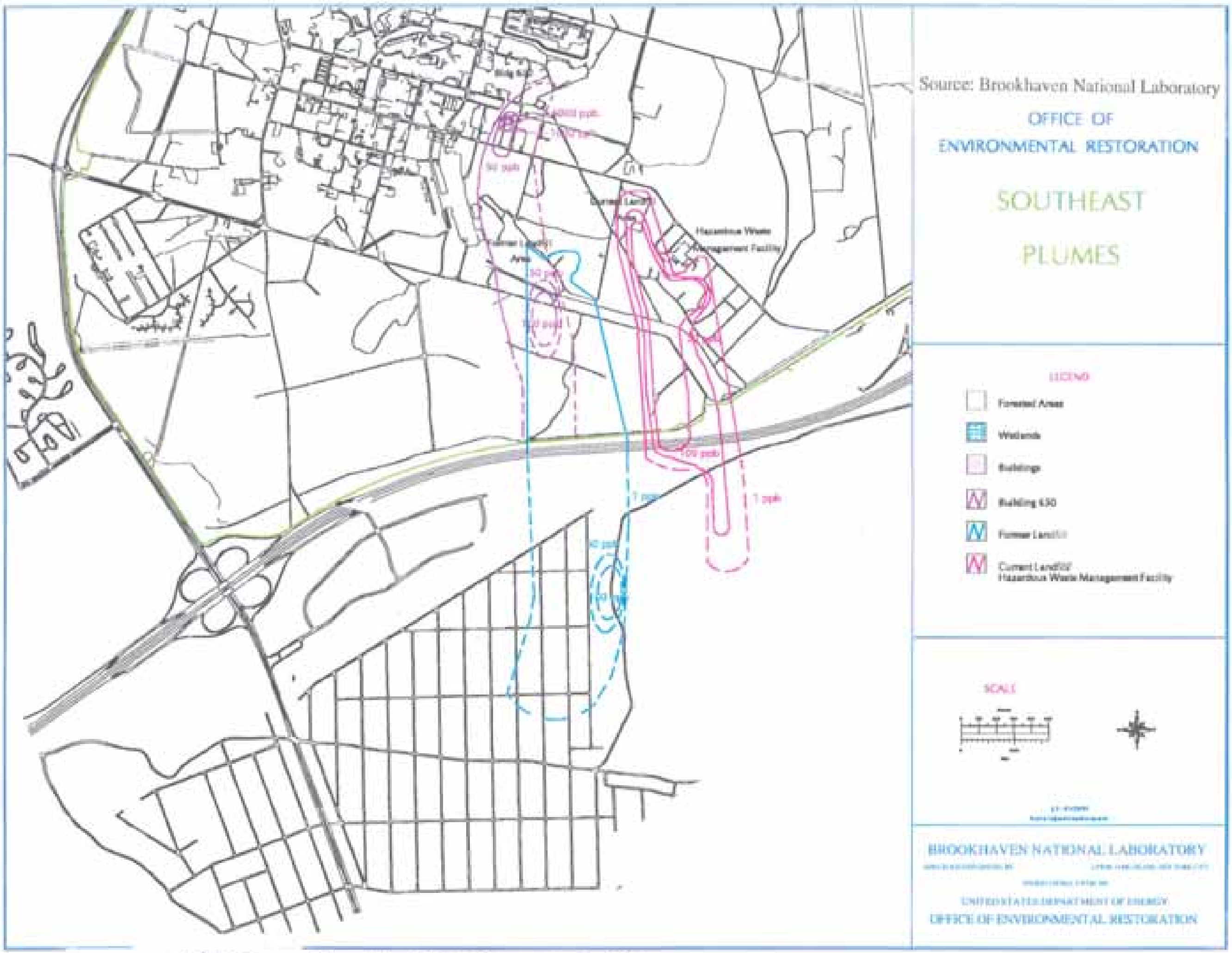


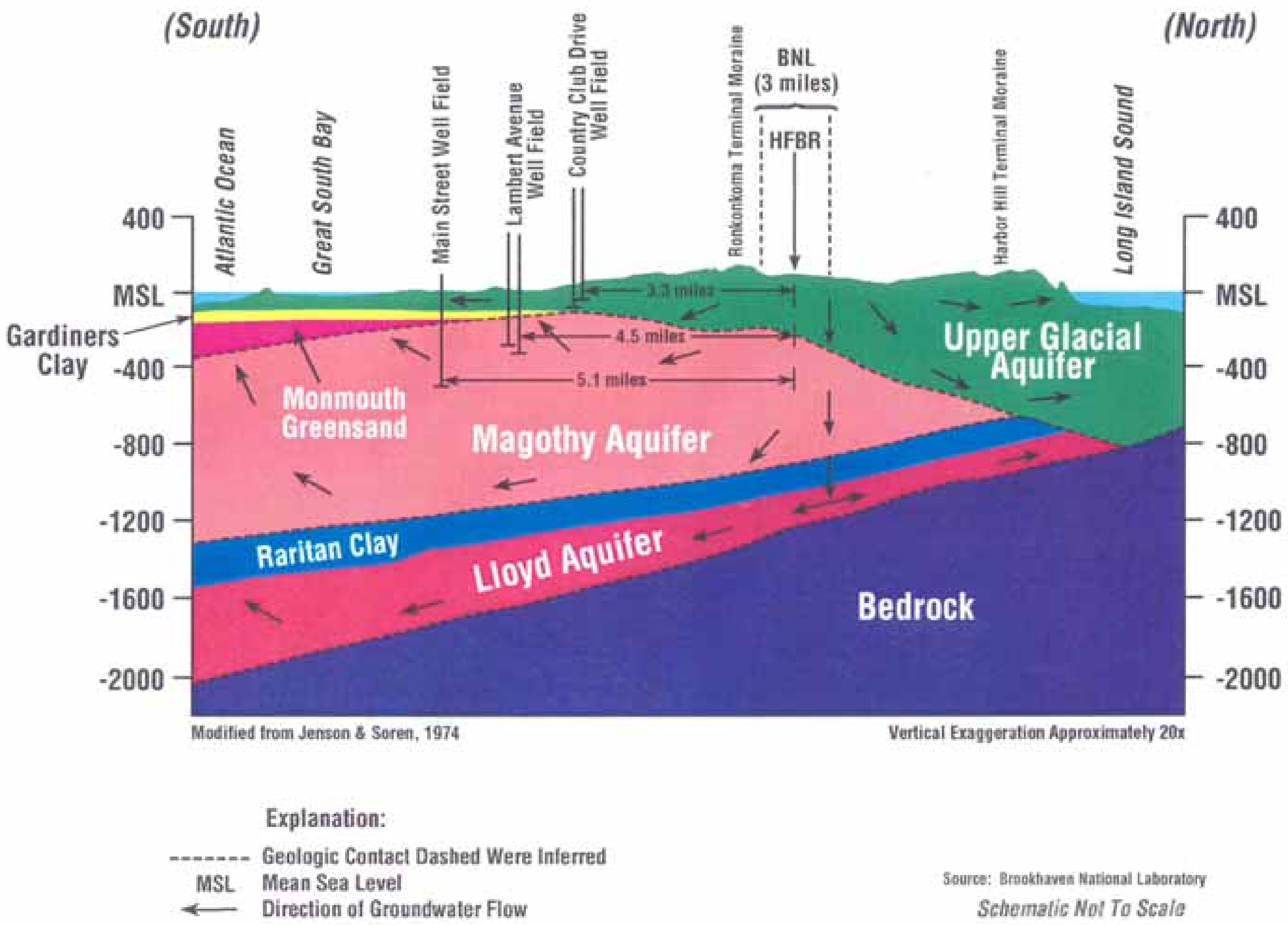
Figure 2 OPERABLE UNIT I SOUTHEAST AREAS OF CONCERN



Source: Brookhaven National Laboratory

Figure 3 Operable Unit 1 Groundwater Plumes

Figure 4. Generalized Geologic Cross Section in Vicinity of Brookhaven National Laboratory



Modified from Jenson & Soren, 1974

Vertical Exaggeration Approximately 20x

Source: Brookhaven National Laboratory

Schematic Not To Scale

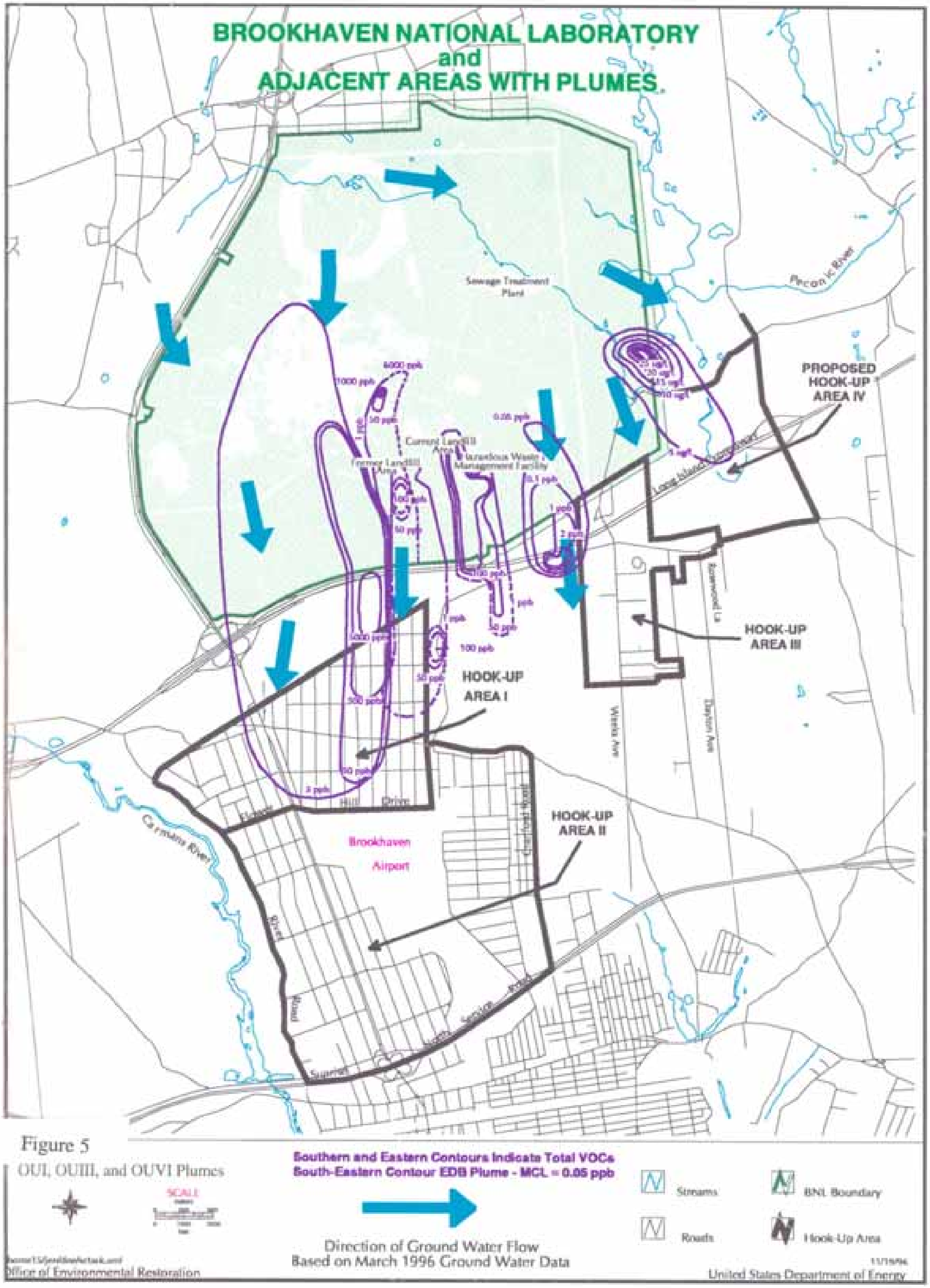
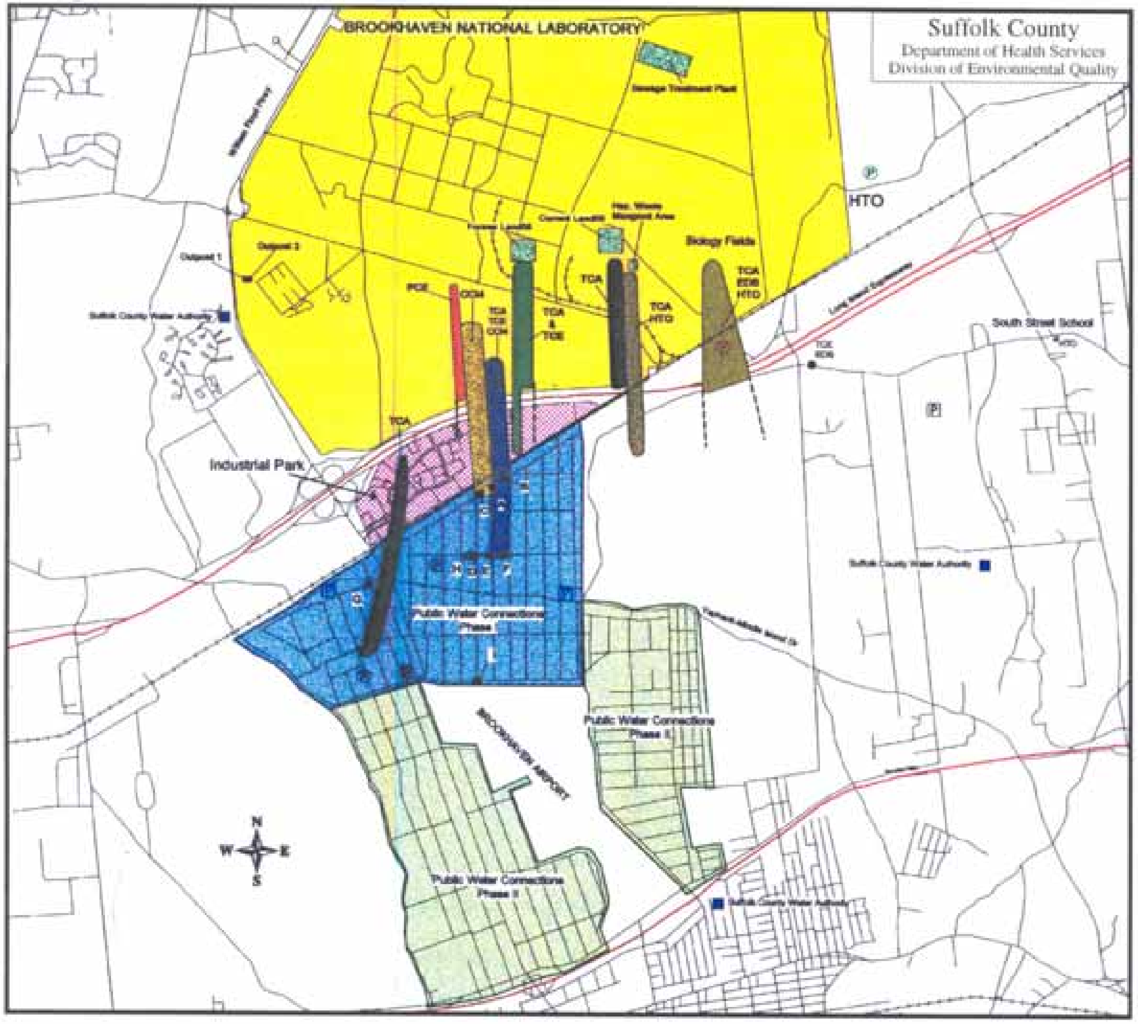


Figure 5

OUI, OUIII, and OUVI Plumes

Figure 5a



Contaminant Key

TCA - 1,1,1 Trichloroethane
TCE - Trichlorethane
PCE - Tetrachloroethene
CCI4 - Carbon Tetrachloride
EDB - 1,2-dibromoethane
HTO - Tritium

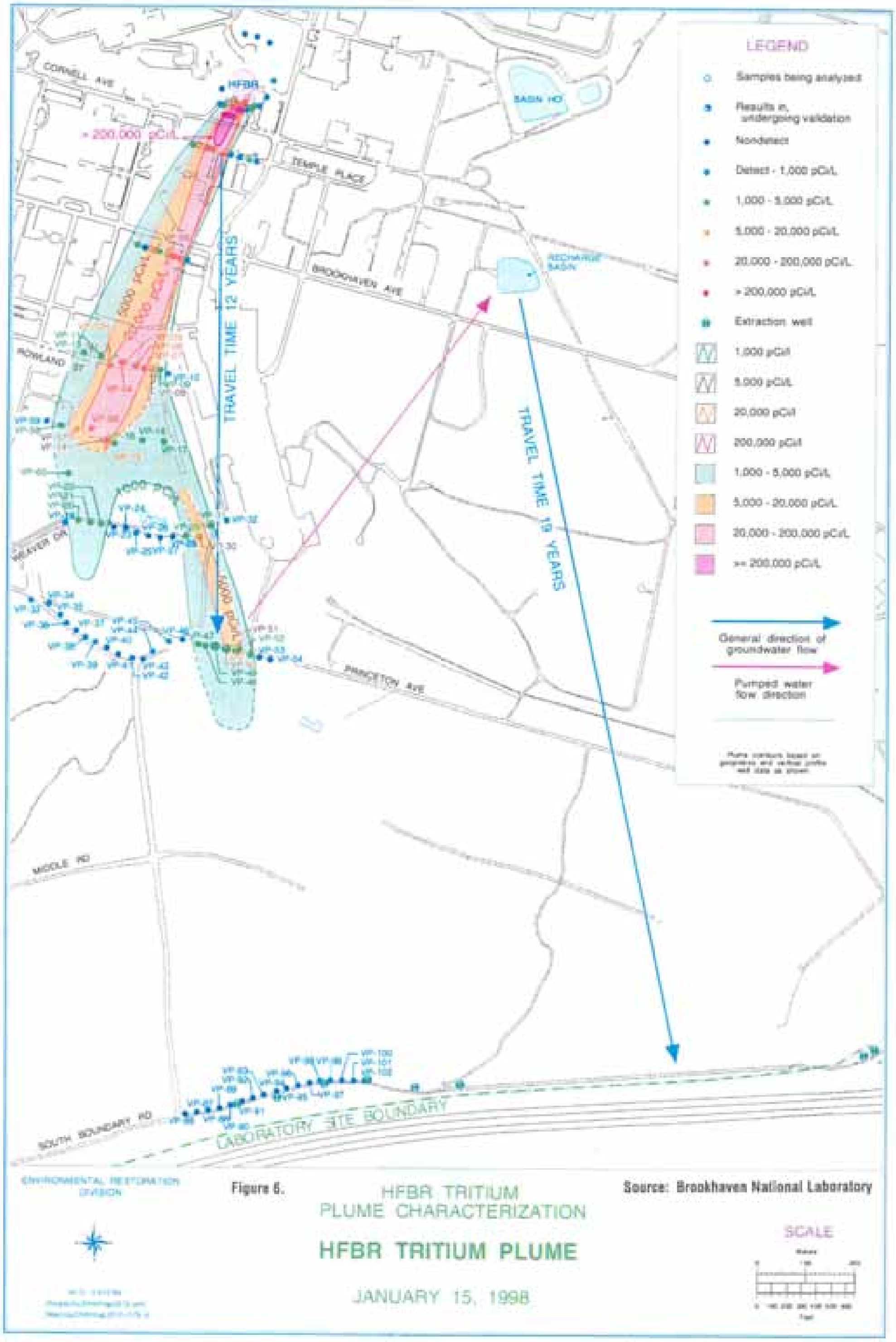


Figure 6. HFBR TRITIUM PLUME CHARACTERIZATION

HFBR TRITIUM PLUME

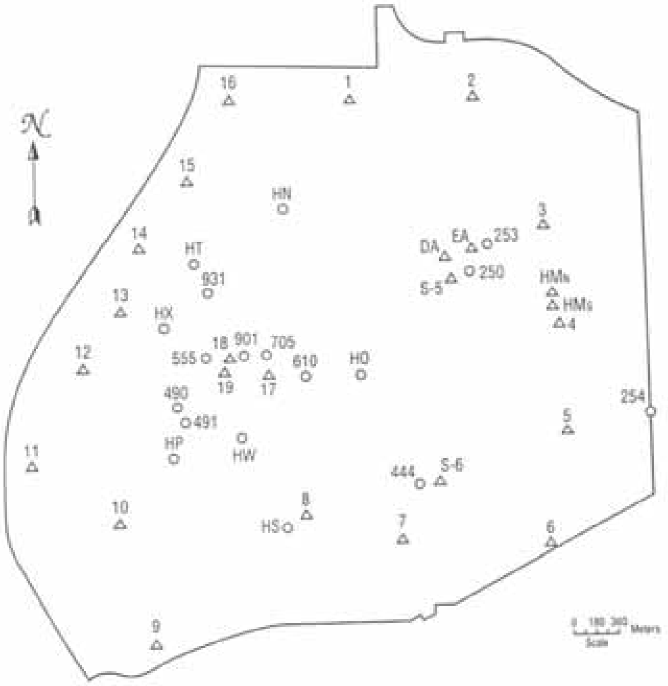
JANUARY 15, 1998

Source: Brookhaven National Laboratory

Figure 7. On Site: Potable and Supply Wells and Recharge Sumps

Source: Brookhaven National Laboratory

Brookhaven National Laboratory
Effluent Release Points and On-site Environmental Monitoring Stations



△ Environmental Monitoring Stations

Air
1 thru 16 Perimeter Stations
S-6 Waste Management Area
S-5 Sewage Treatment Plant
17, 18, 19 Center of Site

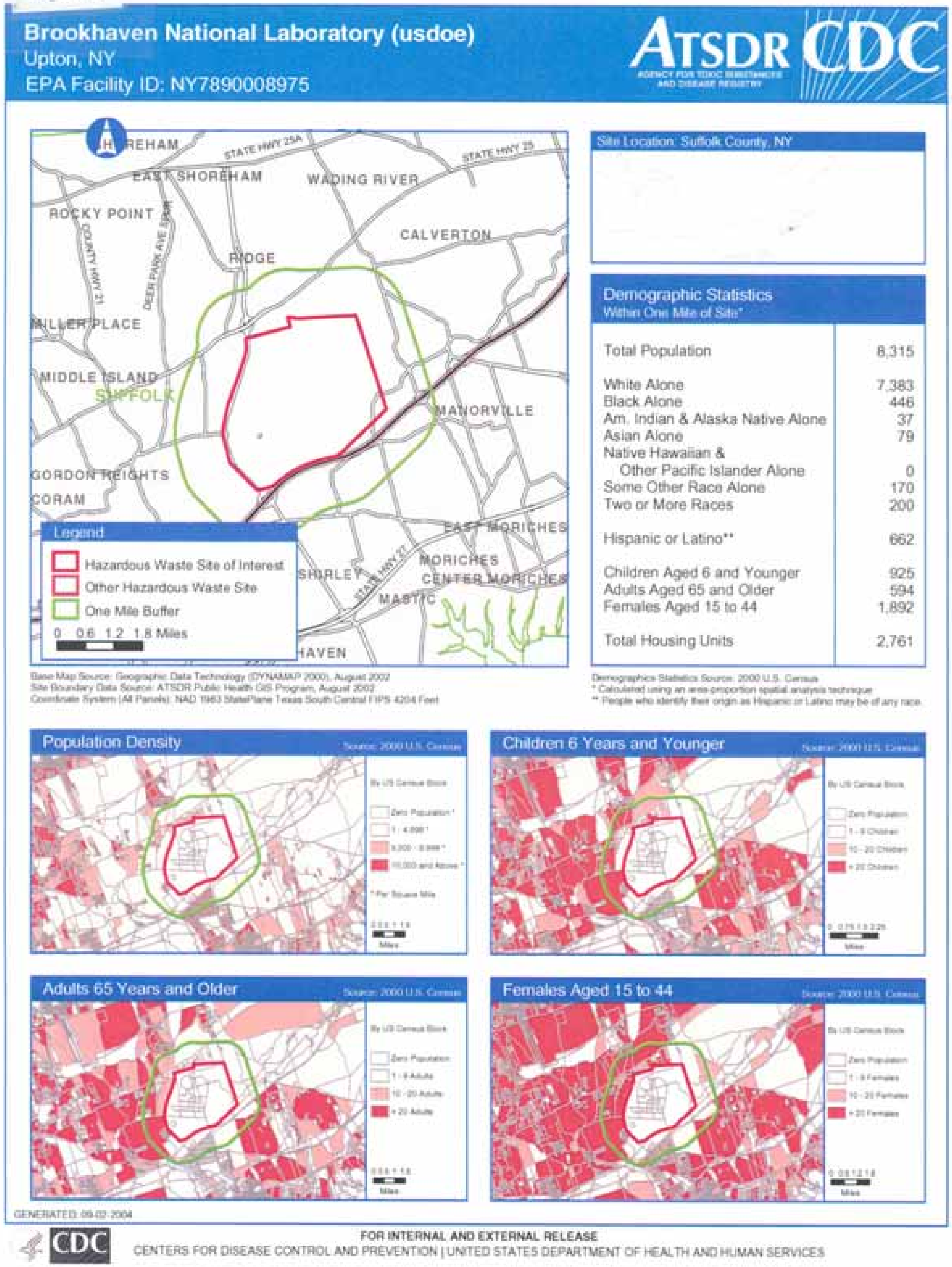
Water
DA Sewage Treatment Plant Influent
EA Sewage Treatment Plant Effluent
HM Peconic River, 0.5 mi. Downstream From Treatment Plant

○ Designation	Effluent Release Point
250	Sand filter Beds
253	Peconic R. Stream Bed
254	Site Boundary
490	MRC Stack
491	MRR Stack
555	Chemistry Stack
705	HFBR Stack
901	Van De Graff Stack
931	BLIF Stack
444	Waste Management Incinerator
610	Steam Plant
HN	Recharge Basin
HO	Recharge Basin
HP	Recharge Basin
HS	Recharge Basin
HT	Recharge Basin
HX	Recharge Basin
HW	Recharge Basin

Figure 8

'94 Env. Report

Figure 9



Brookhaven National Laboratory (usdoe)
Upton, NY
EPA Facility ID: NY7890008975

Base Map Source: Geographic Data Technology (DYNAMAP 2000), August 2002
Site Boundary Data Source: ATSDR Public Health GIS Program, August 2002
Coordinate System (All Panels): NAD 1983 StatePlane Texas South Central FIPS 4204 Feet

Site Location: Suffolk County, NY

Demographic Statistics
Within One Mile of Site*

Total Population	8,315
White Alone	7,383
Black Alone	446
Am. Indian & Alaska Native Alone	37
Asian Alone	79
Native Hawaiian & Other Pacific Islander Alone	0
Some Other Race Alone	170
Two or More Races	200
Hispanic or Latino**	662
Children Aged 6 and Younger	925
Adults Aged 65 and Older	594
Females Aged 15 to 44	1,892
Total Housing Units	2,761

Demographics Statistics Source: 2000 U.S. Census
* Calculated using an area-proportion spatial analysis technique
** People who identify their origin as Hispanic or Latino may be of any race.

Population Density — Source: 2000 U.S. Census

Children 6 Years and Younger — Source: 2000 U.S. Census

Adults 65 Years and Older — Source: 2000 U.S. Census

Females Aged 15 to 44 — Source: 2000 U.S. Census

GENERATED: 09-02-2004

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Appendix C. Tables

Table MW1. On-Site Monitoring Well Contaminants

Chemical	*Concentration Range (ppb)*	*Depth of Contamination(feet below land surface)*	*Comparison Value(ppb)*
Carbon Tetrachloride	NDB179,000	120B230	5 (USEPA MCL)
Chloroform	NDB100	80B240	80 (USEPA MCL)
1,1-Dichloroethane(1,1-DCA)	NDB870	82B225	5 (NYS MCL)
1,1-Dichloroethylene(1,1-DCE)	NDB580	92B200	7 (USEPA MCL)
Ethylene Dibromide(EDB)	NDB0.78	15B69	0.05 (USEPA MCL)
Perchloroethylene(PCE)	NDB6,180	30B95	5 (USEPA MCL)
1,1,1-Trichloroethane(1,1,1-TCA)	NDB1,500	150B200	5 (NYS MCL)200 (USEPA MCL)
Trichloroethylene(TCE)	NDB100	126B260	5 (USEPA MCL)

ppb: parts per billion

USEPA MCL: Environmental Protection Agency Maximum Contaminant Level

NYS MCL: New York State Maximum Contaminant Level

ND: Non-detection

Table MW2. Radionuclides in On-Site Monitoring Wells

Radionuclide	*Concentration Range (pCi/L)*	*Drinking Water Standard (USEPA MCL) (pCi/L)*	*Location (OU)*
Lead-210	130B3,340†	1.2	3,5
Strontium-89	8B24.2	8	3
Strontium-90	8B769	8	1/4, 3, 5
Tritium	245B1,590,000	20,000	1, 3, 5
Potassium-40*	187B660	280	3, 5
Radium-226	17.9B77.3	3	3, 4

Minimum detection limit for tritium was 245 pCi/L

pCi/L: picocuries per Liter

MCL: Maximum Contaminant Level

OU: Operable Unit

* :potassium-40 is a naturally occurring radionuclide

†The maximum concentration of lead-210 was noted as being suspect because of the considerable background interference, large error values, and absence of the parent nuclide radium-226.

Table MW3. Contaminants in BNL and Off-Site Suffolk County Department of Health Services Monitoring Wells

Chemical	*Concentration Range (ppb)*	*Depth of Contamination(feet below land surface)*	*Comparison Value(ppb)*
Carbon Tetrachloride	5B5,100	140B290	5 (USEPA MCL)
Chloroform	1B113	175B185275B295	80 (USEPA MCL)*
1,1-Dichloroethane(1,1-DCA)	1B65.1	125B209	5 (NYS MCL)
1,1-Dichloroethylene(1,1-DCE)	0.6B16	125B230	7 (MCL)
Ethylene Dibromide(EDB)	0.04B3.5	20B70	0.05 (USEPA MCL)
Perchloroethylene(PCE)	0.6B1,000	205B210	5 (USEPA MCL)
Trichloroethylene(TCE)	3B110	79B297	5 (USEPA MCL)

ppb: parts per billion

USEPA MCL: Environmental Protection Agency Maximum Contaminant Level

MCL is for total trihalomethanes.

Chloroform is one chemical within the group of trihalomethanes.

NYS MCL: New York State Maximum Contaminant Level

Table SSC. Summary of Surface Soil Contaminants

Chemical	*Maximum Concentration (mg/kg)*	*Comparison Value (mg/kg)*	*Type*	*Exceedances/ Detections/ Samples***	*Locations of Exceedances*
Aroclor-1260	4.1	0.32	RBC-C	8 / 32 / 124	SB16A, SB18A, SB20A, SB23A, SB29A, SB30A, SB44A, B1-06
Arsenic	28.1	20	CV (C-EMEG-child)	1 / 82 / 155	SB41A
		0.43	RBC-C	82 / 82 / 155	CA0101, CA0201,CP0201, CP0301, CP0401, CP0501, CP0601, CP0701, CP0801, CP0901, CP1001, CP1101, CP1201, CP1301, SB16A, SB17A, SB18A, SB19A, SB20A, SB21A, SB22A, SB23A, SB24A, SB25A, SB26A, SB27A, SB28A, SB29A, SB30A, SB31A, SB32A, SB33A, SB34A, SB35A, SB37A, SB38A, SB39A, SB40A, SB41A, SB42A, SB43A, SB44A, SB45A, SB46A, SB47A,

Chemical	*Maximum Concentration (mg/kg)*	*Comparison Value (mg/kg)*	*Type*	*Exceedances/ Detections/ Samples***	*Locations of Exceedances*
					SB48A, SB49A, SB50A, SB51A, SB52A, SB53A, SB54A, SB55A, SB58A, SB59A, HPB01, HPB02, MN02, MN03, SB01, SB02, SB03, SB13, SB33, SB35, SB36, SB37, SB38, SB39, SB40, SB41, SB42, SB43, SB45, SB46, SB47, SB48, SB49, SB59, SB60, 7703, 7629
Aroclor-1254	1.5	1	CV (C-EMEG-child)	2 / 27 / 123	B1-06, B1-08
Benzo(a)anthracene	7.4	0.87	RBC-C	8 / 35 / 154	B1-01, SB28A, SB30A, SB36A, SB09, SB45, SB46, SB49
Benzo(a)pyrene	5.0	0.087	RBC-C	23 / 30 / 154	SB17A, SB24A, SB25E, SB27A, SB28A, SB29A, SB30A, SB34A, SB36A, SB46A, SB48A, SB50A, B1-01, MN02, MN03, SB72A, SB09, SB18, SB45, SB46, SB49, SB36, SB37
Benzo(b)-fluoranthene	9.0	0.87	RBC-C	11 / 36 / 151	SB27A, SB28A, SB29A, SB30A, SB36A, B1-01, SB09, SB18, SB45, SB46, SB49
Benzo(g,h,i)-perylene	2.8	--	none	-- / 16 / 153	(SB30A)
4-Chloro-3-methylphenol	7.0	--	none	-- / 2 / 156	(SB36A)
Endrin ketone	0.006	--	none	-- / 5 / 124	(SB23A/SB41A)
Indeno(1,2,3-cd)-pyrene	3.5	0.87	RBC-C	4 / 15 / 149	SB28A, SB30A, SB36A, SB46
Iron	43,600	23,000	RBC-N	8 / 170 / 170	SB48A, HPB01, HPB02, MN02, MN03, SB01, SB02, SB03
Mercury	184	7.8	RBC-N*	8 / 78 / 167	SB18A, SB20A, SB41A, SB48A, SB53A, A-01, B1-06, B1-08
N-Nitroso-di-n-propylamine	2.8	0.091	RBC-C	2 / 2 / 156	SB36A, SB56A
Phenanthrene	29.0	--	none	-- / 31 / 155	(SB28A)
Trichloroethylene	0.02	--	none	-- / 1 / 156	(SB38)

Notes:

Location of maximum detection in bold. If there were no exceedances, maximum location is given in parentheses.

RBC = USEPA Region III Risk-Based Concentration (C = Carcinogenic, N = Non-carcinogenic)

C-EMEG-child = Environmental Media Evaluation Guide for Chronic exposure to a child

* RBC for methylmercury

Table SSR. Summary of Radionuclides in Surface Soil

Isotope	*Maximum Concentration (pCi/g)*	*Average Concentration* (pCi/g)*	*Detections / Samples***	*Location of Maximum*
Actinium-228	2.9	0.99	47 / 94	CP0801
Americium-241	5.41	1.23	24 / 116	B-SB03-SB01
Bismuth-212	1.23	0.68	4 / 4	B1-SB16
Bismuth-214	2.2	0.65	63 / 101	CP0801
Cesium-137	810,000	12,100	149 / 175	SB37A
Cobalt-57	0.069	0.069	1 / 1	B-GP13
Cobalt-60	6.5	1.61	21 / 114	SB34, SB50A
Gross alpha	170	17.1	111 / 115	SB45
Gross beta	1,100,000	22,000	114 / 115	SB37A
Lead-210	16	2.62	13 / 100	455Comp
Lead-212	1.7	0.64	124 / 143	CA0201
Lead-214	2	0.62	97 / 129	CP1001
Potassium-40	12	6.86	145 / 154	SB76, SB35A
Radium-224	5.83	2.2	5 / 5	B-GP09
Radium-226	0.63	0.34	26 / 85	C1-GP01
Radium-228	0.61	0.55	7 / 7	MN03
Sodium-22	0.69	0.49	3 / 51	SB47
Strontium-89	6.85	1.21	14 / 64	B-GP07
Strontium-90	1,300	34.4	128 / 175	SB37A
Thallium-208	1.6	0.61	84 / 126	CA0101
Thorium-228	3.63	1.07	4 / 4	B-GP15
Thorium-232	0.25	0.22	3 / 3	SB02
Thorium-234	4.4	1.5	12 / 101	SB76A
Tritium	14	0.67	126 / 175	SB20A
Uranium-234	1.49	0.86	3 / 3	A-GP01
Uranium-235	0.23	0.13	8 / 96	SB91C
Uranium-238	0.72	0.51	3 / 3	A-GP01
Sieved Soil				
Cesium-137	44,000,000	3,500,000	16 / 16	SB37A-C
Gross alpha	450	70	16 / 16	SB36A-C

Isotope	*Maximum Concentration (pCi/g)*	*Average Concentration* (pCi/g)*	*Detections / Samples***	*Location of Maximum*
Gross beta	32,000,000	3,000,000	16 / 16	SB37A-C
Strontium-90	5,600	5,700	15 / 15	SB37A-C

* The average concentration is a representative value for the contaminated areas of the operable unit. This average does not represent an average concentration for the whole operable unit. Nondetected values were not included in the average concentration.

** A total of 59 surface soil and 16 sieved soil samples were collected. Some samples were rejected for quality control reasons.

Table SS1. Surface Soil Contaminants in OU I

Chemical	*Maximum Concentration (mg/kg)*	*Comparison Value (mg/kg)*	*Type*	*Exceedances/ Detections/ Samples***	*Locations of Exceedances*
Aroclor-1260	4.1	0.32	RBC-C	7 / 11 / 43	SB16A, SB18A, SB20A, SB23A, SB29A, SB30A, SB44A
Arsenic	28.10	20	CV (C-EMEG-child)	1 / 55 / 55	SB41A
Benzo(a)anthracene	7.4	0.87	RBC-C	3 / 16 / 42	SB28A, SB30A, SB36A
Benzo(a)pyrene	5.0	0.087	RBC-C	12 / 12 / 40	SB17A, SB24A, SB25E, SB27A, SB28A, SB29A, SB30A, SB34A, SB36A, SB46A, SB48A, SB50A
Benzo(b)-fluoranthene	9.0	0.87	RBC-C	5 / 12 / 39	SB27A, SB28A, SB29A, SB30A, SB36A
Benzo(g,h,i)perylene	2.8	--	none	-- / 8 / 39	(SB30A)
4-Chloro-3-methylphenol	7.0	--	none	-- / 2 / 43	(SB36A)
Endrin ketone	0.006	--	none	-- / 5 / 43	(SB23A/SB41A)
Indeno(1,2,3-cd)-pyrene	3.5	0.87	RBC-C	3 / 7 / 38	SB28A, SB30A, SB36A
Iron	30,100	23,000	RBC-N	1 / 57 / 57	SB48A
Mercury	184	7.8	RBC-N*	5 / 41 / 52	SB18A, SB20A, SB41A, SB48A, SB53A
N-Nitroso-di-n-propylamine	2.8	0.091	RBC-C	2 / 2 / 43	SB36A, SB56A
Phenanthrene	29.0	--	none	-- / 18 / 42	(SB28A)

Notes:

Location of maximum detection in bold. If there were no exceedances, maximum location is given in parentheses.

* RBC for methylmercury

** A total of 57 samples were collected and analyzed for inorganics and a total of 43 samples were collected and analyzed for all other analytes. Some samples were rejected for quality control reasons.

C-EMEG-child = Environmental Media Evaluation Guide for Chronic exposure to a child

RBC = USEPA Region III Risk-Based Concentration (C = Carcinogenic, N = Non-carcinogenic)

Table SS2. Radionuclides Detected in Surface Soil in OU I

Isotope	*Maximum Concentration (pCi/g)*	*Average Concentration* (pCi/g)*	*Detections / Samples***	*Location of Maximum*
Actinium-228	2.9	1.2	21/59	CP0801
Americium-241	4.5	1	6/58	SB36A
Bismuth-214	2.2	0.86	28/59	CP0801
Cesium-137	810,000	36,000	50/59	SB37A
Cobalt-60	6.5	1.6	10/59	SB50A
Gross alpha	110	19	59/59	SB44A
Gross beta	1,100,000	42,000	59/59	SB37A
Lead-210	16	5	4/59	455Comp
Lead-212	1.7	0.8	40/59	CA0201
Lead-214	2	0.93	28/59	CP1001
Potassium-40	12	10.9	51/59	SB35A
Strontium-90	1,300	74	59/59	SB37A
Thallium-208	1.6	0.89	24/59	CA0101
Thorium-234	1.48	1.1	2/59	SB58E
Tritium	14	1.4	59/59	SB20A
Uranium-235	0.08	0.08	1/58	CP0101
Sieved Soil				
Cesium-137	44,000,000	3,500,000	16/16	SB37A-C
Gross alpha	450	70	16/16	SB36A-C
Gross beta	32,000,000	3,000,000	16/16	SB37A-C
Strontium-90	5,600	5,700	15/15	SB37A-C

* The average concentration is a representative value for the contaminated areas of the operable unit. This average does not represent an average concentration for the whole operable unit. Nondetected values were not included in the average concentration.

** A total of 59 surface soil and 16 sieved soil samples were collected. Some samples were rejected for quality control reasons.

Table SS3. Surface Soil Contaminants in OU III

Chemical	*Maximum Concentration (mg/kg)*	*Comparison Value (mg/kg)*	*Type*	*Exceedances /Detections/Samples**	*Locations of Exceedances*
Arsenic	8.1	0.43	RBC-C	7 / 7 / 7	HPB01, HPB02, MN02, MN03, SB01, SB02, SB03
Iron	43,600	23,000	RBC-N	7 / 7 / 7	HPB01, HPB02, MN02, MN03, SB01, SB02, SB03
Benzo(a)pyrene	0.26	0.087	RBC-C	2 / 4 / 5	MN02, MN03
Benzo(g,h,i)perylene	0.15	--	none	-- / 2 / 5	(MN02)
Phenanthrene	0.048	--	none	-- / 1 / 5	(SB01)

Notes:

* PCB/Pesticides were only analyzed for in 5 of the 7 of the surface soil samples.

Location of maximum detection in bold. If there were no exceedances, maximum location is given in parentheses.

RBC = USEPA Region III Risk-Based Concentration (C = Carcinogenic, N = Non-carcinogenic)

Table SS4. Radionuclides Detected in Surface Soil in OU III

Isotope	*Maximum Concentration (pCi/g)*	*Average Concentration * (pCi/g)*	*Detections / Samples***	*Location of Maximum*
Bismuth-212	0.6	0.49	3 / 3	SB02
Bismuth-214	0.5	0.39	5 / 5	MN03
Cesium-137	67.6	26.1	5 / 5	SB03
Cobalt-60	3.06	2.11	3 / 3	SB02
Gross alpha	9.97	9.97	1 / 5	MN02
Gross beta	62.4	33.3	4 / 5	SB03
Lead-210	1.95	1.51	3 / 3	SB02
Lead-212	0.63	0.56	5 / 5	MN02
Lead-214	0.59	0.49	5 / 5	SB02
Potassium-40	6.09	5.36	5 / 5	SB01
Radium-224	1.77	1.49	2 / 2	MN02
Radium-226	0.52	0.43	5 / 5	SB02
Radium-228	0.61	0.59	4 / 4	MN03
Strontium-90	0.94	0.94	1 / 5	MN02
Thallium-208	0.27	0.21	5 / 5	SB03
Thorium-228	0.28	0.22	3 / 3	SB01
Thorium-232	0.25	0.22	3 / 3	SB02
Thorium-234	0.6	0.60	1 / 1	MN02

Tritium	0.1	0.069	5 / 5	SB02

* The average concentration is a representative value for the contaminated areas of the operable unit. This average does not represent an average concentration for the whole operable unit. Nondetected values were not included in the average concentration.

** A total of 5 samples were collected and analyzed for radionuclides. Not all radionuclides were analyzed for in each sample collected.

Table SS5. Surface Soil Contaminants in OU IV

Chemical	*Maximum Concentration (mg/kg)*	*Comparison Value (mg/kg)*	*Type*	*Exceedances /Detections/ Samples**	*Locations of Exceedances*
Arsenic	5.7	0.43	RBC-C	20 / 20 / 20	SB13, SB33, SB35, SB36, SB37, SB38, SB39, SB40, SB41, SB42, SB43, SB45, SB46, SB47, SB48, SB49, SB59, SB60, 7703, 7629
Benzo(a)anthrene	1.8	0.87	RBC-C	4 / 7 / 36	SB09, SB45, SB46, SB49
Benzo(b)fluoranthrene	3.3	0.87	RBC-C	5 / 8 / 36	SB09, SB18, SB45, SB46, SB49
Benzo(a)pyrene	1.9	0.087	RBC-C	7 / 7 / 36	SB09, SB18, SB36, SB37, SB45, SB46, SB49
Benzo(g,h,i)perylene	1.1	none	--	-- / 3 / 36	(SB46)
Indeno(1,2,3-cd)pyrene	1.3	0.87	RBC-C	1 / 3 / 36	SB46
Phenanthrene	2.2	none	--	-- / 5 / 36	(SB09)
Trichloroethylene	0.02	none	--	-- / 1 / 36	(SB38)

Notes:

Location of maximum detection in bold. If there were no exceedances, maximum location is given in parentheses.

RBC = USEPA Region III Risk-Based Concentration (C = Carcinogenic, N = Non-carcinogenic)

* A total of 36 surface soil samples were collected, only 20 samples were analyzed for arsenic.

Table SS6. Radionuclides Detected in Surface Soil in OU IV

Isotope	*Maximum Concentration (pCi/g)*	*Average Concentration* (pCi/g)*	*Detections / Samples*	*Location of Maximum*
Cesium-137	89	18.5	12/16	SB48
Cobalt-60	6.5	1.61	7/16	SB34
Gross alpha	170	25.7	16/16	SB45
Gross beta	73	26.8	16/16	SB45
Sodium-22	0.69	0.49	3/16	SB47
Strontium-90	9.8	2.32	16/16	SB49

Tritium	0.077	-0.0039**	16/16	SB41

* The average concentration is a representative value for the contaminated areas of the operable unit. This average does not represent an average concentration for the whole operable unit. Nondetected values were not included in the average concentration.

**No explanation is provided in the site-related documents regarding this negative concentration.

Table SS7. Surface Soil Contaminants in OU V

Chemical	*Maximum Concentration (mg/kg)*	*Comparison Value (mg/kg)*	*Type*	*Exceedances/ Detections/ Samples*	*Locations of Exceedances*
Aroclor-1254	1.5	1	CV(C-EMEG-child)	2 / 26 / 37	B1-06, B1-08
Aroclor-1260	0.38	0.32	RBC-C	1 / 20 / 37	B1-06
Benzo(a)anthracene	3.2	0.87	RBC-C	1 / 6 / 37	B1-01
Benzo(a)pyrene	0.57	0.087	RBC-C	1 / 4 / 37	B1-01
Benzo(b)fluoranthene	3.3	0.87	RBC-C	1 / 11 / 37	B1-01
Mercury	15.1	7.8	RBC-N*	3 / 31 / 37	A-01, B1-06, B1-08
Phenanthrene	0.77	--	none	-- / 5 / 37	(B1-01)

Notes:

Location of maximum detection in bold. If there were no exceedances, maximum location is given in parentheses.

* RBC for methylmercury

C-EMEG-child = Environmental Media Evaluation Guide for Chronic exposure to a child

RBC = USEPA Region III Risk-Based Concentration (C = Carcinogenic, N = Non-carcinogenic)

Table SS8. Radionuclides Detected in Surface Soil in OU V

Isotope	*Maximum Concentration (pCi/g)*	*Average Concentration * (pCi/g)*	*Detections / Samples***	*Location of Maximum*
Americium-241	5.41	1.31	18 / 18	B-SB03-SB01
Bismuth-212	1.23	1.23	1 / 1	B1-SB16
Bismuth-214	0.35	0.32	2 / 2	B1-GP04
Cesium-137	98.8	9.81	58 / 60	B1-SB07
Cobalt-57	0.069	0.069	1 / 1	B -GP13
Cobalt-60	0.25	0.25	1 / 1	B-GP13
Lead-210	2.7	1.56	3 / 3	B-GP08
Lead-212	0.75	0.39	46 / 46	B1-SB05

Isotope	*Maximum Concentration (pCi/g)*	*Average Concentration * (pCi/g)*	*Detections / Samples***	*Location of Maximum*
Lead-214	0.63	0.34	30 / 30	C1-GP01
Potassium-40	6.33	3.41	55 / 55	B1-SB05
Radium-224	5.83	2.68	3 / 3	B-GP09
Radium-226	0.63	0.32	21 / 21	C1-GP01
Radium-228	0.51	0.49	3 / 3	B-GP04
Strontium-89	6.85	1.21	14 / 60	B-GP07
Strontium-90	1.47	0.47	17 / 60	B-SB03-SB01
Thallium-208	0.31	0.18	24 / 27	B1-SB05
Thorium-228	3.63	3.63	1 / 1	B-GP15
Thorium-234	2.35	1.54	6 / 6	B1-SB13
Tritium	0.25	0.093	11 / 60	D-GP03
Uranium-234	1.49	0.86	3 / 3	A-GP01
Uranium-238	0.72	0.51	3 / 3	A-GP01

* The average concentration is a representative value for the contaminated areas of the operable unit. This average does not represent an average concentration for the whole operable unit. Nondetected values were not included in the average concentration.

** A total of 60 samples were collected. Some samples were rejected for quality control reasons.

Table SS9. Surface Soil Contaminants in OU VI

Chemical	*Maximum Concentration (mg/kg)*	*Comparison Value (mg/kg)*	*Type*	*Exceedances/ Detections/ Samples*	*Locations of Exceedances*
Benzo(a)pyrene	0.13	0.087	RBC-C	1 / 3 / 35	SB-72A
Benzo(g,h,i)perylene	0.076	--	none	-- / 3 / 35	(SB-72A)
Phenanthrene	0.062	--	none	-- / 2 / 35	(SB-72)

Notes:

Location of maximum detection in bold. If there were no exceedances, maximum location is given in parentheses.

* RBC for methylmercury

RBC = USEPA Region III Risk-Based Concentration (C = Carcinogenic, N = Non-carcinogenic)

Table SS10. Radionuclides Detected in Surface Soil in OU VI

Isotope	*Maximum Concentration (pCi/g)*	*Average Concentration * (pCi/g)*	*Detections / Samples*	*Location of Maximum*
Actinium-228	1.60	0.82	26/35	SB80C
Bismuth-214	0.92	0.58	28/35	SB95A
Cesium-137	0.92	0.35	24/35	SB85A
Gross alpha	22.00	10.20	35/35	SB74A
Gross beta	28.00	14.04	35/35	SB80A
Lead-210	2.60	1.60	3/35	SB85A
Lead-212	1.30	0.70	35/35	SB85A
Lead-214	1.10	0.62	34/35	SB96A
Potassium-40	12.00	6.62	34/35	SB76A
Strontium-90	11.00	-0.15**	35/35	SB95A
Thallium-208	1.30	0.79	31/35	SB96A
Thorium-234	4.40	1.99	3/35	SB76A
Tritium	0.14	-0.03**	35/35	SB82A
Uranium-235	0.23	0.14	7/35	SB91C

* The average concentration is a representative value for the contaminated areas of the operable unit. This average does not represent an average concentration for the whole operable unit. Nondetected values were not included in the average concentration.

**No explanation is provided in the site-related documents to explain this negative concentration.

Table SS11. Radionuclides Detected in Surface Soil from Off-Site Areas

Isotope	*Maximum Concentration (pCi/g)*	*Average Concentration * (pCi/g)*	*Detections / Samples*	*Location of Maximum*
Actinium-228	2.24	1.10	9/10	Glover=s Farm
Bismuth-214	1.73	1.06	9/10	Glover=s Farm
Cesium-137	0.44	0.19	8/10	NYS Farm
Lead-212	2.29	1.02	10/10	Glover=s Farm
Lead-214	2.03	1.03	10/10	Glover=s Farm
Potassium-40	11.82	7.45	10/10	Glover=s Farm
Thallium-208	0.76	0.38	10/10	Glover=s Farm
Thorium-232	2.13	1.13	8/10	Glover=s Farm

* This average does not represent an average concentration for the entire BNL surrounding areas. Nondetected values were not included in the average concentration.

Table SW1. STP Discharges (Outfall 001) : 1989B1999

Refer to notes at the end of the table for information on assumptions and selection of health-based comparison values (CVs)

Analyte	*Highest Concentration*	*CV*	*Type of CV*	*Date of maximum*	*Number of samples greater than CV/Number of samples*	*Average Concentration (if highest concentration is above CV)*
1,1,1-Trichloroethane	80 ppb	200 ppb	LTHA	4/30/91	0/130	--
1,2-Dichloroethane	ND	5 ppb	MCL	NA	0/18	--
2-Butanone	5 ppb	6,000 ppb	RMEG-c	8/31/95	0/57	--
Bis(2-Ethylhexyl)Phthalate	14 ppb	100 ppb	EMEG-ic	3/31/99	0/36	--
Bromodichloromethane	ND	200 ppb	RMEG-c	NA	0/18	--
Chlorine, Total	450 ppb	1,000 ppb	RMEG-c	3/31/93	0/126	--
Chloroform	ND	80 ppb	MCL	--	0/18	--
Chromium, Total	413 ppb	100 ppb	LTHA	3/31/99	2/18	53.5 ppb
Copper, Total	2,080 ppb	5,000 ppb	IOM TUIL	3/31/99	0/149	--
Cyanide, Total	20 ppb	200 ppb	RMEG-c	3/31/96	0/92	--
Di-N-butyl phthalate	7 ppb	1,000 ppb	RMEG-c	9/30/97	0/36	--
Iron, Total	15,700 ppb	22,500 ppb	IOM TUIL	3/31/99	0/149	--
Lead, Total	32 ppb	15 ppb	EAL	3/31/90	1/131	7.4 ppb
Manganese, Total	141 ppb	500 ppb	RMEG-c	3/31/99	0/18	--
Mercury, Total	3 ppb	2 ppb	MCL	2/28/99	1/26	0.31 ppb
Methylene chloride	44 ppb	5 ppb	MCL	12/31/95	10/57	4.17 ppb
Nickel, Total	234 ppb	100 ppb	LTHA	3/31/99	2/75	8.04 ppb
Polychlorinated biphenyls	ND	0.5 ppb	MCL	--	0/1	--
Propylene glycol monobutyl ether	1,500 ppb	NA	NA	3/31/98	NA/14	--
Radioactivity	56.3 pCi/L	50.0 pCi/L	SDWA	1/31/89	1/74	15.7 pCi/L

Analyte	***Highest Concentration***	***CV***	***Type of CV***	***Date of maximum***	***Number of samples greater than CV/Number of samples***	***Average Concentration (if highest concentration is above CV)***
Radium-226, Total	3 pCi/L	60 pCi/L	ALI	10/31/94	0/72	--
Silver, Total	713 ppb	50 ppb	RMEG-c	9/30/96	7/166	12.8 ppb
Strontium-90, Total	9.3 pCi/L	500 pCi/L	ALI	1/31/89	0/30	--
Tetrachloroethylene	ND	5 ppb	MCL	--	0/18	--
Toluene	2	200 ppb	EMEG-ic	4/30/97	0/57	--
Tritium, Total	28,900 pCi/L	20,000 pCi/L	SDWA	9/30/92	1/72	6,8400 pCi/L
Zinc, Total	1,160 ppb	2,000 ppb	LTHA	3/31/99	0/149	--

Notes:

Source of data: NYSDEC discharge monitoring data on file.

NA = Not applicable. No date of maximum is listed for contaminants that were never detected in the discharge from outfall 001.

ND = Nondetect. For contaminants not detected in any discharge samples, the maximum concentration is listed as AND@. Nondetects were replaced with concentrations equal to one-half the detection limit to compute average concentrations.

The number of samples varies from contaminant to contaminant primarily because the frequency of sampling required by the SPDES permit also varies from contaminant to contaminant.

Data are not presented for general water quality indicators (e.g., temperature, pH, alkalinity, concentrations of nitrogen, phosphorous, and oil and grease, etc.) or for contaminants that do not have comparison values.

The NYSDEC data does not specify what is meant by Aradioactivity.@ Review of the site environmental reports indicates that gross beta accounts for a much larger portion of the detectable radiation than gross alpha. Thus, the comparison value for gross beta radiation is used here.

All data shown are from the STP discharge (outfall 001). Frequent exposure to the water at this location, whether by ingestion or dermal contact, is not expected to occur. Nonetheless, comparison values that assume people drink the water in the STP discharge were used to examine the health implications of whether these waters are used as a drinking water supply. The following types of comparison values are used in the table:

LTHA	ATSDR Lifetime Health Advisory for drinking water
RMEG-c	ATSDR Reference Dose Media Evaluation Guide for children’s exposure
EMEG-ic	ATSDR Environmental Media Evaluation Guide, for children’s exposure of intermediate duration
IOM TUIL	Institute of Medicine’s Tolerable Upper Intake Level
EAL	USEPA action level for lead in drinking water
MCL	USEPA Maximum Contaminant Level
SDWA	Safe Drinking Water Act level
ALI	Annual Limit on Intake

Contaminants shown in bold font have at least one concentration higher than the corresponding health-based comparison value.

These concentrations would require further evaluation if people were using the effluent from the treatment plant as a water supply. However, exposures to this water are believed to be extremely infrequent, and the periodic elevated concentrations are not believed to be associated with adverse health effects.

The comparison value for hexavalent chromium is used in this table, even though the measurements were for total chromium.

Table SW2. Radiological Contamination in the STP Discharge (Outfall 001): 1977B1999

Contaminant	***Annual Average Data***		***Short-Term Peak Data***		***Screening Values***	
	Highest Concentration(pCi/L)	Year Highest Level Occurred	Highest Concentration (pCi/L)	Year Highest Level Occurred	Magnitude of Screening Value (pCi/L)	Type of Screening Value
Data for radiological contaminants other than for radionuclides						
Gross alpha	2.48	1982	12.34	1993	15	SDWA
Gross beta	28.5	1979	94.2	1989	50	SDWA
Tritium	4,650	1988	67,300 (±1,570)	1997	20,000	SDWA
Data for radionuclides in order of increasing atomic number						
Beryllium-7	3.04	1977	19.13	1977	600,000	ALI
Sodium-22	2.54	1978	31.76	1977	6,000	ALI
Potassium-40	3.78	1982	15.86	1991	4,000	ALI
Chromium-51	0.25	1985	1.00	1985	500,000	ALI
Manganese-54	0.67	1977	1.63	1978	30,000	ALI
Cobalt-57	0.09	1979	0.81	1995	60,000	ALI
Cobalt-58	0.04	1995	0.4	1995	20,000	ALI
Cobalt-60	0.68	1982	1.5	1984	3,000	ALI
Zinc-65	0.65	1981	0.9	1983	5,000	ALI
Rubidium-83	0.26	1983	1.1	1983	9,000	ALI
Rubidium-84	0.12	1983	0.57	1983	7,000	ALI
Strontium-90	3.89	1988	18.6	1988	500	ALI
Iodine-131	1.69	1980	5.1	1984	1,000	ALI
Cesium-134	2.57	1977	6.137	1977	8,000	ALI
Cesium-137	15.57	1989	29.3	1989	700,000	ALI
Cerium-141	0.016	1986	0.115	1986	30,000	ALI
Radium-226	ND	1988	ND	1988	60	ALI

Notes:

Source of data: BNL=s annual Site Environmental Reports, 1977B1999. These reports present summary statistics only and do not contain raw data.

ND = Non detect

Sampling data in this table are from the effluent of the sewage treatment plant. Frequent exposure to the water at this location, whether by ingestion or dermal contact, is not expected to occur. Nonetheless, comparison values that assume people drink the water in the STP discharge were used to examine the health implications of whether these waters are used as a drinking water supply. Contaminants in bold font have at least one measured concentration higher than the corresponding health-based comparison value. The following types of comparison values are used in the table:

ALI	Annual Limit on Intake

SDWA Safe Drinking Water Act

Data presented were collected in the outfall of the STP, which the Site Environmental Reports refer to as sampling location AEA@ or output from the AChlorine House.@

The Site Environmental Reports did not use consistent reporting practices throughout the time frame considered. For instance, some radionuclides have sampling data documented in almost every Site Environmental Report, while other radionuclides have sampling data documented in just one or a few reports. Additionally, the names of parameters reported changed over the site=s history (e.g., BNL reported concentrations of hydrogen-3 from 1977 to 1985, but instead reported concentrations of tritium in the following years; even though these analytes are synonymous). Finally, the descriptive statistics used to summarize the data varied from year to year, and from contaminant to contaminant. For instance, the short-term peak data represent different statistics for different contaminants. For most of the radionuclides listed, the short-term peak data are the highest monthly-average concentration reported. For gross alpha, gross beta, and tritium, however, the short-term peak data are the highest measured concentration (which presumably are 24-hour average results).

BNL did not report measurement uncertainty for any of the discharge monitoring data until 1996. Therefore, uncertainty bounds are presented only for those contaminants with highest concentrations occurring between 1996 and 1999.

As stated above, BNL reported concentrations of hydrogen-3 from 1977 to 1985, and then reported concentrations of tritium from 1986 to 1999. All these sampling records were pooled and are summarized in the field labeled tritium.

Table SW3. Contaminants Measured in On-site Recharge Basins and Wetlands

Refer to notes at the end of the table for information on assumptions and selection of health-based comparison values (CVs).

Contaminant	***Sampling Data***			***Screening Values***	
	Highest Concentration Reported	*Year Concentration Measured*	*Sampling Location*	*Magnitude of Screening Value*	*Type of Screening Value*
Data for inorganic contaminants other than for radionuclides					
Aluminum	38,600 ppb	1994	OUI wetland	20,000 ppb	EMEG-ic
Antimony	25.8 ppb	1999	ACSF@ basin	4 ppb	RMEG-c
Arsenic	8.7 ppb	1994	OUI wetland	3 ppb	RMEG-c
Barium	676.3 ppb	1998	ABMRR@ basin	700 ppb	RMEG-c
Beryllium	1.2 ppb	1994	OUI wetland	4 ppb	MCL
Cadmium	1,520 ppb	1979	AHU@ basin	2 ppb	EMEG-cc
Chromium	8,100 ppb	1979	AHU@ basin	100 ppb	MCL
Cobalt	18.7 ppb	1994	OUI wetland	2,200 ppb	RBC-n
Copper	16,100 ppb	1979	AHU@ basin	5,000 ppb	IOM TUIL
Lead	5,320 ppb	1979	AHU@ basin	15 ppb	EAL
Manganese	1,410 ppb	1994	OUI wetland	500 ppb	RMEG-c

Mercury	0.37 ppb	1998	AHW@ basin	2 ppb	LTHA
Molybdenum	10 ppb	1999	AHW@ basin	40 ppb	LTHA
Nickel	131 ppb	1999	ACSF@ basin	100 ppb	LTHA
Selenium	33.4 ppb	1998	AHO@ basin	50 ppb	EMEG-cc
Silver	70 ppb	1992	AHX@ basin	50 ppb	RMEG-c
Vanadium	342.4 ppb	1999	ACSF@ basin	30 ppb	EMEG-ic

Contaminant	***Sampling Data***				***Screening Values***
	Highest Concentration Reported	*Year Concentration Measured*	*Sampling Location*	*Magnitude of Screening Value*	*Type of Screening Value*
Zinc	95,600 ppb	1979	AHU@ basin	2,000 ppb	LTHA
Data for radiological contamination other than for radionuclides					
Gross alpha	38 (± 13) pCi/L	1994	OUI wetland	15 pCi/L	SDWA
Gross beta	1,858 pCi/L	1979	AHT@ basin	50 pCi/L	SDWA
Tritium	25,590 pCi/L	1979	AHT@ basin	20,000 pCi/L	SDWA
Data for radionuclides in order of increasing atomic number					
Beryllium-7	299 pCi/L	1990	AHN@ basin	600,000 pCi/L	ALI
Sodium-22	3.56 pCi/L	1988	AHN@ basin	6,000 pCi/L	ALI
Sodium-24	182 pCi/L	1998	AHN@ basin	50,000 pCi/L	ALI
Potassium-40	240 (±230) pCi/L	1994	AHS@ basin	4,000 pCi/L	ALI
Vanadium-48	10.5 pCi/L	1995	AHN@ basin	9,000 pCi/L	ALI
Chromium-51	50.1 pCi/L	1995	AHN@ basin	500,000 pCi/L	ALI
Manganese-52	14.7 pCi/L	1990	AHN@ basin	10,000 pCi/L	ALI
Manganese-54	9.59 pCi/L	1991	AHN@ basin	30,000 pCi/L	ALI
Manganese-56	0.16 pCi/L	1985	AHN@ basin	70,000 pCi/L	ALI
Cobalt-56	1.2 (± 0.7) pCi/L	1996	AHN@ basin	6,000 pCi/L	ALI
Cobalt-57	1.26 pCi/L	1990	AHN@ basin	60,000 pCi/L	ALI
Cobalt-58	3.78 pCi/L	1990	AHN@ basin	20,000 pCi/L	ALI
Cobalt-60	17.3 pCi/L	1995	AHN@ basin	3,000 pCi/L	ALI
Zinc-65	3.85 pCi/L	1995	AHN@ basin	5,000 pCi/L	ALI
Strontium-90	11 (± 1) pCi/L	1994	OUI wetland	500 pCi/L	ALI
Cesium-137	44 (± 15) pCi/L	1994	OUI wetland	700,000 pCi/L	ALI
Bismuth-214	58 (± 32) pCi/L	1994	OUI wetland	300,000 pCi/L	ALI
Lead-214	48 (± 28) pCi/L	1994	OUI wetland	100,000 pCi/L	ALI
Thorium-234	147.5 (± 500) pCi/L	1994	OUI wetland	30 pCi/L	ALI

Notes:

Source of data: BNL=s annual Site Environmental Reports, 1977B1999; BNL=s Remedial Investigation reports. Because some of these reports only present summary statistics and not the raw sampling data, average concentrations cannot be calculated.

Data presented were collected in onsite recharge basins and wetlands; data presented only for those contaminants that were detected.

Sampling data in this table are for onsite recharge basins and wetlands, which have extremely restricted access. As a result, frequent exposure to the water at this location, whether by ingestion or dermal contact, is not expected to occur. Nonetheless, comparison values that assume people drink the water at these locations were used to examine the health implications of whether these waters are used as a drinking water supply. Contaminants in bold font have at least one measured concentration higher than the corresponding health-based comparison value. The following types of comparison values are used in the table:

LTHA	ATSDR Lifetime Health Advisory for drinking water
RMEG-c	ATSDR Reference Dose Media Evaluation Guide for children=s exposure
EMEG-ic	ATSDR Environmental Media Evaluation Guide, for children=s exposure of intermediate duration
IOM TUIL	Institute of Medicine=s Tolerable Upper Intake Level
EAL	USEPA action level for lead in drinking water
MCL	USEPA Maximum Contaminant Level
SDWA	Safe Drinking Water Act level
ALI	Annual Limit on Intake

The analytes considered in the recharge basin sampling apparently changed from year to year. For instance, concentrations of molybdenum were apparently not measured until the late 1990s.

BNL did not report measurement uncertainty in many of the Site Environmental Reports. Therefore, uncertainty bounds are not presented for all analytes..

The health-based comparison value for Ahexavalent chromium@ is used to screen concentrations of chromium; the health-based comparison value for Ainorganic mercury@ is used to screen concentrations of mercury; and the ALI for thorium-232 is used to screen concentrations of thorium-234 (because no ALI has been published for thorium-234).

The highest concentrations of cadmium, chromium, copper, iron, lead, and zinc are outliers, and all from a single sample collected in 1979. The second highest concentrations of these analytes are considerably lower.

As the text of the memo describes, exposure to the levels of contamination shown in this table is not expected to occur.

Table SW4. Contaminants Measured in On-site Sections of the Peconic River

Refer to notes at the end of the table for information on assumptions and selection of health-based comparison values (CVs).

Contaminant	***Sampling Data***			***Screening Values***	
	Highest Concentration Reported	Year Concentration Measured	Sampling Location	Magnitude of Screening Value	Type of Screening Value
Data for inorganic contaminants other than for radionuclides					
Aluminum	1,503 ppb	1999	Former site boundary	20,000 ppb	EMEG-ic
Antimony	7.74 ppb	1999	Downstream from STP	4 ppb	RMEG-c
Arsenic	2 ppb	1995	Downstream from STP	3 ppb	RMEG-c
Barium	86.8 ppb	1998	Upstream of STP	700 ppb	RMEG-c
Beryllium	0.63 ppb	1995	Downstream from STP	4 ppb	MCL
Cadmium	3 ppb	1983	Former site boundary	5 ppb	MCL
Contaminant	***Sampling Data***			***Screening Values***	
	Highest Concentration Reported	*Year Concentration Measured*	*Sampling Location*	*Magnitude of Screening Value*	*Type of Screening Value*
Chromium	25 ppb	1987	Former site boundary	30 ppb	RMEG-c
Cobalt	15.3 ppb	1998	Upstream of STP	2,200 ppb	RBC-n
Copper	400 ppb	1987	Former site boundary	5,000 ppb	IOM TUIL
Lead	219 ppb	1979	Former site boundary	15 ppb	EAL
Manganese	514 ppb	1998	Upstream of STP	500 ppb	RMEG-c
Mercury	9 ppb	1989	Former site boundary	2 ppb	LTHA
Nickel	28.7 ppb	1995	Downstream from STP	100 ppb	LTHA
Silver	25 ppb	1996	Site boundary	50 ppb	RMEG-c
Thallium	5.2 ppb	1995	Downstream from STP	0.5	LTHA
Vanadium	17.8 ppb	1995	Downstream from STP	30 ppb	EMEG-ic
Zinc	300 ppb	1997	Former site	2,000 ppb	LTHA

			boundary		
Data for radiological contamination other than for radionuclides					
Gross alpha	21.7 pCi/L	1999	Former site boundary	15 pCi/L	SDWA
Gross beta	132 pCi/L	1986	Former site boundary	50 pCi/L	SDWA
Tritium	37,578 pCi/L	1977	Former site boundary	20,000 pCi/L	SDWA
Data for radionuclides in order of increasing atomic number					
Beryllium-7	42.3 pCi/L	1977	Former site boundary	600,000 pCi/L	ALI
Sodium-22	29.67 pCi/L	1977	Former site boundary	6,000 pCi/L	ALI
Potassium-40	30.9 pCi/L	1990	Former site boundary	4,000 pCi/L	ALI
Chromium-51	0.95 pCi/L	1985	Former site boundary	500,000 pCi/L	ALI
Manganese-54	1.51 pCi/L	1977	Former site boundary	30,000 pCi/L	ALI
Cobalt-57	0.23 pCi/L	1986	Former site boundary	60,000 pCi/L	ALI
Contaminant	***Sampling Data***			***Screening Values***	
	Highest Concentration Reported	*Year Concentration Measured*	*Sampling Location*	*Magnitude of Screening Value*	*Type of Screening Value*
Cobalt-58	0.06 pCi/L	1984	Former site boundary	20,000 pCi/L	ALI
Cobalt-60	6.49 pCi/L	1977	Former site boundary	3,000 pCi/L	ALI
Zinc-65	0.95 pCi/L	1984	Site boundary	5,000 pCi/L	ALI
Rubidium-83	1.4 pCi/L	1983	Former site boundary	9,000 pCi/L	ALI
Rubidium-84	0.047 pCi/L	1983	Site boundary	7,000 pCi/L	ALI
Strontium-89	1.03 pCi/L	1995	Downstream from STP	8,000 pCi/L	ALI
Strontium-90	19.78 pCi/L	1977	Former site boundary	500 pCi/L	ALI
Iodine-131	1.69 pCi/L	1980	Former site boundary	1,000 pCi/L	ALI
Cesium-134	4.396 pCi/L	1977	Former site boundary	900 pCi/L	ALI
Cesium-137	64.6 pCi/L	1989	Former site boundary	700,000 pCi/L	ALI
Europium-152	37.1 pCi/L	1997	Downstream from STP	10,000 pCi/L	ALI

Radium-226	0.27 pCi/L	1986	Former site boundary	60 pCi/L	ALI
Uranium-233/234	0.028 pCi/L	1999	Downstream from STP	300 pCi/L	ALI
Uranium-238	0.062 pCi/L	1999	Downstream from STP	300 pCi/L	ALI
Americium-241	0.058 pCi/L	1999	Downstream from STP	20 pCi/L	ALI

Notes:

Source of data: BNL=s annual Site Environmental Reports, 1977B1999; BNL=s Remedial Investigation and Plutonium Characterization reports.

BNL reported for different analytes from one year to the next: some analytes shown (e.g., tritium) have been sampled extensively for every year with data on record, while other analytes (e.g., europium-152) have been analyzed only in a few samples.

In the Site Environmental Reports from the 1970s, BNL reported activities of radionuclides, rather than reporting concentrations. ERG calculated the concentrations for these data points from the activities and the reported river flow rates.

Data presented only for those contaminants that were detected.

Sampling data in this table are for onsite sections of the Peconic River, which has restricted access and limited or now flow during periods of dry weather. As a result, frequent exposure to the water at this location, whether by ingestion or dermal contact, is not expected to occur. Nonetheless, comparison values that assume people drink the water in the onsite sections of the Peconic River were used to examine the health implications of whether these waters are used as a drinking water supply. Contaminants in bold font have at least one measured concentration higher than the corresponding health-based comparison value. The following types of comparison values are used in the table:

LTHA	ATSDR Lifetime Health Advisory for drinking water
RMEG-c	ATSDR Reference Dose Media Evaluation Guide for children=s exposure
EMEG-ic	ATSDR Environmental Media Evaluation Guide, for children=s exposure of intermediate duration
IOM TUIL	Institute of Medicine=s Tolerable Upper Intake Level
EAL	USEPA action level for lead in drinking water
MCL	USEPA Maximum Contaminant Level
SDWA	Safe Drinking Water Act level
ALI	Annual Limit on Intake

The health-based comparison value for Ahexavalent chromium@ is used to screen concentrations of chromium; the health-based comparison value for Ainorganic mercury@ is used to screen concentrations of mercury; and the ALI for thorium-232 is used to screen concentrations of thorium-234 (because no ALI has been published for thorium-234).

Table SW5. Contaminants Measured in Off-site Sections of the Peconic River

Refer to notes at the end of the table for information on assumptions and selection of health-based comparison values (CVs).

Contaminant	***Sampling Data***			***Screening Values***	
	Highest Concentration Reported	Year Concentration Measured	Sampling Location	Magnitude of Screening Value	Type of Screening Value
Data for inorganic contaminants other than for radionuclides					
Aluminum	515 ppb	1998	Riverhead	20,000 ppb	EMEG-ic
Antimony	3.14 ppb	1999	Schultz Road	4 ppb	RMEG-c
Arsenic	4.2 ppb	1999	Wading River	3 ppb	RMEG-c
Barium	48.1 ppb	1998	Wading River	700 ppb	RMEG-c
Beryllium	0.7 ppb	1995	<1 Mile from Boundary	4 ppb	MCL
Cadmium	2.5 ppb	1977	Calverton	2 ppb	EMEG-cc
Chromium	28 ppb	1979	Schultz Road	30 ppb	RMEG-c
Cobalt	7 ppb	1995	<1 Mile from Boundary	2,200 ppb	RBC-n
Copper	195.1 ppb	1998	Schultz Road	5,000 ppb	IOM TUIL
Lead	17 ppb	1979	Schultz Road	15 ppb	EAL
Manganese	731 ppb	1995	<1 Mile from Boundary	500 ppb	RMEG-c
Mercury	0.31 ppb	1994	Manorville	2 ppb	LTHA
Molybdenum	10 ppb	1999	Schultz Road	40 ppb	LTHA
Nickel	14 ppb	1995	<1 Mile from Boundary	100 ppb	LTHA
Silver	3 ppb	1977	Riverhead	50 ppb	RMEG-c
Thallium	4.8 ppb	1995	<1 Mile from Boundary	0.8	RMEG-c
Vanadium	9.8 ppb	1995	<1 Mile from Boundary	30 ppb	EMEG-ic
Zinc	391 ppb	1995	<1 Mile from Boundary	2,000 ppb	LTHA
Contaminant	***Sampling Data***			***Screening Values***	
	Highest Concentration Reported	*Year Concentration Measured*	*Sampling Location*	*Magnitude of Screening Value*	*Type of Screening Value*
Data for radiological contamination other than for radionuclides					
Gross alpha	45.3 pCi/L	1995	Riverhead	15 pCi/L	SDWA
Gross beta	130 pCi/L	1992	Manorville	50 pCi/L	SDWA
Tritium	24,900 pCi/L	1976	Manorville	20,000 pCi/L	SDWA
Data for radionuclides in order of increasing atomic number					
Beryllium-7	9.13 pCi/L	1991	Wading River	600,000 pCi/L	ALI
Sodium-22	0.16 pCi/L	1989	Schultz Road	6,000 pCi/L	ALI
Potassium-40	6.2 pCi/L	1990	Schultz Road	4,000 pCi/L	ALI
Manganese-54	0.14 pCi/L	1990	Riverhead	30,000 pCi/L	ALI

Cobalt-60	1.67 pCi/L	1989	Manorville	3,000 pCi/L	ALI
Strontium-90	14 pCi/L	1974	Manorville	500 pCi/L	ALI
Cesium-137	19 pCi/L	1992	Manorville	700,000 pCi/L	ALI
Uranium-238	0.044 pCi/L	1999	Grangable Park	300 pCi/L	ALI

Notes:

Source of data: BNL=s annual Site Environmental Reports, 1977B1999; BNL=s Remedial Investigation and Plutonium Characterization reports (IT, 1998; IT, 2000); NYSDOH=s Peconic River sampling data (NYSDOH, 1996). Some of these reports present only summary statistics and do not include raw data. Therefore, average concentrations for the contaminants listed cannot be calculated.

Contaminants in bold font have at least one measured concentration higher than the corresponding health-based comparison value.

BNL reported for different analytes from one year to the next: some analytes shown (e.g., tritium) have been sampled extensively for every year with data on records, while other analytes (e.g., europium-152) have been analyzed only in a few samples.

Sampling data in this table are for offsite sections of the Peconic River, which is not used as a source of public water supply. As a result, exposure to the water at this location is expected to be only periodic ingestion or dermal contact by visitors and recreational users. Nonetheless, comparison values that assume people drink the water in the offsite sections of the Peconic River were used to examine the health implications of whether these waters are used as a drinking water supply. Contaminants in bold font have at least one measured concentration higher than the corresponding health-based comparison value. The following types of comparison values are used in the table:

LTHA	ATSDR Lifetime Health Advisory for drinking water
RMEG-c	ATSDR Reference Dose Media Evaluation Guide for children=s exposure
EMEG-ic	ATSDR Environmental Media Evaluation Guide, for children=s exposure of intermediate duration
IOM TUIL	Institute of Medicine=s Tolerable Upper Intake Level
EAL	USEPA action level for lead in drinking water
MCL	USEPA Maximum Contaminant Level
SDWA	Safe Drinking Water Act level
ALI	Annual Limit on Intake

The health-based comparison value for Ahexavalent chromium@ is used to screen concentrations of chromium; the health-based comparison value for Ainorganic mercury@ is used to screen concentrations of mercury; and the ALI for thorium-232 is used to screen concentrations of thorium-234 (because no ALI has been published for thorium-234).

Data presented only for those contaminants that were detected.

Table SD1. Contaminants in On-Site Sediments

Contaminant	***Highest Sediment Concentration***	***Seasonally***	***Type of CV***

	On-site Peconic River	On-Site Recharge Basins, Wetlands, and Agricultural Fields	***Adjusted Health-Based Comparison Value (CV)***	
Data for radiological contamination in order of increasing atomic number				
Gross alpha	5.38 pCi/g	44 pCi/g	NA	NA
Gross beta	13.8 pCi/g	44 pCi/g	NA	NA
Tritium (hydrogen-3)	0.23 pCi/g	0.39 pCi/g	NA	NA
Beryllium-7	ND	0.93 pCi/g	1,188 pCi/g	NCRP-rs
Sodium-22	NM	9.4 pCi/g	3.24 pCi/g	NCRP-rs
Potassium-40	8.51 pCi/g	20 pCi/g	66.0 pCi/g	NCRP-rs
Cobalt-60	0.49 pCi/g	ND	2.48 pCi/g	NCRP-ps
Strontium-89	0.662 pCi/g	NM	20.56 pCi/g	NCRP-ps
Strontium-90	3.91 pCi/g	1.0 pCi/g	0.864 pCi/g	NCRP-ps
Cesium-137	21.1 pCi/g	13 pCi/g	11.88 pCi/g	NCRP-ps
Europium-152	0.384 pCi/g	ND	9.64 pCi/g	NCRP-rs
Europium-154	0.053 pCi/g	ND	8.96 pCi/g	NCRP-rs
Europium-155	0.141 pCi/g	ND	237.84 pCi/g	NCRP-rs
Thallium-208	0.26 pCi/g	1.2 pCi/g	NA	NA
Lead-210	2.64 pCi/g	14 pCi/g	1.512 pCi/g	NCRP-rs
Lead-212	0.93 pCi/g	1.2 pCi/g	NA	NA
Lead-214	0.62 pCi/g	1.1 pCi/g	NA	NA
Bismuth-214	NM	0.79 pCi/g	NA	NA
Radium-226	0.851 pCi/g	ND	0.40 pCi/g	NCRP-rs
Actinium-228	NM	1.7 pCi/g	NA	NA
Thorium-228	0.3 pCi/g	0.43 pCi/g	2.38 pCi/g	NCRP-rs
Thorium-234	1.02 pCi/g	3.0 pCi/g	NA	NA
Uranium-233/234	1.38 pCi/g	NM	14.04 pCi/g	NCRP-rs
Uranium-235	0.19 pCi/g	0.22 pCi/g	22.72 pCi/g	NCRP-rs
Uranium-238	0.74 pCi/g	NM	67.04 pCi/g	NCRP-rs
Plutonium-238	0.01 pCi/g	NM	34.6 pCi/g	NCRP-rs
Plutonium-239/240	0.16 pCi/g	NM	31.36 pCi/g	NCRP-rs
Americium-241	1.91 pCi/g	ND	35.68 pCi/g	NCRP-rs
Data for inorganic contaminants other than radionuclides				
Contaminant	***Highest Sediment Concentration***		***Seasonally Adjusted Health-Based Comparison Value (CV)***	***Type of CV***
	On-site Peconic River	*On-Site Recharge Basins, Wetlands, and Agricultural Fields*		
Aluminum	14,900 ppm	32,700 ppm	400,000 ppm	EMEG-ci

Arsenic	9.6 ppm	9 ppm	20 ppm	RMEG-c
Barium	197 ppm	90.8 ppm	16,000 ppm	RMEG-c
Beryllium	1.2 ppm	1.1 ppm	200 ppm	EMEG-cc
Cadmium	18.8 ppm	3.2 ppm	40 ppm	EMEG-cc
Chromium	137 ppm	46.3 ppm	800 ppm	RMEG-c
Cobalt	11 ppm	12.9 ppm	18,800 ppm	RBC-n
Copper	1,140 ppm	143 ppm	12,400 ppm	RBC-n
Cyanide	0.11 ppm	ND	4,000 ppm	RMEG-c
Iron	11,200 ppm	31,100 ppm	92,000 ppm	RBC-n
Lead	120 ppm	297 ppm	1,600 ppm	EAL
Manganese	134 ppm	461 ppm	12,000 ppm	RMEG-c
Mercury	24.5 ppm	0.77 ppm	80 ppm	RMEG-c
Nickel	133 ppm	37.8 ppm	4,000 ppm	RMEG-c
Selenium	5.5 ppm	0.89 ppm	1,200 ppm	EMEG-cc
Silver	171 ppm	6.4 ppm	1,200 ppm	RMEG-c
Thallium	1.5 ppm	0.16 ppm	22 ppm	RBC-n
Vanadium	93.5 ppm	85.9 ppm	800 ppm	EMEC-ci
Zinc	681 ppm	806 ppm	80,000 ppm	EMEG-cc
Data for organic contaminants, other than PCBs and pesticides				
Acenaphthylene	0.14 ppm	ND	NA	NA
Acetone	ND	0.12 ppm	20,000 ppm	RMEG-c
Benzo(a)anthracene	0.4 ppm	0.64 ppm	3.48 ppm	RBC-c
Benzo(a)pyrene	0.46 ppm	0.85 ppm	NA	NA
Benzo(b)fluoranthene	1.2 ppm	1.4 ppm	3.48 ppm	RBC-c
Benzo(g,h,i)perylene	0.17 ppm	0.68 ppm	NA	NA
Benzo(k)fluoranthene	0.042 ppm	1.0 ppm	3.48 ppm	RBC-c
Bis(2-ethylhexyl)phthalate	0.63 ppm	3.3 ppm	200 ppm	CREG
2-Butanone	ND	0.03 ppm	120,000 ppm	RMEG-c
Butylbenzylphthalate	ND	0.37 ppm	40,000 ppm	RMEG-c
Chrysene	0.52 ppm	0.84 ppm	348 ppm	RBC-c
Di-n-butylphthalate	0.23 ppm	ND	20,000 ppm	RMEG-c
Di-n-octylphthalate	0.59 ppm	0.22 ppm	80,000 ppm	EMEG-ci
Contaminant	***Highest Sediment Concentration***		***Seasonally Adjusted Health-Based Comparison Value (CV)***	***Type of CV***
	On-site Peconic River	*On-Site Recharge Basins, Wetlands, and Agricultural Fields*		
Fluoranthene	0.95 ppm	1.2 ppm	8,000 ppm	RMEG-c
Indeno(1,2,3-cd)pyrene	0.35 ppm	0.78 ppm	3.48 ppm	RMEG-c

Methylene chloride	ND	0.059 ppm	3000	RMEG-c
Phenanthrene	0.35 ppm	0.52 ppm	NA	NA
Pyrene	0.87 ppm	1.7 ppm	8,000 ppm	RMEG-c
Toluene	0.023 ppm	0.16 ppm	4,000 ppm	EMEG-ci
Data for PCBs and pesticides				
4,4'-DDD	0.096 ppm	0.047 ppm	12.0 ppm	CREG
4,4'-DDE	0.089 ppm	0.16 ppm	8.0 ppm	CREG
4,4'-DDT	0.023 ppm	0.12 ppm	30 ppm	RMEG
alpha-Chlordane	0.073 ppm	0.008 ppm	8.0 ppm	CREG
Aroclor-1254	1.5 ppm	0.51 ppm	4.0 ppm	EMEG-cc
Aroclor-1260	ND	1.8 ppm	1.28 ppm	RBC-c
Chlordane, technical	0.158 ppm	NM	8.0 ppm	CREG
Dieldrin	0.00326 ppm	0.0041 ppm	0.16 ppm	CREG
Endosulfan I	0.018 ppm	0.0052 ppm	400 ppm	EMEG-cc
Endosulfan II	0.0133 ppm	ND	400 ppm	EMEG-cc
Endosulfan sulfate	ND	0.058 ppm	NA	NA
Endrin	0.00142 ppm	ND	80 ppm	EMEG-cc
gamma-Chlordane	0.043 ppm	0.0077 ppm	8.0 ppm	CREG
Methoxychlor	0.398 ppm	ND	1,200 ppm	RMEG-c

Notes:

Source of data: BNL Remedial Investigation Reports and Site Investigation Reports; NYSDEC and NYSDOH sampling data.

NA = not applicable. ERG could not find any health-based comparison values for these contaminants or isotopes.

ND = not detected. Some sediment samples were analyzed for the contaminant, but the contaminant was not detected.

NM = not measured. Not all analytes were measured in the two different categories of sediments.

Following is a key for the health-based comparison values used. These were derived from health-based comparison values for exposures to soils, and then, per ATSDR=s direction, adjusted for seasonal exposures. ERG assumed that exposures to sediments were likely limited to just one season per year and increased all soil comparison values by a factor of four to account for this. Contaminants in bold font had at least one sediment concentration higher than the corresponding health-based comparison value for soils. Many of these comparison values assume prolonged contact with the contaminated medium (sediment, in this case), which is an extremely unlikely exposure scenario for onsite locations at BNL.

NCRP-rs	NCRP recommended soil screening limit for sparsely vegetated rural locations
NCRP-ps	NCRP recommended soil screening limit for sparsely vegetated pasture locations
EMEG-cc	ATSDR Environmental Media Evaluation Guide, for children=s exposure of chronic duration

EMEG-ci ATSDR Environmental Media Evaluation Guide, for children=s exposure of intermediate duration

CREG ATSDR Cancer Risk Evaluation Guide

RMEG-c ATSDR Reference Dose Media Evaluation Guide for children=s exposure

RBC-c USEPA Region 3 Risk-Based Concentration for cancer outcomes

RBC-n USEPA Region 3 Risk-Based Concentration for noncancer outcomes

EAL USEPA Aearly action level@ or soil screening level for lead

The CV for hexavalent chromium was used to screen concentrations of chromium; the CV for mercuric chloride was used to screen concentrations of mercury. In cases where sampling reports documented concentrations of pairs of isotopes (e.g., uranium-233/234), the lowest comparison value of both isotopes was selected. The comparison value for Achlordane@ was used to screen concentrations of alpha-, gamma-, and Atechnical@ chlordane.

Data presented only for those contaminants that were detected in at least one sample, but not including inorganics known to be relatively benign (e.g., calcium, potassium, sodium).

Table SD2. Concentrations of Contaminants in Off-Site Sediments

Contaminant	***Highest Sediment Concentration***		***Seasonally Adjusted Health-Based Comparison Value (CV)***	***Type of CV***
	Off-site Peconic River	Off-site Control Locations		
Data for radiological contamination in order of increasing atomic number				
Gross alpha	29.7 pCi/g	0.909 pCi/g	NA	NA
Gross beta	19.4 pCi/g	1.19 pCi/g	NA	NA
Beryllium-7	0.11 pCi/g	0.90 pCi/g	1,188 pCi/g	NCRP-rs
Potassium-40	5.89 pCi/g	7.74 pCi/g	66 pCi/g	NCRP-rs
Cobalt-60	0.029 pCi/g	0.01 pCi/g	2.48 pCi/g	NCRP-ps
Strontium-90	0.432 pCi/g	0.16 pCi/g	0.864 pCi/g	NCRP-ps
Cesium-137	16.6 pCi/g	1.05 pCi/g	11.88 pCi/g	NCRP-ps
Europium-152	0.223 pCi/g	0.092 pCi/g	9.64 pCi/g	NCRP-rs
Europium-154	ND	0.039 pCi/g	8.96 pCi/g	NCRP-rs
Europium-155	0.163 pCi/g	0.037 pCi/g	237.84 pCi/g	NCRP-rs
Thallium-208	0.05 pCi/g	0.09 pCi/g	NA	NA
Lead-212	0.72 pCi/g	4.77 pCi/g	NA	NA
Lead-214	0.08 pCi/g	0.22 pCi/g	NA	NA
Bismuth-214	0.16 pCi/g	0.19 pCi/g	NA	NA
Radium-226	2.02 pCi/g	1.19 pCi/g	0.40 pCi/g	NCRP-rs
Actinium-228	0.78 pCi/g	0.41 pCi/g	NA	NA
Thorium-228	NM	0.333 pCi/g	2.38 pCi/g	NCRP-rs
Thorium-232	1.14 pCi/g	ND	0.272 pCi/g	NCRP-rs

Uranium-233/234	4.39 pCi/g	4.36 pCi/g	14.04 pCi/g	NCRP-rs
Uranium-235	0.249 pCi/g	0.23 pCi/g	22.72 pCi/g	NCRP-rs

Contaminant	***Highest Sediment Concentration***		***Seasonally Adjusted Health-Based Comparison Value (CV)***	***Type of CV***
	Off-site Peconic River	*Off-site Control Locations*		
Uranium-238	4.01 pCi/g	0.33 pCi/g	67.04 pCi/g	NCRP-rs
Plutonium-238	0.018 pCi/g	0.03 pCi/g	34.6 pCi/g	NCRP-rs
Plutonium-239/240	0.148 pCi/g	0.07 pCi/g	31.36 pCi/g	NCRP-rs
Americium-241	0.615 pCi/g	0.048 pCi/g	35.68 pCi/g	NCRP-rs
Data for inorganic contaminants other than radionuclides				
Aluminum	10,600 ppm	24,500 ppm	400,000 ppm	EMEG-ci
Arsenic	24.2 ppm	9.1 ppm	20 ppm	RMEG-c
Barium	121 ppm	86.4 ppm	16,000 ppm	RMEG-c
Beryllium	1.0 ppm	1.6 ppm	200 ppm	EMEG-cc
Cadmium	6.9 ppm	1.6 ppm	40 ppm	EMEG-cc
Chromium	44.8 ppm	24.2 ppm	800 ppm	RMEG-c
Cobalt	7.4 ppm	3.6 ppm	18,800 ppm	RBC-n
Copper	357 ppm	52.5 ppm	12,400 ppm	RBC-n
Iron	10,300 ppm	20,600 ppm	92,000 ppm	RBC-n
Lead	228 ppm	97.6 ppm	1600 ppm	EAL
Manganese	188 ppm	84.3 ppm	12,000 ppm	RMEG-c
Mercury	9 ppm	0.41 ppm	80 ppm	RMEG-c
Nickel	20.3 ppm	13.2 ppm	4,000 ppm	RMEG-c
Selenium	6.3 ppm	4.9 ppm	1,200 ppm	EMEG-cc
Silver	61.7 ppm	0.48 ppm	1,200 ppm	RMEG-c
Thallium	1.8 ppm	ND	22 ppm	RBC-n
Vanadium	76.5 ppm	73.3 ppm	800 ppm	EMEC-ci
Zinc	385 ppm	158 ppm	80,000 ppm	EMEG-cc
Data for PCBs and pesticides				
4,4'-DDD	0.859 ppm	0.0153 ppm	12.0 ppm	CREG
4,4'-DDE	0.727 ppm	0.10 ppm	8.0 ppm	CREG
4,4'-DDT	0.099 ppm	0.39 ppm	30 ppm	RMEG-c
alpha-Chlordane	0.0736 ppm	0.0102 ppm	8.0 ppm	CREG
Aroclor-1254	0.128 ppm	ND	4.0 ppm	EMEG-cc
Dieldrin	0.0122 ppm	ND	0.16 ppm	CREG
gamma-Chlordane	0.072 ppm	ND	8.0 ppm	CREG

Notes:

Source of data: BNL Remedial Investigation Reports and Site Investigation Reports; NYSDEC and NYSDOH sampling data.

NA = not applicable. ERG could not find any health-based comparison values for these contaminants or isotopes.

ND = not detected. Some sediment samples were analyzed for the contaminant, but the contaminant was not detected.

NM = not measured. Not all analytes were measured in the two different categories of sediments.

Following is a key for the health-based comparison values used. These were derived from health-based comparison values for exposures to soils, and then, per ATSDR=s direction, adjusted for seasonal exposures. ERG assumed that exposures to sediments were likely limited to just one season per year and increased all soil comparison values by a factor of four to account for this. Contaminants in bold font had at least one sediment concentration higher than the corresponding health-based comparison value for soils. Many of these comparison values assume prolonged contact with the contaminated medium (sediment, in this case), which is an extremely unlikely exposure scenario for the sediments in this area.

NCRP-rs	NCRP recommended soil screening limit for sparsely vegetated rural locations
NCRP-ps	NCRP recommended soil screening limit for sparsely vegetated pasture locations
EMEG-cc	ATSDR Environmental Media Evaluation Guide, for children=s exposure of chronic duration
EMEG-ci	ATSDR Environmental Media Evaluation Guide, for children=s exposure of intermediate duration
CREG	ATSDR Cancer Risk Evaluation Guide
RMEG-c	ATSDR Reference Dose Media Evaluation Guide for children=s exposure
RBC-c	USEPA Region 3 Risk-Based Concentration for cancer outcomes
RBC-n	USEPA Region 3 Risk-Based Concentration for noncancer outcomes
EAL	USEPA Aearly action level@ or soil screening level for lead

The CV for hexavalent chromium was used to screen concentrations of chromium; the CV for mercuric chloride was used to screen concentrations of mercury. In cases where sampling reports documented concentrations of pairs of isotopes (e.g., uranium-233/234), the lowest comparison value of both isotopes was selected. The comparison value for Achlordane@ was used to screen concentrations of alpha-, gamma-, and Atechnical@ chlordane.

Data presented only for those contaminants that were detected in at least one sample, but not including inorganics known to be relatively benign (e.g., calcium, potassium, sodium).

Table B1. Summary of 137Cs, 40K, and 90Sr in Biota for On- and Off-site Locations (1977B1999)

Biota Sampled	***Radionuclide Concentrations pCi/g, wet***		
	40K	*137Cs*	*90Sr*
Fish	20.212	25	7.90 ± 0.474
Shellfish	9.21 ± 11.6	0.510 ± 0.036	1.390 ± 0.264

Deer (flesh)	7.72	11.74	0.04 ± 0.10
Other mammals	3.38	8.17	NA
Milk	1.5 x 10-6 μCi/ml	NA	NA
Edible vegetation	6.59 ± 1.10	2.2	0.040 ± 0.008
Inedible vegetation	13.90	1300	

Source: BNL SERs 1977-1999; NYSDOH 1996

Table B2. Potassium-40 concentrations in fish collected from the Peconic River on site (1977B1999)

Fish Species	***Sample Type***	***Maximum Sample Concentration (pCi/g, wet)***	***Year***	***Maximum Sample Concentration (pCi/g, dry)***	***Year***
Yellow Perch	whole	3.58 ± 0.11	1999	NA	NA
Chain Pickerel	flesh	4.09 ± 0.04	1999	11.7	1989
Chain Pickerel	flesh/skin	4.58 ± 1.04	1998	NA	NA
Chain Pickerel	bone/viscera	7.536	1989	15.7	1989
Chain Pickerel	whole	3.74 ± 0.83	1998	NA	NA
Chain Pickerel	deheaded and eviscerated	4.938	1996	NA	NA
Chain Pickerel	not specified	6.713	1987	14.28	1990
Brown Bullhead	flesh/skin	3.22 ± 0.53	1998	NA	NA
Brown Bullhead	bone/viscera	3.06 ± 1.07	1998	NA	NA
Brown Bullhead	whole	2.87 ± 0.56	1998	NA	NA
Brown Bullhead	not specified	6.625	1989	12.5	1989
Sunfish	not specified	3.69	1977	NA	NA
Sunfish	flesh	2.441	1989	6.78	1989
Bass	not specified	5.13	1977	NA	NA
Largemouth Bass	not specified	2.185	1987	NA	NA
Largemouth Bass	flesh	3.475	1989	13.9	1989
Shiner	not specified	4.09	1977	NA	NA
Pumpkinseed	not specified	20.212	1989	65.2	1989
Pumpkinseed	flesh	3.276	1989	12.6	1989
Creek Chub	not specified	1.729	1986	NA	NA
Creek Chub Sucker	whole	2.27 ± 0.43	1998	NA	NA
Goldfish	flesh	3.45	1989	15.0	1989
Daces	not specified	ND	1991	NA	NA

Source: BNL SERs 1977-1999; NYSDOH 1996

Table B3. Strontium-90 Concentrations in Fish Collected from the Peconic River On Site (1977B1999)

Fish Species	*Sample Type*	*Maximum Sample Concentration (pCi/g, wet)*	*Year*	*Maximum Sample Concentration (pCi/g, dry)*	*Year*
Chain Pickerel	not specified	1.846	1989	5.43	1989
Brown Bullhead	not specified	4.786	1989	9.03	1989
Largemouth Bass	not specified	5.447	1989	11.59	1989
Pumpkinseed	not specified	4.752	1989	7.92	1989
Creek Chub Sucker	deheaded and eviscerated	0.45	1996	NA	NA
Trout	not specified	0.075	1989	1.3	1989
Daces	not specified	0.338	1991	NA	NA
Unspecified	bone	0.05	1978	NA	NA
Unspecified	flesh	0.072	1980	NA	NA
Unspecified	not specified	0.42	1987	NA	NA

Source: BNL SERs 1977-1999; NYSDOH 1996

Table B4. Cesium-137 concentrations in fish from the Peconic River on site (1977B1999)

Fish Species	*Sample Type*	*Maximum Sample Concentration (pCi/g, wet)*	*Year*	*Maximum Sample Concentration (pCi/g, dry)*	*Year*
Yellow Perch	whole	0.37 ± 0.20	1999	NA	NA
Chain Pickerel	flesh	3.894	1989	12.6	1989
Chain Pickerel	flesh/skin	0.73 ± 0.17	1998	NA	NA
Chain Pickerel	bone/viscera	9.312	1989	19.4	1989
Chain Pickerel	whole	2.712 ± 0.314	1998	NA	NA
Chain Pickerel	deheaded and eviscerated	0.49	1996	NA	NA
Chain Pickerel	not specified	7.10	1977	NA	NA
Brown Bullhead	flesh/skin	0.34 ± 0.06	1998	NA	NA
Brown Bullhead	bone/viscera	0.689 ± 0.147	1998	NA	NA
Brown Bullhead	whole	1.189 ± 0.152	1998	NA	NA
Brown Bullhead	not specified	8.0	1988	NA	NA
Sunfish	not specified	8.5	1977	NA	NA
Sunfish	flesh	11.016	1989	30.6	1989
Bass	not specified	6.2	1977	NA	NA
Largemouth Bass	not specified	8.0	1988	NA	NA
Largemouth Bass	flesh	0.148	1989	0.593	1989

Fish Species	*Sample Type*	*Maximum Sample Concentration (pCi/g, wet)*	*Year*	*Maximum Sample Concentration (pCi/g, dry)*	*Year*
Shiner	not specified	5.75	1977	NA	NA
Pumpkinseed	not specified	25.0	1988	NA	NA
Pumpkinseed	flesh	6.864	1989	26.4	1989
Creek Chub	not specified	0.588	1986	NA	NA
Creek Chub Sucker	whole	1.988 ± 0.355	1998	NA	NA
Creek Chub Sucker	deheaded and eviscerated	0.527	1996	NA	NA
Goldfish	flesh	0.041	1989	0.18	1989
Daces	not specified	0.305	1991	NA	NA
Unspecified	flesh	1.192	1978	NA	NA
Unspecified	not specified	1.880	1997	NA	NA

Source: BNL SERs 1977-1999; NYSDOH 1996

Table B5. Tritium, Gross Alpha, and Gross Beta concentrations in fish from the Peconic River on site (1977B1999)

Fish Species	*Sample Type*	*Tritium, Maximum Sample Conc .(pCi/g, wet)*	*Year*	*Gross Alpha, Maximum Sample Conc.(pCi/g, wet)*	*Year*	*Gross Beta, Maximum Sample Conc.(pCi/g, wet)*	*Year*
Chain Pickerel	deheaded and eviscerated	0.522	1996	NA	NA	0.487	1996
Creek Chub Sucker	deheaded and eviscerated	0.449	1996	1.65	1996	0.469	1996
Creek Chub Sucker	Fluid	8,100 pCi/L	1986	NA	NA	NA	NA
Unspecified	not specified	NA	NA	NA	NA	20.27	1997

Source: BNL SERs 1977B1999; NYSDOH 1996

Table B6. Uranium-234, Uranium-238, and Americium-241 Concentrations in Fish from the Peconic River On Site (1977B1999)

Fish Species	*Sample Type*	*Uranium-234,Maximum Sample Conc .(pCi/g, wet)*	*Year*	*Uranium-238, Maximum Sample Conc. (pCi/g, wet)*	*Year*	*Americium-241 , Maximum Sample Conc. (pCi/g, wet)*	*Year*
Brown Bullhead	not specified	0.0022 ± 0.0008	1999	0.008 ± 0.0004	1999	0.0036 ± 0.0013	1999
Brown Bullhead	Whole	NA	NA	0.004 ± 0.002	1998	NA	NA
Brown Bullhead	bone/viscera	0.006 ± 0.002	1998	0.008 ± 0.002	1998	NA	NA
Chain Pickerel	not specified	0.0008 ± 0.0004	1999	0.0012 ± 0.0005	1999	0.0004 ± 0.0003	1999
Chain Pickerel	Whole	0.002 ± 0.001	1998	0.004 ± 0.002	1998	NA	NA
Creek Chub Sucker	Whole	0.003 ± 0.002	1998	0.005 ± 0.002	1998	NA	NA

Source: BNL SERs 1977-1999; NYSDOH 1996

Table B7. Inorganic Concentrations in Fish from the Peconic River On Site (1996B1999)

Fish Species	*Sample Type*	*As, Max. Conc. (mg/kg, wet)*	*Ba, Max. Conc. (mg/kg, wet)*	*Cd, Max. Conc. (mg/kg, wet)*	*Cu, Max. Conc. (mg/kg, wet)*	*Pb, Max. Conc. (mg/kg, wet)*	*Mn, Max. Conc. (mg/kg, wet)*	*Hg, Max. Conc. (mg/kg, wet)*	*Ni, Max. Conc. (mg/kg, wet)*	*Ag, Max. Conc. (mg/kg, wet)*	*Zn, Max. Conc. mg/kg wet*	*Fe, Max. Conc. mg/kg wet*
Comparison Values		0.0021(RBC-C)	95(RBC-N)	1.4(RBC-N)	54 (RBC-N)	none	190(RBC-N)	0.14 (RBC-N)	27(RBC-N)	6.8(RBC-N)	410(RBC-N)	410(RBC-N)
Chain Pickerel	flesh	ND	1.62	ND	1.30	ND	2.24	0.10	ND	0.35	21.15	8.63
Chain Pickerel	dehead. and evisc.	NA	NA	NA	NA	0.14	NA	1.6	NA	NA	NA	NA
Chain Pickerel	not specified	NA	NA	0.205	5.42	0.48	NA	0.746	0.157	0.22	NA	NA
Brown Bullhead	flesh	ND	2.11	ND	2.15	ND	2.04	0.40	0.18	ND	14.25	39.3
Brown Bullhead	dehead. and evisc.	NA	NA	NA	2.0	0.14	NA	0.99	NA	NA	NA	NA
Brown Bullhead	not specified	NA	NA	0.196	8.49	0.324	NA	0.694	0.162	0.39	NA	NA

Fish Species	*Sample Type*	*As, Max. Conc. (mg/kg, wet)*	*Ba, Max. Conc. (mg/kg, wet)*	*Cd, Max. Conc. (mg/kg, wet)*	*Cu, Max. Conc. (mg/kg, wet)*	*Pb, Max. Conc. (mg/kg, wet)*	*Mn, Max. Conc. (mg/kg, wet)*	*Hg, Max. Conc. (mg/kg, wet)*	*Ni, Max. Conc. (mg/kg, wet)*	*Ag, Max. Conc. (mg/kg, wet)*	*Zn, Max. Conc. mg/kg wet*	*Fe, Max. Conc. mg/kg wet*
Creek Chub Sucker	dehead. and evisc.	NA	NA	NA	NA	0.14	NA	0.96	NA	NA	NA	NA
Creek Chub Sucker	not specified	NA	NA	0.126	4.17	0.231	NA	0.616	0.167	0.15	NA	NA
Common Shiner	dehead. and evisc.	NA	NA	NA	NA	NA	NA	0.32	NA	NA	NA	NA
Pumpkin-seed	dehead. and evisc.	NA	NA	NA	NA	NA	NA	0.58	NA	NA	NA	NA
Pumpkin-seed	not specified	NA	NA	0.125	3.78	0.643	NA	1.26	0.137	0.28	NA	NA

Source: BNL SERs 1977B1999; NYSDOH 1996

Table B8. Pesticide and PCB Concentrations in Fish from the Peconic River On Site (1996B1999)

Contaminant	*Highest Concentration (mg/kg, fish species, wet)*	*Comparison Value (CV) (mg/kg, fish species)*	*Type of CV*
alpha-BHC	0.0017, pickerel0.0097, bullhead	NA	NA
beta-BHC	0.0017, pickerel0.0017, bullhead	NA	NA
delta-BHC	0.0017, pickerel0.0017, bullhead	NA	NA
gamma-BHC (Lindane)	0.0017, pickerel0.0017, bullhead	NA	NA
Heptachlor	0.0017, pickerel0.0019, bullhead	0.0007	RBC-C
Aldrin	0.0017, pickerel0.0017, bullhead	0.00019	RBC-C
Heptachlor epoxide	0.0017, pickerel0.0017, bullhead	0.00035	RBC-C
Endosulfan I	0.0017, pickerel0.0017, bullhead	8.1	RBC-N
Dieldrin	0.0033, pickerel0.007, bullhead	0.0002	RBC-C
4,4'-DDE	0.0752, pickerel0.0935, bullhead0.0991, pumpkinseed0.0511, creek chub sucker	0.0093	RBC-C
Endrin	0.0033, pickerel0.0033, bullhead	0.41	RBC-N
Endosulfan II	0.0033, pickerel0.0048, bullhead	8.1	RBC-N
4,4'-DDD	0.016, pickerel0.017, bullhead0.142, pumpkinseed0.023, creek chub sucker	0.013	RBC-C
Endosulfan sulfate	0.0033, pickerel0.0033, bullhead	NA	NA
4,4'-DDT	0.00557, pickerel0.0769, bullhead0.0226, pumpkinseed	0.0093	RBC-C
Methoxychlor	0.017, pickerel0.017, bullhead	6.8	RBC-N
Endrin ketone	0.0033, pickerel0.0033, bullhead	0.41	RBC-N
Endrin aldehyde	0.0054, pickerel0.019,	0.41	RBC-N

Contaminant	*Highest Concentration (mg/kg, fish species, wet)*	*Comparison Value (CV) (mg/kg, fish species)*	*Type of CV*
	bullhead		
alpha-Chlordane	0.0136, pickerel0.0325, bullhead0.00788, creek chub sucker	0.009	RBC-C
gamma-Chlordane	0.0015, pickerel0.0015, bullhead	0.009	RBC-C
Toxaphene	0.17, pickerel0.17, bullhead	0.0029	RBC-C
Aroclor-1016	0.033, pickerel0.033, bullhead	0.045	RBC-C
Aroclor-1221	0.067, pickerel0.067, bullhead	0.0016	RBC-C
Aroclor-1232	0.033, pickerel0.033, bullhead	0.0016	RBC-C
Aroclor-1242	0.033, pickerel0.033, bullhead	0.0016	RBC-C
Aroclor-1248	0.033, pickerel0.033, bullhead	0.0016	RBC-C
Aroclor-1254	4.3, pickerel3.68, bullhead4.8, pumpkinseed4.26, creek chub sucker	0.0016	RBC-C
Aroclor-1260	0.047, pickerel0.170, bullhead	0.0016	

Source: BNL SERs 1977B1999; NYSDOH 1996

Table B9. Potassium-40 concentrations in fish from the Peconic River off site (1973B1999)

Fish Species	*Sample Type*	*Maximum Sample Concentration (pCi/g, wet)*	*Year*	*Maximum Sample Concentration (pCi/g, dry)*	*Year*
Yellow Perch	not specified	3.140	1991	NA	NA
Yellow Perch	whole	3.19 ± 0.78	1996	NA	NA
Yellow Perch	bone/viscera	4.21 ± 2.12	1996	NA	NA
Yellow Perch	flesh/skin	3.40 ± 0.65	1998	NA	NA
Chain Pickerel	flesh/skin	5.03 ± 1.45	1996	NA	NA
Chain Pickerel	bone/viscera	3.76 ± 1.52	1996	NA	NA
Chain Pickerel	whole	4.86 ± 1.74	1997	NA	NA
Chain Pickerel	not specified	4.410	1991	NA	NA

Fish Species	*Sample Type*	*Maximum Sample Concentration (pCi/g, wet)*	*Year*	*Maximum Sample Concentration (pCi/g, dry)*	*Year*
Brown Bullhead	flesh/skin	3.97 ± 0.66	1998	NA	NA
Brown Bullhead	bone/viscera	1.65 ± 0.30	1996	NA	NA
Brown Bullhead	whole	2.7	1999	NA	NA
Brown Bullhead	not specified	4.22	1993	NA	NA
Black Crappie	not specified	2.760	1992	NA	NA
Black Crappie	flesh/skin	3.59 ± 0.85	1996	NA	NA
Black Crappie	bone/viscera	2.77 ± 0.61	1996	NA	NA
Largemouth Bass	not specified	4.611	1994	NA	NA
Largemouth Bass	flesh	1.36 ± 0.05	1999	NA	NA
Largemouth Bass	bone/viscera	4.11 ± 0.07	1999	NA	NA
Catfish	not specified	3.0	1989	12.5	1989
Pumpkinseed	not specified	2.573	1994	NA	NA
Pumpkinseed	whole	2.77 ± 0.97	1997	NA	NA
Pumpkinseed	flesh	3.528	1989	14.7	1989
Pumpkinseed	bone/viscera	6.49 ± 5.32	1996	NA	NA
Pumpkinseed	flesh/skin	3.27 ± 0.64	1996	NA	NA
Bluegill	not specified	3.277	1989	11.3	1989
Bluegill	whole	3.46 ± 1.14	1997	NA	NA
Bluegill	bone/viscera	3.32 ± 1.99	1997	NA	NA
Bluegill	flesh/skin	6.40 ± 2.15	1997	NA	NA
Golden Shiner	not specified	4.384	1995	NA	NA
Golden Shiner	whole	4.88 ± 2.59	1997	NA	NA
Golden Shiner	bone/viscera	3.43 ± 0.80	1996	NA	NA
Golden Shiner	flesh/skin	3.82 ± 0.85	1996	NA	NA
Eel	not specified	2.045	1994	NA	NA
Carp	not specified	1.972	1995	NA	NA
Unspecified, bottom feeder	not specified	3.6 ± 0.40	1994	NA	NA
Unspecified, bottom feeder	flesh	3.4 ± 0.50	1992	NA	NA
Unspecified, top feeder	not specified	3.3 ± 0.80	1991	NA	NA
Unspecified, mixed	not specified	3.1 ± 0.40	1995	NA	NA
Unspecified	not specified	3.7 ± 0.70	1983	NA	NA

Source: BNL SERs 1977B1999; NYSDOH 1996

Table B10. Strontium-90 concentrations in fish from the Peconic River off site (1973B1999)

Fish Species	*Sample Type*	*Maximum Sample Concentration (pCi/g, wet)*	*Year*	*Maximum Sample Concentration (pCi/g, dry)*	*Year*
Yellow Perch	not specified	1.025	1985	NA	NA
Yellow Perch	whole	0.24 ± 0.03	1996	NA	NA
Yellow Perch	bone/viscera	0.40 ± 0.05	1996	NA	NA
Yellow Perch	flesh/skin	0.30 ± 0.04	1996	NA	NA
Chain Pickerel	flesh/skin	0.05 ± 0.01	1996	NA	NA
Chain Pickerel	bone/viscera	0.39 ± 0.04	1996	NA	NA
Chain Pickerel	whole	0.04 ± 0.01	1996	NA	NA
Chain Pickerel	not specified	0.788	1992	NA	NA
Brown Bullhead	bone/viscera	0.66 ± 0.05	1996	NA	NA
Brown Bullhead	whole	0.30 ± 0.05	1996	NA	NA
Brown Bullhead	not specified	3.328	1985	NA	NA
Black Crappie	not specified	0.373	1992	NA	NA
Black Crappie	bone/viscera	0.42 ± 0.04	1996	NA	NA
Largemouth Bass	not specified	0.260	1993	NA	NA
Catfish	not specified	0.426	1989	1.64	1989
Pumpkinseed	not specified	0.787	1989	2.81	1989
Pumpkinseed	bone/viscera	0.93 ± 0.06	1996	NA	NA
Pumpkinseed	flesh/skin	0.32 ± 0.02	1996	NA	NA
Bluegill	not specified	0.769	1989	2.65	1989
Bluegill	whole	0.33 ± 0.03	1996	NA	NA
Bluegill	bone/viscera	0.42 ± 0.03	1996	NA	NA
Golden Shiner	not specified	2.597	1985	NA	NA
Golden Shiner	whole	0.37 ± 0.03	1996	NA	NA
Golden Shiner	bone/viscera	0.83 ± 0.06	1996	NA	NA
Golden Shiner	flesh/skin	0.30 ± 0.03	1996	NA	NA
Eel	not specified	0.295	1994	NA	NA
Unspecified, bottom feeder	not specified	0.51 ± 0.040	1974	NA	NA
Unspecified, bottom feeder	flesh	0.26 ± 0.036	1976	NA	NA
Unspecified, top feeder	not specified	1.21 ± 0.073	1976	NA	NA
Unspecified, top feeder	flesh	0.036 ± 0.007	1974	NA	NA
Unspecified, top feeder	bone	7.90 ± 0.474	1974	NA	NA

Fish Species	*Sample Type*	*Maximum Sample Concentration (pCi/g, wet)*	*Year*	*Maximum Sample Concentration (pCi/g, dry)*	*Year*
Unspecified, mixed	not specified	1.80 ± 0.13	1974	NA	NA
Unspecified	not specified	1.22	1997	NA	NA

Source: BNL SERs 1977B1999; NYSDOH 1996

Table B11. Cesium-137 concentrations in fish from the Peconic River off site (1973-1999)

Fish Species	*Sample Type*	*Maximum Sample Concentration (pCi/g, wet)*	*Year*
Yellow Perch	not specified	0.90	1994
Yellow Perch	whole	0.26 ± 0.07	1996
Yellow Perch	bone/viscera	0.89 ± 0.26	1996
Yellow Perch	flesh/skin	1.319 ± 0.171	1998
Chain Pickerel	flesh/skin	1.445 ± 0.211	1998
Chain Pickerel	bone/viscera	0.797 ± 0.137	1998
Chain Pickerel	whole	0.46 ± 0.16	1997
Chain Pickerel	not specified	0.655	1994
Brown Bullhead	flesh/skin	0.46 ± 0.08	1996
Brown Bullhead	bone/viscera	0.19 ± 0.04	1996
Brown Bullhead	whole	0.698	1998
Brown Bullhead	not specified	0.935	1993
Black Crappie	not specified	0.298	1992
Black Crappie	flesh/skin	0.32 ± 0.08	1996
Black Crappie	bone/viscera	0.18 ± 0.05	1996
Largemouth Bass	not specified	0.384	1993
Largemouth Bass	whole	0.29 ± 0.06	1997
Largemouth Bass	flesh	0.10 ± 0.02	1999
Largemouth Bass	bone/viscera	0.38 ± 0.10	1999
Catfish	not specified	1.0	1988
Pumpkinseed	not specified	0.60	1988
Pumpkinseed	whole	0.22 ± 0.12	1997
Pumpkinseed	flesh	0.20 ± 0.06	1999
Pumpkinseed	bone/viscera	0.47 ± 0.29	1997
Pumpkinseed	flesh/skin	0.47 ± 0.20	1996
Bluegill	not specified	0.70	1988
Bluegill	whole	0.42 ± 0.087	1998
Bluegill	bone/viscera	0.25 ± 0.10	1997
Bluegill	flesh/skin	0.20 ± 0.05	1997

Fish Species	*Sample Type*	*Maximum Sample Concentration (pCi/g, wet)*	*Year*
Bluegill	flesh	0.11 ± 0.03	1999
Golden Shiner	not specified	0.961	1994
Golden Shiner	whole	0.70 ± 0.30	1997
Golden Shiner	bone/viscera	0.10 ± 0.02	1996
Golden Shiner	flesh/skin	0.16 ± 0.03	1996
Eel	not specified	0.38	1994
Carp	not specified	0.204	1995
Unspecified, bottom feeder	not specified	1.79 ± 0.14	1973
Unspecified, bottom feeder	flesh	2.33 ± 0.193	1976
Unspecified, top feeder	not specified	2.59 ± 0.13	1975
Unspecified, top feeder	flesh	2.8 ± 0.56	1974
Unspecified, mixed	not specified	1.86 ± 0.074	1976
Unspecified	not specified	1.66	1997

Source: BNL SERs 1977B1999; NYSDOH 1996

Table B12. Tritium, Gross Alpha, and Gross Beta concentrations in fish from the Peconic River off site (1985B1999)

Fish Species	*Sample Type*	*Tritium, Maximum Sample Conc .(pCi/g, wet)*	*Year*	*Gross Alpha, Maximum Sample Conc. (pCi/g, wet)*	*Year*	*Gross Beta, Maximum Sample Conc.(pCi/g, wet)*	*Year*
Unspecified	not specified	NA	NA	2.6	1997	13.85	1997
Bluegill	not specified	0.843	1985	NA	NA	NA	NA
Yellow Perch	not specified	0.926	1985	NA	NA	NA	NA
Chain Pickerel	not specified	0.709	1985	NA	NA	NA	NA
Golden Shiner	not specified	0.841	1985	NA	NA	NA	NA
Brown Bullhead	not specified	1.742	1985	NA	NA	NA	NA

Source: BNL SERs 1977B1999; NYSDOH 1996

Table B13. Uranium-234, Uranium-238, and Plutonium-239/240 concentrations in fish from the Peconic River off site (1977B1999)

Fish Species	*Sample Type*	*Uranium-234, Maximum Sample Conc. (pCi/g, wet)*	*Year*	*Uranium-238, Maximum Sample Conc. (pCi/g, wet)*	*Year*	*Plutonium-239/240, Maximum Sample Conc.(pCi/g, wet)*	*Year*
Bluegill	whole	0.008 ± 0.0006	1999	0.005 ± 0.0005	1999	0.001 ± 0.001	1998
Largemouth Bass	whole	0.1113 ± 0.0006	1999	0.0014 ± 0.0006	1999	NA	NA
Brown Bullhead	whole	0.003 ± 0.002	1998	0.003 ± 0.001	1998	NA	NA
Brown Bullhead	flesh/skin	NA	NA	0.004 ± 0.002	1998	NA	NA
Brown Bullhead	bone/viscera	0.003 ± 0.002	1998	0.003 ± 0.002	1998	NA	NA
Yellow Perch	flesh/skin	0.002 ± 0.001	1998	NA	NA	0.001 ± 0.001	1998
Yellow Perch	bone/viscera	NA	NA	0.002 ± 0.001	1998	NA	NA

Source: BNL SERs 1977B1999; NYSDOH 1996

Table B14. Inorganics Found in Fish from the Peconic River Off Site (1997B1999)

Fish Species	*Sample Type*	*As, Max Conc. (mg/kg wet)*	*Ba, Max. Conc. (mg/kg, wet)*	*Cd, Max. Conc. (mg/kg, wet)*	*Cu, Max. Conc. (mg/kg, wet)*	*Pb, Max. Conc. (mg/kg, wet)*	*Mn, Max. Conc. (mg/kg, wet)*	*Hg, Max. Conc. (mg/kg, wet)*	*Ni, Max. Conc. (mg/kg, wet)*	*Ag, Max. Conc. (mg/kg, wet)*	*Zn, Max. Conc. (mg/kg wet)*	*Fe, Max. Conc. (mg/kg wet)*
Comparison Values		0.0021(RBC-C)	95(RBC-N)	1.4(RBC-N)	54 (RBC-N)	none	190(RBC-N)	0.14 (RBC-N)	27(RBC-N)	6.8(RBC-N)	410(RBC-N)	410(RBC-N)
Bluegill	flesh	ND	2.21	ND	0.59	ND	3.29	0.09	0.15	ND	21.62	ND
Largemouth Bass	flesh	0.91	0.24	0.12	2.05	ND	7.54	ND	0.42	0.20	8.74	31.5
Large mouth Bass	not specified	NA	NA	0.045	2.97	0.359	NA	0.914	0.165	0.009	NA	NA
Creek Chub Sucker	not specified	NA	NA	0.042	6.77	0.127	NA	0.335	0.269	0.02	NA	NA
Brown Bullhead	not specified	NA	NA	0.016	3.01	0.967	NA	0.196	0.177	0.04	NA	NA
Pumpkin-seed	flesh	ND	0.73	ND	0.62	ND	1.02	0.15	0.10	ND	15.55	ND
Pumpkin-seed	not specified	NA	NA	0.033	2.41	0.92	NA	0.418	0.225	0.02	NA	NA
Chain Pickerel	not specified	NA	NA	0.073	5.51	0.535	NA	0.645	0.559	0.06	NA	NA

Table B15. Pesticide and PCB Levels in Fish from the Peconic River Off Site (1996B1999)

Contaminant	*Highest Concentration (mg/kg, fish species, wet)*	*Comparison Value (CV) (mg/kg, fish species)*	*Type of CV*
alpha-BHC	0.0017, bluegill0.0017, largemouth bass0.0017, pumpkin seed	NA	NA
beta-BHC	0.0017, bluegill0.0017, largemouth bass0.0017, pumpkin seed	NA	NA
delta-BHC	0.0017, bluegill0.0017, largemouth bass0.0017, pumpkin seed	NA	NA
gamma-BHC (Lindane)	0.0017, bluegill0.0017, largemouth bass0.0017, pumpkin seed	NA	NA
Heptachlor	0.0017, bluegill0.0017, largemouth bass0.0017, pumpkin seed	0.0007	RBC-C
Aldrin	0.0017, bluegill0.0017, largemouth bass0.0017, pumpkin seed	0.00019	RBC-C
Heptachlor epoxide	0.0017, bluegill0.0017, largemouth bass0.0017, pumpkin seed	0.00035	RBC-C
Endosulfan I	0.0017, bluegill0.0017, largemouth bass0.0017, pumpkin seed	8.1	RBC-N
Dieldrin	0.0033, bluegill0.0033, largemouth bass0.0033, pumpkinseed	0.0002	RBC-C
4,4'-DDE	0.002, bluegill0.0752, largemouth bass0.065, pickerel0.0522, pumpkinseed0.0276, creek chub sucker0.0714, brown bullhead	0.0093	RBC-C
Endrin	0.0033, bluegill0.0033, largemouth bass0.0033, pumpkinseed	0.41	RBC-N
Endosulfan II	0.0033, bluegill0.0033, largemouth bass0.0033, pumpkinseed	8.1	RBC-N
4,4'-DDD	0.0033, bluegill0.0234, largemouth bass0.0689, pickerel0.0531,	0.013	RBC-C

Contaminant	*Highest Concentration (mg/kg, fish species, wet)*	*Comparison Value (CV) (mg/kg, fish species)*	*Type of CV*
	pumpkinseed0.0322, creek chub sucker0.0703, brown bullhead		
Endosulfan sulfate	0.0033, bluegill0.0033, largemouth bass0.0033, pumpkinseed	NA	NA
4,4'-DDT	0.0033, bluegill0.0033, largemouth bass0.0033, pumpkinseed	0.0093	RBC-C
Methoxychlor	0.017, bluegill0.017, largemouth bass0.017, pumpkinseed	6.8	RBC-N
Endrin ketone	0.0033, bluegill0.0033, largemouth bass0.0033, pumpkinseed	0.41	RBC-N
Endrin aldehyde	0.0033, bluegill0.0033, largemouth bass0.0033, pumpkinseed	0.41	RBC-N
alpha-Chlordane	0.0017, bluegill0.0017, largemouth bass0.0017, pumpkin seed	0.009	RBC-C
gamma-Chlordane	0.0017, bluegill0.0017, largemouth bass0.0017, pumpkin seed	0.009	RBC-C
Toxaphene	0.17, bluegill0.17, largemouth bass0.17, pumpkinseed	0.0029	RBC-C
Aroclor-1016	0.033, bluegill0.033, largemouth bass0.033, pumpkinseed	0.045	RBC-C
Aroclor-1221	0.067, bluegill0.067, largemouth bass0.067, pumpkinseed	0.0016	RBC-C
Aroclor-1232	0.033, bluegill0.033, largemouth bass0.033, pumpkinseed	0.0016	RBC-C
Aroclor-1242	0.033, bluegill0.033, largemouth bass0.033, pumpkinseed	0.0016	RBC-C
Aroclor-1248	0.033, bluegill0.033, largemouth bass0.033, pumpkinseed	0.0016	RBC-C
Aroclor-1254	0.423, pickerel0.033,	0.0016	RBC-C

Contaminant	*Highest Concentration (mg/kg, fish species, wet)*	*Comparison Value (CV) (mg/kg, fish species)*	*Type of CV*
	bluegill0.033, largemouth bass0.033, pumpkinseed		
Aroclor-1260	0.033, bluegill0.033, largemouth bass0.033, pumpkinseed	0.0016	RBC-C

Source: BNL SERs 1977B1999; NYSDOH 1996

Table B16. Potassium-40 Concentrations in Fish from Off-Site Control Locations (1973B1999)

Fish Species	*Sample Type*	*Maximum Sample Concentration (pCi/g, wet)*	*Year*	*Maximum Sample Concentration (pCi/g, dry)*	*Year*
Yellow Perch	not specified	2.77	1991	NA	NA
Yellow Perch	whole	2.80 ± 0.57	1996	NA	NA
Yellow Perch	bone/viscera	3.45 ± 1.39	1996	NA	NA
Yellow Perch	flesh/skin	4.60 ± 1.67	1996	NA	NA
Chain Pickerel	not specified	3.865	1994	NA	NA
Brown Bullhead	flesh/skin	4.06 ± 2.54	1996	NA	NA
Brown Bullhead	bone/viscera	3.74 ± 1.00	1996	NA	NA
Brown Bullhead	whole	3.51 ± 0.89	1996	NA	NA
Brown Bullhead	not specified	5.456	1994	NA	NA
Black Crappie	not specified	2.37	1993	NA	NA
Black Crappie	whole	12.91 ± 4.48	1997	NA	NA
Largemouth Bass	not specified	4.548	1995	NA	NA
Largemouth Bass	whole	3.1	1999	NA	NA
Largemouth Bass	flesh/skin	2.69 ± 0.46	1996	NA	NA
Largemouth Bass	bone/viscera	1.76 ± 0.34	1996	NA	NA
Pumpkinseed	not specified	4.29	1993	NA	NA
Pumpkinseed	whole	3.54 ± 1.52	1996	NA	NA
Pumpkinseed	bone/viscera	3.88 ± 2.49	1996	NA	NA
Pumpkinseed	flesh/skin	5.47 ± 1.92	1996	NA	NA
Bluegill	not specified	3.29	1993	NA	NA
Bluegill	whole	2.96 ± 1.36	1996	NA	NA
Bluegill	bone/viscera	3.75 ± 2.11	1996	NA	NA
Bluegill	flesh/skin	4.28 ± 1.54	1996	NA	NA
Golden Shiner	not specified	3.815	1994	NA	NA

Fish Species	*Sample Type*	*Maximum Sample Concentration (pCi/g, wet)*	*Year*	*Maximum Sample Concentration (pCi/g, dry)*	*Year*
Golden Shiner	whole	1.86 ± 0.67	1996	NA	NA
Eel	not specified	2.488	1994	NA	NA
Eel	whole	3.25 ± 0.57	1996	NA	NA
Carp	not specified	6.89	1991	NA	NA
Carp	whole	5.14 ± 3.57	1996	NA	NA
Carp	bone/viscera	2.65 ± 1.06	1997	NA	NA
Brook Trout	not specified	3.549	1987	NA	NA
Pirate Perch	not specified	1.536	1990	8.08	1990
Darter	not specified	0.283	1990	1.286	1990
Redfin Pickerel	not specified	5.297	1990	18.266	1990
Rainbow Trout	flesh/skin	3.21 ± 0.62	1996	NA	NA
Rainbow Trout	bone/viscera	1.34 ± 1.27	1996	NA	NA
Rainbow Trout	whole	2.84 ± 0.97	1996	NA	NA
Gizzard Shad	whole	2.31 ± 0.50	1997	NA	NA
Gizzard Shad	flesh/skin	7.15 ± 2.05	1997	NA	NA
Gizzard Shad	bone/viscera	3.12 ± 0.68	1997	NA	NA
White Perch	whole	2.24 ± 0.38	1998	NA	NA
White Perch	flesh/skin	2.53 ± 0.43	1998	NA	NA
White Perch	bone/viscera	2.85 ± 0.93	1998	NA	NA
Goldfish	flesh/skin	2.33 ± 0.54	1997	NA	NA
Goldfish	bone/viscera	1.40 ± 0.62	1997	NA	NA
Unspecified, bottom feeder	not specified	3.30 ± 0.50	1994	NA	NA
Unspecified, top feeder	not specified	3.20 ± 0.30	1988	NA	NA
Unspecified, mixed	not specified	3.20 ± 0.50	1994	NA	NA
Unspecified	not specified	3.70 ± 0.30	1987	NA	NA

Source: BNL SERs 1977B1999; NYSDOH 1996

Table B17. Strontium-90 Concentrations in Fish from Offsite Control Locations (1973B1999)

Fish Species	*Sample Type*	*Maximum Sample Concentration (pCi/g, wet)*	*Year*	*Maximum Sample Concentration (pCi/g, dry)*	*Year*
Yellow Perch	not specified	0.319	1994	NA	NA
Yellow Perch	whole	0.12 ± 0.02	1996	NA	NA
Yellow Perch	bone/viscera	0.21 ± 0.04	1996	NA	NA
Yellow Perch	flesh/skin	0.07 ± 0.03	1996	NA	NA
Chain Pickerel	not specified	0.125	1994	NA	NA
Brown Bullhead	flesh/skin	0.11 ± 0.01	1996	NA	NA
Brown Bullhead	bone/viscera	1.10 ± 0.06	1996	NA	NA
Brown Bullhead	whole	0.62 ± 0.04	1996	NA	NA
Brown Bullhead	not specified	0.544	1994	NA	NA
Black Crappie	not specified	0.083	1993	NA	NA
Largemouth Bass	not specified	0.137	1992	NA	NA
Largemouth Bass	flesh/skin	0.06 ± 0.02	1996	NA	NA
Largemouth Bass	bone/viscera	0.19 ± 0.03	1996	NA	NA
Pumpkinseed	not specified	0.105	1993	NA	NA
Pumpkinseed	bone/viscera	0.25 ± 0.04	1996	NA	NA
Bluegill	not specified	0.175	1989	0.50	1989
Bluegill	whole	0.90 ± 0.05	1996	NA	NA
Bluegill	bone/viscera	1.78 ± 0.08	1996	NA	NA
Bluegill	flesh/skin	0.40 ± 0.02	1996	NA	NA
Bluegill	flesh			NA	NA
Golden Shiner	not specified	0.245	1994	NA	NA
Eel	not specified	0.110	1994	NA	NA
Eel	whole	0.06 ± 0.03	1996	NA	NA
Carp	not specified	0.027	1991	NA	NA
Rainbow Trout	flesh/skin	0.38 ± 0.02	1996	NA	NA
Rainbow Trout	bone/viscera	0.06 ± 0.03	1996	NA	NA
Catfish	not specified	0.180	1989	0.75	1989
Unspecified, bottom feeder	not specified	0.57 ± 0.40	1975	NA	NA
Unspecified, bottom feeder	flesh	0.130 ± 0.020	1974	NA	NA
Unspecified, bottom feeder	bone	0.920 ± 0.060	1974	NA	NA
Unspecified, top feeder	not specified	0.32 ± 0.030	1989	NA	NA

Fish Species	*Sample Type*	*Maximum Sample Concentration (pCi/g, wet)*	*Year*	*Maximum Sample Concentration (pCi/g, dry)*	*Year*
Unspecified, top feeder	flesh	0.31 ± 0.27	1974	NA	NA
Unspecified, top feeder	bone	1.10 ± 0.077	1974	NA	NA
Unspecified, mixed	not specified	0.125 ± 0.009	1994	NA	NA
Unspecified, mixed	flesh	0.50 ± 0.040	1974	NA	NA
Unspecified, mixed	bone	0.60 ± 0.048	1974	NA	NA
Unspecified	not specified	4.31	1997	NA	NA

Source: BNL SERs 1977B1999; NYSDOH 1996

Table B18. Cesium-137 Concentrations in Fish from Off-Site Control Locations (1973B1999)

Fish Species	*Sample Type*	*Maximum Sample Concentration (pCi/g, wet)*	*Year*	*Maximum Sample Concentration (pCi/g, dry)*	*Year*
Yellow Perch	not specified	0.45	1994	NA	NA
Yellow Perch	whole	0.23 ± 0.05	1998	NA	NA
Yellow Perch	bone/viscera	0.34 ± 0.08	1998	NA	NA
Yellow Perch	flesh/skin	0.43 ± 0.10	1998	NA	NA
Chain Pickerel	whole	0.305	1985	NA	NA
Chain Pickerel	not specified	0.319	1987	NA	NA
Brown Bullhead	flesh/skin	0.66 ± 0.24	1996	NA	NA
Brown Bullhead	bone/viscera	0.28 ± 0.10	1996	NA	NA
Brown Bullhead	whole	0.27 ± 0.07	1996	NA	NA
Brown Bullhead	not specified	1.687	1994	NA	NA
Black Crappie	not specified	0.135	1993	NA	NA
Largemouth Bass	not specified	0.212	1987	NA	NA
Largemouth Bass	whole	0.02	1999	NA	NA
Largemouth Bass	flesh/skin	0.15 ± 0.03	1996	NA	NA
Largemouth Bass	bone/viscera	0.08 ± 0.02	1996	NA	NA
Catfish	not specified	0.30	1988	NA	NA
Pumpkinseed	not specified	0.226	1989	0.902	1989
Pumpkinseed	whole	0.05 ± 0.02	1998	NA	NA
Pumpkinseed	bone/viscera	0.05 ± 0.04	1996	NA	NA
Bluegill	not specified	0.127	1987	NA	NA
Bluegill	whole	0.56 ± 0.11	1996	NA	NA
Bluegill	bone/viscera	0.45 ± 0.10	1996	NA	NA

Fish Species	***Sample Type***	***Maximum Sample Concentration (pCi/g, wet)***	***Year***	***Maximum Sample Concentration (pCi/g, dry)***	***Year***
Bluegill	flesh/skin	0.69 ± 0.17	1996	NA	NA
Golden Shiner	not specified	0.204	1988	0.887	1988
Eel	not specified	0.235	1990	0.783	1990
Eel	whole	0.05 ± 0.01	1996	NA	NA
Carp	not specified	0.19	1991	NA	NA
Carp	whole	0.03 ± 0.01	1998	NA	NA
Brook Trout	not specified	0.105	1987	NA	NA
Darter	not specified	0.056	1990	0.254	1990
Redfin Pickerel	not specified	0.048	1990	0.166	1990
Rainbow Trout	flesh/skin	0.03 ± 0.02	1996	NA	NA
Gizzard Shad	whole	0.02 ± 0.01	1997	NA	NA
White Perch	whole	0.08 ± 0.02	1998	NA	NA
White Perch	flesh/skin	0.08 ± 0.02	1998	NA	NA
Unspecified, bottom feeder	not specified	1.77 ± 0.071	1975	NA	NA
Unspecified, bottom feeder	flesh	0.091 ± 0.014	1974	NA	NA
Unspecified, top feeder	not specified	0.68 ± 0.027	1980	NA	NA
Unspecified, top feeder	flesh	0.18 ± 0.010	1974	NA	NA
Unspecified,mixed	flesh	1.20 ± 0.020	1974	NA	NA
Unspecified	not specified	0.89 ± 0.050	1981	NA	NA

Source: BNL SERs 1977B1999; NYSDOH 1996

Table B19. Gross Beta, Uranium-234, and Uranium-238 Concentrations in Fish from Off-Site Control Locations (1985B1999)

Fish Species	*Sample Type*	*Gross Beta, Maximum Sample Conc.(pCi/ g, wet)*	*Year*	*Uranium-234, Max.Sample Conc.(pCi/g, wet)*	*Year*	*Uranium-238, Max. Sample Conc. (pCi/g, wet)*	*Year*
Unspecified	not specified	12.96	1997	NA	NA	NA	NA
Pumpkinseed	not specified	NA	NA	0.0029 ± 0.0012	1999	0.0019 ± 0.0009	1999
Bluegill	not specified	NA	NA	0.0013 ± 0.0007	1999	0.0013 ± 0.0007	1999

Source: BNL SERs 1977B1999; NYSDOH 1996

Table B20. Inorganic Concentrations in Fish From Off-Site Control Locations (1997)

Fish Species	*Sample Type*	*Cd, Max. Conc.(mg/kg, wet)*	*Cu, Max. Conc.(mg/kg, wet)*	*Pb, Max. Conc.(mg/kg, wet)*	*Hg, Max. Conc.(mg/kg, wet)*	*Ni, Max. Conc. (mg/kg, wet)*	*Ag, Max. Conc. (mg/kg, wet)*
Comparison Values		1.4(RBC-N)	54(RBC-N)	none	0.14 (RBC-N)	27(RBC-N)	6.8(RBC-N)
Largemouth Bass	not specified	0.067	3.54	0.737	0.364	0.222	0.008
Pickerel	not specified	0.074	3.17	0.657	0.197	0.175	0.03
Pumpkinseed	not specified	0.049	1.98	0.762	0.096	0.103	ND
Brown Bullhead	not specified	0.022	2.9	0.653	0.239	0.309	0.01

Source: BNL SERs 1977B1999; NYSDOH 1996

Table B21. Pesticide Concentrations in Fish from Off-Site Control Locations (1997)

Contaminant	*Highest Concentration (mg/kg, fish species, wet)*	*Comparison Value (CV) (mg/kg, fish species)*	*Type of CV*
4,4'-DDE	0.136, largemouth bass0.0202, pickerel0.0724, pumpkinseed0.0433, brown bullhead	0.0093	RBC-C
4,4'-DDD	0.0387, largemouth bass0.00917, pickerel0.10, pumpkinseed0.0401, brown bullhead	0.013	RBC-C

Source: BNL SERs 1977B1999; NYSDOH 1996

Table B22. Cesium-137, Potassium-40, and Strontium-90 Concentrations in Shellfish from Off-Site Control Locations (1987B1999)

Species Sampled	*Year*	*Radionuclide Concentrations pCi/g, wet*		
		Cesium-137	Potassium-40	Strontium-90
Hard shell clam	1987	ND	0.745 (average)	
Clams	1996	ND	1.75 ± 0.89	<0.011
Clams	1997	ND	1.83 ± 0.47	

Source: BNL SERs 1987B1999; NYSDOH 1996

Table B23. Potassium-40 in Deer Collected On Site (1986B1999)

Sample Type	*Maximum Sample Concentration (pCi/g, wet)*	*Year*
Liver	4.72 ± 1.15	1998
Flesh	7.72	1992
Tumor	1.41 ± 0.37	1999

Source: BNL SERs 1986B1999

Table B24. Cesium-137 in Deer From On Site (1986B1999)

Sample Type	*Maximum Sample Concentration (pCi/g, wet)*	*Year*
Liver	14.59 ± 2.88	1998
Flesh	11.74 ± 2.27	1996
Tumor	0.35 ± 0.08	1999

Source: BNL SERs 1986B1999

Table B25. Strontium-90 in Deer From On Site (1986B1999)

Sample Type	*Maximum Sample Concentration (pCi/g, wet)*	*Year*
Liver	<0.10	1996
Flesh	0.04 ± 0.10	1996
Tumor	ND	1999

Source: BNL SERs 1986B1999

Table B26. Potassium-40 in Deer from Off Site (1986B1999)

Sample Type	*Maximum Sample Concentration (pCi/g, wet)*	*Year*
Liver	4.44 ± 1.22	1999
Flesh	6.32 ± 1.46	1998
Thyroid	21.23 ± 18.14	1998

Source: BNL SERs 1986B1999

Table B27. Cesium-137 in Deer from Off-Site (1986B1999)

Sample Type	*Maximum Sample Concentration (pCi/g, wet)*	*Year*
Liver	2.16 ± 0.45	1999
Flesh	4.71 ± 0.80	1997
Thyroid	4.3 ± 2.87	1998

Source: BNL SERs 1986B1999

Table B28. Strontium-90 in Deer from Off Site (1986B1999)

Sample Type	*Maximum Sample Concentration (pCi/g, wet)*	*Year*
Liver	<0.04	1996
Flesh	<0.04	1996
Thyroid	ND	1998

Source: BNL SERs 1986B1999

Table B29. Potassium-40 in Small Mammals from On Site (1986B1993)

Mammal Species	*Sample Type*	*Maximum Sample Concentration (pCi/g, wet)*	*Year*
Fox	flesh	3.380	1992
Fox	liver	1.470	1992
Opossum	flesh	1.740	1992
Opossum	liver	2.580	1992
Cat	flesh	3.220	1992
Cat	liver	1.750	1992
Raccoon	not specified	2.231	1986
Raccoon	flesh	2.760	1992
Raccoon	liver	1.800	1992

Source: BNL SERs 1986B1999

Table B30. Cesium-137 in Small Mammals from On Site (1986B1993)

Mammal Species	*Sample Type*	*Maximum Sample Concentration (pCi/g, wet)*	*Year*
Raccoon	not specified	1.380	1993
Raccoon	flesh	0.480	1992
Raccoon	liver	0.280	1992
Cat	flesh	0.513	1992
Cat	liver	0.339	1992
Opossum	flesh	0.809	1992
Opossum	liver	0.729	1992
Fox	flesh	8.170	1992
Fox	liver	2.980	1992

Source: BNL SERs 1986B1999

Table B31. Cesium-137 in Small Mammals from Off Site (1986B1993)

Mammal Species	*Sample Type*	*Maximum Sample Concentration (pCi/g, wet)*	*Year*
Raccoon	not specified	0.262	1993

Source: BNL SERs 1986B1999

Table V1. Radionuclides in edible vegetation from off site (1984B1999)

Contaminant	*Sample Type*	*Maximum Sample Concentration (pCi/g, wet)*	*Year*
Cesium-137	Strawberries	2.22	1992
Potassium-40	Carrot leaves	6.59 ± 1.10	1996
Beryllium-7	Not specified	0.990	1984
Strontium-90	Carrot leaves	0.040 ± 0.008	1996

Source: BNL SERs 1984B1999

Table V2. Radionuclides in Inedible Vegetation from On Site (1984B1999)

Contaminant	*Sample Type*	*Maximum Sample Concentration (pCi/g, wet)*	*Year*
cesium-137	Tree leaves	1300	1992
potassium-40	Grass	13.90	1990
Beryllium-7	Grass	4.925	1994
Thorium-228	Grass	0.072	1985
Thorium-232	Tree leaves	18.60	1992
Radium-226	Grass	0.469	1988
Cobalt-60	Tree leaves	0.23	1992

Source: BNL SERs 1984B1999

Appendix D. Hydrogeology and Modeling

Evaluation of Groundwater Contaminant Migration and Potential Exposure at Brookhaven National Laboratory, Upton New York

Summary

Groundwater contaminants from the Brookhaven National Laboratory and other off-site industrial sources have been detected in off-site residential drinking water wells. Most of the contaminants are VOCs (1,1,1-TCA; 1,1-DCA; Ctet; Chloroform; EDB; PCE; and TCE). Tritium and strontium-90 have also been detected, but at concentrations much lower than levels of public health concern. The off-site contaminants were initially detected in 1985, and ongoing monitoring has determined the current distributions. Although residents were provided with alternate water during the contaminant discovery process, the distribution and concentrations of contaminants before 1985 is unknown. This contaminant transport modeling study provides estimates of the rate of contaminant migration and estimated concentrations at off-site locations before the contaminant plumes were discovered in 1985.

Eight contaminant plumes have been identified adjacent to BNL facility. Seven of the plumes originate from BNL sources and the eighth from a now defunct off-site industrial facility. Information from source characterization and groundwater monitoring studies was used to derive the approximate times of origin and source locations of the plumes. This information was used to determine significant plume characteristics such as plume duration, distance to BNL boundary, distance to nearest down-gradient wells, and total plume length.

This contaminant transport evaluation is based on 1-D and 3-D analytical groundwater flow equations. The 1-D model is used to evaluate vertical transport, and the 3-D model, lateral transport. Hydrogeological parameters used in the models are derived from several different groundwater monitoring and modeling reports developed by DOE and its contractors, and other published sources. Input variables include groundwater velocity (hydraulic conductivity/porosity x hydraulic gradient), dispersion in X, Y, and Z directions, aquifer thickness, porosity, recharge, and contaminant half- life.

The 3-D model utilized a 6000 x 6000m lateral grid and a vertical dimension of 100m. Analyses were run in a deterministic mode using hydrogeological parameter means to evaluate contaminant distributions over the entire grid. Monte Carlo analyses were run to evaluate contaminant concentrations at points 1500m, 1800m, and 2500m down-gradient of a source at 10-year intervals.

Hydrogeological evaluations of BNL site indicate that downward vertical flow predominates from the ground surface of BNL facility, with southward flow at depth. The 1-D vertical flow model indicates that it takes about four years for contaminants to migrate to a 50 m depth in the aquifer. Consequently, the contaminant transport models used two different source release scenarios that include a four-year time lag for introduction of contaminants to a 50 m depth. A constant release scenario assumed that it took four years to reach a constant concentration of 5000 μg/l (μg/l=ppb) at 50m depth (1 μg/l at year 0; 500 μg/l at year 3; and 5000 μg/l for years

4 to 50). The declining source release scenario emulated a waste spill with the source concentration declining after 9 years (1 μg/l at year 0; 500 μg/l at year 3; 5000 μg/l for years 4 to 9; and 1000 μg/l l for years 10-50).

Contaminant migration rates calculated from plumes with known source times and locations range from about 105 to 120 m/year. The average groundwater transport velocity was adjusted (within the reported range) so that modeled plume migrations matched measured plume migration distances and durations. In the constant source release scenario, down-gradient contaminant concentrations reach a constant level after 20 years for the 1500m location, and after 30 years for the 1800m and 2500m locations. For the five contaminant plumes that match this release scenario, contaminant concentrations have probably never been higher than 1985B87 values, and exposure at those locations was not likely before 1987.

For two plumes that fit the declining source release scenario (OU-IV waste solvent spill and OU-I former landfill plume), contaminant concentrations at specific locations first increase and then decrease as the high concentration pulses migrate past those locations. Contamination has been present in limited off-site areas since about 1980. However, because the high concentration contaminant zones occur at depths below most residential wells, it is unlikely that contaminant concentrations in residential wells have ever been significantly higher than levels reported by the Suffolk County Department of Health Services. A public health consultation by the Agency for Toxic Substances and Disease Registry has determined that exposure to contaminants at reported levels is not of public health concern.

Introduction

Process operations and disposal of hazardous materials have contributed to groundwater contamination at the Brookhaven National Laboratory. Groundwater monitoring has identified eight contaminant plumes that have affected or may potentially affect residential drinking water wells in neighborhoods adjacent to the laboratory (an additional plume, the HFBR tritium plume, has not migrated off-site). Seven of these eight plumes originate from BNL contaminant sources and one from an off-site source. Although the neighboring community has been provided with an alternate water source, it is unknown whether the residents were exposed to contaminants from BNL before the discovery of the off-site contamination and the subsequent provision of alternate water. If such exposure did occur, the duration and concentrations of such exposure are also unknown.

DOE and its contractors have conducted several groundwater modeling analyses that seek to define aquifer properties and to predict the response of the groundwater system to remedial actions (CDM Federal Programs, 1995; CDM, 1996; ITC, 1998). While these models are good representations of the hydrogeological system and provide valuable information about hydrogeological parameters, they do not address the early progression of the contaminant plumes after contaminant introduction, but before detection in off-site wells.

This analysis addresses two questions concerning exposure to groundwater contaminants in neighborhoods adjacent to the Brookhaven National Laboratory. These questions are (1) how long were off-site residential wells contaminated, and (2), could past contaminant concentrations have been higher than the concentrations detected in a series of water tests taken between 1985 and 1995 (Suffolk County, Dept. of Health, 1996; and Suffolk County, Dept. of Health, 1990). The results of this modeling report are applicable to any of the VOCs determined to be contaminants of concern in off-site residential wells (chloroform, 1,1-dichloroethylene, ethylene dibromide, perchloroethylene, 1,1,1-trichloroethane, and trichloroethylene; ATSDR, 1999). Two radionuclides (tritium and strontium-90) have never been detected in residential wells at levels of potential health concern.

Table 1 lists the eight plumes that have contributed to contamination of drinking water wells and the primary contaminants of each plume. The table also lists the estimated duration of each plume (from source introduction to 1997) and the distance from each plume source to off-site residential wells. Source durations, as listed, conservatively overestimate the travel times of the contaminant plumes. Durations are based on time of initiation of source area (i.e., the opening of a landfill or hazardous waste facility). These waste facilities operated for several years, and contaminants may not have been introduced into the source area at the opening. It may also take several years before the contaminants leach out of the source area and into the groundwater. Consequently, the durations assume contamination was co-incident with facility opening and represent maximum migration times.

Distances from source origins to site boundary and closest residential wells (predominately along Carleton Dr. E. and North Street) were measured by use of the ARC/VIEW measurement tool parallel to the direction of groundwater flow (170 to 175 degrees south). Although source locations have been characterized for most of the plumes, the OU-III plume contains several sources with both known and unknown source locations. . For example, several plumes probably originated during World War II-era operations (e.g., the Bldg. 96 truck wash site and the unknown CCl-4 source).

Although there is some uncertainty in assigning a specific time and location of origin to individual plumes, there has been sufficient characterization of most of the sources to permit estimation of durations of plume migration and distances of source origins to residential well locations. Ongoing monitoring has also characterized the current distribution of the contaminant plumes. There is a great deal of uncertainty associated with the initiation of contaminant introduction into the groundwater system and consequently, the duration of plume migration. The plume durations listed in Table 1 represent a maximum duration and represent an estimate of contaminant migration that is protective of public health.

Table 1. Plume durations

PLUMES or SOURCES	***Contaminants***	***Plume Duration***	***Source to fence length***	***Source to off-site wells length***	***Total Plume Length***
1) Precision Concepts	TCA	10B12 years	Off site source	500 mCarleton Dr.	1150 m
2) OU-IIIMultiple Sources a) Bldgs. 96, 208	PCE, TCA, Ctet, TCE	53 years	1400 m	2400 mCarleton Dr.	3900 m
b) Unknown	CCl-4	53 years	3100 m	3900 m	4400 m
3) OU-IV Waste Solvent Spill	TCA, TCE, PCE, DCE, BTEX	20 years	1500 m	2000 m Carleton Dr.	2000 m
4) Former Landfill	TCA, TCE, PCE, DCE,	50 years	1300 m	1600 mNorth St.	2100 m
5) Haz. Waste Mgmt. Area	TCA, H-3	>35 years	1300 m	1600 mNorth St.	2100 m
6) Current Landfill Area	TCA	28 years	1300 m	1600 mNorth St.	2100 m
7) Biology Fields	EDB, TCA, H-3	Unknown (25 years)	800 m	1200 mNorth St.	1500 m
8) Sewage Treatment Plant	TCE, TCA	Unknown	400 m	1600 m	1900 m

Table 1. Distances and durations of eight groundwater contaminant plumes at or adjacent to BNL. Distances are measured to areas of closest residences for each plume using the ARC/VIEW measurement tool. Durations are from several source characterization references (CDM Federal Programs 1995; CDM Federal Programs, 1996b; ITC, 1998).

Off-site contaminants have been measured in a number of residential and monitoring wells. However, there is very little information about off-site contaminant concentrations before 1985B87. The groundwater transport models will be used to evaluate how long contamination may have been present in off-site areas and whether contaminant concentrations could have been greater than the earliest measured values. As such, it is necessary to determine the critical distances and times for evaluation. The shortest flow paths and longest plume duration present the greatest potential for contaminant exposure. From Table 1, the critical flow paths are: plume 2 (OU-III) with a path length of 2400 m and a potential duration of greater than 50 years; plume 4 with a path length of 1600 m and a duration of 45 years; and, plume 5 with a path length of 1600 m and a potential duration of more than 35 years. Contaminant concentrations will be estimated for path lengths of 1500 m, 2000 m, and 2500 m for 10-year time intervals.

Hydrogeological Setting

Groundwater from BNL site flows predominately southward in the unconfined to semi-confined Upper Glacial aquifer. Although net groundwater transport from BNL is southward, BNL facility overlies a deep flow recharge zone such that initial groundwater flow is downward (ITC, 1998).

Under and south of BNL site, the Pleistocene-age Upper Glacial aquifer is from 30 to 60 m in thickness (CDM, 1996). The thicker portions of the glacial deposits are present as valley fill where fluvial erosion has removed the underlying Gardiners Clay and Cretaceous-age Magothy Formation. Bore hole information indicates that the thickness of the Upper Glacial aquifer varies between 35 and 55 m within the area of groundwater contamination (CDM, 1996).

Most of the Upper Glacial aquifer is unconfined such that the upper boundary of the saturated groundwater system is defined by the water table, which is 5 m or less below ground surface. Water table elevations are significantly affected by recharge from settling basins and discharges to streams and pumping wells (ITC, 1998). The Upper Glacial aquifer is partially separated from the underlying Magothy aquifer by the Gardiners Clay and/or Cretaceous-age clays of the Monmouth Group (ITC, 1998). The Upper Glacial aquifer is predominately sandy to gravelly permeable glacial outwash deposits with some finer-grained glacial lake deposits and near-surface silts and clays (CDM, 1996). Although the Magothy aquifer is in direct contact with the Upper Glacial aquifer over a portion of BNL site, groundwater flow occurs preferentially in the Upper Glacial aquifer as a result of much higher permeabilities (ITC, 1998).

Precipitation averages about 122 cm/year, with about 58 cm/year recharge to the aquifer system, and most of the remaining precipitation is lost as evapo-transpiration or surface runoff (CDM Federal Programs, 1996). Surface streams are controlled by groundwater discharge from the Upper Glacial aquifer, which constitutes about 95 percent of the base flow. Upper reaches of the Peconic River and other area streams have intermittent flow and often go dry when the water table is lower than the stream channels (ITC, 1998).

Methods

Contaminant plume migration was evaluated by use of one-dimensional and three-dimensional analytical groundwater flow models with Monte Carlo analysis to address the inherent variability of hydrogeological parameters. The analytical models are part of the ACTS (Analytical Contaminant Transport System) software package developed by the Georgia Institute of Technology for ATSDR (Aral 1998). The analytical equation, required parameters, and citations are presented in Attachment 1. Results of the contaminant transport modeling are compared with contaminant concentrations from offsite wells to ensure that model results reflect the current distribution of the contaminant plumes. Assuming that the model results do describe current conditions, then the model will be used to evaluate plume migration and contaminant concentrations in the years before 1997.

Evaluation of hydrogeological conditions at BNL site indicates that initial hydraulic flow is downward (ITC 1998). The time required for this initial downward flow is estimated by use of a one-dimensional model with relevant vertical hydrogeological parameters (Table 2). The time required for downward transport is represented by a time-lag in introduction of contaminants into the three-dimensional model.

The specific three-dimensional transport equation used in this report assumes an infinite, saturated aquifer with a finite/patch contaminant source and constant dispersion coefficient (Aral 1998). Although several of the plumes modeled at this site contain multiple sources, these multiple, discrete sources can be represented by a source of finite length perpendicular to the direction of groundwater transport. These models assume that the aquifer system is relatively shallow, that vertical dispersion is minimal, and that the contaminant is well mixed in the vertical direction.

The model was run in both deterministic and Monte Carlo modes. The deterministic mode calculates contaminant transport at all grid points in x-y, x-z, and y-z locations. The model grid was a 6000m by 6000m area at 500 m lateral nodes and 10 m vertical nodes. Ten year time steps were calculated for a 0 to 60 year time frame. The deterministic mode uses means of hydrogeological parameters as single input values for the analytical equation and results in a single Abest estimate@ of contaminant concentration at each node.

The Monte Carlo or probabilistic analysis uses multiple solutions to the transport equation and varies the value of the hydrogeological parameters for each solution. The specific values used depend on the frequency distribution of the parameter such that average values are used more frequently than the more rare occurrence of minimum or maximum values. This analysis used 500 iterations of the transport equation, resulting in a probability distribution of a contaminant concentration at specific locations and depths down-gradient of the plume sources.

The aquifer parameters used in the ACTS model are based on values reported in various BNL reports and hydrogeological reference documents. The ACTS Monte Carlo simulation uses parameter ranges and probability distributions in multiple analyses to account for the natural variability present in these parameters. Because most of the hydraulic parameters are directly controlled by the distribution of sedimentological properties and such sediment properties usually vary in a lognormal distribution (USEPA 1991; Myers 1997), most hydraulic properties used in the Monte Carlo simulation are assumed to vary lognormally.

Hydraulic Conductivity: Ranges of horizontal and vertical hydraulic conductivity values were reported as part of a Groundwater Modeling Report (CDM Federal Programs, 1996). These values included measurements from pumping tests, other values reported in the literature, and average values used in other groundwater models. The values presented in that report were converted from ft/day to meters/year and used to generate the distribution of groundwater velocities with corrections for retardation (contaminant transport velocity = hydraulic conductivity/porosity x hydraulic gradient/retardation factor). Specific discharge or Darcy Velocity does not include the porosity term or the retardation factor (Darcy Velocity = hydraulic conductivity/porosity x hydraulic gradient/retardation factor). Hydraulic conductivities and the resulting groundwater velocities are assumed to vary in a triangular distribution.

Table 2. Hydrogeological Flow Parameters

	Mean	***Range***	***Standard Deviation***	***Freq. Distribution***
Darcy Velocity	26 m/yr	4B36 m/yr	7.2	Triangle
Longitudinal Dispersion Coef.	237 m2/yr	30B910 m2/yr	72.0	Lognormal
Lateral Dispersion Coef.	24 m2/yr	3B91 m2/yr	8.5	Lognormal
Vertical Dispersion Coef.	3.8 m2/yr	0.4B5.3 m2/yr	1.2	Lognormal
Aquifer Thickness	60m	40B80m	8.2	Normal
Aquifer Porosity	0.25	0.18B0.30	0.03	Lognormal
Contaminant Half-Life	70 years	55B90 years	4.4	Lognormal
Aquifer Recharge	0.58 m/yr			

Table 2. Values of hydrogeological parameters used in contaminant transport models. Mean values are used for deterministic analyses and frequency distributions are used in Monte Carlo simulations. (Darcy velocity=specific discharge=hydraulic conductivity x hydraulic gradient)

The average groundwater velocity used in this analysis is higher than the average values in the site reports for several reasons. First, although velocities may exhibit a substantial range, transport will preferentially occur within the zones of lowest resistance or higher velocities. Second, documentation of the waste solvent plume (OU-IV) indicates that it migrated 7500ft (2286m) over a period of 20 years (BNL/ERD 1998), which translates to a contaminant transport rate of approximately 114m/year.

Hydraulic Gradient: The hydraulic gradient is the change in water table or aquifer elevation over distance (either horizontal or vertical). Relatively consistent values of 0.001 have been reported and used in other models and are used in this report to convert horizontal hydraulic conductivity values to groundwater velocities (CDM Federal Programs 1996; ITC 1998). A vertical hydraulic gradient of 0.05 (Geraghty & Miller 1996) was used for evaluating vertical transport in the one-dimensional model.

Dispersion: Dispersion is the process of mechanical mixing and molecular diffusion that tends to disperse a solute in conjunction with advective transport. Dispersion occurs in three dimensions (longitudinal, lateral, and vertical). ITC (1997) indicates that 9.1 m is a reasonable estimate of the longitudinal dispersivity and that the lateral dispersion is 1/10 and vertical dispersion 1/100 of the longitudinal dispersion. The analytical equations in ACTS use dispersion coefficients, which are the product of dispersivity and groundwater velocity. Dispersivity coefficients are assumed to vary in a lognormal distribution.

Published values of dispersivity for glacial tills vary considerably from 0.05 to 21m (Gelhar and Welty 1992). The dispersivity value of 9.1m is Aconsidered reasonable for the aquifer system, based on contaminant migration assessments conducted in similar geologic settings and a published range of typical values@ (ITC, 1997). Sensitivity analyses indicate only a 10 percent change in annual contaminant migration rates (100 to 111 m/yr) as dispersion coefficient values vary from 170 to 2100 m2/yr (respectively).

Aquifer Thickness: Estimates of aquifer thickness are based on bore-hole data and cross-sections presented in several reports (CDM Federal Programs 1996; ITC 1998). Model aquifer thickness values are comparable to measured values that range from 35 m to more than 100 m and are estimated to have an average thickness of about 50 m. It is assumed that aquifer thickness varied with a normal frequency distribution.

Aquifer Porosity: Measured porosity values for the Upper Glacial aquifer vary from 0.18 to 0.36, with an average value of 0.25 (CDM Federal Programs 1996; ITC 1998). These values were utilized in the model and are assumed to vary with a lognormal distribution.

Recharge: A constant recharge value of 58 cm/year was used in the analysis. Although this value changes from year to year with precipitation, 58 cm/yr is the long term average precipitation rate. Use of the long term average is justified on the basis of the sixty year period of this analysis.

Source Concentration: Characterization of groundwater contaminant sources has shown concentrations of specific VOCs up to 5,000 Cg/l (CDM, 1996; ITC, 1998). Two source release scenarios are used in this analysis. In the first, a constant release is assumed, with the source concentration of 1 Cg/l at year 0; 500 Cg/l at year 3; and 5,000 Cg/l for years 4 to 50. In the second scenario, a single spill is assumed with 1 Cg/l at year 0; 500 Cg/l at year 3; 5,000 Cg/l for years 4 to 9; and 1,000 Cg/l for years 10 to 50.

The contaminant source geometry (3-D analysis) is assumed to occur along a 30 m line perpendicular to groundwater flow with a center at 50 m below ground surface and an overall thickness of 20 m. Although the specific source geometry is unknown, this dispersed geometry at depth is reasonable due for most sources originating from waste pits, the downward flow gradients in the source areas, and VOC densities greater than water.

Retardation and Contaminant half-life: Transport of groundwater contaminants is often impeded by interactions with aquifer materials. The rate at which contaminant transport is retarded depends on the specific contaminant and the chemistry of the aquifer materials. Most of the contaminants at BNL are volatile organic compounds (VOCs) that are relatively soluble and have minimal retardation. Retardation factors vary from about 1 to more than 4. A conservative retardation factor of 1.1 is used to estimate contaminant transport rates (ITC 1998). Higher retardation factors may reduce measured downgradient contaminant concentrations.

Contaminant half-life is the rate at which contaminants are chemically altered or degraded by interaction with aquifer materials and microbial organisms. Half-lives are also contaminant-specific and vary considerably with aquifer properties. Experimental half-lives of 1,1,1-TCA have been reported to range from 1 year to no degradation (ATSDR 1990) and for PCE from 6B10 years to no degradation. 1,1-DCA can be formed from the degradation of 1,1,1-TCA. The down-gradient concentrations of 1,1-DCA suggest that significant degradation is occurring within the time frame of these contaminant plumes. This analysis uses a half-life for VOCs that ranges from 55 to 90 years, with a 70 year average and a lognormal frequency distribution.

Results

The modeled rate of downward contaminant transport is shown in Figure 1. This figure indicates the amount of time required for a 5,000 μg/l contaminant source, released at the surface, to migrate to different depths in the aquifer (10B50 m below ground surface). Groundwater monitoring data indicate that the highest contaminant concentrations at on-site locations are between depths of 30 to 50 m, with maximum concentrations at about 50 m below ground level (bgl) at the site boundary (BNL/ERD, 1998). Figure 1 shows that it takes about 3 years for measurable contamination to occur at the 50 m depth and only 4 years before the contaminant plume has reached its maximum value at that depth. Consequently, contaminant introduction in the 3-D model, centered on a 50 m depth, will utilize concentrations of 1 Cg/l concentration at year 0; 500 Cg/l at year 3; and 5,000 Cg/l for years 4 to 50.

Contaminant breakthrough curves were calculated for 1500m, 2000m, and 2500m distances downgradient of source by use of the 3-D model in a deterministic mode (using mean values for all hydrogeological parameters). The breakthrough curves for those down-gradient locations at 30 and 40m depths are presented in Figure 2; they show the amount of time required for contaminant migration to reach each point. Notice that the contaminants reach each depth/distance location at the same time, but that peak concentrations are much higher for the locations at 40m depths relative to the 30m depths.

It takes about 10 years for the contaminant plume to travel 1500m down-gradient of the source. After 20 years, contamination concentrations level off at the 1500m location and after 30 years for the 2000m and 2500m locations. At the 2000m location (40m depth), appreciable contaminant concentrations occur after 20 years and reach an asymptotic maximum of 450 Cg/l after 30 years. Maximum concentrations for the 2000m location (30m depth) are about 250 Cg/l after 30 years. At the 2500m location, contamination is present after 20 years, increasing rapidly to about 300 Cg/l for the 40m depth and 200 Cg/l for the 30m depth after 30 years.

Table 3 lists the 50th and 95th percentile concentrations derived from the Monte Carlo simulation. The 50th percentile values are similar to the values shown in the breakthrough curves (Figure 2). In Table 3, maximum contaminant concentrations are observed at the 1500m and 1800m locations after 30 years and at the 2500m location after 40 years. All these estimates of plume concentrations are evaluated at a depth of 30m and along the centerline of the plume.

Table 3. Estimated Concentrations at Downgradient Locations at 30m depth

Duration of Plume	*1500 m50th % – 95th %*	*1800 m50th % – 95th %*	*2500 m50th % – 95th %*
10 years	0 0.31	0 0	0 0
20 years	262 488	13 410	0 28
30 years	324 493	271 427	143 307
40 years	324 493	272 427	178 307
50 years	324 493	272 427	178 307

Table 3. Estimated concentrations at specified distances downgradient of source and durations of plume migration. All concentrations are in Cg/l and are estimated by use of Monte Carlo simulation with 500 iterations. Concentrations listed are the 50th and 95th percentiles of the 500 iterations. All concentrations are calculated at a depth of 30m and are based on a 1Cg/l source at year one; 500 Cg/l at year three, and 5,000 Cg/l for years 4 to 50.

The locations of BNL and Suffolk County offsite monitoring wells with contaminants detected are shown in Figure 3, and the associated contaminant concentrations are listed in Table 4. Most of the measured contaminant values are lower than the modeled values with the exception of carbon tetrachloride in wells 000B112, 000B130, 000B154, and 000B161. All these higher measured values are attributed to the OU-III (a; bldg. 96) plume except the 000B154 samples, which are attributed to the former landfill plume. The samples with high carbon tetrachloride concentrations (>800 μg/l) are all taken from depths greater than 50 m.

Modeled values at the 30m depth (Table 3) are consistently higher than measured values from both monitor and residential wells, with the exception of the carbon tetrachloride samples. However, the down-gradient migration distance of the measured plumes is directly comparable to the modeled plumes. The waste solvent spill plume (OU-IV) has migrated a distance of 2000m over 20 years (1977 to 1997; BNL/ERD 1998). Figure 4 shows the modeled distance at 20 years to be approximately 2000m (for the 5μg/l contour). Similarly, the OU-III plume has migrated approximately 5300m over an estimated 52-year duration (5 μg/l contour; BNL/ERD, 1998), while the modeled 50-year migration has been approximately 5100m (5 μg/l contour; Figure 4). Within the uncertainty of the time of origin of the contaminant sources and of the hydrogeological parameters, the modeled and measured plume migration rates are similar, a fact that allows use of the modeled plume behavior to predict historic trends of groundwater contamination.

In the constant source scenario illustrated in figures 2 and 4, historic contaminant concentrations were probably never higher than the levels detected in monitoring and residential wells. However, if a declining source concentration scenario is assumed, contaminant concentrations before 1985 may have been higher than values measured after 1985 for wells located more than 1500m downgradient of the sources. Figure 5 illustrates the breakthrough curves, assuming source concentrations declined to 1000 Cg/l for years 9B50. The breakthrough curves for the 2000m and 2500m locations peak at 30 years after source introduction and then decline to constant concentrations of less than 100 Cg/l as a high concentration contaminant pulse migrates downgradient.

Although the surficial source releases have been controlled, monitoring information indicates that the on-site contaminant concentrations at depth have not declined (BNL/ERD 1998). Monitoring data suggest that a declining source release is appropriate only for the OU-IV waste solvent spill plume and for the OU-I former landfill/animal/chemical pits and glass holes plume. These plumes do show distinct contaminant pulses with higher down- gradient concentrations. However, for the OU-IV plume, the high concentration pulse has currently not migrated off-site (BNL/ERD 1998). Source concentrations for the other plumes are higher at up-gradient locations compared to down-gradient locations, indicating that a constant source release scenario is more appropriate than a declining source release scenario.

Site-wide hydrogeological studies and contaminant monitoring indicate that initial groundwater flow from BNL is downward, followed by southward lateral transport (BNL/ERD 1998). This modeling analysis reproduces this flow pattern by introducing a four-year time lag for source introduction centered at 50m below ground level. Subsequent lateral migration of modeled contaminant plumes produces plume migration rates that are very close to monitored plume migration rates. These results indicate that modeled plume behavior can be used to interpolate contaminant behavior prior to establishment of the groundwater monitoring network.

Figure 6 shows the 1997 locations of the plumes based on monitoring results in the 1997 site-wide groundwater monitoring report (BNL/ERD, 1998). The leading edge of the plumes (5 Cg/l contour) is shown for 1997 and prior 10-year periods by subtracting the 10-year plume migration rate (~100 m/yr * 10 yr = 1000 m) from each plume. This figure shows that contaminants had migrated to areas of potential contamination for the OU-III plumes and the FLF plume some time between 1977 and 1980. However, this figure ignores the vertical distribution of the plumes and depths of residential wells.

The depth zonation of contaminant concentrations is supported by the results of the analytical model. Figure 7 is an X-Z (distance-depth) plot of modeled concentration contours after 30 years of plume migration in the declining source release scenario. This plot is taken along the centerline of the plume and calculated in a deterministic mode (using average hydrogeological parameters). This figure shows a pulse of high concentrations migrating down- gradient and the effect of depth on those contaminant concentrations. Most of the high concentration portion of the plume is below 30m depth. The depth zonation of the measured groundwater plumes will also be constrained by preferential flow in permeable units. The model assumes a homogeneous aquifer which increases estimated vertical dispersion. Note the exaggeration of the vertical scale in Figure 7. This modeled plume behavior closely matches monitoring results for the former landfill plume (BNL/ERD 1998).

Monte Carlo analyses of the declining release source scenario calculated at a depth of 30m produce modeled results that closely match monitored results (Table 5). The highest estimated contaminant concentration for this scenario is located 1500m down-gradient of the source after 20 years. The 50th percentile value is 166 Cg/l, while the 95th percentile value is 449 Cg/l.

Table 4. Estimated Concentrations Using a Declining Source Scenario

Duration of Plume	***1500 m50th % –95th %***	***1800 m50th % – 95th %***	***2500 m50th % – 95th %***
10 years	0 0.03	0 0	0 0
20 years	166 449	13 401	0 28
30 years	71 150	63 150	53 226
40 years	66 102	56 93	40 73
50 years	65 99	54 85	37 63

Table 4. Estimated concentrations at specified distances down-gradient of source and durations of plume migration. All concentrations are in cg/l and are estimated by use of Monte Carlo simulation with 500 iterations. Concentrations listed are the 50th and 95th percentiles of the 500 iterations. All concentrations are calculated at a depth of 30m and are based on the declining source scenarioC1cg/l source at year one; 500 cg/l at year three; 5,000 cg/l for years 4 to 9; and 1,000 cg/l for years 10 to 50.

Discussion

This report presents the results of a groundwater modeling study that estimates the migration of the contaminant plumes and the potential plume concentrations in the years before the contamination was discovered. The results of this modeling report are applicable to any of the VOCs determined to be contaminants of concern in off-site residential wells (chloroform,

1,1-dichloroethylene, ethylene dibromide, perchloroethylene, 1,1,1-trichloroethane, and trichloroethylene; ATSDR, 1999). Two radionuclides (tritium and strontium-90) have never been detected in residential wells at levels of potential health concern, and modeled concentrations would be additionally reduced by radioactive half-lives that are more rapid than the 70-year average used in the model (12.5 years for tritium and 28.6 years for strontium-90).

The most likely results of this analysis indicate that it is unlikely that groundwater contaminants had migrated to areas of potential off-site exposure prior to 1987 for five of the eight plumes illustrated in Figure 7 (plumes 3,5,6,7, and 8). According to the results of this analysis, portions of plume 2 and plume 3 had reached areas of potential exposure between 1977 and 1980. The source of contamination from the Precision Concepts plume (plume 1) is only about 500m from residential wells, and contaminants from that source likely reached residential wells less than five years after source introduction into the aquifer.

Contaminant concentrations from plume 2, assuming a constant source release, were never higher than measured values. In the constant source release scenario, the modeled values increase to an asymptotic maximum and were never higher than monitored values. However, a declining source concentration scenario (e.g., a contaminant spill event such as the OU-IV waste solvent spill) creates a high concentration pulse that migrates down-gradient. As this pulse migrates past a point, contaminant concentrations increase and then decrease. This type of source scenario is likely for only two of the eight BNL plumes.

The contaminant concentrations derived by use of the analytical transport equation at a 40m depth are generally higher than those detected in either residential or monitoring wells. Modeled concentrations at a 30m depth are comparable to measured values in residential and monitor wells (ATSDR, 1999). Monitoring data indicate that the initial movement of the contaminants is downward. Although knowledge of the depth of residential wells is limited, the data available indicate that most residential wells are relatively shallow, with depths between 30 and 37 m, while the zones of maximum contamination have migrated to depths of 50 m or more (BNL/ERD 1998).

The most significant exception to the depth zonation of contaminant concentrations is the Precision Concepts plume, which has not migrated vertically to the same extent as BNL-originated plumes because vertical hydraulic gradients are much higher in the vicinity of BNL contaminant sources (Geraghty & Miller 1996). Residential wells down-gradient of the Precision Concepts plume also have the highest contaminant concentrations. Because the Precision Concepts plume does not migrate vertically to the same extent as plumes originating on BNL facility, the results of this model are not directly applicable to the Precision Concepts plume. In addition to differences in well and plume depths, the modeled plume concentrations were derived for the exact centerline of the plume, resulting in a maximum plume concentration. Wells located off the plume centerlines will have lower than modeled concentrations.

The contaminant half-life used in the analytical model (70 year average) is quite conservative for VOCs. The presence of 1,1-DCA and chloroform at down-gradient locations indicates that degradation of 1,1,1-TCA and carbon tetrachloride (respectively) are significant with respect to the durations of the plumes. Use of a shorter half-life will lead to lower down-gradient plume concentrations. It is also important to point out that the retardation of the specific VOCs may be higher than assumed for the model. Retardation factors are specific to individual contaminants and to the aquifer materials. For this analysis, the retardation factors are integrated into a composite groundwater velocity. While total contaminant migration rates of modeled and monitored plumes are comparable, increased retardation of specific contaminants would lead to decreased down-gradient concentrations of those contaminants.

Several other factors may also lead to reductions in down-gradient plume concentrations. For example, release of contaminants from landfills, leaking pipes, etc. may have been much more gradual than the source term used in the models. A slower source release will also lead to lower down-gradient concentrations. Additionally, monitoring of on-site production wells has indicated the presence of contaminants several years before detection of the off-site contamination. Removal of contaminants by on-site wells will reduce down-gradient contaminant migration for the limited capture area of those wells. Similarly, this modeling analysis ignores potential effects from the several pump-and-treat extraction systems along the facility boundary. However, these systems were not in place until late 1996, and they did not affect plume migration before that time.

One factor that could lead to increased contaminant concentrations relative to the modeled concentrations is the addition or co-mingling of plumes. As a result of the proximity of several of the OU-III plume sources, the measured concentrations reflect the addition of those plumes. The modeled plume concentrations do not account for the addition of co-mingled plumes. However, plume concentrations are generally much lower along plume margins, so that co-mingling along plume margins will not produce concentrations that exceed centerline concentrations. Measured contaminants from residential and monitoring wells do not have concentrations that reflect co-mingling of the high concentration zones of plumes (2 times plume centerline values).

The agreement between measured and modeled plume distribution and concentrations indicates that the results of this analysis are relevant to understanding the rates of plume migration. The contaminant concentrations for several different source release scenarios, down-gradient locations, and aquifer depths were estimated by use of both deterministic and Monte Carlo modes. Contaminants migrated laterally to the area of residential wells beginning about 1980, or about 5B7 years before initial measurement of contaminants in residential wells.

High concentration pulses have migrated down-gradient for several plumes. Although these pulses present the potential for historical contaminant concentrations that exceed recently measured values, monitoring data and the results of this analysis indicate that the high concentration zones are deeper than residential well depths. It is unlikely that historical contaminant concentrations for the other six plumes have ever exceeded recently measured values.

Conclusions

Eight groundwater contaminant plumes have been detected in the vicinity of the Brookhaven National Laboratory. Seven of these plumes originate from BNL facility, and all eight plumes have migrated to areas of potential exposure. Contaminants were detected in off-site drinking water wells beginning in 1985, and residents were provided with water filters and later with hook-ups to an alternate water source. This study uses an analytical groundwater flow model to evaluate contaminant concentrations and distributions at areas of potential exposure prior to off-site detection of the plumes.

Although several different contaminants have been detected, most of these are VOCs have similar physical properties so that behavior of the different plumes will be very similar. Because all the plumes are adjacent, it is further assumed that hydrogeological properties for the different plume areas are similar. Differences in the plumes are based on distance from plume origin to area of potential exposure and duration of plume migration (based on time of contaminant release at source). Distances of plume migration to areas of potential exposure range from 500 to 3900 m, and migration times from 12 to 53 years.

Initial transport of contaminants from BNL sources is downward.. 1-D vertical modeling indicates that it took about 4 years for contaminants to migrate downward to 50m depth. Including time for vertical transport, contaminants have been migrating southward at a rate of 100 to 125 m/yr. Horizontal contaminant transport is occurring predominantly within the zones of higher hydraulic conductivity.

Assuming a constant source concentration (at 50m depth), concentrations at residential wells were never significantly higher than the values measured in late 1980s and 1990s. Off-site contaminant concentrations could have been higher prior to 1985 for a single spill or a very short-term type of contaminant release. According to source and other on-site monitoring, this scenario is likely for only two plumes (the OU-IV waste solvent plume and the OU-I former landfill plume.)

Depending on the specific plume and residential well location, exposure to several plumes could have occurred 5 to 7 years before initial detection in 1985. However, limited data on depths of residential wells indicate that the zones of highest contaminant concentration are below the screened well depths, so that actual exposures are much lower than potential exposures based on lateral plume migration. Contaminant concentrations estimated for a depth of 30 m are very close to values measured in off-site residential and monitoring wells. Retardation and attenuation of contaminants within the groundwater flow system have reduced the concentrations of potential exposures relative to conservatively modeled concentrations.

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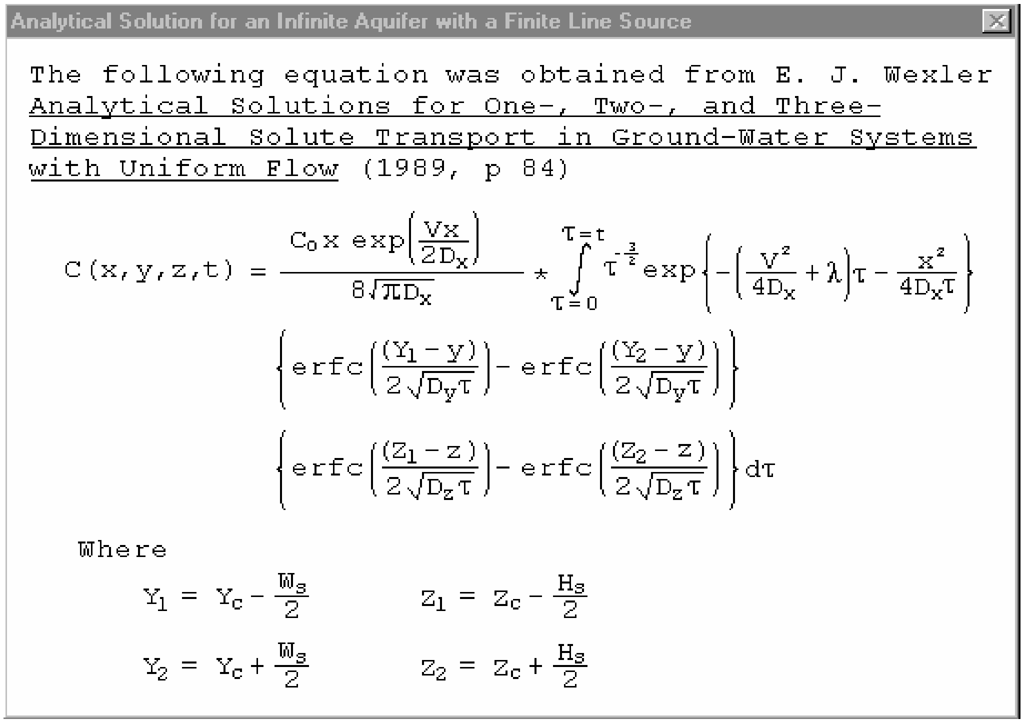


Analytical Solution for an Infinite Aquifer with a Finite Line Source

The following equation was obtained from E. J. Wexler <u>Analytical Solutions for One-, Two-, and Three-Dimensional Solute Transport in Ground-Water Systems with Uniform Flow</u> (1989, p 84)

$$C(x,y,z,t) = \frac{C_o\,x\,\exp\left(\frac{Vx}{2D_x}\right)}{8\sqrt{\pi D_x}} * \int_{\tau=0}^{\tau=t} \tau^{-\frac{3}{2}} \exp\left\{-\left(\frac{V^2}{4D_x}+\lambda\right)\tau - \frac{x^2}{4D_x\tau}\right\}$$

$$\left\{\mathrm{erfc}\left(\frac{(Y_1-y)}{2\sqrt{D_y\tau}}\right) - \mathrm{erfc}\left(\frac{(Y_2-y)}{2\sqrt{D_y\tau}}\right)\right\}$$

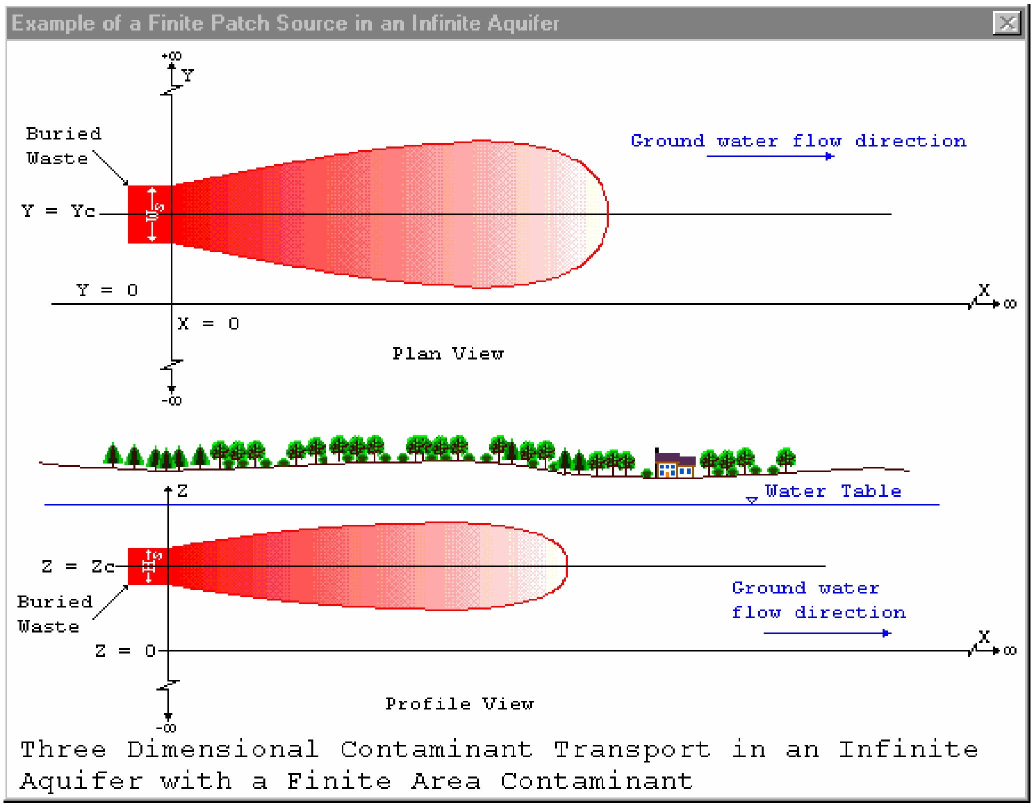
$$\left\{\mathrm{erfc}\left(\frac{(Z_1-z)}{2\sqrt{D_z\tau}}\right) - \mathrm{erfc}\left(\frac{(Z_2-z)}{2\sqrt{D_z\tau}}\right)\right\} d\tau$$

Where

$$Y_1 = Y_c - \frac{W_s}{2} \qquad Z_1 = Z_c - \frac{H_s}{2}$$

$$Y_2 = Y_c + \frac{W_s}{2} \qquad Z_2 = Z_c + \frac{H_s}{2}$$

Example of a Finite Patch Source in an Infinite Aquifer



Three Dimensional Contaminant Transport in an Infinite Aquifer with a Finite Area Contaminant

Appendix E. Operable Unit(s) Contamination

E.1 Operable Unit 1

Operable Unit 1 is in the southeastern area of BNL property. It encompasses approximately 950 acres. Contaminated areas within OU1 include the Former Landfill, Animal/Chemical Pits and Glass Holes, the former Hazardous Waste Management Facility (HWMF), the Current Landfill, the National Weather Service (NWS) stockpiled soil, the southern component of the tritium groundwater plume, Recharge Basin HSBOutfall 005, and the Weaver Road recharge basin.

The Former Landfill was used from the time BNL started operating (1947) until 1966 for the purpose of disposing of a variety of wastes, including chemical and low-level radioactive wastes, sewage sludge, construction debris, and animal carcasses. A series of pits (55) in an area east of the Former Landfill were used between 1960 and 1966 for disposal of glassware containing chemical and radioactive waste and animal carcasses containing radioactive tracers. This area is referred to as the Animal/Chemical pits. Used glassware was also disposed of in shallow pits located north of the Animal/Chemical pits from 1966 through 1981. This area is referred to as the Glass Holes. The Glass Holes are directly east of the Former Landfill, and the Animal/Chemical Pits are southeast of the Former Landfill.

The use of the Current Landfill started in January 1967, after the Former Landfill was filled and covered. The Current Landfill was used for disposal of animal carcasses containing short-lived radionuclides and for disposal of laboratory waste, sewage sludge, and mouse litter containing tritium. This practice was stopped in September 1978. Trash and building materials were disposed of in the landfill starting in 1967. Since February 1981, rotten and foul-smelling garbage (putrescible) has been disposed of off-site at the Brookhaven Town Landfill. The Current Landfill was closed in December 1990.

From 1947 until 1997, the HWMF was the central receiving Resource Conservation Recovery Act (RCRA) facility for processing, limited treatment (neutralization), and storage of radioactive wastes and RCRA hazardous wastes generated through BNL (ITC 1998a). Prior to 1947, the HWMF was a munitions storage area and a livery stable for Camp Upton. Various buildings and operational areas are within the facility. Access to the facility, which is 12 acres in size and fenced, is controlled. Figures 2 and 3 in Appendix B detail the location of the HWMF.

E.1.1 Soil

During the remedial investigation (RI), soil samples were collected from the HWMF and the ash pit within the Former Landfill area. The ash pit is located on the northwestern end of OU I, and the HWMF is located on the northeastern end. All samples were taken from a soil depth of 0 to 6 inches. A total of 59 surface soil samples were collected between January 31, 1994 and November 25, 1994, and between July 24, 1995 and July 27, 1995 (ITC 1998a).

Several areas of contamination within the HWMF area were analyzed as part of the RI: the open burning/detonation area, the spray aeration area, the salvage storage areas, the HWMF fields (Agrassy area@), the drum rinsing area, the radioactive material (fission product) injection site, the miscellaneous spill sites (Apaved area@), the oil-water separator, the neutralization tank and area, the HWMF wetland, the underground storage tank 445-03 area, and the dry well area adjacent to building 444.

The open burning/detonation area was used until 1988 to burn or detonate nonradioactive wastes deemed too hazardous to dispose of under normal procedures. The salvage storage areas are used to store used, slightly radioactive equipment from the Alternating Gradient Synchrotron (AGS). The HWMF fields (Agrassy area@) were sprayed with 1,1,1-trichloroethane for weed control in 1979. The drum rinsing area was used to rinse drums that contained various chemicals. Very little is known about the contents of the drums.

The radioactive material (fission product) injection site consists of a water supply well contaminated in 1960 when a BNL employee accidentally pumped radioactive slurry into the well. Miscellaneous spills of fission products onto the asphalt area at the HWMF occurred from 1950 to 1967 when the Brookhaven Graphite Research Reactor (BGRR) was in operation. Waste materials from the BGRR were handled at the HWMF. The oil-water separator is an above-ground settling tank used to separate non-radioactive miscellaneous oils from water prior to shipment of the oil off site for disposal.

The ash pit was used from 1943 to 1963 for the disposal of ash and slag from an army solid waste incinerator, used from World War I to the early 1950s (ITC 1998a), and for disposing of coal ash from various BNL buildings. Located southwest of the Former Landfill area, the ash pit occupies approximately 2 acres. Surface soil samples were collected from the ash pit and analyzed for inorganic and radiological compounds.

Nine chemicals were detected above ATSDR's CVs or USEPA=s Risk-Based Concentrations (RBCs) in the surface soils collected: Aroclor-1260, arsenic, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, indeno(1,2,3-cd)pyrene, iron, mercury, and N-nitroso-di-N-propylamine (see Table SS1 in Appendix C). Five of these chemicals (Aroclor-1260, benzo(a)pyrene, benzo(b)fluoranthene, mercury, and N-nitroso-di-N-propylamine) were detected at levels more than an order of magnitude above their CVs or RBCs. Four additional pollutants, which have no CVs or RBCs, were detected in surface soil: benzo (g,h,i)perylene, 4-chloro-3-methylphenol, endrin, ketone, and phenanthrene.

Maximum concentrations of many of the semi-volatile compounds (Aroclor-1260, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and benzo(g,h,i)perylene) were detected in the drum rinsing area. Maximum concentrations of arsenic, 4-chloro-3-methylphenol, endrin ketone, and N-nitroso-di-N-propylamine occurred in the miscellaneous spill sites. The highest concentrations of indeno(1,2,3-cd)pyrene and phenanthrene occurred in the HWMF fields.

The main soil contaminants in this OU are radioactive elements, primarily cesium-137 and strontium-90, especially in the HWMF. The 59 samples collected from the ash pit and the HWMF were analyzed for 35 radionuclides. Sixteen radionuclides were detected (see Table SS2). Cesium-137, potassium-40, lead-212, lead-214, and bismuth-214 were detected in at least half the samples. The principal contaminant, cesium-137, was found at concentrations reaching 180,000 picocuries per gram (pCi/g)of soil. Eight samples had cesium-137 concentrations one to two orders of magnitude higher than all other cesium-137 samples. Six of these samples were located in miscellaneous spill sites, one sample was located in the HWMF fields, and one was located in the salvage storage area. Strontium-90 was also detected at levels up to 1,300 pCi/g.

E.1.2 Groundwater

The contaminants of concern found in groundwater monitoring wells within areas of the Former Landfill, the Animal/Chemical Pits, and the Glass Holes are carbon tetrachloride, trichloroethane (TCA), dichloroethylene (DCE), trichloroethylene (TCE), and chloroform. A groundwater plume extends south from these areas approximately 11,500 feet and has reached Crestwood Drive. The highest concentrations within the plume are off site near Stratler Drive in North Shirley, New York. Figure 3 in Appendix B shows the extent of the plumes in OU 1.

E.1.2.1 Volatile Organic Contamination

Routine groundwater monitoring near the HWMF in 1984 indicated levels of 1,1,1-trichloroethane (1,1,1-TCA) above the New York State drinking water standard of 5 ppb. BNL scientists investigated the 1,1,1-TCA contamination and determined the need for a groundwater extraction and treatment system to remove the 1,1,1-TCA from the groundwater. The chosen method of remediation involved the use of a spray-aeration system. Groundwater was extracted from a series of wells and discharged to the atmosphere via spray aeration nozzles as a means of volatilizing the contaminants, and the water was then recharged to the ground downgradient of the HWMF. The spray-aeration system operated continuously from April 1986 until the spring of 1990, with the exception of December 1986 through April 1987, when the spray nozzles experienced problems with freezing (CDM 1995). The operation of the groundwater extraction and treatment system ended in the spring of 1990 because the New York State Department of Environmental Conservation (NYSDEC) was concerned that the air quality impacts had not been evaluated and that the plume was not adequately characterized.

From 1985 through 1989, levels of 1,1,1-TCA, trichloroethene (TCE), perchloroethene (PCE), and chloroform were above New York State drinking water standards in monitoring wells southeast of the HWMF. Before 1991, levels of 1,1,1-TCA were typically found above

250 parts per billion (ppb). For example, in 1985, a maximum concentration of 2,100 ppb was detected in a well south of the HWMF, and in 1988, a maximum concentration was detected in a separate well at 870 ppb (CDM 1995). A maximum PCE concentration of 800 ppb was detected downgradient of the HWMF in 1985.

Monitoring results indicate that groundwater pumping from the spray-aeration system most likely dispersed contaminants both vertically and horizontally and, as a result, the plumes from the HWMF and the Current Landfill, also within OU I, mixed with one another. The co-mingling of the plumes most likely occurred between 1986 and 1989. The spray aeration system was not effective in capturing the vertical extent of contamination because of an unidentified deeper plume from the Current Landfill. The Suffolk County Department of Health Services (SCDHS) conducted groundwater sampling at BNL from July through October 1992 and found concentrations of 1,1-dichloroethane (1,1-DCA) and 1,1,1-TCA at 870 and 150 parts per billion, respectively, near the southeastern site boundary, downgradient of the Current Landfill (CDM

1995). The maximum concentrations of compounds detected in 1992 downgradient of the HWMF included 1,1,1-TCA at 220 ppb, TCE at 16 ppb, PCE at 38 ppb, and dichloroethene (DCE) at 24 ppb (CDM 1995).

Two rounds of groundwater sampling occurred in OU I between August and December 1994. PCE, 1,1,1-TCA, and 1,1-DCA were detected above MCLs in monitoring wells downgradient of the HWMF. The maximum concentrations detected for each contaminant included PCE at 172 ppb, 1,1,1-TCA at 37.9 ppb, and 1,1-DCA at 16.2 ppb (CDM 1996b).

Other areas in OU1 that are sources of VOC contamination include the Former Landfill, the Glass Holes, and the Animal/Chemical Pits. The primary contaminants detected in monitoring wells in the Former Landfill-Animal/Chemical Pits and Glass Holes areas include carbon tetrachloride, 1,1,1-TCA, DCE, TCE, and chloroform. The contaminants are found in the shallow Glacial aquifer near these source areas, and as the plume moves toward the southern site boundary, the contaminants are found in the mid-Upper Glacial aquifer. As the contaminants move off site, they are found in the deep Upper Glacial aquifer to an area near Crestwood Drive. The highest concentrations of VOCs within the plume are in the vicinity of Sleepy Hollow Drive (BNL/ERD 1998).

The compounds that have historically been detected above New York State drinking water standards downgradient of the Former Landfill include 1,1,1-TCA, TCE, and PCE. 1,1,1-TCA was also present in wells near the Glass Holes and the Animal/Chemical Pits. The maximum 1,1,1-TCA concentration detected was equal to 150 ppb. PCE was also detected frequently in wells upgradient and downgradient of the Former Landfill, the Glass Holes, and the Animal/Chemical Pits. A maximum concentration of 23 ppb was detected in a monitoring well downgradient of the Former Landfill.

A maximum concentration of chloroform, 54 ppb, was detected south of the Former Landfill. The chloroform was at depths ranging from 35 feet bgs to 202 feet bgs. The source of chloroform is not known, but it may be a biodegradation product of the carbon tetrachloride present in the area. Carbon tetrachloride is known to transform into chloroform and other products in water (ATSDR 1994).

Chloroform, 1,1-DCA, PCE, TCE, and 1,1,1-TCA have been detected in temporary wells downgradient of the Current Landfill at levels above New York State=s MCLs. The New York State MCLs for these contaminants is 5 ppb, with the exception of chloroform, which has a standard of 100 ppb. Maximum concentrations included chloroform at 100 ppb, 1,1-DCA at 870 ppb, PCE at 37 ppb, 1,1,1-TCA at 150 ppb, and TCE at 22 ppb (CDM 1995). Downgradient of the Current Landfill and at the site boundary, 1,1-DCA was consistently found in 1992 and 1993 at concentrations ranging from 100 to 200 ppb. Concentrations decreased to10 to 50 ppb by late 1993.

E.1.2.2 Radiological Contamination

Groundwater samples obtained from monitoring wells around the HWMF have contained levels of tritium and strontium-90 that exceed New York State MCLs. All radionuclide levels above MCLs in OU I have occurred within or downgradient of the HWMF, the Current Landfill, and the Former Landfill/Animal Pits. Historically, tritium was detected at levels exceeding the MCL of 20,000 picocuries per liter (pCi/L) in 1980B81, 1984, 1986, and 1989. The highest level of tritium detected in 1981 was 64,200 pCi/L, and in 1984 a concentration of 85,000 pCi/L was detected (CDM 1995). In 1987, wells east and downgradient of the HWMF had tritium levels above the MCL.

The groundwater extraction and treatment system previously mentioned might have accelerated the movement of tritium downgradient from the HWMF. Tritium concentrations found above the MCL occurred in the HWMF near the Open Burn Area. A maximum tritium concentration of 70,000 pCi/L was detected in 1989 (CDM 1995). Tritium concentrations have fluctuated in this area over the past decade. By 1992, tritium concentrations were within the 1,000 pCi/L range. However, during 1995, average tritium concentrations downgradient of the HWMF were approximately 2,000 pCi/L, although a maximum of 42,200 pCi/L was detected.

The radionuclide strontium-90 has historically been detected above the MCL (8 pCi/L) near the HWMF. In 1970B71, strontium-90 concentrations ranged from 75 pCi/L to 100 pCi/L (CDM 1995). Over the years, strontium-90 concentrations declined to a range of 10 to 30 pCi/L, but they were still above the MCL. In 1992, concentrations of strontium-90 continued to fluctuate; a maximum concentration was detected at 290 pCi/L. Monitoring of downgradient wells, closer to the southern boundary, has not shown any strontium-90. Unlike tritium, strontium-90 is not very mobile in water. Strontium-90 was also above the MCL in wells near the Former Landfill in 1986 through 1989. Concentrations ranged from 9 pCi/L to 50 pCi/L. Tritium was detected in the same area, but concentrations were below the MCL.

Tritium and strontium-90 concentrations exceeded MCLs in the groundwater downgradient of the Current Landfill in the 1970s and also between 1985 and 1989. The maximum concentration of strontium-90 detected near the Current Landfill was 453 pCi/L in 1971. The well that contained this level has since been abandoned because of the capping of the landfill. Tritium concentrations ranged from 20,000 to 30,000 pCi/L, with a maximum of 60,000 pCi/L. The highest concentrations of tritium have occurred downgradient of the Current Landfill. In 1992, tritium was detected in a monitoring well south of the landfill at a concentration of 20,500 pCi/L.

Strontium-90 was found in a shallow well downgradient of the Animal Pits at 240 pCi/L during the OU 1 remedial investigation. Strontium-90 concentrations averaged 300 pCi/L in a monitoring well in the Animal/Chemical Pits and Glass Holes area from October 1995 until the end of March 1997. Since then, the concentrations have been increasing. Monitoring conducted in September 1997 indicated a maximum concentration of strontium-90 at 769 pCi/L (BNL/ERD 1998). Sampling conducted in January 1998 indicated a strontium-90 concentration around 300 pCi/L. Low levels of strontium-90 have been detected downgradient of this area as far south as Middle Road.

E.1.2.3 Remedial Actions

Personnel from BNL, the New York State Department of Environmental Conservation (NYSDEC), and the Environmental Protection Agency (USEPA) have used groundwater monitoring results to trace the sources of contamination and to determine the best methods of remediation. It appears that the spray aeration was not effective in capturing the vertical extent of contamination because of the presence of a deeper plume from the Current Landfill. A groundwater extraction and treatment system was implemented for the HWMF and Current Landfill contaminant plumes in December 1996. In addition, a hydraulic containment and treatment system was installed to prevent additional off-site migration and to remove the volatile organic compounds to levels below drinking water standards.

The Current Landfill was capped in 1995, and the Former Landfill was capped in 1996. Capping of the landfills will help to prevent water from percolating into the contaminated soil and also prevent further migration of contaminants into the groundwater. The Chemical/Glass Holes and the Animal Pits were remediated during the summer of 1997. The soil and debris were removed and shipped off site to a licensed hazardous waste facility.

Currently, there are seven monitoring wells adjacent to the Former Landfill in upgradient and downgradient locations, and these are monitored on a quarterly basis. Similarly, a network of eleven monitoring wells surround the Current Landfill, and these are also monitored on a quarterly basis.

E.2 Operable Unit II/VII

Operable Unit (OU) II/VII is located in the western half of BNL property, near the center of the property. The areas of concern in OU II/VII include the Waste Concentration Facility (WCF), five fields adjacent to some of the facility=s buildings, the Former Low-Mass Criticality Facility, the Alternating Gradient Synchrotron Storage Yards (Bone Yard), and various piles of contaminated landscaping soils. OU II/VII is shown in figure 1 of Appendix B.

Since 1949, liquid radioactive waste was temporarily stored and eventually distilled to remove particulates as well as suspended and dissolved solids at the WCF. The WCF consisted of three 100,000-gallon aboveground storage tanks (out of service since 1987 and removed in September 1994); six 8,000-gallon underground storage tanks; two 25,000-gallon aboveground storage tanks (added in 1987 to replace the three 10,000 gallon tanks); a 4,000-gallon aboveground receiving tank; two 5,000-gallon aboveground blending tanks (removed in October 1994); and the evaporator/concentration apparatus (no longer in service).

After the liquids were distilled, most of the radionuclides were concentrated in the slurry residue, but tritium was distributed between the distillate and the residue fractions. The distillate was piped to the Sewage Treatment Plant (STP) and then discharged to the Peconic River. This practice was stopped in 1985. From 1985 to 1995, the distillate was trucked to poly-lined hold-up ponds at the STP, where it evaporated and/or mixed with precipitation and diverted effluent from the STP. In 1995, a tritium evaporator facility designed specifically to eliminate Peconic River tritium discharges became operational.

The Waste Concentration Facility is an operational facility that was used since 1949 for reducing the volume of liquid radioactive waste prior to disposal. Three large storage tanks were used in this area from 1949 to 1987, but they were removed in 1994. Cesium-137 and strontium-90 were detected in soils near the facility at maximum concentrations of 1,486 and 454 pCi/g, respectively. They were also detected in soils and sediments at the reclamation facility and in a sump outfall east of the facility, which was used from the late 1950s through the late 1960s to remove radioactive contaminants from clothing and equipment. Water from decontamination of equipment was discharged at the sump outfall area until 1969. Cesium-137 concentrations reached levels up to 2,800 pCi/g. Strontium-90 levels reached 140 pCi/g and plutonium-239/240 was detected at a maximum concentration of 170 pCi/g.

The Upland Recharge/Meadow Marsh Area was used in sewage treatment experiments from 1973 to 1978. Sediments in two of the manmade basins contain elevated levels of copper, zinc, and aluminum. Two storm basins are used to recharge runoff that enters BNL=s storm sewer system. Sediment samples contained elevated levels of copper, lead, and organic chemicals.

E.2.1 Remedial Actions

The contaminated landscaping soils were removed in September 2000, and the area was re-seeded in the spring of 2001.

E.3 Operable Unit III

The OU III study area extends from the central developed region of the site to the southern boundary. OU III is bounded by the northern, southern, and western property boundaries of BNL; it encompasses approximately 50% of the total BNL area. Figure 1 in Appendix B details the location of OU III.

E.3.1 Soil

Surface soil samples were collected from four potential sources of environmental contamination in OU III: the Building 830 pipe leak and underground storage tanks (USTs), the TCE Spill Area, the Recharge Basin HP, and Building 464. These areas are located in the center of OU III.

From July 1984 to August 1986, leakage from a transfer pipe between radioactive liquid waste tanks took place between Building 830 and the USTs. An estimated 825 to 900 gallons of liquid radioactive wastes were released into the soil. A total of seven surface (zero to 6 inches) soil samples were collected from the Building 830 Pipe Leak and UST, TCE Spill Area, and the Recharge Basin HP in OU III on October 10, 1995; November 21, 1995; and September 30, 1996 and analyzed for organics, inorganics, and radionuclides. Three chemicals were detected above CVs and RBCs in surface soil: arsenic, iron, and benzo(a)pyrene. Arsenic was detected one order of magnitude above its RBC. Arsenic and iron were detected above their RBCs in all seven samples. Two additional pollutants that have no CV or RBC were detected in surface soil: benzo (g,h,i)perylene and phenanthrene. Table SS3 in Appendix C indicates the chemicals that were detected.

Of the seven surface soil samples collected from the Building 830 Pipe Leak and UST and TCE Spill Area, five were analyzed for radionuclides. Table SS4 indicates the 19 radionuclides that were detected. Cesium-137 and gross beta were detected at two orders of magnitude higher than most other detected radionuclides. The leaking pipe was removed, and the tanks are currently out of service. The contaminated soil under the waste transfer line was removed during September and October 1988.

The TCE Spill Area was located in an open courtyard in the Building 515 complex. Approximately 5 gallons of cleaning water were released to the environment every other day from January 1951 to August 1953 (BNL 1994a).

The Recharge Basin HP receives cooling water from the Brookhaven Medical Research Reactor (BMRR) and local storm water runoff. In 1990, organic compounds were detected above set limits, and discharges to the basin were halted. The organics were believed to be originating from contaminated supply wells. A carbon absorption unit was installed to the supply well of concern, and discharge operations resumed.

Building 464 was the former chemistry complex for BNL. In 1993, during construction near the building, mercury was discovered in the soil. After further investigation, polychlorinated biphenyls (PCBs) were also discovered. Before remediation procedures took place, sampling conducted during MayBJune 1993 near Building 464 identified mercury concentrations in the range of 0.1 mg/kg to 17,000 mg/kg. PCBs were also detected at levels below 50 mg/kg. Remediation of all contaminated soils was completed by October 7, 1993. All mercury and PCB-contaminated soils were drummed and sent to an RCRA-permitted landfill in Model City, New York, or drummed and stored on site at the HWMF to await off-site disposal (BNL 1994b). The surface soil sampling results presented in Table SS3 do not include levels of contamination previously detected in OU III soils that have since been remediated (BNL 1994b).

E.3.2 Groundwater

Several plumes of volatile organic compounds have been delineated in the OU III area of the site. Three are on-site 1,1,1-trichloroethane (1,1,1-TCA) pockets of contamination in the water table zone. The downgradient extent of the 1,1,1-TCA in the water table zone is located just north of Princeton Avenue. The 1,1,1-TCA contamination is more widespread in the mid glacial zone; it extends off the laboratory boundary to just north of Carleton Drive. 1,1,1-TCA in the mid glacial zone exists as three pockets of contamination between Brookhaven Avenue and South Boundary Road. In the deep glacial zone, the maximum concentration of 1,1,1-TCA (1,120 parts per billion [ppb]) was at the southern boundary of the site. Figure 5 in Appendix B provides a depiction of all the groundwater plumes.

Lower concentrations (less than 10 ppb) have been detected in monitoring wells just south of Carleton Drive off site in the deep glacial zone (BNL 1997a). Monitoring results indicate that the higher concentrations are centered on the Waste Concentration Facility (WCF), the Alternating Gradient Synchrotron (AGS) in the northern portion of the site, and Building 96 in the middle of the site. The sources for the elevated 1,1,1-TCA concentrations around the WCF and the AGS are thought to be the former D-waste tanks at the WCF and the cesspools around the Bubble Chamber Area (BNL 1997b).

A maximum 1,1-dichloroethene (1,1-DCE) concentration, 280 ppb, was also detected in the same location as the detected maximum 1,1,1-TCA concentration. The depth of the maximum

1,1-DCE concentration was 195 feet bgs in the deep glacial zone near South Boundary Road. The source of the 1,1-DCE is most likely a degradation (break-down) product from the 1,1,1-TCA. Under abiotic (free of biological organisms) conditions, the 1,1,1-TCA will degrade to 1,1-DCE.

A PCE plume is present in the central portion of the site, extending to an area south of the southern site boundary. The main source of the PCE appears to be in an area south of Building 96, which was used as a truck wash station. The plume varies in depth across the area. In the central portion of the site, near the source, the contamination is shallow and within the water table zone. A maximum concentration of 15,000 ppb was detected in this area. The plume is within the mid-glacial zone as it moves south of Princeton Avenue on site to just north of the southern boundary. The PCE has also been detected in the deep glacial zone from an area north of Princeton Avenue on site to an area just south of the site's southern boundary (BNL 1997b). It reaches a depth of about 200 feet bgs at the southern site boundary. Beyond the southern boundary (i.e. off site), the maximum concentration detected was 3,900 ppb in the deep glacial zone.

Monitoring results indicate that a carbon tetrachloride plume appears to be 150 to 210 feet below ground surface (bgs) in the deep glacial zone. The maximum detected concentration of carbon tetrachloride (5,100 ppb) was in an off-site monitoring well at a sampling depth of 180 feet bgs. The plume extends north-south from south of Princeton Avenue off site to south of Middle Island-Moriches Road (BNL 1997a). The highest concentrations of carbon tetrachloride, greater than 1,000 ppb, are located between BNL southern boundary and Carleton Drive.

Carbon tetrachloride was also in the Magothy zone (225 to 325 feet bgs), but the vertical extent within the Magothy is still being defined. Carbon tetrachloride has not been detected in the shallower portions of the aquifer, an indication that the carbon tetrachloride has traveled quite a distance into the aquifer. Because of the distance the carbon tetrachloride has traveled, the source of the carbon tetrachloride may not ever be determined. The upgradient extent of the carbon tetrachloride plume is between Princeton Avenue and Middle Road (ITC 1998b).

The presence of 1,1-DCA and chloroform at downgradient locations indicates that degradation of 1,1,1-TCA and carbon tetrachloride (respectively) are significant with respect to the durations of the plumes.

E.3.2.1 Remedial Actions

A hydraulic containment and treatment system, similar to the one operating in OU 1, was installed and began operation at the southern boundary of BNL in June 1997 as a means of preventing any additional off-site migration and beginning remediation of the 1,1,1-TCA and perchloroethylene (PCE) plumes. The method of remediation being used is in-well air stripping. The closed system operates by pumping clean air into the well casing and circulating the air through the system. Recirculating the air eliminates air emissions, and the VOCs are collected on a carbon filter that is changed periodically. Eight pumping wells have been installed at the southern boundary to facilitate the process. In 1999, an additional in-well air stripping system began operating in the area just off site in the industrial park just south of the laboratory's southern boundary.

An air sparging/soil vapor extraction system is currently operating south of Building 96 (a source area) to remove VOCs from the groundwater in that location. Two underground storage tanks and contaminated soils in the area are also being removed because they are thought to be the potential sources of groundwater contamination. Additional systems have been and will continue to be installed off site to capture and remove the VOCs in groundwater off site.

The Record of Decision (ROD) for OU III concluded that additional characterization and monitoring was needed for the Magothy Aquifer before a remedy for the removal of contaminants could be determined. Additional characterization and monitoring have been completed and the selected remedy includes the continued operation of the existing extraction wells for approximately ten years and the installation of two additional extraction wells off site. These wells were installed in the summer of 2004 and they are located at Stratler Drive (south of Carlton Drive) and in the Industrial Park East location (REF Explanation of Significant Differences to Groundwater ROD).

E.3.2.2 Pile Fan Sump

In December 1996, a leaking underground concrete sump (referred to as the Pile Fan Sump) was identified near the formerly active Brookhaven Graphite Research Reactor (BGRR). The sump was used to collect water from the former BGRR fan rooms, from the drains at the base of the

100 meter HFBR stack, from a floor drain in the BGRR's Pile Fan House, and from a low point drain in a 14-inch line of the acid off-gas system from the Hot Laboratory. The sump contained approximately 750 gallons of water. Analysis of the water resulted in the detection of concentrations of tritium up to 340,000 picocuries per liter (pCi/L), strontium-90 up to 2,270 pCi/L, and cesium-137 up to 2,458 pCi/L.

The sump was resampled on March 12, 1997, and tritium was detected at 260,000 pCi/L, as well as cesium-137 at 2,000 pCi/L and radium-226 at 2,300 pCi/L. The results from monitoring wells located approximately 45 feet south of the tank indicate strontium-90 concentrations as high as 566 pCi/L, 70 times the drinking water standard of 8 pCi/L (BNL1997c). The strontium-90, as previously mentioned, is highly immobile in groundwater and is approximately a mile and a half away from the site' s boundary. It would take several hundred years for the strontium-90 to reach the site boundary. Laboratory testing of the Brookhaven National Laboratory's water supply wells has not indicated that this contamination has affected any of them. The water in the sump was pumped out and transferred to the radioactive liquid waste facility.

E.3.2.3 High Flux Beam Reactor Contamination

Groundwater monitoring results from December 1996 indicated that tritium concentrations in wells southeast of the High Flux Beam Reactor (HFBR) exceeded the maximum contaminant level (MCL) (BNL 1997a). The MCL for tritium is 20,000 picocuries per liter (pCi/L). The maximum detected concentration was 44,700 pCi/L. Additional sampling confirmed the presence of tritium above the MCL. A series of test wells were installed north and south of the HFBR to permit tracking the extent and isolating the source of the contamination.

Figure 6 in Appendix B details the locations of the wells and the levels of contamination found in them. Sampling continued in January 1997, and results indicated tritium levels as high as 60,000 Ci/L in the water table zone within 200 feet downgradient of the HFBR. Monitoring results from July 1997 indicated tritium levels as high as 1,590,000 pCi/L in a monitoring well near the spent fuel pool. Other wells in the same proximity contained tritium concentrations in the 100,000B200,000 pCi/L range.

A collection of water samples taken from a series of monitoring wells located along Temple Place, approximately 400 feet south of the HFBR, have indicated the presence of tritium above the MCL. Samples from well #20 indicated a maximum tritium concentration of 175,200 pCi/L, and the samples collected from adjacent wells, numbered 30 and 13, indicated concentrations of 89,200 and 45,700 pCi/L, respectively. As the plume approaches Temple Place, the contamination enters the mid-glacial zone (0 to 60 feet below msl). Six temporary monitoring wells were installed in locations approximately 1,000 feet south of the HFBR and 100 feet south of Brookhaven Avenue in an effort to determine the downgradient extent of the plume. Sampling results from February 1997 indicated a maximum tritium concentration of 102,000 pCi/L in well 37. An adjacent well (# 38) contained a tritium concentration of 30,300 pCi/L. The other four wells had tritium concentrations below the MCL.

Vertical profile wells have been installed along Rowland Street, Weaver Drive, and Princeton Avenue to help in determining the extent of the leading portion of the plume. Tritium concentrations are above the drinking water standard from the HFBR to just south of Rowland Street (ITC 1998b). The plume is approximately 100 feet wide at the HFBR, gradually widening to approximately 200 feet at Rowland Street. The plume is also moving deeper into the Upper Glacial Aquifer. The contamination is confined to the upper 20 feet of the Upper Glacial Aquifer near the source; approximately 2,000 feet away, it is about 175 feet below ground surface (BNL 1997d). As Figure 6 shows, the plume branches out as it approaches Weaver Drive. The concentrations within the leading edge of the plume are below the drinking water standard from north of Weaver Drive to south of Princeton Avenue.

Sampling results from monitoring wells north of the HFBR have not indicated the presence of tritium. Samples from site boundary wells and off-site wells have not indicated tritium levels above normal background concentrations. On-site drinking water supply wells have not been affected by the tritium contamination, because the wells are upgradient of the contamination, and groundwater flow is to the south. The leading edge of the plume is approximately 1 mile from the southern boundary. The tritium contamination does not pose a current threat to the public's health because no one is being exposed to the contamination.

E.3.2.3.1 Remedial Actions

Brookhaven National Laboratory (BNL) personnel determined that the reactor vessel was not the source of the leak because the reactor vessel=s sensitive leak detectors did not detect any leaks. The source of the tritium was the 68,000-gallon spent fuel pool in the lower level of the reactor building (BNL 1997e). A detailed leak-rate test showed that the spent fuel pool was leaking at a rate of 6 to 9 gallons per day. The Department of Energy (DOE) and BNL worked with the USEPA, the NYSDEC, and the SCDHS to address options for cleanup. BNL officials installed a pump-and-recharge system to remedy the situation. The contaminated water was pumped to a recharge basin 3,000 feet north of the existing southern edge of the plume to prevent further migration of the plume. Figure 6 in Appendix B shows the location of the recharge basin and provides the estimated time it will take the plume to reach the site boundary.

The pump-and-recharge system has been operating since May 12, 1997, and sampling has confirmed that water being discharged into the recharge basin contains tritium concentrations of less than 2,000 pCi/L, one-tenth of the drinking water standard (BNL 1997c). The pump-and-recharge system serves as an interim action that may be terminated once the characteristics of the plume have been better defined.

Prior to the spent-fuel pool being emptied, the fuel elements and other equipment within the pool had to be shipped to other DOE facilities. On December 30, 1997, the remaining tritiated water in the spent-fuel was pumped to double-walled tanks on BNL site. Sediment was also removed from the pool bottom. DOE is currently conducting an environmental review of the reactor to determine the future of the reactor.

E.4 Operable Unit IV

Operable Unit (OU) IV is on the east-central edge of the developed area of BNL. It is approximately 91 acres in size. Figure 1 in Appendix B shows the location of OU IV.

There are four potential sources of environmental contamination in OU IV: the Central Steam Facility (CSF), the Reclamation Facility Building 650, the Sanitary and Storm Sewer Lines, and the Recharge Basin HO (CDM 1994).

E.4.1 Soil

Surface soil samples were collected from two potential sources: the CSF and the Reclamation Facility Building 650. Only subsurface soil samples were collected in the remaining potential sources of environmental contamination in OU IV.

The CSF is located in the center of OU IV on the western boundary. It functions to supply heating and cooling to all BNL facilities. This area consists of 21 aboveground receiving and mixing fuel tanks, which are connected via aboveground and underground pipelines (CDM 1994). In 1976, the CSF utilized alternative liquid fuel as a fuel source. This fuel was comprised of a mixture of t Number 6 fuel oil or other heavy oils and government surplus fuels (JP-4, JP-5, and Light Feed Stocks). The CSF is approximately 13 acres in size, divided into 8 areas. Surface soil samples were collected from 6 of these areas, which included Soil Piles; Excavated Trenches, Oil/Solvent, UST Pit/Former Catch Basins; Former Leaching Pits; CSF Fuel Unloading Areas; a Drainage Area; and other potential sources of contamination.

In 1977, approximately 87,055 to 94,625 liters of oil and solvent (roughly 25,000 gallons) were released from a ruptured pipe (CDM 1994). The mixture was composed of 60% Number 6 fuel and 40% mineral spirits. In 1993, soil surrounding the spill was removed.

The Former Leaching Pits were installed in the 1950s or 1960s to receive waste oil and cleaning wash water from Building 610 equipment (CDM 1994). The leaching pit foundation and sludge waste were excavated in 1989.

CSF Fuel Unloading Areas are located in eight locations around the storage tanks; each consists of a four-square-foot area constructed of pavement, bluestone, and concrete (CDM 1994). Numerous small fuel spills have occurred during fuel transfer. In 1988, 1990, and 1993, three separate No. 6 fuel spills of 60 gallons were reported. CSF personnel attempted to contain spills with sand, berms, or absorbent pads; contaminated soil was removed and stored in drums. In 1991, one fluid ounce of mercury was spilled on the concrete slab near Tank 1 and collected with a mercury vacuum.

In 1977, a tank truck was unloading fuel in the Drainage Area and spilled approximately 250 to 500 gallons of No. 6 “Bunker Oil” (CDM 1994). The fuel spilled onto the ground and entered an adjacent catch basin. The amount of oil recovered is unknown.

The Reclamation Facility Building 650 was constructed to serve as a decontamination facility for the removal of radiation from clothing and heavy equipment (CDM 1994). It is located on the northwestern edge of OU IV and extends to the northeast. Wash operations, both outdoors and indoors, began in 1959. Two tanks near Building 650 were used to store the residual wash water. In late 1969, five curies of tritium were accidentally released into the sewer system from the Building 650 Sump. Tritium was not detected at the sewer treatment plant. After further investigation, it was discovered that the drainage pipe behind Building 650 led to a natural depression (Sump Outfall) extending to the northeast. Building 650 is now used as a laundry facility.

A total of 36 surface soil samples collected from two areas in OU IV between February 11, 1993, and April 6, 1993 were chemically analyzed (CDM 1994). Surface and subsurface soil samples were collected from the CSF and the Reclamation Facility Building 650. All samples were taken from a soil depth of 0 to 2 feet. All samples were analyzed for TCL VOCs and TCL SVOCs. Selected samples were analyzed for TCL PCBs/pesticides, TAL inorganics, and radionuclides.

Five chemicals were detected above CVs or RBCs in surface soil: arsenic, benzo(a)anthrene, benzo(b)fluoranthrene, benzo(a)pyrene, and indeno(1,2,3-cd)pyrene (Table SS5). Arsenic and benzo(a)pyrene were detected at levels one order of magnitude or more above their RBCs. Three additional pollutants that have no CVs or RBCs were detected in surface soil: benzo(g,h,i) perylene, phenanthrene, and trichloroethylene.

The maximum concentrations and most exceedances of all chemicals in Table SS5 were found in the Reclamation Facility Building 650. Maximum concentrations of arsenic, benzo(a) anthrene, benzo(b)fluoranthrene, benzo(a)pyrene, benzo(g,h,i)perylene, and indeno(1,2,3-cd)pyrene were detected at sampling points SB45 or SB46. These sampling points are northeast of Building 650 at the Sump Outfall.

Sixteen surface soil samples collected in the Reclamation Facility Building 650 area were analyzed for nine radionuclides. Seven radionuclides were detected, and they are shown in Table SS6. Tritium, strontium-90, gross alpha, and gross beta were detected in all 16 soil samples.

E.4.2 Groundwater

Volatile organic compound (VOC) contamination in groundwater beneath OU IV is from two primary sources. The first source is the decontamination pad area behind Building 650. A VOC plume composed primarily of 1,1,1 trichloroethane (1,1,1-TCA) is near the northern side of Building 650. The maximum 1,1,1-TCA concentration detected was an estimated value of 8.5 parts per billion (ppb) (CDM 1994). The second source is an oil solvent spill that occurred in 1977.

On November 25, 1977, approximately 23,000 to 25,000 gallons of waste oil and solvent were released from a ruptured pipe southeast of the Central Steam Facility (CSF). The pipe ruptured when a nearby empty 5,000-gallon underground storage tank (UST) rose off its mount as a result of water accumulating beneath the tank and the connecting lines being sheared (BNL 1996b). The plume associated with the 1977 oil/solvent spill and UST is composed of VOCs, semi-volatile organic compounds, and polynuclear aromatic hydrocarbons. Investigators collected groundwater samples from monitoring wells near the spill in April 1993. Monitoring results indicated maximum levels of toluene and total xylenes at 2,000 ppb and 1,700 ppb, respectively. A second round of groundwater monitoring, conducted in August 1993, indicated maximum levels of toluene and total xylenes at 2,700 ppb and 2,200 ppb, respectively. Other contaminants detected above their respective MCLs included 1,2 dichloroethene at 64 ppb, 1,1,1-TCA at 14 ppb, TCE at 20 ppb, tetrachloroethene (PCE) at 43 ppb, and ethylbenzene at 590 ppb.

The OU IV plume extends from the 1977 Waste Oil Solvent Spill to an off-site area between the southern site boundary and Carleton Drive. The contamination is present in the shallow Glacial Aquifer near the source area; it enters the deep Glacial Aquifer as it approaches the southern site boundary. The contamination is in the upper Magothy Aquifer as it migrates off site.

E.4.2.1 Radiological Contamination

Radionuclide monitoring conducted in August 1993 indicated the presence of strontium-90 (Sr90) at 53 picocuries per liter (pCi/L), greater than the federal maximum contaminant level (MCL) of

8 pCi/L, in a monitoring well downgradient of the Sump Outfall Area (BNL 1996b). Prior monitoring (April 1993) results did not indicate that strontium-90 was above the MCL. Although there were isolated spots of radionuclide contamination, the contamination of groundwater resulting from radionuclides does not indicate any consistent pattern of MCL violations. Therefore, it was decided in the ROD that remediation of the groundwater for radiological contamination was not required (BNL 1996b). The source of the radionuclides is operations at Building 650 and the 650 Sump Outfall.

Radium-226 was detected by gamma spectroscopy in monitoring wells at a maximum concentration of 41 pCi/L during sampling in 1997. The wells were resampled during early 1998 and analyzed by a more specific method. Radium-226 was not detected above the minimum detection level in any of the wells.

E.4.2.2 Remedial Actions

A 5,000-gallon underground storage tank was removed from this area in October 1993. A remedial investigation determined that the only area that was required to have groundwater remediation was in the CSF, where the 1977 oil/solvent spill occurred.

A selected remedial action for OU IV was presented in the record of decision (ROD) dated March 14, 1996. The method of remediation chosen to remove the VOCs included a combination of soil vapor extraction and air sparging (BNL 1996b). Air sparging involves stripping the volatile and some of the semi-volatile contaminants from the groundwater into their vapor phase. The soil vapor extraction phase involves the collection of the sparged air and the volatile organics from the soil. The system includes 48 air sparging units and 23 soil vapor extraction wells. The system operated from November 1997 until January 2001. Groundwater monitoring in late 2000 indicated levels of VOCs in monitoring wells at levels below drinking water standards. As a result, the system was shut down and monitoring continues. If VOC levels increase toward the drinking water standards, the system can be started again.

E.5 Operable Unit V

Operable Unit (OU) V is on the eastern side of BNL property north of the OU I/VI border. Figure 1 in Appendix B identifies the location of OU V.

There are three potential sources of environmental contamination in OU V: the Sewage Treatment Plant (STP), leaking sewage pipes, and the suspected source of the off-site tritium plume (BNL 1999). The STP processes an average of 0.72 million gallons per day (mgd) of effluent in non-summer months and 1.25 mgd in summer months, with a maximum capacity of 3 mgd (ITC 1998a). This effluent consists of wastewater from all parts of BNL, including residential areas as well as biological and medical research and other research laboratories. In the past, radionuclides were discharged accidentally and routinely to the STP.

Presently, radionuclide levels in STP discharges are analyzed in accordance with BNL Environmental Monitoring Plan. Many of the facilities on site currently have hold-up tanks for wastewater analysis prior to discharge. Outfall from the STP is permitted under a New York State Pollutant Discharge Elimination System permit that limits the releases of specific chemicals. The discharge contains volatile and semi-volatile organic compounds, inorganic compounds, and radionuclides.

Several areas of contamination within the STP were also analyzed as a part of the RI. These areas are parts of the sewage treatment process. The areas sampled include the following: sludge drying beds (4A), sand filter beds (4B), sand filter berms/adjacent areas (4B1), the sludge disposal area (4C1), hold-up ponds (4D), and the satellite disposal area (4E). The sludge drying beds are used to dewater sludge from the Imhoff Tank and the clarifier. The Imhoff Tank (4C) was used from 1947 to 1967 for separation of solids. The sand filter beds receive treated wastewater from the treatment plant and filter the effluent as it percolates through the beds. Sand filter berms and adjacent areas are located around the perimeter of the sand filter beds. Two hold-up ponds (4D) used for emergency storage when influent flow exceeds STP capacity are located adjacent to the sand filter beds. The satellite disposal area is not part of the STP, but it is located nearby. This area was used during the early 1960s for disposal of unknown chemicals and leaking bromine trifluoride cylinders. The cylinders were removed in 1985, along with two boxes of chemicals that were found buried in this area.

Approximately 3,400 feet of underground sewer lines are located within OU V; they were originally installed in 1917 and upgraded in 1942 (BNL 1999). These sewer lines carried wastewater from various laboratories, the Instrumentation Division, film processing operations, medical research, and biology research facilities. Inspection programs in 1987 and 1988 discovered deterioration of the sewer lines that had resulted in an estimated loss of 317,000 gallons per day of wastewater to the surrounding soil and groundwater. The leaking pipes were replaced with a new line in January 1993, but past releases from the leaky lines have resulted in contamination in this area.

E.5.1 Soil

A total of 37 surface soil samples were collected from six areas at the STP between January 23 and March 27, 1995 and chemically analyzed (BNL 1997 ER, 1999). All samples were taken from a soil depth of zero to six inches.

Six chemicals were detected above CVs or RBCs in surface soil: Aroclor-1254, Aroclor-1260, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and mercury (Table SS7). Phenanthrene was detected five times. No chemicals were detected more than an order of magnitude above their CVs or RBCs.

The maximum concentrations of all contaminants were found in area 4B1, the sand filter berms/adjacent areas. Sample B1-08, from a sand filter berm, had the highest concentration of mercury. The locations at which other chemical maximum concentrations were found were all in areas adjacent to the STP. Sample B1-01, just to the northwest of the sand filter beds, contained the maximum concentrations of polycyclic aromatic hydrocarbons (PAHs). The maximum detected concentrations of Aroclor-1254 and Aroclor-1260 were located just to the southeast of the sand filter beds.

The maximum concentrations of radionuclides (Table SS8) were found in the sand filter beds, berms, or adjacent areas (4B or 4B1). It is also noteworthy that the maximum concentration of tritium was detected in the hold-up ponds area. Tritium was also detected in samples from the sand filter beds, berms and adjacent areas, and satellite disposal areas (4B, 4B1, and 4E).

E.5.2 Groundwater

Three areas within OU V are contaminated: the STP, leaking sewer pipes, and an off-site tritium and VOC plume. Groundwater quality within OU V was assessed on the basis of data collected from January 16, 1995, to June 30, 1995 (ITC 1996). The contaminants found in OU V that exceeded ATSDR comparison values are 1,1-dichloroethane (1,1-DCA), chloroform, trichloroethene (TCE), and 1,1,1-trichloroethane (1,1,1 -TCA). Elevated concentrations were mainly found between 170 feet and 260 feet below ground surface. Table MW1 contains the contaminant concentrations from OU V that fall within the respective ranges. No active groundwater supply well exists within OU V (ITC 1996).

The Suffolk County Department of Health Services (SCDHS) collected and analyzed 65 samples from off-site residential wells downgradient of OU V/VI. Three of the 65 wells had levels of VOCs above the New York State MCLs (ITC 1996). The first well contained 4 parts per billion (ppb) of benzene and 33 ppb of total xylenes. These contaminants were not detected in any upgradient or on-site wells at OU V. These contaminants are known to be in petroleum products, and it is possible that a gasoline or an oil spill occurred in the area. The second well contained 0.12 ppb of 1,2-dibromoethane, more commonly referred to as ethylene dibromide (EDB). The source of the EDB is not known, but it could be from pesticide application in the area. The third well contained TCE at the MCL of 5 ppb.

E.5.2.1 Radiological Contamination

The tritium plume in OU V originates from the STP outfall and lies on the eastern boundary of BNL (CDM 1995). Tritium reaches the STP from three sources: High Flux Beam Reactor (HFBR) sanitary system releases; small, infrequent batch releases; and the release of tritiated distillate generated by the on-site liquid waste concentration process. Tritium-contaminated wastewater was released to the STP in late October and early November 1984 (ITC 1996). The source of the tritium was distillate from the evaporation process at the Waste Concentration Facility that was discharged to the STP. Tritium is routinely released from the STP at levels below the drinking water standard. The highest concentration of tritium detected in on-site monitoring wells was 2,280 picocuries per liter (pCi/L), approximately one-tenth of the drinking water standard

(20,000 pCi/L). Results from groundwater samples collected in off-site monitoring wells indicated that some of the wells contained concentrations of tritium at levels exceeding the drinking water standard. BNL requested the SCDHS to collect 21 water samples from private residential wells in an area south of the Peconic River. Low levels of tritium were detected in some of the residential well samples, but all concentrations were below the drinking water standard (ITC 1996).

E.6 Operable Unit VI

Operable Unit VI is in the southeastern portion of the laboratory property. Figure 1 in Appendix B outlines the boundary of the OU. There are four potential areas of environmental contamination in OU VI: the suspected source of the ethylene dibromide (EDB) groundwater plume, the upland recharge/meadow marsh area, the biology fields, and the gamma field (ITC 1998). The EDB plume consists of low concentrations of EDB in groundwater, located within and downgradient of OU VI. Groundwater in this part of the site flows to the south-southeast. EDB has been found above the New York State drinking water standards at BNL site boundary of OU VI and off site. The precise sources and times of release are unknown.

The upland recharge/meadow marsh area was the site of experiments to evaluate the capacity of small natural and man-made terrestrial and aquatic ecosystems to treat sewage and recharging ground and surface waters (ITC 1998). Liquid effluent from residential cesspools and treated and untreated effluent from BNL sewage treatment plant were applied to various study areas within this area. The biology fields consist of four Army spray research fields, two plowed biology fields, and a nursery stock area. The gamma field was used for research to evaluate the effects of gamma radiation, acid preparation, sulfur oxide, and ozone on crop growth.

The suspected source of contamination is the Biology Fields within OU VI. The EDB was used as a soil fumigant to sterilize the soils. USEPA banned EDB as a soil and grain fumigant in 1984 (ATSDR 1992). However, EDB is still used today for controlling termites and bark beetles in wood, for controlling wax moths in beehives, and as a chemical intermediate for dyes, resins, waxes, and gums (ATSDR 1992).

E.6.1 Soil

A total of 35 surface (zero to 6 inches) soil samples were collected from the upland recharge/meadow marsh area, the biology fields, and the gamma field between October 17, 1994, and April 21, 1995. These samples were chemically analyzed for TCL VOCs, TCL SVOCs, TCL PCBs/pesticides, TAL inorganics, EDB, herbicides, and radionuclides including tritium (ITC 1998).

Soil sampling did not reveal any EDB concentrations in the Biology Fields area. Studies performed on EDB at the Connecticut Agricultural Experiment Station showed that it persisted in agricultural topsoils up to 19 years after its last known application to the soil (Steinberg et al 1987). The residual EDB appears to have strong sorptive capabilities with the soil, and that may explain why it is highly resistant to both mobilization and microbial degradation (Steinberg et al 1987). It appears that if there were EDB use in this area, it most likely happened in the 1960s or the early 1970s. One chemical, benzo(a)pyrene, was detected above its RBC (it has no CV) in surface soil (Table SS9).

The maximum concentrations of most organic analytes were found at the southern end of the upland recharge/meadow marsh area (sampling point SB-72). The maximum concentrations of inorganic analytes were also found in the upland recharge/meadow marsh area. The only exceedence of CVs or RBCs for benzo(a)pyrene occurred at sampling point SB-72.

The concentrations of radionuclides (Table SS10) throughout OU VI were approximately equal to background levels. Twelve radionuclides were detected in surface soil samples. Three compounds (strontium-90, lead-212, and tritium) were detected in all samples. The maximum concentrations of all the compounds were detected in the upland recharge/meadow marsh area.

E.6.2 Groundwater

Before 1993, OU VI did not have an extensive network of monitoring wells. The pesticide 1,2 dibromoethane (EDB) was found in on-site monitoring wells in OU VI. A maximum concentration of 0.21 ppb was detected. The New York State MCL for EDB is 0.05 ppb. Results of groundwater monitoring downgradient of the biology fields have indicated levels of EDB above the New York State and federal MCL. In 1993, the SCDHS detected EDB in a private residential well downgradient of OU VI. To determine the horizontal and vertical extent of the EDB plume, the SCDHS installed 30 profile wells on site, along the site boundary, and off site.

Detections of EDB in groundwater near the Biology Fields are at shallow depths; near the site boundary, the detections are at greater depths. In the Biology Fields area, the vertical extent of EDB contamination ranges from 20 feet below ground surface (bgs) to 45 feet bgs. As the plume approaches the property boundary and North Street, the vertical profile of EDB contamination ranges between 50 feet bgs and 145 feet bgs (CDM 1996). Between December 1994 and April 1995, two rounds of sampling for on-site wells south and east of the Biology Fields indicated concentrations ranging from 0.04B0.78 ppb (CDM 1996). Groundwater modeling has indicated that the EDB is migrating toward a wooded area south of North Street and west of Weeks Avenue (CDM 1996). Figure 5 in Appendix B details the extent of the plume. The plume is below the southeastern boundary of the site. Samples also indicated EDB in two private wells on Weeks Avenue and in two adjacent temporary monitoring wells on South Street near its intersection with Weeks Avenue (CDM 1996). EDB was detected in two separate wells on Weeks Avenue between April 1992 and June 1995 (CDM 1996). One well sampled in October 1994 revealed EDB at 1.2 ppb and methyl-t-butyl-ether (MTBE) and 1,2-dichloroethane (1,2-DCA). Resampling of the well in June 1995 indicated a level of EDB at 0.12 ppb. Sampling of the well in December 1992 had not revealed any EDB, MTBE, or 1,2DCA contamination. At the recommendation of SCDHS, the homeowner installed a carbon filter (USDOE 1996). An April 1992 sampling of the adjacent well detected a concentration of 0.2 ppb of EDB. A sample collected from the well, which was drilled deeper sometime between April and September, in September 1992 had undetectable levels of EDB and MTBE.

These off-site detections do not appear to be directly downgradient of the OU VI contamination. Monitoring wells located between the OU VI contaminant plume and the two residential wells on Weeks Avenue have not indicated the presence of EDB. Another source of contamination is possible, and various spills in this area have been reported to the New York State Department of Environmental Conservation (CDM 1996). The presence of MTBE and 1,2-DCA indicate that a gas spill might have occurred. Both these compounds and EDB have been used as leaded gasoline additives.

Samples from two SCDHS wells on South Street in 1993 revealed EDB. EDB was also detected in a SCDHS well on North Street at 3 ppb. In April 1995, EDB was detected in a vertical profile well on North Street at 3.4 ppb (BNL 1996a). EDB has also appeared in an undeveloped area of Manorville, approximately 1,000 feet west of Weeks Avenue and about 500 feet south of North Street (USDOE 1996). The EDB was between 90 and 130 feet deep at concentrations ranging from 1.2 to 3.5 ppb.

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