FINAL
Remedial Investigation Report

Clifton Former MGP Site
Operable Unit 2 (OU-2)

Staten Island, New York
AOC Index No.: D2-0001-98-04
Site No.: 2-43-023

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Abbreviations and Acronyms

AOC	Administrative Order on Consent
BCF	Bioconcentration Factors
BTEX	Benzene, Toluene, Ethylbenzene, Xylene
CCMP	Comprehensive Conservation and Management Plan
COCs	Contaminants Of Concern
COPECs	Chemicals Of Potential Ecological Concern
COPCs	Chemicals of Potential Concern
CPAH	Total Carcinogenic PAHs
CRSM	Conceptual Risk System Model
DNAPL	Dense Non-Aqueous Phase Liquid
DO	Dissolved Oxygen
EPA	United States Environmental Protection Agency
EPCs	Exposure Point Concentrations
FWIA	Fish and Wildlife Impacts Analysis
HASP	Health and Safety Plan
IRM	Intermediate Remedial Measure
MGP	Manufactured Gas Plant
MSDS	Material Safety Data Sheets
NAPL	Non-aqueous Phase Liquids
NAVD	National Astronomic Vertical Datum
NGVD	National Geodetic Vertical Datum
NOAELs	No Observed Adverse Effect Levels
NWI	National Wetland Inventory
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
OU	Operable Unit
ORP	Oxidation/Reduction Potential
OSHA	Occupational Safety & Health Administration
OVA	Organic Vapor Analyzer
PAHs	Polycyclic Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
PID	Photoionization Detector
PVC	Polyvinyl chloride
QHEA	Qualitative Human Exposure Assessment
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation

Abbreviations and Acronyms (cont.)

ROW	Right of Way
RSCOs	Recommended Soil Cleanup Objectives
RSRs	Remediation Standard Regulations
SCGs	Standards, Criteria Or Guidance
SVOC	Semivolatile Organic Compound
TAGM	Technical Adminstrative Guidance Memorandum
TAL/TCL	Target Compound List/Target Analyte List
TCLP	Toxic Characteristic Leaching Procedure
TCN	Total Cyanide
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
TOGs	Technical and Operational Guidance Series
TPAH	Total PAH
UCL	Upper Confidence Limit
USGS	United States Geological Survey
UST	Underground Storage Tank
VOC	Volatile Organic Compound

MEASUREMENTS

bgs	Below Ground Surface
ID	Inner Diameter
MMCF	Million Cubic Feet
ppb	Parts Per Billion
ppm	Parts Per Million
ug/m	Microgram per meter

Glossary

This section includes key definitions and common terms used throughout this document and throughout documents pertaining to the New York State Department of Environmental Conservation (NYSDEC) Division of Environmental Remediation's (DER) remedial program. The purpose of the glossary is to give the reader a better understanding of the fundamental concepts discussed in this document. Additional information on these and other terms applicable to this document may be found in the NYSDEC guidance document DER-10, available at http://www.dec.state.ny.us/website/der/guidance/der10dr.pdf.

Key Definitions

"Manufactured Gas Plant (MGP)" was an industrial facility that produced gas for cooking and lighting of residences and for use by businesses. Gas was produced through a variety of processes that heated coal or oil and drew off the gas, which was stored for distribution to customers. The operation also produced useful byproducts as well as waste materials. MGPs were common in the era before pipelines and distribution systems brought natural gas directly to homes and businesses from fields hundreds or thousands of miles away. The process of manufacturing gas through heating coal or oil and storing the gas in large holders was managed under environmental regulations and standards very different than those in place today, as many of the plants operated as early as the 1850's, and most were shut down and dismantled in the 1950's and 1960's.

"Manufactured Gas Plant site (MGP site)" is the actual property on which an MGP was located, as well as any area, on or off that property, that may have been impacted by its operation. The impact may have occurred through the discharge, spillage, leakage or disposal of material during operations on the property or by the subsurface migration of chemical constituents to adjacent and nearby areas.

"MGP Tar" was a byproduct of the production of gas, and is frequently found on or near former MGP sites. Tars range in consistency from maple syrup to taffy-like and are similar in chemical composition to heating oil or driveway sealer. It may also be referred to as "source material" because many of the chemical constituents related to an MGP site are products of the dissolution or decomposition of tar.

“Chemical Constituent” or **“Contaminant”** is a chemical that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects A chemical constituent may be present in soil or groundwater at an MGP Site and is the result of the breakdown or dissolution of a material. A chemical constituent may or may not be considered hazardous, depending on its known or suspected effect on human health, flora or fauna. Many chemical constituents of MGP-related material are known to be harmless. The source of a chemical constituent may be from the site, off-site sources or background.

“Hazardous Waste” is a material whether deliberately or inadvertently disposed of in the environment that is known or suspected under regulatory standards to cause a risk of harm to human health, flora or fauna if there is exposure to the material. Not all MGP materials are hazardous waste. Both USEPA and NYSDEC define Hazardous Wastes to be wastes that are characteristically hazardous as determined through specific laboratory testing for ignitability, corrosivity, reactivity, and toxicity. These and other wastes that are generated through non-specific sources and through specific industrial sources [so-called “listed wastes”] are documented in the Federal register and in 6 NYCRR Part 371.

“Remediation” is an action, or combination of actions designed to eliminate or reduce the risk associated with exposure or possible exposure to chemical constituents that may pose a risk to people or the environment. Remediation can include removal, reduction, treatment, covering or encapsulation of chemical constituents, or any other process, technology or measure that reduces the potential for exposure to levels deemed protective of human health and the environment according to regulatory standards. Remediation does NOT require “clean-up” or removal of all chemical constituents.

“Interim Remedial Measure (IRM)” is an action or actions of limited scope designed to reduce the potential for exposure to chemical constituents. It can be implemented without extensive investigation and evaluation at any time during the process before a comprehensive Remedial Action Plan can be put in place.

“Remedial Action Plan (RAP)” is a comprehensive program of remediation actions, selected and approved by the NYSDEC, to achieve reduction of potential exposures associated with a former MGP site to levels that are protective of human health and the environment according to regulatory standards.

"Remedial Investigation (RI)" is a comprehensive study of the nature and extent of the environmental impacts of former MGP operations. It is conducted to the requirements of a detailed Work Plan approved by the NYSDEC, which describes the scope of the investigation, the boundaries of where it is to be conducted, how it is to be conducted, how the data are to be produced and analyzed and how the Remedial Investigation Report is to be organized and presented. The purpose of a Remedial Investigation is to provide a sufficient understanding of the impacts of a former MGP site to ensure that a Remedial Action Plan or Interim Remedial Measures are appropriate to the conditions and act to protect human health and the environment according to regulatory standards. A Supplemental Remedial Investigation may be conducted to expand or further refine data and analysis produced under the Remedial Investigation Work Plan.

Common Terms

"Airborne Particulates" are the total suspended particulate matter found in the atmosphere as solid particles or liquid droplets. Sources of airborne particulates include: dust, emissions from industrial processes, combustion products from the burning of wood and coal, and combustion products associated with motor vehicle or other engine exhausts.

"Analyte" is a term used for a specific chemical submitted for laboratory analysis.

"Analytical Services Protocol (ASP)" means the New York State Department of Health's (NYSDOH's) compendium of approved EPA and other laboratory methods for sample preparation and analysis and data handling procedures.

"Aquifer" is generally known as an underground water-bearing soil or rock formation.

"Area of Concern" means any existing or former location where contaminants are or were known or suspected to have been discharged, generated, manufactured, refined, transported, stored, handled, treated, disposed, or where these contaminants have or may have migrated.

"Biota" means all the plant and animal life of a particular region.

"Blebs" means observed discrete sphericals or very fine droplets of NAPL/tar within a soil or groundwater sample matrix that may not otherwise be visibly contaminated. The blebs can be from various sources including MGP and non-MGP (e.g. petroleum) sources, depending on their characteristics. Typically, blebs are residual contamination. See **"MGP Tar"** and **"NAPL"** for more details.

"Brownfields" are abandoned, idled, or under-used properties where expansion or redevelopment is complicated by real or perceived environmental contamination, usually related to a prior use. They typically are former industrial or commercial properties where operations may have resulted in environmental contamination.

"BTEX" is an acronym for benzene, toluene, ethylbenzene and xylenes. This group of volatile organic compounds is most frequently found in soil and groundwater associated with petroleum fuels such as gasoline and fuel oil, but is also associated with former Manufactured Gas Plant (MGP) operations. See **"Hydrocarbons"** and **"Volatile Organic Compounds"** for more details.

"CERCLA" means the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly known as the federal Superfund law. This law is applied by the United States Environmental Protection Agency. Most MGP sites in New York are under the direction of the NYSDEC).

"Coated" is used to when some soil grains are covered by NAPL/tar/petroleum and there is not sufficient free-phase material to fill all the pore spaces between the soil grains.

"Conceptual Site Model" is a general representation of a site describing potential contaminant releases, exposure media, the potential receptors, and the complete exposure pathways to the receptors.

"Confining Layer" is a geologic formation that consists of soils or rock with low permeability that inhibits the flow of water. The "confining layer" acts to keep the contaminated groundwater in a definable area.

"Consent Order" A court enforceable agreement between the NYSDEC and KeySpan, sometimes referred to as an Order on Consent.

"Containment" means actions to limit or prevent discharges or the spread of contamination.

"Contaminant of Concern" – A contaminant identified as contributing to overall cancer or noncancer risk above a specified threshold (e.g. greater than 1.0 to the receptor Hazard Index) or at concentrations indicating potential health risks (i.e. greater than nuisance or risk-based concentrations).

"Contaminant of Potential Concern" is a contaminant chosen based on its occurrence, distribution, fate, mobility, and persistence in the environment and its potential for contact to people.

"Contaminant of Potential Ecological Concern" is any contaminant that is shown to pose possible risk to a flora or fauna.

"Contract Laboratory Program (CLP)" is a program of chemical analytical services developed by the United States Environmental Protection Agency (EPA) to support the federal Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), which is used to guide the analysis of materials produced in a Remedial Investigation.

"Data Usability Summary Report, (DUSR)" is a document that provides a thorough evaluation of the analytical data to determine whether or not the data, as presented, meets the site/project specific criteria for data quality and use.

"De minimis Risk" is risk that is negligible and too small to be of societal concern, which can also mean 'virtually safe'.

"DER" is the Division of Environmental Remediation of the NYSDEC.

"DER-10 Technical Guidance for Site Investigation and Remediation (DER-10)" is a guidance document developed by the DER, with assistance from the New York State Department of Health (NYSDOH) and the NYSDEC Division of Fish, Wildlife and Marine Resources, to allow anyone seeking to investigate or remediate a potentially contaminated site in New York State to anticipate the basic scope of the work required. The guidance is intended to facilitate consistent, accurate, efficient and timely completion of remedial projects and contains the minimum technical activities normally accepted for projects where DER oversight, approval or acceptance is sought or mandated by law. DER will, however, determine the acceptable minimum technical activities for a particular site upon consideration of all the facts and circumstances of such site under the authority of applicable laws and regulations.

"Discharge" means both unintentional and intentional spilling, leaking, pumping, pouring, emitting, emptying, or dumping of waste into or on any land, water or air.

"DNAPL" or a "Dense Non-Aqueous Phase Liquid" is a liquid that tends to exist as a separate phase or layer in water, and has a specific gravity or density greater than water (the greater density causes DNAPL to "sink" in water). DNAPL does not readily mix with water. DNAPL has the potential to sink through a soil formation until it encounters a confining layer. Unlike LNAPLs, DNAPLs may flow down the slope of a geological formation independent of the direction of groundwater flow.

"Endangered species, threatened species and species of special concern" means those species listed by the NYSDEC as provided in 6NYCRR Part 182. Animals, birds, fish, plants, or other living organisms threatened with extinction by anthropogenic (man-caused) or other natural changes in their environment. All plants and animals in these categories need special protection to prevent their extinction, or significant reduction in population. Protections include preventing hunting or capture, provision of habitats or removal of threats to the environment necessary to the survival of the species.

"Engineering Control" means any physical barrier or method employed to actively or passively contain, stabilize, or monitor contaminants, restrict the movement of contaminants to ensure the long-term effectiveness of a remedial program, or eliminate potential exposure pathways to contaminants. Engineering controls include, but are not limited to, pavement, caps, covers, subsurface barriers, vapor barriers, slurry walls, building ventilation systems, fences, access controls, provision of alternative water supplies via connection to an existing public water supply, adding treatment technologies to such water supplies, and installing filtration devices on private water supplies. Engineering controls are used in conjunction with institutional controls, to ensure that the engineering controls remain effective. See "Institutional Controls" for more information.

"Exposure Assessment (EA)" is an evaluation, undertaken as part of a Remedial Investigation, to identify the exposure setting, exposure pathways, and evaluate the fate and transport of the contaminants. The assessment will identify potential risks for specific potential receptors based on complete pathways of exposure to contaminant levels exceeding default "screening criteria," such as the NYSDEC-recommended soil cleanup objectives (RSCOs) and drinking water standards.

"Exposure Pathway" means the route through which humans or animals may come into contact with a contaminant. The five elements of an exposure pathway are: 1) the source of contamination; 2) the environmental media and transport mechanisms (how the contaminant moves); 3) the point of exposure; 4) the route of exposure; and 5) the receptor population. Evaluation of an exposure pathway considers past, present, and future events.

"Exposure Point" is a location of potential contact between a chemical or physical agent and an organism (surface soil, drinking water tap).

"Exposure Point Concentration" is the value representing a conservative estimate of the chemical concentration available from a particular route of exposure.

"Exposure Route" is the method of contact for a chemical or physical agent to an organism (inhalation, ingestion, dermal contact).

"Feasibility Study (FS)" is a study undertaken to develop and evaluate potential remediation alternatives for a site. The term also refers to the report that describes the results of the study.

"Fish and Wildlife Resources" means biota (animals and plants) and the habitats (natural or man-made) which support them.

"Free Product" means an immiscible (non-mixable) or non-aqueous phase liquid (NAPL) existing at the surface or in the subsurface in a potentially mobile state.

"**FWIA"** stands for Fish and Wildlife Impact Analysis. The site-specific analysis will identify the fish and wildlife resources that presently exist and that existed before contaminant introduction at the site in question, and the completed FWRIA will guide the Division of Fish and Wildlife in deciding when, where, and to what extent remediation is warranted for the protection of biotic resources. This analysis conformed with NSYDEC's 1994 publication *Fish and Wildlife Impact Analysis for Hazardous Waste Sites.*

"Groundwater" is water below the land surface in a saturated zone of soil or rock. This includes perched water separated from the main body of groundwater by an unsaturated zone.

"Hydraulic Gradient" is the direction of groundwater flow due to changes in the depth of the water table. The terms "upgradient" and "downgradient" are typically used when referencing groundwater, similar to the use of upstream and downstream when referencing rivers and streams. Hydraulic gradient is equal to the difference in head (pressure) measured at two points (usually wells) divided by the distance separating the two points. Hydraulic Gradient can be thought of as the slope of the water table or "rise over run". The dimensions of head and distance are both lengths, therefore the gradient is expressed as a dimensionless ratio (L/L).

"Hydrocarbons" are chemical compounds that consist of carbon and hydrogen, such as petroleum, natural gas and coal.

"Injury" means an observable (i.e., qualitative) or measurable (i.e., quantitative) adverse change in a natural resource or any impairment of a human or ecological service provided by that resource relative to baseline, reference, or control conditions.

"Institutional Control" means any non-physical means of enforcing a restriction on the use of real property that limits human or environmental exposure, restricts the use of groundwater, provides notice to potential owners, operators, or members of the public, or prevents actions that would interfere with the effectiveness of a remedial program or with the effectiveness and/or integrity of operation, maintenance, or monitoring activities. Institutional controls apply when contaminants remain at a site at levels above the SCGs (see definition), which would allow unrestricted human use of the property. Institutional controls may include, without limitation, restrictions on the use of structures, land and groundwater as well as deed notices and covenants.

"Light Non-aqueous Phase Liquid (LNAPL)" means a liquid which remains as a separate phase or layer and has a specific gravity less than water. LNAPL does not readily mix with water. Because LNAPLs are less dense than water, they tend to float on top of the water table.

"Method detection limit (MDL)" means the minimum concentration of a substance that can be measured and reported with a 99 percent confidence that the substance is present, determined from the analysis of a sample by specific means (instruments, chemicals, technicians).

"NAPL" or "Non-Aqueous Phase Liquid" means a liquid which remains as a separate phase or layer in the environment. See the definitions for DNAPL and LNAPL.

"NYSDEC" is the New York State Department of Environmental Conservation which has statutory authority to enforce State environmental regulations, and to protect the environment.

"NYSDOH" is the New York State Department of Health. The NYSDOH works with the NYSDEC with its environmental program by reviewing project documents and details to ensure the protection of health.
"Operable Unit" is a portion of a site that is addressed separately from the rest to allow for more efficient management or a more timely response.

"PAH" means polycyclic aromatic hydrocarbon. They are a series of related organic compounds that have more than one aromatic ring. For example, naphthalene, a common PAH found in gasoline and petroleum mixtures, is comprised of two aromatic rings. Many PAH's are byproducts of combustion, or heating of fossil fuels, including coal, oil, and gasoline.

"Petroleum" or "Oil" is defined by Article 12 Section 172 of the NYS Navigation Law as oil or petroleum of any kind and in any form including but not limited to oil, petroleum, fuel oil, oil sludge, oil refuse, oil mixed with other wastes and crude oils, gasoline and kerosene. For purposes of this glossary, oil includes mineral oils or any other oil for which an investigation and/or remediation is determined necessary by the DER, to address a spill or discharge or any disposal impacting public health or the environment.

"Purifier Material" is usually comprised of wood chips or granular material from the gas purifier operation typically used at former MGP sites. The purifier material would remove impurities which otherwise would corrode the gas piping, stoves, and lighting fixtures where the gas was burned. Purifier material may contain sulfur or cyanide compounds.

"Quality Assurance" is the total integrated program for assuring the reliability of the monitoring and measurement data on which the analysis, findings and conclusions of a Remedial Investigation or performance of a remedial measure are based. It includes a system for integrating the quality planning, quality assessment and quality improvement efforts to meet data end-use requirements. A "Quality Assurance Project Plan (QAPP)" is a document which presents in specific terms the policies, organization, objectives, functional activities and specific quality assurance/quality control activities designed to achieve the data quality goals or objectives of a specific project or operation.

"Quality Control" means the routine application of procedures for attaining prescribed standards of performance in the monitoring and measurement process.

"QHEA" stands for Qualitative Human Exposure Assessment. A qualitative exposure assessment is defined by the NYSDOH as characterizing the exposure setting (including the physical environment and potentially exposed human populations), identifying exposure pathways, and evaluating contaminant fate and transport. An exposure pathway describes the means by which an individual may be exposed to contaminants originating from a site. Performing the assessment assists the NYSDOH in evaluating whether there are any potential populations exposed to materials related to a site. The QHEA is prepared to meet the NYSDOH's requirements identified in Appendix 3B of the NYSDEC's 2002 .*Draft Technical Guidance for Site Investigation and Remediation*

The QHEA was performed to meet the requirements identified in the NYSDOH's November 9, 2000 guidance memorandum titled *New York State Department of Health, Qualitative Human Health Exposure Assessment (NYSDEC, 2002)*.

"RCRA" means the federal Resource, Conservation and Recovery Act of 1976. This is a federal law that authorizes the EPA to set standards for companies producing, handling, transporting, storing, and disposing of hazardous waste; and established a regulatory system to track hazardous substances from generation to disposal. The law requires safe and secure procedures to be used in treating, transporting, storing and disposing of hazardous substances. The Act is designed to prevent the creation of new, uncontrolled hazardous waste sites.

"Receptor" means any humans or biota which are, or may be expected to be, or have been, exposed to or affected by a contaminant from a site.

"Risk" is the probability that a chemical, biological, or physical agent will cause harm or injury under specified conditions.

"Sediment" means soils or organic material in water, as found in lakes, rivers, streams and other water bodies and in, or in close proximity to, wetland areas. Material found in enclosed sumps, sewers or piping systems not accessible to fish and wildlife and not forming any benthic or aquatic habitat are not considered sediments for the purpose of comparison to the NYSDEC Technical Guidance for Screening Contaminated Sediment.

"Semivolatile Organic Compounds" is a general term for a class of organic compounds that volatilize relatively slowly at standard temperature (20 degrees Celsius) and pressure (1 atm). Examples of semivolatile organic compounds include naphthalene, benzo(a)pyrene, and fluorine. They are amenable to analysis by extraction of the compound from the sample with an organic solvent. Semi-volatiles are those target compounds identified in the statement of work in the current version of the EPA Contract Laboratory Program.

"Sheen" is iridescence (shininess) observed within a soil sample or on the surface of a water sample. A field test for sheen is to put a soil sample in a jar of water and shake the sample (jar shake test), then observe the presence/absence of sheen on the surface of the water in the jar. When evaluated in the field in conjunction with a sample's odor, or other physical characteristics, the origin of the sheen can be estimated (i.e. hydrocarbon sheen, bacterial sheen, etc.).

"Soil Vapor" or **"Soil Gas"** refers to the air and other gases found in the pore spaces of soils above the water table. (Below the water table, these pore spaces are filled with water).

"Stained" is when a soil sample exhibits a discoloration not associated with natural processes. The color of the observed stain is used and if the characteristics of the staining material are discernible, they are also noted (i.e., tar-stained or petroleum-stained).

"Surface Soil Sample" is a representative sample of the unconsolidated mineral and/or organic matter collected from a site to a depth of two inches below ground surface (excluding vegetative, stone, asphalt, or concrete surface cover) for evaluating public health exposure; or, to a depth of six inches below ground surface for garden soils or a fish and wildlife resources impact analysis.

"Target Analyte List (TAL)" is the list of inorganic compounds/elements designated for analysis as contained in the version of the EPA Contract Laboratory Program Statement of Work for Inorganic Analysis, Multi-Media, Multi-Concentration in effect as of the date on which the laboratory is performing the analysis.

"Technical and Operational Guidance Memorandum (TOGs)" are memos providing information, explanation and technical detail for the NYSDEC Division of Water program. The TOGs memos may be used as the basis for SCGs related State Pollutant Discharge Elimination Permits (SPDES), groundwater, water quantity, and other technical and administrative subjects.

"Toxicity Assessment" is a field study, laboratory study and/or literature review conducted to determine the concentration at which a contaminant becomes toxic to an individual or an organism. A contaminant is considered toxic if it causes death, morbidity or sub-lethal effects on growth, reproduction, behavior or physiology of an organism, whether through direct or indirect toxicity or through bioaccumulation.

"Underground Storage Tank (UST)" means any tank or other vessel which is completely covered with earth or other backfill substance. Tanks in subterranean vaults accessible for inspections are not considered underground storage tanks.

"USEPA" stands for the United States Environmental Protection Agency. The EPA leads the nation's environmental science, research, education and assessment efforts. They develop and enforce regulations, offer financial assistance, perform environmental research, sponsor voluntary partnerships and programs, and further environmental education.

"Volatile Organic Compounds" is a general term for a group of organic (carbon-based) compounds that evaporate at room temperature and normal atmospheric pressure. Examples of volatile organic compounds include benzene, toluene, and ethylbenzene. They are amenable to analysis by the purge and trap technique. Analysis of volatile organics means the analysis of a sample for either those priority pollutants listed as amenable for analysis using EPA method 624 or those target compounds identified as volatiles in the version of EPA "Contract Laboratory Program Statement of Work for Organics Analysis, Multi-Media, Multi-Concentration" in effect as of the date on which the laboratory performed the analysis.

"Waters" means all lakes, bays, sounds, ponds, impounding reservoirs, groundwater, springs, wells, rivers, streams, creeks, estuaries, marshes, inlets, canals, the Atlantic Ocean within the territorial limits of the State of New York, and all other bodies of water, natural or artificial, inland or coastal, fresh or salt, public or private, which are wholly or partially within or bordering the State or within its jurisdiction.

"Wetland" means a lowland area, such as a marsh or a swamp that is saturated with moisture. The NYSDEC regulates how different types of wetlands are classified and the activities that can occur within and adjacent to wetlands.

Executive Summary

On behalf of KeySpan Corporation (KeySpan), GEI Consultants, Inc. (GEI) conducted a remedial investigation (RI) and prepared this RI report which addresses environmental conditions at and adjacent to the former manufactured gas plant (MGP) located at 25 and 40 Willow Avenue in the neighborhood of Clifton, Staten Island, New York. The focus of this report is on the property located at 25 Willow Avenue and surrounding properties (Operable Unit 2 [OU-2]). A previous RI report focused on the 40 Willow Avenue property (*Final Remedial Investigation Report Clifton Former MGP Site Operable Unit 1*, GEI and VHB, July 1, 2004). The RI was performed in accordance with an Administrative Order on Consent (Index No. D2-0001-98-04) (AOC), the November 9, 1998 approved RI work plan, and the July 26, 1999, November 28, 1999, October 9, 2001, May 15, 2002, and November 4, 2002 approved RI work plan addenda.

The following is a summary of the principal conclusions of the RI:

- The chemicals encountered within soils and groundwater at OU-2 are consistent with those expected at former MGP sites. Other site operations, including former petroleum storage, have also contributed to the chemicals encountered in on-site soils and groundwater.
- Chemicals from OU-2 have not impacted potable water supplies in the area. Potable water is supplied by the New York City water system.
- There is no indication that the chemicals detected on the site adversely impact fish and wildlife in the area.
- There is no indication that persons working on or visiting the portions of OU-2 not situated at the 25 Willow Avenue parcel are being exposed to site-related chemicals, although chemicals have been detected at off-site locations.
- Soil vapor sampling beneath the building located at 25 Willow Avenue demonstrated that soil vapor concentrations are de minimus and, as such, pose an insignificant human health exposure to any potential workers who may occupy the 25 Willow Avenue building. The building is currently unoccupied and will eventually be demolished.

The RI investigation activities and findings are summarized below.

The RI was implemented in eight rounds of field work completed between February 1999 and December 2004. An investigation of soil conditions and soil vapor concentrations at the One Edgewater Street parcel is currently being performed [Round 8 of the RI]. Findings from this investigation will be submitted as a Supplemental RI Report following completion of the work.

The scope of the RI included the completion of exploratory test pits, soil borings, groundwater monitoring wells, piezometers, and surface-soil, soil vapor, and storm sewer sampling at the 25 and 40 Willow Street parcels and adjacent properties. The parcels have been separated into two operable units as the site progresses towards remedial action. Operable Unit 2 (OU-2) is the focus of this report and includes the following parcels: 25 Willow Avenue, adjacent parcels located to the northwest on Greenfield Avenue, railroad embankment and active railroad ROW, and a small triangular shaped parcel located between Bay Street and Edgewater Street. OU-2 also encompasses the rights of way (ROWs) of Willow Avenue, Edgewater Street and Bay Street adjacent to the 25 Willow Avenue parcel, as well as the property located at One Edgewater Street [currently being investigated].

The scope of the RI completed at OU-2 included nine exploratory test pits, drilling of 46 subsurface-soil borings, drilling and installation of 18 groundwater monitoring wells, installation of two piezometers, sampling of three storm sewer locations and the sampling of 10 background surface-soil locations. One hundred and fourteen subsurface-soil samples, 10 surface-soil samples, 19 groundwater samples, and three storm sewer samples were chemically analyzed to evaluate the environmental conditions within OU-2. Twelve soil vapor samples were also collected from beneath the building at 25 Willow Avenue.

The 25 Willow Avenue parcel is triangular in shape. It encompasses approximately 3.53 acres on the northwestern corner of Bay Street and Willow Avenue. It is bordered on the northwest by a wooded railroad embankment and active railroad ROW, on the northeast by Bay Street, and on the south by Willow Avenue. The 25 Willow Avenue parcel includes a large rectangular commercial building that is currently unoccupied and recently was used for the preparation and repair of new cars. With the exception of a small strip of landscaping along Bay Street, the remainder of the parcel is covered by a parking lot. The 25 Willow Avenue parcel was the site of former tar handling structures associated with the gas production area of the former Clifton MGP. The former MGP is set in an urban residential/commercial area of Staten Island. KeySpan currently owns the parcel. Commercial parcels are located on Greenfield Avenue, an active railroad embankment and an active railroad ROW to the northwest, and a vacant lot (utilized for parking) is located between Bay and Edgewater Streets to the northeast.

Construction of the former MGP began circa 1850 and the plant began production in April of 1857. Throughout the operating life of the plant, most of the operations were located on the 25 Willow Avenue parcel (Staten Island Gas Light/Richmond County Gas Light Company). Sometime prior to 1917, the plant expanded to the 40 Willow Avenue parcel with the addition of Relief Holder No. 2. Between 1937 and 1950, minor expansions occurred on both parcels. The MGP was demolished in 1959.

The geological setting has OU-2 located atop glacial deposits, including ground moraine, terminal moraine, and glacial outwash materials. The Manhattan Schist (bedrock) underlies these glacial deposits. Alluvial materials are also present at shallow to intermediate depths within OU-2. Fill is present at shallow depths across the majority of OU-2.

Topographically, the 25 Willow Avenue parcel is located in a gently sloping bowl-like depression that appears related to a historic stream channel. The nearest surface water body is New York Harbor, which is located approximately 500 to 600 feet to the northeast. Public water supply is currently provided to the parcels included in OU-2 and all surrounding residents and businesses. The source of the public water supply is reservoirs in the Catskill Mountains north of New York City.

Groundwater beneath OU-2 resides in two aquifers, shallow (water table) and deep. Dense, silty ground moraine and terminal moraine deposits create a hydrogeologic confining unit between the aquifers. Groundwater flow direction in the water table aquifer is easterly towards New York Harbor and westerly towards the location of a former stream trace (current storm sewer). Groundwater from the western side of the storm sewer (along Greenfield Avenue and the railroad embankment) flows easterly toward the former stream trace. The groundwater from either side of OU-2 ultimately flows northeasterly towards New York Harbor. An isolated water-bearing zone was also identified within the confining unit at the 25 Willow Avenue parcel along Bay Street and Edgewater Street.

The most extensive observations of tar, tar-staining, sheen, odors, and soil and groundwater containing chemical constituents related to the former MGP are primarily limited to the 25 Willow Avenue parcel in close proximity to the former MGP-related structures. Isolated tar, tar-staining, sheen, and/or tar-like odors were only present in coarse-grained soils beneath the Willow Avenue ROW, the small triangular parcel between Bay Street and Edgewater Street and within Edgewater Street. Additional tar impacts in soils are being investigated at the One Edgewater Plaza parcel. Most of the chemical constituents in these areas were related to the presence of tar found within and adjacent to former MGP-related structures that handled tar as part of the gas production and storage process at the site. Minor amounts of chemical constituents at the site were related to former storage of gasoline and diesel fuels at the site.

Similarly, dissolved chemical constituents in groundwater within the water table aquifer are predominantly limited to the 25 Willow Avenue parcel. Elevated dissolved-phase benzene, toluene, ethylbenzene, and xylene (BTEX) and polycyclic aromatic hydrocarbons (PAHs) were present in groundwater within the water table aquifer at the 25 Willow Avenue parcel in the vicinity of the former tar handling structures. Total cyanide was also detected within the shallow groundwater aquifer downgradient from the former purifying tanks. These concentrations decreased downgradient of the former structures. Total cyanide was also detected within the shallow groundwater aquifer downgradient from the former purifying tanks. These concentrations decreased downgradient of the former structures. Cyanide in groundwater does not represent a complete human exposure pathway under current use because the site is paved and the groundwater is inaccessible.

A water-bearing zone within the confining unit along Bay Street and Edgewater Street contained tar and consequently displayed elevated dissolved concentrations of BTEX and PAHs within monitoring wells RW-17, RW-18, and RW-19.

Only trace detections of dissolved phase BTEX were encountered in the deep aquifer monitoring wells RW-15 and RW-16, and PAHs were not detected.

The findings from the qualitative exposure assessment indicate that chemicals in soils, groundwater, and soil vapor within OU-2 do not present exposure pathways through which individuals could potentially be exposed under the current land uses. The assessment of exposure pathways and chemical occurrence of OU-2 revealed that chemicals were present in surface soils, subsurface soils, and groundwater above applicable regulatory standards. Based upon the current site conditions and site access at the 25 Willow Avenue parcel, there are currently no complete exposure scenarios. The on-site building is unoccupied and will eventually be demolished.

Direct contact with tar seeping through cracks in the pavement adjacent to the former gasometer and the current building at the 25 Willow Avenue site was considered a potential exposure pathway for some on-site receptors. This potential exposure pathway was mitigated by placing steel plates over the tar bubbles in accordance with a NYSDEC approved work plan.

The future site use scenario at the 25 Willow Avenue parcel could have potential pathways of concern if subsurface soils and groundwater are exposed through construction or utility work at the site. Based upon the current site use of off-site parcels and Willow Avenue, the current exposure pathways were considered incomplete and only the future intrusive activities could have potential pathways if soils and groundwater are exposed.

FWIA indicated that the site and surrounding area represent poor environmental resources due to the lack of vegetation in the urban environment. Wildlife species present are adapted to an urban setting and, due to the limited size of vegetated areas, only a few individuals would be present. Concentrations of several chemicals of potential ecological concern (COPECs) in soils pose a potential risk to wildlife; however, this potential risk has minimal ecological significance. Since only transient species and a few individual animals would use this area, the frequency and duration of exposure to COPECs is limited. Therefore, the on-site COPECs do not pose a current risk or an anticipated future risk to wildlife.

The body of this RI report presents the environmental observations and findings. The reader is referred to Sections 6 and 7 for a summary of the conceptual site model and a summary of the environmental and risk findings, respectively.

1. Introduction

GEI Consultants, Inc. (GEI) was retained by KeySpan Corporation (KeySpan) to conduct a remedial investigation (RI) and to prepare this RI report which addresses environmental conditions related to the former manufactured gas plant (MGP) operation at the parcels located at 25 and 40 Willow Avenue in the neighborhood of Clifton in Staten Island, New York (Figure 1-1).

The site has been separated into two operable units (OUs). Operable Unit 2 (OU-2) is the focus of this report and includes the following areas:

- 25 Willow Avenue parcel
- Adjacent active railroad right-of-way (ROW) and its associated embankment to the northwest
- Greenfield Avenue parcels to the northwest
- a vacant lot (utilized for parking) is located between Bay and Edgewater Streets to the northeast
- One Edgewater Street (also referred to as Edgewater Plaza) property to the northeast
- Willow Avenue, Bay Street, and Edgewater Street ROWs.

The remainder of the site (including 40 Willow Avenue, 66 Willow Avenue, Lynhurst Avenue residential parcels [48 through 67] and the Lynhurst Avenue ROW) constitutes OU-1. The findings for OU-1 were summarized in the Final Remedial Investigation Report Clifton Former MGP Site Operable Unit 1 (OU-1) that was prepared by GEI and VHB, dated July 1, 2004., and were submitted to the New York State Department of Environmental Conservation (NYSDEC). Plate 1 presents the extent of each operable unit.

The RI was performed in accordance with the Administrative Order on Consent (AOC) (Index No. D2-0001-98-04) between Brooklyn Union Gas Company (Brooklyn Union) (KeySpan's predecessor) and the NYSDEC for the former Richmond County Gas Light Company MGP located at the 25 and 40 Willow Avenue parcels.

KeySpan currently owns the 25 Willow Avenue parcel. Plate 1 presents the current layout and former MGP configuration for both operable units. The scope of the RI included the completion of exploratory test pits, subsurface borings, groundwater monitoring wells, piezometers, surface-soil, and storm sewer collection points.

Subsection 1.2.1 presents a detailed description of the OU-2 parcels.

The remainder of Section 1 discusses the RI Objectives and Scope (subsection 1.1), background (subsection 1.2), the physical and environmental setting (subsection 1.3), and a summary of previous investigations (subsection 1.4).

Section 2 discusses the RI Scope of Work and methods used during the RI. Section 3 discusses the geology and hydrogeology underlying OU-2. Section 4 discusses the nature and extent of physical observations and chemical constituents. Section 5 discusses the fate and transport of chemical constituents. Section 6 presents a conceptual site model for OU-2, Section 7 presents a QHEA and an FWIA. The findings of the OU-2 RI are summarized in Section 8.

1.1 RI Objectives and Scope

The RI was conducted in accordance with the AOC and as outlined in the approved RI Work Plan, dated November 9, 1998, and its approved addenda listed below. The addenda work plans are included in Appendix A.

- *Remedial Investigation Clifton Former MGP Site, Amendment to the Work Plan, Staten Island, New York (July 26, 1999) (Round 2)*
- *Clifton Former MGP Site, Additional Scope of Work for Residential Lots Adjacent to the 40 Willow Avenue Parcel, Staten Island, New York (November 28, 1999) (Round 3)*
- *Former Clifton MGP Site, Revised Supplemental Investigation (RI) Work Plan, 25 and 40 Willow Avenue Parcels, Staten Island, New York (October 9, 2001) (Round 4)*
- *Former Clifton, Staten Island MGP Site, Supplemental Remedial Investigation (RI) Revised Work Plan (May 15, 2002) (Round 5)*
- *Former Clifton, Staten Island MGP Site, Supplemental Remedial Investigation (RI) Work Plan-Edgewater Street (November 4, 2002) (Round 6)*
- *Sub-Slab Soil Vapor Sampling and Vapor Intrusion Analysis Work Plan , Former Clifton, Staten Island MGP Site, Operable Unit 2 (April 16, 2003) (Round 7)*
- *Clifton, Staten Island Former MGP Site, Supplemental Remedial Investigation (RI) Work Plan-1 Edgewater Street (October 20, 2003) and Soil Vapor Sampling Work Plan Operable Unit 2, 1 Edgewater Street/Edgewater Plaza (December 8, 2004) (Round 8)*

Based upon the findings of the QHEA, a NYSDEC-approved work plan was developed to place steel plates over isolated tar observed within cracks in the pavement at the 25 Willow Avenue parcel. This work plan was implemented to mitigate a potential exposure pathway for direct contact with tar bubbles. In addition, a work plan was developed to complete sub-slab soil vapor sampling and vapor intrusion analysis within the on-site commercial building located at 25 Willow Avenue. This work plan was approved by the NYSDEC on April 30, 2003 and the soil vapor sampling was conducted on June 10 and 11, 2003.

The RI was intended to characterize soil, groundwater, and soil vapor conditions at the 25 Willow Avenue parcel and adjacent parcels included in OU-2. The information gathered during the RI was intended to supplement information available from previous investigations of the 25 Willow Avenue parcel. Three previous investigations were completed at the 25 Willow Avenue parcel and Willow Avenue ROW by LEXICON and Fanning, Phillips, and Molnar (FP&M) between 1993 and 1998. These previous investigations are discussed in subsection 1.4.

1.2 Background

This subsection provides a description of the setting of OU-2 and discusses the surrounding demographics and the history of the former MGP.

1.2.1 Description of Parcels

The 25 Willow Avenue parcel encompasses approximately 3.53 acres. The 25 Willow Avenue parcel is triangular in shape, is located on the northwestern corner of Bay Street and Willow Avenue, and is bordered on the northwest by a wooded railroad embankment and active railroad ROW, on the northeast by Bay Street, and on the south by Willow Avenue (Plate 1). Commercial parcels are located on Greenfield Avenue to the northwest, and a vacant lot, utilized for parking, is located between Bay and Edgewater Streets to the northeast.

The 25 Willow Avenue parcel includes a single-story commercial building with multiple garage bays and is currently unoccupied. Until recently, the building was used as an automobile repair and car preparation facility for new automobiles. The automobile repair operations were conducted within the on-site building and likely required the handling and storage of petroleum products. Petroleum materials (motor oil, gasoline, diesel fuel, etc.) contain many of the same chemicals that are associated with MGP impacts (BTEX, naphthalene, and other semivolatile compounds). Use and handling of these materials may have had an effect on the indoor air quality of the building. Vehicles were also driven into a portion of the building where they are prepared for being delivered to automobile dealerships. Exhaust from the vehicles may have contributed many petroleum-derived compounds to the indoor air. In addition, periodic auto body painting activities were observed within the building, which may also have contributed to VOCs within the indoor air.

With the exception of a small landscaped strip along Bay Street, the remainder of the 25 Willow Avenue parcel is covered with a bituminous pavement parking lot.

Prior to use as an automobile repair and car preparation facility, the 25 Willow Avenue parcel was used as a service center for Brooklyn Union maintenance vehicles and earlier as the site of the gas generating operation of the former MGP. A chain-link fence surrounds the entire perimeter of the parcel (Plate 1).

The Greenfield Avenue parcels, located to the northwest of the 25 Willow Avenue parcel, are in a commercially zoned area along the eastern side of Greenfield Avenue. The parcels included within OU-2 consist of an active transformer yard, current lumber storage yard (formerly an automobile and boat repair yard), a current hardware store/lumber company, and an active railroad ROW (Plate 1). A chain-link fence surrounds the perimeter of each parcel.

The One Edgewater Street parcel is located to the northeast of the 25 Willow Avenue and is currently developed with a commercial office building and a paved parking lot. The property is surrounded by a chain-link fence and also contains a guarded entrance.

The land-use zoning for the OU-2 parcels is manufacturing zoned area (M3-1/M2-1) with a mixed commercial and industrial land use. Population data was obtained from the United States Environmental Protection Agency (EPA) Internet web site based upon 1990 census data. Census data from 1990 indicate that the average population density per square mile within 1 mile of the two parcels is 8,266 (Figure 1-2). There are 10,255 household units and a population totaling about 26,000 within this 1-mile radius. Updated population data obtained from the 2000 Census Internet web site indicates that the population density for Richmond County (Staten Island) ranges between 4,655 and 7,588 persons per square mile.

1.2.2 History

The Clifton former MGP was operated by Richmond County Gas Light Company from 1856 to 1901 and the Staten Island Gas Light Company circa 1884. Plate 1 shows the historic layout of the former plant. From 1901 until 1957, the plant was operated by the New York and Richmond Gas Company. Brooklyn Union acquired that company in 1957, at which point MGP operations ceased. Brooklyn Union (KeySpan) never operated the gas works.

The following discussion regarding the MGP history pertains to both OU-1 and OU-2.

Only a partial history of the former plant is available based on public records; however, through review of documentation at the Staten Island Institute of Arts and Sciences, *Brown's Directory of American Gas Companies (Brown's Directory)*, and available Sanborn Fire Insurance (Sanborn) maps, a general depiction of the former plant development is possible.

The earliest available map of the general vicinity is a Revolutionary War period map of Staten Island for the years 1775 through 1783 (Figure 1-3). Here the location of the future plant is shown as undeveloped with a small (un-named) stream flowing from the uplands to the south toward the northeast into New York Harbor. Bay Street (a.k.a. Shore Road) is essentially a shoreline travel way near the future plant location. Anchorages are also noted just offshore of where the MGP would be built 70 years later. In 1853, a James Butler map of the vicinity depicts substantial changes in the vicinity of the future plant (Figure 1-4). A street grid has been established, the shoreline appears to have bulkheads, and a number of dwellings dot the landscape. The unnamed stream that flows through the former MGP site is illustrated in more detail. This drawing probably represents the community layout at the time the MGP was constructed in 1850. It is documented in the *Richmond County Gazette* that the construction of the MGP began in 1850. At that time, the plant consisted of the following.

- A 30- x 50-foot brick retort house
- A 25- x 30-foot purifying house which contained purifiers, condensers, and a scrubber
- An office and meter house, 20 x 30 feet in dimension
- A single 75-foot-diameter holder having a brick tank 21 feet deep (subsequently referred to as Relief Holder No. 1)
- Lime and coal sheds

The plant was owned by the Richmond County Gas Light Company, which started production in April 1857.

The *1874 F.W. Beers Map of Staten Island* shows what is considered the earliest plant layout. Referring to Plate 1, the first gas holder is the same as Relief Holder No. 1. The main production facilities were located just to the southwest of the holder. Plate 1 indicates three of the original buildings as “purifying,” “retort house,” and “coal shed.”

According to an article written by F. Rider in 1961, titled *Looking Back to Gas Light Era*, a second gas company, the Staten Island Gas Light Company, had previously existed only on paper with no plant or infrastructure improvements on the island. The Staten Island Gas Light Company was indicated to have built a plant adjacent to the Richmond County Gas Light Company (also referred to as the Richmond Gas Works). In 1884, the Staten Island Gas Light Company merged with the Richmond County Gas Light Company and a new carbureted water gas plant was built at the current 25 and 40 Willow Avenue parcels. The Staten Island Company was responsible for production and the Richmond County Gas Light Company distributed the gas.

The 1885 Sanborn map depicts a gas works with a gasometer as “not completed” on the western portion of the 25 Willow Avenue parcel, which are believed to be the Staten Island Gas Light Company operations. The 1885 Sanborn map also shows various operational features of the unlabeled gas works, including a gasometer (referred to in later years and in Plate 1 as Relief Holder No. 1), a fuel oil tank, several coal sheds, a purifying house, a lime house, and a retort house. In the 1898 Sanborn map, a second generating house, gasometer, and associated structures in the western portion of the 25 Willow Avenue parcel (likely the former Staten Island Gas Light Company operations) and a gasometer (referred to in later years as Relief Holder No. 2) are depicted on the 40 Willow Avenue parcel. The 25 Willow Avenue plant is referred to as the Richmond Gas Works in this Sanborn map.

The *1907 Atlas of the Borough of Staten Island, Richmond, City of New York*, indicates that the MGP is referred to as the Richmond County Gas Light Company. The atlas depicts the configuration of the plant to be relatively unchanged from the 1898 Sanborn map.

A 1917 Sanborn map shows that much expansion occurred at the plant between the late 1800s and 1917, including the addition/conversion of the original coal carbonization plant to a water gas plant, and construction of a large-capacity (1 million cubic feet) gas holder (Holder No. 2) at the northern corner of the 25 Willow Avenue parcel near Bay Street. In addition, in the northeastern portion of the site, a tar separator was located east of Relief Holder No. 1 and tanks (later referred to as tar tanks) and two oil tanks are depicted. The MGP is listed as the New York and Richmond Gas Company. This expansion in the plant was accompanied by increased gas production at the site from 38 million cubic feet (MMCF) to 372 MMCF in 1920 *Brown’s Directory* listings (*Brown’s Directory*, 1890 and 1920). The former gas works (Staten Island Gas Light Company) and associated structures have been incorporated into the New York and Richmond Gas Company MGP (also referred to as the Richmond County Gas Light Company) and were used for site operations.

A 1937 Sanborn map shows the expansion of the water gas plant and purifying facilities, the addition of another tar separator, and three fuel oil tanks at the southwestern corner of the 25 Willow Avenue parcel, and the addition of support equipment on the 40 Willow Avenue parcel around Relief Holder No. 2. Gas production continued to increase at the site to 910 MMCF by 1935 (*Brown’s Directory*). Between 1937 and 1950, minor expansions occurred on both sides of Willow Avenue. Gas production at the site continued to increase to 1,230 MMCF by 1945 and reached a peak of 1,400 MMCF in 1955. The gas plant was demolished in the spring of 1959 according to a newspaper article in the “Advance.” The 1977 Sanborn map shows the Brooklyn Union Service Center on the southeastern corner of the 25 Willow Avenue parcel, and a Brooklyn Union natural gas regulator station on the southern side of Willow Avenue (40 Willow Avenue parcel). The natural gas regulator station is the building associated with the gas plant that is depicted on the 1977 Sanborn map.

1.2.3 Water Use

Public water supply is currently provided to the OU-2 parcels and the surrounding area by the New York City Water Department. Mr. Joseph McGuire, a representative from the New York City Departemtn of Environmental Protection, was contacted regarding historic water use on Staten Island (McGuire, 2000). According to Mr. McGuire, all of Staten Island's water supply currently comes from the Catskill Region of New York and is stored in the Clove Lakes area of Staten Island in underground storage tanks (USTs). Staten Island was connected to the New York City water system in 1970, when the Richmond Tunnel was completed across The Verrazzano Narrows.

No wells are known to be currently in use. The nearest former well to OU-2 was an industrial/private water supply well operated by Louis Dejone and Company located at 330 Tompkins Avenue (McGuire, 2000). The well is not active and was located approximately 0.2 mile southwest and upgradient of the OU-2 parcels. Soren (1988) identified another former well approximately 0.2 mile south of the site. The former use of this well is unknown.

In previous investigations at OU-1, an 8-inch steel well that was likely associated with the former MGP was encountered on the site. The discovery and the decommissioning of this well was described within the Final Remedial Investigation Report, Clifton Former MGP Site, Operable Unit 1, dated July 1, 2004.

1.3 Physical and Environmental Setting

The OU-2 parcels are in a locally topographic low, bowl-shaped area that gently slopes to the northwest towards the railroad embankment (Plate 1). The 25 Willow Avenue parcel resides on the edge of a topographic bowl-like depression that appears to be associated with the historic stream that flowed on the northwestern portion of the parcel. Historic maps reveal that an un-named stream was present beneath the existing railroad bed on the northwestern portion of the 25 Willow Avenue parcel (Figures 1-3 and 1-4). This stream appears to have been filled at one point and replaced with the current storm sewer drainage system.
New York Harbor is the closest surface water body to OU-2 and is located approximately 500 to 600 feet northeast (Figure 1-1).

1.3.1 Regional Geology

The OU-2 parcels are located in the Manhattan Prong Geologic Province, which contains bedrock associated with the New York City group (Bennimoff and Ohan, no date). Two other geologic provinces on Staten Island include the Staten Island Serpentinite that makes up the central highlands or spine of Staten Island, and the Newark Basin, which is located on the western portion of Staten Island (Bennimoff and Ohan, no date). OU-2 is believed to be underlain by the Manhattan Schist, which is described as a metamorphosed dark gray micaceous rock unit of Late Proterozoic to Cambrian Age that was folded, faulted and eroded with younger deposits overlying (Soren, 1988). Surficial, unconsolidated Pleistocene age (Wisconsin) glacial deposits lie unconformably on the Manhattan Schist in the northeastern portion of Staten Island (Soren, 1988). Holocene (recent) aged deposits are inferred to be associated with streams, rivers, and marsh deposits.

The OU-2 parcels are indicated as underlain by Harbor Hill Terminal Moraine deposits which consist of unsorted sand, gravel, cobbles, and boulders within a clayey and silty matrix with some occurrences of locally stratified sand and gravel beds (Soren, 1988). A nearby geologic contact indicates that Pleistocene Age (Wisconsin) Ground Moraine deposits are located just to the west of the parcels and are described as a mainly reddish-brown, clayey-till from the surface to approximately 150 feet below ground surface (bgs). The unit is described as having local bodies of stratified sands and gravel bodies within the unit (Soren, 1988).

1.3.2 Regional Hydrogeology

The regional hydrogeology of the northern portion of Staten Island is characterized by groundwater flow from the central highlands easterly towards New York Harbor. Groundwater elevations range from as much as 350 feet above sea level in the central spine of Staten Island to sea level at the shore. The water table is less than 10 feet above sea level in the vicinity of the OU-2 parcels. Water table conditions are encountered on Staten Island where sandy till is present and confined conditions are encountered where silty-till and clayey-till overlie water-bearing units. (Soren, 1988).

The terminal moraine that underlies OU-2 is estimated to have an average hydraulic conductivity of 0.001 feet per day for a clayey till and 0.008 feet per day for a silty till. Horizontal hydraulic conductivities are approximately 10 to 20 times greater than the vertical hydraulic conductivities (Morris and Johnson, 1967, and Soren, 1988). Higher hydraulic gradients were noted within the stratified sand and gravel layers contained within the ground moraine unit.

1.3.3 Climatology

Climatologic records were reviewed for the Newark International Airport in Newark, New Jersey for the time period 1970 through 1997. The Newark International Airport is located approximately 8 miles to the northwest of the 25 Willow Avenue parcel and its weather records are considered representative of weather conditions at the parcels. Based upon a review of this data, the normal maximum and minimum daily temperature, normal monthly and annual precipitation, and mean wind speed and prevailing direction were obtained. Table 1-1 summarizes the climatologic data for the airport. The average daily maximum temperature was 63.4^{o} F and the average daily minimum temperature was 46.1^{o} F.

The lowest normal daily maximum temperature was 37º F recorded for January and the highest normal daily maximum was 87.0º F recorded for July. The annual precipitation (rainfall) for the area is 43.97 inches with the largest amount of monthly precipitation of 4.5 inches, which occurs in July. The annual snowfall in the vicinity is 27.0 inches with the largest monthly amount (9.2 inches) falling in February. The average annual wind speed is 10.2 miles per hour from the south/southwest (230ºE).

1.4 Previous Investigations

Subsurface investigations were conducted by others in and around the 25 Willow Avenue parcels since 1993. These investigations are summarized below.

1.4.1 25 Willow Avenue Investigation

1.4.1.1 LEXICON UST Closure Summary Report (October 15, 1993) Clifton Service Center, 25 Willow Avenue, Staten Island, New York

An investigation completed by Lexicon between September 14 and 15, 1993 is summarized as follows.

- Excavation of the diesel fuel and gasoline UST area
- Removal of one 550-gallon diesel fuel UST, one 4,000-gallon gasoline UST, four previously closed-in-place 550-gallon USTs, the fuel dispenser island, and associated piping
- Removal of a closed-in-place 550-gallon (waste) oil UST adjacent to the northwestern corner of the building
- Removal of approximately 125 cubic yards of soil and 100 cubic yards of concrete and debris; approximately 185 gallons of product and water was removed from the excavation and disposed of off site
- Collection of nine sidewall samples and one excavation water sample from the gasoline and diesel fuel tank excavation, and two sidewall samples from the used oil excavation
- Installation of two monitoring wells (OW-1 and OW-2)

Between September 13 and 15, 1993, Lexicon removed seven USTs from the 25 Willow Avenue parcel. Six of the USTs formerly contained gasoline and diesel fuel and were located in the north-central portion of the 25 Willow Avenue parcel (Plate 1). Grayish-black staining and a gasoline-like odor were observed above the 550-gallon diesel fuel UST, 4,000-gallon gasoline UST, and the four 550-gallon gasoline USTs in the excavation and beneath the fuel dispenser island. The Larry E. Tyree Company removed each of the USTs. The tanks and piping appeared to be in good condition with no evidence of pitting or corrosion. Visible staining was noted on each of the sidewalls of the excavation with dark staining and product-saturated soils at the southern end of the excavation. During the removal of the USTs, a brownish-black product was observed on the groundwater surface in the southern portion of the excavation; it was recovered with a vacuum truck. The source of the product was unknown. Nine sidewall samples and one excavation water sample were collected and two monitoring wells (OW-1 and OW-2) were completed in the gasoline and diesel fuel excavation. The samples from the diesel fuel and gasoline UST excavation revealed elevated levels of VOCs and PAHs in the sidewall soil sample. The excavation was backfilled with clean fill and covered with pavement.

A previously closed-in-place 550-gallon waste oil UST located off the northwestern corner of the building was also removed. The 550-gallon waste oil tank appeared to be in good condition. Two sidewall samples taken from the waste (used) oil UST excavation revealed no detectable levels of PAHs.

1.4.1.2 Fanning, Phillips and Molnar Engineers' Underground Storage Tank Groundwater Investigation at the Brooklyn Union Gas Company, Clifton Station Facility, 25 Willow Avenue, Staten Island

An investigation was completed by FP&M on November 8, 1993 and is summarized as follows.

- Monitoring wells OW-3 and OW-4 were installed on the 25 Willow Avenue parcel
- Groundwater samples were collected

On November 8, 1993, FP&M installed monitoring wells OW-3 and OW-4 adjacent to the former gasoline and diesel UST grave (Plate 1). Soils were screened and visual observations and odors were recorded. Stained soils with lighter hydrocarbons and heavier hydrocarbons were encountered in soils at OW-3 from 0 to 4 feet. Slight petroleum odors were noted in soils from OW-4. The two 4-inch inner diameter (ID) wells were set at 15 feet below grade. Groundwater samples collected from OW-3 and OW-4 detected elevated concentrations of VOCs and PAHs.

1.4.1.3 Fanning, Phillips, and Molnar Engineers' Groundwater Sampling at the Brooklyn Union, Clifton Station Facility, 25 Willow Avenue, Staten Island, New York (August 1994) and Sampling Summary Report for the Former Brooklyn Union Gas Company, Clifton Station Facility, 25 Willow Avenue, Staten Island, New York (May 1998)

Quarterly groundwater monitoring investigations were completed at the 25 Willow Avenue parcel by FP&M from 1994 until 1998.

Since 1994, Brooklyn Union has performed quarterly sampling to characterize groundwater at the 25 Willow Avenue parcel, and has submitted yearly reports summarizing these results to NYSDEC (FP&M, August 1994 and May 1998). The quarterly sampling program identified the presence of benzene, toluene, ethylbenzene, and xylenes (BTEX), naphthalene and low levels of 1,2-dichloroethane in groundwater.

1.4.1.4 Letter from Mary E. Casey at Brooklyn Union to Mark Tibbe at the New York State Department of Environmental Conservation, dated February 11, 1998

Brooklyn Union installed three additional monitoring wells (OW-5 through OW-7) in January 1998 (Plate 1). The analytical results indicated the presence of BTEX and PAHs. Five additional soil borings (SB-9, SB-10, SB-11, SB-12, and SB-13) were completed along Willow Avenue on the sidewalk of the 25 Willow Avenue parcel, and one groundwater sample (MW-4) was collected (Plate 1). Laboratory analysis revealed VOCs and PAHs. The groundwater sample collected from MW-4 in the sidewalk along the western border of the 25 Willow Avenue parcel revealed trace detections of naphthalene.

2. Remedial Investigation Scope of Work

The RI was primarily completed on the parcels located at 25 and 40 Willow Avenue, which contained the primary operations of the former MGP. Some work was completed on adjacent parcels contained within OU-1 and OU-2. The scope of work for OU-2 included the completion of soil borings, test pits, installation of groundwater monitoring wells, soil sampling, hydraulic conductivity testing, groundwater sampling, storm sewer sampling to characterize the soil, soil vapor, groundwater, and storm sewer water conditions. Plate 1 depicts the RI sampling locations at OU-2.

The RI was performed in eight rounds of field work: Round 1 (February through April 1999); Round 2 (July through October 1999); Round 3 (November through December 1999); Round 4 (November 2001 through January 2002); Round 5 (May through June 2002); Round 6 (November through December 2002);Round 7 (June 2003); Round 8 (April 2004 through June 2004 and December 2004). Soil vapor sampling associated with Round 8 of the RI field work has not been completed at this time. The results of the Round 8 field work will be provided following completion of the soil vapor task. Sampling locations were selected to address/identify former MGP structures at the site; to obtain information regarding the soil and groundwater conditions at the 25 Willow Avenue parcel in the vicinity of former structures of the MGP; and to characterize the soil, soil vapor, and groundwater at adjacent areas.

The OU-2 portion of the RI included completion of nine exploratory test pits, drilling of 46 subsurface-soil borings, drilling and installation of 18 groundwater monitoring wells, installation of two piezometers, collection of three storm sewer locations, and the sampling of 10 background surface-soil locations within OU-2. One hundred and fourteen subsurface-soil samples, 10 background surface-soil samples (three surface soil samples were located on the 25 Willow parcel), 22 groundwater samples, and 4 storm sewer samplings were chemically analyzed to evaluate the environmental conditions within OU-2.

This section generally describes the methods used for the sampling in accordance with the NYSDEC-approved work plan and the NYSDEC-approved work plan addenda. Detailed field procedures are located in the work plan and work plan addenda. Soil and groundwater sample were analyzed by Severn-Trent Laboratories (STL), located in Connecticut. The laboratory was originally located in Monroe, Connecticut and subsequently relocated to Shelton, Connecticut. Soil vapor samples were analyzed by Air Toxics Limited, located in Folsom California. These facilities are NYSDEC-approved laboratories.

2.1 Field Work

2.1.1 Round 1 - Investigation of 25 and 40 Willow Avenue Parcels and Willow Avenue ROW (February through April 1999)

The general objective of this phase of the RI was to identify the presence/absence of the former MGP structures and to characterize the subsurface conditions at the 25 and 40 Willow Avenue parcels.

In accordance with the RI work plan, nine test pits (TP-1, TP-2, TP-3, TP-4, TP-5, TP-6, TP-7, TP-8, TP-9) and 21 borings (RW-1, RW-2, RW-3, SB-9, SB-10/10A, SB-11, SB-12, SB-13, SB-14, SB-15, SB-16/16A, SB-19, RW-6/SB-20 and SB-30 to SB-35) were completed at the 25 Willow Avenue parcel and within the Willow Avenue ROW (OU-2) (Plate 1). Of these borings, four were completed as monitoring wells (RW-1, RW-2, RW-3, and RW-6/SB-20) (Plate 1).

Subsurface-soil sampling, groundwater sampling, hydraulic conductivity testing, and groundwater level measurements (at high and low tides) were completed during the first round of the RI.

Within OU-2, the groundwater investigation consisted of the collection of samples from the newly installed monitoring wells (RW-1, RW-2, RW-3, and RW-6) and the previously installed wells (FPM-OW-5, FPM-OW-6, and FPM-OW-7) as part of the Round 1 scope of work. In-situ hydraulic conductivity tests (slug tests) were completed for monitoring wells RW-1, RW-2, RW-3, and RW-6 were conducted to assess the hydraulic conductivities of the groundwater aquifer beneath the 25 Willow Avenue parcel. Monitoring wells RW-1, RW-2, RW-3, RW-6, FPM-OW-5, FPM-OW-6, and FPM-OW-7 were used to determine the groundwater flow direction during Round 1 of the RI. Each monitoring well was gauged for the potential presence of nonaqueous phase liquid (NAPL) during the groundwater sampling event. In addition, a temporary hand-dug piezometer (PZ-1) was installed to provide additional groundwater elevation data at the 25 Willow Avenue Parcel (Plate 1).

Nine air quality stations (AQS-1 to AQS-9) were established to monitor the air quality on the perimeter of the 25 and 40 Willow Avenue parcels during the test pit excavations at OU-1 and OU-2 (Plate 1). Air quality monitoring was also conducted immediately adjacent to test pits (work zone) to document the air quality during the exposure of soils during shallow excavations. The air-monitoring program included the collection of real-time air quality data, time-averaged air quality data, and meteorological data to document potential migration routes of airborne VOCs and particulates.

2.1.2 Round 2 - Investigation of 25 and 40 Willow Avenue Parcels and Adjacent Parcels (July through October 1999)

This portion of the RI was completed to characterize subsurface soils to a confining layer (bedrock), characterize shallow subsurface soils, determine the presence of additional former MGP structures at the site, characterize groundwater conditions within the upper and lower aquifers, evaluate the lateral and vertical extent of subsurface conditions, and evaluate surface-soil conditions on adjacent residential and other abutting parcels.

Within OU-2, 16 soil borings were drilled and sampled (SB-37, SB-39, SB-45/RW-8, SB-46/RW-9, SB-47/RW-10, SB-48/RW-11, SB-49/RW-12, SB-50/RW-13, SB-51, SB-52, SB-53, SB-54, SB-55, SB-55A/RW-15, SB-56/RW-16, and SB-57) with 8 of these borings completed as a monitoring well (SB-45/RW-8, SB-46/RW-9, SB-47/RW-10, SB-48/RW-11, SB-49/RW-12, SB-50/RW-13, SB-55A/RW-15, and RW-16/SB-56).

Subsurface-soil sampling, groundwater sampling, hydraulic conductivity testing, and groundwater level measurements (at high and low tide stages) were completed at boring and monitoring well locations on the 25 Willow Avenue parcel, adjacent Greenfield Avenue parcels, and the railroad ROW within OU-2. In-situ hydraulic conductivity tests (slug tests) were completed for monitoring wells RW-8, RW-12, and RW-13 to assess the hydraulic conductivities of the groundwater aquifer beneath the Greenfield Avenue parcels. A single well pumping test was completed for monitoring well RW-15 to evaluate the deep groundwater aquifer hydraulic conductivity beneath 25 Willow Avenue. Groundwater samples were collected from monitoring wells RW-1, RW-2, RW-3, RW-4, RW-6, RW-8, RW-9, RW-10, RW-11, RW-12, RW-13, RW-15, and RW-16 and previously installed monitoring wells (FPM-OW-5, FPM-OW-6, and FPM-OW-7). Monitoring wells (RW-1, RW-2, RW-3, RW-4, RW-6, RW-8, RW-9, RW-10, RW-11, RW-12, RW-13, FPM-OW-5, FPM-OW-6, and FPM-OW-7) and piezometer (PZ-4) were used to determine water table groundwater flow directions at OU-2. Monitoring wells RW-15 and RW-16 were used to determine the groundwater flow within the deep aquifer at the site. Groundwater information for the shallow and deep groundwater aquifers collected for OU-1 was used to supplement groundwater information collected within OU-2.

In addition to the proposed work described in the work plan addenda, the hand-dug piezometer (PZ-1) was abandoned because it was replaced with a permanent monitoring well (RW-13). A GeoProbe®-installed piezometer (PZ-4) with sand packs and protective wellhead was also installed in the vicinity of Bay Street (Plate 1). The proposed soil boring (SB-38) was not completed inside the existing building as part of the Round 2 investigation. This boring was not completed because elevated VOC measurements around the borehole for SB-37 (completed within the building) suggested that further subsurface drilling in the vicinity of the relief holder could potentially result in VOCs being released to the indoor air of the building as soil cuttings were brought up from beneath the building. Therefore, to avoid any potential impacts to the work environment, boring SB-38 was not completed.

2.1.3 Round 3 - Investigation of Lynhurst Avenue Residential Lots and Commercial Lot at 66 Willow Avenue (November through December 1999)

This phase of the RI was conducted to characterize the soil conditions beneath the residential lots in OU-1. In addition, further characterization of surface soils at OU-1 was performed and background surface-soil samples were collected to establish the condition of background soils in the vicinity of the former MGP (OU-1 and OU-2). Ten background surface-soil samples (SS-33 through SS-42) were collected at accessible locations in the vicinity of the 25 and 40 Willow Avenue parcels. Three of the surface soils (SS-34, SS-35, and SS-36) were collected within grassed area of the 25 Willow Avenue parcel to evaluate surface-soil conditions at the parcel. The background surface samples were collected to establish background conditions for surface soils in the vicinity of OU-1 and OU-2 (Plate 1).

2.1.4 Round 4 - Former Clifton MGP Site, Revised Supplemental Investigation (RI) Work Plan, 25 and 40 Willow Avenue Parcels, Staten Island, New York (October 9, 2001) (November 2001 through January 2002)

This phase of the RI was conducted to evaluate soil conditions and the orientation of the glacial till surface along Bay Street and (at the request of NYSDEC) to evaluate the vertical extent of tar adjacent to three specific former MGP structures. Water samples were also collected from the storm sewer located on the northeastern portion of 25 Willow Avenue.

In accordance with the RI work plan addendum dated October 9, 2001, ten soil borings (SB-68, SB-69/RW-17, SB-70, SB-70A/RW-18, SB-71, SB-72, SB-73, SB-74, SB-75, and SB-76) were installed with a Resonant Sonic drilling rig on the 25 Willow Avenue parcel. Two of these borings (SB-69/RW-17 and SB-70A/RW-18) were completed as monitoring wells. Subsurface soil samples were collected from these borings. Groundwater samples and groundwater level measurements were collected at existing and newly installed monitoring well locations on the 25 Willow Avenue parcel, adjacent Greenfield Avenue parcels, and the Railroad ROW within OU-2. Groundwater elevations from the shallow groundwater aquifer at OU-1 were used to supplement groundwater information collected within OU-2. Storm sewer samples STRM-01, STRM-02, and STRM-03 were collected from within Willow Avenue, within the site, and at a manhole prior to exiting the site.

The proposed test pit location (TP-11) along Bay Street was not completed during the Round 4 RI because subsurface-soil information collected from soil borings SB-68, SB-69/RW-17, SB-70 and SB-70A/RW-18 suggested that impacts were encountered below the practical depth that an excavator could reach.

2.1.5 Round 5 - Former Clifton, Staten Island MGP Site, Supplemental Remedial Investigation (RI) (May through June 2002)

This phase of the RI was conducted to further characterize the presence and integrity of the glacial till layer along Bay Street.

In accordance with the RI work plan addendum dated March 14, 2002, three subsurface-soil borings (SB-81, SB-82, and SB-82A) were drilled and sampled with a GeoProbe® drill rig within a triangular parcel located between Bay Street and Edgewater Street. The proposed boring SB-83 was not completed as part of this investigation because tar was not observed at the location of borings SB-82/82A and because of administrative issues related to parcel access.

In addition to the scope described in the work plan addenda, two additional subsurface-soil borings (SB-88 and SB-89) were installed adjacent to the storm sewer line located on the 25 Willow Avenue parcel to evaluate the potential migration of tar adjacent to the storm sewer.

2.1.6 Round 6 - Former Clifton, Staten Island MGP Site, Supplemental Remedial Investigation (RI) Work Plan-Edgewater Street (November 4, 2002) (November through December 2002)

This phase of the RI was conducted to evaluate the migration of tar upon a glacial till layer within the Edgewater Street ROW.

In accordance with the RI work plan addendum dated November 4, 2002, nine subsurface-soil borings (SB-90/A/B/C, SB-91/91A, SB-92, SB-93, and SB-94) were drilled and sampled with a GeoProbe® drill rig within the Edgewater Street ROW. One monitoring well (RW-19) was installed adjacent to SB-94 during this supplemental investigation. Tar was gauged and removed from well RW-19 as part of this mobilization.

2.1.7 Round 7 - Former Clifton, Staten Island MGP Site, Sub-Slab Soil Vapor Sampling and Vapor Intrusion Analysis Work Plan-OU-2 (April 16, 2003) (June 2003)

This phase of the RI was conducted to evaluate the soil vapors beneath the slab of the building at 25 Willow Avenue.

In accordance with the Sub-Slab Soil Vapor Sampling and Vapor Intrusion Analysis work plan, dated April 16, 2003, twelve soil gas points (SG-1 through SG-12) were installed and sampled for TO-15 at 25 Willow Avenue.

2.1.8 Round 8 - Former Clifton, Staten Island MGP Site, Supplemental Remedial Investigation (RI) Work Plan-1 Edgewater Street (October 20, 2003) (April through June 2004) and Soil Vapor Sampling Work Plan, Operable Unit 2, 1 Edgewater Street/Edgewater Plaza (December 8, 2004) (December 2004)

This phase of the RI was conducted to evaluate the off site tar related impacts at 1 Edgewater Street/Edgewater Plaza.

In accordance with the RI work plan addendum dated October 20, 2003, forty-five subsurface-soil borings (SB-95 through SB-139) were drilled and sampled with a GeoProbe® drill rig at 1 Edgewater Street/Edgewater Plaza. Three monitoring wells, RW-20, RW-21, and RW-22, were installed adjacent to SB-137, SB-126, and SB-95 during this supplemental investigation. Based on the field observations from these borings, a soil vapor sampling program was developed (December 8, 2004 Work Plan) and approved by NSYDEC. The collection of the soil vapor samples has not yet been conducted.

The findings from the soil investigations and the soil vapor sampling tasks will be submitted as a Supplemental RI report following completion of the soil vapor task and evaluation of those data.

2.2 Field Methods

Several pieces of heavy equipment were mobilized and various sampling techniques were utilized to complete the RI. This subsection generally describes the sampling procedures utilized. For details refer to the approved RI work plan and addenda.

2.2.1 Air Monitoring

2.2.1.1 Perimeter Air Monitoring

Round 1 RI Air Monitoring

Ambient air monitoring was completed during the excavation of test pits at nine perimeter air quality stations (AQS-1 to AQS-9) during Round 1 of the RI (Plate 1). The air quality monitoring program was designed to evaluate the potential migration of volatile organic compounds (VOCs) and particulates off the perimeter of the site where excavation occurred, and to document the levels of VOCs and particulates in air at the property boundaries. A photoionization detector (PID) organic vapor analyzer (OVA) and MiniRAM™ particle detector were used in the collection of the air quality data at each air quality station. Each instrument was calibrated prior to use. Measurements were taken hourly at each sampling station while test pit excavation occurred. The perimeter air quality-monitoring program was supplemental to and discrete from, the air monitoring program implemented for purposes of evaluating worker health and safety.

Meteorological data, including wind speed, wind direction, and temperature, were monitored throughout the air sampling program to evaluate potential migration pathways of VOCs and particulates. These data were collected from a weather station temporarily mounted on the roof of the building at the 25 Willow Avenue parcel during Round 1 of the RI.

Round 2, 4, 5, and 6 RI Air Monitoring

Ambient air monitoring was completed for subsurface soil boring activities during Round 2, Round 4, Round 5, and Round 6 of the RI. No air monitoring was collected within OU-2 during Round 3 because only surficial soil samples were collected. The air quality within the perimeter of the work zone was monitored during subsurface boring and groundwater well installation activities to evaluate that potential migration of VOCs in accordance with the approved work plan.

2.2.1.2 Worker Health and Safety Air Quality Monitoring

Round 1 RI Air Monitoring

As specified in the work plan and addenda, two particulate meters were used during the test pit activities (Round 1 of the RI in OU-2) to monitor dust generation during excavation of test pits. One unit was placed upwind of the excavations and the remaining unit was placed downwind of the excavations. The particulate meters were placed approximately 10 to 20 feet away from the excavation activities. The units were moved as appropriate during the excavation activities, based on wind direction. Potential organic vapor emissions were also monitored using a PID-OVA approximately 10 to 20 feet downwind of excavation activities. In addition, personnel working on excavating and logging each test pit monitored total VOCs within their workspace-breathing zone with a PID-OVA.

Round 2, 4, 5, and 6 RI Air Monitoring

Ambient air monitoring was completed within the work zone during subsurface soil boring activities during Round 2, Round 4, Round 5, and Round 6 of the RI. No air monitoring was collected within OU-2 during Round 3 because only surface soil samples were collected. The air quality in the perimeter was monitored during subsurface boring and groundwater well installation activities to evaluate that potential migration of VOCs in accordance with the approved work plan.

In addition, the work zone was monitored for cyanide during Round 6 of the RI. The Dragger Miniwarn electronic cyanide and a Dragger CMS analyzer were utilized to measure the ambient air conditions within the work zone.

Subsection 2.3 discusses the results of the air-monitoring program.

2.2.2 Soils (Test Pits, Borings, and Surface-Soil Sampling)

This subsection describes the methodology used at OU-2 to collect soil samples during the RI. Table 2-1 identifies the rationale for conducting each boring, submittal of each sample for laboratory analysis, and the analyses completed for each sample. Generally, soils were logged and screened in accordance with the RI work plan. Selected soil samples were placed directly into certified pre-cleaned containers and placed directly into ice-filled coolers. The samples were then shipped to STL under chain-of-custody or were picked up by laboratory courier and delivered to the laboratory for analysis. Boring logs and monitoring well construction logs are presented in Appendix B. Test pit logs and photographs are presented in Appendix C.

2.2.2.1 Test Pit Excavations

A backhoe was used to perform excavation of test pits TP-1, TP-2, TP-3, TP-4, TP-5, TP-6, TP-7, TP-8, and TP-9 at the 25 Willow Avenue parcel (Plate 1). Soil from the test pits was excavated, logged and screened with a PID-OVA according to the RI Work Plan. Test pit logs are provided in Appendix C. If historic structures were encountered in a test pit, the structure was described and its location was noted in the field book. Four soil samples were collected from the test pits for analytical testing (Table 2-1). Soils from TP-1, TP-3, and TP-8 were analyzed for BTEX (EPA Method 8260); semivolatile organic compounds (SVOCs) and 20 tentatively identified compounds (TICs) (EPA Method 8270); Resource Conservation and Recovery Act (RCRA 8) metals (EPA Method 6010); and total cyanide (TCN) (EPA Method 9012). The soil sample collected from TP-4 was analyzed for VOCs (BTEX) and SVOCs. The soil sample collected from TP-8 was also analyzed for polychlorinated biphenyls (PCBs) and pesticides (EPA Method 8081). Once test pits were logged, the test pits were backfilled in the reverse sequence that they were excavated and asphalt pavement was replaced to grade at the completion of each test pit.

2.2.2.2 Soil Borings

Eighty-eight borings and 18 borings completed as monitoring wells were completed as part of the RI for OU-2. Table 2-1 provides the boring IDs, as well as the rationale for sample selection. Soil boring logs and monitoring well construction logs are provided in Appendix B. Soil boring samples were collected utilizing GeoProbe®, hollow-stem auger, drive casing (drive and wash), and Rotosonic™ drilling methods. The objective of these borings was to evaluate the shallow and deep geologic conditions, and to install monitoring wells to screen the groundwater quality at the OU-2 parcels.

Within each boring, soil samples were generally collected from intervals exhibiting the greatest observed occurrence of tar, staining, sheen, odors, and/or PID readings, and from a deeper interval not exhibiting these physical observations. Soils with discrete intervals of observed tar, staining, sheen, odors, and/or PID detections, soils at the completion depth of selected borings, soils at significant geologic unit changes, and soils from the water table interface were also submitted for analysis. Generally, soils were analyzed for VOCs (full scan and BTEX fraction only), SVOCs (full scan and PAH fraction only), metals (RCRA-8 and Target Compound List/Target Analyte List [TAL/TCL]), and TCN as specified in the RI Work Plan and addenda. Selected samples were also analyzed for total organic carbon (TOC), bulk density, and grain size (Table 2-1).

Soils were logged, screened with a PID-OVA, and visual and olfactory observations were noted according to the RI work plan and work plan addenda. At sampling locations that are overlain by pavement, sampling generally began immediately beneath the pavement and the underlying gravel base.

Hollow-stem auger, drive casing, GeoProbe®, and Rotosonic™ drilling methods used were described in the work plan and/or agreed to in the field by GEI representatives and the NYSDEC field representative.

2.2.2.3 Monitoring Well Installation and Well Development

Eighteen monitoring wells (RW-1, RW-2, RW-3, RW-6, RW-8, RW-9, RW-10, RW-11, RW-12, RW-13, RW-15, RW-16, RW-17, RW-18, RW-19, RW-20, RW-21, and RW-22 and two piezometers (PZ-1 and PZ-4) were completed at OU-2 as part of the RI. Table 2-2 provides a summary of all the OU-2 monitoring wells installed during and prior to the RI, and Appendix B presents the well construction logs. Monitoring wells RW-1, RW-3, RW-6, RW-8, RW-9, RW-10, RW-11, RW-12, and RW-13 were installed utilizing the hollow-stem auger drilling method. RW-2 was installed utilizing drive and wash drilling method. RW-15, RW-16, RW-17, and RW-18 were installed utilizing Rotosonic™ drilling methods. Monitoring wells RW-19, RW-20, RW-21, and RW-22 were installed utilizing a Geoprobe™ drilling rig.

Each well (except RW-15, RW-16 and RW-19) was completed as a 2-inch ID monitoring well with flush-threaded polyvinyl chloride (PVC) 0.0010-inch slotted screen, solid PVC riser, and a flush-mounted cover. The annular space between the well screen, the borehole wall, and approximately 2 feet above the screen was backfilled with a sand pack. A 1- to 4-foot bentonite clay seal was placed above the sand pack. The thickness of the bentonite seal in some monitoring wells was less than specified in the work plan because of shallow groundwater conditions. The remaining annular space was filled to grade with a cement-bentonite grout. A concrete pad surrounds each flush-mounted well cover. Each well was sealed with an expandable well cap that was secured with a padlock.

Monitoring well RW-15 and RW-16 were installed utilizing the Rotosonic™ drilling method. Monitoring wells RW-15 and RW-16 were completed to the top of the saprolite layer (weathered bedrock) to characterize and monitor the deep aquifer water conditions. This well was constructed with 4-inch ID, flush-threaded PVC 0.0010-inch slotted screen, solid PVC riser, and a flush-mounted cover. The annular space between the well screen and the borehole wall was backfilled with a sand pack to approximately 3 feet above the screen. A 4- to 5-foot bentonite seal was placed above the sand pack. The remaining annular space was tremie-grouted to grade with a cement-bentonite grout slurry. Each well was sealed with an expandable well cap that was secured with a padlock. A concrete pad surrounds the flush-mounted well cover for each of the wells.

Monitoring well RW-19 was a 1-inch inner diameter, flush-threaded PVC monitoring well installed via GeoProbe drilling methods. The sand pack was installed to 2.5 feet above the screen interval, a 6-foot bentonite seal was installed above the sand pack, and the remainder of the borehole was grouted/sealed with bentonite/concrete to the surface. The well was completed with a flush-mounted roadway box.

Monitoring wells RW-20, RW-21, and RW-22 were 2.5-inch outer diameter, 1.5-inch inner diameter, flush-threaded PVC monitoring well installed via GeoProbe drilling methods. The sand pack consisted of 2-5 foot prepacked Geoprobe screens and sand to approximately 3 feet above the screen interval, an approximately 2-foot bentonite seal was installed above the sand pack, and the remainder of the borehole was grouted/sealed with bentonite/concrete to the surface. The well was completed with a flush-mounted roadway box.

Following installation, each monitoring well was developed to remove silt and clays from the well and to stabilize the well filter pack. Development was done in accordance with the RI work plan.

2.2.2.4 Surface-Soil Sampling

Three surface soil samples (SS-34, SS-35, and SS-36) were collected from the grassed area within the landscaped strip of land adjacent to Bay Street on the 25 Willow Avenue parcel as part of the collection of background surface-soil samples in the vicinity of the 25 and 40 Willow Avenue parcels during Round 3 of the RI. Background surface soil locations (SS-33 and SS-37 through 42) were collected from areas surrounding OU-1 and OU-2 (Plate 1). No surface soil samples were collected from the footprint of the former MGP because asphalt pavement and a building cover the entire area. Table 2-1 provides a summary of the rationale for surface-soil collection and analysis. Each surface-soil sample was collected from 0 to 2 inches of mineral soil immediately beneath the sod.

Each surface-soil sample was collected using decontaminated, stainless-steel sampling tools. Soils were placed into certified pre-cleaned sampling containers. Surface soil samples SS-33 through SS-42 were analyzed for VOCs (BTEX), SVOCs, RCRA 8 metals, TCN, TOC and grain size distribution (Table 2-1).

2.2.3 Groundwater

Groundwater sampling was conducted at OU-2 in April 1999, October 1999, January 2002, and June 2004. The April 1999 sampling event (Round 1) included monitoring wells RW-1, RW-2, RW-3, RW-6, and previously installed monitoring wells (FPM-OW-5 through FPM-OW-7). Round 2 groundwater sampling (October 1999) included the Round 1 monitoring wells and the newly installed groundwater table monitoring wells RW-8 through RW-12 located on the northwest parcels and within deep groundwater monitoring wells RW-15 and RW-16. No groundwater sampling was completed as part of Round 3 (November 2001) of the RI at OU-2. In January 2002 (Round 4), groundwater sampling included monitoring wells RW-17 and RW-18 and groundwater elevations were collected from the shallow groundwater aquifer monitoring wells (RW-1, RW-2, RW-3, RW-6, RW-8, RW-9, RW-10, RW-11, RW-12, FPM-OW-5, FPM-OW-6, and FPM-OW-7) and piezometer PZ-4. No groundwater sampling was completed as part of Rounds 5 or 6 of the RI. In June 2004 (Round 8), groundwater sampling included monitoring wells RW-20, RW-21 and RW-22 and groundwater elevations were collected from the shallow groundwater aquifer monitoring wells (RW-2, RW-3, RW-6, RW-8, RW-12, RW-20, RW-21, RW-22, FPM-OW-5, FPM-OW-6, and FPM-OW-7) and piezometer PZ-4. Table 2-2 provides a summary of monitoring well information, including the screened interval and groundwater elevations.

At monitoring wells where groundwater was sampled, groundwater levels were measured prior to sampling, followed by purging and sampling of the monitoring wells. Groundwater depths were measured from the surveyed top of the PVC riser pipe for each well. Following sampling, the groundwater levels were again measured in each monitoring well. Sampling was completed in accordance with the RI work plan and work plan addenda.

2.2.3.1 Purging

Each well was purged prior to sampling to ensure that a representative sample from the aquifer was obtained. Sampling and purging were conducted using low-flow methods employing a peristaltic pump with dedicated down hole tubing for monitoring wells RW-1, RW-2, RW-3, RW-6, RW-8, RW-9, RW-10, RW-11, RW-12, RW-13, RW-17, RW-18, RW-20, RW-21 and RW-22. Purging rates varied because of the aquifer conditions; however, pumping rates ranged between 60 milliliters (ml) and 720 ml per minute in the shallow groundwater aquifer. Regardless of the purge rate, draw down of the static water level was minimized at all times.

A submersible Grundfos® pump with dedicated tubing was used to purge and sample groundwater in deep monitoring wells RW-15 and RW-16. These wells were screened in the deep groundwater aquifer, which displayed artesian conditions and required higher pumping rates to obtain a representative sample from the formation. These monitoring wells were purged at a rate of 2 liter to 4 liters per minute. These monitoring wells were able to be pumped at higher rates with minimal draw down of the water column.

All wells were monitored for field parameters (temperature, pH, conductivity, dissolved oxygen [DO], and oxygen reduction potential [ORP]) with flow-through cells during purging. In addition to these parameters, purge water from each well was monitored for turbidity in Round 1, salinity in Round 2, and turbidity and salinity in Rounds 4 and 8. Measured flow rates and purge volumes were recorded coincidently with field parameter measurements. When at least three well volumes were purged and/or values of measured field parameters remained within a 10 percent difference over several consecutive readings, each well was sampled.

2.2.3.2 Sampling

After each well was purged, groundwater samples were collected and placed into preserved containers provided by STL. Groundwater samples were analyzed for VOCs, SVOCs, TCN, and RCRA 8 metals for the Round 1, Round 2, and Round 4 sampling events and BTEX, PAH, TCN and RCRA 8 metals for the Round 8 sampling event. In addition, analyses of polychlorinated biphenyls (PCBs), total dissolved solids (TDS), 11 additional metals and salinity were completed for groundwater samples obtained from wells RW-1, RW-2, RW-3, RW-4, RW-6, RW-7, OW-5, OW-6, and OW-7 during Round 1. VOCs were collected using a dedicated single check-ball bailer for the shallow aquifer groundwater samples; double check-ball bailers were used for the deep aquifer samples. Sample aliquots for analysis of SVOCs, metals, TCN, TDS (EPA Method 160.1), PCBs (EPA Method 8081), and salinity (EPA Method 2520B) were collected through dedicated tubing utilizing a peristaltic pump or a Grundfos® pump. A peristaltic pump was used for sampling shallow monitoring wells and groundwater was sampled at approximately 100 ml/minute. A Grundfos® pump was used for groundwater sample collection from deep wells RW-15 and RW-16. The pump rate for the Grundfos® pump was approximately 1,000 ml/minute while sampling because this was the lowest flow rate the Grundfos® pump could maintain before it disengaged. Following collection, groundwater samples were placed into an ice-filled cooler and shipped under chain of custody to STL Laboratories for analysis.

2.2.4 Storm Sewer Water Sampling

Storm sewer sampling was completed during Round 4 of the RI. Three storm sewer water samples were collected within OU-2:

- (STRM-01) upgradient within the Willow Avenue ROW
- (STRM-02) on-site location at the T-shaped grate
- (STRM-03) at a manhole location at the point the storm sewer line exist the 25 Willow Avenue parcel

Each storm sewer sample was collected utilizing a pre-cleaned polyethylene bailer and/or a peristaltic pump and dedicated tubing. Samples were collected and placed into preserved containers provided by STL. Each storm sewer sample was analyzed for BTEX, SVOCs, RCRA-8 metals, TCN and hardness.

2.2.5 Sub-Slab Soil Vapor Sampling

Sub-slab soil vapor sampling was completed during Round 7 of the RI. Twelve sub-slab soil vapor samples were collected within OU-2 at 25 Willow Avenue, SG-1 and 2 were collected at the automobile service and repair area, SG-3 through SG-9 were collected at the automobile detailing and preparation area, SG-10 was collected in the former storage area, and SG-11 and SG-12 were collected in the office area.

Each sub-slab soil vapor sample was collected using a 6-liter capacity Summa canister with a calibrated flow controller valve, provided by Air Toxics Ltd, over an 8-hour timeframe. Each soil vapor sample was analyzed for VOCs, including naphthalene, by method TO-15.

2.2.6 Survey

At the conclusion of the RI field activities, each boring and well location was surveyed by a GEI-employed New York State licensed surveyor (New York License No. 050156) with reference to the state coordinate grid system. The lateral accuracy of the survey was 0.1 foot and the vertical accuracy was 0.01 foot. The data were tied into a United States Geological Survey (USGS) benchmark to ensure that all groundwater elevations are referenced to the 1983 National Geodetic Vertical Datum (NGVD) and the 1988 National Astronomic Vertical Datum (NAVD). A reference point on the bulkhead at the harbor was surveyed to facilitate monitoring of tidal fluctuations during Round 1 and Round 2. Surface-soil and test pit sampling locations were either surveyed or field measured relative to known features.

2.3 Air Monitoring Findings

2.3.1 Meteorological Observations

Throughout the test pit excavation program of Round 1, wind blew out of the north at speeds ranging from 1 to 20 miles per hour (mph), with an overall average of 8 mph. Wind gusts ranged from 3 to 29 mph and averaged 13 mph. The outside temperature ranged from 20° F to 47° F, with an average of 35° F. Wind chill ranged from -3.9° F to 46° F, with an overall average of 27° F.

2.3.2 Perimeter Air Monitoring Findings

Air monitoring at the perimeter of the 25 and 40 Willow Avenue parcels was conducted in accordance with Section 5 of the Health and Safety Plan (HASP). At no time did total organic vapor levels exceed 5 parts per million (ppm) above background at the perimeter of the 25 and 40 Willow Avenue parcels during test pit activities.

There were five occurrences where the upwind perimeter particulate levels exceeded the downwind particulate levels by at least 150 $\mu g/m^3$ (two-minute maximum readings). The upwind exceedances occurred at stations along Bay Street, where heavy automobile and truck traffic likely resulted in high upwind (background) dust levels.

During Round 1 of the RI, there were five occurrences where the upwind perimeter particulate levels exceeded the downwind particulate levels by at least 150 $\mu g/m^3$ (two-minute maximum readings). The upwind exceedances occurred at stations along Bay Street and automobile and truck traffic likely resulted in high upwind (background) dust levels. There were 11 occurrences where the downwind perimeter particulate levels exceeded the upwind particulate levels by at least 150 $\mu g/m^3$ (two-minute maximum readings). Only three of these 11 occurrences had downwind two-minute time-weighted averages at least 150 $\mu g/m^3$ greater than the upwind particulate levels, indicating that 8 of the 11 occurrences were very brief. For the three occurrences where the downwind time-weighted averages exceeded the upwind time-weighted averages, it was noted that dust-generating activities other than excavation (pavement sawing) were occurring nearby and likely accounted for the occurrences.

There were no instances where PID readings exceeded a reading of 5.0 ppm at the perimeter of the work area were noted during the subsequent soil boring work within Round 2 (October 1999), Round 4 (November/December 2002), Round 5 (May 2002), and Round 6 (November 2002) in accordance with the approved work plan.

There were no instances where the 15-minute average of the PID readings exceeded 5.0 ppm or the 15-minute average of the particulate meter exceeded 0.150 ug/m^3 during the soil boring work within Round 8 (April and May 2004) in accordance with the approved work plan.

2.3.3 Worker Health and Safety Air Monitoring Results

Approximately 500 PID-OVA data points were recorded during excavation and backfilling at test pits on the 25 and 40 Willow Avenue parcels during Round 1 (April 1999) of the RI. Only two data points showed readings greater than 0.0 ppm. A reading of 0.2 ppm was recorded downwind of TP-08. A reading of 3.7 ppm was recorded downwind of TP-04, at which time it was noted that the PID was downwind of exhaust fumes from pavement cutters. At no time did the PID readings exceed 5.0 ppm.

There were no instances where the average downwind particulate levels exceeded 150 µg/m^3 during the test pit monitoring. Two upwind (background) occurrences were noted where the overall average particulate concentration was greater than 150 µg/m^3. These occurred upwind of TP-4 and TP-5, which were excavated one after the other on February 23, 1999. It was noted at the beginning of the TP-4 excavation that the upwind particulate data logger was located downwind of pavement cutting and the particulates were attributed to these activities.

There were no instances where PID readings exceeded a sustained reading of 5.0 ppm at the perimeter of the work area were noted during the subsequent soil boring work within Round 2 (October 1999), Round 4 (November/December 2002), Round 5 (May 2002), and Round 6 (November 2002). Minor detections were noted within the work zone when soils with the occurrence of tar and tar stained soils were encountered; however, these detections quickly dissipated or were controlled with engineering controls in accordance with the approved work plan.

3. Site Geology and Hydrogeology

This section documents the geology and hydrogeology beneath the 25 Willow Avenue parcel and the surrounding vicinity.

3.1 Geology

Four major stratigraphic units were identified during the RI drilling program: (1) fill, (2) alluvial/marsh deposits, (3) glacial deposits, and (4) weathered bedrock (saprolite). The general stratigraphy beneath OU-2 consists of the saprolite overlain by the glacial deposits, alluvial deposits, and fill in order of decreasing depth. Cross-sections A-A' through C-C′ (Plate 2) and cross-sections D-D′ through G-G′ (Plate 3) were developed to illustrate the geology underlying OU-2. Plate 1 indicates the location of each cross section. These cross-sections also depict the physical observations of tar, tar blebs, staining, sheen, and odors. Table 3-1 summarizes the geologic units encountered during the RI. The distribution of chemicals and the physical observations of tar are described in Section 4. Detailed geologic descriptions and well construction details are provided in boring logs and test pit logs located in Appendices B and C.

A general description of the four stratigraphic units is provided below.

3.1.1 Fill

Fill is present at the ground surface or immediately beneath a thin layer of topsoil or asphalt (Plates 2 and 3). Fill consists of silt, sand, and gravel mixed with slag, coal, brick, concrete, wood, metal, ash and clinkers. Foundations (constructed of brick/mortar and concrete) of former MGP-related structures were also encountered with the fill at the site. Typically, the fill is loose and non-cohesive. Fill was encountered in each of the test pits, soil borings, and monitoring well locations completed at the 25 Willow Avenue parcel and adjoining properties (Plates 2 and 3). Fill on the 25 Willow Avenue parcel ranged from inches thick (as in boring SB-16 bordering Bay Street) to a maximum of 9 feet thick in SB-13 (Cross-section B-B′, Plate 2 and Cross-section F-F′, Plate 3). Generally, the fill unit was thicker in the central to northeastern portion of the 25 Willow Avenue parcel than within adjacent areas along Willow Avenue, Bay/Edgewater Street, and the Greenfield Avenue parcels. Fill was also present from the ground surface to the bottom of the following subsurface structures of the former MGP facility: Relief Holder No. 1 (SB-37), Tar Separator (SB-39), Tar Tank/Gasometer (SB-53), Tar Separator (SB-10A, TP-2), Tar Tank (adjacent to tar tank/gasometer) (TP-3), and Tar Well (SB-54 and SB-75) (Plates 1, 2 and 3).
Fill was also present at parcels adjacent to the 25 Willow Avenue parcel at the Greenfield Avenue parcels as observed in borings RW-8/SB-45, RW-9/SB-46,

RW-10/SB-47, RW-11/SB-48, RW-12/SB-49, within the Willow Avenue ROW within borings SB-30 through 35, and in the Bay Street/Edgewater Street ROW within borings SB-81 through 82A and SB-90 through SB-94.

3.1.2 Alluvial Deposits

A mix of alluvial/marsh deposits was encountered, generally beneath a layer of fill, at the 25 Willow Avenue parcel, and within borings located within the Willow Avenue ROW, the Bay Street/Edgewater Street ROW, and on the northwest parcels on Greenfield Avenue. The alluvial/marsh deposits consist of sub-units of sand, gravelly-sand, gravelly-silt, silt, silt-clay, and peat, and are present throughout the majority of OU-2. Historical maps of the area indicate that an un-named stream had previously flowed along the north-central portion of the adjacent 25 Willow Avenue parcel and into New York Harbor. The former stream and its tributaries likely deposited these alluvial/marsh deposits within OU-2.

Deposits encountered during the RI drilling are consistent with a former active stream depositional environment and an associated lower energy (marsh) environment. For this discussion, the deposits are broken down into the alluvial deposits (sorted sands and gravelly sands) associated with the former active stream environment, and marsh deposits (silts, silt-clay, gravelly silt and peat deposits) associated with a lower energy depositional environment. The sand and gravelly-sand units are typically gray, brown, red-brown fine to coarse sand and gravelly-sand with trace silt, and were generally loose and non-cohesive. The alluvial deposits are illustrated in cross-sections B-B′ and C-C′ (Plate 2) and D-D′ through G-G′ on Plate 3. As shown on these cross-sections, these alluvial deposits extend to approximately 44 feet bgs at borings SB-56/RW-16 in the central portion of the 25 Willow Avenue parcel. The alluvial deposits were inter-stratified with marsh/quiet energy deposits.

An inferred scour into the underlying glacial deposits extends from north of RW-16/SB-56 in SB-52 at south of SB-14/SB-76 (Plate 2 and Plate 3). This scour is interpreted as a former stream channel that crossed the 25 Willow Avenue parcel. Historical maps of the area discussed in subsection 1.2.2 show an un-named historic stream flowing through the northern portion of the 25 Willow Avenue parcel. The stratified sand units encountered in borings at the central to south-central portion of the 25 Willow Avenue parcel are consistent with former alluvial deposits. These deposits ranged between 12 and 25 feet bgs in borings SB-12, SB-13, and SB-54 (Plates 2 and 3).

The alluvial sand was also encountered at parcels along Willow Avenue, Bay/Edgewater Street, and Greenfield Avenue. The sand and gravelly-sand unit was also encountered beneath Willow Avenue in borings SB-31, SB-32, and SB-33 from approximately 17 to 24 feet bgs (Plate 2) and along Bay/Edgewater Street within SB-91/91A and SB-92 to approximately 12 feet bgs (cross-section G-G', Plate 3). These sand units are also likely associated with the former historic stream that previously occupied the site.

Silt, silt-clay and peat units were encountered on the western and southern portions of the 25 Willow Avenue parcel, the adjacent northwest parcels on Greenfield Avenue, portions of the Willow Avenue and Edgewater Street ROWs. These deposits are believed to be associated with a former marsh (possibly inter-tidal) that was located adjacent to the former stream and New York Harbor. These units are described as black, olive, gray to brown, soft, and slightly cohesive to cohesive. The western portion of the 25 Willow Avenue parcel and the parcels to the west had thicker silt, silt-clay, and peat units than in the remainder of the northeastern and eastern portions of 25 Willow Avenue parcel and the Bay Street areas. The thickness of these units ranged from 6 feet in RW-1 to approximately 20 feet in RW-13 and RW-8 on the western portion of the 25 Willow Avenue parcel. On the eastern portion of the 25 Willow Avenue parcel, the marsh deposits were absent at SB-19, RW-6, and RW-3.

Marsh deposits were also encountered within borings RW-8/SB-45 and RW-9/SB-46, located adjacent to the elevated railroad located within the Willow Avenue ROW within borings SB-30 and CNY#8 and CNY#9. Thinner deposits of marsh deposits were encountered within the remainder of the borings located to the northeast on Willow Avenue.

Marsh deposits were also encountered within the Bay/Edgewater Street area where marsh deposits were ranged from approximately 4 feet in SB-91/91A to approximately 10 feet within boring SB-93.

The OU-2 marsh deposits were thicker and located at greater depths to the northeast across the site and are primarily located in the topographic bowl-shaped feature at the site. This is consistent with the historic stream that formerly flowed across the site.

3.1.3 Glacial Deposits

Glacial deposits were encountered beneath the alluvial/marsh deposits and above the saprolite layer at 25 Willow Avenue, the Greenfield Avenue parcels, Bay Street/Edgewater Street, and beneath Willow Avenue. The glacial deposits can be classified into two sub-units based upon previous geologic investigations by Soren, 1988: the Harbor Hill Terminal Moraine and the Ground Moraine. According to Soren, 1988, a geologic contact between the Harbor Hill Terminal Moraine and the Ground Moraine is located within the vicinity of OU-2. The Ground Moraine and Harbor Hill Terminal Moraine were encountered in a number of borings during the RI within OU-2 (Plates 2 and 3).

The Ground Moraine consists of a silt to silt-sand mixture, with little to some cobbles and gravels, is dense to very dense and is slightly moist, which is consistent with the descriptions by Soren (1988). This unit is believed to be the confining unit for downward tar migration on the 25 Willow Avenue parcel (see Section 4). The top of the Ground Moraine varies from 33.5 feet deep in the vicinity of the SB-68 to approximately 65 feet deep in the vicinity of

Willow Avenue. The Ground Moraine was encountered at shallower depths in the northern portion of the site (SB-68, RW-17/SB-69, and SB-70A/RW-18 in the vicinity of Bay Street (cross-section F-F', Plate 3). The Ground Moraine was located at increasing depths in the central portion of the 25 Willow Avenue parcel at 30 feet bgs in RW-15/SB-55A (cross-section B-B', Plate 2) to approximately 44 feet bgs in RW-16 (cross-section F-F', Plate 3). The unit is located at greater depth in the vicinity of Willow Avenue (cross-sections D-D' and E-E', Plate 3). The unit extends to the top of the weathered bedrock. Stratified graded sand layers were noted within the lower portions of this unit at RW-15 and RW-16 (cross-section B-B', Plate 2). The Ground Moraine is believed to act as a leaky hydrologic confining unit between the water table aquifer and the deeper confined unit (see subsection 3.2); however, the unit has acted as an effective confining unit to the downward migration of tar at the 25 Willow Avenue parcel.

The Ground Moraine was inter-stratified with sand and gravelly sand layers at the northeastern portion of the site within borings (SB-68, RW-17/SB-69, RW-18/SB-70A, and SB-89. These localized, sand layers were red-brown sands to gravelly sands that occurred within glacial materials and contained rip-up clasts of glacial till material and were located on a weathered glacial till surface. These glacially derived units were likely glacial outwash during the retreat and advance of the glaciers over the site.

The Harbor Hill Terminal Moraine was also encountered in a number of borings within OU-2 along Bay Street and Willow Avenue. The Harbor Hill Terminal Moraine was encountered in borings completed adjacent to Bay Street (SB-71, SB-72, SB-73, RW-6/SB-20, and RW-3 (cross-section F-F', Plate 3) as shallow as 8 feet in RW-3 and also along Willow Avenue within borings SB-74 and SB-75 (cross-section C-C', Plate 2 and cross-sections D-D' and F-F', Plate 3).

The Harbor Hill Terminal Moraine deposits appear to be acting as a lateral barrier to the migration of tar along Bay Street at the 25 Willow Avenue parcel. From the geologic information collected at the site and published papers, it appears that the Harbor Hill Terminal Moraine was deposited at the frontal edge of the glacier over the Ground Moraine at the site. It is hypothesized that the deposition of the terminal moraine resulted in a local topographical high point along Bay Street that acted as a dam to the glacial meltwaters of the retreating glacier at the site. Consequently, a topographic low area was created adjacent to the Terminal Moraine after the ice retreated that subsequently became a pathway for the former stream and associated marsh (previously discussed in section 3.1.2).

3.1.4 Saprolite

Saprolite, or weathered bedrock, was encountered beneath the glacial deposits (sand layers) at the 25 Willow Avenue parcel in borings RW-15/SB-55A and RW-16/SB-56 (cross-section B-B', Plate 2, and cross-sections D-D' E-E', Plate 3). The top of the saprolite ranged between

–105.05 feet NAVD within RW-15/SB-55A and –116.18 feet NAVD within RW-16/SB-56. Based on these data points and additional points at OU-1 where the saprolite was encountered (within boring SB-78, -108.76 feet NAVD and within boring RW-14/SB-48 at -116.00 feet NAVD), the saprolite unit appears to dip to the north. The saprolite was formed by in-situ weathering of bedrock; likely the Manhattan Schist based on descriptions of the bedrock by Soren, 1988.

The encountered saprolite was a red to red-brown, gray to green-gray clay with some silts and relict schist-like texture, which included muscovite and biotite mica mineral layers. The unit was very dense and dry. The saprolite is believed to be the lower confining layer of the deep aquifer beneath OU-2.

3.2 Hydrogeology

No surface water bodies are located at or immediately adjacent to the OU-2 parcels. However, a stream formerly traversed the 25 Willow Avenue parcel (Plates 2 and 3). A storm sewer line follows the approximate trace of the historic stream and extends along the northwestern border of the adjacent 25 Willow Avenue parcel within OU-2. The storm drain empties into New York Harbor approximately 500 to 600 feet to the northeast.

Two aquifers are present beneath OU-2: a shallow, unconfined (water table) aquifer and a deep confined aquifer. Additionally, a water-bearing zone was also encountered within the semi-confining unit, which also displays artesian conditions. The shallow groundwater aquifer is located in fill, alluvium/marsh, and shallow glacial deposits. The water table elevations (shallow aquifer) ranged from 4.02 feet (NGVD) in FPM-OW-7 to 8.99 feet (NGVD) in RW-12 along Greenfield Avenue (Table 2-2).

The deep aquifer is under confining pressure and the wells tapping it exhibited flowing artesian conditions (RW-15 and RW-16). These wells are screened in stratified silty-sand and gravelly sand layers within the glacial deposits located above bedrock. Static head elevations in the deep aquifer ranged between 9.89 feet (NGVD) in RW-15 and 13.88 feet (NGVD) in RW-16 (Table 2-2). The dense silt ground moraine and Harbor Hill Terminal Moraine form a confining to semi-confining layer separating the water table aquifer from the deep aquifer. The water-bearing unit within the semi-confined aquifer (RW-17, RW-18, and RW-19) is under confining pressure and exhibited higher elevations than nearby water wells at the water table aquifer (FPM-OW-7 and RW-2). These wells were screened in localized sand/gravelly-sand bodies contained within the glacial deposits. The static head in wells within these wells ranged between 4.20 feet (NAVD) in RW-19 to 7.89 feet (NAVD) in RW-17.

Groundwater table elevations were measured in Round 1 (April 1999) and Round 2 (October 1999) (Table 2-2). A slight seasonal variation in the water table elevation (between 0.04 foot and 0.53 foot) was observed between Round 1 and Round 2. Round 2 elevations were generally lower than elevations measured in April 1999. However, no change in the groundwater flow pattern was observed between these two events. This decrease in groundwater elevation is likely attributable to the severe drought experienced by the Northeast in the summer of 1999. Additional seasonal variation in the groundwater table was observed between the Round 2 and the Round 4 gauging events, with lower elevations measured in the Round 4 for the majority of the wells gauged within OU-2. This was likely attributable to the drought conditions experienced within the winter and summer of 2002.

Groundwater elevations were measured in monitoring wells during each round, at both high tide and low tide, to evaluate possible tidal influences on groundwater flow. Tidal influence on the shallow groundwater aquifer is apparently minimal based upon groundwater elevations gathered from Round 1 and Round 2 of the RI. In the deep groundwater aquifer, a decrease in groundwater elevations (-0.1 foot) was observed between high tide and subsequent low tide groundwater measurements (Table 2-2).

Groundwater contour maps were created for the shallow groundwater aquifer and deep .aquifer using the groundwater elevations collected at high tide on October 13, 1999 (Round 2) which are summarized on Plate 4 and Plate 5, respectively. A groundwater aquifer map was created for the shallow groundwater aquifer using groundwater elevations collected during Round 4 (January 2002), which is summarized on Plate 6.

3.2.1 Water Table Aquifer

Groundwater flow within the water table aquifer appears to be dominated by two features: groundwater moving toward the former stream trace in the northern portion on the 25 Willow Avenue parcel, and groundwater flowing directly toward New York Harbor near the eastern portion of the 25 Willow Avenue parcel. As shown by Plate 3 and Plate 5, groundwater flows toward the former stream trace (current stormwater sewer) from west of the 25 Willow Avenue parcel and from the majority of the 25 Willow Avenue parcel. Groundwater moving along the actual trace of the former stream is expected to discharge to New York Harbor.

An apparent divide between the influence of the local former stream trace and the more regional influence of New York Harbor exists on the eastern corner of the 25 Willow Avenue parcel and Willow Avenue that extends into OU-1. Groundwater on the western side of this divide is flowing toward the former stream trace, while groundwater on the eastern side of the divide is flowing directly toward New York Harbor.

The average horizontal hydraulic gradients of the shallow groundwater aquifer range from 0.014 to 0.03 foot/foot in the Round 2 (October 1999) sampling event. The steepest hydraulic gradients occurred on the northern portion of the 25 Willow Avenue parcel near monitoring wells RW-2, FPM-OW-7, FPM-OW-6, and PZ-4. Lower hydraulic gradients are evident in the southwestern portion of the parcel. The water table flow directions and gradients are generally consistent with previous studies (FP&M, 1998) and the Round 1 groundwater contour patterns.

Hydraulic conductivities were calculated for water table wells using data generated from single well permeability tests (slug tests). Slug tests were completed on monitoring wells RW-1, RW-2, RW-3, RW-6, RW-8, RW-12, and RW-13. A summary of the hydraulic conductivities is presented in Table 3-2. Appendix D includes the slug test data files and the hydraulic conductivity calculations. The hydraulic conductivities (K) ranged from 3.2 x 10-4 centimeters/second (cm/sec) (0.9 feet/day) at RW-12 to 1.6 x 10-2 (cm/sec) (45 feet/day) at RW-13. These values are consistent with those expected for the silty-sand (Freeze and Cherry, 1979).

Monitoring wells RW-1, RW-8, and RW-13 have hydraulic conductivities generally an order of magnitude higher than monitoring wells RW-2, RW-3, RW-6 and RW-12. Wells RW-1 and RW-13 on the southwestern to western portions of the 25 Willow Avenue parcel, and RW-8 at an adjacent parcel to the west, are screened in coarser-grained and organic (and therefore more permeable) materials related to stream deposits (Table 3-2, Plate 2). Monitoring wells RW-2 and RW-3 on the eastern portion of the 25 Willow Avenue parcel along Bay Street are screened in finer-grained (and therefore less permeable) silt-sand related to the glacial deposits.

Average linear flow velocities for the water table aquifer were calculated based on the measured hydraulic conductivities and the horizontal hydraulic gradients using the following equation:

$$V = ki/n$$

where:

k = hydraulic conductivity of the formation
i = hydraulic gradient
n = effective porosity of the formation

Assuming an effective porosity of 30%, hydraulic gradients between 0.1 foot/foot along the western property line near the RW-13 location and 0.03 foot/foot in the vicinity of RW-6 (eastern portion of the 25 Willow Avenue parcel), and the calculated hydraulic conductivities, the average linear flow velocity of the water table aquifer ranges from 52.3 feet/year on the eastern portion of the 25 Willow Avenue parcel to 547.5 feet/year along the western portion of the parcel. Higher flow velocities along the southwestern portion of the parcels are believed to be associated with highly permeable silty-sands associated with the inferred former stream channel. The relatively low velocities along Bay Street are a result of the less permeable glacial deposits comprising the shallow aquifer.

3.2.2 Deep Aquifer

The groundwater contour pattern for the deep aquifer is depicted in Plate 5. An apparent groundwater divide is oriented roughly north-south through the middle of the 25 Willow Avenue parcel. Groundwater on the western side of the divide appears to be flowing westerly and groundwater on the eastern side of the divide appears to be flowing easterly. It is unclear whether this divide actually exists or if it is an artifact of tidal influence. This apparent groundwater flow pattern may be the result of tidal lag influences. In other words, one or more of the deep aquifer monitoring wells may be “feeling” the effects of a tidal cycle, while other well(s) may not have been influenced by the tidal effect at the time these measurements were collected.

In the deep aquifer, the average horizontal hydraulic gradient was determined to be 0.00044 foot/foot in the vicinity of RW-15 on the 25 Willow Avenue parcel.

The hydraulic conductivity was calculated for the deep aquifer wells using data generated from a single-well pump test completed in well RW-15. This monitoring well was screened in relatively low permeability silt to silty fine-to-coarse sands related to the glacial deposits. Table 3-2 presents a summary of the hydraulic conductivity values, and Appendix D presents the pump test data and hydraulic conductivity calculations. The hydraulic conductivity (K) for RW-15 was calculated as 3.5 x 10-5 cm/sec (0.09 foot/day).

A similar calculation of the average linear flow velocity for the deep groundwater aquifer was performed. The average linear flow velocity of the groundwater was calculated to be 0.49 foot/year near RW-15.

Vertical hydraulic head potentials between the shallow aquifer and the deep aquifer were calculated for the following well clusters or nearby shallow and deep aquifer pairs: RW-13/RW-15 and FPM-OW-05/RW-16. The upward vertical head potentials for these well pairs ranged between 0.055 and 0.073 foot/foot. Vertical head potentials were greater between well pairs FPM-OW-05/RW-16 on the northeastern portion of the 25 Willow Avenue parcel, than between the well pair (RW-13/RW-15) on the southwestern portion of the parcel. Based upon additional groundwater elevations collected from OU-1 from a three-well cluster (RW-7, RW-14 and PZ-3), the deep groundwater aquifer in the vicinity of the 25 Willow Avenue parcel behaves as one hydrologic unit once below the semi-confining layer. There was virtually no vertical head potential between RW-7 and RW-14 both located in the deep groundwater aquifer, while a vertical gradient existed between these wells and the water table piezometer PZ-3.

3.2.3 Water Bearing Zone Within the Confining Unit

A localized water-bearing zone within the confining unit was encountered in borings completed along Bay Street on the 25 Willow Avenue parcel and within Edgewater Street during the RI. Groundwater within the water-bearing unit within the glacial materials was apparently under confining pressure. A comparison of groundwater elevations within the water bearing unit and the water table aquifer reveals a difference of 2.35 feet between the RW-17/RW-2 nested pair and 2.9 feet between the RW-18/FPM-OW-7 nested pair. The calculated vertical head potentials for these well pairs were essentially identical (0.11 foot/foot [RW-17/RW-2] to 0.13 foot/foot [RW-18/OW-7]). Geologic information collected through borings SB-68, RW-17/SB-69, RW-18/SB-70A, and SB-89 depict this water-bearing zone as discontinuous sandy to gravelly-sand layer. During the groundwater sampling, monitoring wells RW-17 and RW-18 could only sustain low purging rates of approximately 100 ml/minute withdrawing down the well; consequently, this water-bearing zone is likely an isolated unit. Groundwater flow direction and the hydraulic conductivity was not calculated for this unit because of its likely discontinuous and isolated nature.

4. Nature and Extent

This section summarizes the physical observations made during the RI, presents the analytical findings of the investigation, and discusses the degree and extent of observed tar, staining, sheen, odors, and chemical constituents detected during the RI. The sample locations are shown on Plate 1. The terminology and descriptions used to describe the visual and olfactory observations made during the field investigation and used in this report section are defined in the Glossary of this report.

Subsection 4.1 discusses the soil findings and is subdivided by parcel. The soil findings for each parcel are further divided into surface-soil and subsurface-soil sections. Subsection 4.2 discusses groundwater conditions for the entire OU-2 study area of the RI.

The nature and extent of the chemical constituents is determined by the geologic conditions, groundwater flow patterns, and historic parcel use, processes and structures located at the site. During the drilling of soil borings and the excavation of test pits, tar-saturated soil, staining from tar, and odors characteristic of tar were observed. These physical observations were recorded on the boring and test pit logs (Appendices B and C) and were depicted on the geologic cross sections A-A′ through G-G′ for OU-2 parcels on Plates 2 and 3.

In addition to the physical observations, this section also discusses the analytical results of the surface-soil, subsurface-soil, groundwater, and storm sewer samples collected during the RI and previous sampling programs. Tables 4-1 and 4-2 present the detected laboratory analytical results for surface-soil and subsurface-soil samples, respectively. Table 4-3 presents a statistical summary of the surface soil samples collected on 25 Willow Avenue and background surface-soil results. Table 4-4 presents the detected laboratory analytical results for groundwater samples. Table 4-5 presents the detected laboratory analytical results for storm sewer samples. Appendices E and F present the chain-of-custody forms, validated laboratory Form I reports, and data validation reports for the soils and groundwater samples collected.

BTEX compounds were the principal VOCs detected and are the common VOCs associated with tar. SVOCs were also detected at the site with PAHs being the common subset of SVOCs in tar. For purposes of this report, PAHs include the compounds listed below.

2-Methylnaphthalene	Acenaphthene
Acenaphthylene	Anthracene
Benz(a)anthracene	Benzo(a)pyrene
Benzo(b)fluoranthene	Benzo(g,h,i)perylene

Benzo(k)fluoranthene	Dibenz(a,h)anthracene
Chrysene	Fluoranthene
Fluorene	Indeno(1,2,3-cd)pyrene
Naphthalene	Phenanthrene
Pyrene	

Of these PAHs, the following constituents are considered carcinogenic PAHs by EPA.

Benz(a)anthracene	Benzo(k)fluoranthene
Benzo(a)pyrene	Benzo(b)fluoranthene
Chrysene	Dibenz(a,h)anthracene
Indeno(1,2,3-cd)pyrene	

The analytical results of the RI and previous investigations are discussed relative to the total BTEX, total PAHs (TPAHs), and total carcinogenic PAHs (CPAHs).
Tables 4-1 and 4-2 include the sum of PAHs, the sum of carcinogenic PAHs, sum of the non-carcinogenic PAHs, and the sum of BTEX constituents for surface soil and subsurface soil, along with the analytical results for individual analytes. For non-detect results ("U" qualified), the value used in these sums was 0.00. For estimated values ("J" qualified), the value used in the sums was the numerical result for each analyte.

At the request of the NYSDEC, a comparison of detected analytes to the New York State Recommended Soil Cleanup Objectives (RSCOs) was also completed. The exceedances were highlighted and bolded on the tables.

Table 4-4 includes the sum of PAHs, carcinogenic PAHs, non-carcinogenic PAHs and BTEX for groundwater, along with the analytical results for individual analytes. At the request of the NYSDEC, a comparison of detected analytes to the New York State Ambient Groundwater Standards and guidance values for a GA area for all groundwater samples collected was completed. Exceedances of the established criteria have been highlighted and bolded in the table.

Table 4-5 includes the sum of PAHs, carcinogenic PAHs, non-carcinogenic PAHs and BTEX for storm sewer water samples, along with the analytical results for individual analytes. Table 4-6 presents a summary of detected analytes in soil gas samples collected beneath the slab for the building at 25 Willow Avenue.

A statistical summary of detected analytes for each matrix (surface soil, subsurface soil, groundwater) is presented in Table 4-7.

4.1 Soil

Surface Soils

Three surface-soil samples were collected on the 25 Willow Avenue parcel as part of the collection of background surface-soil samples in the vicinity of the 25 and 40 Willow Avenue parcels. The background soil samples are discussed below in subsection 4.2. Table 4-1 summarizes the detected analytes for these three surface-soil samples and the background surface-soil samples. Appendix E includes the validated laboratory Form I reports and chain-of-custody forms for the RI samples. Plate 1 depicts the surface-soil sample locations.

Subsurface Soils

Subsurface-soil samples were collected from the 25 Willow Avenue parcel, the Greenfield Avenue commercial parcels, the Willow Avenue ROW, and in the Bay Street/Edgewater Street area. Table 4-2 is organized by parcel and summarizes the detected analytes for all subsurface-soil samples collected during the RI and during previous investigations. Appendix E includes the validated laboratory Form I reports and chain-of-custody forms for the RI samples. Plate 1 depicts the subsurface-soil sample locations (soil borings, test pits, monitoring wells).

The overall extent of tar, staining, sheen, odors, and chemical constituents detected in soils was located primarily adjacent to the immediate vicinity surrounding historic structures that handled tar on the 25 Willow Avenue parcel. However, discrete intervals of tar-related materials were noted at depth beneath the Willow Avenue and beneath Bay Street/Edgewater Street. As shown by cross-sections C-C′, F-F′, and G-G′ (Plates 2 and 3), isolated tar, tar-staining or tar-related sheens, and/or odors were observed in discrete areas beneath the Willow Avenue ROW and the Bay Street/Edgewater Street ROWs.

In general, elevated levels of TPAH, CPAH, and BTEX correlated with the occurrence of observable tar, odors and/or sheen. Where physical evidence of tar was not encountered, analyses indicated generally low to trace levels of these chemical constituents. As with the observed extent of tar, staining, odors, etc., the overall extent of chemical constituents was generally limited to the 25 Willow Avenue parcel, and to isolated discrete intervals beneath Willow Avenue, and Bay Street/Edgewater Street. Plates 7, 8, and 9 depict a summary of total BTEX, total PAHs, total carcinogenic PAHs, and total CN in soils in three different depth intervals: unsaturated soils, saturated soils above the confining layer, and saturated soils below the confining layer.

In addition to these analytes, RCRA 8 metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver), total cyanide, and TOC were analyzed for in certain soil samples. Total cyanide was only detected in 20 subsurface-soil samples; all detections except one was significantly below 100 ppm[1] with the exception of one sample, (SB-54 [4 to 6 feet]), which contained a total cyanide detection of 139 ppm. Elevated detections of cyanide (39.8 ppm to 59.6 ppm) were encountered within borings SB-11, SB-12, and SB-53, which were completed in the vicinity of the former MGP gas purifying area. Detections of cyanide within subsurface soils will be discussed in subsection 4.1.1 (Purifying Tanks). Based upon analytical data collected, total cyanide in subsurface soils does not appear to be of concern.

4.1.1 25 Willow Avenue

Surface Soil

Three surface-soil samples (SS-34, SS-35, and SS-36) were collected within the grassed yard of the 25 Willow Avenue parcel. The remainder of the 25 Willow Avenue parcel is covered by a building and an asphalt parking lot. These samples were collected as part of background soil screening in the vicinity of the former MGP located at 25 and 40 Willow Avenue. Surface-soil samples were collected from just below the vegetative root mat from 0 to 2 inches.

The BTEX ranged from non-detected within SS-36 to 0.8 parts per billion (ppb) within SS-35. The total PAHs ranged from 11.1 ppm within SS-36 to 91.9 ppm within SS-34. The CPAHs exhibited a similar trend with the 5.9 ppm detected within SS-36 and 54.0 ppm within SS-34. Total cyanide was not detected within the three surface-soil samples. Metals were detected in each of the subsurface-soil samples that appeared to fall into the range of detection the background surface-soil samples collected.

Subsurface Soil

At the 25 Willow Avenue parcel, the lateral extent of chemical constituents is generally limited to the immediate vicinity surrounding historic structures that handled tar. The vertical extent of tar, staining, sheen, odors, and chemical constituents at some locations has been specifically documented, while at others, specific borings were terminated within soils containing tar, stains, etc. Two deep Rotosonic™ soil borings (SB-55/SB-55A and SB-56) and six intermediate depth Rotosonic™ borings (SB-68, SB-70A, SB-72, SB-73, SB-75, and SB-76) were completed to characterize deep soil conditions on the 25 Willow Avenue parcel. Soil boring SB-55/55A was placed adjacent to the former Tar Tank/Gasometer, SB-56 was placed adjacent to former Relief Holder No. 1, SB-75 was placed within a former tar well, and SB-76 was placed adjacent to a former tar well; these former structures were believed to have previously held tar.

[1] Generic Soil Screening Level (USEPA March 2001)

As discussed in subsection 3.1, a dense silt unit was encountered beneath the 25 Willow Avenue parcel in borings SB-55/SB-55A, SB-56 and SB-75 (cross-section B-B on Plate 2, and cross-sections D-D′ and E-E′ on Plate 3). In addition to acting as a hydrogeologic confining unit between the water table and deep aquifers, observations of tar and tar staining at SB-55/55A and SB-56 demonstrate that the dense silt unit effectively acts as a confining layer to the downward mobility of tar. At both locations, tar stopped at the top of the dense silt unit, and observed tar-like odors only permeated the top few feet of the silt. A glacially derived clayey-silt unit was also encountered beneath the 25 Willow Avenue parcel in borings RW-3, SB-19, SB-71, SB-72, and SB-73 along Bay Street (cross-section F-F, Plate 3). This layer generally appears to act as a lateral barrier to tar at the site along Bay Street with the exception of an isolated gravelly-sand layer (glacial outwash layer) in the vicinity of SB-68, RW-17/SB-69, RW-18/SB-70A, and SB-89 where tar and tar-stained soils were encountered (cross-section F-F', Plate 3). These observations will be summarized with the Bay Street/Edgewater Street discussion in subsection 4.1.3.

The remainder of this subsection discusses the occurrence and extent of tar, staining, sheen, odors and chemical constituents relative to the following specific historic structures on the 25 Willow Avenue parcel.

- Relief Holder No. 1
- Tar Separator Beneath Existing Building (at SB-39)
- Tar Tank/Gasometer and Adjacent Tar Tank (southwestern corner of parcel) (at SB-53 and SB-13)
- Tar Separator (at SB-10/10A and TP-2)
- Accumulator Tank (at TP-6 and SB-13)
- Tar Well (at SB-54 and SB-75)
- Tar Well (at TP-7, SB-14, and SB-76)
- Purifier Tanks (at TP-4, TP-5, and TP-6)
- Fuel Tanks (southwestern corner of parcel)
- Naphtha Tank and Tar Tanks (at RW-13/SB-50)
- Gas Holder No. 2 (at SB-57, SB-15, and TP-9)
- Former UST area

Plate 1 indicates the locations of the historic structures, soil borings, and surface-soil sample locations. Plates 2 and 3 summarize the geologic conditions, and the physical observations with respect to the former MGP structures.

Relief Holder No. 1

Subsurface-soil conditions were evaluated at this location through the completion of test pit TP-8, Geoprobe® soil boring SB-37, and Rotosonic™ boring/monitoring well SB-56/RW-16. Test pit (TP-8) confirmed that fill containing tar was present within and outside of the holder wall. Soil boring SB-37 determined that approximately 5 feet of clean sand fill is present beneath the floor slab of the existing building. Below this clean fill, tar-saturated soil is present to a depth of 20 feet, where refusal was encountered and concrete chips recovered, likely on the floor of the former relief holder.

Soil boring/monitoring well SB-56/RW-16 was completed to characterize the deep soil conditions adjacent to Relief Holder No. 1. As shown in cross-section B-B' (Plate 2) and cross-section E-E′ (Plate 3), tar-saturated soil was encountered within generally coarse-grained alluvial materials (sand/gravelly-sand layers) to a depth of about 44 feet bgs. Silty soil lenses above 44 feet bgs exhibited only odors, staining, and discrete blebs of tar. At 44 feet bgs, a dense silt unit was encountered which appears to act as a confining unit and has limited the downward migration of tar at this location.

Analytical results from test pit TP-8, and borings SB-37 and SB-56/RW16, detected PAHs and BTEX at shallow depths coinciding with the presence of observed tar. The 2-foot depth sample from TP-8 exhibited the highest TPAH (96,060 ppm), CPAH (12,660 ppm), and BTEX (6,100 ppm) values for samples analyzed from this holder area. Sample SB-37 (14.5 to 19 feet), collected from within the holder, contained detections of TPAH of 11,804 ppm; CPAH of 1,024 ppm; and BTEX of 2,790 ppm.

Outside of the holder, BTEX and PAHs were present to a depth of 44 feet bgs where the dense silt unit stopped the downward migration of tar. Sample RW-16/SB-56 (43 to 44 feet) contained 9,858 ppm TPAH, 621 ppm CPAH, and 1,134 ppm BTEX. As shown by sample RW-16/SB-56 (63 to 63.5 feet), no CPAH or BTEX compounds were present and only trace TPAH (0.01 ppm) was detected below the top of the dense silty layer at 44 feet bgs.

A clayey-silt unit was encountered within soil borings SB-19, SB-71, SB-72, SB-73, and SB-74. Analytical results from soil borings SB-19, SB-72, SB-73, SB-88 and RW-6/SB-20 confirm that tar has not spread laterally eastward toward Bay Street from former Relief Holder No. 1 in the vicinity of these borings. Analytical results from borings to the east of the tar separator, indicate trace to low levels of PAHs and BTEX, thereby substantiating that the elevated PAHs and BTEX observed at RW-16/SB-56 and TP-8 are limited to the immediate vicinity of the former Relief Holder No. 1.

Tar Separator Beneath Existing Building

Geoprobe® soil boring SB-39 was completed within the building to assess soil conditions at the former location of the tar separator. Approximately 2 feet of clean fill was present beneath the concrete slab of the building. Tar-saturated material was encountered from 4 to 5.5 feet below the floor slab, where refusal on a concrete surface was encountered and the boring was terminated.

Analytical results from boring SB-39 indicate the presence of PAHs and BTEX at shallow depths below the building floor slab. Sample SB-39 (0 to 4 feet) contained 7,277 ppm TPAH, 839 ppm CPAH, and 149 ppm BTEX. Sample SB-39 (5.5 feet) contained 52,210 ppm TPAH, 5,770 ppm CPAH, and 209 ppm BTEX.

Soil borings SB-20/RW-6, SB-16 (16A), SB-72, SB-73, and RW-3 confirm that tar has not spread easterly toward Bay Street from the tar separator. Analytical results from these borings to the east of the tar separator, indicate trace to low levels of PAHs and BTEX, thereby substantiating that the elevated PAHs and BTEX observed at SB-39 are limited to the immediate vicinity of the former tar separator.

Tar Tank/Gasometer and Adjacent Tar Tank (Southwestern corner of parcel)

Subsurface conditions were evaluated at this location through the completion of test pit TP-3, hollow-stem auger boring SB-53, Geoprobe® boring SB-11, Rotosonic™ boring/monitoring well RW-15/SB-55A, and soil boring SB-55. Cross sections B-B' and D-D' (Plates 2 and 3) depict the extent of observed tar, staining, sheen, and odors at this location.

Test pit TP-3 identified tar just below the water table to at least 5 feet deep within the tar tank/gasometer and between the tar tank/gasometer and the adjacent tar tank. Soil boring SB-11 identified tar-saturated soils extending from 2 to 6 feet bgs in the vicinity of the adjacent tar tank. A peat and clay layer below 6 feet appears to have limited the downward migration of tar at SB-11. Discrete tar-saturated layers of sand were encountered within the clay layer and tar-stained soils were encountered within a sand/silt unit at the completion of the boring.

Boring SB-53 was advanced to 14.2 feet bgs where refusal was encountered on the holder floor. Tar-saturated soil/fill materials were present from 5.0 feet bgs to the bottom of the holder.

Outside the tar tank/gasometer there appears to be a limited amount of tar-saturated soil. Rotosonic™ boring SB-55 only encountered two discrete lenses of tar-saturated soil from 9.5 to 13.0 feet bgs (near the holder bottom) and from 18.0 to 21.0 feet bgs. Tar-saturated soil was not encountered in Rotosonic™ boring/monitoring well location SB-55A/RW-15 (approximately 15 feet away from SB-55). Only tar staining, discrete tar blebs, sheens, and odors were observed extending to a maximum depth of 34 feet bgs (cross-section B-B', Plate 2, and cross-section D-D', Plate 3).

At the location of Former Tar Tank Gasometer, a dense silt unit was encountered which acts as a confining unit and has limited the downward migration of tar at this location. Tar-like odors extended about 5 feet into the top of the dense till unit, but no indications of tar, staining, sheen, or odors were observed below 34 feet bgs.

BTEX, TPAH, and CPAH concentrations in this area ranged from non-detect in the 123- to 125-foot sample from boring RW15/SB-55A to a maximum of 1,111 ppm, 38,420 ppm, and 3,680 ppm, respectively, in sample SB-53 (13.5 feet) collected within the former gasometer.

Within the footprint of the former tar tank/gasometer, analytical data just below the pavement indicate the presence of 258.4 ppm TPAH, 73 ppm CPAH, and 0.3 ppm BTEX (TP-3 [1 foot]). PAH and BTEX constituents increase in concentration with depth and with the presence of tar within the holder, as evidenced by the 13.5-foot sample from SB-53 that indicated 38,420 ppm TPAH; 3,990 ppm CPAH; and 1,111 ppm BTEX.

Outside the holder, concentrations are generally lower as evidenced by analytical results from boring SB-11 (Table 4-2). Borings RW-15/SB-55A and SB-55 were completed outside the holder and indicate that the vertical extent of tar, BTEX, and PAHs was limited by the presence of the dense silt unit that limited the downward migration of tar. Sample SB-55 (56 to 58 feet) was collected from below the top of the dense silt unit and exhibited only 0.01 ppm TPAH, only trace total BTEX, and no carcinogenic PAHs.

Tar Separator (at SB-10 and TP-2, SB-10A and SB-74)

This tar separator was evaluated by completion of test pit TP-2, Geoprobe® borings SB-10 and SB-10A, and one Rotosonic boring SB-74. Test pit TP-2 identified discrete tar blebs within fill material from about 2 feet to 5 feet bgs within the tar separator. Tar-saturated soil was present outside the tar separator down to at least 5 feet bgs. Soil boring SB-10A identified tar blebs and sheens within the tar separator to a depth of at least 8 feet. Boring SB-10A reached 13 feet bgs where refusal was encountered; however, sample recovery from below 8 feet was not possible. Outside the separator, soil boring SB-10 identified tar-saturated soils from about 2 to 6.5 feet bgs and tar-stained soils were observed within SB-74 from 1.5 to 28.5 feet where they subsequently terminated at the top of a clayey-silt unit. No visual observations of tar were observed within SB-74 28.5 feet deep to the termination of the boring at 45 feet. The clayey-silt layer appears to act as a tar-confining unit at this portion of the site.

Three subsurface soil samples were collected and analyzed from outside the tar separator in this area: SB-10 (5.0 to 6.5 feet), SB-74 (21.0 to 21.5 feet), SB-74 (34.5 to 35 feet). A shallow soil sample was collected from SB-10 that exhibited tar-coated soil grains with sheen and mixed fuel oil/tar odor. The sample contained 1,421 ppm TPAH; 115 ppm CPAH; and 14.1 ppm BTEX. Deeper subsurface-soil samples were collected from SB-74 with a slight naphthalene/tar odor at 21.0 to 21.5 feet and at 35.0 feet near the contact of the clayey-silt. BTEX, TPAH and CPAH concentrations decreased with depth adjacent to the tar separator. BTEX ranged from 76.2 ppm within the 21.0- to 21.5-foot sample to 0.088 ppm within the 34.5- to 35.0-foot sample interval. TPAH/CPAH concentrations ranged from 705 ppm/64.2 ppm within the 21.0- to 21.5-foot sample to 0.530 ppm to non-detected within the 34.5- to 35.0-foot sample interval which, also coincided with the decreasing frequency of the occurrence of tar.

Accumulator Tank (at TP-6 and SB-13)

Cross-section B-B' (Plate 2) depicts the observed subsurface conditions at the accumulator tank. Test pit TP-6 identified the presence of rubble and fill exhibiting a slight tar-like odor down to about 5 feet bgs. One Geoprobe® soil boring (SB-13) identified tar-saturated soil from 2.5 to 9.0 feet bgs, with discrete tar-saturated layers extending up to about 18 feet bgs.

Analytical data from soil boring SB-13 indicate that PAHs and BTEX constituents extend to 20 feet bgs, coinciding with the observation of tar-saturated soil lenses. Two samples were analyzed from this boring. The 7- to 9-foot sample contained 348.7 ppm TPAH, 73.5 ppm CPAH, and 20.9 ppm BTEX. The 18- to 20-foot sample contained 345 ppm TPAH, 44.2 ppm CPAH, and 208 ppm BTEX.

Tar Well (SB-54 and SB-75)

One hollow-stem auger boring (SB-54) and one Rotosonic™ boring (SB-75) were completed to evaluate the former tar well at this location. The tar well structure was encountered at approximately 4 to 5 feet bgs where fragments of wood and concrete were encountered during the completion of SB-75, which are consistent with the construction of this feature. Tar-saturated and tar-stained soil was present from 2 to 25 feet bgs, where the boring SB-54 was terminated. Within boring SB-75, tar-saturated and tar-stained soils were encountered from 5 to 23 feet bgs, and tar staining within soil fractures and staining of coarse-grained materials were noted from 23 to 58 feet bgs. Naphthalene and tar like odors were present within SB-75 from 58 to 65 feet bgs where physical observations of tar and odors diminished. One Geoprobe® soil boring (SB-12) was also completed near the tar well where tar-saturated soils were encountered down to 11 feet bgs. Tar-like odors were observed to a depth of 16 feet bgs.

Three soil samples were analyzed from boring SB-54: (4 to 6 feet, 9 to 11 feet, and 23 to 25 feet); two soil samples were analyzed from SB-75 (52 to 52.5 feet and 70 to 72 feet); and one soil sample was analyzed from boring SB-12 (4 to 6 feet). BTEX concentrations ranged from 204 ppm in sample SB-12 (4 to 6 feet) to 1,530 ppm in sample SB-54 (9 to 11 feet) within shallow subsurface soils. BTEX concentrations decreased with depth and only a trace detection of BTEX was noted within soil sample SB-75 (70 to 72 feet). TPAH ranged from 2,971 ppm in sample SB-54 (9 to 11 feet) to 9,673 ppm in sample SB-54 (23 to 25 feet) within the shallow subsurface soils beneath the tar well. TPAH concentrations decreased with depth from 2,838 ppm TPAH detected in soil sample SB-75 (52 to 52.5 feet) to 1.1 ppm detected in sample SB-75 (70 to 72 feet). CPAH ranged from 116 ppm in sample SB-12 (4 to 6 feet) to 585 ppm in sample SB-54 (23 to 25 feet) within the shallow subsurface soils beneath the tar well. CPAH concentrations decreased from 120 ppm CPAHs detected within soil sample SB-75 (52.0 to 52.5 feet) to non-detected within sample SB-75 (70 to 72 feet). The detections of PAHs and BTEX coincided with tar observed to a depth of 25 feet bgs in boring SB-54 and tar-stained soils within SB-75 to a depth of 58 feet bgs.

Tar Well (at TP-7, SB-14, and SB-76)

This tar well was evaluated by completion of test pit TP-7, Geoprobe® soil boring SB-14, and Rotosonic™ boring SB-76. The test pit identified the presence of tar within the former tar well to a depth of at least 4 feet bgs. Soil boring SB-14 was completed outside of the tar well and only identified the presence of tar-saturated soil from 5.5 to 7.0 feet bgs. Tar-like odors and staining were observed extending to about 16 feet bgs. Boring SB-76 identified the presence of tar-stained soils from approximately 2 to 21 feet bgs and from 35 to 40 feet bgs. A tar-saturated layer of gravelly sand was encountered from 40.0 to 45.5 feet. This unit was located atop very dense silt that is likely a former weathering surface of the glacial till. Below this dense silt layer, only isolated sheens and odors were noted from 45 to 50 feet bgs and odors were noted from 50 to 58 feet bgs at the completion of the boring.

Shallow-subsurface soil samples from 6 to 8 feet and 24 to 28 feet were analyzed from soil boring SB-14, and deep subsurface soils from boring SB-76 were analyzed from 44.0 to 44.5 feet and 58 to 58.5 feet. The 6- to 8-foot sample contained 1,260 ppm BTEX, 5,175 ppm TPAH, and 704 ppm CPAH and coincided with the shallow presence of tar-saturated soil. The 24- to 28-foot sample, which contained 3.0 ppm TPAH, 0.4 ppm CPAH, and 0.5 ppm BTEX, was collected at the termination of SB-14 where tar/naphthalene odors were encountered. Soil sample SB-76 (44 to 44.5 feet) contained 5,970 ppm BTEX, 30,250 ppm TPAH, and 2,540 ppm CPAH and coincided with a tar-saturated sand layer. The 58- to 58.5-foot sample from SB-76 contained 0.001 ppm of BTEX, 17.4 ppm TPAH, and 2.2 ppm of CPAH at the completion of the boring.

Purifier Tanks

The former purifier tanks were evaluated through the completion of test pits TP-4, TP-5, TP-6, and Geoprobe® boring SB-12 (Plate 2). Test pit TP-4 encountered tar, staining, and tar-like odors to a depth of about 5 feet bgs. Test pit TP-5 could not be excavated below a concrete slab approximately 1 foot bgs. Test pit TP-6 encountered fill with a light tar odor and tar-saturated wood. As discussed above, tar-saturated soil was observed in soil boring SB-12 to about 11 feet bgs.

During completion of these test pits and soil boring, no visible evidence of purifier materials (such as oxide box wastes) was encountered. The purifier tanks were aboveground structures. At test pit TP-4, a “purifier odor” (sulfur-like) was noted along with a tar-like odor at the water table.

Analytical data from the vicinity of the purifier tanks was obtained from test pit TP-4 (3 feet) and from boring SB-12 (4 to 6 feet). The data from TP-4 indicate 482.9 ppm TPAH; 142 ppm CPAH; and 78.2 ppm BTEX. The results from boring SB-12 indicate 204 ppm BTEX, 7,826 ppm TPAH, and 116 ppm CPAH. The analytical sample from SB-12 (4 to 6 feet) contained 47.6 ppm total cyanide.

Fuel Tanks (southwestern corner of parcel)

The subsurface conditions near the fuel tanks in the southwestern corner of the parcel were evaluated with test pit TP-1, hollow-stem auger soil boring SB-9, and hollow-stem auger boring/monitoring well RW-1. Tar blebs and odors were observed at boring SB-9 and soil samples from 8 to 10 feet; the 24- to 26-foot sample contained tar-saturated soil and tar odors, which was located within a discrete sand lens. Petroleum was also observed in the subsurface in this vicinity at RW-1 and TP-1. In addition, petroleum odors mixed with tar-like odors were noted at nearby well/boring RW-13/SB-50 that is discussed in the naphtha/tar tank subsection listed below. This well is located adjacent to the storm sewer line along the northwestern section of the 25 Willow Avenue parcel.

Analytical data from the area of the former fuel tanks was obtained for samples from test pit TP-1 and soil boring SB-9. BTEX was detected in subsurface soils in this area ranging from non-detect in samples SB-9 (33 to 34 feet) and RW-1 (17 feet) to 1,513 ppm in sample SB-9 (8 to 10 feet). TPAH was detected ranging from 0.02 ppm in sample SB-9 (33 to 34 feet) to 1,931 ppm in sample SB-9 (24 to 26 feet). CPAH was detected ranging from 2.2 ppm in sample RW-1 (17 feet) to 225 ppm in sample SB-9 (24 to 26 feet).

At SB-9, the BTEX and PAHs detected corresponded with the observed occurrence of tar. However, the 33- to 34-foot sample from SB-9 was collected from just below the top of the dense silty layer where tar was not observed and only contained 0.02 ppm TPAH and 0.01 ppm CPAH; BTEX constituents were not detected.

Naphtha Tank and Tar Tanks

Subsurface conditions in the vicinity of the former naphtha tank and tar tanks were evaluated through completion of hollow-stem auger boring SB-50 for the installation of RW-13. Black-stained soils with petroleum and tar odors were noted from 3 to 9 feet bgs within fill material. Slight tar/petroleum odors were observed from 9 to 19 feet and naphthalene-like odors were observed from 19 to 35 feet.

Analytical data from this area was obtained from three soil samples collected from RW-13/SB-50 from 9 to 11 feet, 17 to 19 feet, and 39 to 41 feet. BTEX concentrations ranged from non-detected within the 39- to 41-foot sample to 30.6 ppm in the 9- to 11-foot sample. TPAH concentrations ranged between 0.32 ppm in the 39- to 41-foot sample to 826 ppm in the 9- to 11-foot sample. CPAH concentrations also ranged from non-detected within the 39- to 41-foot interval to 155 ppm within the 9- to 11-foot interval.

Gas Holder No. 2

Subsurface conditions in the vicinity of gas holder No. 2 were evaluated through completion of test pit TP-9, and Geoprobe® soil boring SB-15 and hollow-stem auger soil borings SB-52 and SB-57. Test pit TP-9 identified the edge of the slab-on-grade holder floor. The test pit revealed fill, but did not identify the presence of tar, staining, sheen, or odors. No tar, staining, sheen, or tar-like odors were observed in boring SB-15. At soil boring SB-52, black staining and mixed gasoline and tar-like odors were observed from 3.0 to 9.0 feet bgs. A sheen was noted between 5.0 and 6.2 feet bgs. Fuel oil-like odors mixed with naphthalene-like odors were encountered beneath the slab for Gas Holder No. 2 in boring SB-57 between 5 and 6.5 feet bgs, which is adjacent to a former 550-gallon fuel oil tank.
In this area, subsurface-soil analytical results were obtained from soil borings SB-15, SB-52, and SB-57. BTEX ranged from non-detect in sample SB-52 (39 to 41 feet) to 8 ppm in sample SB-52 (5 to 7 feet). TPAHs were not detected in the 11- to 13-foot and 39- to 41-foot samples from SB-52, and ranged up to 272.8 ppm in sample SB-57 (5 to 7 feet). CPAHs were not detected in the 11- to 13-foot and 39- to 41-foot samples from SB-52 or in the 29- to 31-foot sample from SB-57. The maximum detected CPAH was in sample SB-57 (5 to 7 feet) at 135 ppm.

Former UST Area

Physical observations in the area of the former USTs were obtained from previous investigation boring logs FPM-OW-3, FPM-OW-4, and through the completion of RI hollow-stem auger borings SB-51 and SB-52. Petroleum odors mixed with tar-like odors were observed at and below the water table in boring FPM-OW-3. A slight petroleum odor was observed from 7 to 15 feet bgs in boring FPM-OW4. Mixed gasoline and tar-like odors were observed in boring SB-52 from 3 to 9 feet bgs. Gasoline odors were also present from 1 to 13 feet bgs in boring SB-51.

Subsurface-soil analytical data from this area are available from the September 1993 excavation sidewall samples collected by Lexicon following the removal of the USTs, and from nearby borings SB-51 and SB-52. The majority of these samples contained detections of PAHs and BTEX constituent. BTEX ranged from non-detect in sample SB-52 (39 to 41 feet) to 10.5 ppm in the sidewall sample LEX-SS-10. TPAHs were not detected in sidewall samples LEX-SS-2 and LEX-3 and in the 11- to 13-foot and 39- to 41-foot samples from boring SB-52. CPAHs were not detected in sidewall samples LEX-SS-2 and LEX-SS-3, in the 39- to 41-foot sample from boring SB-51, or in the 11- to 13-foot and 39- to 41-foot samples from boring SB-52. The highest TPAH (823 ppm) and CPAH (453 ppm) concentrations were detected in sidewall sample LEX-SS10 and LEX-SS9, respectively.

4.1.2 Willow Avenue

Between the 25 and 40 Willow Avenue parcels, within Willow Avenue and the sidewalk, subsurface conditions were evaluated through completion of previous borings CNY-8 through CNY-13 completed by the City of New York, FPM-SB-9 through FPM-SB-13 completed by Fanning Phillips and Molnar, and through RI Geoprobe® soil borings SB-30 through SB-35. Tar-saturated soil was present at FPM-SB-9 from just below the pavement to approximately 5 feet bgs; blebs of tar extended to 16 feet bgs. Tar blebs, staining, sheen, and odors were detected at the following boring locations in Willow Avenue: CNY-11, CNY-12, FPM-SB-10, FPM-SB-13, SB-33, and SB-34.

Analytical data were obtained from previous borings FPM-SB-9 through FPM-SB-12 and from RI borings SB-30 through SB-35, completed within Willow Avenue and the sidewalk, that indicate the presence of PAHs and BTEX constituents. BTEX in subsurface soils ranged from non-detect in samples FPM-SB-10 (8 to 9 feet) (elevated detection limit), FPM-SB-11 (4 feet), FPM-SB-11 (8 feet), SB-31 (7 to 11 feet), SB-35 (6 to 10 feet), and SB-35 (18 to 22 feet), to 1,683 ppm in sample FPM-SB-9 (0.5 to 4.0 feet). TPAHs ranged from non-detect in samples SB-31 (7 to 11 feet) and SB-35 (6 to 10 feet), to 1,424 ppm in sample FPM-SB-9 (0.5 to 4.0 feet). CPAHs ranged from non-detect in samples SB-30 (19 to 23 feet), SB-31 (7 to 11 feet), SB-31 (15 to 19 feet), SB-32 (20 to 23 feet), SB-34 (9 to 13 feet), and SB-35 (6 to 10 feet), to 64 ppm in sample FPM-SB-10 (8 to 9 feet).

4.1.3 Bay Street/Edgewater Street

Bay Street

The subsurface soil conditions within the Bay Street/Edgewater Street area were evaluated through Rotosonic™ borings SB-68, RW-17/SB-69, RW-18/SB-70A, and SB-70; Geoprobe® soil borings SB-81, SB-82/82A, SB-88, SB-89, SB-90 through SB-94; the drive and wash soil boring for monitoring well RW-2; and previous investigation boring FPM-OW-7.

Along Bay Street, on the 25 Willow Avenue parcel, tar staining and tar-saturated soils were observed within boring RW-18/SB-70A. Within this boring, tar-stained soil was encountered from approximately 28 to 31 feet bgs. Tar-saturated gravelly-sands were encountered from about 31 to 32.5 feet bgs. Below this depth, only tar-stained soil was encountered within sand lenses from 42 to 45 feet bgs.

Tar-stained soils were also encountered within a gravelly-sand lens within RW-17/SB-69 at approximately 33 to 33.5 feet bgs. Other borings along Bay Street (SB-68 and SB-89) to the northwest or the southeast of the site were completed within the similar geologic sands and gravelly-sands and naphthalene-like odors were noted. This confirms that the majority of observations of tar and tar-stained soils are isolated to the gravelly-sand unit located 32 to 32.5 feet (cross-section F-F', Plate 3).

Analytical data from soil borings SB-68, RW-17/SB-69, RW-18/SB-70A, SB-88, and SB-89 indicate the presence of PAH and BTEX constituents at the northern boundary of the 25 Willow Avenue parcel. BTEX concentrations ranged from non-detected within SB-68 (54.5 to 55 feet) and SB-88 (44 to 48 feet) to 1,140 ppm within RW-18/SB-70A (33.0 to 33.5 feet). TPAH concentrations ranged from non-detected within samples collected from SB-68 (54.0 to 54.5 feet) and SB-88 (44 to 48 feet) to a maximum of 21,140 ppm in a sample collected from RW-18/SB-70A (feet). CPAH concentrations ranged from non-detected within samples from boring SB-68 (33.0 to 33.5 feet and 54.0 to 54.5 feet), SB-69 (44.5 to 45.0 feet), SB-70A (54.5 to 55.0 feet), SB-88 (28 to 32 feet and 44 to 48 feet), and SB-89 (8 to 12 feet and 35 to 39 feet). The highest concentrations of BTEX and TPAH corresponded to the isolated tar stained and saturated gravelly-sand layer.

Isolated tar occurrence was also noted along Bay Street beneath a triangular parcel located between Bay Street and Edgewater Street. Tar-stained soils and soils with sheen were encountered from 13 to 21 feet bgs within a sand lens and abruptly stopped at a dense silt unit encountered at 21 feet bgs (Appendix B). Only slight naphthalene-like odors were noted within the silt unit. No tar, tar staining, sheens or odors were encountered within a nearby boring (SB-82/82A) to the northwest.

Analytical data from soil boring SB-81 and SB-82A indicate the presence of BTEX and/or PAH constituents beneath the triangular-shaped parcel. BTEX concentrations ranged from non-detected within sample SB-82/82A (5 to 9 feet and 25 to 29 feet) to 141.7 ppm within boring SB-81 (17 to 21 feet). TPAH concentrations ranged from non-detected within SB-82A (25 to 29 feet) to 3,823 ppm within SB-81 (17 to 21 feet). CPAH concentrations ranged from non-detected within SB-82/82A (5 to 9 feet and 25 to 29 feet) and SB-81 (41 to 45 feet) samples to 259 ppm within the SB-81 (17 to 21 feet) sample interval.

Edgewater Street

Isolated tar and tar-stained soils were noted beneath the Edgewater Street ROW only at the locations of SB-93, SB-94, and RW-19. Tar stained soils were confined to a silty-sand layer from approximately 22 to 24 feet bgs in boring SB-94. Visible tar abruptly stopped within a dense glacial silt unit at 24 feet bgs where only odors were encountered. Solid, viscous tar-stained soils and tar-like odors were encountered within SB-93 from 4 feet and 12 feet bgs on top of alluvial marsh deposits. Petroleum-like (motor oil-like) odors were noted within borings SB-90/90C, SB-91/91A and SB-92 at the apparent groundwater table.

Analytical data obtained from soil borings SB-90C through SB-94 indicated the presence of PAHs and BTEX constituents. Total BTEX concentrations ranged from non-detected in samples SB-90C (20 to 24 feet and 32 to 36 feet), SB-91 (8 to 12 feet), SB-91A (36 to 40 feet), and SB-92 (5 to 9 feet and the 37 to 41 feet) to 30.3 ppm in sample SB-94 (20 to 24 feet) and 44 ppm in sample SB-93 (8 to 12 feet). TPAH concentrations ranged from non-detected in samples SB-90C (20 to 24 feet and 32 to 36 feet), SB-91A (36 to 40 feet), and SB-92 (37 to 41 feet) to 14,950 ppm in sample SB-93 (8 to 12 feet). CPAH concentrations ranged from non-detected in samples SB-90C (20 to 24 feet and 32 to 36 feet), SB-91A (36 to 40 feet), SB-92 (37 to 41 feet), SB-93 (36 to 40 feet) and SB-94 (36 to 40 feet) to 2,720 ppm in sample SB-93 (8 to 12 feet). The occurrence of elevated BTEX and PAH concentrations occurred within soils that contained tar observations. Tar observations encountered within SB-93 and SB-94 are isolated to a very small lateral area and are laterally discontinuous based upon boring information collected within Edgewater Street. As previously discussed, an investigation of the One Edgewater Street parcel, to the east of these borings, is being performed. The findings of this investigation will be submitted in a subsequent supplemental RI Report.

4.1.4 Northwest Parcels

Surface Soil

The purpose of RI activities on these parcels was to install groundwater monitoring wells to confirm the hydraulic influence caused by the presence of the former stream bed (current storm drain line) on 25 Willow Avenue. Therefore, no surface-soil samples were collected on these parcels.

Subsurface Soil

Soil conditions at parcels to the northwest of the 25 and 40 Willow Avenue parcels were evaluated through completion of borings RW-8/SB-45, RW-9/SB-46, RW-10/SB-47, RW-11/SB-48, and RW-12/SB-49. Tar, staining, sheen, and odors were not observed at any boring location along Greenfield Avenue. Within one boring (SB-48/RW-11) diesel fuel-like odors were present from the water table (3 feet bgs) to 9 feet bgs in boring SB-48/RW-11. A petroleum sheen and petroleum staining were also observed from 3 to 7 feet bgs at this location. These observations are unrelated to the former MGP operations

BTEX was not detected in samples RW-8 (13 to 15 feet) (19 to 21 feet) (37 to 39 feet), RW-9 (15 to 17 feet), RW-10 (5 to 7 feet) (39 to 41 feet), RW-12 (9 to 11 feet) (39 to 41 feet). The highest BTEX concentration detected was 0.29 ppm in sample RW-11 (3 to 5 feet). TPAHs were not detected in the soil samples collected at the termination of borings RW-8, RW-9, RW-10, RW-11 or RW-12 (ranging in depth from 37 to 41 feet bgs). The highest TPAH value detected was 2,319 ppm in sample RW-11 (3 to 5 feet). CPAHs were not detected in the 19- to 21-foot sample from boring RW-8, the 9- to 11-foot sample from boring RW-12, and the samples collected at the termination of borings RW-8, RW-9, RW-10, RW-11 or RW-12 (ranging in depth from 37 to 41 feet bgs). The highest CPAH value detected was 931 ppm in sample RW-11 (3 to 5 feet). The BTEX and PAHs detected in sample RW-11 (3 to 5 feet) corresponded with the observation of diesel odors, petroleum staining, and a sheen at this sample interval, and are not related to the former MGP operations.

4.1.5 Background Locations

Surface Soil

Ten surface-soil samples (SS-33 through SS-42) were collected from locations around the 25 and 40 Willow Avenue parcels (Plate 1). Three of these locations (SS-34, SS-35, and SS-36) were located on the 25 Willow Avenue parcel and were discussed in above subsection 4.1.1. No physical observations of tar or tar-related impacts were noted in the background surface soils collected. A summary of the detections within background surface soils is presented below.

BTEX ranged from non-detect in samples SS-37, SS-38, and SS-41 to 0.001 ppm in sample SS-40. TPAH ranged from 5.3 ppm in sample SS-41 to 56 ppm in sample SS-40. CPAH ranged from 3.1 ppm in sample SS-41 to 29.7 ppm in sample SS-40. The mean of the BTEX values was calculated as 0.00031 ppm and the mean of the TPAH was calculated as

17.2 ppm. Table 4-1 summarizes the detected analytes for all the background surface-soil samples. Appendix E includes the validated laboratory Form I reports and chain-of-custody forms for the RI samples. Plate 1 depicts the surface-soil sample locations. Table 4-3 presents these calculated mean values along with the maximum and minimum values. Table 4-3 also presents the maximum, minimum, and mean values of RCRA 8 metals and total cyanide for these samples.

Subsurface Soil

No background subsurface-soil samples were collected.

4.2 Groundwater

All available groundwater analytical data from the RI and previous investigations are summarized in Table 4-4. Appendix F includes, the chain-of-custody reports, validated laboratory Form I reports, and data validation reports from the RI investigation. A summary of TPAH, CPAH, and BTEX results from the October 1999 RI sampling event is presented on the shallow aquifer and deep aquifer groundwater contour maps (Plate 4 and Plate 5, respectively). A summary of the January 2002 (Round 4) RI groundwater sampling results is presented on the shallow groundwater aquifer contour map (Plate 6). Information regarding groundwater elevations, monitoring well construction, and groundwater aquifer classification for each monitoring well is summarized in Table 2-2.

Groundwater samples in the vicinity of former tar handling structures located on the 25 Willow Avenue parcel contained BTEX constituents and the lighter molecular weight SVOCs (also referred to as non-carcinogenic PAHs), which are generally more soluble than the heavier molecular weight SVOCs. Heavier molecular weight SVOCs (also referred to as carcinogenic PAHs) were encountered in wells where tar was observed. Concentrations of BTEX, non-carcinogenic PAHs, and carcinogenic PAHs, were noted at higher concentrations in the vicinity of the former tar handling structures and notably decreased by orders of magnitude away from the structures. Total cyanide was also detected within groundwater at the site and was generally detected in wells located downgradient from where the former MGP purifying activities occurred.
The shallow groundwater aquifer and water-bearing unit within the confining unit beneath the 25 Willow Avenue parcel contain chemical constituents associated with the former MGP located at the site. The deep groundwater aquifer located beneath the 25 Willow Avenue parcel only contained trace BTEX and non-detected PAHs.

4.2.1 Shallow Aquifer

Measurements for the presence of NAPL (dense and light) were taken at each groundwater monitoring well during Round 1, Round 2, Round 4, Round 6, and Round 8 of the RI groundwater sampling events. No measurable NAPL was observed in any shallow groundwater monitoring wells or piezometer sampled as part of OU-2. Discrete tar blebs and petroleum-like odors (fuel-oil) were detected in the water column of well RW-1, and petroleum and/or tar-like odors were observed within FPM-OW-5, FPM-OW-6, and RW-13.

As discussed in subsection 3.2.1, groundwater is generally flowing toward the former stream trace on the western portion of the 25 Willow Avenue parcel, and directly toward New York Harbor at the eastern corner of the 25 Willow Avenue parcel. Plate 4 presents a summary of BTEX, TPAH, and CPAH analytical findings on the water table (shallow aquifer) contour map for the Round 2 RI groundwater sampling event (October 1999). Plate 6 presents water table elevation contours and analytical results for wells sampled within the water-bearing zone within the confining unit in January 2002.

The shallow groundwater aquifer contains detections of BTEX and TPAH in the vicinity of former MGP-related structures. Groundwater at the southwestern corner of the 25 Willow Avenue parcel (RW-1) contained a trace detection of BTEX (0.005 ppm) and low levels of PAHs (4.6 ppb TPAH and 1.2 ppb CPAH). Groundwater samples along the trace of the former stream/storm sewer line (RW-13) in the vicinity of the former MGP structures contain BTEX at 111 ppb and TPAH at 219 ppb; CPAH was non-detected. The groundwater sample from FPM-OW-5 contains 254.0 ppb TPAH; 2.8 ppb CPAH; and 2,150 ppb BTEX, and the groundwater sample from FPM-OW-6 contains 187 ppb BTEX and low levels of PAHs. These wells are located adjacent to the former gasoline/diesel UST grave and are in close vicinity to the former waste oil tanks. Groundwater samples at the eastern boundary of the 25 Willow Avenue parcel at RW-2 and OW-7 detected low levels of PAHs and BTEX constituents. RW-2 exhibits the highest concentrations with 2.2 ppb TPAH; 1.1 ppb CPAH; and 4 ppb BTEX.

Total cyanide was also detected in the shallow groundwater aquifer at the site. Detections of cyanide were generally noted downgradient from the former gas purifying area. As discussed in subsection 4.1.1 (Purifying Tanks), detections of cyanide were present within subsurface soils collected from soil borings within the area of the former purifying tanks. Groundwater samples collected from the northwestern and northern portion of the 25 Willow Avenue site revealed cyanide concentrations ranging from non-detected in monitoring wells RW-2, RW-3, and RW-6 along Bay Street to a maximum concentration of 0.568J ppm at FPM-OW-5. Total cyanide concentrations from the adjacent northwestern parcels revealed only one detection of 0.038 ppm within RW-8.

4.2.2 Water Bearing Zone within Semi-Confining Unit

As discussed above within subsection 3.2.2, a water-bearing zone (sand-silt and gravelly sand) was encountered on the northern portion of the 25 Willow Avenue and within the Edgewater Street ROW. Measurements for the presence of NAPL (dense and light) were taken during Round 4 (January 17, 2002) at monitoring wells RW-17 and RW-18 and at monitoring well RW-19 during Round 6 (December 10, 2002) of the RI. A measurable amount of DNAPL (tar) was measured on the bottom of RW-18 and RW-19 during each gauging event. DNAPL thickness in the bottom of RW-18 was approximately 3 feet during Round 4 at the 25 Willow Avenue parcel. Discrete tar blebs and tar odors were observed within the water column of RW-17. Approximately 5.47 feet of DNAPL was also measured in RW-19 during Round 6 of the RI. Tar was removed from each of these wells during the respective samplings.

Groundwater quality within a discrete water-bearing zone of the confining unit was assessed by the collection of groundwater samples from RW-17 and RW-18 on the 25 Willow Avenue parcel (Plate 1). A summary of the BTEX, TPAH, and CPAH concentrations is presented in Table 4-4. The BTEX concentrations ranged from 3.2 ppm in RW-18 to 5.2 ppm in RW-17. The TPAH concentrations ranged from 5.9 ppm in RW-18 to 8.1 ppm in RW-17. CPAHs were not detected above the detection limit. The elevated BTEX and TPAH concentrations coincided with the occurrence of DNAPL. No groundwater samples were collected from RW-19 during Round 6 because the presence of DNAPL in the 1-inch diameter monitoring well precluded the ability to obtain a groundwater sample that did not contain DNAPL. Only trace concentrations of total cyanide were detected within the water-bearing zone of the confining unit. Total cyanide concentrations within the water bearing zone within the confining unit ranged from non-detected within monitoring wells RW-17 and RW-18 to 0.0059 ppm within the duplicate groundwater sample of RW-18.

4.2.3 Deep Aquifer

Measurements for the presence of NAPL (dense and light) were taken at each groundwater monitoring well during Round 1 (April 1999) and Round 2 (October 1999) of the RI groundwater sampling events. No measurable NAPL or odors were observed in either deep well sampled during these events.

Groundwater quality in the deep aquifer was assessed by the collection of groundwater samples from wells RW-15 and RW-16 on the 25 Willow Avenue parcel (see Plate 5). A summary of the TPAH, CPAH, and BTEX analytical results is shown on Plate 5 along with the groundwater elevation contours from October 13, 1999. Only trace levels of BTEX (0.7 and 0.6 ppb) were detected in samples from RW-15 and RW-16, respectively. PAHs were not detected in either of these groundwater samples. Total cyanide was not detected in either groundwater sample collected from the deep groundwater aquifer at the 25 Willow Avenue site.

4.3 Storm Sewer Sampling

The storm sewer located on the northeastern portion of the 25 Willow Avenue and Willow Avenue was sampled at three locations during Round 4 (January 18, 2002) (of the RI. One storm sewer sample was collected upstream of OU-2 from a manhole within Willow Avenue ROW (STRM-01). A second sample was obtained from the 25 Willow Avenue parcel at a T-shaped grate where an off-site storm sewer flows onto the parcel (STRM-02). A third sample was collected from a manhole in a vault at the downstream location of the storm sewer line on the 25 Willow Avenue parcel, (STRM-03). Visual observations were noted during the collection of each storm sewer sample. The storm sewer water analytical data from the RI summarized in Table 4-5. Appendix F includes the validated laboratory Form I reports from the RI investigation. A summary of stormwater concentrations is presented below.

The BTEX concentrations detected ranged from 10 ppb within STRM-01, to 661 ppb within STRM-02, and 387 ppb with STRM-03. The TPAH concentrations detected ranged from 1.2 ppb within STRM-01, to 371 ppb within STRM-02, and 324 ppb within STRM-03. No CPAH concentrations were detected. A spotty sheen was noted for the storm sewer water sample STRM-01 within the Willow Avenue ROW. A moderate petroleum-like sheen was noted within STRM-02 on the 25 Willow Avenue parcel. At this location, an off-site sewer from Greenfield Avenue connects with the storm sewer on the site. Previous sheens have been noted in the stormwater flowing onto the 25 Willow Avenue parcel from the storm sewer line that receives drainage from properties along Greenfield Avenue. Groundwater with petroleum odors and elevated BTEX and PAH concentrations was sampled at monitoring well RW-11, which is located adjacent to the storm sewer line. Petroleum odors were noted within STRM-03. The site is currently vacant and recently was utilized as an automobile service repair and preparation facility. This facility likely handles and stores petroleum products as part of operations. The waste handling activities of this operation was not evaluated at this time.

Cyanide was detected in STRM-01 at 14.5 ppb, in STRM-02 at 164 ppb, and in STRM-03 at 110 ppb. Detections of total cyanide within STRM-02 and STRM-03 may be related to the detections of cyanide within monitoring wells OW-5, OW-6, and OW-7 located adjacent to the storm sewer sample points. These sample points were located downgradient from the former purifying tanks located on the 25 Willow Avenue parcel.

4.4 Soil Vapor – 25 Willow Avenue

Twelve (12) soil vapor samples were collected by GEI on June 11, 2003 from beneath the building slab at 25 Willow Avenue (Figure 4-1). Table 4-6 presents a summary of detected compounds in the soil vapor samples. Maximum and average soil vapor concentrations found in the sub-slab soil pores were compared to occupational health standards.

An analysis of the potential risk to workers posed by these soil vapor results is presented in Section 7.1.5, however in summary, conservative vapor intrusion modeling suggests a greater than 1000 times dilution for the contaminants at the above slab level. Therefore, soil vapor concentrations, in themselves, do not pose a risk to human health and the environment (that is, a de minimis human exposure assessment). Because soil gas concentrations do not pose a health risk to workers, additional indoor air sampling is not necessary to quantify exposure. In addition, the building is currently unoccupied and will eventually be demolished; therefore, there are no current receptors.

5. Fate and Transport

This section provides an analysis and discussion of the data presented in previous sections to provide an interpretation of the interaction between physical and chemical processes that affect the behavior of chemical constituents in the subsurface. Through an understanding of these physical and chemical processes, mechanisms affecting the fate and transport of chemicals at the site will be evaluated.

The following analysis takes into account the physical characteristics of the OU-2 parcels, including the 25 Willow Avenue parcel, adjacent northwest parcels, the Willow Avenue ROW, and the Bay Street/Edgewater Street ROW; the interaction of the surface and groundwater hydrogeology; the nature of chemical compounds encountered during the sampling and analysis program; and any apparent trends in the distribution of these materials within the OU-2 parcels. This section provides a discussion of the physical and chemical characteristics of BTEX and PAHs, and a discussion of the sources and transport pathways for these constituents.

The chemical constituents can exist in four different phases, nonaqueous phase liquid, dissolved in an aqueous phase, sorbed to a solid, or as a vapor. Transport of chemical constituents between these four phases will depend upon the physical and chemical properties of the specific chemicals and the physical characteristics of the OU-2 parcels. The transport pathway and how it relates to chemical constituents is discussed below.

- **Solubility.** Is the measure of a chemical's ability to dissolve in water. Chemical constituents sorbed to soil or in a NAPL may dissolve in water as groundwater flows through the soil matrix, or may dissolve in stormwater runoff. BTEX compounds have a high solubility. PAHs have a varying degree of solubility. The lighter molecular weight PAHs are generally more soluble while the heavier molecular weight PAHs are less soluble and typically do not dissolve into an aqueous phase.

- **Sorption.** Sorption is usually defined as the reversible binding of a chemical to a solid matrix. However, there is evidence in the published literature that, at MGP sites, interactions between tar and the soil matrix may result in a modified matrix that does not represent independent characteristics of either pure tar phase or the original soil matrix. The presence of weathered and/or residually trapped tar phase enhances the sorption capacity of the soil matrix. Hence, the impacted soil matrix is often more sorptive than carbon-based hydrophobic domains in natural organic matter. Furthermore, soils at MGP sites may exhibit a high potential for hysteretic and irreversible sequestration of chemicals, resulting in a different chemical release mechanism from the impacted soil matrix than what was observed during the adsorption mode. These phenomena lead to a partially irreversible sorbed fraction that is not available for partitioning and dissolution (Brusseau, et al., 1989; Brusseau, et al., 1991; Loehr, et al., 1996; Lee, et al., 1998; and EPRI TR-110516-V2, 1999).

- **Volatilization.** Describes the movement of a chemical from the surface of a liquid or solid matrix to a gas or vapor phase. BTEX constituents are highly volatile and are therefore readily transported into the atmosphere from surficial soil. PAHs are nonvolatile and transport of these chemicals by this process is not considered a major pathway for transport.

Sorption of the COCs to solids limits the fraction available for other fate processes such as volatilization and/or solubility. In general, BTEX compounds have low sorption potential, coupled with high water solubility and volatility, which make sorption a relatively minor environmental fate process for BTEX compared to other mechanisms. PAHs exhibit varying degrees of binding affinity to organic matter and soil particles and this affinity is dependent upon their individual molecular structures. In general, the higher molecular weight PAHs, (e.g., benzo(a)pyrene) are strongly sorbed, whereas the lighter PAHs (e.g., naphthalene) are less strongly sorbed (EPA, 1979; EPA, 1986). Therefore, the lighter-molecular weight PAHs may be desorbed and transported by other mechanisms.

Once released into the environment, COCs have the potential to interact with organisms. The following is a brief summary of the process of the bioconcentration of MGP-related compounds.

Bioconcentration factors (BCFs), which relate the concentration of the chemical in an organism at equilibrium to the concentration of the chemical in water, are used to assess the potential for chemical bioconcentration. BCFs are related to the octanol/water partition coefficient and solubility of a chemical. Since VOCs have log K_{ow} and high water solubilities, these chemicals have a low potential to bioconcentrate in organisms (Howard, 1990).

PAHs contain only carbon and hydrogen and consist of two or more fused benzene rings in linear, angular or cluster arrangements. In general, most PAHs can be characterized as having low vapor pressure, low to very low water solubility, low Henry's Law constant, high log K_{ow}, and high organic carbon partition coefficient (K_{oc}). Thus, PAHs remain bound to soil and do not freely enter groundwater.

High partition coefficients and low solubilities suggest that PAHs are likely to be sorbed onto sediment particles. Conversely, these properties indicate that most PAHs will not readily volatilize into the atmosphere.

Although PAHs are regarded as persistent in the environment, they are degradable by microorganisms. Environmental factors, microbial flora and physicochemical properties of the PAHs themselves influence degradation rates and degree of degradation. Important environmental factors influencing degradation include temperature, pH, redox potential (the tendency of a chemical to accept or donate electrons, or to become reduced or oxidized) and microbial species. Physicochemical properties, which influence degradation, include chemical structure, concentration, and lipophilicity ("fat-loving" tendency). In general, PAHs show little tendency to biomagnify in food chains despite their high lipid solubility because most PAHs are rapidly metabolized by the organisms that are exposed to them (Eisler, 1987).

Metals, which do mobilize from the soil into groundwater, are usually mobile under acid conditions. Higher pH usually reduces their bioavailability (McIntosh, 1992).

A qualitative human health exposure assessment and fish and wildlife impact analysis is presented in Section 7.

The environmental media that are of primary concern for the subject properties are NAPL, subsurface and surface soil, and groundwater. Section 4 provides a detailed description of the nature and extent of chemical constituents. Plates 2 and 3 illustrate the vertical and lateral extent of tar, staining, sheen, and odors, along with the geology and hydrogeology at the OU-2 parcels.

5.1 NAPL

NAPL (tar) is present at the site. NAPL is considered to include the visual observation of tar-saturated material or soil containing tar blebs or tar lenses (see Section 4 for a description of these terms). NAPL was observed within the subsurface foundations of the former MGP structures and in the subsurface materials surrounding the former structures that handled tar. The chemical constituents addressed that are in NAPL include BTEX and PAHs.

NAPL (tar) generally migrated downward through permeable fill and other permeable soils on the 25 Willow Avenue parcel. At isolated locations beneath Willow Avenue, Edgewater Street, and triangular parcel along Bay Street NAPL appears to have migrated laterally through coarse-grained materials atop less permeable soil layers. NAPL was observed to a maximum depth of 44 feet on the 25 Willow Avenue parcel where the dense silty ground moraine stopped its migration (SB-58/RW-16). Evidence of residual NAPL (staining) is present beneath to a depth of 55 feet the 25 Willow Avenue parcel (SB-75). NAPL was generally observed in near proximity to the former historic structures.

NAPL present within the subsurface will desorb and contribute to chemical constituents in the soil and groundwater beneath 25 Willow Avenue, Willow Avenue ROW, and Bay Street/Edgewater Street. BTEX and lighter molecular weight PAHs will dissolve into groundwater and can be transported with groundwater flow. Heavier PAHs will sorb to soil and will remain relatively immobile. BTEX in NAPL above the water table on the 25 Willow Avenue parcel, Willow Avenue ROW and the Bay Street Edgewater Street ROW can also volatilize and diffuse through the soil pore spaces in the vadose zone.

5.2 Subsurface Soil

In general, the distribution of BTEX and PAHs in subsurface soil correlates with the presence of NAPL (tar). Chemicals sorbed to soils in the subsurface will continue to be a source of dissolved chemical constituents in groundwater. BTEX and lighter molecular weight PAHs can desorb from soil, dissolve into groundwater, and be transported with groundwater flow. BTEX can also volatilize from soil and diffuse through the vadose zone. Heavier molecular weight PAHs will remain sorbed to soil and will remain relatively immobile.

5.3 Surface Soil

Three surface-soil samples were collected from the grassed area of 25 Willow Avenue and at background surface soil locations. PAHs were identified in surface soil present on the 25 Willow Avenue parcel and total BTEX concentrations in surface soil range from non-detect to 0.0008 ppm.

Lighter molecular weight PAHs could desorb and become dissolved in infiltrating precipitation. PAHs dissolved in infiltrating precipitation could be transported to shallow groundwater and move with groundwater flow. It is unlikely that PAHs will potentially dissolve in runoff that could be transported through storm sewer systems given that the vast majority of the site is paved or covered by the on-site building. PAHs sorbed to soil could be transported off the 25 Willow Avenue parcel as airborne particulates or as particulates entrained in surface water runoff; however this scenario also is unlikely under current conditions because the majority of the site is paved or covered by the on-site building.

5.4 Groundwater

Two groundwater aquifers (shallow and deep) have been identified at OU-2 and are described in Section 3. An isolated water-bearing unit was encountered within the confining unit along Bay Street/Edgewater Street. Chemical constituents detected in the shallow groundwater aquifer and water bearing zone within the confining unit included BTEX and PAHs. Only trace concentrations of BTEX and non-detected PAH concentrations were present in groundwater within the deep aquifer at the well locations of RW-15 and RW-16.

BTEX and PAHs dissolved in groundwater are present in the vicinity of NAPL. Groundwater in the shallow aquifer under the OU-2 parcels flows to the northwest and northeast. Elevated BTEX and PAH concentrations were noted within a water bearing zone of the confining layer at the 25 Willow Avenue and along Bay Street and Edgewater Street. This coincides with observed NAPL within this unit within RW-17, RW-18 and RW-19.

Groundwater flow direction in the deep aquifer is unclear and is either split along a divide or is heterogeneously affected by tidal influences. Based on the available data, it appears that on the eastern portions of the 25 Willow Avenue parcel, groundwater flow in the deep aquifer is generally to the east towards the bay. On the eastern portion of the 25 Willow Avenue parcel and Willow Avenue, groundwater flow in the deep aquifer appears to be toward the southwest.

Dissolved BTEX and lighter molecular weight PAHs will be transported with groundwater flow within the shallow groundwater towards the former stream trace along the northwestern portion of OU-2 and towards New York Harbor. A decrease in concentrations of BTEX and PAH was noted away from MGP structures at the 25 Willow Avenue site. The decrease in concentrations away from the former MGP structures makes this unlikely. Groundwater elevations within the deep groundwater aquifer reveal flow towards the harbor; however, based upon the trace detected concentrations it is unlikely that the deep groundwater aquifer is impacted within OU-2.

6. Conceptual Site Model

This section discusses the conceptual site model as it pertains to the nature of the physical observations of tar, staining, sheening and odors, migration pathways and receptors. From the six successive rounds of investigation that have taken place at the site, it has become apparent that the primary areas of concern within OU-2 are the former tar handling structures (former Relief Holder No. 1, tar tank/gasometer, and various tar tanks and tar wells) associated with the former MGP operations located at the 25 Willow Avenue parcel.

The majority of the former tar-handling structures are located over the central portion of the 25 Willow Avenue site. Many of the former foundations still exist at the site today, such as the former Relief Holder No. 1, former tar tank/gasometer, former tar wells (at SB-54/ SB-74), tar separator beneath the building (SB-39) and tar separator (SB-10). Upon the decommissioning of these structures, fill material was likely used to backfill the former tar handling structures. Some tar and tar-impacted material may have remained within these structures and mixed with the fill. This tar, in conjunction with tar historically produced and handled on site during the operation of the former MGP, appears to represent the source of DNAPL (tar) observed within soils on site. Cross-section B-B′ located on Plate 2 and D-D′, E-E′, and F-F′ located on Plate 3 depict the soil conditions at the 25 Willow Avenue in the former footprint of the MGP. Isolated DNAPL (tar) lenses were also observed within the Willow Avenue ROW, which likely were associated with nearby tar handling structures and piping to Relief Holder No. 2 located on the adjacent 40 Willow Avenue parcel. Isolated tar lenses were also noted within the Edgewater Street ROW.

The 25 Willow Avenue parcel is located within a topographic bowl that has historically been occupied by a stream prior to development of the site. Inferred alluvial sand and gravel associated with the former stream is located just below many of the former tar handling structures in the central portion of the site. These layers may have been impacted by the seepage of some tar through the holder (Relief Holder No. 1) and various tar wells, tanks, separators, and other former tar-handling structures located in central and western portions of the site. Once released, the tar is hypothesized to have continued to migrate downward through the subsurface by micro-fractures and grain-to-grain movement within coarser-grained materials and loose materials, and preferentially collected within localized sand and sand-gravel layers. The ground moraine (dense silt) unit acts as a confining unit for tar under the site. A relatively dense coarse-grained clay-silt unit (inferred as the Harbor Hill Terminal Moraine) unit bounds the tar and acts as a lateral barrier to tar on the north and east of the site. Isolated coarse-grained sand and gravelly-sand layers also may have allowed small amounts of tar to migrate from the vicinity of the former Relief Holder No. 1 laterally to the north as far as Edgewater Street and from the tar well (located at SB-54/75) into the subsurface soils beneath Willow Avenue. The coarser-grained terminal moraine located along Willow Avenue allowed DNAPL (tar) to migrate downward to a depth of 55 feet. In the vicinity of the former tar handling structures, no physical observations of tar odors were present below the confining unit at the site or at the top of weathered bedrock interface at approximately 115 feet bgs.

Groundwater exhibits concentrations of BTEX and PAHs in the areas associated with DNAPL residuals in the vicinity of the MGP foundations. Dissolved tar-related constituents (BTEX and PAHs) are limited in extent to the vicinity of the former tar handling structures and concentrations decrease with depth and away from the former structures within the shallow groundwater aquifer in the direction of New York Harbor. No tar-related impacts were noted in the deep groundwater aquifer on the 25 Willow Avenue parcel.

Soil vapors beneath the 25 Willow Avenue building are related to soil and groundwater contamination beneath the building. Soil vapors concentrations beneath the building, in themselves, do not pose a risk to human health and the environment (that is, a de minimis human exposure assessment). The building is currently unoccupied and will eventually be demolished.

7. Qualitative Human Exposure Assessment and Fish and Wildlife Impact Analysis

This report section presents the qualitative human exposure assessment (QHEA) and fish and wildlife impact analysis (FWIA) for the site. These assessments consider the chemical distribution at the site in terms of possible human exposure and impact(s) to fish and wildlife. The QHEA and FWIA are part of an Order on Consent (Index No. D2-0001-98-11) between KeySpan and the NYSDEC concerning the former MGP site located in Clifton, Staten Island, New York. These assessments used data collected as part of GEI's initial remedial investigation and supplemental data collected in 2001 and 2002. The QHEA was performed to meet the requirements identified in the NYSDOH's November 9, 2000 guidance memorandum titled *New York State Department of Health, Qualitative Human Health Exposure Assessment (NYSDEC, 2002)*. The ecological portion of the assessment presented here is consistent with the NYSDEC's *Fish and Wildlife Impact Analysis* guidance (NYSDEC 1994b). The objectives of the assessments are:

- To identify chemicals of potential concern (COPCs) that are related to the former gas manufacturing activities conducted at the site;
- To identify potential pathways of exposure to people, plants, animals, and fish;
- To estimate and characterize the potential ecological impact associated with these exposures; and
- To indicate whether there is a need for mitigative measures to reduce potential exposures.

For purposes of the qualitative human health exposure assessment, OU-2 is discussed in terms of potential on-site exposures associated within the former plant parcel (25 Willow Avenue); and potential off-site exposures associated with three parcels adjacent to 25 Willow Avenue: a wooded railway embankment to the northwest (herein referred to as the Northwest parcel) which also includes a few commercial properties along Greenfield Avenue, a roadway parcel beneath Willow Avenue, and a second roadway parcel beneath Bay Street and Edgewater Street. The City has indicated that they have plans to reconstruct the storm sewer system beneath Willow Avenue. Since there are plans to breach the paved surface and reconstruct the storm sewer, this area is evaluated separately. The site location and description are discussed in Section 1 of this report. The site-specific hydrogeologic characteristics of OU-2 are discussed in Section 3. The current site plan for OU-2 is presented in Figure 7-2A.

With the exception of a grass strip abutting Bay Street, the entire ground surface within the on-site parcel of 25 Willow Street is either covered with the footprint of the commercial building, or is paved and used for parking. This lack of exposed ground surface would normally eliminate exposure to on-site surface soil (from 0 to 2 inches below ground surface) for all current receptors, both human and ecological. The presence of isolated tar bubbles seeping through a limited number of cracks in the pavement adjacent to the former tank/gasometer located at the southwestern portion of the 25 Willow Avenue site ,posed a potential exposure to workers and visitors to the site. This potential exposure was mitigated by the placement of steel plates over the exposed tar bubbles, thereby preventing any potential contact with the tar.

While the parcels underneath the roadways are also considered to be completely beneath a paved surface, the Northwest parcel is not entirely covered. However, no surface soil sampling was performed within the off-site parcels with the consent of NYSDEC. Therefore, all current exposure pathways associated with off-site surface soil are eliminated and the qualitative human exposure assessment does not include off-site surface soil as an exposure medium of concern. Future exposure pathways, such as a potential construction worker, assess potential exposure to surface soils as part of exposures to soils, both surface and subsurface, as a result of assumed subsurface activities.

7.1 Qualitative Human Exposure Assessment

7.1.1 Nature and Extent of Chemical Constituents

BTEX constituents were the principal VOCs detected in soil and groundwater samples at the site and are the common VOCs associated with former MGP operations. SVOCs also were detected at the site. PAHs are the common subset of SVOCs associated with former MGP operations. Sixteen metals (including arsenic, lead, and mercury) and cyanide are also commonly associated with MGP sites (WDNR 1999). Soil vapor sampling beneath the 25 Willow Avenue building identified the presence of BTEX as well as chlorinated VOCs. Section 4 of this report provides a detailed description of the nature and extent of chemical constituents found on-site and at relevant off-site locations. Section 5 of this report provides a detailed description of the fate and transport of analytes commonly associated with the former MGP operations. The potential migration pathways for chemical constituents are illustrated in Figure 7-1.

7.1.2 Selection of Chemicals of Potential Concern

Several classes of chemicals were detected in soil and groundwater. COPCs were selected following the practice established by EPA in the Risk Assessment Guidance for Superfund, Volume I, Part A (EPA, 1989). Selection criteria were as follows:

- Chemicals not detected at least once above the limit of detection were automatically excluded from the assessment, regardless of the size of the data set;

- Frequency of detection was considered. Chemicals with a frequency of detection of less than 5% in a data set of 20 or more samples were excluded from the assessment; and

- Chemicals that are not associated with MGP operations were not considered COPCs.

Tables 7-1 through 7-5 list for each medium (*i.e.*, subsurface soil and groundwater) and location, the chemicals reported at least once above the limit of detection, their frequency of detection, and their minimum and maximum detected concentrations. The chemicals listed in these tables are those that meet the frequency of detection criteria listed above. Additionally, these tables present the 95% upper confidence limit (UCL) of the mean when appropriate for the applicable data set, and relevant and appropriate standards, criteria, and guidance values (SCGs) (*i.e.,* NYSDEC TAGM and TOGS concentrations for subsurface soil and groundwater, respectively). COPCs that are both MGP-related and exceed applicable NYSDEC SCGs appear in bold italics in these tables. All analytical data obtained from the 1999, 2002, and all previous field investigations were combined to estimate the average concentration and the 95% UCL.

Data sets were developed to estimate the UCL according to the exposure scenario being evaluated. For off-site exposure scenarios, subsurface soil and groundwater sample results from the Northwest parcel and Bay Street and Edgewater Avenue roadways were combined and used to evaluate exposure pathways. A separate data set for the samples underneath Willow Avenue is considered separately. For the on-site exposure scenarios, subsurface soil and groundwater samples collected from the 25 Willow Avenue parcel were used to evaluate the exposure pathways. It is important to note that samples considered ‘on-site’ are only those within the fence line of 25 Willow Avenue. Samples collected to a maximum depth of 16 feet were used to estimate exposure point concentrations (EPCs).

The 95% UCL is determined from the detected concentrations and the substitution of one-half the limit of detection for samples reported as non-detected (U-qualified). U-qualified chemical concentrations were used in the exposure assessment at one-half the limit of detection if other samples in the data set were reported at least once above the limit of detection (EPA 1989).

Prior to calculating the 95% UCL, statistical tests were performed to identify the best distributional assumption of the data (*i.e.*, lognormal or normal). Normally distributed data are those that, when plotted, exhibit a bell-shaped curve, while log normally distributed data exhibit a skewed curve. Most data sets in this assessment contained fewer than 50 samples; consequently, the data were evaluated using the W-test developed by Shapiro and Wilk (Gilbert 1987). For a few groundwater constituents (BTEX and naphthalene), the data sets contained greater than 50 samples. These data sets were subsequently evaluated using the W-test developed by D'Agostino (Gilbert 1987). If the results of the W-test indicated the data did not represent a normal distribution (the data did not exhibit a bell-shaped curve), then a lognormal distribution was assumed. The appropriate equation was then used to calculate the 95% UCL concentrations (EPA 2002).

If the data set was found to be consistent with the normal distribution, then the 95% UCL was calculated from the following equation (EPA 2002):

$$95\%\ UCL = \bar{x} + t\left(\frac{s}{\sqrt{N}}\right)$$

where:

- $\bar{x}$ = mean of the (untransformed) data;
- t = Student t-statistic (from Gilbert 1987);
- S = standard deviation of the (untransformed) data;
- N = number of samples.

If the data set was assumed to be consistent with the lognormal distribution, then the 95% UCL concentration was calculated from the following equation (EPA 2002):

$$95\%\ UCL = e^{\left(\bar{x} + 0.5s^2 + \frac{SH}{\sqrt{N-1}}\right)}$$

where:

- e = base of the natural log = 2.718;
- $\bar{x}$ = mean of the log transformed data;
- S = standard deviation of the log transformed data;
- H = H-statistic (interpolated from Gilbert 1987); and
- N = number of samples.

Maximum concentrations were used to represent the mean concentration in small data sets (sample size < 10). Additionally, if the calculated 95% UCL exceeded the maximum detected concentration for a data set, the maximum concentration was used to represent the mean (EPA 1992). These representations of the data are considered the EPC for each dataset, or COPC.

In order to aid remedial planning for the site, the EPCs calculated for subsurface soil were compared to NYSDEC TAGM concentrations (Tables 7-1 and 7-2, NYSDEC 1994). Concentrations detected in groundwater samples were compared to NYSDEC TOGS (Tables 7-3 and 7-4, NYSDEC 1998). These comparisons are discussed in Section 7.2.7.

7.1.3 Current and Reasonably Foreseeable Site Use

It is anticipated that the 25 Willow Avenue site will continue as a commercial property for the foreseeable future. Furthermore, the 25 Willow Avenue parcel, the Northwest parcel, and the Willow Avenue roadway are located in a M3-1 zone and the Bay Street and Edgewater Avenue roadway is located in a M2-1 zone. Both zones indicate manufacturing at different levels (heavy and medium). Consequently, the land use of the property is not expected to change substantially from the current commercial/manufacturing use (see Figure 7-2D). Additionally, no new residences or community facilities are permitted under either zoning classification. Therefore, a future on-site residential scenario was not considered in this exposure assessment.

7.1.4 Exposure Setting and Identification of Potentially Exposed Populations

The human health exposure assessment provides qualitative descriptions of potential exposures to site-related COPCs for human populations who may reasonably be expected to contact site media under present or future conditions. The exposure assessment is comprised of two components:

- Description of exposure setting and identification of potentially exposed populations; and
- Identification of exposure pathways.

Under current and future site use conditions, the potentially exposed populations (*i.e.*, potential receptors) are those that might come into contact with those COPCs identified above. Figure 7-1 presents a conceptual risk system model (CRSM), and Table 7-6 identifies the potential exposure routes for current and future on-site and off-site human populations. Potentially exposed populations and pathways of exposure, as outlined in the CRSM and Table 7-6, are described below.

25 Willow Avenue Parcel (On Site) Current Scenarios

The 25 Willow Avenue parcel is the location of the former gas plant production operations and is currently being leased from KeySpan for use as a vehicle preparation and service center. It includes a one-story commercial building and a paved bituminous parking lot used for automobile storage. A chain link fence surrounds the entire perimeter of the parcel.

While there are institutional controls limiting access available to trespassers (the property is gated and locked at night), the potential for trespassers at the site remains a possibility and trespassers are therefore included in this assessment.

Thus, the receptors considered in the assessment under current site conditions include (Figure 7-1 and Table 7-6):

- On-site employees/commercial visitors – i.e., those employees working at the vehicle preparation and service station and the intermittent visitor to the site.
- On-site trespassers – adult, adolescent, and child.

25 Willow Avenue (On-site) Future Scenarios

As stated previously, future uses of the site and immediate off-site areas are not expected to change substantially from the current commercial/manufacturing uses allowed under the property zoning classification. As a consequence, the current exposure scenario also holds for future use of the site (i.e. commercial workers/visitors and trespassers). However, to account for the possibility that construction activities may occur at the site to accommodate facility expansion or reorganization or conversion for other commercial use, a future on-site construction worker were also considered (see Figure 7-1 of this report). Other potential exposure populations include utility workers.

Off-Site Parcels Current Scenarios

The Northwest parcel evaluated in this assessment is immediately adjacent to the northwest boundary of the 25 Willow Avenue parcel. The area contains a wooded railroad embankment and a few commercial properties along Greenfield Avenue. The only current potential receptors for this parcel are trespassers; child, adolescent, and adult. The gradient of the embankment just outside the fence line of 25 Willow Avenue is fairly steep and the surface drainage runs from the embankment towards 25 Willow Avenue. This makes the migration of contaminants from 25 Willow Avenue to surface soils of the Northwest parcel unlikely. Given the lack of surface soil data (per NYSDEC consent) and the surface gradient of the railroad embankment, exposures to surface soils within the Northwest parcel are not evaluated in this assessment.

Exposures to surface soils underneath the roadways and adjacent sidewalks are not considered complete pathways and therefore are not evaluated in this assessment

Off-Site Parcels Future Scenario

As discussed above, future uses of the off-site parcels are not expected to change substantially from the current transportation/commercial uses. However, to account for the possibility that construction activities may occur at these parcels to accommodate redevelopment for other use, a future off-site construction worker and a future off-site utility worker were considered (see Figure 7-1 of this report). These receptor scenarios are particularly relevant for the Willow Avenue roadway as planned reconstruction of the storm sewers beneath this area is planned in the near future. For other exposures at the roadway parcels, it is extremely unlikely that a future residential receptor will occur, however, this receptor is included as the most conservative receptor possible within the off-site areas.

7.1.5 Identification of Exposure Pathways

Generally, human populations may be potentially exposed to COPCs in the following impacted media: surface soil, subsurface soil, groundwater, ambient air, and indoor air. Ambient air is considered to be outdoor air that may be impacted by site COPCs in two ways; volatilization of surface soil COPCs and inhalation of particulate matter. However, the only identified surface soil component at the site is surface soil as tar bubbles seeping through cracks in the pavement. This type of media is not expected to contribute significantly to outside air and therefore, exposure to ambient air is not considered a complete exposure pathway for current exposure scenarios.

25 Willow Avenue Parcel (On Site)

Currently the on-site building (25 Willow Avenue) is not used as a commercial facility and will eventually be demolished. Therefore, there is no potential exposure to workers at the building. Previously the building use included commercial activities. Under the prior use of the building two potential exposure pathways were identified: 1) the inhalation of accumulated COPCs in indoor air from vapor intrusion for on-site employees and adult and child visitors, and 2) on-site employees and trespassers potentially being exposed to surface soil (as tar bubbles) through dermal contact. The potential for contact to the tar bubbles was mitigated by placing steel plates over the tar bubbles thereby breaking the potential exposure pathway for any previous workers of potential future trespassers.

The potential for prior workers exposure to COPCs through vapor intrusion was assessed by the collection of twelve (12) soil vapor samples beneath the footprint of the on-site building. Soil and groundwater contamination resides below the concrete working surface at the site. However, conservative vapor intrusion modeling suggests a greater than 1000 times dilution for the contaminants at the above slab level. Therefore, soil vapor concentrations, in themselves, do not pose a risk to human health and the environment (that is, a de minimis human exposure assessment). Because soil gas concentrations to not pose a health risk to workers, additional indoor air sampling is not necessary to quantify exposure.

Given the nature of their work (*i.e.*, trenching, excavation, installing deep piles, etc.), future on-site construction workers may reasonably be expected to contact surface and subsurface soil via ingestion, dermal contact, inhalation of soil particulates, and vapor inhalation. In addition, construction workers may contact groundwater during trenching activities, since the depth to groundwater is relatively shallow and in places less than eight feet below ground surface. Chemical exposures for on-site utility workers may occur because of the presence of subsurface sewer, telephone, gas, and water facilities in the area. The exposure pathways through which this population could be potentially exposed are identical to those for the construction worker.

There is no current on-site use of groundwater for consumptive or other purposes. Therefore, there are no current exposure pathways that can be considered complete for direct contact with groundwater. Consequently, the only potential complete exposure pathways for groundwater are future dermal contact and inhalation of vapors emanating from the groundwater. These potential future exposures are most likely to occur for the construction worker and the utility worker.

Off-Site Parcels

Under current off-site conditions, there are no exposure scenarios that are considered complete for this evaluation.

Given the nature of their work (*i.e.*, trenching, excavation, installing deep piles, etc.), future off-site construction workers may reasonably be expected to contact surface and subsurface soil via ingestion, dermal contact, inhalation of soil particulates and vapor inhalation. In addition, construction workers may contact groundwater during trenching activities, since the depth to groundwater is one to eight feet below ground surface. Exposure pathways for off-site utility workers may be complete, due to the presence of subsurface sewer, telephone, gas, and water facilities in the area. The exposure pathways through which this population could be potentially exposed are identical to those for the construction worker. It is important to note that modifications to the storm sewer beneath Willow Avenue are planned in the near future by the State of New York. Therefore, the exposure pathways described for a future off-site construction worker and a future off-site utility worker are highly possible in the Willow Avenue roadway area. For this reason, the COPCs in this area are evaluated separately in this assessment.

A future resident may be exposed to soils via ingestion, dermal contact, and inhalation of ambient air (soil particulate and vapor inhalation). While future surface soil exposures for this receptor are likely, exposures to subsurface soils are unlikely, yet included, in the event that a future resident engages in excavation activities at their home. This scenario would also possibly expose a future resident to groundwater via dermal contact and inhalation of vapors. Possible vapor intrusion of volatile constituents in soil and groundwater to indoor air could be a complete exposure pathway for a future resident if their home is built within one of the off-site parcels. While this exposure pathway is included in this evaluation for an ultimate conservative approach, it should be noted that the likelihood of future residential property within the off-site areas is highly unlikely.

There is no off-site use of groundwater for consumptive or other purposes. Therefore, there are no current exposure pathways that can be considered complete for off-site groundwater. Consequently, the only potential complete exposure pathways for groundwater are dermal contact and inhalation of vapors emanating from the groundwater. These potential future exposures are most likely to occur for the construction worker and the utility worker, but are also included in the future resident scenario.

7.1.6 Screening Level Assessment

The EPCs determined for each portion of OU-2, the 25 Willow Avenue parcel (on-site), and the off-site parcels, were compared to appropriate NYSDEC concentrations, and the results of this screening are as follows.

25 Willow Avenue (On-Site)

Subsurface Soils

Subsurface soil concentrations at the 25 Willow Avenue Parcel were compared to NYSDEC TAGM concentrations where available. This comparison indicates that the majority (33/41) of chemicals are present at concentrations that exceed applicable TAGM concentrations (Table 7-1).

Groundwater

Evaluation of groundwater concentrations at the 25 Willow Avenue parcel indicates that 18 of 41 COPCs exceed applicable TOGS concentrations. TOGS concentrations were not available for some of the detected chemicals (Table 7-4). It is also important to note that the TOGS concentration for benzo(a)pyrene is listed as ‘ND’, which means that any detected concentration above the applicable method detection limit is considered above NYSDEC guidelines.

Off-Site Parcels

Subsurface Soil Beneath Willow Avenue

Chemicals detected in subsurface soils at the off-site area beneath Willow Avenue were also compared to NYSDEC TAGM concentrations (Table 7-2). Results of this comparison indicate that 17 of 36 COPCs exceed applicable TAGM concentrations.

For the groundwater beneath Willow Avenue, only one monitoring well (FPM-MW-04) is considered to be within this defined area. Results of groundwater sampling from this well detected only naphthalene at 0.003 mg/L, well below the TOGS concentration of 0.01 mg/L for this chemical.

Subsurface Soil Beneath Other Off-Site Parcels

Chemicals detected in subsurface soils at the remaining off-site parcels were also compared to available NYSDEC TAGM concentrations (Table 7-3). Results of this comparison indicate that the majority (25/33) of chemicals are present at concentrations that exceed the applicable TAGM concentration.

Off-Site Parcels – Groundwater

Eight chemicals (benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, phenol, lead, and selenium) were detected at concentrations above TOGS recommended concentrations. As stated above, the TOGs concentration for benzo(a)pyrene is essentially below the applicable method detection limit. Concentrations of toluene, ethylbenzene, and xylenes (total) were compared to appropriate TOGS concentrations and are present at concentrations that are lower than the TOGS concentration (Table 7-5). Benzene was not detected in these off-site groundwater samples.

7.1.7 Conclusions

7.1.7.1 25 Willow Avenue (On Site)

A majority of the chemicals detected in subsurface soil at the 25 Willow Avenue parcel exceed the applicable TAGM concentrations. Consequently, potential exposure to these soils may be considered a pathway of concern. However, under current site conditions due to the lack of exposed ground surface at the site, the subsurface soils at the site are considered inaccessible. The potential for inhalation of COPCs through potential vapor intrusion was assessed through soil vapor sampling The results showed the following:

- The maximum (and average) concentrations of all contaminants were below occupational health standards. The data suggest that prior or future workers could breathe sub-slab soil vapor concentrations for 8 hours a day/ 50 weeks a year without adverse health effects. Regardless, there are currently no workers occupying the building and the building will eventually be demolished.

- The maximum sub-slab soil vapor concentrations are, in most cases, several orders of magnitude below health criteria.

- If the soil vapor transport is considered, conservative air intrusion modeling suggests that it would be diluted by at least 1,000 times below concentrations found in the sub-surface soil pores.

These results suggest that the soil vapor concentrations are de minimus and, as such, pose an insignificant human health exposure to prior workers at Clifton.

Potential exposure to tar bubbles in the parking lot area of the 25 Willow Avenue parcel was mitigated by placing steel plates over the tar bubbles, thereby preventing any potential contact by the former workers or current/future trespassers or visitors.

Because future redevelopment of the site or conversion to another commercial use would likely entail construction and utility work and, by definition, direct contact with subsurface soils, the concentrations of chemicals detected in subsurface soil at the 25 Willow Avenue parcel indicate that direct contact with these soils may be a future exposure pathway of concern.

Several chemicals in groundwater are present at concentrations that exceed TOGS. The groundwater is not used as a potable water source and potential direct contact exposures to groundwater are expected to be limited to those individuals engaged in excavation work (e.g., construction worker, KeySpan employee, and utility worker). Results of the screening analysis indicate that only future direct contact exposure may be as a pathway of potential concern. However, under current site conditions, direct contact with groundwater is an incomplete exposure pathway.

7.1.7.2 Off-Site Beneath Willow Avenue

Results of subsurface soil screening indicate that some COPCs are present at concentrations above TAGM concentrations and the potential exposure pathways for a future construction worker and utility worker are considered complete and likely in the near future. Currently, there are no complete pathways for exposure to subsurface soils beneath Willow Avenue.

Groundwater beneath Willow Avenue is considered a potentially complete exposure pathway for a future construction worker or utility worker, however, only one COPC (naphthalene) was identified in the single monitoring well in this area and the concentration was below the applicable TOGS concentration.

7.1.7.3 Other Off-Site Parcels

Results of subsurface soil screening indicate that while some chemicals are present at concentrations above the TAGM concentrations, the potential for future exposure to subsurface soils at these parcels is minimal for two reasons: 1) the infrequent nature of excavation work among roadways and along a railroad embankment and 2) the infrequent nature of excavation work in a residential setting, in the very unlikely event their parcels ever become designated as residential. Currently, there are no complete pathways for exposure to subsurface soils at either of the remaining off-site parcels.

A few of the chemicals detected in groundwater are present at concentrations above applicable TOGS concentrations. However, groundwater wells were not observed during the field investigation and the property and the surrounding communities are served by a municipal water supply. It is expected that any new construction would be connected to the municipal water supply. Consequently, exposure to potentially MGP-related constituents that may be present in groundwater does not occur under existing conditions (i.e., potential exposure to groundwater is an incomplete exposure pathway), and is limited to dermal contact and vapor inhalation entailing subsurface construction/utility work for future exposure pathways.

7.1.8 Summary

Based upon the QHEA, there currently are no complete exposure pathways that were identified within OU-2 that are of potential concern. Potential dermal contact by visitors or trespassers to tar bubbles in the parking lot area of 25 Willow Avenue has been mitigated by placing steel plates over the tar bubbles. The potential for an inhalation exposure pathway to prior workers at the 25 Willow Avenue building was evaluated through soil vapor sampling that demosntrated a de minimus risk to the workers based on the soil vapor concentration themselves, not even accounting for dilution and attenuation as vapors potentially migrate through the floor slab. The building is currently un-occupied and eventually will be demolished.

The rest of the chemicals present in subsurface soil and groundwater within the OU-2 boundary are either not of concern or the exposure pathways through which individuals could potentially be exposed to these chemicals are incomplete. Data for the areas within the OU-2 boundary indicate that under potential future site use conditions, and absent remedial measures, exposure to subsurface soil and groundwater are potential pathways of concern. This is of special importance for the future construction worker and future utility worker for the Willow Avenue roadway. Planned reconstruction of storm sewers in this area make these exposure pathways probable in the near future.

7.2 Fish and Wildlife Impact Analysis (FWIA)

This FWIA has been conducted to identify actual or potential impacts to fish and wildlife residing in the vicinity of the site from chemicals potentially migrating from the former MGP. Specifically, it focuses on impacts associated with site-related chemicals detected in soil and groundwater.

This analysis contains:

- Site descriptions including a characterization of the floral and faunal resources present and the concentration of these resources to humans;

- The identification of applicable regulatory standards and criteria for fish and wildlife;

- Evaluations of potential exposure pathways to fish and wildlife from site-related chemicals of potential ecological concern (COPECs);

- Comparison of chemical concentrations for COPECs to regulatory criteria or derived toxicological benchmarks for the protection of fish and wildlife; and

- Conclusions regarding the potential of exposure and possible impacts to fish and wildlife on or about the site.

This FWIA was initially prepared for the RI report issued in 2000 that encompassed the entire Clifton site. Because the conclusions regarding the potential for adverse impacts to flora and fauna were not significantly altered by the additional data collected during the supplemental RI, a decision was made not to revise the previously submitted FWIA. Consequently, the initial FWIA is being re-issued in this report and is reproduced in its entirety on the following pages.

7.2.1 Fish and Wildlife Resources

Terrestrial Resources

The U.S. Fish and Wildlife Service and the NYSDEC Natural Heritage Program were contacted regarding species of concern, significant habitats, and fishery resources within two miles of the site. In addition, a field reconnaissance survey of the site and surrounding 0.5-mile radius was conducted on September 2, 1999. The objectives of the survey were to:

- Map and describe plant communities and aquatic resources on and adjacent to the site;
- Observe wildlife species;
- Identify significant ecological resources; and
- Observe evidence of stress to plants and animals, if any, from site-related chemicals.

Approximately two-thirds of the area within the 0.5-mile radius of the site is upland. Currently, commercial uses dominate the land within 0.5 mile of the site. The residential areas consist of buildings surrounded by maintained lawns and ornamental plantings. Commercial establishments are covered by buildings and asphalt. Little vegetation exists to support wildlife populations. As a result, much of the area is classified as paved road or urban structure exterior. The paved road category includes much of the site, parking lots, streets, and sidewalks. The residential areas consist of buildings surrounded by maintained lawns and ornamental plantings.

Aquatic Resources – New York Harbor

The site lies within the New York Harbor drainage basin. A Comprehensive Conservation and Management Plan (CCMP) has been developed for the Harbor. The areas of concern outlined in the CCMP are: habitat and living resources, toxic contamination, nutrients and organic enrichment, pathogenic contamination, dredged material management, floatable debris, and rainfall-induced discharges. The NYSDEC classifies the New York Harbor as "SI" indicating the water is suitable for fish propagation and fish survival.

The Narrows section of New York Harbor is approximately 600 feet to the east and northeast of the site. The drowned mouth of the Hudson River forms much of New York Harbor. The physical constraints of Manhattan and New Jersey, Brooklyn and Staten Island define the harbor in the area known as the Upper Bay. The Narrows links the Upper Bay to the Lower Bay, south of Staten Island and the Atlantic Ocean.

The estuarine setting to the east of the site within the 0.5-mile radius includes intertidal and subtidal communities formed largely by artificial conditions and the influence of the Hudson River. To the south-southeast of the site and south of commercial piers, the intertidal and higher shoreline consists of rip/rap and artificial structures. The developed shoreline within 0.5-mile southeast and east of the site involves pilings from two former piers that remain in near-shore water north of the site. The pilings and shoreline bulkheads that extend through intertidal and subtidal zones provide substrate for sedentary life forms, such as microbes, algae and invertebrate epifauna (hydroids, polychaete worms, amphipods and bryozoans), as well as refuge, browsing habitat and spacial reference for mobile organisms, such as crabs and fish, including such species as tautog (*Tautoga onitis*) and cunner (*Tautogolabrus ad.spersus*).

Offshore, beyond the piers, the Narrows constitute a coastal inlet between the Atlantic Ocean and the Hudson River. Resident and seasonal fish species known from the coastal ocean and lower Hudson estuary could be expected in the Narrows. Resident fish include bay anchovy (Anchoa mitchilli), silverside (Membras martinica and Menidia spp.), scup (Stenotomus chrysops), spot (Leiostomus xanthurus), and winter flounder (Pseudopleuronectes americanus). Seasonal species include warm-weather visitors: menhaden (Brevortia tyrannus), Atlantic needlefish (Strongylura marina), juvenile bluefish (Pomatomus saltatrix), weakfish (Cynoscion regalis); and anadromous species, that pass through the area when moving to and from Hudson River waters, such as Atlantic sturgeon (Acipenser oxyrhynchus), shad (Alosa sapidissima) and striped bass (Morone saxatilis).

Redevelopment of the Staten Island waterfront to the northeast and north of the site, between 0.5 and 1 mile away, occurred during the early 1990s as part of the US Navy's Stapleton Homeport Program. Former piers were removed, a million cubic yards of dredging occurred and a new pier was constructed. One maintenance-dredging event occurred following construction of the new pier. Planned Navy use of the new facility never occurred, but the US Coast Guard operated from the facility until recently (USACOE, 2000). As a result of the Homeport project, significant modification occurred during the past 10 years within the subtidal and intertidal zones between 0.5 and 1.0 miles from the site.

The Narrows area is inherently a relatively deep part of the harbor. The waters northeast and southeast between one and two miles of the site include areas with depths >50 feet. In the vicinity of active piers, water depths may be as much as 40 feet.

7.2.2 Freshwater and Tidal Wetlands

Wetlands have been identified on the U.S. Fish and Wildlife National Wetland Inventory (NWI) Maps (The Narrows and Jersey City, NY-NJ quadrangles) and NYSDEC Tidal Wetland Maps (see Figure 7-2C). There are no wetlands in or associated with OU2. Portions of the New York Harbor near the site are mapped as an estuarine, intertidal, aquatic bottom, agael, regularly flooded wetland (E2AB1N). Some of the remaining wetlands are downgradient from the site. However, there are no known direct migration pathways from the site into the wetlands. Also, due to distance involved and fate and transport mechanisms, no significant effects on wetlands are expected.

7.2.3 Fish and Wildlife Resources

Wildlife uses in the area were evaluated using literature sources and field observations. Wildlife sightings included direct observations and identifications based on vocalizations, tracks, browse, and scat. General wildlife values (*e.g.*, food and cover availability) also were noted.

Federally listed endangered, threatened or species of concern are not known to occur within two miles of the site (Clough, 1999). Seven state-listed endangered species were identified as occurring within two miles of the site (Christoffel, 2000) (see Figure 7-2C). In addition, one significant habitat, serpentine barrens, was identified as occurring within two miles of the site.

The surrounding two-mile radius consists of residential homes and industrial/ commercial properties. These areas typically consist of mowed lawns interspersed with trees and shrubs, which often times are introduced exotics used for ornamental purposes. These areas do not support an abundance of wildlife because of the lack of vegetation, which could provide food and cover, and constant human activity. The unmowed lot near the gate station and the narrow strip of vegetation along the right-of-way do provide habitat for wildlife. However, the small size limits the size of the population it can support. The herptile (amphibian and reptile), bird, and mammal species that may potentially occur within and adjacent to the site based on the land uses identified during the field reconnaissance are listed in the table below. The species observed during the field reconnaissance (which are representative for the point in time of the field reconnaissance) are also identified.

7.2.4 Observation of Stress

Signs of stress to vegetation and wildlife from site-related chemicals were not observed during the field reconnaissance.

7.2.5 Value of Habitat to Associated Fauna

The site and adjoining terrestrial properties are of little value to wildlife. The area is developed, and only isolated pockets of vegetation exists, and in most cases these areas are maintained by frequent mowing. The wildlife expected to occur in the vicinity of the site includes more urbanized bird and mammalian species such as mockingbird (*Mimus polyglottos*), gray squirrel (*Sciurus carolinensis*), and Norway rat (*Rattus norvegicus*).

Species That May Potentially Occur on or Adjacent to the Site

Common Name	Scientific Name	Habitat Preference
Northern brown snake	*Stirerua dekayi*	Ubiquitous.
Eastern garter snake	*Thamnophis sirtalis*	Ubiquitous.
Eastern American toad	*Bufo americanus*	Found in almost any habitat.
Killdeer	*Charadrius vociferous*	Lawns, open areas.
Rock dove[a]	*Columba livia*	Open areas near human habitations.
Mourning dove	*Zenaida macroura*	Open areas, lawns, and woodland edges.
Chimney swift	*Chaetura pelagica*	The vicinity of buildings in towns, cities and farms.
Barn swallow	*Hirundo rustica*	Man-made structures near open areas.
House wren	*Troglodytes aedon*	Near human dwellings with sufficient wooded vegetation.
European starling	*Sturnus vulgaris*	Farms, cities, gardens, parks.
Common grackle	*Quiscalus quisscula*	Suburbs, parks, cities.
House Finch	*Carpodacus mexicanus*	Suburban and Urban yards.
House sparrow[a]	*Passer domesticus*	Villages, cities.
Eastern mole	*Scalopus aquaticus*	Lawns.

Common Name	Scientific Name	Habitat Preference
Norway rat	*Rattus norvegicus*	Near human habitation.
House mouse	*Mus musculus*	Buildings.
Meadow	*Microtis pennsylvanicus*	Fields, lawns.

Notes:
[a] Species observed by sight or sound during field reconnaissance.
Source: DeGraaf and Rudis, 1983; Conat and Collins, 1975; Burt and Grossenheider, 1976

7.2.6 Value of Resources to Humans

The site and surrounding area are of little value to humans for recreational use of wildlife. Bird feeders may be in residential yards. The developed nature of the area precludes small game and deer hunting.

7.2.7 Applicable Fish and Wildlife Criteria and Standards

Site-specific criteria protective of fish and wildlife resources associated with the site that may be applicable to future remediation are included in:

- Migratory Bird Treaty Act, which protects migratory birds, their eggs and nests from harm.

7.2.8 Exposure Pathways Analysis

Chemicals of Potential Ecological Concern

A number of substances were detected in soil and groundwater. Some are naturally occurring. Some are less toxic than others. In order to focus the FWIA on those chemicals that may pose risks to the environment, COPECs were selected.

For this assessment, the chemicals detected in groundwater are not considered COPECs for ecological receptors except indirectly as a potential source of contamination to the surface water or sediment downgradient of the site. The depth to groundwater is generally greater than three feet bgs, which is below the root zone of most plants. Where groundwater is less than three feet bgs, the area is unvegetated and/or paved. Therefore, no exposure routes exist, and the chemicals detected in groundwater are not discussed.

Surface and subsurface soil samples were collected from the site and analyzed for VOCs, SVOCs, RCRA metals and total cyanide. Only shallow subsurface soils (up to four feet below ground surface) were considered in this FWIA. A total of 64 samples (36 surface soil and 28 subsurface soil) were analyzed in this depth interval. Data for deeper subsurface soils were not evaluated due to lack of exposure routes to wildlife. Most burrowing animals create dens in the upper four feet of soil. In addition, the deeper subsurface soil samples (*i.e.*, greater than four feet) are below the root zone of most plants. Essential nutrients (calcium, iron, potassium, sodium and magnesium) are not considered COPECs.

Sec-butylbenzene, 3-Nitroaniline, di-n-butylphthalate, hexachlorobenzene and isophorone were detected infrequently (*i.e.*, in less than 5% of the samples with sample sizes greater than 20 samples). Therefore, these chemicals are not considered COPECs for this assessment.

Chemical Migration and Fate

The COPECs consist of VOCs, PAHs and metals.

Volatile Organic Compounds – The VOCs of concern have high vapor pressures and, therefore, would be expected to volatilize readily from surface soil to the atmosphere. Once released to the atmosphere, these compounds are rapidly photodegraded.

In deeper soils, these compounds degrade slowly, are water-soluble and may leach into groundwater. These compounds have low octanol/water coefficients (log K_{ow}) and, therefore, do not sorb to sediment or particulate matter present in the water column.

PAHs - PAHs are a major component of coal tars. PAHs contain only carbon and hydrogen and consist of two or more fused benzene rings in linear, angular or cluster arrangements. The number of rings in a PAH molecule affects its biological activity, and fate and transport in the environment. In general, most PAHs can be characterized as having low vapor pressure, low to very low water solubility, low Henry's Law constant, high log K_{ow}, and high K_{oc}.

Although PAHs are regarded as persistent in the environment, they are degradable by microorganisms. Environmental factors, microbial flora and physicochemical properties of the PAHs themselves influence degradation rates and degree of degradation. Important environmental factors influencing degradation include temperature, pH, and redox potential and microbial species. Physicochemical properties, which influence degradation, include chemical structure, concentration and lipophilicity.

Metals – In a terrestrial setting, trace elements released to the environment accumulate in the soil (Sposito and Page, 1984). Mobility of these trace elements in soil is low and accumulated metals are depleted slowly by leaching, plant uptake, erosion, or chelation. The half-life of trace elements in temperate climate ranges from 75 years for cadmium to more than 3,000 for zinc.

The transport of trace elements in soil may occur via the dissolution of metals into pore water and leaching to groundwater, or colloidal or bulk movement (*i.e.*, wind or surface water erosion). The rate of trace element migration in soil is affected by the chemical, physical and biological characteristics of the soil. The most important characteristics include:

- Eh-pH system;
- Cation exchange capacity and salt content;
- Quantity of organic matter;
- Plant species;
- Water content and temperature; and
- Microbial activity.

Metals that do mobilize from the soil into the water column are most mobile under acid conditions and increasing pH usually reduces their bioavailability (McIntosh, 1992).

The migration pathways for chemicals are illustrated on Figure 7-1 of the report.

Exposure Pathways

Wildlife resources in the commercial/residential area surrounding the site are limited due to the lack of food and cover. Also, constant human disturbance limits the population to wildlife species more tolerant of human activity. No state or federally listed species were identified as occurring on the site. Several wetlands were identified in the two-mile radius study area. These wetlands are currently too distant and/or up-gradient of the site for any likely exposure to site-related chemicals. Also, some of the COPECs are selected metals and PAHs. The fate and transport mechanisms of these chemicals reduce the likelihood of future migration into these areas. Thus, exposure is likely to be limited to wildlife on, near, or immediately downgradient from the site.

Plant roots are not discriminating in the uptake of small organic molecules (molecular weight less than 500) except on the basis of polarity. The more water-soluble molecules pass through the root epidermis and translocate throughout the plant and are eventually volatilized from the leaves (Efroymson *et al.*, 1997a). Plants selectively uptake metals in soil by absorption from soil solution by the root. Metals may be bound to exterior exchange sites on the root and not actually taken up. They may enter the root passively in organic or inorganic complexes or actively by way of metabolically controlled membrane transport (Kabata-Pendias and Pendias, 1992). Once in the plant, a metal can be stored in the root or translocated to other plant parts. Potential exposure to wildlife could occur through direct contact with or accidental ingestion of contaminated soil or through the terrestrial food chain.

7.2.9 Criteria-Specific Toxicity Assessment

Soil

The NYSDEC does not have soil cleanup criteria relating to the protection of wildlife and the availability of applicable soil screening values in scientific literature is limited. The screening of soil COPECs was conducted by comparing the chemical concentrations to available screening benchmark values derived by the Oak Ridge National Laboratory (Efroymson *et al.*, 1997a, 1997b and Sample *et al.*, 1996) for the U.S. Department of Energy. The benchmark values are the 10^{th}-percentile of the distribution of various toxic effects threshold for the chemicals in soil for a group of organisms.

Transformation or loss due to environmental degradation is not considered in this assessment. It is assumed that following uptake, concentration in soil will equal concentrations in organisms. This assumption overestimates potential risk in that wildlife has limited contact with these chemicals in soil and plants.

Benchmark values for three groups of organisms, where available or derived, are presented in Table 7-8. Terrestrial plants were selected since they are critical in nutrient cycling and are a source of food in the diets of higher animals. Also, plants readily take up the COPECs. Earthworms were selected because of their importance in maintaining soil fertility through burrowing and feeding activities. Also, earthworms are at the base of the food chain and are an important food for higher organisms. Meadow voles were selected to represent an herbivorous small mammal. The benchmark values for meadow vole is presented as dietary concentrations in milligram (mg) of chemical per kilogram (kg) of diet that would result in no observed adverse effect levels (NOAELs). For screening purposes, it was assumed that the chemical concentration in soil would be found in the food items of each species. As stated previously, this is a conservative approach that should result in the overestimation of potential exposure and risk.

As indicated in the table on the following page, screening values are available for a few of the COPECs. Therefore, the methodology of the Oak Ridge National Laboratory (Sample *et al.*, 1996) was used to derive toxicological benchmarks for the meadow vole from published toxicological data for laboratory animals. Literature sources included IRIS (EPA, 2000), HEAST (EPA, 1997), and the National Toxicology Program. It should be emphasized that the resulting benchmarks obtained from this methodology and toxicological data are based on a conservative approach whose resulting relationship to potential population effects is uncertain.

No observed adverse effect levels (NOAELs) and lowest observed adverse effect levels (LOAELs) are daily dose levels normalized to the weight of the test animal [*e.g.*, mg of chemical per kg body weight per day (mg/kg/day)]. The presentation of toxicity data on a mg/kg/day basis allows for comparison across species with appropriate consideration for differences in body sizes. If a NOAEL (or LOAEL) for a mammalian test species ($NOAEL_t$) is available, then the equivalent NOAEL (or LOAEL) for a mammalian wildlife species ($NOAEL_w$) can be calculated by using an adjustment factor for the difference in body size:

$$NOAEL_w = NOAEL_t \times \left({bw_t}/{bw_w} \right)^{1/4}$$

where:

$NOAEL_w$ = No observed adverse effect level for wildlife species (mg/kg/day)
$NOAEL_t$ = No observed adverse effect level for test species (mg/kg/day)
bw_w = Body weight for wildlife species (kg)
bw_t = Body weight for test species (kg)

In some cases, a NOAEL for a specific chemical was not available, but a LOAEL or lethal dose (LD_{50}) had been determined experimentally. The NOAEL can be estimated by applying an uncertainty factor (UF) to the LOAEL or LD_{50}. In the USEPA methodology (USEPA, 1989), the LOAEL or LD_{50} can be reduced by a factor of 10 or 50, respectively, to derive the NOAEL.

The dietary level or concentration in food (C_f) of a chemical in mg of chemical per kg of food that would result in a dose equivalent to the NOAEL can be calculated from the food factor (*f*):

$$C_f = \frac{NOAEL_w}{f}$$

The food factor, (*f*) is the amount of food consumed per day per unit of body weight. The table below provides the body weight, food intake and food factors used in the derivation of chemical-specific NOAELS for the meadow vole. Table 7-7 provides the derived toxicological benchmarks for the meadow vole. When literature values were not available for a chemical, a structurally similar surrogate was used. These surrogates are provided in Table 7-7.

Parameters for Calculation of Toxicological Benchmarks

Organism	**Body Weight** (kg)	**Food Intake** (kg/day)	**Food Factor** *f*
Mouse	0.03	0.0055	0.18
Rat	0.35	0.028	0.08
Dog	12.7	0.301	0.024
Rabbit	3.8	0.135	0.034
Meadow vole	0.044	0.005	0.114

Screening the maximum concentrations of the COPECs against the literature and derived benchmark values (Table 7-8) indicated:

- Several chemicals did not exceed their respective benchmark values and do not pose a risk to environmental receptors. These include 1,3,5-trimethylbenzene, n-butylbenzene, n-propylbenzene, p-isopropyltoluene, tert-butylbenzene, isopropylbenzene, benzene, ethylbenzene, isopropylbenzene, methylene chloride, styrene, anthracene, benzoic acid, benzo(k)fluoranthene, benzyl alcohol, butylbenzylphthalate, diethylphthalate, fluoranthene, bis(2-ethylhexyl)phthalate, beryllium, chromium, cobalt, manganese, nickel, selenium, cyanide, dieldrin, heptachlor, indeno(1,2,3-cd)pyrene, and endosulfan sulfate.

- Several chemicals exceeded their respective benchmark values and may pose a risk to environmental receptors. They include benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, chrysene, dibenzo(a,h)anthracene, dibenzofuran, 1,2,4-trimethylbenzene, acetone, carbon tetrachloride, toluene, xylene, 2,4-dimethylphenol, 2-methylnaphthalene, 4-methylphenol, acenaphthene, carbazole, di-n-octylphthalate, fluorene, n-nitrosodiphenylamine, naphthalene, phenanthrene, phenol, pyrene, antimony, arsenic, barium, cadmium, copper, lead, mercury, silver, thallium, vanadium, and zinc.

7.2.10 Conclusions

Habitat Characteristics

The site reconnaissance conducted as part of this analysis indicates the site and surrounding area are poor quality environmental resources, due to the limited presence of vegetation. The site is mostly covered with buildings and asphalt. Wildlife species typically present are adapted to urban setting. Due to the size of the vegetated areas, only a few individuals will be present. The New York Harbor and several wetland areas are located within 2 miles of the site. Potential migration of COPECs into these resources should be prevented.

Soil

Several COPECs were detected at concentrations greater than the toxicological benchmark values. This suggests that these chemicals may pose a risk to wildlife. In addition, toxicological benchmarks were not derived for several COPECs. However, these potential effects have minimal ecological significance.

The potential risk from COPECs is minimal, for several reasons. Exposure frequency, chemical concentration (especially within the upper 6 inches), mechanism of exposure, and duration of exposure determines risk. The commercial area (*i.e.*, paved areas, buildings, etc.) provides minimal habitat in the form of "weedy" patches that would not support a wildlife population. This area experiences constant physical disturbance that prevents populations of wildlife from developing. Because only transient species and a few individual animals would use this area, the frequency and duration of exposure is limited. Thus, the observed chemicals detected on-site do not pose a current impact, nor is any expected in the future.

8. Summary of Findings

The overall extent of tar, staining, sheen, odors, and chemical constituents detected in soils was located primarily adjacent to former tar handling structures located at the 25 Willow Avenue parcel because the dense Ground Moraine unit and Harbor Hill Terminal Moraine impede the lateral and vertical migration of tar. The majority of tar impacts are contained within alluvial deposits (stratified sands) located within an inferred scour into the under-lying ground moraine located beneath the 25 Willow Avenue parcel ranging from 33 feet bgs in the vicinity of Bay Street to 65 feet bgs in the vicinity of Willow Avenue. Localized sand and gravely-sand units were noted at the northern edge of the site within Bay Street/ Edgewater Street and also along the eastern portion of the site along Willow Avenue. Isolated lenses of tar in these units migrated laterally beneath Willow Avenue and as far north as Edgewater Street.

In general, elevated levels of TPAH, CPAH, and BTEX correlated with the occurrence of observable tar, odors and/or sheen. Where physical evidence of tar was not encountered, analyses indicated generally low to trace levels of these chemical constituents. As with the observed extent of tar, staining, odors, etc., the overall extent of chemical constituents was generally limited primarily to the 25 Willow Avenue parcel; however, discrete intervals beneath the isolated portions of Willow Avenue, Bay Street, and Edgewater Street were observed that contained elevated levels of TPAH, CPAH, and BTEX. An investigation of the soil, groundwater, and soil vapor quality beneath the One Edgewater Street parcel is being conducted and the findings will be transmitted in a Supplemental RI Report.

Surface-soil analytical data from 25 Willow Avenue indicate that surface soil conditions at the 25 Willow Avenue parcels were generally consistent with background conditions with the exception of elevated PAH concentrations that are likely associated with fill material used in development of the 25 Willow Avenue parcel.

Similarly, dissolved chemical constituents in groundwater within the water table aquifer appear predominantly limited to the 25 Willow Avenue parcel. Elevated concentrations of BTEX and PAH were observed within monitoring wells within the water bearing zone of the confining unit were tar was encountered on the 25 Willow Avenue parcel and extending as far north as Edgewater Street. Only trace detections of BTEX were present in groundwater within the deep aquifer at well RW-15 and RW-16 at the 25 Willow Avenue parcel. Total cyanide was primarily detected within monitoring wells (OW-5, OW-6 and OW-7) along the northern boundary of the site and within the adjacent storm sewer samples STRM-02 and STRM-03 that were located downgradient from the former purify tanks on the 25 Willow

Avenue parcel. Cyanide in groundwater does not represent a complete human exposure pathway under current use because the site is paved and the groundwater is inaccessible.

The findings of the human health risk assessment indicate that there are no complete exposure pathways for the current land usage within OU-2. Remedial measures are required to mitigate potential future exposure scenarios to site-related chemicals at the 25 Willow Avenue parcel and potential futures use within isolated sections beneath Willow Avenue, Bay Street, and Edgewater Street. A feasibility study report is currently being prepared to assess the appropriate means to mitigate the conditions related to the former tar handling structures on the 25 Willow Avenue parcel and tar impacted media within OU-2.

An assessment of soil, groundwater, and soil vapor conditions at One Edgewater Street is being performed. The findings and potential risks posed by these conditions will be provided in a Supplemental RI Report following completion of the assessment.

References

Bennimoff, A. I. and A.A. Ohan (no date). *The Geology of Staten Islan*d. Pp. 3. Internet Web Site, www.library.csi.cuny.edu/dept/as/geo/sigeo.html, accessed on 12/21/99.

Beers, F.W. 1874. *Map of Clifton, Staten Island*. Provided by the Staten Island Institute of Arts and Sciences.

Brown's Directory of American Gas Companies, 1886 to 1965.

Brusseau, M. L. and P.S.C. Rao (1989). "The Influence of Sorbate-Organic Matter Interactions on Sorption Nonequilibrium." *Chemosphere*. Vol. 18, pp 1691-1706.

Brusseau, M. L., R.E. Jessup, and P.S.C. Rao (1991). "Nonequilibrium Sorption of Organic Chemicals: Elucidation of Rate-Limiting Processes." *Environmental Science and Technology*. Vol. 25, pp 134-142.

Burt, W.H. and R.P. Grossenheider, 1976, *Field Guide to the Mammals*, Houghton Mifflin Company, Boston, MA.

Butler, James. 1853. Map of Staten Island or Richmond County, New York. Surveyed, Drawn, and published by James Butler C.F. and surveyor. Provided by the Staten Island Institute of Arts and Sciences.

Casey, Mary E., February 11, 1998, *Letter from Mary E. Casey at Brooklyn Union to Mark Tibbe at the New York State Department of Environmental Conservation.*

Christoffel, H. 2000. Personal Communication. New York State Department of Environmental Conservation, Division of Fish, Wildlife & Marine Resources. NYS Natural Heritage Program. Latham, NY.

Clough, M.W. 1999. Personal Communication. United States Department of the Interior, Fish and Wildlife Service, Cortland, New York.

Conat, R. and J.T. Collins, 1975, *A Field Guide to Reptiles and Amphibians of Eastern and Central North America.* Houghton Mifflin Company. Boston, MA.

DeGraaf, R.M. and D.D., Rudis, 1983, *New England Wildlife: Habitat, Natural History, and Distribution*. General Technical Report NE-108. Northeast Forest Experiment Station. Amherst, MA.

Efroymson, R.A., M.E. Will, and G.W. Suter III. 1997a. *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision.* ES/ER/TM-126/R2. Oak Ridge National Laboratory, Oak Ridge, TN.

Efroymson, R.A., M.E. Will, G.W. Suter III and A.C. Wooten. 1997b. *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision.* ES/ER/TM-126/R2. Oak Ridge National Laboratory, Oak Ridge, TN.

Eisler, R., 1987, Polycyclic Aromatic Hydrocarbon Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. Biological Report 85(1.11) U.S. Fish and Wildlife Service, Laurel, MD.

EPRI, 1999. *Estimating release concentrations of multi-ring aromatic hydrocarbons from MGP soils*. EPRI. TR-110516-V2, pp 1-2.

Fanning, Phillips and Molnar Engineers, 1993, *Underground Storage Tank Groundwater Investigation at the Brooklyn Union Gas Company, Clifton Station Facility, 25 Willow Avenue, Staten Island*

Fanning, Phillips, and Molnar Engineers, August 1994, *Groundwater Sampling at the Brooklyn Union, Clifton Station Facility, 25 Willow Avenue, Staten Island, New York.*

Fanning, Phillips, and Molnar Engineers, May 1998, *Sampling Summary Report for the Former Brooklyn Union Gas Company, Clifton Station Facility, 25 Willow Avenue, Staten Island, New York*

Fanning, Phillips & Molnar Engineers. July 1993. *Soil and Groundwater Quality at the Brooklyn Union Gas Company Clifton Station Facility, Staten Island, New York.*

Freeze, R.A., and Cherry, 1979. *Groundwater;* Prentice-Hall, Inc. Englewood Cliffs, NJ, p. 604.

Gilbert, R.O., 1987, Statistical Methods for Environmental Pollution Monitoring, New York: John Wiley & Sons, Inc.

Howard, P.H., 1990, Handbook of Environmental Fate and Exposure Data for Organic Chemicals, Lewis Publishers, Chelsea, MI.

Kabata-Pendias, A. and H. Pendias. 1992. *Trace Elements in Soils and Plants.* P.T. Kostecki, E.J. Calabrese, eds. Lewis Publishers, Inc. Chelsea, Michigan.

Lee, L.S., N.D. Priddy, and D.C.M. Augustijn. 1998. Estimating mass transfer of polyaromatic hydrocarbons from coal-tar contaminated soil. In Non-Aqueous Phase Liquids-Contamination and Reclamation. Springer-Verlag.

Loehr, Raymond C. and Matthew T. Webster (1996). "Behavior of Fresh vs. Aged Chemicals in Soil." *Journal of Soil Contamination.* Vol. 5, pp 361-383.

LEXICON UST Closure Summary Report. October 15, 1993. Clifton Service Center, 25 Willow Avenue, Staten Island, New York

McGuire, J., New York City Department of Environmental Protection, Personal Communication, January 3, 2000.

McIntosh, A., 1992, Trace Metals in Freshwater Sediments: A Review of the Literature and an Assessment of Research Needs. In: Metal Ecotoxicology Concepts & Applications. Edited by M.C. Newman and A.W. McIntosh, Lewis Publishers, Inc. Chelsea, MI.

Morris, D.A., and A.I. Johnson, 1967. "Summary of Hydrologic and Physical Properties of Rock and Soil Materials, as Analyzed by the Hydrologic Laboratory of the U.S. Geological Survey, 1948-60": U.S. Geological Survey Water-Supply Paper, 1839-D, p. 42.

New York State Department of Environmental Conservation. 1989. *Guidelines for Remedial Investigations and Feasibility Studies*, Technical and Administrative Guidance Memorandum (TAGM), HWR-89-4025.

New York State Department of Environmental Conservation. 1994. *Technical and Administrative Guidance Memorandum #4046, Determination of Soil Cleanup Objectives and Cleanup Levels*.

New York State Department of Environmental Conservation. 1994b. *Fish and Wildlife Impact Analysis for Hazardous Waste Sites.* Division of Fish and Wildlife, Albany, New York.

New York State Department of Environmental Conservation, 1998, Ambient Water Quality Standards and Guidance Values and Groundwater Effluent Limitations, (TOGS 1.1.1), June 1998.
New York State Department of Health. 2002. *Qualitative Human Health Exposure Assessment.*

Normals, Means, and Extremes for Newark, New Jersey. National Oceanic Atmospheric Administration: National Climatic Data Center, Ashville, North Carolina. 1968-1997.

Rider, F.H.J. 1961. *Looking Back to Gas Light Era. Richmond County Gazette*.

Robinson, E. 1907 *Atlas of the Borough of Staten Island Richmond*. City of New York, 2nd Edition. Provided by the Staten Island Institute of Arts and Sciences.

Sample, B.E., D.M. Opresko and G.W. Suter. 1996. *Toxicological Benchmarks for Wildlife: 1996 Revision.* ES/ER/TM-86/R3. Prepared for the U.S. Department of Energy, Office of Environmental Management, Oak Ridge National Laboratory, Oak Ridge, TN.

Sanborn Fire Insurance Maps. 1885, 1898, 1917, 1937, 1950, 1977, and 1996.

Soren, J. (1988) *Geologic Hydraulic Reconnaissance of Staten Island, New York.* United States Geological Survey Water Resources Investigations Report 87-4048.

Sposito, G. and A.L. Page, 1984, “Cycling of Metal Ions in the Soil Environment.” Chapter 9 *Metal Ions in Biological Systems. Volume 18*, in: H. Sigal (ed.) Circulation of Metals in the Environment. Marcel Dekker, Inc. New York, NY.

Taylor and Skinner Map. 1781. A Map of Staten Island During The Revolution 1775-1783. Plan No. 31 Du Comp Anglo-Hessois Dons Staten Island De 1780-1783. Provided by the Staten Island Institute of Arts and Sciences.

US Census Bureau, 2000, *Population Estimates for Counties by Age, Race, Sex and Hispanic Origin: Annual Time Series, July 1, 1990 to July 1, 1998*, available from the Census Bureau’s web page.

United States Environmental Protection Agency (USEPA), 1989, Risk Assessment Guidance for Superfund, Human Health Evaluation Manual (Part A), Interim Final, Office of Emergency and Remedial Response, EPA/540/1-89/002.

United States Environmental Protection Agency (USEPA), 1992, Supplemental Guidance to RAGS: Calculating the Concentration Term, Office of Emergency and Remedial Response, Hazardous Site Evaluation Division, NTIS Publication No. PB92-963373.

United States Environmental Protection Agency (USEPA), 1997, *Health Assessment Effects Summary Tables*. FY 1997 Update. Washington, D.C.

United states Environmental Protection Agency (USEPA), Office of Emergency and Remedial Response, March 2001, *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites*, Peer Review Draft. OSWER 9335.4-24. Washington, D.C.

United States Environmental Protection Agency (USEPA), 2002, Calculating Exposure Point Concentrations at Hazardous Waste Sites, Draft, Office of Emergency and Remedial Response, OSWER 9285.6-10, July 2002.

United States Environmental Protection Agency (USEPA), 2000 and 2002, Integrated Risk Information System on-line database, http://www.epa.gov/ngispgm3/iris/index.html; INTERNET.

Wisconsin Department of Natural Resources (WDNR). (1996) *Assessing Sediment Quality at Manufactured Gas Plant Sites.* Table 1. Available at: http://www.dnr.state.wi.us/org/water/wm/wqs/sediment/assessment/mgp/mgpguide.htm.