OPERABLE UNIT 6
REMEDIAL INVESTIGATION REPORT

Sunnyside Yard
Queens, New York

May 14, 1999

Prepared for:

National Railroad Passenger Corporation
30th Street Station
4th Floor South
Philadelphia, Pennsylvania 19104

Prepared by:

ROUX ASSOCIATES, INC.
1377 Motor Parkway
Islandia, New York 11788

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1.0 INTRODUCTION

The National Railroad Passenger Corporation (Amtrak) currently owns and operates a train makeup and maintenance facility known as Sunnyside Yard, located at 39-29 Honeywell Street in Queens County, a borough of New York City, New York (Figure 1). The Sunnyside Yard (Yard) is listed as a Class II Site in the New York State Department of Environmental Conservation (NYSDEC) Registry of Inactive Hazardous Waste Disposal Sites. As a result of the listing, Amtrak, the New Jersey Transit Corporation (NJTC), and the NYSDEC entered into an Order on Consent Index #W2-0081-87-06 effective October 1989.

In accordance with the Order on Consent, several investigations have since been performed at the Yard. In 1989, Amtrak retained Roux Associates, Inc. (Roux Associates) to perform a Phase I Remedial Investigation, which included a ground-water investigation. The Phase I Remedial Investigation results were reported to the NYSDEC and accepted as final on January 22, 1992 (Roux Associates, Inc., 1992a). Phase II and Phase II Addendum Remedial Investigations (and associated work) have been performed by Roux Associates since acceptance of the Phase I Remedial Investigation report. Although the results of the Phase II and Phase II Addendum Remedial Investigations (and associated work) were submitted to the NYSDEC in a February 15, 1995 document titled "Phase II Remedial Investigation," the report has not yet been accepted by the NYSDEC. However, these remedial investigations have identified areas of the Yard where levels of contamination require remedial efforts. Accordingly, these investigations have identified numerous areas of the Yard that do not require remediation (i.e., former Areas of Concern 3, 5, 6, 7, and 10 through 16).

AREA 7 HAD SHEAN IN SAT. SOIL

1) REMAINS TO BE AGREED UPON
2) AREA 17 NEEDS TO BE INVESTIGATED.

After submittal of the Phase II Remedial Investigation report (Roux Associates, Inc., 1995), a portion of the Yard was designated by Amtrak as the site for the construction of the High Speed Trainset Facility (HSTF) Service and Inspection (S&I) Building. With the NYSDEC's concurrence, the Yard was subdivided into six operable units to accommodate the HSTF S&I Building construction schedule and still address remedial efforts in a timely and orderly manner. These operable units are:

- Operable Unit 1 (OU-1) designated as the soil above the water table within the footprint of the proposed HSTF S&I Building;

- Operable Unit 2 (OU-2) designated as the soil above the water table within the footprint of the HSTF S&I Building ancillary structures (i.e., the access road and utilities route, the parking area, the construction easement area which surrounds the building, and the construction laydown area);
- Operable Unit 3 (OU-3) designated as the soil and separate-phase petroleum accumulation above the water table in Area 1 of the Yard, as defined in the Phase I Remedial Investigation report (OU-3 and Area 1 are used interchangeably in this report);
- Operable Unit 4 (OU-4) designated as the soil above the water table in the remainder of the Yard;
- Operable Unit 5 (OU-5) designated as the sewer system beneath the Yard; and
- Operable Unit 6 (OU-6) designated as the ground water including the saturated soil beneath the Yard.

Ground-water investigations since submittal of the Phase II Remedial Investigation report (February 15, 1995) have included monitoring well installation in the vicinity of the proposed construction (i.e., OU-1 and OU-2), monitoring well abandonment, and water-level monitoring and ground-water sampling of monitoring wells located in OU-1 through OU-4 (Roux Associates, Inc., 1996, 1997a and 1997b).

Because the Phase II Remedial Investigation report has not yet been accepted by the NYSDEC, complete descriptions of all ground-water investigation tasks performed after submittal of the Phase I Remedial Investigation report are presented in this report and are referred to as part of the OU-6 Remedial Investigation. All data discussed in this report were used to develop recommendations for OU-6.

1.1 Site Description

The Yard is located in an urban area in northwestern Queens County, a borough of New York City, New York. The East River is located approximately one mile to the west (Figure 1). The Yard consists of a railroad maintenance and storage facility that encompasses approximately 105 acres. It functions primarily as a maintenance facility for electric locomotives and railroad cars for both Amtrak and NJTC. Commercial, light industrial and residential areas surround the Yard.

1.2 Site History

The Yard was originally constructed in the early 1900's by the Pennsylvania Tunnel and Terminal Company, a subsidiary of the Pennsylvania Railroad (later known as the Penn Central Transportation Company). On April 1, 1976, the Consolidated Rail Corporation (Conrail) acquired the Yard, and the same day conveyed it to Amtrak, which has continued to operate it as a storage and maintenance facility for railroad rolling stock. Prior to September 29, 1961, the Long Island Rail Road (LIRR) owned a portion of the Yard. Today, the LIRR maintains right-of-ways through the Yard.

1.3 Previous Investigations

Previous ground-water investigations performed at the Yard include an investigation by Geraghty and Miller in 1986 and a Phase I Remedial Investigation by Roux Associates. These investigations are detailed in Appendix A, and summarized below.

Geraghty & Miller conducted an investigation of the former underground storage tank (UST) area, the Engine House, the former Oil House, and the former fuel transfer area to determine if leakage of hydrocarbon compounds had occurred and, if so, to determine the extent of contamination in both soil and ground water. In their June 1986 report, Geraghty & Miller concluded that a plume of separate-phase petroleum exists in the area east of the Engine House, and that this plume appears to have originated at the USTs of the former fuel storage area and has migrated beyond the Yard's northern property boundary. Polychlorinated biphenyls (PCBs) were detected in this separate-phase petroleum plume and in soil samples, but no PCBs were detected in ground water (Geraghty & Miller, Inc., 1986; Amtrak, 1989).

Roux Associates, on behalf of Amtrak and the NJTC, performed a Phase I Remedial Investigation (RI) at the Yard from October 1990 through March 1991. With respect to ground water, the Phase I RI was performed to develop site-specific hydrogeologic and ground-water quality information to determine the nature and extent of other areas of contamination at the Yard (Roux Associates, Inc., 1992a).

Sixteen areas of concern at the Yard had been identified in the Work Plan for the Remedial Investigation and Feasibility Study (Roux Associates, Inc., 1990) as possible sources of contamination. In addition, Area 17 (the 68 Spur) was noted as an area of concern during performance of the Phase I RI (Plate 1). As part of the Phase I, ground water was investigated in the areas of concern and also outside of those areas to determine the "facility-wide" environmental conditions. Hydrogeologic characteristics of the Yard and ground-water quality were investigated. The results of the Phase I RI shallow ground-water monitoring (excluding Area 1) indicated that:

- no volatile organic compounds (VOCs) or semivolatile organic compounds (SVOCs) (including polycyclic aromatic hydrocarbons [PAHs]) were detected above standards;
- only a limited number of SVOCs (predominantly PAHs) were detected;
- PCBs were detected in only one monitoring well (which contained separate-phase petroleum); and
- iron, lead, manganese, and sodium were detected at concentrations above the standards in most of the facility-wide ground-water quality samples, which is indicative of background conditions in an industrialized urban environment with a history of saltwater intrusion.

Separate-phase petroleum accumulations present in Area 1 extend northward from the Metro Shop past the northern property boundary on the LIRR property. However, the following data indicates that the accumulation has not significantly affected ground-water quality.

- No VOCs were detected above standards in shallow ground-water quality samples collected along the perimeter of the separate-phase petroleum accumulation. In addition, low concentrations of only a limited number of SVOCs were detected. PCBs were detected in two Area 1 monitoring wells; however, the PCBs were attributable to separate-phase petroleum since a petroleum sheen was present in each of these wells. Therefore, no dissolved PCBs were detected in ground water.
- Iron, lead, manganese and sodium exceed standards in most of the shallow monitoring wells sampled in Area 1, which is indicative of background conditions in an industrialized urban environment with a history of saltwater intrusion.

- Ground-water quality samples collected from the one deeper Upper Glacial aquifer monitoring well (MW-23D) detected ethylbenzene and total xylenes. This well is screened beneath the separate-phase petroleum accumulation, therefore these detections may be attributable to residual contamination from the well installation. Low concentrations of bis(2-ethylhexyl)phthalate and 2-methylnaphthalene were also detected in MW-23D, however, bis(2-ethylhexyl)phthalate is a common laboratory contaminant.

Based on the Area 1 and facility-wide ground-water quality data, Yard ground-water quality appears to have been only minimally affected by the separate-phase petroleum accumulation in Area 1 and by the facility-wide Yard activities, including activities performed in Area 2 through Area 16.

Roux Associates completed two follow-up investigations to the Phase I RI:

- delineation of the off-site extent of the separate-phase petroleum accumulation in Area 1; and
- investigation and abandonment of the UST located in Area 2.

Although the results of these investigations were previously reported to the NYSDEC (Roux Associates, 1992b; 1992c) and are summarized in Appendix A, the data from these investigations that apply to OU-6 have been incorporated into this report.

2.0 METHODS OF INVESTIGATION AND SCOPES OF WORK

The methods of investigation employed during the OU-6 RI at the Yard are based on Roux Associates Standard Operating Procedures (Appendix B) and are described in the "Addendum to the August 5, 1992 Work Plan for the Phase II Remedial Investigation" (Roux Associates, Inc., 1993a). Summaries of these methods are provided in Section 2.1. The scopes of work performed for OU-6 since submittal of the Phase I RI report are provided in Section 2.2.

2.1 Methods of Investigation

The field and analytical methods utilized during the OU-6 RI are described below. Any necessary modifications to the methods are discussed in the appropriate scope of work or results sections.

2.1.1 Field Methods

Field investigations pertaining to ground water at the Yard included the following four tasks:

- Task I: Monitoring Well Installation;
- Task II: Monitoring Well Abandonment;
- Task III: Water-Level and Separate-Phase Petroleum Thickness Measurements; and
- Task IV: Ground-Water Sampling.

Task I: Monitoring Well Installation

To further evaluate hydrogeologic and ground-water quality conditions at the Yard, thirty-six 4-inch diameter monitoring wells, five 2-inch diameter monitoring wells and eight 2-inch diameter temporary wellpoints were installed during the OU-6 RI. Monitoring wells and temporary wellpoints were installed under the direction of Roux Associates. All monitoring wells were installed in pilot boreholes drilled with a hollow-stem auger rig or were hand dug.

The eight temporary wellpoints and all but seven of the monitoring wells were installed with the top of the well screen set approximately two to three feet above the existing water table, when conditions permitted. The remaining seven deep monitoring wells (designated with a "D") were installed with the top of the well screen set approximately 25 feet below the existing water table (Table 1).

Temporary Wellpoints TW-1 through TW-3 were constructed by driving the wellpoints into the ground, and Temporary Piezometers TP-1 through TP-5 were constructed by installing screen into hand dug open borings. Although the ground-water analytical data from these wellpoints are discussed in this report, none of these wellpoints were constructed with a gravel pack or developed. Since a lack of well development results in ground-water samples that are generally turbid, the samples contain high amounts of silt and suspended solids which can result in elevated concentrations of non-volatile constituents (e.g., metals, PCBs). Therefore, the analytical results from these wellpoints are considered a screening tool, and more emphasis has been placed on data generated from monitoring wells.

With the exception of slight changes due to auger refusals, only Monitoring Well MW-60 was not installed at its originally proposed location. Monitoring Well MW-60 was originally proposed as an additional monitoring well (designated MW-64) in a December 22, 1993 letter to the NYSDEC (Roux Associates, Inc., 1993b) to address the need for additional delineation in the Turntable Area, as specified in the Addendum work plan (Roux Associates, Inc., 1993a). The well's designation was later changed to remain sequential.

Monitoring well construction details are summarized in Table 1. Since the Phase I RI, nine monitoring wells (MW-50 through MW-56, MW-58 and MW-60) were installed within the separate-phase petroleum accumulation. As per the NYSDEC requirement adhered to during the Phase I RI, 4-inch diameter, 20-slot (0.020 inch) stainless steel well screens were used to construct these wells. This construction was also used for Monitoring Well MW-41, which was installed to investigate the UST in Area 2 and, therefore, had the potential to contain separate-phase petroleum. The remaining monitoring wells were constructed of polyvinyl chloride (PVC) screen. All wells were constructed with PVC riser pipe. Each 4-inch diameter monitoring well has 10 feet of 10-slot (0.010 inch) or 20-slot (0.020 inch) PVC flush-threaded well screen. Two of the wells (TP-6 and TP-7) were constructed with 5 feet of 2-inch diameter, 10-slot (0.010 inch) PVC well screen and 2-inch diameter PVC riser. The remaining three wells (TP-8 through TP-10) were constructed with 10 feet of 2-inch diameter, 10-slot (0.010 inch) PVC well screen and 2-inch diameter PVC riser.

The 10-slot PVC screened wells were packed with No. 0 Morie sand. The 20-slot PVC and stainless steel-screened wells were packed with No. 2 Morie sand. The gravel pack extended approximately 1 to 2 feet above the well screen, followed by a 1-foot thick layer of bentonite. The remaining annular space was then filled with a bentonite/cement grout to approximately 1 to 2 feet below land surface (bls). An outer locking, steel protective casing was then placed over the well casing and the remaining annular space filled with concrete. In areas where the water table was extremely shallow (i.e., less than 5 feet bls) the installation procedure was modified based on the actual conditions encountered. Monitoring well construction logs are included in Appendix C.

When possible, split-spoon samples were collected at continuous 2-foot intervals during drilling above the water table, and every 5 feet thereafter. However, the combination of a shallow water table (1 to 2 feet bls) and running sand in a majority of the boreholes prevented the collection of samples from below the water table. All split-spoon samples were examined for lithology, visual evidence of contamination, and field screened for VOCs using a photoionization detector. All observations were recorded in a field book. Geologic logs are included in Appendix D.

Following installation, each well was developed to ensure hydraulic connection with the surrounding saturated deposits. All wells were developed until the pH, conductivity, and temperature of the discharged water had stabilized, and the turbidity was less than or equal to 50 nephelometric turbidity units (NTUs) or had stabilized. Temporary Wellpoints TW-1 through TW-3 were not developed prior to sampling and were removed immediately following sampling. Temporary Piezometers TP-1 through TP-7 were not developed or sampled. Each monitoring well was surveyed for horizontal and vertical coordinates by Topometrics, Islandia, New York.

Task II: Monitoring Well Abandonment

Prior to February 1995, Monitoring Wells MW-2, MW-24, MW-25 and MW 26 were determined to be unusable, and therefore, were abandoned. With the exception of MW-26, the well screens and casings were removed. A cement/bentonite grout was then used to seal the borehole to within 5 feet of land surface. The remaining borehole was then backfilled with soil and compacted.

Monitoring Well MW-26 was damaged and the casing broken approximately 5 feet bls during construction of the new Car Washer Area. Due to the Car Washer construction, the area was not accessible to a drill rig, and therefore, the well screen and remaining casing were not removed. The screen zone was first sealed with a cement/bentonite grout to approximately 4 feet bls. A cement mixture was then used to fill the remaining borehole to land surface and finish flush with the existing concrete pad.

Since February 1995, Yard construction activities have destroyed numerous monitoring wells and temporary piezometers (including TP-1 through TP-5), and put several other wells within the construction envelope at risk of being damaged. Wells MW-58 and TP-6 were abandoned during 1997 by removing the well screens and casings. A cement/bentonite grout was then used to seal each borehole to land surface. Well MW-32 was destroyed during construction of the static frequency converter, and therefore cannot be properly abandoned. On April 30, 1998, Roux Associates completed abandonment of 18 monitoring wells within the HSTF construction envelope (MW-17, MW-22, MW-25A, MW-31, MW-40D, MW-47, MW-51, MW-55 through MW-60, MW-63 through MW-65, MW-67 and TP-8), many of which had been previously damaged. With the exception of MW-47, the well screens and casing were removed. A cement/bentonite grout was then used to seal the remaining borehole to grade. Monitoring Well MW-47 was damaged and the casing broken at the screen, approximately five feet below grade (a concrete roadway). The screen zone was first sealed with a cement/bentonite grout to approximately three feet below grade and a cement mix was then used to fill the remaining borehole to grade and finished flush with the existing roadway. Monitoring Well MW-33 (in the central portion of the Yard) is currently inaccessible beneath blacktop paving. If located, MW-33 will be properly abandoned. Wells MW-53, MW-66, TP-7 and TP-9 are not currently visible at ground surface, but these wells lie within the construction envelope. Therefore, these wells will be located by surveyor and properly abandoned during future work at the Yard.

Task III: Water-Level and Separate-Phase Petroleum Thickness Measurements

Multiple rounds of water-level measurements have been performed during the OU-6 RI (Table 2).

- July 1991 to February 1997 frequent water-level measurements were collected within Area 1 as part of the Interim Remedial Measure (IRM) system monitoring;
- February 8, 1993 (following Phase II RI monitoring well installation and development);
- February 1, 1994 and June 14, 1994 (following the Phase II RI Addendum monitoring well installation and development);
- May 2, 1996 (following the Limited Phase II Environmental Site Assessment monitoring well installation and development); and
- June 17 through 19, 1997 (following the OU-2 RI monitoring well installation and development).

Water levels were measured to the nearest 0.01 foot using a steel measuring tape and chalk, or an electronic oil/water interface probe. In wells containing separate-phase petroleum, the water level and petroleum thickness were measured to the nearest 0.01 foot using an electronic oil/water interface probe. Detections of petroleum at less than 0.01 foot (i.e., sheen) were visually verified with the use of a clear Teflon™ bailer.

Task IV: Ground-Water Sampling

Roux Associates conducted ground-water sampling at the Yard on November 6, 1991; January 15, 22 and 26, 1993; February 8 and 9, 1993; December 6, 1993; February 17, 1994; May 2, 3 and 9, 1996; June 18 through 20, 1997; and July 17, 1997. In addition, ground-water samples collected by the Transit Authority's consultant were split with Roux Associates on February 6 and 21, 1997; March 27, 1997; November 14, 1997; and April 9, 1998. Ground-water samples were only collected from wells that did not contain separate-phase petroleum. Monitoring wells were purged then sampled within 24 hours after purging was completed. After collection, ground-water samples were packed on ice and submitted to Northeastern Analytical Corporation

(NAC) or IEA laboratory for analyses including, but not limited to, Target Compound List (TCL) VOCs, TCL SVOCs, PCBs and Target Analyte List (TAL) metals. Temperature, pH, and conductivity measurements of the ground-water samples were taken and recorded in the field. Samples collected June 18 through 20, and July 17, 1997 were also analyzed for total dissolved solids and chloride since these parameters must be within standard for water to be suitable as drinking water.

2.1.2 Analytical Methods

Analytical services for the delineation of the off-site extent of the separate-phase petroleum accumulation and the Area 2 UST investigation were performed by NAC of Marlton, New Jersey. Analytical services for all the OU-6 RI work were performed by IEA, with one exception. The April 9, 1998 split samples were analyzed by ICM, a division of AnaLab, Edison, New Jersey. NAC, IEA and ICM were at the time of sampling certified New York State Department of Health Environmental Laboratory Approval Program (ELAP) laboratories. IEA and ICM are New York State certified Analytical Services Protocols (ASP) laboratories. Phase II and Addendum data were validated by Data Validation Services. The data validation reports are included in Appendix E. The associated data usability report prepared by Roux Associates is included in Appendix F.

For ease of discussion, the data validation qualifiers assigned to each analytical value are not included in the text. These qualifiers are included in the data tables along with explanations to define each qualifier.

In cases where primary and duplicate sample results are not the same, the highest usable concentration detected for each constituent was (conservatively) considered the actual value. In cases where a sample was diluted and re-run, analytical results from the diluted sample were only used for those constituents that exceeded the instrument range in the first run (undiluted) sample.

The ground-water sample collected from MW-41 on November 6, 1991 was analyzed for TCL VOCs by United States Environmental Protection Agency (USEPA) Method 624, according to NYSDEC December 1989 ASP procedures.

For ground-water sampling performed during 1993 and 1994, the following methods were performed in accordance with the NYSDEC 1991 ASP (as specified in the Phase II RI and Addendum work plans, and approved by the NYSDEC).

- TCL VOCs - USEPA Method 8240;
- TCL SVOCs - USEPA Method 8270;
- PCBs - USEPA Method 608; and
- TAL metals - USEPA Methods 6010 and 7000 series.

Differences in quality assurance/quality control (QA/QC) requirements for the USEPA Test Methods for Evaluating Solid Waste (SW-846) specified above, and the ASP methods, required IEA to develop the modifications discussed below.

- TCL VOCs in water were analyzed by USEPA Method 8240 using a capillary column and TCL SVOCs were analyzed by Method 8270 integrating QA/QC from the 1991 ASP as follows:
    1. response factors were updated from the 50 parts per billion (ppb) calibration check standard; and
    2. tentatively identified compounds (TICs) are reported.
- Aqueous samples requiring a low detection limit for PCBs were analyzed using Method ASP 89-3.
- Analyses of inorganics were performed using the ASP digestion procedures followed by the requirements for the specific SW-846 methods (i.e., 6010 and 7000 series).

The sample results are presented in the format required by ASP (i.e., Category B deliverables package). The suite of TCL VOCs, TCL SVOCs and PCBs are collectively referred to as the TCL throughout this report for ease of discussion.

During 1996 (as specified in the Limited Phase II Environmental Site Assessment work plan), ground-water samples were analyzed by the following SW-846 methods.

- TCL VOCs - USEPA Method 8240A;
- TCL SVOCs - USEPA Method 8270A;
- PCBs - USEPA Method 8081; and
- TAL metals - USEPA Methods 6010 and 7000 series.

During June and July 1997, the OU-6 RI baseline ground-water samples were analyzed in accordance with the NYSDEC 1995 ASP using the following SW-846 methods.

- TCL VOCs - USEPA Method 8260A;
- TCL SVOCs - USEPA Method 8270B;
- PCBs - USEPA Method 8081; and
- TAL metals - USEPA Methods 6010 and 7000 series.

The OU-6 baseline ground-water samples were additionally analyzed for the following wet chemistry parameters in accordance with the Methods of Chemical Analysis of Water and Wastes (USEPA, 1983).

- Chloride - Method 325.2; and
- total dissolved solids (TDS) - Method 160.1.

Ground-water samples collected by the New York City Transit Authority's consultant and split with Roux Associates on February 6 and 21, 1997, March 27, 1997, November 14, 1997 and April 9, 1998 were analyzed according to the NYSDEC 1995 ASP using the following SW-846 methods.

- Priority Pollutant Base/Neutrals - USEPA Method 8270;
- PCBs - USEPA Method 8081 (USEPA Method 8082 for the April 9, 1998 analyses); and
- total suspended solids (TSS) – USEPA Method 160.2.

The ground-water samples collected from MW-35 on November 14, 1997 were additionally analyzed for TCL VOCs (USEPA Method 8260).

2.2 Scopes of Work

Since completion of the Phase I RI, Roux Associates has performed the following OU-6 RI-related work at the Yard:

- IRM System Monitoring Within Area 1;
- Delineation of the Off-Site Extent of the Separate-Phase Petroleum Accumulation in Area 1;
- Investigation and Abandonment of the UST Located in Area 2;
- Phase II RI;
- Phase II RI Addendum;
- Limited Phase II Environmental Site Assessment (i.e., HSTF S&I Building/OU-1 area);
- Focused RI for OU-2;
- Baseline Ground-Water Sampling; and
- Split Sampling for the Transit Authority's 63rd Street Tunnel Project.

As previously discussed, to more completely understand the current conditions at the Yard, all ground-water results from the above-referenced work are summarized in the nature and extent section of this report. The scopes of work that apply to ground water are detailed in Appendix G and summarized below.

2.2.1 IRM System Monitoring Within Area 1

Water-level and product thickness measurements were collected from Area 1 monitoring wells between July 1991 and February 1997 as part of the IRM System Monitoring Program. These water-level measurements have been included in Table 2 and incorporated into the hydrographs in Appendix H.

2.2.2 Delineation of the Off-Site Extent of the Separate-Phase Petroleum Accumulation in Area 1

The off-site delineation work to define the extent of separate-phase petroleum migration north of the Yard included:

- installing Monitoring Wells MW-35 and MW-36 to determine if the sewer line affected ground-water flow or the migration of separate-phase petroleum; and
- inspecting Monitoring Wells MW-20, MW-35 and MW-36 for the presence of separate-phase petroleum.

The results of the off-site delineation work have been incorporated into the extent of the separate-phase petroleum accumulation shown on Plates 1 through 6, and is discussed in Section 4.1.

2.2.3 Investigation and Abandonment of the UST Located in Area 2

To characterize ground-water quality downgradient of the UST, Monitoring Well MW-41 was installed on October 30, 1991 approximately 30 feet northwest (hydraulically downgradient) of the UST (Plate 1). One week after development, a ground-water sample was collected for TCL VOC analysis.

2.2.4 Phase II Remedial Investigation

With respect to OU-6, the Phase II RI was designed to:

- further delineate the extent of contaminants detected during the Phase I RI;
- determine if migration of contaminants in ground water is occurring either onsite or offsite;
- develop additional information regarding the hydraulic relationship between the shallow deposits and the deeper Upper Glacial aquifer underlying the Yard; and
- confirm the analytical results presented in the Phase I RI report.

Three of the Phase II RI scope of work field tasks included OU-6 work.

- Task I: Additional Delineation Investigation;
- Task II: Investigation of the Upper Glacial Aquifer; and
- Task IV: Confirmatory Sampling.

These tasks are discussed briefly in the following sections.

2.2.4.1 Task I: Additional Delineation Investigation

This task consisted of an additional investigation of hydrogeologic, soil quality, and ground-water quality conditions at the Yard to further delineate the extent of known contamination in areas of concern and to delineate potential contaminant source areas identified in the Phase I RI. The OU-6 investigation consisted of:

- installing eight additional monitoring wells and two temporary wellpoints;
- sampling 11 monitoring wells and two temporary wellpoints; and
- collecting a comprehensive round of water-level measurements (February 8, 1993).

Ground-water quality sampling is summarized in Table 3.

2.2.4.2 Task II: Investigation of the Upper Glacial Aquifer

This task consisted of a hydrogeologic investigation to:

- determine the relationship between the shallow deposits and the deeper Upper Glacial aquifer;
- determine vertical hydraulic gradients and deeper ground-water flow patterns; and
- characterize ground-water quality in the Upper Glacial aquifer.

These objectives were accomplished by installing and sampling two deep and nine shallow monitoring wells.

2.2.4.3 Task IV: Confirmatory Sampling

The goal of this task was to confirm the usability of portions of the analytical data collected during the Phase I RI, as presented in the October 5, 1991 Revised Data Usability Report (Roux Associates, Inc., 1991). This included collecting and analyzing five ground-water samples (MW-1, MW-23D, MW-25, MW-27 and MW-29) that duplicate the sampling and analyses performed as part of the Phase I RI. Confirmatory ground-water samples were collected from previously sampled monitoring wells.

2.2.5 Phase II Remedial Investigation Addendum

The objectives of the Phase II RI Addendum were to complete the previously postponed Phase II RI tasks and to adequately delineate (using permanent monitoring wells) the extent of the separate-phase petroleum accumulation recently detected to the east and southeast of the previously delineated accumulation. The Addendum scope of work with respect to OU-6 included the following:

- completion of the field work previously proposed for Area 1 (i.e., installation and sampling of one shallow and three deep monitoring wells) in the August 5, 1992 work plan for the Phase II RI;
- installation and sampling of 13 monitoring wells to delineate the nature and extent of the separate-phase petroleum accumulation in Area 1 including the recently detected area south of the Metro Shop;
- proper abandonment of Monitoring Wells MW-24 and MW-26 that were found during the Phase II RI to have been destroyed;
- installation and sampling of one shallow monitoring well to replace the destroyed Monitoring Wells MW-24 and MW-26;
- installation and sampling of one deep monitoring well in a cluster with the MW-24 and MW-26 replacement well to further characterize the hydraulic relationship between the shallow deposits and the deeper Upper Glacial aquifer;
- resampling of three monitoring locations to verify the absence of dissolved PCBs in ground water; and
- installation and sampling of a temporary wellpoint (TW-3) in the vicinity of MW-26.

The scope of work regarding OU-6 was divided into the following four tasks:

- Task 2: Monitoring Well Abandonment;
- Task 3: Monitoring Well Installation;
- Task 4: Water-Level Measurements; and
- Task 6: Sampling and Analysis.

2.2.5.1 Task 2: Monitoring Well Abandonment

Monitoring Wells MW-24 (located along the loop track) and MW-26 (Car Washer Area) were abandoned on November 11, 1993 as part of the Phase II RI Addendum field work (Plate 1).

2.2.5.2 Task 3: Monitoring Well Installation

Thirteen monitoring wells to replace the Geraghty & Miller-installed monitoring wells located in Area 1 and Monitoring Well MW-61 that replaces Monitoring Wells MW-24 and MW-26 located along the loop tracks were installed as part of the Phase II RI Addendum. In addition, a deep well (MW-62D) was installed as a cluster with shallow Monitoring Well MW-61. At the request of the NYSDEC, a temporary wellpoint (TW-3) was also installed in the immediate vicinity of MW-26 (abandoned) so that a ground-water sample could be collected, as proposed for MW-26 as part of the Phase II RI.

2.2.5.3 Task 4: Water-Level Measurements

Following installation of the new monitoring wells, two comprehensive rounds of water-level and separate-phase petroleum thickness measurements (February 1, 1994 and June 14, 1994) were performed at all specified monitoring wells (i.e., all existing monitoring wells in Area 1 except Geraghty & Miller wells, all newly-installed replacement wells, all newly-installed additional delineation wells and the newly-installed remaining Phase II RI wells).

2.2.5.4 Task 6: Sampling and Analysis

Ground-water samples were collected from 12 monitoring wells and one temporary wellpoint as part of the Phase II RI Addendum. All samples were analyzed using the USEPA and NYSDEC ASP methods specified in the Addendum work plan (Roux Associates, Inc., 1993a).

2.2.6 Limited Phase II Environmental Site Assessment

From April 9 to May 9, 1996, an intrusive field investigation was performed at the proposed HSTF S&I Building footprint (i.e., OU-1) and adjacent portions of the Yard. With respect to OU-6, monitoring wells, piezometers, and temporary wellpoints were installed, ground-water samples were collected and analyzed, and water levels were measured. Summaries of the scope of the investigation are described below.

2.2.6.1 Confirmation of Separate-Phase Petroleum Delineation

To confirm that the location of the separate-phase petroleum accumulation had not changed in the vicinity of OU-1, five hand borings (TP-1 through TP-5) were completed to approximately two feet below the water table on April 9, 1996. The boreholes were left open for approximately one hour and the presence of petroleum, if any, was noted. Finally, the borings were completed as temporary wellpoints.

2.2.6.2 Monitoring Well and Piezometer Installation and Construction

To further evaluate hydrogeologic and ground-water quality conditions in and around OU-1, six monitoring wells (MW-64 through MW-68, and MW-69D) were installed outside the proposed HSTF S&I Building footprint between April 19 and April 24, 1996. Additionally, two soil boring locations (TP-6 and TP-7) within the proposed HSTF S&I Building footprint were completed as 2-inch diameter temporary piezometers. Monitoring well and temporary piezometer construction details are summarized in Table 1.

2.2.6.3 Water-Level and Separate-Phase Petroleum Thickness Measurements

On May 2, 1996, water-level and separate-phase petroleum thickness measurements were performed to determine current ground-water elevations and ground-water flow patterns and to determine the location of the separate-phase petroleum accumulation in the vicinity of the proposed HSTF S&I Building.

2.2.6.4 Ground-Water Sampling

On May 2, 1996, Roux Associates collected ground-water samples from five new monitoring wells (MW-64 through MW-68) and three previously-installed monitoring wells (MW-57, MW-59 and MW-63) surrounding the proposed HSTF S&I Building footprint. Due to a well development delay, MW-69D was sampled on May 9, 1996.

2.2.7 Focused Remedial Investigation for OU-2

As part of the intrusive field investigation performed in OU-2 on March 24 and 25, 1997, three 2-inch diameter monitoring wells (TP-8 through TP-10) were installed to evaluate ground-water elevations and flow directions. These wells were eventually incorporated into the OU-6 RI and used to develop ground-water quality data. Monitoring well construction details are summarized in Table 1.

2.2.8 Baseline Ground-Water Sampling

Monitoring wells installed during the Focused RI for OU-2 were developed and sampled as part of this scope of work for OU-6. Water-level measurements were collected from all usable Yard wells on June 17 through 19, 1997. From June 18 through 20, 1997, Roux Associates collected baseline ground-water samples in accordance with a June 2, 1997 letter to the NYSDEC (Roux Associates, Inc., 1997b) and the sampling procedures detailed in the Phase II Addendum work plan (Roux Associates, Inc., 1993a). All active monitoring wells and temporary piezometers at the Yard that did not contain evidence of separate-phase petroleum were sampled for TCL VOCs, TCL SVOCs, PCBs and TAL metals according to the NYSDEC 1995 ASP. Thirty-two monitoring wells and three temporary piezometers were sampled. Samples were also analyzed for TDS and chloride.

2.2.9 Split Sampling for the Transit Authority's 63rd Street Tunnel Project

As part of the Transit Authority's 63rd Street Tunnel project, a major dewatering of the Upper Glacial aquifer is being performed along Northern Boulevard in close proximity to the Yard. This dewatering, which began in mid to late 1996, may be affecting ground-water flow directions and hydraulic gradients in the northern portion of the Yard. Under the "special conditions" section of their dewatering permit (#2-6304-009/00001), the Transit Authority is monitoring the effects of the dewatering, including periodically sampling two Yard wells near the area of pumping. In an agreement with Amtrak, the Transit Authority's consultant collects samples from Monitoring Wells MW-19 and MW-35, and provides split samples to Amtrak's consultant to confirm the Transit Authority's analytical program. Ground-water samples from Monitoring Wells MW-19 and MW-35 were collected by Louis Berger and Associates, Inc. (an Environmental company working for the Transit Authority) and split with Roux Associates on the following dates: February 6 and 21, 1997, March 27, 1997, November 14, 1997 and April 9,

1998. Roux Associates' samples were shipped to IEA or ICM for Priority Pollutant base/neutrals, PCBs, and TSS analyses. The November 14, 1997 sample collected from MW-35 was additionally analyzed for TCL VOCs.

Since these samples were designed to confirm the Transit Authority's dewatering analytical program rather than augment the RI, the analytical results are not detailed in Section 4 (i.e., Nature and Extent of Contamination) and are not included in the OU-6 RI tables. Roux Associates compared the results of the split samples (analyzed by ICM) with the Transit Authority's samples. The comparison indicates good agreement between both sets of VOC and SVOC data; therefore, the organic split sample results were considered confirmatory data for the MW-19 and MW-35 ground-water samples collected during the comprehensive RI sampling rounds. These data are discussed with respect to the RI findings in Section 7. However, the PCB results are inconsistent between the two laboratories. The poor agreement is attributed to the very high turbidity observed in the samples. Since PCB detections in turbid samples are indicative of PCBs adsorbed to particulates as opposed to dissolved PCBs, these data are not discussed further. The split sample results are included in Appendix I.

3.0 PHYSICAL CHARACTERISTICS OF THE YARD

Physical characteristics of the Yard, including surface features, geology and hydrogeology, have been investigated throughout the RI process and are discussed below.

3.1 Surface Features

The Yard encompasses approximately 105 acres and lies in a basin-like area with ground elevations that range from approximately 10 to 25 feet below the surrounding land surface. The topography is generally flat and slopes gently to the west. The Yard topography and drainage patterns are strongly influenced by the large number of railroad tracks and bulkheaded areas throughout the Yard. Overland surface runoff does not appear to be a source of contamination to adjacent properties.

The Yard is underlain by a combined sanitary/storm sewer drainage system, consisting of two drainage subsystems that connect catch basins located throughout the Yard. The primary subsystem serves approximately 90 percent of the Yard. Storm water from the primary subsystem leaves the Yard to the north, approximately 360 feet west of Honeywell Street. The secondary drainage subsystem is located in the southwest corner of the Yard and services approximately 10 percent of the Yard. Storm water from the secondary subsystem exits the Yard to the south, approximately 360 feet west of the intersection of Skillman and Thompson Avenues.

OU-3 discharges storm-water runoff into the primary sewer drainage system from the following identified sources:

- storm-water runoff into catch basins located throughout OU-3;
- water from service bays Pit 3 and Pit 4 located directly north of the Engine House; and
- water from the service bay located in the Metro Shop.

In OU-3, much of the sewer appears to be located below the water table, and storm-water runoff with sheens was observed flowing into some of the catch basins during periods of precipitation.

3.2 Geology

Published geologic data, historical maps and documents, and geologic logs for borings drilled during the RI process were evaluated to define the current geologic conditions observed at the Yard.

3.2.1 Regional Geology

The Yard is located within the Atlantic Coastal Plain Physiographic Province. The regional subsurface geology consists of unconsolidated sand, silt, clay and gravel deposits that overlie crystalline bedrock. The strata in the area dip gently to the southeast, following the topography of the bedrock surface (Soren, 1978). Boreholes drilled within northwestern Queens County indicate that the unconsolidated deposits are predominantly Upper Pleistocene glacial deposits that range from approximately 30 to 150 feet in thickness. These borehole logs also indicate that Lower Pleistocene deposits, consisting of the Jameco gravel overlain by the Gardiner's clay unit, may be discontinuously present beneath the Yard. These Lower Pleistocene deposits unconformably overlie bedrock.

A thin veneer of recent and Holocene deposits overlie the Upper Pleistocene deposits. Unconsolidated Upper Pleistocene glacial (ground moraine) deposits of unstratified, poorly sorted mixtures of sand and silt with some gravel and cobbles (Buxton, et al., 1981) overlie the Lower Pleistocene deposits (where present), which overlie crystalline bedrock. The saturated portion of the Upper Pleistocene deposits form the Upper Glacial aquifer of Long Island.

3.2.2 Yard Geology

The geologic logs of soil borings drilled on the Yard during the RI process indicate that the Yard is underlain by the following units (in order by increasing depth): fill (where present), recent and Holocene deposits (where present), Upper Pleistocene glacial deposits (including both till and channel deposits), and crystalline bedrock. Fill activities, which were part of major topographic changes engineered at the Yard, are summarized below.

Fill and Historical Topographic Changes

The fill is predominantly comprised of reworked glacial deposits (unstratified sand, silt, clay and gravel) and railroad ballast (including cinders and ash), with lesser amounts of ash, cinders and construction debris. With the exception of paved areas and land occupied by buildings, the railroad ballast is ubiquitously present at land surface throughout the Yard. As discussed below, additional information has been obtained that indicates that between 1906 and 1910 Upper Pleistocene glacial deposits were excavated from topographically high areas of the Yard and re-deposited as fill in lower lying areas of the Yard. However, during Roux Associates' earlier investigations of the Yard, these reworked glacial deposits were often visually indistinguishable from the underlying unstratified glacial deposits, since geologically they are the same formation. In addition, many factors indicated large volumes of fill including early reports that the Yard was a reclaimed marshland, the construction of the elevated LIRR right-of-way, and several extensive bulkheaded areas throughout the Yard. Based on this information, the Phase I RI reported that the entire Yard was underlain by fill, ranging in thickness from 8 to 27 feet. However, documentation describing the origin of the current topography has recently been obtained and is summarized below.

During evaluation of the geologic and hydrogeologic data for the Yard, two historical topographic maps were obtained for reference: the first covering western Queens dated 1890 (Julius Bien & Co., 1890), and the second covering the Yard and surrounding area dated December 1906 (Pennsylvania Tunnel and Terminal Railroad Company, 1906). In addition, a Chief Engineering Report (Pennsylvania Tunnel and Terminal Railroad Company, circa 1910) and associated cross-sections of the Yard (dated August 16, 1907) describe the topographic changes implemented at the Yard between December 1906 and August 1909. Utilizing the engineering report, topographic maps, Amtrak-supplied 1910 and 1917 Yard maps, and recent area maps, a comparison was made between the historical and current topographic features of the Yard. This comparison indicated that:

- the majority of topographic changes that occurred at the Yard took place between December 1906 and August 1909;
- current land surface elevation throughout much of the eastern half of the Yard (i.e., east of Honeywell Street) is actually lower than pre-development elevation;

- current land surface elevation throughout much of the western half of the Yard (i.e., west of Honeywell Street) is actually higher than pre-development elevation;
- two former surface-water bodies at the Yard have been filled; and
- current elevation of the LIRR main line is actually higher than the pre-development (1890) elevation.

The topography shown on the 1890 map for the land now occupied by the Yard is much different than present topographic conditions (Figure 2). A wetland existed along Northern Boulevard (formerly Jackson Avenue) near the northeast corner of the Yard. The 1890 map also indicates that Dutch Kills flowed through the western portion of the Yard, flowing southwest to Newtown Creek. Approximately 750 feet east of Dutch Kills, land surface begins a rapid increase from less than 10 to greater than 60 feet above mean sea level west of Honeywell Street. Although this topographic high is still present south of the Yard, the mound no longer exists across the Yard. West of Honeywell Street land surface gradually sloped to the north, from a high elevation of approximately 80 feet above mean sea level along Skillman Avenue (designated "Skilman Avenue" on the 1890 map) to a low of about 30 feet above mean sea level at the wetland along Northern Boulevard (designated "Jackson Avenue" on the 1890 map).

The natural topography of the Yard still plays an integral role in the ground-water flow patterns, hydraulic gradients, and saline conditions occurring at the Yard, as will be discussed in Sections 3.3.1 and 3.3.2.

A Chief Engineering Report (Pennsylvania Tunnel and Terminal Railroad Company, circa 1910) describes the topography (and acreage) of the Yard prior to December 1906, when major construction began at the Yard. A 40-acre swamp was located west of Honeywell Street, with the remaining 168 acres of the Yard consisting of "rolling ground" with elevations from "10 to 70 feet above the swamp." Existing data indicate that major topographic changes took place at the Yard between 1906 and 1910, bringing the Yard close to its present, topographic condition. These changes are discussed below.

Cross-sections of the Yard dated August 1907 show both pre-construction and post-construction profiles of the Yard. The construction consisted of moving railroad tracks, grading the Yard, and constructing bridges, roads and buildings. Natural Upper Pleistocene glacial deposits were excavated from parts of the Yard and deposited as fill in other parts of the Yard to create the current, generally flat topography. Part of the construction involved moving the LIRR passenger tracks to extend across the swamp (filling the swamp) and connect with the old passenger tracks west of Hunter's Point Avenue. During the construction the following areas were excavated:

- the loop track under LIRR main line and south of LIRR main line;
- the north portion of Yard both east and west of 39th Street (formerly Harold Avenue);
- beneath the 39th Street bridge (approximately from the LIRR main line to Skillman Avenue) to accommodate the main line and loop tracks;
- the north part of the Yard (east of Queens Boulevard) to create the Multiple Unit Yard; and
- from the retaining wall between the north and south yards south to the LIRR main line, to accommodate the body tracks and buildings, and to create the Pullman and Coach Yard.

The following areas were filled with the excavated Upper Pleistocene glacial deposits.

- The LIRR main line east of the Yard to bridge 43rd Street (formerly Laurel Hill Avenue);
- 39th Street (formerly Harold Avenue) to create the 39th Street bridge between Northern Boulevard (formerly Jackson Avenue) and Skillman Avenue, and the 39th Street ramp into the Yard;
- the north part of the Yard (west of Queens Boulevard) to create the Multiple Unit Yard;
- the swamp associated with Dutch Kills to accommodate the Multiple Unit Yard, Pullman and Coach Yard, and the LIRR main line; and
- Meadow Street to create the Thompson Street bridge.

Holocene Deposits

In the southwestern portion of the Yard, a Holocene wetland deposit was encountered below the fill and above the Upper Pleistocene formation. This deposit, which is the buried Dutch Kills Creek and swamp, consists of organic silty clay and meadow mat. As a result of filling Dutch Kills, the Dutch Kills drainage was culverted beneath the northwest corner of the Yard, through a 48-inch diameter sewer line. This sewer line is charted on the Amtrak-supplied 1910 Yard map.

Upper Pleistocene Deposits

As previously described, the Upper Pleistocene glacial deposits consist mainly of ground moraine deposits; unstratified, poorly sorted mixtures of sand, silt, clay and gravel. Based on geologic logs for seven deep boreholes drilled at the Yard, an approximately 4-foot thick cobble zone is located in the subsurface at locations MW-40D, MW-44D and MW-48D. The cobble unit is encountered at an elevation of approximately 2.3 feet above mean sea level at MW-48D, and deepens to the west, where it is encountered at approximately 18 feet below mean sea level at MW-44D. This unit may be a relict stream channel deposit that was formed by glacial meltwaters. Based on 1997 ground-water quality data, a narrow band of saline ground water occurring in the northern part of the Yard closely correlates with this cobble layer. These data suggest that the cobble layer is a narrow, yet continuous buried channel deposit beneath the Yard, extending from the former Dutch Kills Creek and swamp (near MW-44D) east to the buried wetland in the northeast corner of the Yard in the vicinity of MW-48D (Plate 4).

Bedrock

Based on published data, the crystalline bedrock is of Precambrian age and consists of folded and faulted gneisses and schists that were eroded to a peneplain prior to deposition of the overlying glacial deposits (Soren, 1978). Based on information obtained from a file and well search at the NYSDEC, the bedrock surface appears to be highly irregular in this area. Boreholes drilled adjacent to the Yard indicate that the depth to bedrock ranges from approximately 30 to 150 feet bls (i.e., 10 to 130 feet below mean sea level). As part of the New York City and New York State Departments of Transportation (NYCDOT and NYSDOT) reconstruction of the Queens Boulevard bridge over Sunnyside Yard, eight boreholes were drilled to the bedrock surface. The depth to bedrock ranged from 50 to 86 feet below land surface (Environmental Planning &

Management, Inc., 1997). These depths are estimated to correspond to 40 to 70 feet below mean sea level, with bedrock deepening to the south. As part of Roux Associates' additional work at the Yard one borehole (P-3D), located approximately 15 feet from Monitoring Well MW-40D, was drilled to the bedrock surface. Bedrock was encountered at a depth of 74 feet (53 feet below mean sea level). The circa 1910 Chief Engineering Report stated that bedrock was exposed in the stream bed of Dutch Kills Creek, near the south abutment of the Thompson Avenue bridge and under the LIRR freight tracks on the north side of the Yard. This report also states that bedrock was generally located 30 to 50 feet beneath the swamp (during approximately 1907).

3.3 Hydrogeology

Published hydrogeologic data and Yard-specific water-level elevation and aquifer test data were evaluated to define the current hydrogeologic conditions observed at the Yard. These data were used to prepare water-level elevation maps and hydrographs, calculate horizontal and vertical gradients, estimate the hydraulic coefficients, and calculate ground-water flow rates.

3.3.1 Regional Hydrogeology

Ground water in the area occurs under water-table (unconfined) conditions in the Upper Glacial aquifer. Regional ground-water flow in the area is to the northwest, eventually discharging to the East River approximately one mile northwest of the Yard (McClymonds and Franke, 1972). Vertical flow within the aquifer changes from a downward flow in central Queens to an upward flow nearing the East River, where ground water discharges. The published horizontal hydraulic conductivity of the Upper Glacial aquifer in Queens County ranges from 214 feet per day (McClymonds and Franke, 1972) to 270 feet per day (Franke and Cohen, 1972).

To obtain historical pumping and ground-water flow data for northwestern Queens, Roux Associates performed a Freedom of Information Act (FOIA) file and well search at the NYSDEC offices. This search identified numerous wells and test borings within a 2-mile radius of the Yard. Well construction details, date of installation, geologic logs, abandonment information, pumping/injection rates, historical water-level elevations, general water quality and water use were provided on a well completion report for many of these wells. Geologic logs, including the depth to bedrock, were available for many of the test borings. A summary of the information obtained from the well search is included in Appendix J.

Although pumping information and the status of the well was provided on many of the well completion forms, according to the NYSDEC this information has not been updated in many years. From the available well information, approximately 21 Upper Glacial aquifer wells may still be active. Of these 21 Upper Glacial wells, five are described as being diffusion wells, while the remainder are pumping wells. These pumping wells are (or were) predominantly used to supply water for car washing, with a smaller number of wells used to supply cooling water. Approximately ten of the bedrock wells identified during the well search are potentially active pumping wells. All wells that were active upon last inspection (for which the NYSDEC was unable to supply dates) were installed between 1924 and 1966. This suggests that many of these "potentially" active wells may no longer be in use.

In addition to the FOIA search, hydrogeologic information for northwestern Queens was solicited from the United States Geological Survey (USGS). During the RI process, Roux Associates discussed the hydrogeology of the area with Julian Soren, who has performed numerous studies on Long Island geology and hydrogeology. Mr. Soren provided Roux Associates with information regarding pumping wells in northwestern Queens County. Water-level data were obtained for USGS observation well Q-3122, located approximately 1,400 feet north of the Yard. A hydrograph of these data indicates that water levels have fluctuated more than 3 feet since 1982 (Fanning, Phillips & Molnar Engineers, 1992).

Published water-level data for Long Island show that from the early 1930s to about 1960 the water table within Kings County and western Queens County was depressed to elevations below sea level due to over pumpage. The cone of depression caused significant salt-water intrusion into the Upper Glacial and confined aquifers beneath these areas, and as far inland as the center of Kings County (Smolensky, 1983). Historical data for wells near the Yard indicate that salt-water intrusion also affected the aquifers beneath the Yard. In documentation obtained during the FOIA search, two bedrock wells (Q-173 and Q-58) are noted as having brackish water conditions during 1925 and 1932, respectively. Both wells are located northeast of the Yard, with well Q-173 being the closest (within 500 feet of the Yard). Due to the corrosive nature of the water, well Q-173 went out of use around 1921 and well Q-58 eventually went dry in 1936. However, published data indicate that by the late-1950s the cone of depression within Queens County had recovered (Smolensky, 1983). Current water-level elevations at the Yard range from 8 to 23 feet above mean sea level, precluding salt-water intrusion in this area. However, the effects of the historical salt-water intrusion can still be detected in ground-water quality, which exhibits elevated concentrations of sodium, chloride and total dissolved solids (Soren, 1971). May 1997 data presented in this report indicate that saline ground-water conditions still exist beneath much of the Yard.

Currently, extensive pumping of the Upper Glacial aquifer is being performed for the New York City Transit Authority's 63rd Street Tunnel Project. This dewatering, which began in mid to late 1996, is being performed along Northern Boulevard in close proximity to the Yard and may be affecting ground-water flow directions and hydraulic gradients in the northern portion of the Yard.

Regional ground-water quality of the Upper Glacial aquifer is characterized as having a wide range of iron and manganese concentrations (Buxton, et al., 1981). Concentrations of iron and manganese increase as conditions become anoxic (i.e., as the dissolved oxygen content decreases). Anoxic conditions are typically associated with swamp or wetland deposits, such as those buried in the northeastern and western portions of the Yard.

3.3.2 Yard Hydrogeology

Ground water beneath the Yard occurs under water-table (unconfined) conditions. The water table lies between 1 and 15 feet below land surface and occurs in either fill deposits or the Upper Pleistocene glacial deposits. The saturated Upper Pleistocene deposits comprise the Upper Glacial aquifer. Beneath the Yard, the saturated fill deposits and the shallow Upper Glacial aquifer were not always distinguishable, and are, therefore, collectively referred to as shallow deposits (which contain the water table). Deeper wells at the Yard (designated by a "D") are screened approximately 25 feet below the water table, but are still within the Upper Glacial aquifer.

During the OU-6 RI, water-level measurements were collected from monitoring wells at the Yard on the following dates: February 8, 1993, February 1, 1994, June 14, 1994, May 2, 1996 (limited number of wells), and June 17 through 19, 1997, with frequent measurements collected from July 1991 to November 1995 as part of IRM system monitoring. Water-level elevations were then computed relative to the North American Vertical Datum (NAVD) 1988 mean sea level (Table 2). Ground-water flow patterns for the water table and deeper Upper Glacial aquifer at the Yard during June 1997 are shown in Plates 2 and 3, respectively.

The water-level data collected during the OU-6 RI (as described above) were used to prepare hydrographs. For each monitoring well at the Yard that has been gauged more than five times since completion of the Phase I RI, a hydrograph was prepared to illustrate water-level fluctuations over time (Appendix H). For monitoring wells that contain separate-phase petroleum, a graph of product thickness fluctuations over time is included with the hydrograph.

From February 1994 through February 1995, monthly water-level measurements were collected (with the exception of January 1995). These data indicate that the seasonal high water table occurs during February (winter), and the seasonal low water table occurs during June (summer). During the gauging period (July 1991 through June 1997), the maximum water-level fluctuation measured has been 2.2 feet within Monitoring Well MW-30, which is the Yard well nearest to the point where Dutch Kills resurfaces south of the Yard to eventually join Newtown Creek.

Multiple rounds of water-level measurements were taken in the well clusters at the Yard to determine vertical hydraulic gradients, ground-water flow patterns within the Upper Glacial aquifer, and the hydraulic relationship between the water table and the deeper Upper Glacial aquifer. Prior to wells MW-40D, MW-47 and MW-57 being damaged and subsequently abandoned (April 1998), eight well clusters existed across the Yard: four clusters within Area 1 (MW-19/MW-39D, MW-16/MW-23D, MW-49/MW-38D and MW-57/MW-40D) and four clusters facility wide (MW-43/MW-44D, MW-47/MW-48D, MW-61/MW-62D and MW-68/MW-69D). Water-level data for these wells are included in Table 2. Measurements obtained from Monitoring Well MW-16 were not used because the well contains separate-phase petroleum and was part of the IRM system. Vertical hydraulic gradient calculations are included in Table 4.

Ground-Water Flow Patterns

Ground water within the shallow deposits flows predominantly west beneath the Yard (Plate 2). However, between Queens Boulevard and Honeywell Street, ground water flows northerly and northwesterly toward the buried flow path of Dutch Kills Creek and/or the East River. This flow pattern was exhibited in all three comprehensive water-level rounds measured at the Yard (i.e., February 1994, June 1994 and June 1997).

The ground-water flow lines shown in Plate 2 appear to mimic the topographic contours of the 1890 map, which depict a topographic high (presumably consisting of glacial till) in the area between Queens Boulevard and Honeywell Street, and Dutch Kills Creek flowing through the western portion of the Yard. Since in-situ glacial till is much less permeable than reworked glacial till (fill), horizontal flow gradients are expected to be much steeper within the in-situ deposits. The water-level contours in the western portion of the Yard parallel the former flow path of Dutch Kills Creek (Plate 4), indicating that the buried Dutch Kills stream bed along the western edge of the Yard remains a ground-water discharge area. Water-level elevations at the Yard may also be affected by a tidal influence associated with the relict stream channel of Dutch Kills, extensive bulkheaded areas, and parking lot drainage.

Water-level elevations from the deep (i.e., "D") wells were used to prepare a water-level elevation map to determine ground-water flow patterns within the deeper Upper Glacial aquifer (Plate 3). In the deeper deposits, ground water predominantly flows west across the Yard. The area of northerly flow shown in the water-table map is not evident on the deep ground-water flow map; however, this may be an expression of the limited distribution of monitoring points, rather than natural conditions.

As shown in Plates 2 and 3, monitoring wells TP-9, TP-10, MW-30, MW-34 and clusters MW-47/MW-48D and MW-61/MW-62D were installed at hydraulically upgradient portions of the Yard. During the OU-6 RI and related work, ground-water analytical data from these wells were used to determine background ranges for metals in ground water. Additionally, data from these upgradient wells were used to determine background ground-water quality, and identify contaminants migrating onto the Yard from upgradient, off-site sources.

Horizontal Gradients

Horizontal flow gradients within the shallow deposits range from approximately 0.001 feet per foot from the Metro Shop area east to Area 14, up to 0.009 feet per foot in the northeast corner of the Yard. The average shallow horizontal flow gradient for the Yard, calculated between the eastern-most contour (22 feet) and well MW-42, is 0.004 feet per foot. An average horizontal flow gradient for the Yard of 0.004 feet per foot was calculated for the deeper deposits between the eastern-most contour (18 feet) and well MW-44D. These values are indicative of a relatively flat water-table surface.

When compared to the geologic features of the Yard, lower horizontal gradients (i.e., a flatter water-table or potentiometric surface) appear to correspond with areas of the Yard known to have been filled. These filled areas generally contain much less compact and, therefore, more permeable materials than the undisturbed glacial deposits. These areas include the western portion of the Yard north of the LIRR right-of-way, and the central portion of the Yard between the Turntable and Area 17. Areas of the Yard showing steeper horizontal gradients (i.e., less permeable deposits) include the northeast portion of the Yard, and the southwest portion of OU-3.

Vertical Gradients

The vertical gradients at each well cluster were calculated according to the following formula.

$$\frac{[Water - Level\ Elevation\ (shallow\ well)] - [Water - Level\ Elevation\ (deep\ well)]}{[Elevation\ of\ Screen\ Center\ (shallow\ well)] - [Elevation\ of\ Screen\ Center\ (deep\ well)]}$$

Based on this formula, a negative number represents an upward gradient, and a positive number represents a downward gradient. Vertical gradients were calculated using the February 8, 1993 measurements for the three clusters that existed at that time. These calculations (Table 4) indicate the following:

- at upgradient cluster MW-47/MW-48D, ground water is flowing downward at an approximate vertical gradient of 0.0801 feet per foot (ft/ft);
- at OU-3 cluster MW-16/MW-23D, the vertical direction of ground water cannot be determined with any certainty due to the significant separate-phase petroleum thickness present in Monitoring Well MW-16; and
- at downgradient cluster MW-43/MW-44D, ground water is flowing slightly upward with an approximate vertical gradient of -0.0030 ft/ft.

An additional round of water levels was completed at the Yard on June 14, 1994. These data were utilized to determine vertical gradients for all newly-installed clusters and confirm the vertical gradients previously calculated for clusters MW-43/MW-44D and MW 47/MW 48D. As previously stated, vertical gradients were not calculated for cluster MW 16/MW-23D due to the significant separate-phase petroleum thickness within Monitoring Well MW-16. The June 1994 data indicate that:

- at upgradient cluster MW-47/MW-48D, ground water is flowing downward at an approximate vertical gradient of 0.1212 ft/ft, confirming the previous flow direction calculated for this cluster;
- at upgradient cluster MW-61/MW-62D, ground water is flowing slightly downward at an approximate vertical gradient of 0.0011 ft/ft;
- at OU-3 clusters MW-19/MW-39D and MW-49/MW-38D, ground water is flowing upward with approximate vertical gradients of -0.0274 and -0.0270 ft/ft, respectively, while ground water is flowing very slightly upward at -0.0008 ft/ft (nearly horizontal flow) at cluster MW-57/MW-40D; and
- at downgradient cluster MW-43/MW-44D, ground water is flowing slightly upward with an approximate vertical gradient of -0.0015 ft/ft, confirming the previous upward flow direction calculated for this cluster.

Since the installation of cluster MW-68/MW-69D, an additional comprehensive round of water levels has been measured (June 17 through 19, 1997). Vertical gradients calculated using the June 1997 data indicate similar findings to those listed above for clusters MW-47/MW-48D

(0.1287 ft/ft, downward), MW-19/MW-39D (-0.0272 ft/ft, upward), MW-49/MW-38D (-0.0254 ft/ft, upward), and MW-57/MW-40D (-0.0016 ft/ft, slightly upward). Data for the new well cluster indicate a slightly upward vertical gradient of -0.0007 ft/ft (nearly horizontal flow) at MW-68/MW-69D, similar to nearby cluster MW-57/MW-40D. However, the June 1997 data indicate vertical gradient changes as follows:

- at upgradient cluster MW-61/MW-62D, ground water was calculated as flowing slightly upward at a vertical gradient of -0.0008 ft/ft (nearly horizontal flow), reversing the previous flow direction calculated for this cluster during 1994; and
- at downgradient cluster MW-43/MW-44D, ground water was calculated as flowing slightly downward at a vertical gradient of 0.0035 ft/ft, reversing the previous flow direction calculated for this cluster during 1993 and 1994. This reversal is likely due to extensive dewatering for the New York City Transit Authority's 63rd Street Tunnel Project. The dewatering has been occurring along Northern Boulevard in close proximity to the Yard since mid to late 1996.

The downward gradients at cluster MW-47/MW-48D indicate that the area near the northeastern corner of the Yard is a ground-water recharge area. Recharge is expected in this location based on historical information, which shows that a wetland was located in this area prior to being filled. In general, vertical gradients change from downward to upward with nearing proximity to the buried flow path of Dutch Kills Creek and the East River, the ground-water discharge areas. The upward flow measured beneath OU-3, and sometimes present along the downgradient property boundary, indicate that the northwest portion of the Yard is a discharge zone. Historical documentation confirms upward flow in the central portion of the Yard. State of New York Conservation Department Water Power and Control Commission field investigation notes document four wells (approximately 30 feet deep) located onsite west of Honeywell Street between Northern Boulevard and Skillman Avenue, and describe these wells as being "partly flowing" (Appendix J). These wells were abandoned during 1926. A second group of four flowing wells was formerly located south of Skillman Avenue and west of Bridge Plaza (59th Street).

Stronger upward gradients are expected to occur with closer proximity to the buried flow path of Dutch Kills Creek and the East River. Strong upward gradients are apparent in OU-3 clusters MW-19/MW-39D and MW-49/MW-38D, when compared to the slight upward flow (nearly horizontal flow) seen at cluster MW-57/MW-40D. During the 1993 and 1994 water-level rounds, downgradient cluster MW-43/MW-44D also showed a stronger upward gradient compared to cluster MW-57/MW-40D. The upward flow observed beneath OU-3 and the downgradient portion of the Yard (with the exception of June 1997) reduces or prevents the downward migration of contaminants within the aquifer, if present. In addition, the upward gradients beneath OU-3 assist in containment of the separate-phase petroleum accumulation by reducing or preventing the petroleum's impact on underlying ground-water quality.

Hydraulic Coefficients

Hydraulic coefficients for the saturated fill deposits and Upper Glacial aquifer at the Yard were determined during the Phase I RI and a preliminary evaluation of the feasibility of dewatering should it become necessary during the construction of the proposed HSTF S&I Building. Initially, estimates of the horizontal hydraulic conductivity (K_H) were calculated from slug tests performed during the Phase I RI. These data suggest a K_H range of 0.59 to 60 feet per day (ft/d).

During the dewatering feasibility work, a pumping test and multiple slug tests were performed within OU-3 wells, and two slug tests were performed south of OU-3. Six piezometers were installed in the vicinity of Monitoring Well MW-40D prior to performing the pumping test on this well (Figure 3). Well construction and geologic logs for these piezometers are included in Appendices C and D, respectively.

Hydraulic coefficients derived from these additional slug tests suggest that K_H values beneath OU-3 are higher than those determined facility-wide, with calculated values ranging from 2.36 ft/d in the shallow deposits (MW-49) to approximately 127 ft/d in the deeper deposits (MW-40D). The higher values determined for OU-3 wells, particularly the deeper OU-3 wells, are attributed to the 4-foot thick cobble layer present in the subsurface from the vicinity of MW-44D in the west, through OU-3 and MW-40D, and continuing to MW-48D near the eastern boundary of the Yard. The following hydraulic coefficients for the water-table aquifer were calculated from data derived during the pumping test performed on well MW-40D:

- an average K_H of 462 ft/d;
- an average transmissivity (T) of 33,135 square feet per day (ft^2/d);
- an elastic storage coefficient range of 0.00001 to 0.036;

- a specific yield or water-table storage coefficient range of 0.02 to 0.280; and
- an average vertical hydraulic conductivity (K_V) of 48 ft/d.

Using the average values calculated for K_H and K_V, the anisotropy (K_V:K_H) of the water-table aquifer was calculated to be 0.10. All calculations are based on a saturated thickness of 70.59 feet determined near MW-40D.

These hydraulic coefficients suggest that the aquifer is highly transmissive. In general, higher K_H and T values were obtained for wells screened within the deeper deposits. The average K_H and T values calculated for the shallow wells/piezometers near MW-40D are 410 ft/d and 28,950 ft^2/d, respectively. The average K_H and T values calculated for the deeper deposits screened by MW-40D and nearby piezometers are 500 ft/d and 35,300 ft^2/d, respectively. Since the pumping well (MW-40D) screens a cobble layer, the calculated hydraulic coefficients were compared to published values for gravels, sand and gravel, and coarse sands of the Upper Glacial aquifer. According to McClymonds and Franke (1972), the average K_H for these deposits is 270 to 400 ft/d, which approximates the K_H value calculated for the Yard within OU-3. Since the hydraulic coefficients derived from pumping test data are considered more accurate than slug test data and agree with published values, these data are used in the ground-water flow rate calculations presented below.

Ground-Water Flow Rates

Based on data previously derived for the Yard (hydraulic conductivity values) and horizontal flow gradients calculated from recent water-level data, an average ground-water flow velocity was calculated for the Yard using the following equation:

$$v = K_H \frac{I_H}{n_e}$$

where

v = the velocity of ground water along a segment of a flow line (ft/d);

K_H = the horizontal hydraulic conductivity of the aquifer (ft/d);

I_H = the horizontal hydraulic gradient along a segment of a flow line (ft/ft); and

n_e = the effective porosity of the aquifer (dimensionless).

Using an average K_H of 410 ft/d for the shallow deposits at the Yard, an average horizontal hydraulic gradient of 0.004 ft/ft for the water table on June 17-19, 1997, and an estimated effective porosity of 0.25 (Walton, 1991), the ground-water flow velocity through the shallow deposits was calculated to be 6.6 ft/d. Using an average K_H of 500 ft/d for the deeper deposits at the Yard, an average horizontal hydraulic gradient of 0.004 ft/ft for the deeper deposits on June 17-19, 1997, and an average effective porosity of 0.35 for coarser deposits (Walton, 1991), the ground-water flow velocity through the deeper deposits was calculated to be 5.7 ft/d.

4.0 NATURE AND EXTENT OF CONTAMINATION

The nature and extent of ground-water contamination was determined from data collected during the OU-6 RI and related work at the Yard. These data consist of three rounds of ground-water sampling and analyses:

- January 1993-February 1994 (Phase II and Addendum round);
- May 1996 (Limited Phase II Environmental Site Assessment round [for the HSTF S&I Building/OU-1]); and
- June-July 1997 (OU-6 Baseline Ground-Water Sampling round).

Analytical results of the ground-water sample collected from Monitoring Well MW-41 on November 6, 1991 as part of the UST investigation in Area 2 are included in the January 1993 - February 1994 discussion.

Since the separate-phase petroleum accumulation in OU-3 affects water-level elevations and precludes ground-water sampling from numerous wells, the extent of the accumulation is described in Section 4.1 and is shown in all Plates. Although the separate-phase petroleum accumulation is part of OU-3, an evaluation of the affect of the petroleum accumulation on ground-water quality was performed as part of the OU-6 RI. A detailed description of the separate-phase petroleum accumulation delineation work will be included in the OU-3 RI report.

<u>January 1993 - February 1994</u>

The Phase II and Addendum sampling events are discussed as one sampling round because the Addendum was performed to fill in Phase II data gaps that emerged as a result of Geraghty & Miller well construction problems. Since construction errors caused the misdelineation of the separate-phase petroleum accumulation, modifications to the original Phase II were required. Therefore, the Addendum work is actually an extension of the Phase II scope of work.

From January 1993 through February 1994, ground-water samples were collected from 25 monitoring wells and three temporary piezometers at the Yard. Eleven of the 18 shallow wells were sampled for TCL VOCs, TCL SVOCs, PCBs and TAL metals. The remaining seven shallow wells were sampled for a more focused set of parameters. Parameters were chosen to either confirm previous analytical data or target the constituents of concern for a specific location. All seven deep wells were sampled for TCL VOCs, TCL SVOCs and PCBs, with three of these wells (two upgradient and one downgradient) additionally sampled for TAL metals. The temporary piezometers were analyzed for parameters that target the constituents of concern for a specific location. The sampling program is summarized in Table 3.

On November 6, 1991, a ground-water sample was collected from Monitoring Well MW-41 and analyzed for TCL VOCs. This individual sample is addressed as part of the January 1993 - February 1994 sampling round.

May 1996

During the Limited Phase II Environmental Site Assessment for the HSTF S&I Building (i.e., OU-1), eight shallow monitoring wells were sampled. One new deep well, MW-69D, was also sampled the same month. All ground-water samples were analyzed for TCL VOCs, TCL SVOCs, PCBs and TAL metals.

June-July 1997

The OU-6 Baseline Ground-Water Sampling round is the most recent and the most comprehensive of the three ground-water sampling and analysis rounds; therefore, the most weight is placed on the data from this round. A total of 35 monitoring wells were sampled. Ground-water samples from 26 shallow and seven deep monitoring wells were analyzed for TCL VOCs, TCL SVOCs, PCBs, TAL metals, chloride and total dissolved solids (TDS). The two remaining wells (MW-39D and MW-68) appeared to contain slight hydrocarbon sheens. Ground water from MW-39D was sampled and analyzed for PCBs, TDS and chloride. A ground-water sample (with a sheen) was collected from MW-68 and analyzed for PCBs only.

All detections from the three sampling rounds are discussed in Section 4.2, with the following exceptions:

- any organic compound detection qualified with a "B", indicating that the compound was detected in a field blank or laboratory blank; and
- any detection of methylene chloride or phthalate esters, which are common laboratory contaminants and not constituents of concern at the Yard.

All analytical data from the three ground-water sampling rounds are summarized in Tables 5 through 9. In addition, historical (i.e., Phase I) ground-water analytical data are provided in Appendix K.

4.1 Separate-Phase Petroleum Accumulation in OU-3

As previously discussed, an accumulation of separate-phase petroleum is present on the ground water in OU-3. Work performed at the Yard to define the nature and extent of the separate-phase petroleum accumulation will be detailed in the OU-3 RI report (i.e., Area 1 soil and separate-phase petroleum accumulation). However, since the separate-phase petroleum accumulation has the potential to affect ground-water quality and does alter water-level measurements, the extent of the separate-phase petroleum accumulation is summarized below.

The off-site extent of the separate-phase petroleum accumulation was determined by performing monitoring well installation, inspecting sumps within off-site buildings, completing hand borings, and sampling the sewer that parallels the northern property boundary. The delineation work commenced on October 15, 1991 in the presence of the NYSDEC. The results of the off-site delineation work indicated that the separate-phase petroleum accumulation had not migrated northward beyond the sewer line, was not present beneath the buildings located along Northern Boulevard, and was probably not migrating offsite in the sewer. The sewer line which parallels the northern boundary of the LIRR property is apparently acting as a physical barrier to the northward migration of ground water and the floating separate-phase petroleum accumulation.

Following completion of the Phase I RI, further delineation of the on-site extent of the separate-phase petroleum accumulation in OU-3 was accomplished by:

- completing four phases of hand borings;
- drilling 24 soil borings during the Phase II Addendum; and
- installing and gauging 13 monitoring wells during the Phase II Addendum.

The results of the additional delineation hand borings, Phases 1 through 4, indicated that the previously delineated northern, western and southwestern boundaries of the separate-phase petroleum accumulation were accurate. However, the extent of the accumulation was not fully delineated to the east and southeast. The information obtained during Phases 1 through 4 was used to modify the locations of permanent monitoring wells proposed for the Phase II RI, and determine locations of additionally required wells resulting from the newly-delineated extent of separate-phase petroleum.

Soil boring data collected from the Turntable Area indicate that separate-phase petroleum is present west of the Turntable and between the retaining walls, but is absent at a soil boring drilled approximately 115 feet west-northwest of the Turntable and north of that location. In addition, separate-phase petroleum was measured in Monitoring Well MW-60, located west of the Turntable and between the retaining walls. Based on these results and observations of surface soil, the separate-phase petroleum detected west of the Turntable is a part of the larger previously identified accumulation. Phase II data collected south of the Metro Shop indicate that separate-phase petroleum is present south of both the Metro Shop and Locker Room/Shop, but does not extend south beyond the retaining wall. Soil borings completed around former Geraghty & Miller wells MW-10 (south of the Engine House) and MW-12 indicate that the separate-phase petroleum near these wells are isolated occurrences, and not related to the previously identified separate-phase petroleum accumulation located east of the Engine House.

In addition to the soil borings, the 13 monitoring well locations in OU-3 (MW-49 through MW-60 and MW-63) were designed to confirm the extent of the separate-phase petroleum accumulation. During drilling activities, hydrocarbon odor and/or staining was observed within soil below the water table at locations MW-50 through MW-56, MW-58 and MW-60. No evidence of petroleum was noted in soil at locations MW-49, MW-57, MW-59 and MW-63. The results of February and June 1994 monitoring well gauging were used to define the areal extent of the separate-phase petroleum accumulation. Compared to previous data, the northwestern and western limits of the accumulation have not changed significantly, but have been more accurately delineated. Based on the installation of Monitoring Well MW-49, the western edge of the accumulation does not extend as far west as previously estimated. However, the upgradient edge of the petroleum accumulation now extends east to the Turntable, and southeast beyond the Locker Room/Shop to the retaining wall. The locations of Monitoring Wells MW-21, MW-55 and MW-56 appear to delineate the upgradient boundary of the separate-phase petroleum accumulation. At least nine of the 13 monitoring wells installed to confirm the extent of the separate-phase petroleum accumulation have since been destroyed by construction activities at the Yard or determined to be at risk of being damaged (i.e., within the construction envelope), with eight of these wells being subsequently abandoned during April 1998 (Table 1).

During May 1996, the southwestern extent of the separate-phase petroleum accumulation was confirmed by completing five hand borings along the previously delineated edge of the petroleum accumulation. These borings were performed as part of the Limited Phase II Environmental Site Assessment to confirm that the separate-phase petroleum accumulation did not extend beneath OU-1, the footprint of the HSTF S&I Building. The borings were finished as temporary piezometers (TP-1 through TP-5) by installing 2-inch diameter PVC well screens. This task confirmed that the previously determined extent of the separate-phase petroleum accumulation was accurate near the western portion of the Site (Plate 1). All five temporary piezometers have since been destroyed by construction activities.

Between February 1997 and April 1998, the Transit Authority sampled Monitoring Wells MW-19 and MW-35 five times as part of their dewatering monitoring program. Separate-phase petroleum was not present in these wells during the five sampling events, confirming the current delineation of the northwest corner of the separate-phase petroleum accumulation.

4.2 Ground-Water Quality

Data from all wells located within the Yard along the upgradient boundaries were used to determine background ground-water quality conditions, and identify contaminants migrating onto the Yard from upgradient, off-site sources.

To be conservative, in cases where a duplicate sample contains a concentration higher than that in the primary sample, the higher value was reported. For ease of discussion, data validation qualifiers are not included with concentrations referred to in the text. Qualifiers are included in Tables 5 through 9, and in the summary tables within the text.

4.2.1 VOCs

The following VOCs were detected in ground water during the OU-6 RI:

- benzene, toluene, ethylbenzene and xylene (BTEX);
- chlorinated solvents;
- styrene;
- carbon disulfide; and
- 4-methyl-2-pentanone (i.e., MIBK).

The following sections discuss these detections in relation to known and potential source areas. Complete VOC data are provided in Table 5.

4.2.1.1 January 1993-February 1994

During the January 1993-February 1994 sampling round, 13 shallow and seven deep monitoring wells were sampled for VOC analysis (Table 3). Two temporary piezometers (TW-1 and TW-2) were also sampled for TCL VOC analysis. A previous sample (November 6, 1991) had also been collected from MW-41 for TCL VOC analysis. Seventeen detections of VOCs occurred in ground water from 10 monitoring wells at the Yard. Eight different VOCs were detected; ethylbenzene, total xylene, and six chlorinated solvents. The chlorinated solvents consisted of 1,1,1-trichloroethane, tetrachloroethene and the following four degradation products of tetrachloroethene: 1,1,2,2-tetrachloroethane, trichloroethene, 1,2-dichloroethene (total), and 1,1-dichloroethane. VOC detections are summarized below.

VOC	Number of Wells	Range of Detected Concentrations (µg/L)	Well(s) Containing Highest Concentration
tetrachloroethene	4	3J - 23	MW-63
1,1-dichloroethane	3	2J - 3J	MW-38D, MW-63
trichloroethene	3	11 - 75	MW-44D
1,2-dichloroethene (total)	3	2J - 46	
1,1,2,2-tetrachloroethane	1	2J	
1,1,1-trichloroethane	1	1J - 2J	MW-45
ethylbenzene	1	2J	MW-41
total xylene	1	1J	MW-23D

Ethylbenzene and xylene were each detected once at concentrations below the quantitation limit, and appear to be isolated occurrences. The detection of ethylbenzene in Monitoring Well MW-41 on February 9, 1993 is most likely attributable to the former UST in Area 2, although no VOCs were detected in MW-41 ground water on November 6, 1991. The detection of xylene in MW-23D may be attributable to the overlying separate-phase petroleum accumulation being pulled into the underlying soil during drilling activities, or may be attributable to the SMP site, since BTEX concentrations up to 3,430 micrograms per liter (µg/L) were detected in SMP ground water during 1991-1992. Since the top of the screen zone in MW-23D lies more than 23 feet below the water table (and therefore below the separate-phase petroleum accumulation) and there is an upward hydraulic gradient present in OU-3, it is likely that the detection of xylene at this depth is attributable to SMP's dissolved source of BTEX and not the separate-phase petroleum accumulation.

The detections of chlorinated solvents in ground water define three distinct plumes:

1. OU-3; plume includes MW-23D, MW-38D, MW-40D and MW-63.
2. West of Honeywell Street; plume includes MW-43, MW-44D and MW-45.
3. Southeast corner of the Yard; plume includes MW-61 and MW-62D.

Based on ground-water flow patterns determined for the Yard and knowledge of the compounds used at the Yard, these detections of chlorinated solvents are not attributable to Yard operations, but rather to off-site, upgradient sources.

OU-3

Standard Motor Products, Inc. (SMP), which is located at 39th Street between Northern Boulevard and the Yard, lies hydraulically upgradient (east) of Monitoring Well MW-63 and OU-3. As documented in the Remedial Investigation Report for Standard Motor Products, Inc. (Holzmacher, McLendon & Murrell, P.C., 1992), both soil and ground water beneath the SMP site have been contaminated with chlorinated solvents. The source of this contamination appears to be the SMP loading dock area, where drum washing took place and VOCs are present in soil greater than 20 feet bls.

Per the SMP RI report, total VOCs were detected in SMP soil at concentrations of up to 35,300 micrograms per kilogram (μg/kg). However, many of the SMP soil samples were collected below the water table, which suggests that the analytical results are more representative of ground-water quality. Known contamination reportedly extends to a depth of greater than 20 feet bls at the SMP site (Holzmacher, McLendon & Murrell, P.C., 1992). All six wells installed on the SMP site contained VOCs. A total of ten different VOCs (six chlorinated solvents and BTEX) were detected beneath the SMP site (Holzmacher, McLendon & Murrell, P.C., 1992). These solvents, which include all four VOCs detected in Monitoring Well MW-63, were detected in concentrations equal to or greater than those found in MW-63 ground water. In addition, the RI report for SMP concluded that the contaminants detected at the site have migrated radially outward from the SMP loading dock in both stormwater runoff and ground water. Water-level data collected by Roux Associates indicate that ground water is flowing west (parallel to the sewer line) from the SMP site toward the northern part of OU-3 (i.e., MW-63). However, the water table is nearly flat beneath the eastern part of OU-3, causing the VOC plume to spread radially outward from its source (Plate 2). These hydrological conditions also explain the detection of tetrachloroethene in deep Monitoring Well MW-40D and the detection of 1,1-dichloroethane in deep Monitoring Well MW-38D. Although MW-23D screens ground water beneath the separate-phase petroleum accumulation, the SMP plume is the likely source of xylene in MW-23D. This is based on the fact that the screen zone in MW-23D lies more than 23 feet beneath the water table (and therefore the separate-phase petroleum accumulation), there is an upward hydraulic gradient within OU-3, and BTEX concentrations up to 3,430 μg/L were detected in SMP ground water during 1991-1992.

West of Honeywell Street

During January 1993-February 1994, a plume of chlorinated solvents was also detected west of Honeywell Street affecting Monitoring Wells MW-43, MW-44D and MW-45. Degradation products of tetrachloroethene were detected in Monitoring Wells MW-43 and MW-44D at concentrations of 13 and 123 µg/L total chlorinated solvents, respectively. Only 1,1,1-trichloroethane (2 µg/L) was detected in MW-45. During this round of sampling it was unclear whether the source of chlorinated solvents was located onsite or offsite. However, ground-water flow patterns indicate that the source of chlorinated solvents lies south to southeast of well cluster MW-43/MW-44D.

Southeast Corner

During January 1993-February 1994, a plume of chlorinated solvents was also detected at upgradient monitoring well cluster MW-61/MW-62D. Tetrachloroethene was detected in both wells at concentrations below 10 µg/L. The direction of ground-water flow at this cluster (approximately west-northwest) indicates that the chlorinated solvents appear attributable to an off-site, upgradient source.

4.2.1.2 May 1996

During May 1996, one deep and eight shallow monitoring wells in and around OU-1 (i.e., the footprint of the HSTF S&I Building), OU-2 and OU-3 were sampled and analyzed for VOCs (Table 3). As shown in Plate 1, OU-1 and OU-2 are adjacent to OU-3. Because of the proximity of these operable units, the data collected during this round extended our understanding of the VOC plume beneath OU-3 described in the preceding section.

OU-3

Three VOCs, 1,2-dichloroethene (total), tetrachloroethene, and trichloroethene (all chlorinated solvents), were detected in ground-water samples from four of the nine monitoring wells sampled (MW-63, MW-64, MW-65 and MW-67). Concentrations of total chlorinated VOCs in these four wells ranged from 3 to 7 µg/L. Compared to the previous sampling round, the concentration of chlorinated VOCs in MW-63 significantly decreased from 64 to 4 µg/L, and VOCs remained undetected in Monitoring Wells MW-57 and MW-59. Based on ground-water flow patterns determined for the north-central portion of the Yard (i.e., generally westerly) and knowledge of the compounds used at the Yard, these detections of chlorinated solvents are not attributable to Yard operations, but rather appear to be directly attributable to an off-site, upgradient source (i.e., SMP). SMP, which is located between Northern Boulevard and the Yard, lies hydraulically upgradient (east) of Monitoring Wells MW-63, MW-64, MW-65 and MW-67. As previously stated, the source of this contamination is most likely the SMP loading dock area, where drum washing took place and VOCs are present in soil greater than 20 feet bls. Because more wells were present in the eastern part of OU-3 during the May 1996 sampling round, the known areal extent of the chlorinated VOC plume has increased to the east compared to the previous sampling round.

The chlorinated solvents detected in Monitoring Wells MW-63, MW-64, MW-65 and MW-67 were detected at significantly higher concentrations at the SMP site (Holzmacher, McLendon & Murrell, P.C., 1992). As previously stated, the RI Report for SMP concluded that the contaminants detected at that site have migrated radially outward from the SMP loading dock in both stormwater runoff and ground water. Water-level data collected by Roux Associates confirms that ground water is flowing west-northwest from the SMP site; however, SMP's VOC plume is spreading radially outward from its source due to a nearly flat water table (Plate 2). As expected, concentrations of total chlorinated VOCs decrease with increasing distance from the SMP loading dock area (i.e., the source area).

4.2.1.3 June-July 1997

During June-July 1997, ground-water samples were collected for VOC analysis from 26 shallow and seven deep monitoring wells throughout the Yard (Table 3). The data from this sampling round:

- provided a better understanding of the three chlorinated VOC plumes previously identified (i.e., OU-3, west of Honeywell Street, and southeast corner of the Yard) that are migrating onto the Yard from off-site, upgradient sources;
- identified one BTEX plume migrating beneath the northeast corner of the Yard (i.e., TP-9, MW-47/MW-48D) from an off-site, upgradient source;

- identified another BTEX plume migrating beneath the Yard north of the separate-phase petroleum accumulation in OU-3 (i.e., MW-35) from an off-site, upgradient source;
- identified a potential source of 4-methyl-2-pentanone (i.e., MIBK) in MW-59;
- identified a potential source of benzene, carbon disulfide and 4-methyl-2-pentanone in MW-27; and
- identified isolated occurrences of BTEX compounds, 4-methyl-2-pentanone and other miscellaneous VOCs.

These data are discussed below.

OU-3

Compared to the previous sampling round, the areal extent of this chlorinated VOC plume has slightly decreased (i.e., chlorinated VOCs were not detected at MW-67 during this sampling round). No VOCs were detected in MW-23D ground water. Monitoring Wells MW-38D and MW-40D (within OU-3) contained low levels of chlorinated VOCs similar to those previously detected. The plume of chlorinated VOCs was also confirmed to extend along the north property boundary into MW-64 (8 μg/L) and MW-65 (13.9 μg/L [using the higher duplicate value]), as shown in Plate 5. The water table is nearly flat in the area of these wells. This water-table configuration suggests that the chlorinated VOCs are migrating radially outward (i.e., pancaking) from the source area north of the Yard (Plate 5). The source of this plume is the SMP loading dock area, as previously stated.

During the June-July 1997 sampling round, three BTEX compounds and styrene were detected at low concentrations (i.e., estimated and below the practical quantitation limit) in Monitoring Well MW-38D. MW-38D is located near the western, downgradient edge of the OU-3 separate-phase petroleum accumulation. However, the separate-phase petroleum accumulation does not appear to be the source of the BTEX detection (4.6 μg/L) in MW-38D because:

- the top of the screen zone in MW-38D is more than 26 feet below the water table (and therefore, more than 26 feet below the separate-phase petroleum accumulation);
- no VOCs were detected in ground water directly beneath the separate-phase petroleum accumulation (i.e., MW-23D) during this round of sampling;

- there is an upward hydraulic gradient at location MW-38D (-0.0254 ft/ft); and
- all VOCs, including BTEX, were non-detect in the shallow well clustered with MW-38D (i.e., MW-49).

Since SMP's VOC plume had BTEX concentrations ranging from 2,440 to 3,430 µg/L in 1991 and 1992 (Holzmacher, McLendon & Murrell, P.C., 1992), SMP is the likely source of the BTEX detection in MW-38D.

Three BTEX compounds and carbon disulfide were detected at low concentrations (i.e., estimated and below the practical quantitation limit) in Monitoring Well MW-35. MW-35 is located near the northwest, downgradient edge of the separate-phase petroleum accumulation in OU-3, and is also located north of the sewer line that parallels the northern boundary of the LIRR property. Data shows that this sewer line is apparently acting as a physical barrier to the northward migration of ground water and the separate-phase petroleum accumulation. Considering ground-water quality from other monitoring wells adjacent to OU-3, the separate-phase petroleum accumulation is not a likely source of these contaminants. A possible source of the BTEX compounds is SMP, which is also located on the north side of the sewer and is hydraulically upgradient of MW-35 (Plate 2). As previously stated, BTEX has been detected in SMP ground water at concentrations of 3,430 µg/L. If SMP is the source of the contaminants present in MW-35 ground water, these detections may indicate the leading edge of the VOC plume affecting MW-64 and MW-65. Another potential source of BTEX are the USTs associated with buildings along Northern Boulevard, although the contents of these USTs are unknown. However, evidence of actual USTs has been found only downgradient of Monitoring Wells MW-35, MW-19 and MW-39D.

Monitoring Well MW-59 contained one VOC, 4-methyl-2-pentanone (1,300 µg/L). This compound is also known as methyl isobutyl ketone, or MIBK. Based on historical information regarding chemical use at the Yard, this detection is attributable to an on-site point source.

West of Honeywell Street

The June-July 1997 data has increased the known areal extent of this plume. The plume previously encompassed Monitoring Wells MW-43, MW-44D and MW-45. Although Monitoring Well MW-45 no longer contains detectable concentrations of chlorinated VOCs, three other wells are now known to (MW-28, MW-34 and MW-42) in addition to MW-43 and MW-44D. The highest concentration of total chlorinated VOCs detected at the Yard (398 μg/L) is found in upgradient boundary Monitoring Well MW-34, located on the southern boundary of the Yard. This new data indicates that the plume migrates onto the Yard from an unknown off-site source located south of the Yard, and extends north through the Yard and offsite toward the ground-water discharge area (i.e., the buried flow path of Dutch Kills Creek). Monitoring Well MW-42 at the leading edge of this plume (i.e., north end) contains total chlorinated VOCs at a concentration of 102 μg/L. During 1993, chlorinated VOCs were not detectable in MW-42. The areal extent of this plume showing concentrations of total chlorinated VOCs is presented in Plate 5.

Southeast Corner

The plume of chlorinated VOCs that was detected in upgradient monitoring well cluster MW-61/MW-62D during the 1993-1994 sampling round has not significantly changed. During the June-July 1997 sampling round, total chlorinated VOCs were detected at 7 μg/L (MW-61) and 5.9 μg/L (MW-62D). One additional VOC, carbon disulfide, was detected in MW-62D at a low concentration (i.e., estimated and below the practical quantitation level). This well cluster is located on the southern property boundary of the Yard. Ground-water flow patterns indicate that an off-site source east to southeast of the well cluster is responsible for this chlorinated VOC plume (Plate 5).

Northeast Corner

VOCs were detected for the first time in the northeast corner of the Yard. One BTEX compound, toluene, was detected at a concentration of 0.6 μg/L in Monitoring Well MW-48D. Another BTEX compound, xylene, was detected at 0.8 μg/L in MW-47 and at 1 μg/L in TP-9. All of these VOC detections were below the quantitation limit. These BTEX detections in nearby Yard wells TP-9 and MW-47/MW-48D (located along the upgradient boundary of the Yard) indicate that a BTEX plume is migrating onto the Yard from an off-site, upgradient source. Based on the ground-water flow direction in the northeast corner of the Yard, the source or sources of these VOCs are located east of the Yard (Plate 5).

MW-27

Three significant detections of VOCs occurred in Monitoring Well MW-27; 4-methyl-2-pentanone (5,200 µg/L), benzene (130 µg/L) and carbon disulfide (110 µg/L). Based on historical information regarding chemical use at the Yard, the detection of 4-methyl-2-pentanone (i.e., MIBK) is attributable to an on-site point source. Analytical data indicate that ground water containing these three compounds has not affected adjacent or downgradient wells, and therefore appears confined to the vicinity of MW-27.

Two other wells contained detections of 4-methyl-2-pentanone during the June-July 1997 sampling round: MW-59 (1,300 µg/L, discussed as part of OU-3 above) and MW-41 (4 µg/L). The MW-41 sample contained an estimated concentration of 4-methyl-2-pentanone below the quantitation limit. The Material Control Storage Area is located upgradient of MW-41, and is therefore a potential source of this isolated occurrence of 4-methyl-2-pentanone.

4.2.2 SVOCs

The following SVOCs were detected in ground water during the OU-6 RI:

- 14 PAHs (2-methylnaphthalene, acenaphthene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, naphthalene, phenanthrene, and pyrene);
- 1,2,4-trichlorobenzene;
- 4-methylphenol;
- benzoic acid; and
- dibenzofuran.

The following sections discuss these detections in relation to known and potential source areas. As previously stated, detections of phthalate esters are not discussed since these compounds are common laboratory contaminants and not constituents of concern at the Yard. Complete SVOC data are provided in Table 6.

4.2.2.1 January 1993-February 1994

During the January 1993-February 1994 sampling round, 19 monitoring wells and one temporary wellpoint were sampled for SVOCs (Table 3). Detections of SVOCs occurred in ground water from seven monitoring wells and one temporary wellpoint at the Yard. Ten different SVOCs were detected, which included eight PAHs, benzoic acid and dibenzofuran. Concentrations of total SVOCs ranged from 0.4 to 33 μg/L, with only one detection occurring above the practical quantitation limit: 23 μg/L of 2-methylnaphthalene in MW-23D. This well also contained the highest concentration of total SVOCs (i.e., 33 μg/L). The detections in MW-23D ground water may be attributable to the overlying separate-phase petroleum accumulation being pulled into soil below the accumulation during drilling activities, or may be attributable to SMP. Five of the seven monitoring wells to contain SVOCs were located in OU-3: MW-23D, MW-35, MW-39D, MW-49, and MW-63. In addition, MW-37 is located downgradient of OU-3. Considering the proximity of these six wells to the separate-phase petroleum accumulation in OU-3, the SVOCs detected in these wells may be attributable to the separate-phase petroleum. Although no SVOC data was presented in the 1992 Holzmacher, McLendon & Murrell, P.C. report, high VOC concentrations were detected in SMP ground water during 1991-1992, including BTEX concentrations up to 3,430 μg/L. Since the source of this SMP plume is petroleum hydrocarbons, SVOCs may be present in the plume in addition to VOCs. During 1990, an area of soil (approximately 2,700 square feet) containing petroleum hydrocarbons and VOCs was delineated and excavated from the SMP property. However, SMP soil and ground-water samples were not analyzed for SVOCs. Nonetheless, the SVOCs detected in Yard ground-water samples (i.e., PAH compounds) are degradation products of petroleum hydrocarbons and, therefore, may be attributable to SMP.

Three SVOCs were detected in the ground-water sample from Temporary Wellpoint TW-3; two PAH compounds and benzoic acid. Naphthalene was detected at 1 µg/L, pyrene at 0.7 µg/L, and benzoic acid at 10 µg/L. Temporary Wellpoint TW-3 was located downgradient of Area 12 near the southeast corner of the Yard, but very close to the upgradient boundary of the Yard. The low levels of SVOCs detected in this sample may be attributable to the former Car Washer activities performed in Area 12 or to an upgradient, off-site source. However, it is important to note that this sample was collected from an undeveloped temporary wellpoint and was turbid.

The only other well containing an SVOC was MW-62D, an upgradient boundary well located in the southeast corner of the Yard. Naphthalene was detected at 0.4 µg/L. Based on ground-water flow directions at MW-62D, this detection appears attributable to an upgradient, off-site source.

4.2.2.2 May 1996

During May 1996, one deep and eight shallow monitoring wells in and around OU-1 (i.e., the footprint of the HSTF S&I Building), OU-2 and OU-3 were sampled and analyzed for SVOCs (Table 3). Five of the wells sampled contained SVOCs: MW-59, MW-63, MW-66, MW-68 and MW-69D. SVOCs detected included 13 PAHs, dibenzofuran and 1,2,4-trichlorobenzene, with all detections occurring at low concentrations (0.1 to 3 µg/L). All detections were below the practical quantitation limit. Three wells sampled during May 1996 were also sampled during the previous round (i.e., MW-57, MW-59, and MW-63). Compared to the previous sampling round, only MW-59 showed a significant change, increasing from non detect to approximately 2 µg/L total SVOCs.

Considering the proximity of MW-59 and MW-63 to the separate-phase petroleum accumulation, the very low concentrations of SVOCs in these wells may be attributable to the separate-phase petroleum. As previously mentioned, no SVOC data exist for SMP, but that site is located upgradient of wells MW-59 and MW-63 and, therefore, may be the source of the SVOC detections. The low levels of SVOCs in MW-66 appear to be attributable to SMP, the adjacent site, from which a 2,700 square foot area of soil containing petroleum hydrocarbons and VOCs was excavated during 1990. The nearby heavy equipment fueling area is the likely source of the very low levels of SVOCs detected in MW-68/MW-69D. These detections are not related to the separate-phase petroleum accumulation in OU-3.

4.2.2.3 June-July 1997

During June-July 1997, ground-water samples collected from 26 shallow and seven deep monitoring wells throughout the Yard were analyzed for SVOCs (Table 3). SVOCs were detected in eight of the wells (all shallow) sampled: MW-19, MW-27, MW-29, MW-35, MW-37, MW-41, MW-49, and MW-59. SVOCs detected included five PAHs, 4-methylphenol and dibenzofuran. All detections occurred at low concentrations (0.2 to 5 µg/L) and were below the practical quantitation limit, with one exception (i.e., 20 µg/L of 2-methylnaphthalene in MW-35).

Excluding MW-63 (which was destroyed during Yard construction activities) and MW-68 (which contained a petroleum sheen during June 1997), all wells sampled during May 1996 were sampled for SVOCs during the June-July 1997 round. Total SVOCs decreased in three of these wells (MW-59, MW-66 and MW-69D), with MW-66 and MW-69D reduced to non detectable levels. Four other wells remained non detect for SVOCs (MW-57, MW-64, MW-65 and MW-67). Therefore, only MW-59 still contained low concentrations of SVOCs compared to the previous sampling round. However, MW-68, which previously contained low levels of total SVOCs (approximately 4 µg/L), contained a petroleum sheen during June 1997. A hydrocarbon scan performed on this ground-water/sheen sample identified the product as diesel. This isolated occurrence of diesel explains the detection of total SVOCs during the previous sampling round. The nearby heavy equipment fueling area is the likely source of the diesel and occasional low detections of SVOCs. Considering the proximity of MW-19, MW-35, MW-49, and MW-59 to the separate-phase petroleum accumulation, the SVOC detections in these wells may be attributable to the separate-phase petroleum. However, it is more likely that these detections are attributable to SMP, from which a 2,700 square foot area of soil containing petroleum hydrocarbons and VOCs was excavated during 1990. As previously mentioned, no SVOC data exist for the SMP site, but that site is located upgradient of Area 1 and Monitoring Wells MW-19, MW-35, MW-49 and MW-59.

4.2.3 PCBs

The following PCBs were detected in ground-water samples during the OU-6 RI:

- Aroclor-1254; and
- Aroclor-1260.

PCBs were only detected at six out of 37 ground-water monitoring locations since 1993 and the results were reproducible at only one location (i.e., MW-25A): MW-1 (which was replaced by MW-63), MW-23D, MW-25A, MW-35, MW-46, and TW-3. Specific detections are discussed in the sections below. Complete PCB data are provided in Table 7.

4.2.3.1 January 1993-February 1994

During a January-February 1993 sampling round, four out of 11 monitoring wells sampled contained detectable concentrations of total PCBs: MW-1, MW-25A, MW-35 and MW-46. However, it was suspected that the PCBs detected in the ground-water samples were actually caused by high silt content in the turbid samples (i.e., PCBs adsorbed to particulates were being detected, as opposed to dissolved PCBs). As a result, MW-63 was installed as a replacement well for MW-1, which had a history of silting problems. During February 1994, MW-63 was sampled and Monitoring Wells MW-35 and MW-46 were redeveloped and resampled. This time, PCBs were not detected in any of the three wells, proving that PCBs are not present in ground water but are present in the soil at these locations.

On December 6, 1993, Aroclor-1254 (2.4 µg/L) and Aroclor-1260 (1.9 µg/L) were detected in Temporary Wellpoint TW-3. Based on the high turbidity of this sample, it is suspected that these PCB detections are probably attributable to suspended particles and are not representative of ground-water quality. These conditions also occurred in other Yard wells, as discussed above. But since TW-3 was a temporary wellpoint, there was no gravel pack installed around the screen zone, the wellpoint was not developed, and the wellpoint was removed following its December 1993 sampling. Therefore, redevelopment and resampling could not be performed on TW-3. However, for all monitoring wells that contained turbid ground water and associated PCBs, redevelopment and resampling proved that PCBs are not present in ground water.

During a February 1994 sampling round (the Phase II RI Addendum), no PCBs were detected in the 12 monitoring wells sampled. This includes eight monitoring wells within OU-3, four of which are downgradient of the separate-phase petroleum accumulation (MW-35, MW-38D, MW-39D and MW-49). In addition, Monitoring Well MW-37 is located downgradient of OU-3 and the separate-phase petroleum accumulation. Although PCBs were detected in a turbid ground-water sample from MW-35 on February 9, 1993, the well was redeveloped and resampled as part of the Addendum. As previously discussed, no PCBs were detected in the second (February 17, 1994), non-turbid sample.

4.2.3.2 May 1996

No PCBs were detected in ground water from the nine monitoring wells sampled (Table 3) during the May 1996 sampling round (i.e., MW-57, MW-59, MW-63 through MW-68, and MW-69D).

4.2.3.3 June-July 1997

During this sampling round, PCBs were detected in ground water from two out of 34 monitoring wells sampled (Table 3). Monitoring Well MW-23D, which screens the Upper Glacial aquifer beneath the separate-phase petroleum accumulation in OU-3, contained 0.010 µg/L of Aroclor-1260. As previously stated, this well was installed through the separate-phase petroleum accumulation and residual contamination may have been carried down by the drilling process. Monitoring Well MW-25A also contained Aroclor-1260 at a concentration of 0.019 µg/L.

During the June-July 1997 sampling round a petroleum sheen was present in Monitoring Well MW-68. However, a sample of the ground water (with a sheen) was collected and analyzed for PCBs (Table 3). As shown in Table 7, the sample contained 0.077 µg/L of Aroclor-1260. As previously discussed, a hydrocarbon scan determined the petroleum in this well to be diesel fuel. This diesel fuel is attributable to spillage in the heavy equipment fueling area, located directly upgradient of Monitoring Well MW-68. Since only virgin diesel is dispensed in the heavy equipment fueling area, the PCBs detected in the MW-68 sample are attributable to soil. PCBs bound to soil would be mobilized by contact with petroleum, such as the diesel spilled directly onto soil in the heavy equipment fueling area. The petroleum sheen in this well is further addressed in the recommendations section.

4.2.4 Metals

Since metals naturally occur in both soil and ground water, background concentrations of metals in ground water were determined for the Yard. As previously discussed, monitoring wells TP-9, TP-10, MW-30, MW-34 and clusters MW-47/MW-48D and MW-61/MW-62D were installed along the hydraulically upgradient boundary of the Yard (Plates 2 and 3). During the OU-6 RI and related work, ground-water analytical data from these wells were used to determine background ranges for metals in ground water. On-site, upgradient well data from all three rounds of sampling were used to determine the background ranges. The background ranges were compared to concentrations of metals in on-site monitoring wells so that impacts from the Yard could be differentiated from indigenous concentrations of metals in ground water. Only detections of metals that exceed the background ranges are discussed in the following sections. Complete metals data are provided in Table 8.

4.2.4.1 January 1993-February 1994

During the January 1993-February 1994 sampling round, ground water was collected from 17 monitoring wells for metals analysis (Table 3). Four of these 17 wells are background wells (i.e., MW-47, MW-48D, MW-61 and MW-62D), and therefore are not discussed further. Of the remaining 13 wells, the following eight contained at least one metal above background range: MW-1, MW-25, MW-29, MW-35, MW-43, MW-44D, MW-46 and MW-49. Eighteen of the 23 TAL metals exceeded background ranges at least once. Exceedances are tabulated below in order of frequency of exceedance.

Metal	Background Concentration (µg/L)	No. of Wells Exceeding Background	Range of Concentrations Exceeding Background (µg/L)	Well Containing Highest Concentration
Lead	21.9 JV	4	37.8 - 207	MW-35
Arsenic	3.6 B	4	5.4 B - 16.5	
Barium	275	3	330 - 1,030	MW-46
Copper	65.0 JV	3	98.1 - 421	
Iron	46,500 JV	3	50,000 JV - 152,000	
Manganese	2,650	3	3,030 - 9,410	

Metal	Background Concentration (µg/L)	No. of Wells Exceeding Background	Range of Concentrations Exceeding Background (µg/L)	Well Containing Highest Concentration
Cobalt	23.3 B	2	26.1 B - 111	
Nickel	48.1	2	56.3 - 186	
Magnesium	47,600	2	49,800 - 51,900	MW-1
Mercury	0.33	2	0.4 - 0.49	MW-35
Calcium	132,000	1	148,000	MW-44D
Aluminum	28,400 JV	1	80,000	MW-46
Beryllium	1.8 B	1	3.7 B	
Cadmium	2.2 B	1	4.4 B	
Chromium	70.9 JV	1	146	
Potassium	11,900	1	19,800	
Vanadium	72.9	1	205	
Zinc	160 JV	1	696	

As shown above, eight of the metals exceeded the background ranges only once, with seven of the metals exceeding background only within Monitoring Well MW-46. Thirteen of the highest metals concentrations also occurred in MW-46. These detections are attributed to the high amount of suspended particles within the MW-46 ground-water sample due to turbidity (as confirmed during the 1997 sampling round).

Excluding MW-46, the following seven wells contained at least one metal above the background ranges: MW-1, MW-25, MW-29, MW-35, MW-43, MW-44D and MW-49. Three of these wells (i.e., MW-1, MW-35 and MW-49) are located within OU-3 and downgradient of SMP. In addition, MW-25 is located in close proximity to SMP and the water table in this area is nearly flat. Analytical data within the Holzmacher, McLendon & Murrell, P.C. report (1992) indicate that ten metals exceed ground-water standards beneath the SMP site. Since the SMP site is located upgradient of the OU-3 wells containing metals above background, metals in SMP ground water were compared to metals detections within wells MW-1, MW-25, MW-35 and MW-49. The results of this comparison indicate that all ten metals detected above background ranges within these four wells were detected at significantly greater concentrations beneath the SMP site. These data indicate that for the four aforementioned wells (at a minimum), the concentrations of metals in ground water are indicative of local upgradient ground-water quality and are attributable to the known source of metals at the SMP site. In addition, the metals concentrations detected at SMP exceed <u>all</u> metals detections at the Yard, with the exception of manganese in MW-46 ground water during February 1993.

Monitoring Well MW-29 and the MW-43/MW-44D well cluster are located along the Yard's northwest (downgradient) property boundary. At the well cluster, MW-43 contained only manganese and MW-44D contained calcium and magnesium above the background ranges. Elevated manganese concentrations (i.e., to greater than 10,000 µg/L) are indicative of ground-water quality within the Upper Glacial aquifer (Buxton, et al., 1981), while elevated calcium and magnesium levels are associated with salt-water intrusion (Weast, 1984). Monitoring Well MW-29 contained arsenic and lead above the background ranges. Since no areas of concern are located upgradient of MW-29, the source(s) of these metals is unclear. However, it is important to note that MW-29 is located adjacent to a LIRR maintenance shop. Complete results are provided in Table 8.

4.2.4.2 May 1996

During May 1996, all nine wells sampled were analyzed for metals (Table 3). Four of these wells contained at least one metal above background range: MW-64, MW-66, MW-68 and MW-69D. Six metals exceeded background ranges at least once. Exceedances are tabulated below in order of frequency of exceedance.

Metal	Background Concentration (µg/L)	No. of Wells Exceeding Background	Range of Concentrations Exceeding Background (µg/L)	Well Containing Highest Concentration
Manganese	2,650	2	3,180 - 4,750	MW-68
Arsenic	3.6 B	2	4.1 B - 5.2 B	MW-66
Barium	275	1	282	
Potassium	11,900	1	14,900	
Selenium	10.1	1	11.4	
Zinc	160 JV	1	534	MW-64

As shown above, four of the metals exceeded the background ranges only once, with three of these exceedances occurring in MW-66. Manganese and arsenic were the only metals to exceed background more than once; however, the two exceedances of manganese occurred within a well cluster (i.e., MW-68/MW-69D). The two exceedances of arsenic occurred in Monitoring Wells MW-66 and MW-69D. Due to a flat water table in this area, Monitoring Wells MW-66, MW-68 and MW-69D are located hydraulically downgradient of SMP, a source of metals in ground water (Plates 2 and 3). As previously discussed, the metals concentrations detected at SMP exceed <u>all</u> metals detections at the Yard (with the exception of manganese in MW-46 ground water during February 1993). Therefore, the data indicate that the concentrations of metals in MW-66, MW-68 and MW-69D are indicative of local upgradient ground-water quality and are therefore attributable to the known source of metals at the SMP site. Complete results are provided in Table 8.

4.2.4.3 June-July 1997

During the June-July 1997 sampling round, 33 of the 35 wells sampled were analyzed for metals. Eight of these 33 wells are background wells (i.e., MW-30, MW-34, MW-47, MW-48D, MW-61, MW-62D, TP-9 and TP-10), and therefore are not discussed further. Of the remaining 25 wells, 15 contained at least one metal above background range. Sixteen of the 23 TAL metals exceeded background ranges at least once. Exceedances are tabulated below in order of frequency of exceedance.

Metal	Background Concentration (µg/L)	No. of Wells Exceeding Background	Range of Concentrations Exceeding Background (µg/L)	Well Containing Highest Concentration
Arsenic	3.6 B	5	5.4 B - 22.3	MW-49
Manganese	2,650	5	2,980 - 6,310	MW-59
Mercury	0.33	5	0.34 - 0.42	MW-64
Barium	275	4	291 - 601	MW-27
Copper	65.0 JV	3	69.2 JV - 119 JV	TP-8
Iron	46,500	3	73,300 JV - 104,000 JV	
Beryllium	1.8 B	2	2.5 B - 7.1	
Cobalt	23.3 B	2	33.3 B - 38.8 B	
Nickel	48.1	2	52.8 - 69.4	
Magnesium	47,600	2	48,200 - 50,000	MW-40D
Zinc	160 JV	2	269 JV - 763 JV	MW-64
Calcium	132,000	1	137,000	MW-44D
Aluminum	28,400	1	38,000 JV	TP-8
Chromium	70.9 JV	1	161 JV	
Lead	21.9 JV	1	60.5 JV	
Vanadium	72.9	1	181	

No metals were detected above background in the following ten wells: MW-25A, MW-29, MW-37, MW-41, MW-42, MW-43, MW-45, MW-46, MW-57, and MW-66. In addition, the following seven wells each contained only one metal above the background range: MW-19, MW-23D, MW-28, MW-38D, MW-40D, MW-44D, and MW-67. With the exception of TP-8 and MW-27, the remaining wells contained either two or three metals above the background ranges.

Most of the exceedances shown above (i.e., 35 percent) occurred in Monitoring Well TP-8, with 14 metals detected above the background ranges. Furthermore, of the 16 metals that exceeded background at the Yard, nine of the highest concentrations of metals occurred in TP-8. Five of the metals exceeded the background ranges only once, with four of these exceedances occurring in TP-8. Five metals exceeded the background range in Monitoring Well MW-27. Complete results are provided in Table 8.

Although TP-8 is not technically a background well, no areas of concern at the Yard are located upgradient of TP-8. Monitoring Well TP-8 is located along the northeast property boundary of the Yard, adjacent to a gas station, car dealership, and an abandoned, burnt-out vehicle. This well is located in a low-lying, swale-like area, accepting runoff from neighboring properties to the east, north and south. TP-8 is also in close proximity to SMP and the water table is nearly flat between TP-8 and SMP, allowing contaminated ground water to spread radially from a known source (i.e., SMP [Standard Motor Products]). The four metals detected exclusively in TP-8 are each used in the automobile industry:

- aluminum is used as structural material and is present in paints;
- chromium is present in chrome-plated metals;
- lead is used in tank linings and batteries, and was present in gasoline until the late 1980s; and
- vanadium is present in catalytic converters and rust-resistant steel.

This information suggests that many of the metal detections in TP-8 may be attributable to the abandoned vehicle, the neighboring properties, and/or SMP.

The majority (i.e., 12 of 15) of the wells that contain at least one metal above background ranges are located either in close proximity to SMP or directly downgradient of SMP (within OU-3). SMP produces automobile parts and components, with metal fabrication and machining taking place at the facility. Past operations included chrome plating, painting automobile parts, die casting, rubber production and degreasing using chlorinated solvents (Holzmacher, McLendon & Murrell, P.C., 1992). Analytical data within the Holzmacher, McLendon & Murrell, P.C. report (1992) indicate that ten metals exceed ground-water standards beneath the SMP site. Since the SMP site is located upgradient of OU-3 and in close proximity to three other wells containing metals above background, metals in SMP ground water were compared to metals detections within nine OU-3 wells (MW-19, MW-23D, MW-35, MW-38D, MW-40D, MW-49, MW-59, MW-64 and MW-65) plus TP-8, MW-67 and MW-69D. The results of this comparison indicate that all 15 metals detected above background ranges within these 12 wells were detected at significantly greater concentrations beneath the SMP site. These data indicate that for the 12 aforementioned wells (at a minimum), the concentrations of metals in ground water are indicative of local, upgradient ground-water quality and are attributable to the known source of metals at the SMP site. Although the metals in TP-8 may be attributable to the adjacent burnt-out car and/or runoff, SMP remains a potential source.

The three remaining wells containing metals above the background ranges are: MW-27 (barium, cobalt, iron, manganese and nickel), MW-28 (manganese), and MW-44D (calcium). MW-27 is located downgradient of Area 9; however, no metals data exist for Area 9. According to published and Yard hydrogeologic data, the Upper Glacial aquifer is known to contain elevated concentrations of manganese and iron. Yard data confirm that elevated concentrations of manganese and iron are indicative of ground-water quality within the shallow deposits. According to published data for Queens County (Buxton, et al., 1981), manganese concentrations vary within the Upper Glacial aquifer from less than 100 μg/L to greater than 10,000 μg/L, increasing as conditions become anoxic. Anoxic conditions are found in wetlands, such as the buried wetlands located beneath the western portion of the Yard and the northeast corner of the Yard. Published data also indicate that high manganese concentrations are associated with high iron concentrations. Elevated calcium concentrations are associated with salt-water intrusion, as the average concentration of calcium in sea water is 400,000 μg/L (Weast, 1984). This information suggests that the concentrations of iron, manganese and calcium in MW-27, MW-28 and MW-44D are indicative of natural aquifer conditions.

4.2.5 Additional Water Quality Parameters

In addition to the analytical parameters previously discussed, all monitoring wells that did not contain separate-phase petroleum were analyzed for chloride and total dissolved solids during the June-July 1997 sampling round. Results are discussed below.

June-July 1997

During the June-July 1997 sampling round, 34 of the 35 monitoring wells sampled were analyzed for chloride and total dissolved solids (TDS) to determine the salinity/potability of ground water. (MW-68 was not analyzed for these parameters because it contained a petroleum sheen.) The NYSDEC Water Quality Regulations define saline ground waters as "ground water that has a chloride concentration of more than 250 mg/L or a total dissolved solids concentration of more than 1,000 mg/L."

The concentration of chloride ranged from 7 to 725 milligrams per liter (mg/L), and the TDS concentration ranged from 100 to 1,480 mg/L. The results of these analyses determined that saline ground water exists at 38 percent of the monitoring locations tested (i.e., 13 wells). The following nine wells in the southwest half of the Yard are classified as saline: MW-27 through MW-30, MW-34, MW-41, MW-44D, MW-45 and MW-62D. The areal extent of saline ground water is shown in Plate 4, and complete analytical results are provided in Table 9.

In general, higher concentrations of chloride and TDS were detected in the southwest portion of the Yard. These data indicate that salt-water intrusion affects the southwest half of the Yard. In addition, saline ground water is present along the north side of the Yard at locations MW-38D, MW-40D, MW-66 and MW-69D. These four locations closely correlate with the location of a 4-foot thick cobble zone present in the subsurface from the west-central portion of the Yard (MW-44D) northeast to MW-40D and continuing east to MW-48D. The cobble unit may be a relict stream channel deposited by glacial meltwaters. The top of this unit is encountered at an elevation of approximately 2.3 feet above mean sea level at MW-48D, and deepens to the west, where it is encountered at approximately 18 feet below mean sea level at MW-44D (marking the current northern extent of saline ground water). The cobble unit intersects the screen zones of both MW-44D and MW-40D. If this is a continuous unit, it explains the preferential flow of saline ground water from the southwest half of the Yard northeast to locations MW-38D and MW-40D, and east to locations MW-69D and MW-66.

The apparent sources of the salt-water intrusion are both Dutch Kills and Newtown Creek. Salt-water intrusion affects the southwest half of the Yard and continues through the cobble zone, explaining the presence of saline ground water along the north side of the Yard.

5.0 PRELIMINARILY IDENTIFIED ARARs

Consistent with the National Contingency Plan (NCP) (USEPA, 1990) and the "CERCLA Compliance with Other Laws Manual" (USEPA, 1988), applicable or relevant and appropriate requirements (ARARs) continue to be developed at multiple stages of the remedy selection process for OU-6, including during the scoping and Yard characterization phases of the RI. Preliminary potential ARARs identified during the scoping phase were presented in the Work Plan for the Remedial Investigation and Feasibility Study (Roux Associates, Inc., 1990). Site characterization data obtained during this RI were used to further identify potential chemical- and location-specific ARARs. The results of the identification of action-specific ARARs will be presented in the feasibility study (FS). Continued development of ARARs will be performed during the FS, and a final presentation of chemical-, location-, and action-specific ARARs will be provided in the FS report.

In the following sections, an overview of ARARs in the remedy selection process is presented, the procedure used to identify ARARs for the Yard is outlined, and chemical- and location-specific ARARs that are Yard-specific are presented.

5.1 Definition and Overview of ARARs

ARARs are defined as follows (40 CFR 300.5) (USEPA, 1990).

Applicable requirements are:

"Those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations, promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable."

Relevant and appropriate requirements are:

"Those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. Only those state standards that are identified in a timely manner and are more stringent than federal requirements may be relevant and appropriate."

The three different types of ARARs are:

1. Ambient- or chemical-specific ARARs are health- or risk-based numerical values or methodologies. Chemical-specific ARARs establish the amount or concentration of a chemical that may be found in, or discharged to, the environment;

2. Action-specific ARARs are usually technology- or activity-based requirements or limitations on actions taken with respect to hazardous wastes; and

3. Location-specific ARARs set restrictions on the concentration of hazardous substances or the conduct of activities based on the specific location of the site (USEPA, 1988).

In New York State, remedy selection must also conform to standards and criteria that are generally applicable, consistently applied, and officially promulgated. The site's program should be designed with consideration being given to guidance determined, after the exercise of engineering judgment, to be applicable on a case-specific basis.

The terms "standards and criteria" and "guidance" (SCGs) include both those of the state and those of the United States to the extent that they are more stringent than those of this state (6 NYCRR 375-1.10).

In addition to ARARs/SCGs, to-be-considered materials (TBCs) are also identified as part of the remedy selection process. TBCs are nonpromulgated advisories, criteria, or guidance developed by Federal or State governments that may be useful in developing CERCLA remedies (40 CFR 300.400[g][3]) (USEPA, 1990).

CERCLA Section 121 requires selection of a remedial action that is protective of human health and the environment (42 USC 9621[b][1][G]). The two threshold criteria for selection of a remedial alternative are overall protection of human health and the environment and compliance with ARARs (40 CFR 300.430[f][1][i][A]) (USEPA, 1990).

During the FS, remedial action objectives will be established and will specify contaminants and media of concern, potential exposure pathways, and remediation goals. Initially, preliminary remediation goals are determined based on readily available information, such as chemical-specific ARARs or other reliable information. Final remediation goals are determined when the remedy is selected. Remediation goals establish acceptable exposure levels that are protective of human health and the environment and are developed by consideration listed below.

- ARARs, if available, and the following factors:
    - For systemic toxicants, acceptable exposure levels shall represent concentrations to which the human population can be exposed without adverse effect during a lifetime or part of a lifetime, incorporating an adequate margin of safety;
    - For known or suspected carcinogens, acceptable exposure levels are generally concentration levels that represent an excess upper bound lifetime cancer risk to an individual of between 10^{-4} and 10^{-6}. The 10^{-6} risk level is used as the point of departure for determining remediation goals for alternatives when ARARs are not available or are not sufficiently protective because of the presence of multiple contaminants at a site or multiple pathways of exposure;
    - Factors related to technical limitations such as detection/quantitation limits for contaminants;
    - Factors related to uncertainty;
    - Other pertinent information (40 CFR 300.430[e][2][i][A][1 through 5]) (USEPA, 1990);
    - Maximum Contaminant Level Goals (MCLGs) set at levels above zero are to be attained by remedial actions for ground water or surface waters that are current or potential sources of drinking water, where MCLGs are relevant and appropriate under the circumstances of the release based on the factors in 40 CFR 300.400(g)(2). If an MCLG is determined not to be relevant and appropriate, or if an MCLG is set at a level of zero, the corresponding Maximum Contaminant Level (MCL) shall be attained where relevant and appropriate to the circumstances of the release based on the factors in 40 CFR 300.400(g)(2) (USEPA, 1990);

  - In cases involving multiple contaminants or pathways where attainment of chemical-specific ARARs would result in cumulative risk in excess of 10^{-4}, criteria listed at 40 CFR 300.430(e)(2)(i)(A) (USEPA, 1990) may be considered when determining the cleanup level to be attained;

  - Water quality criteria established under Sections 303 or 304 of the Clean Water Act are to be attained where relevant and appropriate under the circumstances of the release;

  - An alternate concentration limit may be established in accordance with CERCLA Section 121(d)(2)(B)(ii); and

  - Environmental evaluations are to be conducted to assess threats to the environment, especially sensitive habitats and critical habitats of species protected under the Endangered Species Act (40 CFR 300.430[e][2][i][B through G]) (USEPA, 1990).

5.2 Procedure for Identifying ARARs

The process of identifying potential ARARs/SCGs and TBCs for the Yard consisted of the following activities.

- Pertinent facts concerning the chemicals detected in Yard media and the location of the Yard were identified.

- Federal regulations and State SCGs were reviewed to identify potential ARARs.

- The "CERCLA Compliance with Other Laws Manual" (USEPA, 1988) was reviewed for lists of all potential chemical- and location-specific Federal ARARs. Requirements contained in these lists, together with any requirements promulgated subsequent to the issuance of the "CERCLA Compliance with Other Laws Manual" were considered during the identification of potential Federal chemical- and location-specific ARARs for the Yard. The list of potential State ARARs, together with any requirements promulgated subsequent to the publication date of the list, were considered during the identification of potential State chemical- and location-specific ARARs for the Yard.

- Provisions of each potential ARAR were reviewed to obtain pertinent information, including the following:

  - substances regulated by the requirement;

  - types of facilities regulated by the requirement;

  - locations regulated by the requirement; and

  - persons or entities regulated or affected by the requirement.

- The concentrations of contaminants detected in Yard soil and ground water and facts concerning the type and location of facility were compared to the provisions of the identified potential ARARs/SCGs. If all pertinent provisions for a requirement were met, the requirement was deemed applicable. If all pertinent provisions for a requirement were not met, the following comparison of Yard-specific factors was made to determine if a requirement was both relevant and appropriate:
  - the purpose of the requirement and the purpose of the action at the Yard;
  - the medium regulated or affected by the requirement and the medium contaminated or affected at the Yard;
  - the substances regulated by the requirement and the substances found at the Yard;
  - the type of place regulated and the type of place affected by the release;
  - the type and size of structure or facility regulated and the type and size of structure or facility affected by the release; and
  - any consideration of use or potential use of affected resources in the requirement and the use or potential use of the affected resource at the Yard (40 CFR 300.400 [g] [2] [i through iii and vi through viii]) (USEPA, 1990).

A requirement may have been determined to be potentially relevant because it closely matched the Yard on some of the factors listed above, but may have been determined to be not appropriate because the Yard circumstances differed significantly on other key factors. Portions of a requirement may be relevant and appropriate even if a requirement in its entirety is not (USEPA, 1988).

In addition to ARARs/SCGs, TBCs were also identified from the list contained in the "CERCLA Compliance with Other Laws Manual" (USEPA, 1988), as well as from TBCs issued after publication of the "CERCLA Compliance with Other Laws Manual."

5.3 Potential Chemical-Specific ARARs

The data developed during the baseline sampling for OU-6 (June-July 1997) were used, since these data represent current conditions, to further define the potential chemical-specific ARARs/SCGs and TBCs for ground water. Chemical-specific SCGs and TBCs for ground water are discussed below.

Pursuant to the New York Environmental Conservation Law, Article 17, it is declared to be public policy of the State of New York to maintain reasonable standards to safeguard the waters of the state from pollution by preventing any new pollution and abating pollution existing to protect public health and permit management of the ground waters for their best usage.

The New York Public Water Supply Regulations (10 NYCRR 5-1) regulate the water systems within the state that supply drinking water that may affect public health. This regulation sets MCLs for select inorganic and organic constituents listed under the federal regulations (40 CFR 141.11 through 141.91 and 143.3). The NCP requires that where relevant and appropriate under the circumstances of the release, non zero MCLGs and MCLs are to be attained for remedial actions for ground waters that are current or potential sources of drinking water (300 CFR 430[e][2][i][b and c]) (USEPA, 1990). MCLs and MCLGs are considered potentially relevant and appropriate requirements.

New York water classifications and quality standards for ground water are the maximum allowable concentrations which may be tolerated without creating a threat to human health, or which would otherwise render the ground water unsuitable for its intended best usage (6 NYCRR 700-704). Ambient Water Quality Standards and Guidance Values for toxic and non-conventional pollutants are presented in the NYSDEC Division of Water Technical and Operational Guidance Series (1.1.1). The authority for these values is derived from Article 17 of the Environmental Conservation Law and 6 NYCRR Parts 700 through 705, Water Quality Regulations. The standards and guidance values are the maximum allowable concentrations which may be tolerated to protect human health and drinking water sources and are referenced to protect the best usage of the water body as specified by the water classifications at the location of the discharger at locations that may be affected by such discharge.

The ground water at the Yard is classified as both GA (fresh ground water) and GSA (saline ground water). Fresh ground water is defined as having chloride concentrations less than or equal to 250 mg/L and TDS less than or equal to 1,000 mg/L (6 NYCRR Part 700.1). The GA classification is intended for ground waters that are considered suitable for drinking in their natural state, but may require treatment to improve quality related to natural conditions. Saline ground water is defined as having chloride concentrations greater than 250 mg/L or TDS greater than 1,000 mg/L (6 NYCRR Part 700.1). The GSA classification is a source of potable mineral waters for conversion to fresh potable waters. Thirteen of the monitoring wells sampled contain saline ground water based on the concentrations of chloride (greater than 250 mg/L) or TDS (greater than 1,000 mg/L).

The NYSDEC Water Quality Standards for Class GA are considered applicable due to the media and the type of substances detected at the Yard. All ground-water samples, including duplicates and samples from background wells from both Class GA and Class GSA monitoring wells, were compared to the Class GA ambient water quality standards. It should be noted that there are no chemical-specific standards for Class GSA ground water, therefore, the comparison provided below is conservative. Furthermore, the ground water in western Queens County is degraded and not used as a source of drinking water.

Four VOCs and ten metals exceeded the ambient water quality standards for Class GA ground water. A summary of concentrations for the June-July 1997 ground-water samples for each well (i.e., the most recent comprehensive sampling round) and the maximum allowable concentration exceedances is presented below.

- 1,2-Dichloroethene (total): Not detected (ND) to 33 μg/L (0.033 ppm) detected; exceeded ground-water standard of 5 μg/L (0.005 ppm) in five samples.
- Trichloroethene: ND to 34 μg/L (0.034 ppm) detected; exceeded ground-water standard of 5 μg/L (0.005 ppm) in four samples.
- Tetrachloroethene: ND to 360 μg/L (0.360 ppm) detected; exceeded ground-water standard of 5 μg/L (0.005 ppm) in three samples.
- Benzene: ND to 130 μg/L (0.130 ppm) detected; exceeded ground-water standard of 0.7 μg/L (0.0007 ppm) in two samples.
- Antimony: ND to 8.6 μg/L (0.0086 ppm) detected; exceeded ground-water guidance value of 3 μg/L (0.003 ppm) in seven samples.
- Beryllium: ND to 7.1 μg/L (0.0071 ppm) detected; exceeded ground-water guidance value of 3 μg/L (0.003 ppm) in one sample.

- Chromium: ND to 161 µg/L (0.161 ppm) detected; exceeded ground-water standard of 50 µg/L (0.050 ppm) in two samples.

- Iron: 67.9 µg/L (0.0679 ppm) to 104,000 µg/L (104.000 ppm) detected; exceeded ground-water standard of 300 µg/L (0.300 ppm) in 30 samples.

- Lead: ND to 60.5 µg/L (0.0605 ppm) detected; exceeded ground-water standard of 25 µg/L (0.025 ppm) in one sample.

- Magnesium: 1,130 µg/L (1.130 ppm) to 50,000 µg/L (50.000 ppm) detected; exceeded ground-water guidance value of 35,000 µg/L (35.000 ppm) in nine samples.

- Manganese: ND to 6,310 µg/L (6.310 ppm) detected; exceeded ground-water standard of 300 µg/L (0.3 ppm) in 21 samples.

- Selenium: ND to 10.1 µg/L (0.0101 ppm) detected; exceeded ground-water standard of 10 µg/L (0.010 ppm) in one sample.

- Sodium: 7,960 µg/L (7.960 ppm) to 216,000 µg/L (216.000 ppm) detected; exceeded ground-water standard of 20,000 µg/L (20.000 ppm) in 28 samples.

- Zinc: 11.7 µg/L (0.0117 ppm) to 763 µg/L (0.763 ppm) detected; exceeded ground-water standard of 300 µg/L (0.300 ppm) in one sample.

5.4 Location-Specific ARARs

The Federal Floodplain Management Act (16 USC 661 et seq) evaluates adverse effects associated with direct and indirect development of a floodplain. This act is not considered applicable (no development presently occurring), but it is considered potentially relevant and appropriate for future use (including potential remediation).

The Federal Fish and Wildlife Coordination Act (16 USC 661 through 666) states that whenever waters of any stream are controlled or modified for any purpose, the department or agency of the United States responsible for the stream or the public or private agency managing the stream under Federal permit or license, must consult with the Department of the Interior and the United States Fish and Wildlife Service. Although not presently applicable, this regulation is considered potentially relevant and appropriate due to the presence of buried wetlands at the Yard.

The National Historic Preservation Act (36 CFR Part 65) addresses facilities where alteration of terrain may threaten significant scientific, prehistorical, historical, or archeological data. Although there is no knowledge that the Yard has historical significance, this regulation is considered a potential ARAR.

6.0 CONTAMINANT FATE AND TRANSPORT

An evaluation of the environmental fate and transport of contaminants at the Yard was performed to support the FS. This evaluation consisted of: 1) compilation of information regarding physicochemical properties that can influence the fate of contaminants; and 2) an evaluation of contaminant transport and degradation processes.

6.1 Physicochemical Properties of Contaminants

Physical and chemical properties that will affect the fate and transport of contaminants in ground water include:

- solubility;
- specific gravity;
- vapor pressure;
- Henry's Law constant;
- organic carbon partition coefficient (K_{oc}); and
- octanol-water partition coefficient (K_{ow}).

Solubility is the maximum concentration of a chemical that will dissolve in water at a given temperature without forming a separate phase.

Specific gravity is the ratio of the density of a pure chemical to the density of water. As a separate phase, a compound with a specific gravity less than 1.0, such as benzene, will float on top of the water table, while a chemical with a specific gravity greater than 1.0, like trichloroethene, will sink.

Vapor pressure is a property of a chemical in its pure state and is an indicator of the rate of volatilization of a chemical in an aqueous environment.

Henry's Law constant is the ratio of a chemical's concentration in the vapor phase above water to its concentration in the aqueous phase, at equilibrium. It indicates the tendency of the chemical to evaporate from a water solution.

The <u>organic carbon partition coefficient</u> (K_{oc}) is the ratio of a chemical's concentration bound to soil organic carbon to its concentration in soil pore water, at equilibrium.

The <u>octanol-water partition coefficient</u> (K_{ow}) is the ratio of a chemical's concentration in the n-octanol phase to its concentration in the aqueous phase of an octanol-water mixture at equilibrium. The K_{ow} gives an indication of how the chemical will preferentially distribute into a solvent or water. Low K_{ow} values indicate that the contaminant is more hydrophilic; that is, a large fraction will be dissolved in the water phase. Low K_{ow} values also imply higher mobility.

Table 10 lists values for these properties obtained from literature references for the organic contaminants detected above ground-water standards during June-July 1997 at the Yard.

6.2 Processes Affecting Contaminant Migration

The processes by which chemicals at the Yard can migrate include: 1) leaching from soil to ground water; 2) transport in ground water; 3) discharge from ground water to surface water; and 4) volatilization from surface water. The parameters controlling contaminant transport by these processes are described below.

6.2.1 Leaching From Soil to Ground Water

The leaching of contaminants from soil into ground water depends on the degree of binding of the chemical to soil, the amount of water the soil-bound chemical comes in contact with, and the chemical characteristics of the soil and recharging water. The degree of soil binding is reflected in the K_{oc} values, with higher K_{oc}'s indicating greater binding and lower leaching rates. Since K_{oc} values are available for only a few chemicals, it should be noted that K_{oc} has been found to be directly related to K_{ow}, so that higher K_{ow}'s also indicate greater binding to soil. The actual distribution coefficient (the ratio of bound to dissolved concentration at equilibrium, K_d) for the binding of chemicals to soil must take into account the soil's organic content. This is included in the K_d value, as discussed later. The amount of water available to leach chemicals is a function of annual rainfall and the fraction of rainfall that percolates downward. The key chemical characteristics of the soil and water that influence the ability to leach contaminants are Eh (redox potential), pH and the presence of dissolved co-solvents. Eh influences the predominant oxidation state of metals, and therefore the solubilities of those metals. Water with low pH (acidic) is more efficient in leaching some metals from the soil. Co-solvents act to increase the solubilities of organic chemicals in water.

6.2.2 Transport in Ground Water

The transport of contaminants in ground water is affected by the hydrologic properties of the aquifer, chemical composition of the aquifer and chemical nature of the contaminants. The hydrologic properties of the aquifer are described in terms of advective and dispersive flow. The aquifer's organic carbon content and physical properties, along with the K_d of the chemical, are then used to calculate a retardation factor (R) for the chemical in the aquifer.

Advection and Dispersion

Advective flow is used to describe the transport of a non-reactive, water-soluble tracer at an average ground-water velocity (Freeze and Cherry, 1979). Darcian flow is assumed. Advective flow is usually the dominant transport mechanism in aquifer systems. The equation to describe advective flow is:

$$v = K_H \frac{I_H}{n_e}$$

where

v = the velocity of ground water along a segment of a flow line (ft/d);

n_e = the effective porosity of the aquifer (dimensionless);

K_H = the horizontal hydraulic conductivity of the aquifer (ft/d); and

I_H = the horizontal hydraulic gradient along a segment of a flow line (ft/ft).

The advective flow equation describes the flow velocity in an ideal system (that is, a system where the seepage velocity depends only on the aquifer properties and the hydraulic gradient). The main application of the simple advective flow equation is to determine the average time it takes for water to reach a certain location.

Dispersion can result in a spreading of the arrival time of this idealized ground-water flow. The arrival time of the center of mass of the contaminant can be calculated by the advection equation, but some of the contaminant arrives earlier than the center of mass, and some contaminant arrives later. Dispersion is controlled by molecular diffusion and mechanical mixing within the aquifer.

Retardation

Advection determines the rate of flow of ground water in a formation. However, because most contaminants have chemical properties different from those of ground water, the contaminants can move at velocities slower than that of ground water due to binding reactions with the solids in the aquifer matrix. This is termed retardation.

Sorption on naturally-occurring organic matter is the predominant mechanism by which organic compounds are retarded in ground-water systems. The rate of movement of these compounds relative to ground water has been directly linked to the K_{ow} for the individual compounds (Lyman et al., 1982). The K_{ow} is a measurement of a compound's tendency to concentrate in an organic phase in preference to water. In ground-water systems, the compounds with lower K_{ow} values concentrate in the mobile water phase rather than in the immobile solid organic matter phase. Therefore, those compounds will migrate faster than other compounds with higher K_{ow} values.

The retardation of a specific compound is strongly influenced by the amount of organic matter in the aquifer matrix. The distribution coefficient, K_d, is calculated prior to determining retardation factors and provides another means of ranking organic compound mobilities in a specific geologic material. An equation of the form:

$$\log K_d = 1.00 \log K_{ow} + \log (f_{oc}) - 0.21$$

can be used to estimate K_d values (Lyman et al., 1982). The fraction organic carbon (f_{oc}) is obtained from the percentage of organic matter in the aquifer matrix. The equation to calculate K_ds assumes the organic carbon content has a uniform effect on all contaminants, although this is not always the case (Garbarini and Lion, 1986).

The K_ds calculated using the above equation incorporate the chemical characteristics of the organic contaminant and the aquifer material into one term. The overall retardation characteristics of the aquifer are included in the calculation of retardation factors (R) by the equation:

$$R = 1 + (\frac{\rho}{n})\, K_d = \frac{v}{v_c}$$

where ρ is the bulk density of the soil, and n is the soil porosity (Freeze and Cherry, 1979). The retardation factor is the ratio of the velocity of the ground water (v) compared to the velocity of the compound of interest (v_c). Compounds that have K_ds of zero would move at the same velocity as the ground water, and hence have a retardation factor of 1.0.

Table 11 shows the results of calculating R-values for the organic contaminants detected above ground-water standards during June-July 1997 at the Yard, and categorizes chemicals with regard to their relative mobility based upon R. Contaminants which have R values ranging from 1.0 to 2.0 (i.e., those chemicals which would travel at velocities greater than one-half of the ground-water velocity) are classified as having a high relative mobility; contaminants for which R ranges from 2.1 to 20 are classified as having medium relative mobility; contaminants for which R ranges from 21 through 50 are classified as having low relative mobility; and those compounds with R greater than 50 are considered relatively immobile. The classification scheme described above is useful for comparing the relative mobilities of the contaminants found at the Yard. The only aromatic to be detected above ground-water standards was benzene, which has medium mobility. The remainder of the organic compounds detected above ground-water standards are halogenated aliphatics (e.g., trichloroethene) which are rated either medium or highly mobile.

The mobility of cationic metals depends upon the ground-water conditions and the nature of the aquifer matrix. For example, most metals are adsorbed more readily under alkaline pH conditions. The presence of clay minerals and iron hydroxides will also increase the extent of adsorption. Precipitation can also play a role in reducing contaminant concentrations for most metals. The metal can either form its own mineral phase or can be incorporated as a trace metal in another precipitating solid. The redox potential of the ground water, Eh, can affect the redox state of metals dissolved in ground water. Lower Eh values indicate the presence of reducing potential (for instance, Fe++), and can lead to the prevalence of the reduced forms of redox-active metals like chromium, iron, and manganese.

6.2.3 Discharge from Ground Water to Surface Water

Dissolved contaminants can be transferred from ground water to surface water offsite by discharge of the ground water to the East River and Dutch Kills. Discharge of ground water to surface water will occur when the hydraulic head of ground water is higher than the head of surface water to which it is hydraulically connected. This process can cause removal of some of the dissolved organics in the ground water by adsorption to the river bottom sediments, because the latter often contains a higher organic content than the aquifer matrix. As ground water discharges through the sediments, contaminants can be immobilized temporarily or permanently. The relative f_{oc}-values of stream sediment and aquifer matrix will determine the degree of binding during discharge. The higher the f_{oc} of the stream sediment, the greater will be the binding of dissolved organic contaminants from ground water. Contaminants bound to stream sediments would then be subject to migration downstream if the sediment were carried with the surface water.

6.2.4 Volatilization from Surface Water

Volatilization can be an important migration mechanism whereby contaminants are removed from surface water, and (to a lesser extent) ground water, and transferred to air. Chemicals with high vapor pressures and low solubilities are generally most affected by this process. Those compounds with large Henry's Law constants (Table 10) will readily evaporate into the atmosphere (Nyer et al., 1991) where they may be degraded by reaction with sunlight (photolysis, as described in Section 6.3). Although a Henry's Law constant was unavailable for benzene, it would be predicted from its vapor pressure and solubility that an aromatic compound would have a Henry's Law constant large enough for significant removal from waters by this process. The more soluble compounds, such as the phenols, and the less volatile compounds, such as the PCBs, are not readily volatilized from water.

6.3 Degradation Processes

Degradation processes include biologically mediated degradation and chemical, or abiotic, degradation. Various naturally-occurring processes can result in the transformation of organic compounds to other compounds of the same type, to products of a different type (such as conversion of alcohols to carboxylic acids), or to the ultimate degradation products of organics: carbon dioxide and water (Nyer et al., 1991). Several factors must be considered in the evaluation of these reactions. The biological and abiotic degradation pathways for a given contaminant may produce different products, and the proportion of these products may vary depending upon the various reaction rates. Typically, the biologically mediated reactions will be faster than the strictly abiotic reactions. However, the biological reaction rates are also much more variable than the abiotic rates because of the extreme dependence of biological degradations on the conditions around the microbial colonies in the soil and aquifer matrix. These conditions include pH, Eh, temperature, contaminant concentration, and the presence of other nutrients or biological toxins in the soil pore water or ground water. It is therefore not possible to predict degradation rates with certainty.

According to Howard et al. (1991), the unacclimated aqueous biodegradation rate (i.e., half life) for benzene ranges from 5 to 16 days under aerobic conditions and from 112 to 720 days under anaerobic conditions. For benzene, the high range half lives are associated with rivers (i.e., fresh water), while the low range half lives are associated with sea water (i.e., saline water). Therefore, benzene will attenuate more rapidly under aerobic, saline conditions. The unacclimated aqueous biodegradation rate (i.e., half life) for 4-methyl-2-pentanone (i.e., MIBK) ranges from 1 to 7 days under aerobic conditions and from 4 to 28 days under anaerobic conditions.

Photolysis occurs when a compound is broken down to smaller compounds by the action of light. It is dependent upon non-chemical-specific factors such as the intensity of the sunlight and the depth and turbidity of the surface-water body.

6.4 Contaminant Fate and Transport at the Yard

For the groups of compounds identified in Table 11, the following processes are considered to be important in affecting their concentrations over time. The aromatics and halogenated aliphatics display varying degrees of mobility in ground-water systems. Volatilization from soil and ground water occurs very slowly, due to lack of mixing of ground water and tortuous diffusion pathways in soil. Volatilization from these two media is not considered to be a significant transport route. Volatilization from surface water may be a factor in reducing the concentrations of aromatic and halogenated aliphatic compounds. Degradation of aromatics and halogenated aliphatics is observed to occur at measurable rates in soil and ground water, although the rates carry large uncertainties (Howard et al., 1991).

The migration of contaminants in each of the media at the Yard are discussed below.

Soil

Contaminants within the unsaturated soil at the Yard are generally not covered with pavement or buildings (Plate 1). Moreover, the depth to ground water is very shallow (i.e., varying from 1 to 15 ft across the Yard), thereby increasing the potential for contaminated soil to impact ground water.

Soil contamination at the Yard is primarily characterized by PAHs and PCBs of low or zero mobility (Roux Associates, Inc. 1995). These compounds tend to remain tightly bound to soil particles, and do not have as great a potential for migration into ground water as smaller and more soluble compounds.

The metals detected in soil at the Yard may be subject to migration via leaching from soil to ground water. The metals detected in soil above background concentrations or recommended soil cleanup objectives or site-specific cleanup levels were: antimony, barium, beryllium, chromium, copper, iron, lead, magnesium, manganese, sodium, and zinc. Of these metals, seven (beryllium, chromium, iron, lead, magnesium, manganese and zinc) have been detected in ground water during June-July 1997 above both ground-water standards and background concentration ranges. (Even when Class GA Standards are applied to saline wells, this list of seven metals remains the same.) These data only indicate a potential for these seven metals to leach from Yard soil to ground water; while the actual pattern of metals exceedances in ground water point to SMP as the source. As previously discussed, all of the metals exceedances in ground water occurred in the northern portion of the Yard and are attributable to SMP, a known source of metals contamination in ground water. The fate and transport of the seven mobile metals are discussed below. The other metals are presumably immobilized in soil at the Yard. Their mobilization and release from the soil could only occur as a result of a release of strong acid or alkali onto the soil at the Yard.

Ground Water

Ground-water contamination in the saturated fill and the Upper Glacial aquifer at the Yard is characterized by the presence of petroleum-derived VOCs. Chlorinated VOCs were also detected in four areas. The non-chlorinated VOC (i.e., benzene) has a medium mobility in water, and in the dissolved state will migrate along with the ground-water flow, being partially retarded due to adsorption on the aquifer matrix. The chlorinated VOCs show high or medium mobility.

Ground water beneath the Yard also contains the following metals at concentrations above both ambient water quality standards and background concentration ranges: beryllium, chromium, iron, lead, magnesium, manganese, and zinc. These metals exhibit different chemical properties that control their migration abilities in ground water. Beryllium and magnesium exist as soluble metal ions and are mobile in ground water. Chromium, iron, lead, manganese and zinc can exist in different oxidation states. The two major chromium oxidation states, Cr(VI) and Cr(III), show drastically different properties. Cr(VI) is very mobile in water as chromate, $CrO^{=}_{4}$, which is a carcinogen. Cr(III), on the other hand, forms insoluble $Cr(OH)_3$ at neutral pH and is immobile. Since Cr(VI) is a strong oxidant, the Cr(III) form predominates due to the reduction of Cr(VI) in the presence of almost any reductant, including organic contaminants. The oxidized forms of lead [Pb(II)] and zinc [Zn(II)] all form insoluble hydroxides at mildly acidic to mildly alkaline pH's. Under oxidizing conditions, iron exists as Fe(III), which forms insoluble FeO(OH), ferric oxyhydroxide, at neutral or alkaline pH. Under reducing conditions, iron will exist as soluble Fe(II) species. Manganese forms insoluble MnO_2 in the oxidized [Mn(IV)] form and exists as soluble Mn(II) species in the reduced form. Since ground water at the Yard is generally neutral and probably tends toward anaerobic (reducing) conditions due to the buried wetland environment present in the western half and northeastern corner of the Yard, some of the iron and manganese would be expected to migrate as soluble species with very little retardation in ground water.

Ground-water flow is controlled by natural and artificial (i.e., resulting from historic cut and fill activities) hydraulic gradients. As shown in Plates 2 and 3, horizontal flow in the saturated fill and Upper Glacial aquifer underlying the Yard is generally toward the west and northwest, toward the buried flow path of Dutch Kills Creek and/or the East River. Dutch Kills, which is buried in the western portion of the Yard, emerges south of the Yard and discharges into Newtown Creek. No surface-water sampling has been performed to confirm or eliminate this potential migration pathway.

Calculated vertical hydraulic gradients between the shallow deposits and the deeper Upper Glacial aquifer deposits indicate that ground-water flow is predominantly horizontal, but has both downward and upward components at different locations at the Yard. All Yard ground water discharges upward as it moves west and northwest toward the buried flow path of Dutch Kills Creek and/or the East River.

7.0 SUMMARY AND CONCLUSIONS

All data that Roux Associates has developed for OU-6 and has included in this report is summarized in the following sections. The conclusions reached based on these data are discussed in Section 7.4.

7.1 Geology

The geologic logs of soil borings drilled at the Yard during the Roux Associates' investigations indicate that the Yard is underlain by the following units (in order by increasing depth): fill (where present), recent and Holocene deposits (where present), Upper Pleistocene glacial deposits (including both till and channel deposits), and crystalline bedrock. Fill activities, which were part of major topographic changes engineered at the Yard, are summarized below.

Fill and Historical Topographic Changes

The fill is predominantly comprised of reworked glacial deposits (unstratified sand, silt, clay and gravel) and railroad ballast, with lesser amounts of ash, cinders and construction debris. With the exception of paved areas and land occupied by buildings, the railroad ballast is ubiquitously present at land surface throughout the Yard. Between 1906 and 1910 Upper Pleistocene glacial deposits were excavated from topographically high areas of the Yard and re-deposited as fill in lower lying areas of the Yard. These reworked glacial deposits were often visually indistinguishable from the underlying unstratified glacial deposits, since geologically they are the same formation.

Utilizing an engineering report (Pennsylvania Tunnel and Terminal Railroad Company, circa 1910), topographic maps (Julius Bien & Co., 1890; Pennsylvania Tunnel and Terminal Railroad Company, 1906), Amtrak-supplied 1910 and 1917 Yard maps, and recent area maps, a comparison was made between the historical and current topographic features of the Yard. This comparison indicated that:

- the majority of topographic changes that occurred at the Yard took place between December 1906 and August 1909;
- current land surface elevation throughout much of the eastern half of the Yard (i.e., east of Honeywell Street) is actually lower than pre-development elevation;

- current land surface elevation throughout much of the western half of the Yard (i.e., west of Honeywell Street) is actually higher than pre-development elevation;
- two former surface-water bodies at the Yard have been filled (i.e., a wetland in the northeast corner of the Yard, and Dutch Kills [and its associated wetland], which flowed through the western portion of the Yard southwest into Newtown Creek); and
- current elevation of the LIRR main line is actually higher than the pre-development (1890) elevation.

During these topographic changes, construction at the Yard consisted of moving railroad tracks, grading the Yard, and constructing bridges, roads and buildings. Natural Upper Pleistocene glacial deposits were excavated from parts of the Yard and deposited as fill in other parts of the Yard to create the current, generally flat topography. Despite the significant changes to Yard topography, the natural topography of the Yard still plays an integral role in the ground-water flow patterns, hydraulic gradients, and saline conditions occurring at the Yard.

Holocene Deposits

In the southwestern portion of the Yard, a Holocene wetland deposit was encountered below the fill and above the Upper Pleistocene formation. This deposit, which is the buried Dutch Kills Creek and swamp, consists of organic silty clay and meadow mat. As a result of filling Dutch Kills, the Dutch Kills drainage was culverted beneath the northwest corner of the Yard, through a 48-inch diameter sewer line. This sewer line is charted on the Amtrak-supplied 1910 Yard map.

Upper Pleistocene Deposits

The Upper Pleistocene glacial deposits consist mainly of ground moraine deposits; unstratified, poorly sorted mixtures of sand, silt, clay and gravel. An approximately 4-foot thick cobble zone is located in the subsurface at locations MW-40D, MW-44D and MW-48D. This unit deepens to the west, and may be a relict stream channel deposit that was formed by glacial meltwaters. Based on 1997 ground-water quality data, a narrow band of saline ground water occurring in the northern part of the Yard closely correlates with this cobble layer. These data suggest that the cobble layer is a narrow, yet continuous buried channel deposit beneath the Yard, extending from the former Dutch Kills Creek and swamp (near MW-44D) east to the buried wetland in the northeast corner of the Yard in the vicinity of MW-48D (Plate 4).

Bedrock

Based on published data, the crystalline bedrock is of Precambrian age and consists of folded and faulted gneisses and schists that were eroded to a peneplain prior to deposition of the overlying glacial deposits (Soren, 1978). Based on information obtained from a file and well search at the NYSDEC, the bedrock surface appears to be highly irregular in this area. Boreholes drilled adjacent to the Yard indicate that the depth to bedrock ranges from approximately 30 to 150 feet bls (i.e., 10 to 130 feet below mean sea level). Boreholes drilled at the Yard during the NYCDOT/NYSDOT reconstruction of the Queens Boulevard bridge over Sunnyside Yard encountered the bedrock surface from 50 to 86 feet bls (Environmental Planning & Management, Inc., 1997). These depths are estimated to correspond to 40 to 70 feet below mean sea level, with bedrock deepening to the south. Beneath the northeastern portion of OU-3, bedrock was encountered at a depth of 74 feet (53 feet below mean sea level). The circa 1910 Chief Engineering Report stated that bedrock was exposed in the stream bed of Dutch Kills Creek, near the south abutment of the Thompson Avenue bridge and under the LIRR freight tracks on the north side of the Yard. This report also states that bedrock was generally located 30 to 50 feet beneath the swamp (during approximately 1907).

7.2 Hydrogeology

Regional and Yard hydrogeology are summarized below.

7.2.1 Regional Hydrogeology

Regional ground-water flow in the area is to the northwest, eventually discharging to the East River approximately one mile northwest of the Yard (McClymonds and Franke, 1972). Vertical flow within the aquifer changes from a downward flow in central Queens to an upward flow nearing the East River, where ground water discharges.

Published water-level data for Long Island show that from the early 1930s to about 1960 the water table within Kings County and western Queens County was depressed to elevations below sea level due to over pumpage. The cone of depression caused significant salt-water intrusion into the Upper Glacial and confined aquifers beneath these areas, and as far inland as the center of Kings County (Smolensky, 1983). Historical data for wells near the Yard indicate that salt-water intrusion also affected the aquifers beneath the Yard. Current water-level elevations at the Yard range from 8 to 23 feet above mean sea level, precluding salt-water intrusion in this area. However, the effects of the historical salt-water intrusion can still be detected in ground-water quality, which exhibits elevated concentrations of sodium, chloride and total dissolved solids (Soren, 1971). May 1997 data presented in this report indicate that saline ground-water conditions still exist beneath much of the Yard.

Regional ground-water quality of the Upper Glacial aquifer is characterized as having a wide range of iron and manganese concentrations (Buxton, et al., 1981). Concentrations of iron and manganese increase as conditions become anoxic (i.e., as the dissolved oxygen context decreases). Anoxic conditions are typically associated with swamp or wetland deposits, such as those buried in the northeastern and western portions of the Yard.

7.2.2 Yard Hydrogeology

Ground water beneath the Yard occurs under water-table (unconfined) conditions. With the exception of the LIRR mainline, the water table lies between 1 and 15 feet below land surface throughout the Yard and occurs in either fill deposits or the Upper Pleistocene glacial deposits. The saturated Upper Pleistocene deposits comprise the Upper Glacial aquifer.

Ground-Water Flow Patterns

Ground water within the shallow deposits flows predominantly west beneath the Yard. However, between Queens Boulevard and Honeywell Street, ground water flows northerly and northwesterly toward the buried flow path of Dutch Kills Creek and/or the East River (Plate 2). In the deeper deposits, ground water predominantly flows west across the Yard. The area of northerly flow shown in the water-table map is not evident on the deep ground-water flow map; however, this may be an expression of the limited distribution of monitoring points, rather than natural conditions (Plate 3).

Horizontal Gradients

Horizontal flow gradients within the shallow deposits range from approximately 0.001 ft/ft from the Metro Shop area east to Area 14, up to 0.009 ft/ft in the northeast corner of the Yard. The average shallow horizontal flow gradient for the Yard is 0.004 ft/ft. An average horizontal flow gradient for the Yard of 0.004 ft/ft was also calculated for the deeper deposits. These values are indicative of a relatively flat water-table surface.

Vertical Gradients

Vertical gradients calculated for the Yard (1993 to 1997) range from 0.1287 ft/ft downward at cluster MW-47/MW-48D to -0.0274 ft/ft upward at cluster MW-19/MW-39D. The downward gradients at cluster MW-47/MW-48D indicate that the area near the northeastern corner of the Yard is a ground-water recharge area (corresponding with the buried northeast wetland). The upward gradients present beneath OU-3, and sometimes present along the downgradient property boundary, indicate ground-water discharge areas (including the buried flow path of Dutch Kills Creek). In general, vertical gradients change from downward to upward with nearing proximity to the buried flow path of Dutch Kills Creek and the East River, the ground-water discharge areas. The upward flow observed beneath OU-3 and the downgradient portion of the Yard (with the exception of June 1997) reduces or prevents the downward migration of contaminants within the aquifer, assists in containment of the separate-phase petroleum accumulation, and lessens the petroleum's impact on underlying ground-water quality.

Hydraulic Coefficients

Hydraulic coefficients for the saturated fill deposits and Upper Glacial aquifer at the Yard (determined from a pumping test and multiple slug tests) suggest that K_H values beneath OU-3 are higher than those determined facility-wide. Calculated values for K_H range from 2.36 ft/d in the shallow deposits (MW-49) to 577 ft/d in the deeper deposits (P-2D). Data derived during the pumping test performed on well MW-40D indicate an average K_H of 410 ft/d and an average T of 28,950 ft^2/d for the water-table aquifer. The average K_H and T values calculated for the deeper deposits are 500 ft/d and 35,300 ft^2/d, respectively. These hydraulic coefficients agree with published data and suggest that the aquifer is highly transmissive.

Ground-Water Flow Rates

Using an average K_H of 410 ft/d for the shallow deposits at the Yard, an average horizontal hydraulic gradient of 0.004 ft/ft for the water table on June 17-19, 1997, and an estimated effective porosity of 0.25 (Walton, 1991), the ground-water flow velocity through the shallow deposits was calculated to be 6.6 ft/d. Using an average horizontal hydraulic conductivity of 500 ft/d for the deeper deposits at the Yard, an average horizontal hydraulic gradient of 0.004 ft/ft for the deeper deposits on June 17-19, 1997, and an average effective porosity of 0.35 for coarser deposits (Walton, 1991), the ground-water flow velocity through the deeper deposits was calculated to be 5.7 ft/d.

7.3 Nature and Extent of Contamination

The nature and extent of ground-water contamination was determined from data collected during the OU-6 RI and related work at the Yard. The June-July 1997 baseline round was both the most recent and the most comprehensive of the three ground-water sampling and analysis rounds. Therefore, unless otherwise stated, current ground-water conditions are described based on the June-July 1997 data.

To evaluate any metals impacts to ground-water quality, wells located along the upgradient boundary of the Yard (i.e., MW-30, MW-34, MW-47/MW-48D, MW-61/MW-62D, TP-9 and TP-10) were selected to develop a range of background metals concentrations. Only metals detected above both background ranges and the applicable ambient water quality standards are discussed in this section.

Since the separate-phase petroleum accumulation in OU-3 has the potential to affect ground-water quality and alters water-level measurements, the extent of the separate-phase petroleum accumulation is shown in all Plates. A detailed description of the separate-phase petroleum accumulation delineation work will be included in the OU-3 RI report.

7.3.1 Separate-Phase Petroleum in OU-3

The results of separate-phase petroleum accumulation investigations delineated the accumulation as shown in all Plates. Compared to pre-1994 data, the northwestern and western limits of the accumulation have not changed significantly, but have been more accurately delineated. Based on the installation of Monitoring Well MW-49, the western edge of the accumulation does not extend as far west as previously estimated. However, the upgradient edge of the petroleum accumulation now extends east to the Turntable, and southeast beyond the Locker Room/Shop to the retaining wall. Monitoring Well MW-21 and former wells MW-55 and MW-56 appear to delineate the upgradient boundary of the separate-phase petroleum accumulation.

The results of the off-site delineation work indicated that the separate-phase petroleum accumulation had not migrated northward beyond the sewer line, was not present beneath the buildings located along Northern Boulevard, and was probably not migrating offsite in the sewer. The sewer line which parallels the northern boundary of the LIRR property is apparently acting as a physical barrier to the northward migration of ground water and the floating separate-phase petroleum accumulation.

Upward vertical gradients (i.e., upward ground-water flow) exist beneath the west and northwest portions of the Yard, including OU-3. The upward flow of ground water reduces or prevents the downward migration of petroleum-related contaminants from the OU-3 separate-phase petroleum accumulation into the Upper Glacial aquifer. Ground-water quality data confirm that petroleum-related VOCs, SVOCs, PCBs and metals are not contaminating ground water beneath or downgradient of the separate-phase petroleum accumulation in OU-3. Since ground water is flowing at a rate of approximately 6 ft/d, any dissolved contaminants present in ground water beneath the separate-phase petroleum accumulation would have had ample time to reach and be detected in the on-site downgradient monitoring wells. However, with the exception of low concentrations (i.e., estimated and below the practical quantitation limit) of BTEX in MW-35 and MW-38D, no regulated petroleum-related contaminants were detected. As previously discussed, the separate-phase petroleum accumulation is not a likely source of BTEX in these wells because:

- MW-35 is located on the north side of the sewer line which is acting as a physical barrier to the northward migration of ground water and the separate-phase petroleum accumulation;

- local dewatering by the Transit Authority may be causing nearby USTs or SMP to impact ground-water quality within MW-35;

- SMP, a known source of BTEX in concentrations up to 3,430 µg/L, is located on the north side of the sewer and is hydraulically upgradient of both MW-35 and MW-38D;

- the top of the screen zone in MW-38D is more than 26 feet below the water table (and therefore, more than 26 feet below the separate-phase petroleum accumulation);

- no VOCs were detected in ground water directly beneath the separate-phase petroleum accumulation (i.e., MW-23D);

- there is an upward hydraulic gradient beneath OU-3, reducing or preventing the downward flow of contaminants; and

- all VOCs, including BTEX, were non-detect in the shallow well clustered with MW-38D (i.e., MW-49).

7.3.2 Ground-Water Classification

During the May 1997 round, samples were analyzed for chloride and TDS to determine if ground water beneath the Yard is classified as saline ground water by the NYSDEC. The NYSDEC Water Quality Regulations define saline ground waters as "ground water that has a chloride concentration of more than 250 mg/L or a total dissolved solids concentration of more than 1,000 mg/L." The results of these analyses determined that saline ground water exists at 38 percent of the monitoring locations tested (i.e., 13 wells). The areal extent of saline ground water is shown in Plate 4.

The following nine wells are classified as saline: MW-27 through MW-30, MW-34, MW-41, MW-44D, MW-45 and MW-62D. These data indicate that salt-water intrusion affects the southwest half of the Yard. In addition, saline ground water is present along the north side of the Yard at locations MW-38D, MW-40D, MW-66 and MW-69D. These four locations closely correlate with the location of a 4-foot thick cobble zone present in the subsurface from the west-central portion of the Yard (MW-44D) northeast to location MW-40D and continuing east to MW-48D. The cobble unit may be a relict stream channel deposited by glacial meltwaters. The top of this unit is encountered at an elevation of approximately 2.3 feet above mean sea level at MW-48D (adjacent to the buried wetland in the northeast corner of the Yard), and deepens to the west, where it is encountered at approximately 18 feet below mean sea level at MW-44D (marking the current northern extent of saline ground water and the eastern edge of the buried Dutch Kills swamp). The cobble unit intersects the screen zones of both MW-44D and former well MW-40D. If this is a continuous unit, it explains the preferential flow of saline ground water from the southwest half of the Yard northeast to locations MW-38D and MW-40D, and east to locations MW-69D and MW-66. The apparent sources of the salt-water intrusion are both Dutch Kills and Newtown Creek.

Since there are no chemical-specific standards for Class GSA saline ground water, saline ground water is not discussed further. The minimum present extent of saline ground water at the Yard is shown in green in Plates 4 through 6.

7.3.3 Ground-Water Quality

The June-July 1997 analytical data for the 21 monitoring wells at the Yard containing fresh ground water were compared to Class GA ambient ground-water standards. Although the GA standards were used for comparison, the ground water in western Queens County is degraded and is not used as a drinking water source. Therefore, this comparison is considered overly conservative. The results of this comparison are summarized below. Wells that contain saline ground water, for which no chemical-specific standards apply, are shown in green in Plates 4 through 6.

VOCs

Three plumes of chlorinated VOCs in ground water and two plumes of BTEX in ground water have migrated beneath the Yard from off-site sources. These plumes are shown in Plate 5.

The highest concentration of total chlorinated VOCs detected at the Yard (398 μg/L) is found in upgradient boundary Monitoring Well MW-34, located on the southern boundary of the Yard. This plume migrates onto the Yard from an unknown off-site source located south of the Yard, and extends north through the Yard and offsite toward the ground-water discharge area (i.e., the buried flow path of Dutch Kills Creek). The majority of this plume is within saline ground water. However, Monitoring Well MW-42 at the leading edge of this plume (i.e., north end) contains three chlorinated VOCs in concentrations above their Class GA ground-water standards of 5 µg/L: tetrachloroethene (75 µg/L), trichloroethene (12 µg/L) and 1,2-dichloroethene (15 µg/L).

A second plume of chlorinated VOCs above Class GA ground-water standards has migrated onto the Yard from the north. The plume appears to be limited to two Class GA monitoring wells located on the north property boundary of the Yard. Total chlorinated VOCs were detected at concentrations of 8 µg/L (MW-64) and 13.9 µg/L (MW-65 [duplicate]). Each well contained one compound above its applicable Class GA ground-water standard of 5 µg/L. Tetrachloroethene was detected at a concentration of 6 µg/L in MW-64, and 1,2-dichloroethene was detected at a concentration of 9 µg/L in MW-65. The source of this plume is SMP, located immediately north of the Yard.

A third plume of chlorinated VOCs was detected in well cluster MW-61/MW-62D, located on the southern property boundary of the Yard. This cluster marks the saline/fresh ground-water interface: deep well MW-62D is saline, while shallow well MW-61 is a Class GA well. Total chlorinated VOCs were detected at 7 µg/L (MW-61) and 5.9 µg/L (MW-62D), with none of the VOCs present above Class GA or GSA standards. Ground-water flow patterns indicate that an off-site source east of the well cluster is responsible for this chlorinated VOC plume.

Two plumes of BTEX have migrated onto the Yard from the north and the northeast. Currently, only one of these plumes (north [i.e., MW-35]) exceeds ground-water standards. Of the BTEX compounds detected in MW-35, benzene was detected at 3 µg/L, exceeding its standard of 0.7 µg/L. Analysis of the November 14, 1997 split sample from MW-35 (collected as part of the Transit Authority's dewatering monitoring program) confirmed this exceedance (2 µg/L benzene).The source of this BTEX plume may be SMP or the USTs associated with buildings along Northern Boulevard. A BTEX plume was also identified in the northeast corner of the Yard (i.e., MW-47/MW-48D and TP-9). This plume does not currently exceed ground-water standards. Since former well TP-9 and former cluster MW-47/MW-48D (MW-47 was abandoned April 1998) were upgradient boundary wells, these detections are attributed to an off-site source, located east of the Yard.

SVOCs

No SVOCs were detected above ambient ground-water standards.

PCBs

No PCBs were detected above ambient ground-water standards.

Metals

Only five monitoring wells at the Yard contained one or more metals above both Yard background ranges and Class GA standards: MW-49 (iron), MW-59 (manganese), MW-64 (zinc), MW-65 (magnesium), and TP-8 (beryllium, chromium, iron, lead, manganese). A total of seven different metals were detected above both background ranges and Class GA standards: beryllium, chromium, iron, lead, manganese, magnesium and zinc. With the exception of iron and manganese, each of these metals exceeded both background ranges and Class GA standards only once. These exceedances are shown in Plate 6.

The five wells containing metals above both background and standard are located downgradient or in close proximity to SMP. The exceedances of beryllium, chromium, lead and zinc occurred in two wells close to SMP (former wells TP-8 and MW-64). In addition, lead was not detected above both background and standard in any other Yard wells, including those wells screened beneath or downgradient of the separate-phase petroleum accumulation in OU-3. The magnesium detected in MW-65 may be partly attributable to salt-water intrusion, which affects former nearby well MW-66. Magnesium is associated with salt-water intrusion, with 1,350,000 μg/L being the average concentration of magnesium in sea water (Weast, 1984).

Both the background range and standard for manganese were exceeded in two monitoring wells (MW-59 and TP-8), and for iron in two monitoring wells (MW-49 and TP-8). According to published and Yard hydrogeologic data, the Upper Glacial aquifer is known to contain elevated concentrations of manganese and iron. Published data for Queens County (Buxton, et al., 1981) indicate that manganese concentrations within the Upper Glacial aquifer can exceed 10,000 µg/L; the highest manganese detection at the Yard was 6,310 µg/L. Manganese concentrations increase as conditions become anoxic. Anoxic conditions are found in wetlands, such as the buried wetlands located beneath the western portion of the Yard and the northeast corner of the Yard where TP-8 was located (Plate 4). Published data also indicate that high manganese concentrations are associated with high iron concentrations. In addition, iron and manganese (and sodium) exceeded standards most often at the SMP site, and exceeded standards by the greatest margins (Holzmacher, McLendon & Murrell, P.C., 1992).

As shown in Plate 6, all five wells that contain a metal exceedance are located downgradient of or in close proximity to SMP, a known source of metals-contaminated ground water. Concentrations of metals shown in Plate 6 were compared to concentrations of metals detected at SMP. As previously stated, all metals detected in ground water at the Yard have been detected in higher concentrations in ground water beneath the SMP property. Concentrations of metals at SMP ranged from approximately 150 to 1,400 percent higher than the concentrations of the same metals detected at the Yard, indicating that SMP is the probable source of metals exceedances in ground water from SMP (and possibly location TP-8) west through OU-3.

In summary, seven metals exceeded both Yard background ranges and Class GA standards. These exceedances occurred in five wells located along the northern boundary of the Yard, with the known SMP metals contamination being the likely source.

Water Quality Parameters

Of the 21 Class GA monitoring wells sampled, five exceeded the TDS standard of 500 mg/L, while remaining below the 1,000 mg/L TDS and 250 mg/L chloride levels which would classify the ground water as saline (i.e., Class GSA). The locations of these wells generally correlate with either the buried Dutch Kills swamp (i.e., MW-43), the buried northeast swamp (i.e., MW-47/MW-48D) or the buried channel (i.e., a cobble unit) connecting these two buried swamps, present from MW-44D to MW-40D to MW-48D (i.e., MW-39D, MW-65 and cluster

MW-47/MW-48D). As previously discussed, saline ground water is present within some wells which are adjacent to or screen the cobble unit. The proximity of the cobble unit (and associated saline ground water) may account for the elevated TDS levels at locations MW-39D, MW-65, and cluster MW-47/MW-48D (Plate 4).

7.3.4 Additional Detections

Unregulated detections occurred in two wells at the Yard, and a petroleum sheen was observed in one well outside of OU-3 (i.e., an isolated occurrence that is not part of the separate-phase petroleum accumulation delineated in OU-3). These detections differ from the exceedances discussed in previous sections, in that they are the only ones attributable to sources at the Yard.

- A petroleum sheen is present in Monitoring Well MW-68;
- benzene is present in MW-27 ground water; and
- 4-methyl-2-pentanone (i.e., MIBK) is present in Monitoring Well MW-27 and former MW-59 location ground water.

Although there is no specific Class GA ground-water standard for oil and other floating substances, a petroleum sheen can impair the ground water for its best usage. The benzene detected in Monitoring Well MW-27 is unregulated because this well contains Class GSA saline ground water. There are no standards available for MIBK in either Class GA or Class GSA ground water. It is important to note that none of these constituents were detected (above 1 μg/L) in ground water downgradient of the wells in which the detections occurred, indicating that these are isolated occurrences.

7.3.4.1 Separate-Phase Petroleum Sheen in MW-68

The petroleum sheen present in MW-68 was identified as diesel fuel (or similar), and was analyzed for PCBs. The PCB Aroclor-1260 was detected at a concentration of 0.077 μg/L. This sheen appears to be an isolated occurrence, and not connected to the separate-phase petroleum accumulation in OU-3. Since Monitoring Well MW-68 is located immediately downgradient of the heavy equipment fueling area, the petroleum sheen on the water table is attributable to fuel spillage onto soil in this area. Since only virgin diesel is dispensed in the heavy equipment fueling area, the PCBs detected in the MW-68 sample are attributable to soil. PCBs bound to soil would be mobilized by contact with petroleum, such as the diesel spilled directly onto soil in the heavy equipment fueling area. Therefore, this sheen will be addressed in the recommendations section.

7.3.4.2 Benzene in MW-27

Benzene was detected at a concentration of 130 µg/L in the saline ground water of MW-27. However, this is an unregulated detection since it occurs in ground water with a Class GSA designation. According to published data (Howard et al., 1991), aqueous biodegradation for benzene occurs more rapidly under aerobic, saline conditions (i.e., half life as low as 5 days). Under anaerobic, saline conditions, the half life increases to 112 days.

7.3.4.3 MIBK in MW-27 and MW-59

MIBK (i.e., 4-methyl-2-pentanone) was detected at a concentration of 5,200 µg/L in the saline ground water of MW-27, and at a concentration of 1,300 µg/L in the Class GA ground water of MW-59. Although these detections are attributable to Yard activities, these are unregulated detections because there is no standard for MIBK in either fresh or saline ground water. Based on published data, MIBK attenuates rapidly. The unacclimated aqueous biodegradation rate (i.e., half life) for MIBK ranges from 1 to 7 days under aerobic conditions and from 4 to 28 days under anaerobic conditions (Howard, et al., 1991). Furthermore, the use of MIBK at the Yard has been discontinued and product containing MIBK has been removed from the Yard. During the beginning of 1999, Amtrak switched to use of an alcohol that does not contain MIBK. In addition, employees are now trained regarding the proper use and handling of chemicals to prevent future spillage.

7.4 Conclusions

Based on all data presented in this report, the following conclusions have been reached regarding OU-6.

- OU-6 consists of the saturated soil and ground water beneath the Yard which comprise the Upper Glacial aquifer. The Upper Glacial aquifer is present beneath the entire Yard.

- Ground water within the Upper Glacial aquifer flows predominantly west at an average rate of 5.7 to 6.6 ft/d, discharging to the buried flow path of Dutch Kills Creek in the western portion of the Yard and/or the East River, located approximately one mile from the Yard. Although Dutch Kills is now buried in the western portion of the Yard, it emerges south of the Yard before joining Newtown Creek.

- Upward vertical gradients (i.e., upward ground-water flow) exist beneath the west and northwest portions of the Yard, including OU-3, reducing or preventing the downward migration of petroleum-related contaminants from the OU-3 separate-phase petroleum accumulation into OU-6. This is supported by analytical data from monitoring wells screened either beneath or hydraulically downgradient of the separate-phase petroleum accumulation. In addition, the upward gradients assist in containment of the OU-3 separate-phase petroleum accumulation. Transit Authority monitoring as recent as April 1998 confirms that the separate-phase petroleum accumulation has not migrated offsite to the north (i.e., MW-19 and MW-35).

- Saline ground water is present throughout the southwest half of the Yard, and along the north side of the Yard where it correlates with a buried channel (i.e., cobble zone) that trends east-west through the Yard, connecting the buried Dutch Kills and saline ground-water lens with the buried northeast wetland. There are no chemical-specific standards for saline ground water (i.e., Class GSA). Thirteen Yard wells (38 percent) contain saline ground water (i.e., chloride >250 mg/L and/or TDS >1,000 mg/L).

- Three plumes of chlorinated VOCs in ground water have migrated onto the Yard from off-site sources, and are not related to Yard activities. Two of these plumes exceed ground-water standards. One plume originates south of the Yard (south of MW-34) and extends north through the Yard and MW-42: the source of this plume is unknown. The second plume originates at SMP (i.e., the known source) and has migrated south to locations MW-64 and MW-65.

- Two plumes of BTEX in ground water have migrated onto the Yard from off-site sources, and are not related to Yard activities. Benzene within one plume exceeds ground-water standards (i.e., MW-35 on June 18, 1997). (This exceedance was confirmed by a Transit Authority split sample collected November 14, 1997.)

- Seven metals were detected above both background ranges and ground-water standards. All of these exceedances are attributable to an off-site, upgradient source (i.e., SMP), with salt-water intrusion of the aquifer contributing to the concentrations of magnesium, and anoxic conditions within the aquifer (e.g., the buried northeast wetland) contributing to the concentrations of iron and manganese.

- No SVOCs were detected in Yard ground water above ground-water standards. In addition, the only SVOC to be detected above the practical quantitation limit occurred in Monitoring Well MW-35. MW-35 is located north of the sewer line that parallels the northern boundary of the Yard and is hydraulically downgradient of SMP.

- No PCBs were detected in Yard ground water above ground-water standards. Low concentrations of Aroclor-1260 were only detected in two monitoring wells: MW-23D and MW-25A. Monitoring Well MW-23D is located beneath the OU-3 separate-phase petroleum accumulation, and residual contamination may exist. MW-25A was located near the north property boundary and no clear source has been identified for the low detection.

- Ground-water quality data confirm that petroleum-related VOCs, SVOCs, PCBs and metals are not contaminating ground water beneath or downgradient of the separate-phase petroleum accumulation in OU-3. The source of the low BTEX concentrations (i.e., below ground-water standards and below the practical quantitation limit) detected within MW-38D is something other than the OU-3 separate-phase petroleum accumulation because:

    1. the top of the screen zone in MW-38D is more than 26 feet below the water table (and therefore, more than 26 feet below the separate-phase petroleum accumulation);

    2. no VOCs were detected in ground water directly beneath the separate-phase petroleum accumulation (i.e., MW-23D);

    3. there is an upward hydraulic gradient at location MW-38D (-0.0254 ft/ft); and

    4. all VOCs, including BTEX, were non-detect in the shallow well clustered with MW-38D (i.e., MW-49, where the screen zone straddles the water table and is at the same elevation as the separate-phase petroleum accumulation).

- Five wells contain TDS concentrations above the Class GA standard but below the concentration that defines saline ground water (i.e., Class GSA). The proximity of these wells to the buried wetlands and/or buried channel (i.e., cobble zone) suggests that the TDS levels are attributable to historical salt-water intrusion of the aquifer.

- Yard-related impacts to ground water are limited to a hydrocarbon sheen in one well, MW-68, and unregulated detections in two wells: former well MW-59 (MIBK) and saline well MW-27 (benzene and MIBK).

8.0 RECOMMENDATIONS

Based on the findings of the OU-6 RI, the following activities are recommended for the Yard.

- Although data indicate that the separate-phase petroleum accumulation is not contributing dissolved contaminants to ground water, the separate-phase petroleum accumulation in OU-3 will be properly addressed in the OU-3 RI and FS.
- Monitor ground water downgradient of the separate-phase petroleum accumulation, using the existing well network plus three proposed upgradient wells (locations to be determined following construction in the vicinity of the HSTF S&I Building), to verify that the accumulation is not impacting ground water (Figure 4).
- Remediate the source of the sheen observed on the water table at Monitoring Well MW-68. Change fueling practices to prevent future spillage.

No action is recommended for the chlorinated VOC plumes that have migrated onto the Yard from off-site sources, since these plumes are not Yard-related.

No action is recommended for the metals exceedances (i.e., above both Yard background ranges and ground-water standards), since these exceedances are attributable to off-site sources and salt-water intrusion.

Ground-water quality downgradient of the separate-phase petroleum accumulation will be monitored annually according to the following program.

- Water levels and product thicknesses (where present) will be measured in all functional Yard wells;
- eight shallow and four deep monitoring wells will be sampled; and
- ground-water samples will be analyzed for either the full suite of analytes (i.e., Class GA wells) or for the contaminants of concern at the Yard (i.e., Class GSA wells).

Specifically, two proposed monitoring wells upgradient of the separate-phase petroleum accumulation (i.e., MW-71 [to replace former wells MW-57 and MW-67] and MW-72 [to replace former well MW-59]), one existing monitoring well cross-gradient of the separate-phase petroleum accumulation (i.e., MW-46), and five existing monitoring wells downgradient of the separate-phase petroleum accumulation (i.e., MW-13, MW-19, MW-35, MW-37 and MW-49) will be sampled. All of these existing wells are shallow, Class GA monitoring wells. Samples from these existing and proposed wells will be analyzed for VOCs, SVOCs, PCBs, metals, TDS and chloride. Four deep monitoring wells will also be sampled: proposed monitoring well MW-70D (to replace former well MW-40D upgradient of the separate-phase petroleum accumulation), and existing wells MW-23D (screened beneath the separate-phase petroleum accumulation), MW-38D and MW-39D (downgradient of the separate-phase petroleum accumulation). Monitoring Wells MW-23D and MW-39D are both Class GA wells, and samples from these wells will be analyzed for VOCs, SVOCs, PCBs, metals, TDS and chloride. However, former well MW-40D and existing well MW-38D contained Class GSA saline ground water, and therefore MW-70D and MW-38D will only be sampled for the contaminants of concern at the Yard (i.e., carcinogenic PAHs, PCBs and lead). Although these locations are saline, they will be sampled as part of the monitoring program because of their proximity to the separate-phase petroleum accumulation: MW-70D will be installed as the closest deep well situated upgradient, and MW-38D is the closest deep well situated downgradient of the separate-phase petroleum accumulation. Locations for the three proposed wells will be chosen following construction in the vicinity of the HSTF S&I Building. Ground-water data will be compared to previous analyses to monitor any changes in ground-water quality and track the migration of dissolved constituents in ground water at the Yard. The proposed ground-water monitoring network is shown in Figure 4.

Since Yard soil is the suspected source for the petroleum sheen in MW-68, the remediation and monitoring of this location will be addressed in an IRM as part of the OU-4 RI.

Respectfully Submitted,

ROUX ASSOCIATES, INC.

Harry Gregory

Harry Gregory
Senior Hydrogeologist/
Project Manager

Joanne Yeary HG

Joanne Yeary
Senior Hydrogeologist

Joseph D. Dumin

Joseph D. Duminuco
Principal Hydrogeologist

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