

**ADDENDUM TO THE AUGUST 5, 1992
WORK PLAN FOR THE PHASE II
REMEDIAL INVESTIGATION**

**Sunnyside Yard
Queens, New York**

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1.0 INTRODUCTION

This Addendum to the August 5, 1992 "Work Plan for the Phase II Remedial Investigation, Sunnyside Yard, Queens, New York" was prepared by Roux Associates, Inc. (Roux Associates) on behalf of the National Railroad Passenger Corporation (AMTRAK) and the New Jersey Transit Corporation (NJTC). This Addendum was necessary because the integrity of monitoring wells previously installed at the Sunnyside Yard, Queens, New York (Yard) was called into question and therefore, so was the current delineation of the separate-phase petroleum accumulation previously defined at the Yard. A brief summary of the events leading to this addendum is presented below.

1.1 Background

On behalf of AMTRAK and the NJTC, a Phase I Remedial Investigation (RI) was performed at the Yard (Figure 1) by Roux Associates from October 1990 through March 1991. The RI was undertaken in accordance with the March 14, 1989 "Work Plan for the Remedial Investigation and Feasibility Study, Sunnyside Yard, Queens, New York" (Roux Associates, Inc., 1989). The Work Plan was prepared in accordance with the provisions of the Order on Consent (OOC), Index #W2-0081-87-06 between the New York State Department of Environmental Conservation (NYSDEC), AMTRAK, and the NJTC.

The Remedial Investigation of the Yard was intended to:

- evaluate the nature, extent, and potential migration pathways of separate-phase petroleum containing concentrations of polychlorinated biphenyls (PCBs) which have previously been identified in a limited area of the Yard; and
- develop hydrogeologic, soil quality and ground-water quality information to determine the nature and extent of other areas of contamination at the Yard.

The report titled "Phase I Remedial Investigation, Sunnyside Yard, Queens, New York" (Roux Associates, Inc., 1992) was accepted by the NYSDEC on January 16, 1992. The Phase I RI report summarized all soil and ground-water quality, geologic and hydrogeologic data generated by Roux Associates as part of this investigation. This information was utilized in conjunction with information developed during previous investigations to characterize environmental conditions at the Yard. Additionally, the Phase I RI report identified areas that required additional delineation and confirmatory sampling.

To address the recommended additional delineation and confirmatory sampling, the August 5, 1992 "Work Plan for the Phase II Remedial Investigation, Sunnyside Yard, Queens, New York" (Phase II Work Plan) was prepared by Roux Associates in accordance with the provisions of the OOC, Index #W2-0081-87-06.

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 on-site or off-site;
- develop additional information regarding the hydraulic relationship between the shallow fill deposits and the deeper Upper Glacial deposits underlying the Yard;
- investigate the potential for off-site migration of contaminants through the sewer system; and
- confirm the analytical results presented in the Phase I RI report.

These data will be used to conduct a risk assessment (RA), and will be used during the feasibility study (FS) to identify and evaluate remedial alternatives, if needed. The Phase II RI scope of work was organized into the following tasks to permit efficient acquisition of data necessary to support the RA and FS.

- Task I: Additional Delineation Investigation;
- Task II: Investigation of the Upper Glacial Aquifer;
- Task III: Sewer System Investigation;
- Task IV: Confirmatory Sampling; and
- Task V: Data Evaluation and Report Preparation.

During performance of the Phase II RI, the integrity of a monitoring well previously installed at the Yard by Geraghty & Miller, Inc. (Geraghty & Miller) was deemed questionable and, therefore, so was the current delineation of the separate-phase petroleum accumulation in Area 1. Monitoring Well MW-2 (Plate 1) was destroyed by Yard activities and on January 7, 1992, an attempt was made by Roux Associates to install Monitoring Well MW-40 and a replacement well (MW-2R) while properly abandoning MW-2. At that time, in the presence of the NYSDEC, separate-phase petroleum was noted flowing into a 3-foot

deep hand-dug excavation prior to installing MW-2R at a location downgradient of MW-2. Subsequently, additional hand-dug excavations were completed adjacent to, and upgradient of MW-2. The excavation adjacent to MW-2 also contained separate-phase petroleum, however, only petroleum sheens were noted at the two upgradient locations. At the request of the NYSDEC, the remaining upper portion of MW-2 was exposed for examination. Bentonite and cement grout was found within the top 1.5 to 2 feet of the screen zone (the section of the screen which intersected the top of the water table), thus preventing the petroleum from entering the well.

As a result of this observation, the NYSDEC verbally informed Roux Associates and AMTRAK that the integrity of all monitoring wells installed by Geraghty & Miller were now considered questionable, as well as the data previously derived from them. Furthermore, before any additional data would be accepted from the wells, the integrity and usability of each of the Geraghty & Miller wells needed to be determined. At that time, all of the Phase II RI work scheduled for Area 1 was postponed.

1.1.1 Preliminary Screening Results

To address the NYSDEC's concern regarding the integrity and usability of the Geraghty & Miller wells, a preliminary screening was conducted on January 11 and 12, 1993. The results of the preliminary screening were conveyed to the NYSDEC during a January 13, 1993 telephone conversation with Roux Associates. Based upon the results of the screening (i.e., the poor correlation between the observations made in the hand-dug boreholes adjacent to the wells and observations made within the actual wells) the NYSDEC determined that the wells should no longer be used as monitoring points since the data obtained from them was invalid. As a result, the NYSDEC required additional delineation of the separate-phase petroleum accumulation in Area 1. The results of the preliminary screening were reported to the NYSDEC in a January 19, 1993 letter report, a copy of which is included in Appendix A.

1.1.2 Additional Delineation Results

The additional delineation of the separate-phase petroleum in Area 1 of the Yard was performed in a phased approach by Roux Associates, in the presence of the NYSDEC, from January through April, 1993. The results of each phase of the investigation were reported to the NYSDEC in separate letter reports, copies of which are included in Appendix A.

As discussed in Appendix A, the additional delineation was performed primarily by advancing hand borings to the water table, driving a split-spoon sampler a minimum of two feet below the water table and observing the soil samples collected and the ground water entering into the borehole. Based upon these observations, a determination regarding the extent of petroleum accumulation was made. The shaded separate-phase petroleum accumulation depicted in Plate 2 was drawn using data collected on February 8, 1993 during a synoptic water-level and petroleum-thickness measurement round during the Phase II RI. The additional delineation results are shown in Plate 2 as a dashed line depicting the current delineation of the accumulation. In addition, a few areas of separate-phase petroleum and/or petroleum sheens were detected outside of the previously delineated accumulation. These detections appear to be isolated occurrences of petroleum and, at the request of the NYSDEC, will require additional delineation.

The results of the investigations indicated that the previously delineated northern, western and southwestern boundaries of the separate-phase petroleum accumulation were accurate (Plate 2). However, the extent of the accumulation was not fully delineated to the east and southeast (Plate 2).

1.2 Objectives

The objectives of the Phase II RI Addendum are to complete the previously postponed Phase II RI and to adequately delineate the extent of the separate-phase petroleum accumulation recently detected to the east and southeast of the previously delineated accumulation.

2.0 SCOPE OF WORK

The Addendum scope of work includes the following:

- completion of the field work previously proposed for Area 1 (i.e., installation of one shallow and three deep monitoring wells) in the August 5, 1992 Work Plan for the Phase II RI.
- proper abandonment of eleven monitoring wells previously installed by Geraghty & Miller in Area 1;
- installation and sampling of nine replacement wells to delineate the extent of the separate-phase petroleum accumulation in Area 1;
- installation of up to 22 soil borings and four monitoring wells (with a minimum of five soil analyses) to delineate the nature and extent of the separate-phase petroleum accumulations recently detected in the area south of the Metro Shop, adjacent to MW-10, MW-12 and to the north and west of the Turntable in Area 1;
- proper abandonment of Monitoring Wells MW-24 and MW-26 that were found during the Phase II RI to have been destroyed;
- installation of one shallow monitoring well to replace the destroyed Monitoring Wells MW-24 and MW-26;
- installation 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 fill deposits and the Upper Glacial deposits;
- installation and sampling of a temporary wellpoint in the vicinity of MW-26; and
- performance of bail-down tests on monitoring wells containing greater than one foot of separate-phase petroleum to determine the true thickness of the separate-phase petroleum accumulation in the surrounding formation and to estimate petroleum recharge rates.

The scope of work is divided into the following six tasks:

- **Task 1:** Soil Borings;
- **Task 2:** Monitoring Well Abandonment;
- **Task 3:** Monitoring Well Installation;
- **Task 4:** Water-Level Measurements;
- **Task 5:** Bail-Down Testing; and
- **Task 6:** Sampling and Analysis.

The following project operation plans (POPs) are included in the Work Plan Addendum:

- Sampling and Analysis Plan (SAP);
- Health and Safety Plan (HASP);
- Site Management Plan (SMP); and
- Quality Assurance Project Plan (QAPP).

The SAP (Appendix B) describes the types of samples (i.e., soil, ground water and separate-phase petroleum) to be collected and the procedures to be followed (i.e., drilling, decontamination, sample collection) during site characterization and remedial investigation activities conducted at the Yard. Therefore, the procedures will not be presented separately in each task description but will be referred to in Appendix B. The HASP (Appendix C) has been prepared in accordance with 20 CFR 1910.120 Occupational Safety and Health Administration (OSHA) Hazardous Waste Operations Rule, Roux Associates Standard Operating Procedures (SOPs) and Site-specific safety rules. The SMP (Appendix D) identifies operating procedures which have been developed to minimize exposure, risks and the spread of contamination during field investigations at the Yard. The QAPP (Appendix E) presents the organization, objectives, functional activities and specific quality assurance/quality control activities associated with the RI.

2.1 Task 1 - Soil Borings

The details of the soil boring procedures are included in the SAP (Appendix B). Soil borings will be drilled using either a truck-mounted or an all-terrain vehicle (ATV)-mounted hollow stem auger drill rig, depending on the location and access constraints. The locations and justifications for the proposed soil borings are included in Table 1 and discussed in Sections 2.1.1, 2.1.2 and 2.1.3.

Split-spoon soil samples will be collected continuously from three feet below land surface (bls) to the water table. Once the water table is encountered the split-spoon sampler will be driven two feet below the water table and the borehole will be left open for at least one hour to allow the separate-phase petroleum, if present, to flow into the borehole. The split-

spoon samples and ground water will be examined for any visual evidence of petroleum accumulation (e.g., staining, separate-phase petroleum, petroleum sheens) and also by using a photoionization detector (PID).

The results of Task 1 will be evaluated to determine if additional monitoring wells are needed in the area south of the Metro Shop or in the Turntable area. If needed, the monitoring wells will be installed as discussed in Section 2.3.

2.1.1 Turntable Area

As shown in Plate 2, petroleum was not detected hydraulically upgradient (to the east) of the Turntable, however, petroleum sheens were encountered to the northwest (PD-24 and PD-41) and southwest (GM-2B and GM-2C) of the Turntable. To determine the source of the petroleum sheens (e.g., emanating from the Turntable or a part of the previously identified accumulation), five soil borings to the water table are proposed. The proposed locations of S-118 through S-121 and S-129 are shown in Plate 3. The boreholes will be installed and sampled as previously described. Based upon field observations, one soil sample exhibiting evidence of contamination (e.g., staining, sheen, odors) from Soil Boring S-129 will be selected for laboratory analysis. If evidence of significantly different contamination is observed from Soil Borings S-118 through S-121, additional soil samples may be collected for analysis. In addition, soil samples collected from monitoring well boreholes in the former fuel storage area that exhibit evidence of contamination may be collected for analysis.

If necessary, the locations of proposed Monitoring Wells MW-51, MW-54, MW-55 and MW-63 (Plate 3) will be re-evaluated based upon a review of the results of the soil borings.

2.1.2 Area South of Metro Shop

As shown in Plate 2, the extent of the separate-phase petroleum accumulation is not fully delineated in the area south of the Metro Shop and the adjacent locker room/shop in Area 1. The results of the additional delineation hand borings (PD-13, PD-30 and PD-44) indicate that the petroleum accumulation may extend to the south of the retaining wall shown in Plate 2, but appears to be satisfactorily delineated in the remaining areas. The results of the additional delineation hand borings (PD-46 and PD-53), indicate the

petroleum accumulation does not extend significantly beyond the northwest corner of the former inspection pit (Plate 2). One soil sample exhibiting evidence of contamination will be collected for analysis from a monitoring well pilot borehole in this area.

A phased approach is proposed to evaluate the possible extent of the petroleum accumulation south of the retaining wall. Between two and seven soil borings are proposed to be drilled to the water table. The tentatively proposed locations for Soil Borings S-122 through S-128 are shown in Plate 3. Based upon field observations, one soil sample exhibiting evidence of contamination from this area will be selected for laboratory analysis. If evidence of significantly different contamination is observed, additional soil samples may be collected for analysis.

The following approach will be implemented.

Phase 1

- Complete Soil Borings S-122, S-123 and S-124; and
- If no separate-phase petroleum is encountered in Soil Borings S-122, S-123 or S-124, then install Monitoring Well MW-60 at the location shown in Plate 3 which completes work in this area.

Phase 2

- If separate-phase petroleum is encountered in Soil Boring S-122, then drill Soil Boring S-126;
- If separate-phase petroleum is encountered in Soil Boring S-123, then drill Soil Borings S-125 and S-127;
- If separate-phase petroleum is encountered in either Soil Boring S-124 or S-125, the need for additional delineation will be evaluated;
- If separate-phase petroleum is encountered in either Soil Boring S-126 or S-127, then complete Soil Boring S-128; and
- If no separate-phase petroleum is encountered in Soil Borings S-124 through S-127, then install Monitoring Well MW-60 at the location shown in Plate 3 which completes work in this area.

Phase 3

- If no separate-phase petroleum is encountered in Soil Boring S-128, then install Monitoring Well MW-60 at the alternate location (Soil Boring S-128) shown in Plate 3.

If the extent of separate-phase petroleum has not been delineated after the seven soil borings have been completed (i.e., separate-phase petroleum is encountered in Soil Borings S-126, S-127 or S-128), the results will be re-evaluated and an alternate approach will be determined.

2.1.3 Areas Adjacent to Monitoring Wells MW-10 and MW-12

As shown in Plate 2 and discussed in Section 1.1.2, isolated occurrences of separate-phase petroleum were detected adjacent to Monitoring Well MW-10 and west of the Engine House near Monitoring Well MW-12. The proposed locations for Soil Borings S-130 through S-139 are shown in Plate 3. To determine the extent of these isolated occurrences, four soil borings to the water table are proposed in each area. To determine the nature of contamination in these areas, one soil sample exhibiting evidence of contamination will be collected from Soil Borings S-134 and S-139 for laboratory analysis. If evidence of significantly different contamination is observed from any of the other borings, additional soil samples may be collected for analysis.

2.2 Task 2 - Monitoring Well Abandonment

As previously discussed, due to their questionable integrity, the Geraghty & Miller monitoring wells previously installed in Area 1 will be abandoned. In addition, Monitoring Wells MW-24 (located along the loop track) and MW-26 (Car Washer Area) were determined to be destroyed, and therefore, will be abandoned (Plate 3). With the exception of MW-26, which is addressed in Section 2.2.2, the procedures to be followed are described below.

- Over boring or removal of the casing to the greatest extent possible followed by perforation of any casing left in place. All casing and well installations in the upper five feet of the boring will be removed.

- Sealing by pressure injection with cement bentonite grout using a tremie pipe or other method acceptable to the NYSDEC will extend the entire length of the boring to five feet below the ground surface. The screened interval of the borehole will be sealed separately and tested to ensure its adequacy before sealing the remainder of the borehole. The upper five feet will be backfilled with appropriate native materials compacted to avoid settlement.
- The sealed site will be restored to a safe condition. The site will be inspected periodically after sealing for settlement.

2.2.1 Area 1 Geraghty & Miller Wells

Currently the following Geraghty & Miller-installed monitoring wells remain in service at the Yard (Plate 1):

- MW-1;
- MW-3;
- MW-5;
- MW-7;
- MW-8;
- MW-9;
- MW-10;
- MW-11;
- MW-12; and
- MW-15.

At the request of the NYSDEC, all ten of the remaining Geraghty & Miller monitoring wells will be removed from service. To preclude the possibility of the wells acting as conduits for contamination to migrate to the ground water, all the wells will be abandoned. As discussed in Section 2.3, appropriate replacement wells will be installed. In addition, the Geraghty & Miller-installed Monitoring Well MW-14 (Plate 1), which was found during the Phase I investigation to have been destroyed, will be properly abandoned.

Upon completion of the abandonment program, contaminated materials removed from within the separate-phase petroleum accumulation will be disposed of in accordance with applicable state and federal regulations.

2.2.2 Monitoring Wells MW-24 and MW-26

Monitoring Well MW-24 (which was installed with a locking steal protective casing) appears to have been filled with railroad ballast and destroyed by vandals. Since the well is no longer a useable monitoring point, MW-24 will be taken out of service and abandoned.

Monitoring Well MW-26 was destroyed but left in place during construction of the new car washer in Area 12. Since the well is surrounded by a thick concrete slab, overdrilling will not be practical. Therefore, the remaining portion of the well casing will be grouted to one foot below land surface and only the top one foot of casing will be removed and the open hole will be plugged with grout to preclude the possible introduction of contaminants in the well or around the annular space outside of the casing.

2.3 Task 3 - Monitoring Well Installation

The details of the monitoring well installation and development procedures are included in the SAP (Appendix B). The justifications for each monitoring well are included in Table 2. Monitoring wells will be installed in pilot boreholes drilled by either a truck-mounted or ATV-mounted hollow stem auger drill rig. Pilot boreholes for shallow (i.e., water table) monitoring wells will be advanced through the fill underlying the Yard to a depth of approximately 10 feet below the water table. Pilot boreholes for deep monitoring wells will be advanced to approximately 25 feet below the water table. Deep monitoring wells have previously been installed at the Yard during the Phase I RI (MW-23) and the Phase II RI (MW-44 and MW-48). In addition, four deep monitoring wells are proposed to be installed as part of the Addendum as discussed in Sections 2.3.1.2 and 2.3.3. At this time, we propose to denote the deep monitoring wells at the Yard with a "D" following the monitoring well numbers, including previously installed monitoring wells.

2.3.1 Replacement Wells

As previously discussed, the Geraghty & Miller-installed monitoring wells located in Area 1 (Plate 3) and Monitoring Wells MW-24 and MW-26 located along the Loop tracks (Plate 4) will be replaced.

2.3.1.1 Area 1 - Geraghty & Miller Wells

Since the Geraghty & Miller-installed wells are to be abandoned, additional shallow monitoring wells must be installed to allow for the continued delineation of the petroleum accumulation. Some of the wells are designed to be monitoring points within the accumulation, and others are designed to delineate the extent of accumulation (i.e., perimeter). Eight monitoring wells (MW-49 through MW-55, MW-57 and MW-63) are

proposed at the locations shown in Plate 3. The locations were chosen based upon a review of previous monitoring data, data derived from Roux Associates-installed monitoring wells in Area 1, and the results of the additional delineation (Appendix A).

2.3.1.2 Monitoring Wells MW-24 and MW-26

The isolated location of MW-24 renders it susceptible to additional acts of vandalism, therefore, a replacement well at the same location is not recommended. Rather, a location (MW-61) was chosen between monitoring well locations MW-24 and MW-26 that will provide sufficient hydraulic control to characterize the shallow ground-water flow in the southeast portion of the Yard (Plate 4). However, based upon a preliminary review of the Phase II RI ground-water analytical results, a well cluster is proposed to be installed at this location consisting of a shallow monitoring well (MW-61) and a deep monitoring well (MW-62D). The installation of a well cluster will result in the following:

- a determination of the hydraulic relationship between the shallow fill deposits and the deeper Upper Glacial aquifer;
- a determination of the vertical hydraulic gradients and deeper ground-water flow; and
- a characterization of the ground-water quality entering the Yard in the Upper Glacial aquifer.

In addition, at the request of the NYSDEC, a temporary well point (TW-3) will be installed in the immediate vicinity of MW-26 (Plate 4) and a sample will be collected to be analyzed for semivolatile organic compounds (SVOCs) and PCBs as proposed in the Phase II Work Plan.

2.3.2 Additional Delineation of the Separate-Phase Petroleum Accumulation in Area 1

To further delineate the extent of the petroleum accumulations located south of the Metro Shop (Plate 2) and possibly in the vicinity of the Turntable (Plate 2), additional monitoring wells will be installed. Some wells will be located within the petroleum accumulation and others will be located around the perimeter. If, during the installation of the first few monitoring wells, a reasonable correlation does not exist between observations made during the previous phases of additional delineation and observations made in the new wells, the placement of the remaining monitoring wells will be re-evaluated.

2.3.2.1 Turntable Area

As discussed in Section 2.3.1.1, Monitoring Well MW-61 will be installed adjacent to Monitoring Well MW-1, which is scheduled to be abandoned. Based upon a review of the results from Soil Borings S-118 through S-121 and S-129, and Monitoring Well MW-61, the need for additional wells in this area will be re-evaluated.

2.3.2.2 Area South of the Metro Shop

As previously described in Section 1.0, the determinations of separate-phase petroleum, petroleum sheens, or the absence of petroleum were based upon visual examination of hand-dug boreholes. Monitoring well locations have been proposed based upon those determinations.

Four monitoring wells (MW-56, and MW-58 through MW-60) are proposed in this area and the locations are shown in Plate 3. In addition, the results of the soil borings in the area will be evaluated to determine the need for additional monitoring wells to the south of the retaining wall (Plate 3). Based upon a review of the results of the soil boring and sampling data from these areas, the need for additional wells will be re-evaluated.

2.3.2.3 Areas Adjacent to Monitoring Wells MW-10 and MW-12

As previously discussed in Sections 1.1.2 and 2.1.3, additional delineation of the separate-phase petroleum accumulation in these areas was requested by the NYSDEC. Based upon a review of the results of the soil boring and sampling data from these areas, the need for additional wells will be re-evaluated.

2.3.3 Completion of Proposed Phase II RI

Due to the postponement of the Phase II RI in Area 1, previously proposed Monitoring Wells MW-37 (shallow), and MW-38, MW-39 and MW-40 (deep) have not been installed. The monitoring wells will be installed in accordance with the Phase II Work Plan. Since the proposed deep Monitoring Wells MW-38 and MW-40 were to be installed as clusters adjacent to existing Geraghty & Miller-installed wells, the proposed locations of the wells have been revised based upon the monitoring well installation program discussed in Section 2.3 (Plate 3). In addition, MW-37 was relocated to a downgradient position.

2.4 Task 4 - Water-Level Measurements

Following installation of all new monitoring wells, a round of water-level and separate-phase petroleum thickness measurements will be performed at all specified monitoring wells (i.e., all existing monitoring wells in Area 1, all newly installed Geraghty & Miller replacement wells, all newly installed additional delineation wells and the newly installed remaining Phase II RI wells). Water levels will be measured to the nearest 0.01 foot using a steel measuring tape and chalk. In wells containing separate-phase petroleum, the petroleum thickness and water levels will be measured to the nearest 0.01 foot using an oil/water interface probe. The protocols that will be followed during the measurement of water levels and petroleum thicknesses are described in the SAP (Appendix B).

2.5 Task 5 - Bail-Down Testing

Separate-phase petroleum bail-down tests will be conducted in all monitoring wells at the Yard containing significant (i.e., greater than 1.0 feet) thicknesses of petroleum. The newly installed wells will be monitored to determine when the separate-phase petroleum accumulations have equilibrated before testing will be performed. The tests will be conducted to evaluate the true petroleum accumulation thickness in the formation, as well as petroleum recharge rates. These data will result in more accurate estimates of the total volume of separate-phase petroleum beneath Area 1 and the total recoverable volume. This information will be used to support the feasibility study.

The bail-down tests will be conducted in accordance with the procedures specified in the technical paper titled "Two Techniques for Determining the True Hydrocarbon Thickness in an Unconfined Sandy Aquifer" (Hughes, et. al.; 1988), a copy of which is included in Appendix F. The separate-phase petroleum removed from the wells during the bail-down tests will be placed in the on-site holding tank connected to the interim remedial measures (IRM) system.

2.6 Task 6 - Sampling and Analysis

Soil, ground-water and separate-phase petroleum sampling procedures are provided in the SAP (Appendix B). All samples will be analyzed using the United States Environmental Protection Agency (USEPA) and NYSDEC Analytical Services Protocols (ASP) methods

listed in the SAP for PCBs, volatile organic compounds (VOCs), SVOCs and metals. A summary of the proposed soil sampling plan is included in Table 3. A summary of the proposed ground-water and separate-phase petroleum sampling plan is included in Table 4.

Summaries of the practical quantitation limits (PQLs) for VOC, SVOC and PCB analyses in soil are provided in Tables 5, 6 and 7, respectively. The NYSDEC recommended soil cleanup objectives are included in the tables for comparison purposes only at the request of the NYSDEC. PQLs are included in the tables rather than Method Detection Limits (MDLs) because soil analyses are so variable (e.g., pH, moisture content, total organic carbon content, matrix interferences, etc.) that MDLs are not available. Summaries of the PQLs and MDLs for VOC, SVOC and PCB analyses in ground water are provided in Tables 9, 10 and 11, respectively. Contractually Required Detection Limits (CRDLs) are provided for metals analyses in soil and ground water in Table 8 and Table 12, respectively. Analytes detected below the PQLs and CRDLs will be reported, but will be flagged as estimated.

It is important to note that in the NYSDEC August 1992 STARS Memo #1 - Petroleum-Contaminated Soil Guidance Policy, that PQLs are listed rather than MDLs. Furthermore, the NYSDEC states the following, "The Method Detection Limit (MDL) is the best possible detection. Laboratories report the Practical Quantitation Limit (PQL), which is generally 4 times the MDL. Efforts should be made to obtain the best detection possible when selecting a laboratory. When the Guidance Value or Standard is below the detection limit, achieving the detection limit will be considered acceptable for meeting the Guidance Value or Standard."

2.6.1 Soil Sampling

The details of the soil sampling and analysis procedures are included in the SAP (Appendix B). As previously discussed, a minimum of five soil samples will be submitted for laboratory analysis. However, with the exception of Soil Borings S-129, S-134 and S-139, the remaining sampling locations have not been determined. The remaining locations will be chosen based upon the actual field conditions encountered. The soil samples will be analyzed for Target Compound List (TCL) VOCs, TCL SVOCs, PCBs and the Target Analyte List (TAL) metals. In addition, hydrocarbon scans will be performed to determine the type(s) of petroleum encountered.

2.6.2 Ground-Water Sampling and Analysis

The details of the ground-water sampling and analysis procedures are included in the SAP (Appendix B). Prior to sampling, the proposed monitoring wells will be screened for the presence of separate-phase petroleum accumulations, including sheens. Ground-water samples will not be collected from any monitoring wells containing evidence of separate-phase petroleum. A summary of the proposed ground-water sampling plan is included in Table 3.

All newly installed monitoring wells around the perimeter of the separate-phase petroleum accumulation in Area 1 (i.e., replacement wells, additional delineation wells, previously proposed Phase II wells) will be sampled and analyzed for TCL VOCs, TCL SVOCs, PCBs and the TAL metals.

2.6.2.1 Monitoring Well MW-26

A ground-water sample was proposed to be collected from Monitoring Well MW-26, located in the Car Washer Area, during the Phase II RI. Since MW-24 and MW-26 will be replaced with a single monitoring well, located approximately equidistant between the two, an alternate sampling point is needed in the Car Washer Area. As requested by the NYSDEC, a temporary wellpoint will be installed in the immediate vicinity of MW-26 and will be sampled for TCL SVOCs, and PCBs. Details of the temporary wellpoint installation procedures are included in the SAP (Appendix B). Justification for the temporary wellpoint is included in Table 2.

2.6.3 Separate-Phase Petroleum Sampling

As previously discussed in Sections 2.3.1 and 2.3.2, Monitoring Wells MW-50 through MW-56, and MW-58 are proposed to be installed within the separate-phase petroleum accumulation in Area 1. If sufficient volumes exist, the petroleum in the monitoring wells will be sampled and analyzed for PCBs, specific gravity and kinematic viscosity. In addition, hydrocarbon scans will be performed to determine the type(s) of petroleum encountered. The standing separate-phase petroleum in the wells will be purged prior to sample collection. This may be accomplished during Task 5, Bail-Down Testing. These data will be used to evaluate the potential for multiple source areas and will be used to support the FS.

3.0 DATA EVALUATION AND INCLUSION IN THE PHASE II RI REPORT

With the exception of the work included in this Addendum, the remainder of the Phase II RI scope of work has been completed. Upon completion of this scope of work, the data will be evaluated in conjunction with the data previously collected at the Yard. The Phase II RI report will present the data developed during all phases of the investigation, findings, conclusions and any recommendations that may be appropriate.

4.0 SCHEDULE

The proposed schedule included in the Phase II Work Plan was modified based upon the previously discussed developments that occurred during performance of the Phase II RI Field Investigation in Area 1.

The proposed schedule to implement the Phase II Addendum and complete the Phase II RI Report is provided in Figure 2. This schedule was prepared assuming that field work will commence within eight weeks of the approval of the Addendum by the NYSDEC. The proposed schedule for field work is an estimate only and the schedule will be altered if unforeseen conditions are encountered. Every effort will be made to adhere to the proposed schedule and the NYSDEC will be notified immediately if any changes are necessary.

5.0 REFERENCES

- Hughes, J.P., C.R. Sullivan, and R.E. Zinner. 1988. Two Techniques for Determining the True Hydrocarbon Thickness in an Unconfined Sandy Aquifer. Proceedings of the Conference on Petroleum Hydrocarbons and Organic Chemicals in Ground Water: Prevention, Detection, and Restoration, Houston, Texas, 1988.
- Roux Associates, Inc., 1990. Work Plan for the Remedial Investigation and Feasibility Study, Sunnyside Yard, Queens, New York. Prepared for: National Railroad Passenger Corporation, Washington, D.C.
- Roux Associates, Inc., 1992. Phase I Remedial Investigation, Sunnyside Yard, Queens, New York, Final Report. Volumes 1-3. Prepared for: National Railroad Passenger Corporation, Washington, D.C.

Table 1. Soil Boring Justifications, Sunnyside Yard, Queens, New York

Soil Boring	Approximate Location	Justification
S-118	Area 1 - north of Metro Shop and west of Turntable	Delineate extent of additional separate-phase petroleum accumulation
S-119	Area 1 - north of Metro Shop and west of Turntable	Delineate extent of additional separate-phase petroleum accumulation
S-120	Area 1 - north of Metro Shop and west of Turntable	Delineate extent of additional separate-phase petroleum accumulation
S-121	Area 1 - north of Metro Shop and west of Turntable	Delineate extent of additional separate-phase petroleum accumulation
S-122	Area 1 - south of Metro Shop	Delineate extent of additional separate-phase petroleum accumulation
S-123	Area 1 - south of Metro Shop	Delineate extent of additional separate-phase petroleum accumulation
S-124	Area 1 - south of Metro Shop	Delineate extent of additional separate-phase petroleum accumulation
S-125 ⁽¹⁾	Area 1 - south of Metro Shop	Delineate extent of additional separate-phase petroleum accumulation
S-126 ⁽²⁾	Area 1 - south of Metro Shop	Delineate extent of additional separate-phase petroleum accumulation
S-127 ⁽¹⁾	Area 1 - south of Metro Shop	Delineate extent of additional separate-phase petroleum accumulation
S-128 ⁽³⁾	Area 1 - south of Metro Shop	Delineate extent of additional separate-phase petroleum accumulation
S-129	Area 1 - north of Metro Shop and west of Turntable	Determine nature of additional separate-phase petroleum accumulation
S-130	Area 1 - vicinity of MW-10	Delineate extent of isolated separate-phase petroleum accumulation
S-131	Area 1 - vicinity of MW-10	Delineate extent of isolated separate-phase petroleum accumulation
S-132	Area 1 - vicinity of MW-10	Delineate extent of isolated separate-phase petroleum accumulation
S-133	Area 1 - vicinity of MW-10	Delineate extent of isolated separate-phase petroleum accumulation
S-134	Area 1 - adjacent to MW-10	Determine nature of isolated separate-phase petroleum accumulation
S-135	Area 1 - vicinity of MW-12	Delineate extent of isolated separate-phase petroleum accumulation
S-136	Area 1 - vicinity of MW-12	Delineate extent of isolated separate-phase petroleum accumulation
S-137	Area 1 - vicinity of MW-12	Delineate extent of isolated separate-phase petroleum accumulation
S-138	Area 1 - vicinity of MW-12	Delineate extent of isolated separate-phase petroleum accumulation
S-139	Area 1 - adjacent to MW-12	Determine nature of separate-phase petroleum accumulation

- Notes:
- (1) - If evidence of separate-phase petroleum is detected in Soil Boring S-123, then Soil Borings S-125 and S-127 will be completed.
 - (2) - If evidence of separate-phase petroleum is detected in Soil Boring S-122, then Soil Boring S-126 will be completed.
 - (3) - If evidence of separate-phase petroleum is detected in either Soil Boring S-126 or S-127, then Soil Boring S-128 will be completed.

Table 2. Monitoring Well Justifications, Sunnyside Yard, Queens, New York

Well Number	Screen Setting	Approximate Location	Justification
MW-49	Shallow	Area 1 - north of Engine House	Characterize shallow ground-water flow and quality downgradient from the separate-phase petroleum accumulation.
MW-50	Shallow	Area 1 - north of Engine House	Characterize nature and extent of separate-phase petroleum accumulation.
MW-51	Shallow	Area 1 - north of Metro Shop	Characterize nature and extent of separate-phase petroleum accumulation.
MW-52	Shallow	Area 1 - south of Engine House	Characterize nature and extent of separate-phase petroleum accumulation.
MW-53	Shallow	Area 1 - north of Metro Shop	Characterize nature and extent of separate-phase petroleum accumulation.
MW-54	Shallow	Area 1 - north of Metro Shop	Characterize nature and extent of additional separate-phase petroleum accumulation.
MW-55	Shallow	Area 1 - north of Metro Shop	Characterize nature and extent of additional separate-phase petroleum accumulation.
MW-56	Shallow	Area 1 - south of Metro Shop	Characterize nature and extent of additional separate-phase petroleum accumulation.
MW-57	Shallow	Area 1 - south of Metro Shop	Characterize shallow ground-water flow and quality upgradient from the additional separate-phase petroleum accumulation.
MW-58	Shallow	Area 1 - south of Metro Shop	Characterize nature and extent of additional separate-phase petroleum accumulation.
MW-59	Shallow	Area 1 - south of Metro Shop	Characterize shallow ground-water flow and quality upgradient from the additional separate-phase petroleum accumulation.
MW-60	Shallow	Area 1 - south of Metro Shop and retaining wall (exact location to be determined by field conditions encountered)	Characterize shallow ground-water flow and quality upgradient from the additional separate-phase petroleum accumulation.

Table 2. Monitoring Well Justifications, Sunnyside Yard, Queens, New York

Well Number	Screen Setting	Approximate Location	Justification
MW-61 MW-62D (Cluster)	Shallow Deep	Loop tracks near 39th Street and Skillman Avenue	Characterize shallow and deep ground-water flow and quality; determine the hydraulic relationship between shallow fill deposits and the Upper Glacial aquifer; access the potential for on-site migration of contaminants.
MW-63	Shallow	Area 1 - north of Turntable near MW-1	Replacement of Geraghty & Miller Monitoring Well MW-1 and to characterize shallow ground-water quality upgradient from the separate- phase petroleum accumulation
TW-3 ^(a)	Shallow	Area A-12 - northwest of Car Washer	Characterize shallow ground-water quality downgradient of Area A-12 (Car Washer) since MW-26 was destroyed by construction activities.

Notes:

- Shallow - screen bridging the water table
 Deep - screen set approximately 40 feet below land surface in the Upper Glacial Aquifer
 (a) - temporary well

Table 3. Summary of Analytical Parameters for Soil Samples, Sunnyside Yard, Queens, New York

Sampling Location/Designation	Analytical Parameters
S-129	TCL VOCs, TCL SVOCs, PCBs, TAL Metals, Hydrocarbon Scan
S-134	TCL VOCs, TCL SVOCs, PCBs, TAL Metals, Hydrocarbon Scan
S-139	TCL VOCs, TCL SVOCs, PCBs, TAL Metals, Hydrocarbon Scan

- TCL - Target Compound List
- TAL - Target Analyte List
- VOCs - Volatile Organic Compounds
- SVOCs - Semivolatile Organic Compounds
- PCBs - Polychlorinated Biphenyls

Note: The remaining additional soil samples will be analyzed for the suite of parameters listed above.

Table 4. Summary of Analytical Parameters for Ground-Water and Separate-Phase Petroleum Samples, Sunnyside Yard, Queens, New York

Sampling Location/Designation	Analytical Parameters
Ground Water Samples	
MW-37	TAL Metals*
MW-49	TCL VOCs, TCL SVOCs, PCBs, TAL Metals
MW-57	TCL VOCs, TCL SVOCs, PCBs, TAL Metals
MW-59	TCL VOCs, TCL SVOCs, PCBs, TAL Metals
MW-60	TCL VOCs, TCL SVOCs, PCBs, TAL Metals
MW-61	TCL VOCs, TCL SVOCs, PCBs, TAL Metals
MW-62D	TCL VOCs, TCL SVOCs, PCBs, TAL Metals
MW-63	TCL VOCs, TCL SVOCs, PCBs, TAL Metals
TW-3	TCL VOCs, TCL SVOCs, PCBs, TAL Metals
	TCL SVOCs, PCBs
Separate-Phase Petroleum Samples	
MW-50	PCBs, Hydrocarbon Scan, Specific Gravity, Kinematic Viscosity
MW-51	PCBs, Hydrocarbon Scan, Specific Gravity, Kinematic Viscosity
MW-52	PCBs, Hydrocarbon Scan, Specific Gravity, Kinematic Viscosity
MW-53	PCBs, Hydrocarbon Scan, Specific Gravity, Kinematic Viscosity
MW-54	PCBs, Hydrocarbon Scan, Specific Gravity, Kinematic Viscosity
MW-55	PCBs, Hydrocarbon Scan, Specific Gravity, Kinematic Viscosity
MW-56	PCBs, Hydrocarbon Scan, Specific Gravity, Kinematic Viscosity
MW-58	PCBs, Hydrocarbon Scan, Specific Gravity, Kinematic Viscosity

- TCL - Target Compound List
- TAL - Target Analyte List
- VOCs - Volatile Organic Compounds
- SVOCs - Semivolatile Organic Compounds
- PCBs - Polychlorinated Biphenyls

* This analysis is in addition to those proposed for the Phase II RI

Table 5. Summary of Practical Quantitation Limits for Volatile Organic Compound Analyses in Soil Samples, Sunnyside Yard, Queens, New York

Compound	Practical Quantitation Limit ($\mu\text{g}/\text{kg}$)	New York State Cleanup Objectives (ppm)
Chloromethane	10	NA
Bromomethane	10	NA
Vinyl Chloride	10	0.2
Chloroethane	10	1.9
Methylene Chloride	10	0.1
Acetone	10	0.2
Carbon Disulfide	10	2.7
1,1-Dichloroethene	10	0.4
1,1-Dichloroethane	10	0.2
1,2-Dichloroethene (total)	10	0.3 (trans)
Chloroform	10	0.3
1,2-Dichloroethane	10	0.1
2-Butanone	10	0.3
1,1,1-Trichloroethane	10	0.8
Carbon Tetrachloride	10	0.6
Bromodichloromethane	10	NA
1,2-Dichloropropane	10	NA
cis-1,3-Dichloropropene	10	NA
Trichloroethene	10	0.7
Dibromochloromethane	10	NA
1,1,2-Trichloroethane	10	NA
Benzene	10	0.06
trans-1,3-Dichloropropene	10	NA
Bromoform	10	NA
4-Methyl-2-pentanone	10	1.0

Table 5. Summary of Practical Quantitation Limits for Volatile Organic Compound Analyses in Soil Samples, Sunnyside Yard, Queens, New York

Compound	Practical Quantitation Limit ($\mu\text{g}/\text{kg}$)	New York State Cleanup Objectives (ppm)
2-Hexanone	10	NA
Tetrachloroethene	10	1.4
1,1,2,2-Tetrachloroethane	10	0.6
Toluene	10	1.5
Chlorobenzene	10	1.7
Ethylbenzene	10	5.5
Styrene	10	NA
Xylene (total)	10	1.2

NA - Not Available
 $\mu\text{g}/\text{kg}$ - micrograms per kilogram (0.001 ppm)
 ppm - parts per million

Note: All Practical Quantitation Limits (PQLs) are shown with no dilution and are based on wet weight. PQLs will be higher based on the percent of moisture in each sample. In addition, PQLs are highly matrix dependent.

PQLs are shown instead of Method Detection Limits (MDLs) because soil analyses are so variable (e.g., pH, moisture content, total organic carbon content, matrix interferences, etc.) that MDLs are unavailable. Detections of analytes below the PQLs will be reported, but flagged as estimated.

New York State Soil Cleanup Objectives are included for comparison purposes only at the request of the New York State Department of Environmental Conservation (NYSDEC). These Objectives were taken from the November 16, 1992 NYSDEC TAGM No. HWR-92-4046: Determination of Soil Cleanup Objectives and Cleanup Levels.

Table 6. Summary of Practical Quantitation Limits for Semivolatile Organic Compound Analyses in Soil Samples, Sunnyside Yard, Queens, New York

Compound	Practical Quantitation Limit ($\mu\text{g}/\text{kg}$)	New York State Cleanup Objectives (ppm)
2,4-Dinitrophenol	800	0.200 or MDL
4-Nitrophenol	800	0.100 or MDL
Dibenzofuran	330	6.2
2,4-Dinitrotoluene	330	NA
Diethylphthalate	330	7.1
4-Chlorophenyl-phenylether	330	NA
Fluorene	330	50.0
4-Nitroaniline	800	NA
4,6-Dinitro-2-methylphenol	800	NA
N-Nitrosodiphenylamine (1)	330	NA
4-Bromophenyl-phenylether	330	NA
Hexachlorobenzene	330	0.41
Pentachlorophenol	800	1.0 or MDL
Phenanthrene	330	50
Anthracene	330	50
Carbazole	330	NA
Di-n-butylphthalate	330	8.1
Fluoranthene	330	50
Pyrene	330	50
Butylbenzylphthalate	330	50
3,3'-Dichlorobenzidine	330	NA
Benzo(a)anthracene	330	0.22 or MDL
Chrysene	330	0.4
bis(2-Ethylhexyl)phthalate	330	50
Di-n-octylphthalate	330	50

Table 6. Summary of Practical Quantitation Limits for Semivolatile Organic Compound Analyses in Soil Samples, Sunnyside Yard, Queens, New York

Compound	Practical Quantitation Limit ($\mu\text{g}/\text{kg}$)	New York State Cleanup Objectives (ppm)
Benzo(b)fluoranthene	330	1.1
Benzo(k)fluoranthene	330	1.1
Benzo(a)pyrene	330	0.061 or MDL
Indeno(1,2,3-cd)pyrene	330	3.2
Dibenzo(a,h)anthracene	330	0.014 or MDL
Benzo(g,h,i)perylene	330	50
Phenol	330	0.03 or MDL
bis(2-Chloroethyl)ether	330	NA
2-Chlorophenol	330	0.8
1,3-Dichlorobenzene	330	1.6
1,4-Dichlorobenzene	330	8.5
1,2-Dichlorobenzene	330	7.9
2-Methylphenol	330	0.100 or MDL
2,2'-oxybis(1-Chloropropane)	330	NA
4-Methylphenol	330	0.9
N-Nitroso-di-n-propylamine	330	NA
Hexachloroethane	330	NA
Nitrobenzene	330	0.200 or MDL
Isophorone	330	NA
2-Nitrophenol	330	0.330 or MDL
2,4-Dimethylphenol	330	NA
bis(2-Chloroethoxy)methane	330	NA
2,4-Dichlorophenol	330	0.4
1,2,4-Trichlorobenzene	330	3.4
Napthalene	330	13.0

Table 6. Summary of Practical Quantitation Limits for Semivolatile Organic Compound Analyses in Soil Samples, Sunnyside Yard, Queens, New York

Compound	Practical Quantitation Limit ($\mu\text{g}/\text{kg}$)	New York State Cleanup Objectives (ppm)
4-Chloroaniline	330	0.220 or MDL
Hexachlorobutadiene	330	NA
4-Chloro-3-methylphenol	330	0.240 or MDL
2-Methylnaphthalene	330	36.4
Hexachlorocyclopentadiene	330	NA
2,4,6-Trichlorophenol	330	NA
2,4,5-Trichlorophenol	800	0.1
2-Chloronaphthalene	330	NA
2-Nitroaniline	800	0.430 or MDL
Dimethylphthalate	330	2.0
Acenaphthylene	330	41.0
2,6-Dinitrotoluene	330	1.0
3-Nitroaniline	800	0.500 or MDL
Acenaphthene	330	50

- NA - Not Available
 $\mu\text{g}/\text{kg}$ - micrograms per kilogram (0.001 ppm)
 ppm - parts per million
 MDL - Method Detection Limit

Note: All Practical Quantitation Limits (PQLs) are shown with no dilution and are based on wet weight. PQLs will be higher based on the percent moisture in each sample. In addition, PQLs are highly matrix dependent.

PQLs are shown instead of Method Detection Limits (MDLs) because soil analyses are so variable (e.g., pH, moisture content, total organic carbon content, matrix interferences, etc.) that MDLs are unavailable. Detections of analytes below the PQLs will be reported, but flagged as estimated.

New York State Soil Cleanup Objectives are included for comparison purposes only at the request of the New York State Department of Environmental Conservation (NYSDEC). These Objectives were taken from the November 16, 1992 NYSDEC TAGM No. HWR-92-4046: Determination of Soil Cleanup Objectives and Cleanup Levels.

Table 7. Summary of Practical Quantitation Limits for Polychlorinated Biphenyl Analyses in Soil Samples, Sunnyside Yard, Queens, New York

Compound	Practical Quantitation Limit ($\mu\text{g}/\text{kg}$)	New York State Cleanup Objectives* (ppm)
Aroclor-1016	33	1.0 (surface), 10.0 (subsurface)
Aroclor-1221	67	1.0 (surface), 10.0 (subsurface)
Aroclor-1232	33	1.0 (surface), 10.0 (subsurface)
Aroclor-1242	33	1.0 (surface), 10.0 (subsurface)
Aroclor-1248	33	1.0 (surface), 10.0 (subsurface)
Aroclor-1254	33	1.0 (surface), 10.0 (subsurface)
Aroclor-1260	33	1.0 (surface), 10.0 (subsurface)

$\mu\text{g}/\text{kg}$ - micrograms per kilogram (0.001 ppm)

ppm - parts per million

* - Concentrations (i.e., 1.0 and 10.0 ppm) represent the sum of all Aroclors.

Note: All Practical Quantitation Limits (PQLs) are shown with no dilution and are based on wet weight. PQLs will be higher based on the percent moisture in each sample. In addition, PQLs are highly matrix dependent.

PQLs are shown instead of Method Detection Limits (MDLs) because soil analyses are so variable (e.g., pH, moisture content, total organic carbon content, matrix interferences, etc.) that MDLs are unavailable. Detections of analytes below the PQLs will be reported, but flagged as estimated.

New York State Soil Cleanup Objectives are included for comparison purposes only at the request of the New York State Department of Environmental Conservation (NYSDEC). These Objectives were taken from the November 16, 1992 NYSDEC TAGM No. HWR-92-4046: Determination of Soil Cleanup Objectives and Cleanup Levels.

Table 8. Summary of Contractually Required Detection Limits for Metals Analyses in Soil Samples, Sunnyside Yard, Queens, New York

Element	Contractually Required Detection Limit (mg/kg)	New York State Cleanup Objectives (ppm)
Aluminum	40	SB
Antimony	12	SB
Arsenic	60	7.5 or SB
Barium	40	300 or SB
Beryllium	1	1.0 or SB
Cadmium	1	1 or SB
Calcium	1,000	SB
Chromium	2	10 or SB
Cobalt	10	30 or SB
Copper	5	25 or SB
Iron	20	2,000 or SB
Lead	20	30 or SB
Magnesium	1,000	SB
Manganese	3	SB
Mercury	0.04	0.1
Nickel	8	13 or SB
Potassium	1,000	SB
Selenium	100	SB
Silver	2	2 or SB
Sodium	1,000	SB
Thallium	2	SB
Vanadium	10	150 or SB
Zinc	4	20 or SB

mg/kg - milligrams per kilogram (ppm)
 ppm - parts per million
 NA - Not Available
 SB - Site Background Concentration

Note: Analytes detected below the CRDLs will be reported, but will be flagged as estimated.

New York State Soil Cleanup Objectives are included for comparison purposes only at the request of the New York State Department of Environmental Conservation (NYSDEC). These Objectives were taken from the November 16, 1992 NYSDEC TAGM No. HWR-92-4046: Determination of Soil Cleanup Objectives and Cleanup Levels.

Table 9. Summary of Method Detection Limits and Practical Quantitation Limits for Volatile Organic Compound Analyses in Ground-Water Samples, Sunnyside Yard, Queens, New York

Compound	Method Detection Limit ($\mu\text{g/L}$)	Practical Quantitation Limit ($\mu\text{g/L}$)	New York State Water-Quality Standards ($\mu\text{g/L}$)
Chloromethane	0.62	10	NA
Bromomethane	0.43	10	NA
Vinyl Chloride	0.62	10	2
Chloroethane	0.38	10	NA
Methylene Chloride	0.26	10	5
Acetone	0.23	10	NA
Carbon Disulfide	0.59	10	NA
1,1-Dichloroethene	0.34	10	5
1,1-Dichloroethane	0.29	10	5
1,2-Dichloroethene (total)	0.35	10	5 (trans)
Chloroform	0.34	10	7
1,2-Dichloroethane	0.32	10	5
2-Butanone	0.40	10	NA
1,1,1-Trichloroethane	0.41	10	5
Carbon Tetrachloride	0.37	10	5
Bromodichloromethane	0.43	10	NA
1,2-Dichloropropane	0.37	10	5
cis-1,3-Dichloropropene	0.32	10	5
Trichloroethene	0.41	10	5
Dibromochloromethane	0.53	10	50 (GV)
1,1,2-Trichloroethane	0.40	10	5
Benzene	0.43	10	0.7
trans-1,3-Dichloropropene	0.36	10	5
Bromoform	0.37	10	50 (GV)

Table 9. Summary of Method Detection Limits and Practical Quantitation Limits for Volatile Organic Compound Analyses in Ground-Water Samples, Sunnyside Yard, Queens, New York

Compound	Method Detection Limit ($\mu\text{g/L}$)	Practical Quantitation Limit ($\mu\text{g/L}$)	New York State Water-Quality Standards ($\mu\text{g/L}$)
4-Methyl-2-pentanone	0.30	10	NA
2-Hexanone	0.35	10	50 (GV)
Tetrachloroethene	0.40	10	5
1,1,2,2-Tetrachloroethane	0.35	10	5
Toluene	0.36	10	5
Chlorobenzene	0.37	10	5
Ethylbenzene	0.37	10	5
Styrene	0.39	10	5
Xylene (total)	0.44	10	5

NA - No Standard or Guidance Value Available
 GV - Guidance Value - Standard Not Available
 $\mu\text{g/L}$ - micrograms per liter

Note: New York State Water Quality Standard and Guidance Values were taken from the November 15, 1991 NYSDEC Division of Water TOGS: Ambient Water Quality Standards and Guidance Values.

Detections of analytes below the Practical Quantitation Limit will be reported, but flagged as estimated.

Table 10. Summary of Method Detection Limits and Practical Quantitation Limits for Semivolatile Organic Compound Analyses in Ground-Water Samples, Sunnyside Yard, Queens, New York

Compound	Method Detection Limit ($\mu\text{g/L}$)	Practical Quantitation Limit ($\mu\text{g/L}$)	New York State Water Quality Standard ($\mu\text{g/L}$)
2,4-Dinitrophenol	4	25	NA
4-Nitrophenol	4	25	NA
Dibenzofuran	1	10	NA
2,4-Dinitrotoluene	1	10	5
Diethylphthalate	2	10	50 (GV)
4-Chlorophenyl-phenylether	1	10	NA
Fluorene	1	10	50 (GV)
4-Nitroaniline	4	25	5
4,6-Dinitro-2-methylphenol	2	25	NA
N-Nitrosodiphenylamine (1)	2	10	50 (GV)
4-Bromophenyl-phenylether	1	10	NA
Hexachlorobenzene	1	10	0.35
Pentachlorophenol	4	25	1*
Phenanthrene	1	10	50 (GV)
Anthracene	1	10	50 (GV)
Carbazole	10	10	NA
Di-n-butylphthalate	6	10	50
Fluoranthene	4	10	50 (GV)
Pyrene	2	10	50 (GV)
Butylbenzylphthalate	2	10	50 (GV)
3,3'-Dichlorobenzidine	5	10	5
Benzo(a)anthracene	1	10	0.002 (GV)
Chrysene	1	10	0.002 (GV)
bis(2-Ethylhexyl)phthalate	7	10	50

Table 10. Summary of Method Detection Limits and Practical Quantitation Limits for Semivolatile Organic Compound Analyses in Ground-Water Samples, Sunnyside Yard, Queens, New York

Compound	Method Detection Limit ($\mu\text{g/L}$)	Practical Quantitation Limit ($\mu\text{g/L}$)	New York State Water Quality Standard ($\mu\text{g/L}$)
Di-n-octylphthalate	6	10	50 (GV)
Benzo(b)fluoranthene	2	10	0.002 (GV)
Benzo(k)fluoranthene	1	10	0.002 (GV)
Benzo(a)pyrene	1	10	ND
Indeno(1,2,3-cd)pyrene	1	10	0.002 (GV)
Dibenzo(a,h)anthracene	1	10	NA
Benzo(g,h,i)perylene	1	10	NA
Phenol	2	10	1*
bis(2-Chloroethyl)ether	1	10	1
2-Chlorophenol	2	10	NA
1,3-Dichlorobenzene	1	10	5
1,4-Dichlorobenzene	1	10	4.7
1,2-Dichlorobenzene	1	10	4.7
2-Methylphenol	5	10	NA
2,2'-oxybis(1-Chloropropane)	1	10	NA
4-Methylphenol	4	10	NA
N-Nitroso-di-n-propylamine	1	10	NA
Hexachloroethane	1	10	5
Nitrobenzene	1	10	5
Isophorone	1	10	50 (GV)
2-Nitrophenol	2	10	NA
2,4-Dimethylphenol	8	10	NA
bis(2-Chloroethoxy)methane	1	10	5
2,4-Dichlorophenol	2	10	1*

Table 10. Summary of Method Detection Limits and Practical Quantitation Limits for Semivolatile Organic Compound Analyses in Ground-Water Samples, Sunnyside Yard, Queens, New York

Compound	Method Detection Limit ($\mu\text{g/L}$)	Practical Quantitation Limit ($\mu\text{g/L}$)	New York State Water Quality Standard ($\mu\text{g/L}$)
1,2,4-Trichlorobenzene	1	10	5
Napthalene	1	10	10 (GV)
4-Chloroaniline	1	10	5
Hexachlorobutadiene	1	10	5
4-Chloro-3-methylphenol	2	10	NA
2-Methylnaphthalene	1	10	NA
Hexachlorocyclopentadiene	1	10	5
2,4,6-Trichlorophenol	2	10	NA
2,4,5-Trichlorophenol	6	25	NA
2-Chloronaphthalene	1	10	10 (GV)
2-Nitroaniline	1	25	5
Dimethylphthalate	1	10	50 (GV)
Acenaphthylene	1	10	NA
2,6-Dinitrotoluene	2	10	5
3-Nitroaniline	3	25	5
Acenaphthene	1	10	20 (GV)

- NA - No Standard or Guidance Value Available
 GV - Guidance Value - Standard Not Available
 $\mu\text{g/L}$ - micrograms per liter
 ND - Not Detected
 * - Value listed applies to the sum of these substances

Note: New York State Water Quality Standards and Guidance Values were taken from the November 15, 1991 NYSDEC Division of Water TOGS: Ambient Water Quality Standards and Guidance Values.

Detections of analytes below the Practical Quantitation Limit will be reported, but flagged as estimated.

Table 11. Summary of Method Detection Limits for Polychlorinated Biphenyl Compound Analyses in Ground-Water Samples, Sunnyside Yard, Queens, New York

Compound	Method Detection Limit ($\mu\text{g/L}$)	New York State Water-Quality Standard* ($\mu\text{g/L}$)
Aroclor-1016	0.065	0.1
Aroclor-1221	0.065	0.1
Aroclor-1232	0.065	0.1
Aroclor-1242	0.065	0.1
Aroclor-1248	0.065	0.1
Aroclor-1254	0.065	0.1
Aroclor-1260	0.065	0.1

$\mu\text{g/L}$ - micrograms per liter

* - Concentrations (i.e., 0.1 $\mu\text{g/L}$) represent the sum of all Aroclors

Note: New York State Water Quality Standards and Guidance Values were taken from the November 15, 1991 NYSDEC Division of Water TOGS: Ambient Water Quality Standards and Guidance Values.

Detection of analytes below the Practical Quantitation Limit will be reported, but flagged as estimated.

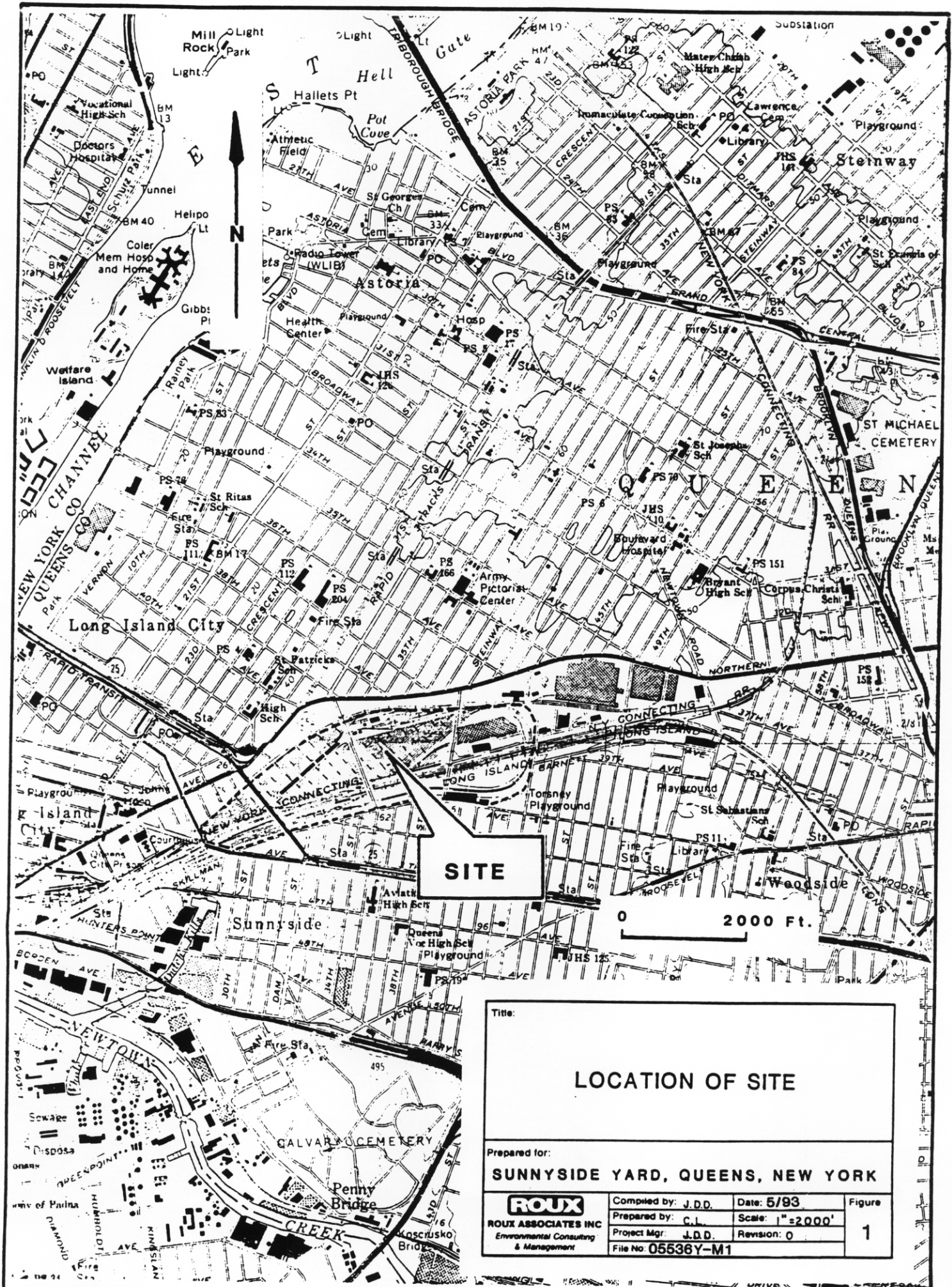
Table 12. Summary of Contractually Required Detection Limits for Metals Analyses in Ground-Water Samples, Sunnyside Yard, Queens, New York

Element	Contractually Required Detection Limit ($\mu\text{g/L}$)	New York State Water-Quality Standards ($\mu\text{g/L}$)
Aluminum	200	NA
Antimony	60	3 (GV)
Arsenic	300	25
Barium	200	1,000
Beryllium	5	3 (GV)
Cadmium	5	10
Calcium	5,000	NA
Chromium	10	50
Cobalt	50	NA
Copper	25	200
Iron	100	300
Lead	100	25
Magnesium	5,000	35,000
Manganese	15	300
Mercury	0.2	2
Nickel	40	NA
Potassium	5,000	NA
Selenium	500	10
Silver	10	50
Sodium	5,000	20,000
Thallium	10	4 (GV)
Vanadium	50	NA
Zinc	20	300

- NA - No Standard or Guidance Value Available
 $\mu\text{g/L}$ - micrograms per liter
 GV - Guidance Value - Standard Not Available

Note: Analytes detected below the CRDLs will be reported, but will be flagged as estimated.

New York State Water Quality Standard and Guidance Values were taken from the November 15, 1991 NYSDEC Division of Water TOGS: Ambient Water Quality Standards and Guidance Values



SITE

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Title:

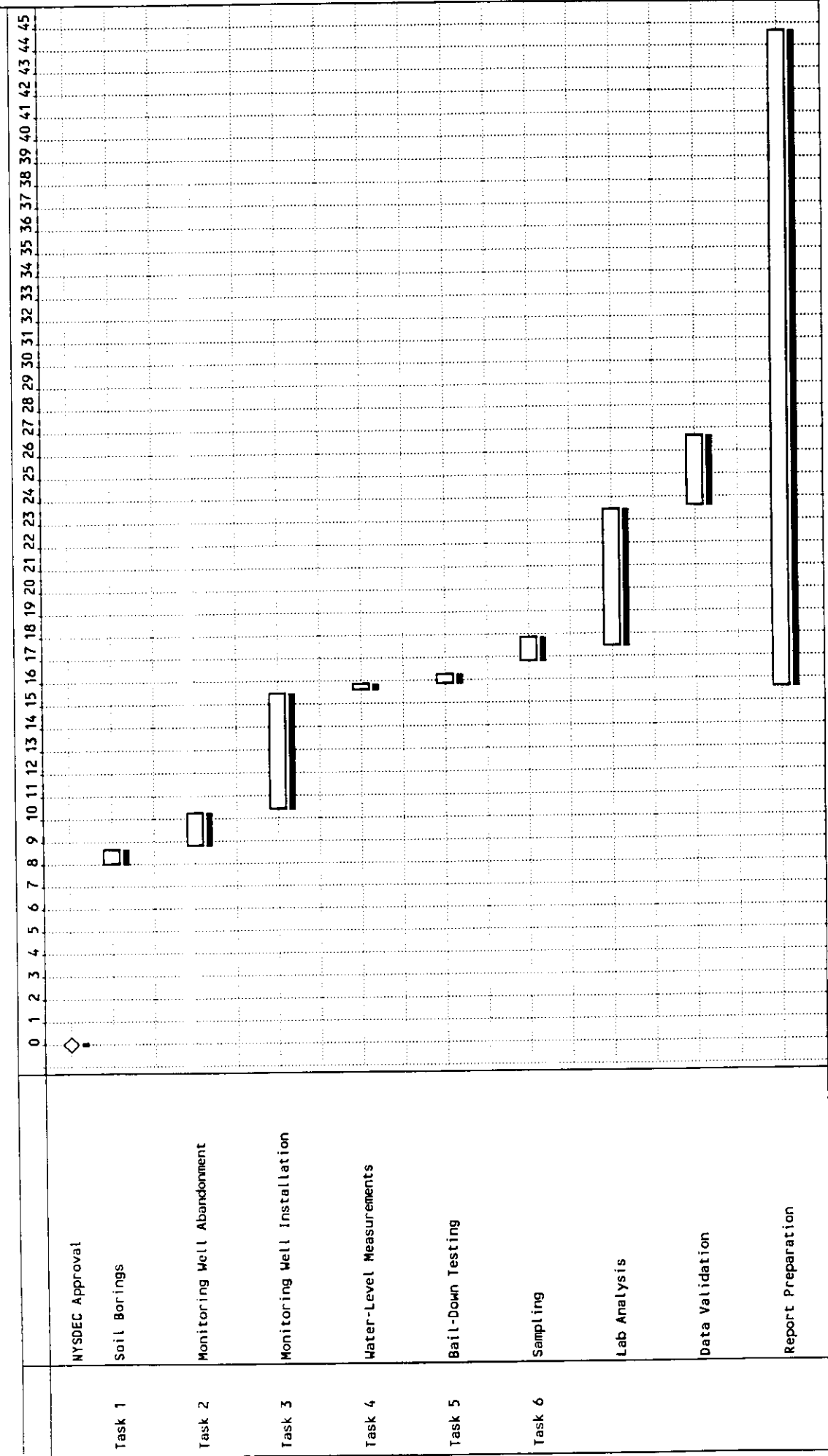
LOCATION OF SITE

Prepared for:

SUNNYSIDE YARD, QUEENS, NEW YORK

<p>ROUX ROUX ASSOCIATES INC Environmental Consulting & Management</p>	Compiled by: J.D.D.	Date: 5/93	<p>Figure 1</p>
	Prepared by: C.L.	Scale: 1"=2000'	
	Project Mgr: J.D.D.	Revision: 0	
	File No: 05536Y-M1		

Figure 2. Estimated Schedule for the Phase II Remedial Investigation Addendum, Sunnyside Yard, Queens, New York.



Note: Time Scale Shown is in Weeks From NYSDEC Approval of Work Plan

APPENDIX A

**Letter Reports to the
New York State Department of
Environmental Conservation**

ROUX ASSOCIATES INC



THE HUNTINGTON ATRIUM
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HUNTINGTON, NEW YORK 11743 TEL: 616 673 1200 FAX: 616 673 1216

January 19, 1993

Mr. James Quinn, P.E.
Environmental Engineer
New York State Department of Environmental Conservation
Division of Hazardous Waste Remediation
Bureau of Eastern Remedial Action
50 Wolf Road
Albany, New York 12233

Re: Results of Preliminary Screening of Some Monitoring Wells Installed by Geraghty & Miller, Inc. in Area - 1 at the Sunnyside Yard, Queens, New York

Dear Mr. Quinn:

As you are aware, Roux Associates, Inc. (Roux Associates) is conducting a Phase II Remedial Investigation (RI), on behalf of National Railroad Passenger Corporation (AMTRAK) and New Jersey Transit Corporation, at the Sunnyside Yard, Queens, New York (Yard). This letter report summarizes the results of the preliminary screening performed by Roux Associates of some monitoring wells previously installed by Geraghty & Miller, Inc. (Geraghty & Miller) in Area-1 at the Yard.

During a previous investigation performed in 1986 at the Yard, Geraghty & Miller (an environmental consultant) installed fifteen monitoring wells in Area-1. The investigation is summarized in the June 1986 Geraghty & Miller report titled "Results of Hydrogeologic Investigation at the AMTRAK, Sunnyside, Queens, New York Train Yard". Well construction details and locations as well as separate-phase petroleum measurements are included in the June 1986 report. The locations of the Geraghty & Miller wells are shown in Plate 1 (attached) of the August 5, 1992 Work Plan for the Phase II Remedial Investigation, prepared by Roux Associates. The current status of the wells is summarized below:

- Previously abandoned
MW-4, MW-6 and MW-14
- Replaced
MW-13 (Roux Associates, 1990)
- Recently destroyed and abandoned
MW-2

Mr. James Quinn, P.E.

January 19, 1993

Page 2

- Intact, located within separate-phase petroleum accumulation
MW-5, MW-7, MW-8 and MW-15
- Intact, presumably located outside perimeter of separate-phase petroleum accumulation
MW-1, MW-3, MW-9, MW-10, MW-11 and MW-12

As you are aware, Monitoring well MW-2 was recently destroyed by Yard activities and an attempt was made by Roux Associates to install a replacement well (MW-2R) while properly abandoning MW-2. At that time, under direct supervision of the NYSDEC, separate-phase petroleum was noted flowing into a 3-foot deep hand-dug excavation prior to installing MW-2R at a location downgradient of MW-2. Subsequently, additional hand-dug excavations were completed adjacent to, and upgradient of MW-2. The excavation adjacent to MW-2 also contained separate-phase petroleum, however, only petroleum sheens were noted at the two upgradient locations. At the request of the NYSDEC, the remaining upper portion of MW-2 was exposed for examination. Bentonite and cement grout was found within the top 1.5 to 2 feet of the screen zone (the section of the screen which intersected the top of the water table), thus preventing the petroleum from entering the well.

As a result of this observation, the NYSDEC considered the integrity of all monitoring wells installed by Geraghty & Miller to be in question, as well as the data derived from them. Furthermore, before any additional data would be accepted from the wells, the integrity and usability of each of the wells needed to be determined. At that time, all of the Phase II RI work scheduled for Area-1 was postponed.

The NYSDEC, AMTRAK and Roux Associates discussed the situation and Roux Associates on January 11 and 12, 1993 then proceeded to implement an initial screening procedure to assess the integrity of four other selected Geraghty & Miller wells.

The methods used to perform the screening procedure and the findings are discussed below. Monitoring Wells MW-3, MW-9, MW-10 and MW-12 were chosen based upon their locations relative to the separate-phase petroleum accumulation and historical information. A 3- to 4-foot deep excavation was dug by hand adjacent to each of the monitoring well locations and a split-spoon sampler was driven by hand approximately 2 feet below the bottom of the excavations. The ground water flowing into the excavations/boreholes and soil samples were examined for visual evidence of separate-phase petroleum accumulations or sheens. In addition, a photoionization detector (PID) was used (weather permitting) to measure the concentrations of volatile organic compounds (VOCs) during the procedure. Prior to performing the excavations, water-level and petroleum thickness measurements were obtained and the monitoring wells were examined for odors, sheens and petroleum accumulations. The fluid levels measured in the monitoring wells correlated with the fluid levels noted in the excavations. After examining Monitoring Well MW-12 and detecting separate-

phase petroleum, Roux Associates also examined MW-11 (not previously proposed) located downgradient of MW-12. The results of the screening procedure are summarized below.

Screening Location	Adjacent Monitoring Well Results	Hand Excavation Results
MW-2	No petroleum or odors noted	Petroleum accumulation in excavation
Downgradient of MW-2	Not applicable (NA)	Petroleum accumulation in excavation
Upgradient (2) of MW-2	NA	Petroleum sheen and elevated PID readings
MW-3	Very slight petroleum sheen, very slight petroleum odor	Very heavy petroleum sheen, very strong petroleum odor
MW-9	No petroleum or odors noted	No petroleum or odors noted
MW-10	No petroleum or odors noted	Petroleum accumulation in excavation
MW-11	No petroleum or odors noted (at this time, water table is above screened interval)	No petroleum or odors noted
MW-12	No petroleum or odors noted	Very heavy petroleum sheen noted

Based upon a review of the above-mentioned results of the screening procedures and discussions between Roux Associates, AMTRAK and the NYSDEC, a proposed scope of work for an additional investigation will be submitted to the NYSDEC in the near future.

Mr. James Quinn, P.E.
January 19, 1993
Page 4

If you have any questions or require additional information, please do not hesitate to call.

Sincerely,



Joseph D. Duminuco
Senior Hydrogeologist/
Project Manager

Attachment

cc: R. Noonan, AMTRAK
C. Lin, AMTRAK
J. Roberts, Esq., AMTRAK
J. Quirk, P.E., AMTRAK
R. Lavell, AMTRAK
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G. Ridsdale, P.E., New Jersey Transit



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February 4, 1993

Mr. James Quinn, P.E.
Environmental Engineer
New York State Department of Environmental Conservation
Bureau of Hazardous Waste Remediation
Division of Eastern Remedial Action
50 Wolf Road
Albany, New York 12233

Re: Results of the Additional Delineation of the Separate-Phase Petroleum Accumulation in Area-1 in Connection with the Geraghty & Miller, Inc. Wells, Sunnyside Yard, Queens, New York

Dear Mr. Quinn:

Roux Associates, Inc. (Roux Associates), on behalf of the National Railroad Passenger Corporation (AMTRAK), performed additional delineation of the separate-phase petroleum accumulation in Area-1 at the Sunnyside Yard, Queens, New York (Yard). This letter presents the results of this investigation.

As you are aware, this additional delineation was requested by the New York State Department of Environmental Conservation (NYSDEC) because the integrity of the monitoring wells previously installed by Geraghty & Miller, Inc. at the Yard is in question and, therefore, so is the current delineation of the separate-phase petroleum accumulation in Area-1.

The delineation work was performed in accordance with the January 22, 1993 Proposed Scope of Work for the Additional Delineation of the Separate-Phase Petroleum Accumulation in Area-1 in Connection with the Geraghty & Miller, Inc. Wells, Sunnyside Yard, Queens, New York submitted by Roux Associates to the NYSDEC. Some modifications to the proposed scope of work were necessary based upon the actual field conditions encountered and are discussed later.

As you are aware, the majority of the investigation was performed on January 25, 1993, in your presence (two boreholes were dug to assess the usability of this procedure on January 22, 1993). As proposed in the January 22, 1993 Scope of Work, the boreholes were dug by hand, where possible, to a depth below the water table or a split-spoon sampler was driven to a depth below the water table.

In borings in which no separate-phase petroleum was clearly evident, at least one 2-foot long split-spoon sampler was driven below the water table. Boreholes were left open for approximately one hour to allow separate-phase petroleum to accumulate, if present. The soil cuttings and ground water were visually examined for separate-phase petroleum and petroleum sheens and were monitored for volatile organic compounds (VOCs) using a photoionization detector (PID).

A total of 18 boreholes were dug by hand, 16 of the 21 originally proposed and two additional boreholes (Plate 1). The results of the investigation are summarized below and are included in Plate 1.

Borehole Designation	Depth of Borehole (feet below land surface)	Observations/Comments
PD-1	5	No petroleum or sheen present on water
PD-2	NA	Omitted because water table too deep to reach by hand
PD-3	NA	Same as above
PD-4	8	Sheen present on water
PD-5	5	Sheen present on water
PD-6	2.5	Petroleum present on water
PD-7	3	Sheen present on water
PD-8	NA	Omitted because water table too deep to reach by hand
PD-9	5	Petroleum present on water
PD-10	4.5	Petroleum present on water
PD-11	3.5	Petroleum present on water
PD-12	3	Petroleum present on water
PD-13	3.5	No petroleum or sheen present on water
PD-14	3.5	No petroleum or sheen present on water

Borehole Designation	Depth of Borehole (feet below land surface)	Observations/Comments
PD-15	6	No petroleum or sheen present on water
PD-16	3	Petroleum present on water
PD-17	2	No petroleum or sheen present on water
PD-18	6	No petroleum or sheen present on water
PD-19	8	Sheen present on water
PD-20	NA	Omitted because no petroleum or sheen was present on water at PD-17 and PD-18
PD-21	NA	Same as above
PD-22	3	Petroleum present on water. Added because PD-11 and PD-12 both contained petroleum.
PD-23	4	Petroleum present on water. Added because petroleum in PD-10 appeared anomalous.

Note: NA - Not Applicable

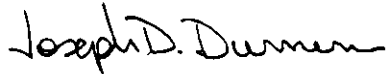
With the exception of petroleum detected in hand borings GM-12 and PD-19, completed on January 11, 1993, no detections of petroleum were recorded hydraulically downgradient of the previously determined location of the separate-phase petroleum accumulation. However, as shown in Plate 1, petroleum was detected upgradient and sidegradient of the accumulation.

A proposed scope of work to perform additional delineation of the separate-phase petroleum accumulation will be submitted to the NYSDEC in the near future.

Mr. James Quinn
February 4, 1993
Page 4

If you have any questions or require additional information, please do not hesitate to call.

Sincerely,



Joseph D. Duminuco
Senior Hydrogeologist/
Project Manager



Paul Roux
President

Attachment

cc: R. Noonan, AMTRAK
C. Lin, AMTRAK
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ENVIRONMENTAL CONSULTING & MANAGEMENT
ROUX ASSOCIATES INC



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February 25, 1993

Mr. James Quinn, P.E.
Environmental Engineer
New York State Department of Environmental Conservation
Division of Hazardous Waste Remediation
Bureau of Eastern Remedial Action
50 Wolf Road
Albany, New York 12233

Re: Results of Phase 3 of the Additional Delineation of the Separate-Phase
Petroleum Accumulation in Area-1, Sunnyside Yard, Queens, New York

Dear Mr. Quinn:

On February 19, 1993, Roux Associates, Inc. (Roux Associates), on behalf of the National Railroad Passenger Corporation (AMTRAK), performed Phase 3 of the additional delineation of the separate-phase petroleum accumulation in Area-1 at the Sunnyside Yard, Queens, New York (Yard). This letter presents the results of this investigation.

As you are aware, additional delineation was requested by the New York State Department of Environmental Conservation (NYSDEC) because the integrity of the monitoring wells previously installed by Geraghty & Miller, Inc. at the Yard was in question and, therefore, so was the current delineation of the separate-phase petroleum accumulation in Area-1. Phase 1 of the additional delineation work consisted of the inspection of nine preliminary screening hand borings adjacent to the Geraghty & Miller Inc. wells completed on January 11 and 12, 1993. Phase 2, which was based upon the data obtained from Phase 1, consisted of the inspection of 18 additional delineation hand borings completed on January 22 and 25, 1993. Phase 3, based upon the data obtained from Phase 2, consisted of the inspection of 15 additional delineation hand borings completed on February 19, 1993.

The Phase 3 delineation work was performed in accordance with the February 10, 1993 Proposed Scope of Work for the Additional Delineation of the Separate-Phase Petroleum Accumulation in Area-1 Sunnyside Yard, Queens, New York submitted by Roux Associates to the NYSDEC. Some modifications to the proposed scope of work were necessary based upon the actual field conditions encountered and are discussed later.

As you are aware, the investigation was performed on February 19, 1993, in your presence. As proposed in the February 10, 1993 Scope of Work, the boreholes were dug by hand, where possible, to a depth below the water table or a split-spoon sampler was driven to a depth below the water table. Because of difficult hand digging (i.e., frozen ground, railroad ballast, obstructions in the fill material and paved areas) a jack hammer was used to begin most of the boreholes.

In borings in which no separate-phase petroleum was clearly evident, at least one 2-foot long split-spoon sampler (conditions permitting) was driven below the water table. Boreholes were left open for approximately one hour to allow separate-phase petroleum to accumulate, if present. The soil cuttings and ground water were visually examined for separate-phase petroleum and petroleum sheens and were monitored for volatile organic compounds (VOCs) using a photoionization detector (PID).

A total of 15 of the 17 originally proposed boreholes were dug by hand and the results of the investigation are summarized below and are included in Plate 1.

Borehole Designation	Depth of Borehole (feet below land surface)	Observations/Comments
PD-24	7.5	Sheen present on water
PD-25	6	No petroleum or sheen present on water
PD-26	6	No petroleum or sheen present on water, split spoon only driven 1 foot below water due to refusal
PD-27	3.6	Petroleum present on water
PD-28	4.4	Sheen present on water, petroleum present in spoon, split spoon only driven 1.4 feet below water due to refusal
PD-29	3.8	Sheen present on water, split spoon only driven 1.5 feet below water due to refusal
PD-30	4	Sheen present on water, split spoon only driven 1.8 feet below water due to refusal
PD-31	NA	Omitted because a wooden walkway was present in proposed location

Borehole Designation	Depth of Borehole (feet below land surface)	Observations/Comments
PD-32	4.5	No petroleum or sheen present on water, split spoon only driven 1.5 feet below water due to refusal
PD-33	NA	Borehole omitted due to time constraints
PD-34	4.8	No petroleum or sheen present on water
PD-35	6	Sheen present on water
PD-36	6	Petroleum present on water
PD-37	4.7	No petroleum or sheen present on water
PD-38	8	Sheen present on water
PD-39	4	No petroleum or sheen present on water, split spoon only driven 1.2 feet below water due to refusal
PD-40	7.5	No petroleum or sheen present on water
Note: NA - Not Applicable		

During this phase, previous detections of petroleum sheens (PD-19) and separate-phase petroleum (GM-10 and GM-12) were further investigated to determine the extent of those detections. As shown in Plate 1, the data indicates these areas most likely represent isolated occurrences of petroleum since adjacent downgradient boreholes show no separate-phase petroleum accumulations.

The additional delineation work performed during this phase in the area south of the Metro Shop and east of the Locker Room/Shop (Plate 1) has not defined the extent of the separate-phase petroleum accumulation in that area.

The results obtained from the boreholes in the area of the turntable (Plate 1) indicate no petroleum detections hydraulically upgradient from the turntable (PD-25 and PD-26) and only a sheen downgradient of the turntable (PD-24).

A proposed scope of work to perform the next phase of work will be submitted to the NYSDEC in the near future.

Mr. James Quinn
February 25, 1993
Page 4

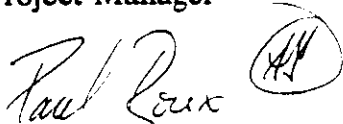
If you have any questions or require additional information, please do not hesitate to call.

Sincerely,

ROUX ASSOCIATES, INC.



Joseph D. Duminuco
Senior Hydrogeologist/
Project Manager



Paul Roux
President

Attachment

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April 26, 1993

Mr. James Quinn, P.E.
Environmental Engineer
New York State Department of Environmental Conservation
Division of Hazardous Waste Remediation
Bureau of Eastern Remedial Action
50 Wolf Road
Albany, New York 12233

Re: Results of Phase 4 of the Additional Delineation of the Separate-Phase
Petroleum Accumulation in Area-1, Sunnyside Yard, Queens, New York

Dear Mr. Quinn:

On April 7, 1993, Roux Associates, Inc. (Roux Associates), on behalf of the National Railroad Passenger Corporation (AMTRAK), performed Phase 4 of the additional delineation of the separate-phase petroleum accumulation in Area-1 at the Sunnyside Yard, Queens, New York (Yard). This letter presents the results of this investigation.

As you are aware, additional delineation was requested by the New York State Department of Environmental Conservation (NYSDEC). This work was required because the questionable integrity of the monitoring wells previously installed by Geraghty & Miller, Inc. at the Yard raised concerns about the accuracy of the current delineation of the separate-phase petroleum accumulation in Area-1. Phase 1 of the additional delineation work consisted of nine preliminary screening hand borings adjacent to the Geraghty & Miller Inc. wells. The hand borings were completed on January 11 and 12, 1993. Phase 2, which was based upon the data obtained from Phase 1, consisted of 18 additional delineation hand borings completed on January 22 and 25, 1993. Phase 3, based upon the data obtained from Phase 2, consisted of 15 additional delineation hand borings completed on February 19, 1993. Phase 4, completed on April 7, 1993, consisted of 9 additional delineation hand borings, based upon data obtained from Phase 3, and the collection of two soil samples for polychlorinated biphenyl (PCB) analyses from plume delineation hand borings PD-45 and PD-47.

The Phase 4 delineation work was performed in accordance with the March 12, 1993 Proposed Scope of Work for the Additional Delineation of the Separate-Phase Petroleum Accumulation in Area-1 Sunnyside Yard, Queens, New York submitted by Roux Associates to the NYSDEC. A minimum of eight and a maximum of 13 hand borings were proposed in the March 12, 1993 Scope of Work. Some modifications to the proposed scope of work were necessary based upon the actual field conditions encountered and are discussed later.

As you are aware, the Phase 4 investigation was performed on April 7, 1993, in your presence. As proposed in the March 12, 1993 Scope of Work, the boreholes were dug by hand to a depth below the water table or a split-spoon sampler was driven to a depth below the water table. Because of difficult hand digging (i.e., railroad ballast, obstructions in the fill material and paved areas) a jack hammer was used to begin most of the boreholes.

In borings in which no separate-phase petroleum was clearly evident, at least one 2-foot long split-spoon sampler was driven below the water table. Boreholes were left open for approximately one hour to allow separate-phase petroleum which might be present to accumulate. The soil cuttings and ground water were visually examined for separate-phase petroleum and petroleum sheens and were monitored for volatile organic compounds (VOCs) using a photoionization detector (PID). In two locations where there was evidence of petroleum contamination (PD-45 and PD-47), soil samples were collected for PCB analyses. These samples are intended for screening purposes only and thus did not follow the December 1991 NYSDEC Analytical Services Protocols.

The results of the investigation are summarized below and are included in Plate 1.

Borehole Designation	Depth of Borehole (feet below land surface)	Observations/Comments
PD-41	5.5	Sheen present on water
PD-42	6	No petroleum or sheen present on water
PD-43	6.5	No petroleum or sheen present on water
PD-44	7	No petroleum or sheen present on water
PD-45	4	Petroleum present on water
PD-46	6	No petroleum or sheen present on water

Borehole Designation	Depth of Borehole (feet below land surface)	Observations/Comments
PD-47	7	Sheen present on water
PD-48	5	No petroleum or sheen present on water
PD-53	6	No petroleum or sheen present on water

Following the completion and screening of soil borings PD-41 through PD-48, as proposed, it was determined that only one of the proposed additional borings (PD-53) was required. Therefore, soil borings PD-49 through PD-52 were not completed.

During this phase, the extent of separate-phase petroleum accumulation was further delineated in the following areas shown in Plate 1:

- the area south of the Metro Shop and east of the Locker Room/Shop;
- the area west of the Engine House; and
- the area north of the Metro Shop and west of the Turntable.

Soil samples PD-45 and PD-47 were analyzed for PCBs by IEA Laboratory, Monroe, Connecticut using United States Environmental Protection Agency (USEPA) Method 8080. The results indicate that low-level (i.e., less than 1 part per million) PCBs were detected in both samples. Soil sample PD-45 (3 to 4 feet) contained only PCB Aroclor 1260 at an estimated concentration of 14 micrograms per kilogram ($\mu\text{g}/\text{kg}$). The concentration is estimated because it is below the method detection limit.

Soil sample PD-47 (6.5 to 7 feet) contained PCBs in the following concentrations: Aroclor 1242 at 140 $\mu\text{g}/\text{kg}$; Aroclor 1254 at 390 $\mu\text{g}/\text{kg}$; Aroclor 1260 at 270 $\mu\text{g}/\text{kg}$.

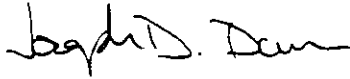
The results of Phase 4 of the additional delineation investigation and previous phases of the additional delineation of the separate-phase petroleum accumulation in Area 1 at the Yard will be used to prepare an addendum to the August 5, 1992 Work Plan for the Phase II Remedial Investigation, Sunnyside Yard, Queens, New York.

Mr. James Quinn, P.E.
April 26, 1993
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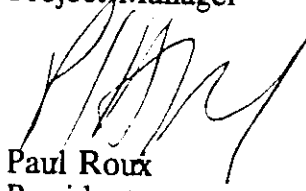
If you have any questions or require additional information, please do not hesitate to call.

Sincerely,

ROUX ASSOCIATES, INC.



Joseph D. Duminuco
Senior Hydrogeologist/
Project Manager



Paul Roux
President

Attachment

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APPENDIX B
Sampling and Analysis Plan

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1.0 OBJECTIVES

This sampling and analysis plan (SAP) describes the types of samples to be collected, the analysis proposed and the procedures to be followed during site characterization and remedial investigation activities at the Sunnyside Yard, Queens, New York (Yard). Data generated by this SAP will be used to support the screening and evaluation of remedial alternatives for the site and the performance of a health-based risk assessment.

2.0 SAMPLING LOCATIONS

The locations of all proposed monitoring wells and soil borings are identified in Plate 3 and Plate 4 of the Work Plan Addendum. The rationale for the selection of these locations is provided in Section 2.0 of the Work Plan Addendum. All monitoring well locations will be surveyed vertically to a reference datum (mean sea level) by a licensed New York State professional land surveyor.

3.0 SAMPLE CATALOGING

Soil borings will be identified by the prefix S (Soil Boring). The boring location number will follow the prefix. When more than one soil sample is collected from a single boring, the recorded sampling depth interval will distinguish each sample. An example is "S-120, 0 to 2 feet", which identifies a sample collected from soil boring number one hundred twenty at a depth interval of 0 to 2 feet below land surface.

Boreholes drilled for the installation of monitoring wells will be identified by an MW prefix (Monitoring Well). The monitoring well location number will follow the prefix. All soil samples collected during the installation of monitoring wells will be identified by the well number and sampling depth interval. For example, if a soil sample was collected from 2 to 4 feet below land surface at monitoring well number fifty two the sample will be identified as "MW-52, 2-4 feet".

Ground-water and separate-phase petroleum samples will also be identified by the prefix MW and the well number from which they were collected and the date.

These sample designations will be used by all contracted laboratories to identify samples collected for analysis during the sampling program. All chain-of-custody documentation will also adhere to these numbering systems.

4.0 PROTOCOL FOR SOIL SAMPLING

This protocol outlines procedures and equipment for soil sampling at the Yard. Soil samples will be collected with a hollow stem auger drilling rig or hand tools (i.e., post hole digger or shovel).

4.1 Equipment Preparation

Prior to mobilization, the drill rig and all tools and accessories must be thoroughly cleaned to remove all remains of previous operations (i.e., dirt, mud, dust and liquids). Cleaning of the machinery includes wheels or tracks, under carriage, chassis and cab. Acceptable cleaning methods include, but are not limited to:

- brushing or sweeping loose material and soil;
- detergent wash and tap water rinse; and
- steam cleaning.

In addition to the general cleaning outlined above, specific items will also require cleaning i.e., split-barrel samplers, auger flights, and all other down-hole tools. All contractors hired for sample collection purposes will be expected to provide acceptably clean equipment.

4.2 Equipment Cleaning Procedures

Drilling or digging will, in general, be performed beginning in areas of least contamination and proceed toward areas of greatest known contamination. Decontamination of equipment will take place at the recently completed soil boring location prior to moving to the next drilling location.

The cleaning procedure for equipment will be as follows:

- remove all loose material and soil from equipment;
- wash thoroughly with detergent and tap water utilizing a scrub brush;
- rinse with tap water; and
- steam clean.

4.3 Sampling Tool Decontamination Procedures

Prior to soil sampling, all tools used for sample collection will be decontaminated in the following manner:

- remove all loose material and soil from tools;
- wash thoroughly with detergent and tap water, utilizing a scrub brush;
- rinse with tap water;
- rinse with distilled or deionized water;
- rinse with pesticide-grade methanol; and
- rinse with distilled or deionized water.

4.4 Soil Sampling Procedures

When augering with a drill rig, soil samples will be collected from depths greater than four feet below land surface using a split-spoon sampler in the following manner:

- samples will be collected using a standard, 2 or 3-inch outside diameter (O.D.) split-spoon sampler;
- loose material will be brushed off the external surface of the sampler prior to opening;
- the sampler will be placed on clean plastic sheeting and opened;
- a photoionization detector (PID) will be used to screen for volatile organic compounds (VOCs);
- total recovery will be measured and recorded;
- a representative composite of recovered material will be immediately placed in the proper container, sealed and labelled;
- any non-representative material (i.e., cinders, pieces of railroad ties, asphalt), when observed, will not be placed in the sample container;
- equipment used for filling sample containers will be decontaminated prior to each subsequent use as outlined in Section 4.3; and
- any soil samples selected for laboratory analyses will be placed on ice and protected from light immediately after collection and until delivery to the laboratory.

Because of safety concerns related to the abundance of unmarked and unmapped underground utility lines and cables, Yard supervisory personnel require that the first three feet of all soil borings be advanced by hand. Soil samples in the 0 to 2 feet and 2 to 4 feet intervals will each be collected by placing the excavated soil on plastic sheeting, homogenizing it, and collecting a representative sample from the interval. The tools used for the excavation (i.e., shovel, post hole digger, and hand trowels) will be subjected to the same decontamination procedures as the split-spoon samplers.

The above-mentioned procedure will not be used for sampling for VOCs since the agitation of the soils will result in volatilization of some of the compounds. As a result, VOC samples will be collected from the 2 to 4 feet interval as rapidly as possible with minimal agitation.

4.5 Sample Containers

It will be the responsibility of the contracted laboratory to provide clean sampling containers for the requested analyses. The sampling containers will be filled according to laboratory specifications.

4.6 Sample Handling

All samples intended for laboratory analyses will be placed on ice and protected from light immediately after collection and during transport to the lab. All samples will be delivered to the laboratory within 48 hours after collection. The December 1991 NYSDEC ASP will be followed for each parameter listed below including guidelines for sample containers, preservatives and holding times. The analytical results for the parameters listed below will be reported at the Practical Quantitation Limit (PQL) or the Contractually Required Detection Limit (CRDL). PQLs, without dilution, for VOC, SVOC and PCB analyses are shown in Tables 5, 6 and 7, respectively, of the Addendum. CRDLs for metals analyses are shown in Table 8. Analytes detected below the PQLs and CRDLs will be reported, but will be flagged as estimated.

Parameter	Container	Preservative	Maximum Holding Time by Laboratory
Volatile Organic Compounds (VOCs) by USEPA Method 8240	Amber widemouth glass with Teflon lined lid - 4 oz	Cool to 4° C	7 days before analysis
Semivolatile Organic Compounds (SVOCs) by USEPA Method 8270	Amber widemouth glass with Teflon lined lid - 2 - 8 oz	Cool to 4° C	5 days before extraction 40 days after receipt by laboratory
Polychlorinated Biphenyls (PCBs) by USEPA Method 8080	Amber widemouth glass with Teflon lined lid - 2 - 8 oz	Cool to 4° C	5 days before extraction 40 days after receipt by laboratory
Metals (TAL) Mercury by USEPA Method 7470 all others by USEPA Method 6010/7000	Amber widemouth glass with Teflon lined lid - 2 - 8 oz	Cool to 4° C	26 days before analysis 180 days before analysis

4.7 Quality Assurance/Quality Control

Field sample collection procedures will be monitored through the use of trip blanks and field blanks.

4.7.1 Trip Blanks

A trip blank will accompany all samples collected for VOC analysis through the entire sampling program. The trip blank will be prepared by the laboratory and analyzed for VOCs when returned to the laboratory. The results of this analysis will validate both glassware cleanliness and field sample handling techniques. A minimum of one trip blank must accompany each shipment of samples for VOC analysis delivered to the laboratory.

4.7.2 Field Blanks

Prior to any sampling, a field blank will be collected from decontaminated sampling equipment (i.e., split spoon sampler, hand auger, etc.). This will be accomplished by collecting a rinse of laboratory supplied distilled/deionized water poured over decontaminated sampling equipment. Analyses of the field blanks for the same parameters as the soil samples will verify the efficacy of the equipment decontamination procedure.

4.8 Record Keeping

All field data will be recorded in the field sampler's bound notebook. These data will include: weather conditions, location of boring, depth of sample, sample designation and the sequence in which the borings were taken. A chain of custody will be implemented during sample collection.

All samples collected will be prelabeled with the following information:

- borehole or well number;
- time and date of sample collection;
- type of analysis to be performed; and
- affiliation of person(s) collecting the sample.

4.9 Analytical Laboratory

All soil samples will be submitted via chain of custody to a New York State certified laboratory. Samples will be analyzed according to the December 1991 NYSDEC Analytical Services Protocols (ASP). Method required QA/QC protocols (including, but not limited to, matrix spike and matrix spike duplicate analysis) will be followed by the analytical laboratory. ASP QA/QC follow-up documentation will be provided.

All laboratory analytical data developed during the Phase II RI will be submitted to an independent contractor for data validation purposes. Validation of analytical data will be performed in accordance with criteria noted in the December 1991 ASP.

5.0 PROTOCOL FOR MONITORING WELL INSTALLATION

This protocol outlines procedures and equipment that will be used in the drilling and installation of monitoring wells at the Yard. Where appropriate, wells will be installed using a hollow stem auger drilling rig.

5.1 Drilling Equipment Preparation

Prior to use, the drill rig and all tools and accessories will be thoroughly cleaned to remove all remnants of previous drilling operations (e.g., dirt, mud, dust and liquids). Cleaning of the drill rig shall include the wheels or tracks, undercarriage, chassis and cab. The cleaning of the drilling equipment will consist of but not be limited to:

- brushing or sweeping loose dirt;
- detergent wash and tap water rinse; and
- steam cleaning.

All downhole tools and sampling equipment, as well as tools which come into immediate contact with this equipment, will be cleaned in the same manner as the drilling equipment. Split-barrel samplers, drill stems and all other downhole tools must be free of grease, oil and other forms of contamination during the drilling and installation of the well.

5.2 Drilling Procedures

The order of monitoring well installation will proceed from areas of least known contamination to areas of greatest known contamination, where possible.

5.3 Drilling Equipment Cleaning Procedures

All drilling equipment will be decontaminated at the recently completed monitoring well location prior to moving to the next drilling location.

The procedure will be as follows:

- the rig will be cleaned of all loose material and soil;
- wash thoroughly with detergent and potable tap water utilizing a scrub brush;
- rinse with potable tap water; and
- steam clean.

All contaminated clothing, gloves, boot covers and rags will be collected in on-site receptacles and disposed of in accordance with applicable state and federal regulations.

Upon completion of the drilling program, contaminated soil from the drilling process will be disposed of in accordance with applicable state and federal regulations.

5.4 Monitoring Well Installation

The shallow (water-table) monitoring wells will be installed with the top of the well screen set approximately two to three feet above the existing water table. The deep monitoring wells (designated with a "D") will be installed with the top of the well screen set approximately 25 feet below the existing water table.

All permanent monitoring wells (with the exception of those installed within an area of separate-phase petroleum) will be constructed of four-inch diameter PVC casing with 10 feet long, PVC flush threaded well screens. As per the NYSDEC requirement adhered to during the Phase I RI, if separate-phase petroleum is encountered during the drilling of a monitoring well borehole, a 20-slot (0.020 inch) stainless steel well screen will be installed instead of PVC. The screen slot size and gravel pack size of PVC well screens will be determined based upon a review of the type and grain size of the material adjacent to the well screen zones. Depending on the conditions, either a 10-slot (0.010 inch) or 20-slot well screen will be installed to accommodate more fine grained and more coarse grained sediments, respectively. The 10-slot PVC screened wells will be packed with an equivalent of Morie No. 0 gravel. The 20-slot stainless steel and PVC screened wells will be packed with an equivalent of Morie No. 2 gravel. The gravel pack will extend approximately one to two feet above the well screen. The annular space above the gravel pack will be filled with a one-foot layer of granular bentonite followed by a bentonite-based grout to approximately two feet below grade. An outer locking, steel protective casing will be placed over the well casing and the remaining unfilled portion of the annulus filled with concrete. In areas where the water table is shallow (i.e., less than five feet below land surface), the above-mentioned installation procedure will be modified based on the actual conditions encountered in the field.

Where practical, split-spoon samples will be collected during drilling at continuous two-foot intervals above the water table and every five feet thereafter. It is noted that running sand was encountered in most boreholes during the Phase I and Phase II RI while drilling below the water table. Due to the shallow water table (sometimes less than one ft bls) and the nature of the sediments (i.e., fined grained, but not cohesive), most attempts to alleviate the running sand problem were unsuccessful. In many cases, this condition prevented the collection of split-spoon samples. This condition is expected to continue during the performance of the Phase II Addendum. Therefore, if several unsuccessful attempts have been made to alleviate the running sand and representative samples remain unattainable, the monitoring well pilot borehole will be drilled to the proposed total depth with an end-plug in the hollow stem augers, and split-spoon samples will not be collected.

At locations where well clusters (i.e., deep and shallow) are being installed, the deep borehole will be drilled first. If the borehole remains open, the deep well will be installed. If the borehole does not remain open at depth, the shallow well will be installed in that borehole instead. The second monitoring well pilot borehole drilled at each well cluster location will be advanced using hollow stem augers with an end plug.

All split-spoon samples will be examined for lithology, evidence of contamination (presence of oil, odor, staining) and degree of saturation. In addition, each split-spoon will be tested for the presence of volatile organic compounds (VOCs) using a photoionization detector (PID). All PID readings will be recorded in the field book. Finally, all split-spoon samples will be retained on-site in masonry jars for potential future use.

All permanent monitoring wells to be installed and sampled during the Phase II Addendum will be developed until the pH, conductivity, and temperature of the discharged water has stabilized and the turbidity is less than or equal to 50 NTUs or has stabilized. Wells will be developed by mechanical surging and pumping. Since the source of contamination is defined, well development water will be allowed to infiltrate into the ground in the immediate area of the well head, and contained to preclude runoff from the site. The area used, the "recharge pit", will be covered with clean soil when it is no longer needed.

5.4.1 Temporary Well Installation

The temporary well will be constructed with 5 feet of 2-inch diameter, 20-slot (0.020 inch) black carbon steel well screen and 2-inch diameter steel riser. The top of the well screen will be set approximately one foot above the existing water table.

To minimize the possibility of compressing or clogging the well screen during installation, continuous split-spoon samples will be collected to the water table. These samples will be examined for lithology, evidence of contamination and degree of saturation. The temporary well screen will then be inserted into the open borehole and driven to the desired depth. The temporary well will not be developed prior to sampling. The well will be removed following sampling and the borehole properly abandoned.

5.5 Record Keeping

All field data will be recorded by the on-site hydrogeologist in a bound notebook. This data will include, but not be limited to, weather conditions, well location, depth of well, sequence in which the wells were completed and well completion data. A drill log will be completed for each well by the on-site hydrogeologist. The compiled logs will be based upon drill cuttings, rig reaction and split-spoon samples, if taken.

Data compiled in the logs will also include: soil color and type, approximate grain size, physical characteristics (e.g., moisture, visible contamination), horizon depth and thickness, depth to ground water and PID readings.

6.0 PROTOCOL FOR GROUND-WATER SAMPLE COLLECTION

This protocol outlines procedures and equipment for the collection of representative ground-water samples from monitoring wells at the Yard. There will be a minimum of one week between well development and purging for sample collection and a maximum of 24 hours between purging and sampling. After collection, these samples will be submitted to a certified contract laboratory for analyses including but not limited to VOCs, semivolatile organic compounds (SVOCs), polychlorinated biphenyls (PCBs), and metals.

6.1 Equipment Decontamination Procedures

The following decontamination procedures will apply for equipment used for the collection of ground-water samples.

6.1.1 Purging Equipment

Submersible pumps, discharge hoses, and cables will be decontaminated prior to initial use and after pumping each well in the following manner:

- external surfaces will be brushed free of all loose material, washed with detergent solution and rinsed with clean tap water;
- internal surfaces will be cleaned by placing the pump in a clean drum containing detergent solution followed by clean tap water and allowing the pump to operate; and
- pump, discharge hose and cable will be wrapped in plastic sheeting for transportation and storage.

6.1.2 Bailers

Bailers will be decontaminated prior to initial use and after each subsequent use in the following manner:

- detergent wash;
- tap water rinse;
- distilled water rinse;
- pesticide-grade methanol rinse;
- distilled water rinse; and
- wrap in aluminum foil for transportation and storage.

6.2 Sample Collection and Handling

Sampling will be performed by a team with experience in environmental sampling. The senior member of the team (sample coordinator) will be responsible for complete documentation of sampling which will be kept in a bound field notebook with pages numbered sequentially in ink, appropriately dated and signed. The sampling team will be responsible for the preservation and chain of custody records for all samples until they are transported to the laboratory for analysis.

Monitoring wells will be unlocked immediately prior to initiating sampling procedures. All wells will be re-secured when sampling is completed and at any time the sampling crew leaves the area of the well.

The diameter, water level and total depth of each well will be measured to calculate the volume of the water column. Measurements will be made with a steel tape, electric water-level indicator (M-scope), or an oil/water interface probe, to the nearest 0.01 foot. The measuring device will be decontaminated prior to initial use and between each subsequent use by the following procedure:

- wipe with a pesticide-grade methanol soaked paper towel; and
- wrap in foil for transportation and storage.

Prior to sampling, the volume of standing water in each well will be calculated. All wells will be purged before any sampling takes place. The amount of water removed will be determined by the condition of the well and the ability of the aquifer to transmit water. In no case will a well be sampled unless all water standing in the well casing has been replaced by fresh ground water from the aquifer. Purging will continue until a minimum of three volumes of water have been removed from each well or until the well goes dry. All wells will be purged, and allowed to recover a maximum of 24 hours prior to the collection of any samples. Purged water will be allowed to recharge in the immediate area of the wellhead. During performance of the Phase II Addendum, Roux Associates proposes to follow the same modifications to the Phase I Remedial Investigation Work Plan ground-water sampling procedures regarding sampling of wells containing separate-phase petroleum that were agreed to by the NYSDEC in a January 8, 1991 letter to Roux Associates. Accordingly,

monitoring wells that contain separate-phase petroleum will not be purged prior to sampling, and only a separate-phase petroleum sample will be collected. Petroleum samples will be analyzed for PCBs, hydrocarbon scan, specific gravity and kinematic viscosity.

Samples will be obtained after the purging procedure, when applicable, is completed. If possible, samples will be taken with a bottom loading teflon bailer. Bailers will be decontaminated in accordance with procedures noted in Section 5.1.2. Clean polypropylene cord will be used to lower bailers into the wells. New cord and new disposable gloves will be used on each well. Disposable gloves will be worn when handling bailers and cord. Care will be taken to prevent bailers or cord from coming into contact with any contaminants.

One bailer volume from each well will be discarded prior to collecting a sample. Bailers will be lowered gently into the wells to minimize agitation of the ground water. Ground-water samples will be poured from the bailers directly into bottles previously prepared. Pouring will be accomplished in a manner that will minimize agitation of samples.

All samples intended for laboratory analysis will be placed on ice and protected from light immediately after collection and during transport to the laboratory. All samples will be delivered to the laboratory no longer than 48 hours after collection.

The December 1991 NYSDEC ASP will be followed for VOC, SVOC, and TAL metals analyses, including guidelines for sample containers, preservatives and holding times. Aroclor-specific data will be reported for all PCB analyses. As requested by the NYSDEC, all ground-water PCB samples will be analyzed following a modified 1989 ASP to allow a low detection limit. All separate-phase petroleum PCB samples will be analyzed following USEPA Method 8080. Method detection limits (MDLs) and PQLs, without dilution, for VOC, SVOC and PCB analyses are shown in Tables 9, 10 and 11, respectively, of the Addendum. The CRDLs for metals analyses are shown in Table 12. The analytical results for the parameters listed will be reported at the PQL or CRDL. Detections of analytes below the PQLs or CRDLs will be reported, but will be flagged as estimated.

Specific gravity and kinematic viscosity will be determined for all separate-phase petroleum samples using the American Society for Testing and Materials (ASTM) Methods D-1298 and D-445, respectively. In addition, hydrocarbon fingerprinting will be performed using gas chromatograph analysis, with a flame ionization detector (GC/FID), following the analytical laboratories internal standard operating procedure.

Parameter ⁽¹⁾	Container ⁽²⁾	Preservative	Maximum Holding Time by Laboratory
Volatile Organic Compounds (VOCs) by USEPA Method 8240	40 ml septum vial with/teflon container, must not contain air bubbles	Cool to 4°C Cool to 4°C, HCl to pH < 2	7 days before analysis 10 days before analysis
Semivolatile Organic Compounds (SVOCs) by USEPA Method 8270	Amber colored glass with teflon lined lid - 1 liter	Cool to 4°C	5 days before extraction, 40 days after receipt by laboratory
Polychlorinated Biphenyls (PCBs) in ground water by modified 1989 ASP	Amber colored glass with teflon lined lid - 1 liter	Cool to 4°C	5 days before extraction, 40 days after receipt by laboratory
PCBs in Separate-phase petroleum by USEPA Method 8080	Amber colored glass with teflon lined lid - 1 liter	Cool to 4°C	5 days before extraction, 40 days after receipt by laboratory
Metals (TAL) Mercury by USEPA Method 7470 all others by USEPA Method 6010/7000	Plastic - 500 ml	HNO ₃ to pH < 2, Cool to 4°C	26 days before analysis 180 days before analysis
<p>(1) Practical Quantitation Limits (PQL) will be reported for the analytical methods listed. (2) All samples should be collected with a 1-inch air space in container, with the exception of Volatile Organics.</p>			

6.3 Quality Assurance/Quality Control

Field sample collection procedures will be monitored through the use of blind field replicates, trip and field blanks.

6.3.1 Field Replicates

A total of 5 percent blind field replicates will be collected for purposes of validating the precision of the sampling technique.

6.3.2 Trip Blanks

A trip blank will accompany all samples collected for VOC analysis through the entire sampling program. The trip blank will be prepared by the laboratory and analyzed for volatile organics when returned to the laboratory. The results of this analysis will validate both glassware cleanliness and field sample handling techniques. A minimum of one trip blank must accompany each shipment of samples for VOC analysis delivered to the laboratory.

6.3.3 Field Blanks

Prior to any sampling, a field blank will be collected from a cleaned bailer from the final rinse of deionized/distilled water. The analytical laboratory performing the analysis will supply the deionized/distilled water. Analyses of the field blanks for the same parameters as the ground-water samples will verify the efficacy of the equipment cleaning procedure.

6.4 Record Keeping

All field data will be recorded in the field sampler's bound notebook. This data will include: weather conditions, volume of water removed from the well, static water depth prior to sampling, the sample designation, and the sequence in which the samples were collected. A chain of custody will be implemented during sample collection.

6.5 Analytical Laboratory

All samples will be submitted via a chain of custody to a laboratory certified by the New York State Department of Health Environmental Laboratory Acceptance Program. PCBs in ground-water will be analyzed by a modified 1989-3 ASP method to allow a NYSDEC required lower detection limit. All other samples will be analyzed according to the December 1991 NYSDEC ASP. Method required QA/QC protocols (including, but not limited to, matrix spike, matrix spike duplicate and matrix spike blank analysis) will be followed by the analytical laboratory. ASP QA/QC follow-up documentation will be provided.

All laboratory analytical data developed during the Phase II RI will be submitted to an independent contractor for data validation purposes. Validation of analytical data will be performed in accordance with criteria noted in the December 1991 ASP.

APPENDIX C
Health and Safety Plan

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1.0 INTRODUCTION

This plan outlines health and safety procedures to be followed by Roux Associates, Inc. (Roux Associates) employees and subcontractors hired by Roux Associates during any site investigation and cleanup activities performed at the Sunnyside Yard, Queens, New York (Yard). This health and safety plan was developed in accordance with current Occupational Safety and Health Administration (OSHA) guidelines outlined in 29 CFR Part 1910.

These procedures include emergency chain of command, personnel protective equipment, basic safety equipment, air monitoring, training program, employee medical surveillance program, and decontamination of personnel and equipment.

A Health and Safety Officer (HSO) will be appointed to ensure that all Health and Safety Plan (HASP) activities are correctly implemented. The HSO's resume will be submitted to the New York State Department of Environmental Conservation (NYSDEC) prior to the start of the investigation.

2.0 EMERGENCY PROCEDURES

If a medical emergency occurs, only limited first aid will be available onsite. If the victim(s) cannot be transported without substantial risk, call for an ambulance. If the victim(s) can be transported without substantial risk of additional injury, the nearest hospital is :

Astoria General Hospital
25-10 30th Avenue
Astoria, NY
General Phone Number : (718) 932-1000

2.1 Emergency Phone Numbers

In case of the need for emergency help, the following phone numbers will be maintained at the site:

Police Emergency	911
AMTRAK Police	(212) 630-7113
AMTRAK Environmental Control	(212) 630-7249
AMTRAK Yard Facility Manager	(212) 630-7565
Fire Emergency	847-6600

Ambulance	911
Poison Control Center	(800) 962-1253
National Response Center	(800) 424-8802

2.2 Chain of Command

In case of difficulties at the site requiring notification of Roux Associates, the following is Roux Associates' contacts listed in order of priority:

Roux Associates, Inc.
775 Park Avenue, Suite 255
Huntington, New York 11743
Phone Number: (516) 673-7200

Joseph Duminuco, Project Manager
Home Phone Number: (516) 735-3140

Harry Gregory, Site Health and Safety Officer

3.0 PERSONNEL PROTECTIVE EQUIPMENT

Based on the available information, it is anticipated that a modified version of Level D protection will be adequate for most tasks to be performed at the site.

The modified Level D protection will consist of:

- coveralls, disposable (poly-coated Tyvek);
- gloves, chemical resistant, disposable;
- boots, chemical resistant, disposable or Super Dielectric overboot;
- hard hat; and
- safety glasses or chemical splash goggles.

A photoionization detector will continuously monitor air in the work zone for changes in organic vapor levels. Level D areas are defined as areas where gross ambient organic vapor levels in air (monitored on a real time basis) range from site background up to 5 parts per million (ppm).

Level D protection will be upgraded to Level C protection if concentrations of organic vapors in ambient air exceed 5 ppm or the presence of toxic airborne substances is known or suspected.

Level C areas are defined as areas where gross ambient organic vapor levels in air (monitored on a real-time basis) are greater than 5 ppm but less than 500 ppm, or where the presence of toxic airborne substances is known or suspected.

Level C Protection consists of:

- full face air-purifying respirator (OSHA/National Institute for Occupational Safety and Health [NIOSH] approved);
- coveralls, disposable (poly-coated Tyvek or Saranex);
- gloves, chemical resistant, disposable (taped to coveralls);
- boots, chemical resistant, disposable (taped to coveralls); and
- hard hat.

Work will cease if levels of organic vapors exceed 500 ppm. If this condition persists in the work zone, the Work Plan will be modified to a higher level of protection.

When the possibility exists that explosive gases may be released from the soils during excavation and drilling operations, the atmosphere will be monitored with an explosimeter. When levels approach the lower explosive limit (25 percent L.E.L.), work will cease until explosive gases have sufficiently dispersed.

It will be the responsibility of the senior on-site Roux Associates representative to inform all on-site Roux Associates personnel of the level of personnel protection required in all work situations. All contractors and subcontractors are responsible for supplying their personnel with the necessary safety equipment.

Basic safety equipment will be kept on-site for monitoring and responding to emergency situations. In addition to equipment previously mentioned, basic safety equipment will include, but is not limited to, the following:

- portable eye wash;
- ABC type fire extinguishers;
- first aid kits; and
- photoionization detector.

4.0 EMPLOYEE MEDICAL SURVEILLANCE PROGRAM

All Roux Associates employees involved in field operations have had medical examinations. Follow-up exams are conducted at a frequency of every 12 months for employees involved in field investigations. All contractors and subcontractors are responsible for their own medical surveillance programs.

5.0 TRAINING PROGRAM

All personnel who enter the work zone (the designated area where activities are being performed pursuant to this Work Plan) must have received a minimum of forty hours of comprehensive health and safety training in accordance with 29 CFR Part 1910. All contractors and subcontractors will assume responsibility for the training of their personnel.

It will be required that all Roux Associates personnel (including all contractors and subcontractors) scheduled to perform work in the work zone review a copy of this HASP.

In addition to the procedures outlined in this HASP, all Roux Associates personnel (including all contractors and subcontractors) will be informed of any applicable Yard safety rules to be observed while working at the Yard.

6.0 DEFINITION OF WORK AREAS AND DECONTAMINATION PROCEDURES

Based on health and safety considerations, certain areas at the Yard where soil sample collection will be conducted may be considered a restricted "work zone" while work is taking place. If restricted access is necessary, the appropriate work zone, including but not limited to any drill rig and all associated sampling equipment located therein, will be a

restricted access area. Entry to and exit from the work zone will be provided only to those persons directly involved in tasks associated with the Work Plan and only if the prescribed level of personal protection is worn. Prior to leaving a restricted access area all personnel and equipment will be decontaminated.

If 5 ppm of organic vapor is exceeded in the ambient air or the work (exclusion) zone, air monitoring will be undertaken between the exclusion zone and the nearest downwind, non-Remedial Investigation (RI) related target population. Work will be suspended if readings exceed 5 ppm outside of the exclusion zone.

Areas are defined as Levels C or D corresponding to the level of personal protection required for each situation.

6.1 Restricted Access Area Level D

Level D access will apply to areas in which no health hazards are known to exist and where organic vapor concentrations are below 5 ppm in ambient air. All Roux Associates personnel entering the work zone are required to be wearing Level D personal protection as described in Section 3.0 of this HASP.

Decontamination procedures prior to leaving Level D areas will consist of brushing loose soil from clothing and equipment, and washing equipment with mild detergent and water. Disposable gloves, boots, scoops, paper towels and Tyvek suits will be discarded in the trash receptacles provided within these areas. Drill rigs will be brushed clean of soil and, if necessary, proceed to the heavy equipment cleaning zone.

6.2 Restricted Access Area Level C

Level C access will apply to those areas where organic vapors exceed 5 ppm (but are less than 500 ppm) in ambient air, or where the presence of toxic airborne substances is known or suspected to exist.

Entry to Level C areas will be provided only to those Roux Associates and subcontractor personnel wearing Level C personal protection as described in Section 3.0 of this HASP.

Level C areas will be delineated into a work zone and a decontamination zone. When exiting the work zone, workers will enter the decontamination zone. The decontamination zone will be provided with a plastic liner to contain wash solutions and contaminated soil. Instruments, sample containers, and reusable equipment will be placed on a plastic covered table. These items will be cleaned with the appropriate solutions. The workers will then decontaminate their protective clothing. Disposable items will be discarded in trash receptacles which will be provided within the decontamination area.

After decontamination, personnel will leave the decontamination zone, with respirators being removed last. Drilling and heavy equipment will be cleaned of gross contamination while in the work zone, after which the equipment will be moved to the heavy equipment cleaning area.

Dry material such as suits and gloves will be disposed in accordance with state and federal guidelines.

APPENDIX D
Site Management Plan

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2.0 EQUIPMENT DECONTAMINATION 1

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1.0 INTRODUCTION

The Site Management Plan (SMP) identifies operating procedures which have been developed to minimize exposure, risks and/or the spread of contamination during field investigations at the Sunnyside Yard, Queens, New York (Yard). Specifically, the SMP addresses the following principal concerns and considerations:

- protocol for decontamination of field equipment;
- site security/access procedures;
- enforcement of safety procedures; and
- coordination of field activities.

Strict adherence to the conditions imposed by the SMP will be required of all on-site personnel (contractors and observers) to ensure efficient and safe field operations.

2.0 EQUIPMENT DECONTAMINATION

The decontamination of field equipment (i.e. drill rig, drilling tools, sampling equipment, etc.) is essential to avoid the spread of contamination beyond the work zone as well as to avoid cross-contamination during subsequent sampling operations. Heavy equipment decontamination will be performed at central staging areas. Wash water will be obtained from the nearest hydrant, tap or other source of potable water. Decontamination procedures for specific items are described below.

Sampling Devices - Split-spoon core samplers, hand augers, post-hole diggers, shovels, trowels, pumps, and bailers will be decontaminated between uses following the protocols outlined in Appendix B.

Tools - Tools such as wrenches and shovels used during the drilling operation that come into contact with sediment and/or water from the borehole will be cleaned with a scrub brush and soapy water. A steam cleaner and scrub brush will be used for decontaminating larger tools.

Heavy Equipment - The drill rig and all drilling equipment (i.e. split spoons, auger flights, etc.) will be steam cleaned prior to and at the conclusion of the program. This measure ensures that no transfer of contamination occurs between this and other drilling locations and eliminates the possibility of exposing the public to contaminated equipment. In addition, all heavy equipment will be steam cleaned immediately after the completion of each borehole or monitoring well where contamination (e.g. odors, visible staining, PID readings) was detected to eliminate the possibility of spreading contaminants from one drill hole to the next. Similarly, split-spoon sampling equipment will be routinely decontaminated to minimize the chances of vertical cross contamination in the soil sampling program.

3.0 SITE SECURITY

No one will be admitted to a work zone without the express approval of the project hydrogeologist and AMTRAK. The project manager or his designee will maintain a separate log which will record the time of arrival to departure from the work zone during field operations for all personnel, their affiliation and the reason for their presence.

In addition, at night, the drilling rig and other heavy equipment will remain on the site and be parked in a secured area provided by the facility manager of the Yard.

4.0 ENFORCEMENT OF SAFETY PROCEDURES

It will be the responsibility of the project manager and his designee to enforce the established health and safety procedures outlined in Appendix A. All workers within each work zone, including all subcontractors, will be given oral and written instructions regarding site health and safety procedures by both the contractor and AMTRAK. The project hydrogeologist will, if necessary, stop ongoing work at any time if an unsafe condition occurs until the condition is corrected.

5.0 COORDINATION OF FIELD ACTIVITIES

The project manager, project hydrogeologist and subcontractor representatives will meet with the facility manager of the Yard throughout the project to coordinate schedules, discuss access requirements, review all safety concerns, and establish procedures to arrange access to necessary areas for the specific periods required to perform the various field activities.

APPENDIX E
Quality Assurance Project Plan

CONTENTS

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1.0 INTRODUCTION

This Quality Assurance Project Plan (QAPP) presents the policies, organization, objectives and functional activities that will be utilized to ensure that all data collected and recorded during field investigations at the Sunnyside Yard, Queens, New York (Yard) are representative of existing conditions.

2.0 PROJECT ORGANIZATION

The project manager will be responsible for the overall management of the project, including field supervision of all drilling and sampling activities and all environmental and hydrogeologic data. Primary responsibility for project management is with the project manager. Project oversight will be provided by the project officer. Responsibility for quality assurance/quality control (QA/QC) review is with the project quality control officer. Where quality assurance problems or deficiencies requiring special action are identified, the project quality control officer will identify and implement the appropriate corrective action with the project officer and project manager's concurrence.

3.0 FIELD ORGANIZATION

The field investigation will be organized according to the sampling activities to be undertaken. For on-site sampling work, the actual sampling team make-up will depend on the type and extent of sampling and will consist of a combination of the following:

- Project Manager;
- Project Hydrogeologist;
- Health and Safety Officer; and
- Sampling Coordinator.

The project manager will be responsible for the coordination of the personnel onsite and for providing technical assistance when required. The project manager or his designee will be present whenever sampling occurs and will also keep a general site log describing activities conducted in the work zone, identifying personnel entering the work zone and noting general observations regarding work zone activity.

The project hydrogeologist will be responsible for providing technical supervision of the drilling subcontractor during the installation and development of the monitoring wells. In addition, the project hydrogeologist will be responsible for geologic logging and soil sampling to be performed during the installation of the monitoring wells and the drilling of soil borings.

The health and safety officer will be responsible for assuring that all team members adhere to the applicable health and safety requirements. In addition, the health and safety officer will regularly update equipment or procedures based upon new information gathered during site inspections. Based on this information, the levels of protection proposed for the work zone will be modified appropriately.

The sampling coordinator will be responsible for the coordination of all sampling efforts and will assure the availability and maintenance of the necessary shipping/packing materials and sampling equipment. The sampling coordinator will: 1) supervise the completion of all sampling documentation; 2) ensure the proper handling and shipping of the samples; 3) be responsible for the accurate completion of a field notebook; and 4) provide close coordination with the project manager.

4.0 QUALITY ASSURANCE OBJECTIVES

The general quality assurance objective is to ensure the environmental monitoring data (laboratory chemical data) developed is of known and acceptable quality. The environmental data collection efforts will adhere to QA/QC procedures developed by Roux Associates, Inc. for the collection and preservation of environmental samples and by the analytical laboratory for its analyses.

4.1 Precision

The QA/QC aim in testing the precision is to demonstrate the reproducibility of the data. The precision of analytical project measurements will be evaluated and reported along with the method reference number in the manner consistent with previously published data on precision. Moreover, precision measurements will be done with high purity materials,

knowledgeable laboratory personnel, internal quality controls and will be based on New York State Department of Environmental Conservation (NYSDEC) analytical services protocols (ASP).

4.2 Accuracy

Accuracy is the relationship of the reported data to the "true" value, and will be: 1) reported with the data; 2) attained by independent audits using standards which are different from those used during routine operations, and 3) consistent with any previously published accuracy data from the applicable literature, federal and state regulations and the ASP program.

4.3 Completeness

Completeness is a measure of the amount of data obtained from a measurement program, compared to the amount that would be expected to be obtained under normal conditions. The database will be routinely assessed on the basis of expected versus actual data to ensure that it meets the completeness objective.

4.4 Representativeness

All data should be representative of the actual conditions at the sampling location. Considerations and evaluations of representativeness of the data include, but are not limited to, the location being sampled, the methods used to obtain environmental samples at the site, and the appropriateness of the analytical method to the type of sample obtained.

4.5 Comparability

All data will be reported in units consistent with both federal and state regulations, methods and guidelines. Comparability between databases will also be achieved by citing standardized sampling and analysis methods in data formats. Any deviation in the standard operating procedures will be noted and data will be qualified for comparative purposes.

5.0 SAMPLE HANDLING

All samples (soil, water, sediment and oil) will be collected according to the appropriate protocols (Appendix B). Samples will be placed in the appropriate pre-cleaned jars or bottles provided by the laboratory for the specific analyses to be performed. All jars and bottles will be pre-labeled with the following information:

- the borehole, manhole or well number;
- sample depth (if appropriate);
- type of sample;
- date and time of collection; and
- affiliation of person collecting sample.

6.0 SAMPLE CUSTODY

Samples collected during the site investigation will be the responsibility of identified persons from the time they are collected until they or their arrived data are incorporated into the final report. Stringent chain-of-custody procedures will be followed to maintain and document sample possession at all times.

7.0 BLANKS AND SPLIT SAMPLES

Trip blanks, field blanks and replicate samples will be used to verify the quality of the field sampling and the laboratory results. A brief description of each follows.

Trip Blank - Trip blanks for VOCs will be prepared by the analytical laboratory and shipped along with the sample bottles and will be analyzed at the same time as all other samples.

Field Blank - The efficacy of the field cleaning protocols will be monitored by the use of field blanks. Laboratory pure water will be run through newly cleaned bailers just prior to sampling to obtain a field blank. The sample will then be handled in the same manner as the actual samples.

Replicate Samples - "Blind" replicate samples will be collected and submitted to the analyzing laboratory for comparison of analytical results. Also, replicate samples of water, organic liquid, soil or sediment will be made available to the NYSDEC upon request. The NYSDEC will provide all sample bottles for duplicate splits.

8.0 RECORD KEEPING

All information pertinent to field activities will be recorded in a bound, waterproof field book. Duplicates of all notes will be prepared and kept in a secure place away from the site. Proper documentation will consist of detailed records of all work accomplished. Photographs will be used to document field observations where appropriate. Items, such as the date, time, location and sequential number of the photograph and roll number will be recorded in the field book.

Each sample collected in the field will be labeled using waterproof ink. Label information (e.g., sample number, date, time, etc.) will also be recorded in the log book.

Strict chain-of-custody procedures will be maintained for each sample. The chain of custody will be in accordance with procedures approved by the NYSDEC.

APPENDIX F

Bail-Down Test Technical Paper

**Two Techniques for Determining the True Hydrocarbon Thickness
in an Unconfined Sandy Aquifer**

BY

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ABSTRACT

In unconfined sandy aquifers, the hydrocarbon thickness in a monitoring well exceeds - sometimes by a large amount - the "true" thickness of the mobile hydrocarbon layer in the formation. This paper presents two techniques designed to provide a more accurate estimate of the true thickness. A companion paper in this volume (Sullivan et. al) presents a descriptive model for the occurrence of hydrocarbon on an unconfined aquifer.

The opening sections of the present paper provide a straightforward explanation of the exaggeration theory, and discuss a number of practical reasons why it's important to obtain accurate information on the true thickness of the mobile hydrocarbon layer in the formation. There are a number of ways in which using the apparent well thickness can create problems. The efficient design and placement of recovery wells, and the calculation of realistic estimates of the volume of liquid hydrocarbon beneath a site both depend on knowing the actual thickness of the mobile hydrocarbon layer. The search for the true thickness, therefore, becomes more than simply an academic exercise. It can also have an impact on the overall costs of the site assessment and clean-up.

The remainder of the paper is devoted to examining several methods of making a more accurate estimate of the true thickness of the mobile hydrocarbon layer in the formation. The first method involves well test techniques. Two types of well tests are described. The first is conducted in wells that have been pumped to establish steady-state conditions. The second is equivalent to a slug test and is appropriate for use where hydrocarbon accumulations are thin. Data on the hydrocarbon recharge rates generated by the test are first evaluated graphically and then combined with simple algebraic equations to calculate the true hydrocarbon thickness in the formation. The interpretation of the test data is based on the model presented in Sullivan et. al.. The well tests can easily be repeated in the future to track changes in the hydrocarbon thickness with time.

The second method of estimating the true thickness of hydrocarbon in the well, involves continuous coring through the zone of interest. This provides a "snap-shot in time" look at the hydrocarbon saturated interval. In addition to the standard core analysis techniques, we have

found that the natural fluorescence of hydrocarbons provides an additional method of delineating the contaminated zone and making a qualitative estimate of the saturation present, when the core is examined under an ultraviolet light.

1.0 INTRODUCTION

Those involved in groundwater contamination work have long accepted the concept that the hydrocarbon thickness in a monitoring well exceeds - sometimes by a large amount - the "true" thickness of the mobile hydrocarbon layer in the formation (CONCAWE, 1979, Blake and Hall, 1984, Hall et. al., 1984, and Gruszczenski, 1987). This causes a series of problems when the monitoring well data is used to make decisions about such things as the most efficient place to locate recovery wells or the volume of hydrocarbon in place beneath the site. A relatively simple method of measuring the thickness in the formation, however, has, for the most part, remained elusive. As a result, people in the field simply use the monitoring well data but note that it is probably an overestimate of the true thickness.

Except for the fact that it has something to do with the "capillary fringe", the theory behind the exaggeration phenomenon has not always been well understood. A companion paper in this volume (Sullivan et. al.) includes a detailed discussion of the theory behind the exaggeration and some implications for hydrocarbon recovery. The present paper approaches the subject from a somewhat more applied perspective. We begin by providing a simple explanation of the exaggeration theory. Next, we look at why using the apparent monitoring well thickness as a basis for decisions can cause a variety of problems. Finally, we examine a couple of relatively straightforward techniques designed to give us a closer approximation of the true thickness of the mobile hydrocarbon layer in the formation. A third technique, involving the use of a dielectric logging tool, is the subject of another paper in this volume (Keech).

2.0 EXAGGERATION THEORY

2.1 The Capillary Zone

The liquid hydrocarbon thickness in a monitoring well is different than the true thickness of the mobile hydrocarbon layer in the aquifer because hydrologic conditions in the well are different than those in the aquifer. In unconfined sandy aquifers, a capillary zone forms above the water table, in which water is drawn up into the soil column by surface tension forces. Capillary rise is a common phenomenon in our everyday lives. In an oil lamp, for example, it causes the oil from the lower reservoir to rise up the wick so that it can be burned in the flame.

The height of the capillary zone above the water table depends primarily on the size of the pores in the formation - that is, the size of the open spaces between the sand grains. In a well sorted sand, the size of the pores is directly related to the size of the grains. -the larger the grains, the larger the pores. Consequently, the finer the grain size the higher the capillary rise and the coarser the grain size, the smaller the capillary rise.

The removal of the formation matrix during the drilling and installation of a well, in effect, creates one large "macro pore" (the size of the casing diameter) inside the well. As a result, there is virtually no capillary rise inside the casing. By installing the well we have, therefore, created an anomalous zone in the aquifer. Outside the well a capillary fringe exists but inside the casing the capillary fringe is missing. It

is this missing capillary fringe inside the well that allows an exaggerated thickness of hydrocarbon to accumulate in the well.

When a well is installed in an unconfined aquifer containing no hydrocarbon, water will rise in the casing until it reaches the elevation of the water table. This horizon represents the surface in both the aquifer and the well at which the pressure is equal to the atmospheric pressure. As you move down (or deeper) below the water table in either the aquifer or the well, the pressure steadily increases. As you move up (or shallower) in the aquifer above the water table, the pore pressure steadily decreases, until the top of the capillary zone is reached. There is a pressure discontinuity at the top of the capillary zone caused by interfacial tension forces. The pressure in the water filled pores just below the interface is at some value less than atmospheric - the magnitude of that amount being proportional to the height of the interface above the water table. The pressure in the air filled pores just above the interface is atmospheric and from that point on up the pore pressure remains constant. Pressure in the well at any elevation above the water table remains constant at atmospheric pressure. Figure 2-1 illustrates these ideas, showing pressure diagrams for vertical slices through both the formation (A) and the well (B). Notice that the water from the capillary zone does not flow into the well. Yet the pores in the capillary zone are full of water which can flow between the sand grains within the formation. The solution to this apparent contradiction, lies in the fact that different pressures exist on the opposite sides of the well casing. Figure 2-1 (pressure diagram B), shows that the pressure in the well anywhere above the water table is equal to atmospheric pressure. On the opposite side of the slots in the capillary zone (Figure 2-1, pressure diagram A), the pore pressure is less than the ambient pressure. Since the pressure in the well is higher than the pressure in the formation, water from the capillary fringe cannot flow into the well. The edge of the well, therefore, acts as a pressure barrier preventing this capillary water from flowing into the well. As a result, the water level in the well will be lower than the top of the water saturated zone in the formation.

2.2 The Exaggeration Mechanism

2.2.1 General The capillary forces outside the well support a portion of the weight of the liquid hydrocarbon pool above the water table (Figure 2-2). Inside the well there are no capillary forces to support the hydrocarbon, and the product, therefore, rests directly on the water table. The top of the hydrocarbon layer in the well will rise to the same elevation as the top of the mobile hydrocarbon layer in the formation. [For the

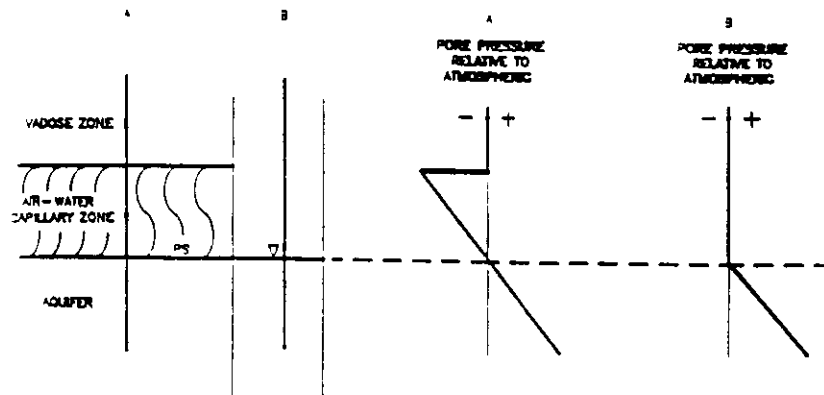


FIGURE 2-1 PRESSURE RELATIONSHIPS.

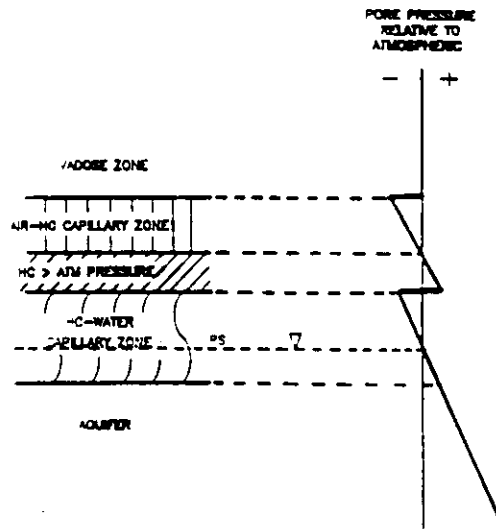


FIGURE 2-2 FLUID DISTRIBUTION AND PRESSURE PROFILE IN A HOMOGENEOUS ISOTROPIC FORMATION.

purposes of this paper, we will use the term "mobile hydrocarbon" to refer to that portion of the hydrocarbon pool which is at greater than atmospheric pressure.] The bottom of the the hydrocarbon/water contact, however, will initially be lower in the well than in the formation (Figure 2-3a). A thicker column of hydrocarbon can accumulate in the well, therefore, than in the formation. This thicker column of hydrocarbon in turn displaces some additional water in the well resulting in an even thicker column of hydrocarbon in the casing. Eventually this thickening in the well stabilizes when the weight of the hydrocarbon above the hydrocarbon/water interface is exactly balanced by the buoyant forces of the water below the hydrocarbon/water interface (Figure 2-3b).

It may help to better understand this situation if we look at the opposing forces acting on the hydrocarbon/water interface. In the formation there are three forces (indicated by the arrows in Figure 2-4) acting on this contact. The weight of the hydrocarbon (P_{hc}) naturally pushes down. The buoyant force of the water (P_w) resists the downward push of the hydrocarbon and presses up on the interface. The capillary pressure (P_c) also pushes up against the weight of the hydrocarbon. In a stabilized system, therefore, P_w and P_c work together to exactly balance P_{hc} . When a monitoring well is installed, however, the capillary forces are removed and consequently, the value of P_c goes to zero. P_w is therefore left on its own to bear the full weight of the hydrocarbon (P_{hc}). It is unsuccessful in this effort, however, and the hydrocarbon/water interface in the well slowly "retreats" (i.e. falls) in the face of the greater force (P_{hc}). As the water is displaced, more hydrocarbon flows into the well to take its place. This retreat of the hydrocarbon/water interface and the thickening of the hydrocarbon column in the well, continues until the weight of the water that is being displaced exactly balances the extra column of hydrocarbon in the well. In other words, the hydrocarbon column in the well will continue to thicken until P_w in the well equals P_{hc} in the well.

2.2.2 After the Initial Exaggeration At this point, the effects of the missing capillary zone have been compensated for, and the initial exaggeration process is essentially complete. From here on out, any additional hydrocarbon reaching the area will accumulate in both the formation and the well in equal proportions. If an extra foot of

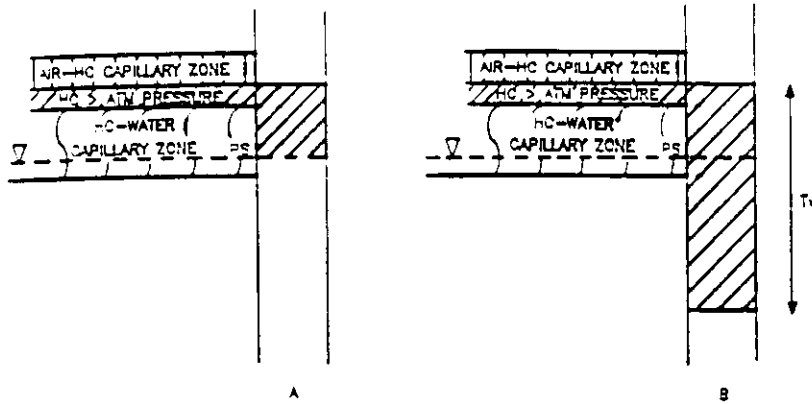


FIGURE 2-3 EXAGGERATION MECHANISM.

hydrocarbon is added to the formation (i.e. a new or continued leak), the gauged well thickness will also increase by one foot. Note that something interesting now begins to happen to the ratio of the thickness of hydrocarbon in the well compared to the thickness of the mobile hydrocarbon layer in the formation. Let us say that at the moment when the initial exaggeration completes, this ratio is 5:1. In other words, there is only one foot of mobile hydrocarbon in the formation but 5 feet of gauged hydrocarbon in the well. Let's now assume, that because of a new leak, an additional foot of hydrocarbon accumulates in the formation. Because the exaggeration process is already complete, the monitoring well thickness also increases by just one foot. The ratio of the well thickness to formation thickness is now 6:2 or 3:1. Where the well formally showed 5 times the

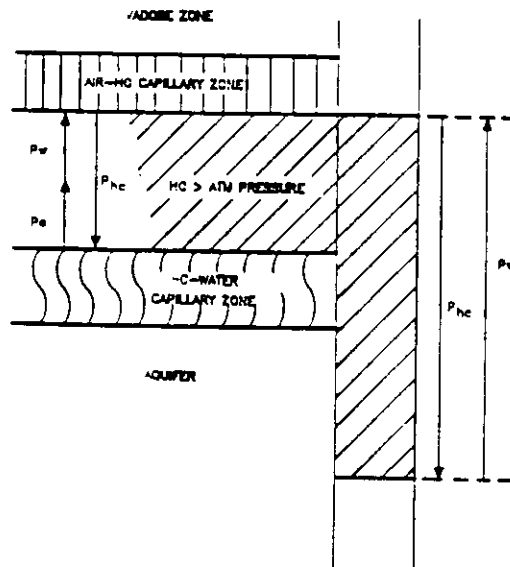


FIGURE 2-4 BALANCE OF FORCES IN THE FORMATION AND IN THE WELL.

thickness that was in the formation, it is now showing only three times the formation thickness. If the leak continues and 2 more feet of hydrocarbon accumulates in the formation (thereby adding 2 more feet to the well), the ratio of well thickness to formation thickness now drops to 8:4 or 2:1. If 4 more feet are added to both the formation and well the ratio becomes 12:8 or 1.5:1. Figure 2-5 shows a plot of the situation just described here. Note that the curve drops steeply in the beginning as new hydrocarbon is added, then flattens out as it approaches - but never quite reaches - a ratio of 1:1.

Now consider what happens when you begin recovering hydrocarbon. Let us use the same conditions that we had at the end of the last example. The initial exaggeration has occurred (5:1) and then sufficient additional hydrocarbon has accumulated so that there is now 12 feet in the well but only 8 feet of mobile hydrocarbon in the formation (a ratio of 1.5:1). After a certain period of time the recovery well(s) will have pulled enough hydrocarbon from the subsurface to reduce the thickness of the mobile hydrocarbon layer in the formation from 8 feet to 4 feet. This would also result in a 4 foot decrease in the gauged hydrocarbon thickness in the monitoring well, and we'd be back up to a 2:1 ratio. As recovery continued, you would work your way back along the curve in Figure 2-5, through a 3:1 and then to a 5:1 ratio. At this point, even though there is only a thin mobile hydrocarbon layer in the formation, there would still be 5 feet of gauged hydrocarbon in the well. Clearly then, the amount of exaggeration (i.e. the ratio of the thickness of hydrocarbon in the well to the thickness of the mobile hydrocarbon layer in the formation) will vary depending on where you are along the curve shown in Figure 2-5.

2.2.3 Factors Controlling the Amount of Exaggeration It is the presence of a capillary zone in the formation and its absence in the well that initiates the exaggeration process. It seems reasonable, therefore, that the thickness of the capillary zone in the formation is one factor that determines the amount of exaggeration that initially develops in the well. The greater the thickness of the capillary zone, the greater the exaggeration. The other factor that controls the ultimate exaggeration is the specific gravity of the

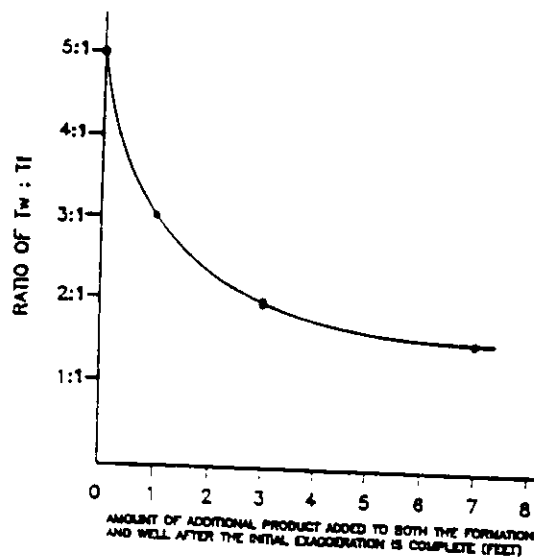


FIGURE 2-5 CHANGES IN THE EXAGGERATION FACTOR (RATIO) OVER TIME.

hydrocarbon that displaces the water, as the former enters the well. A foot of gas oil (with a specific gravity of say 0.91) weighs more than a foot of gasoline (which has a specific gravity of something on the order of 0.75). In a standard 4 inch observation well, this foot of gas oil would weigh roughly a pound more than a foot of gasoline. The extra weight would push down on the hydrocarbon/water interface with a greater force. Consequently, a longer column of water will have to be displaced from the well before the weight of that displaced water equals the weight of the heavier column of gas oil.

2.3 Miscellaneous Implications

2.3.1 A Cross Section of a Plume Sullivan et. al. (this volume, Figure 1) presented a sequence showing the accumulation of hydrocarbon in a monitoring well. It assumed that the well was in place prior to hydrocarbon reaching the water capillary zone, and then traced the development of the initial exaggeration of hydrocarbon in the well. Figure 2-6 (this paper) shows a cross sectional view of a portion of a hydrocarbon plume. It represents a situation in which the hydrocarbon pool has formed and stabilized prior to the installation of the monitoring wells. Well "A" might represent the initial well, in which the hydrocarbon is "discovered". Wells "B", "C", and "D" would then indicate "step-out" wells drilled in order to find the "limit and extent" of the hydrocarbon pool. Notice that there are large variations in the ratio of well : formation hydrocarbon thickness. If a single "correction" factor (based on data from any one well) was used to correct gauging data from all the other wells in the pool, large errors would result. Not surprisingly, the ratio is smallest (i.e. closer to 1:1) near the center of the pool where the thickness of the layer of hydrocarbon at greater than atmospheric pressure is the largest. Toward the edge of the pool, where the thickness of the layer of hydrocarbon at greater than atmospheric pressure decreases, the ratios are noticeably greater. Well "C" represents an extreme case, in which the layer of hydrocarbon at greater than atmospheric pressure is so thin, that there is only sufficient hydrocarbon to allow the initial exaggerated thickness to form in the well. Figure 2-6 supports the common assumption that the exaggeration is greater near the edge of the plume, and smaller (i.e. closer to 1:1) near the center of the pool.

2.3.2 Too Little Hydrocarbon in the Well If the system we have described is correct, then another rather intriguing question has just been raised. If the presence of even a modest capillary fringe and a thin mobile hydrocarbon layer in the formation can result in a several foot accumulation of hydrocarbon in a monitoring well, how is it possible to have a well with just a few inches or perhaps a foot of gauged hydrocarbon? Given these conditions, it would seem unlikely that you could have such a small accumulation in the well. For simplicity's sake, we have ignored the effects of the filter pack envelope around the well in our previous discussions. It appears, however, that the presence of a filter pack between the formation and the well can alter the natural conditions sufficiently to allow a small amount of normally "immobile" hydrocarbon from the air/hydrocarbon capillary fringe, to enter the well. Sullivan et. al. (this volume) describes this phenomenon which permits some hydrocarbon into the well even before sufficient hydrocarbons have accumulated to allow the formation of a mobile hydrocarbon layer in the aquifer.

2.4 Summary

There are a number of factors which contribute to the amount of hydrocarbon which accumulates in a monitoring well, only one of which is the actual thickness of the

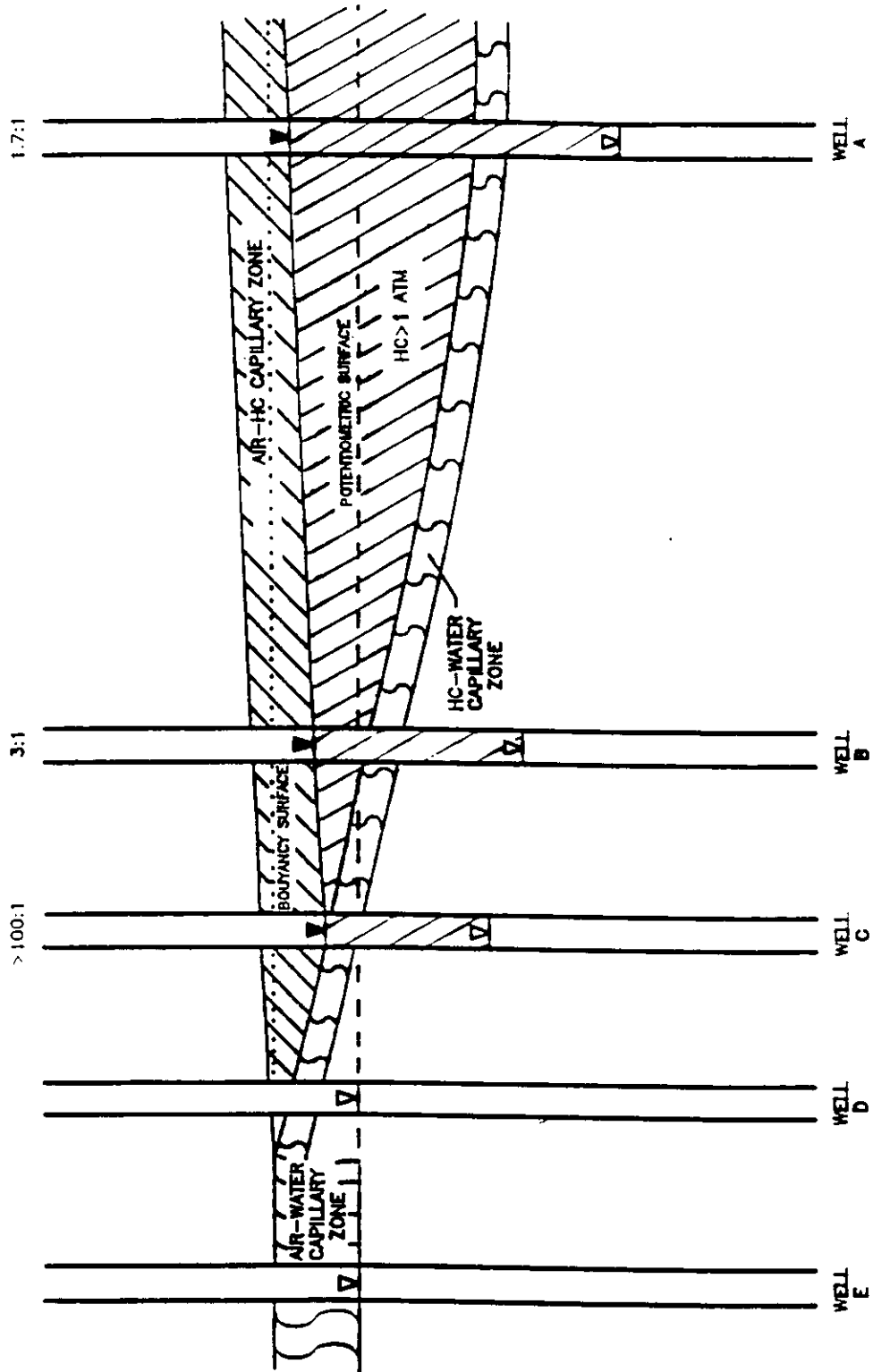


FIGURE 2-6 WELL TO FORMATION HYDROCARBON THICKNESS RATIOS IN A CROSS-SECTION OF A HYDROCARBON POOL.

mobile hydrocarbon layer in the formation. In summary, it is the presence of a capillary zone outside the well and the absence of a capillary zone inside the well which allows a thicker column of hydrocarbon to initially accumulate inside the well, than exists in the formation. Once the initial exaggeration occurs, additional hydrocarbon that reaches the area is added to both the formation and the well in equal proportions. Even if you were successful in calculating the amount of the initial exaggeration factor (say 4:1), it would only remain valid as long as there were no increases or decreases in the actual thickness of the mobile hydrocarbon layer in the formation. And yet these kinds of changes could be caused by any number of events, such as new spills or continuing leaks or the pumping that occurs during hydrocarbon recovery efforts. Consequently, taking the gauged thickness from a monitoring well and always dividing that thickness by the same calculated exaggeration factor (4 in this case), could lead to potentially large errors over time. Also, keep in mind that some large sites may have a variety of grain sizes and, hence, a variety of capillary zone thicknesses. They may also have a range of hydrocarbon types and, hence, a range of specific gravities. In such cases, you'd have to calculate a different initial exaggeration factor for each capillary zone/specific gravity pair. You couldn't simply divide all monitoring well thicknesses by a common exaggeration factor. We are left, then, with the realization that not only might we have a different exaggeration factor (ratio) for every well, each of those factors could vary over time. Attempting to accurately "correct" monitoring well data with calculated exaggeration factors should probably be avoided. The "corrected" hydrocarbon thicknesses could potentially be as much in error as are the "raw" gauging data. The danger in using "corrected" data, therefore, lies in the fact that you mistakenly believe that the resulting hydrocarbon thicknesses are accurate. With "raw" monitoring well data, at least you know the thicknesses are wrong.

A monitoring well has many uses. It provides access deep into the aquifer allowing, among other things, the measurement of fluid levels, the calculation of the potentiometric surface, the detection of hydrocarbon, and the collection of hydrocarbon and water samples for fingerprinting and analysis. What it does not provide, however, is an accurate measurement of the true mobile hydrocarbon thickness in the formation.

In spite of their short comings, however, wells remain the best all around tool for monitoring what is going on in the aquifer. The authors believe that the recharge technique described later in this paper is one method of overcoming the complications just discussed. It provides a way of estimating the true mobile hydrocarbon thickness in the formation, without having to deal with "correction" factors.

3.0 SOME IMPACTS OF USING THE EXAGGERATED WELL THICKNESSES

An accurate estimate of the hydrocarbon thickness is essential for knowing both the magnitude of the problem at a site, and designing an effective hydrocarbon recovery system.

3.1 Locating Recovery Wells

Experience with several liquid hydrocarbon skimming wells at our site suggested that areas with at least 5 to 7 feet of gauged hydrocarbon would make good locations for additional wells (i.e. would produce reasonable quantities of hydrocarbon). [Note: Although dual pump wells provide the bulk of the recovery at the site, limits on our ability to handle large quantities of produced water mean that skimmer wells will continue to be an integral part of our clean up efforts, for at least the foreseeable future.] Additional skimmer wells were installed in several areas of the site with between 5 and 7 feet of gauged hydrocarbon thickness. All of the wells were installed

carefully and showed similar (water) pumping test results. It turned out, however, that there were wide variations in the rate of liquid hydrocarbon recovered, with production ranging from 30 to almost 300 gallons per day - an order of magnitude difference. Apparently not all areas of 5 to 7 feet of gauged hydrocarbon thickness are created equal - at least in terms of their ability to produce reasonable quantities of hydrocarbon.

The results of the well tests described later showed that in one case, 7 feet of gauged thickness translated into 3.5 feet of actual thickness in the formation (a 2:1 exaggeration). In another case, however, 5 feet of gauged thickness turned out to be less than 8 inches of actual mobile liquid hydrocarbon thickness in the formation. The skimmers with poor production had apparently been inadvertently located in areas with very little actual mobile hydrocarbon. Clearly, then, the use of gauged hydrocarbon thicknesses to pick locations for skimming wells leaves something to be desired. A recovery well - including the costs of drilling, materials, piping and equipment - can be rather expensive. Consequently, the desire to know the true thickness of the plume, has more driving it than simply academic interest. It is also a matter of dollars and cents.

3.2 Estimating Volumes.

Knowing the true thickness of the hydrocarbon column in the aquifer also allows one to make more accurate estimates of how large a volume of hydrocarbon exists beneath the project site. There are at least two reasons for wanting this information. Firstly, only by knowing the actual volume of hydrocarbon in place, can all parties (clients, regulatory agencies, etc.) understand the true magnitude of the problem with which they are dealing. As an example, assume that the "raw" (i.e. gauged) monitoring well data at a site indicates that the apparent volume of mobile hydrocarbon in place is something on the order of a million gallons. That sort of number tends to make frightening headlines in local papers. It doesn't help much that somewhere in the middle of the article, the reporter mentions the fact that well thicknesses are usually exaggerated, and that the real volume may be much less. By that time, the damage is probably already done. Ideally then, we need something better than raw monitoring well data to estimate the actual volume of hydrocarbon beneath a site, before that volume is widely reported.

The second reason for wanting an accurate volume estimate has to do with one of the requirements appearing with increasing frequency in regulatory directed clean-up orders. This clause requires the agent responsible for the clean up to "show evidence of a substantial reduction in hydrocarbon volume" by a certain date. It's easy to understand the difficulty you would have in meeting this requirement if you weren't even sure of how much hydrocarbon you had to begin with! Using the example numbers from the preceding paragraph, let's say that over a certain period of time, pumps at the site recover 100,000 gallons of hydrocarbon from the sub-surface. That amounts to only 10% of the one million gallons apparently beneath the site based on the "raw" monitoring well data - hardly a "substantial reduction". Suppose, however, that the true volume beneath the site is more like 200,000 gallons (i.e. a 5 : 1 exaggeration). In that case, 50% of the volume in place would have been recovered - a much more significant reduction.

3.3 Summary.

With an understanding, then, of why exaggerated thicknesses occur in monitoring wells and with an appreciation of the variety of practical problems that those exaggerations can cause, the remainder of this paper will be devoted to examining some practical methods of calculating a more accurate estimate for the actual thickness of mobile hydrocarbon in the formation. The first technique involves recharge and/or

bail-down tests in either existing monitoring or production wells. The second method consists of analysis of cores cut during either the installation of a well or as part of a separate reconnaissance effort.

4.0 WELL TESTS

4.1 General

The basic problem one encounters in trying to use gauging data from a monitoring well to determine the actual thickness of mobile hydrocarbon in the formation is illustrated in Figure 2-2b. The top of the hydrocarbon column (hydrocarbon/air interface) in the well corresponds to the top of the mobile hydrocarbon layer in the formation. Because of the exaggeration of liquid hydrocarbon in the well, however, the bottom of the hydrocarbon zone (hydrocarbon/water interface) in the well does not correspond to the bottom of the mobile hydrocarbon zone in the formation. What we need then, is either some method of locating the hydrocarbon/water interface in the formation, or else a method of calculating the true hydrocarbon thickness without knowing the location of that interface.

Two procedures are described for estimating the true thickness of hydrocarbon in the formation. The first method is a recharge test which allows us to estimate the true hydrocarbon thickness without knowing the elevation of the hydrocarbon/water interface. Under the right conditions, the bail-down test method described second, can be used to directly estimate the thickness of mobile hydrocarbon, because it locates the hydrocarbon/water interface in the formation. The basis for the interpretation of the recharge tests and the assumptions and limitations of the tests are discussed in Sullivan et. al. (this volume).

4.2 Recharge Test

4.2.1 *Theory* Figure 4-1 shows the relationship between a column of hydrocarbon in a well and the regional potentiometric surface. The column of hydrocarbon has settled

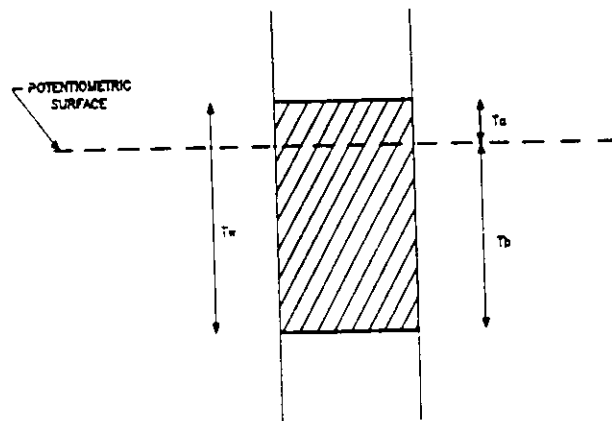


FIGURE 4-1 HYDROCARBON BUOYANCY IN A WELL

part way below the potentiometric surface displacing the water, in much the same way that an ice cube settles part way below the fluid level in a drink. The amount of settlement depends on the relative densities of the hydrocarbon and water. For the purposes of this paper, we will assume that the density of water is equal to 1.0 g/cm.³ In the future, therefore, we will substitute the term "specific gravity" for "density". Figure 4-1 shows the ratio of the height of the hydrocarbon column above and below the potentiometric surface for hydrocarbon with a specific gravity of 0.80. Table 4-1 shows some examples of this ratio for various other hydrocarbon types. Ice, by the way, has a specific gravity of roughly 0.91 in fresh water, or about the same specific gravity as gas oil. The Ta/Tb ratio for an ice cube, therefore, would be a bit more than 1:10

Table 4-1

Comparison of Ratios of the Amount of Hydrocarbon Above and Below the Potentiometric surface, for Products with Varying Specific Gravities

Specific Gravity of the Product (SGhc)	Ta	Tb*
0.70	1	2.33
0.75	1	3.00
0.80	1	4.00
0.85	1	5.67
0.90	1	9.00
0.95	1	19.00

$$*Tb = \{(Ta) [(SGhc)/(SGw - SGhc)]\}$$

As hydrocarbon is either added or removed from the well, the relative amounts above and below the potentiometric surface will be maintained. For example, if 5 feet of additional .8 gravity hydrocarbon is added to the well, 1/5th of that amount (or 1 foot) will be added above the potentiometric surface while 4/5ths (or 4 feet) will settle below the potentiometric surface.

One of the common uses of this relationship is in correcting the elevation of the water found in a monitoring well, in order to calculate the potentiometric surface (i.e. the level to which the water would rise in the well if there were no liquid hydrocarbon present). In that application, you typically start with the elevation of the hydrocarbon/water interface as gauged in the well. You then add to that elevation, an amount equal to Tb, where:

$$Tb = [(Tw) (SGhc)] \quad (1)$$

which is the distance that the total column of hydrocarbon (Tw) has displaced the original water surface in the well. Note, however, that you could just as easily (and just as correctly) have started with the gauged elevation of the top of the hydrocarbon in the well and then subtracted an amount equal to Ta, where:

$$Ta = [(Tw) (1 - SGhc)] \quad (2)$$

which is the amount of the total column of hydrocarbon above the potentiometric surface. It also follows that if you knew the thickness of the hydrocarbon column above the potentiometric surface, (T_a), and the specific gravity of the hydrocarbon, you could calculate the total thickness of hydrocarbon, (T_w), by the simple equation:

$$T_w = T_a / (1 - SG_{hc}) \quad (3).$$

It is just this sort of calculation that will allow us to estimate the true mobile hydrocarbon thickness in the formation without knowing the location of the bottom of the oil/water interface.

The hydrocarbon column in the formation forms around a buoyancy datum just as it does in a well. The potentiometric surface defines this datum in the well and we will refer to the equivalent datum in the formation as the buoyancy surface. Just as with the potentiometric surface in the well, hydrocarbon that is added (or removed) from the formation will be added (or removed) above and below the buoyancy surface according to the ratios shown in Figure 4-1 and Table 4-1. As an illustration, Figure 4-2a shows a stable hydrocarbon pool and a non pumping skimming well. In Figure 4-2b, the liquid hydrocarbon skimming pump has been turned on and the fluid levels allowed to restabilize. [Note that these diagrams assume homogeneous conditions.] As hydrocarbon is removed from the well, a small drawdown cone forms in the hydrocarbon layer in the formation near the well. At the same time, the hydrocarbon/water interface in both the well and the formation rebound in response to the removal of the hydrocarbon. During this process, the elevation of both the top and bottom surfaces of the mobile liquid hydrocarbon layer in the formation, always maintain the proper relative distances from the buoyancy surface and converge on that plane, intersecting it at the well. That intersection point ("X") is the entry point of hydrocarbon into the well during continued skimming. Using the same sort of relationships developed in the previous section for hydrocarbon, water and the potentiometric surface in a well, we can say that the distance

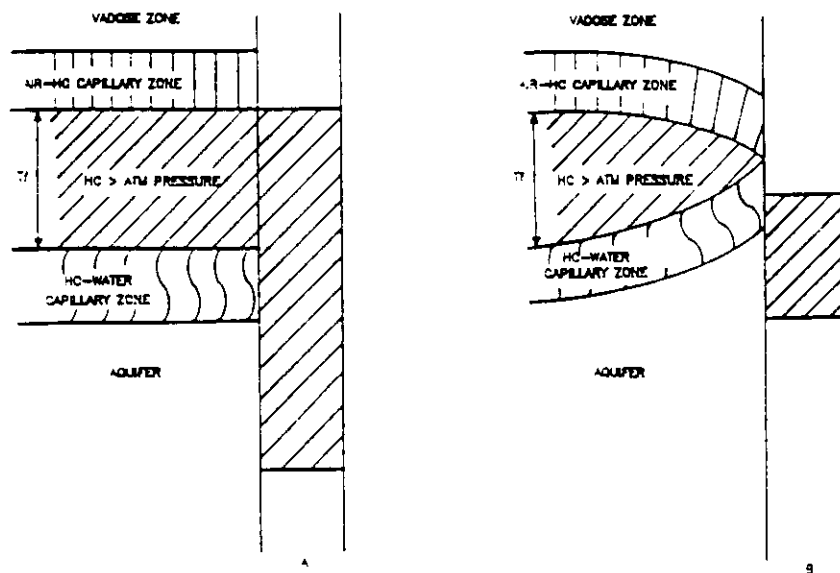


FIGURE 4-2 RESPONSE OF A THREE PHASE AQUIFER SYSTEM TO PUMPING.

from the buoyancy surface to the base of the mobile liquid hydrocarbon layer in the formation is given by T_d , where:

$$T_d = [(T_f) (SG_{hc})] \quad (4)$$

and that the distance from the buoyancy surface to the top of the mobile liquid hydrocarbon layer in the formation is defined as T_c , where:

$$T_c = [(T_f) (1 - SG_{hc})] \quad (5)$$

These relationships are shown in Figure 4-3. Rearranging this equation gives:

$$T_f = T_c / (1 - SG_{hc}) \quad (6)$$

Note that this is very similar to equation 3. The only difference is that equation 3 calculates the thickness of the liquid hydrocarbon column in the well (T_w), while equation 6 computes the thickness of the mobile hydrocarbon zone in the formation (T_f). If we can calculate T_c , the distance between the top of the mobile hydrocarbon layer and the buoyancy surface, then assuming the specific gravity of the hydrocarbon is known, the "true" thickness of the mobile hydrocarbon layer in the formation may be calculated.

In order to calculate the distance T_c , we need to know the elevation of the top of the mobile hydrocarbon layer, as well as the elevation of the buoyancy surface (which is defined by "X", the hydrocarbon entry point into the well). The top of the mobile liquid hydrocarbon layer can be readily obtained simply by gauging the well for the air/hydrocarbon interface prior to turning on the skimmer pump. All that remains is to figure out a method of locating point "X", and we can then calculate the true formation thickness (T_f) from equation 6. The recharge test technique provides us such a method.

The recharge test involves pumping hydrocarbon from the well until steady state conditions are reached, and then recording the elevation of the air/hydrocarbon interface over time as hydrocarbon recharges into the well. These data are then plotted on a graph, as shown in Figure 4-3, with the slope of the resulting curve being the recharge rate of the liquid hydrocarbon into the well. All other things being equal, this recharge rate will be controlled primarily by the height of the mobile hydrocarbon column (i.e. the "head") above the entry point (X). That head, and consequently the recharge rate will remain constant until the air/hydrocarbon interface rises to the hydrocarbon entry

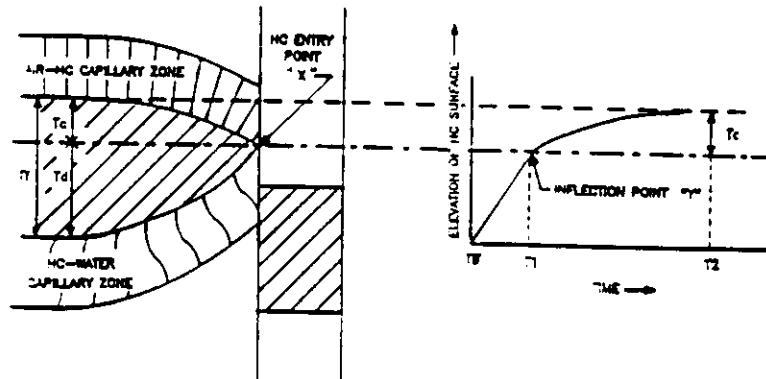


FIGURE 4-3 DIAGRAMMATIC RECHARGE TEST PLOT.

point (Figure 4-4). As the air/hydrocarbon interface rises beyond the entry point, the head steadily decreases with the result that the recharge rate also decreases. In Figure 4-3, the constant recharge part of the recovery appears as the straight line portion from T_0 to T_1 . Point "Y", the inflection point on the curve corresponds with the elevation of the hydrocarbon entry point (X) in the well. The curved portion of the plot, from T_1 to T_2 represents the steadily decreasing hydrocarbon recharge rate as the air/hydrocarbon interface rises from the hydrocarbon entry point toward the pre-pumping level, which is equal to the top of the mobile hydrocarbon layer in the formation. Point "Y" corresponds to the elevation of the hydrocarbon entry point into the well (X) and consequently, the elevation of the buoyancy surface. The distance "Z", which can be measured from the graph in Figure 4-3, is, therefore, equal to T_c in equation 6. We now have all the information we need to calculate the "true" thickness of mobile hydrocarbon in the formation.

Given an ideal, homogeneous formation, the recharge method could be used to calculate the exact thickness of mobile hydrocarbon. In naturally occurring situations (i.e. non-homogeneous conditions), however, the method provides only an estimate of the true hydrocarbon thickness. Noise in the recharge data may make it difficult to pick the inflection point ("Y") exactly. In addition, the pressure of the hydrocarbon in the formation at the elevation of "Y" may not be atmospheric (Sullivan et. al., this volume), and the result of equation (6) would, therefore, not be the exact thickness of the mobile hydrocarbon layer. Nevertheless, even in situations where this is the case, the recharge method can be used to accurately track the change in hydrocarbon thickness. This is because, by definition, the elevation of the buoyancy surface -and hence the hydrocarbon entry level - of a particular well will not change as the hydrocarbon thickness in the vicinity of the well changes.

4.2.2 Test procedure

Step 1 : Pump hydrocarbon from the well, and continue the pumping until steady state conditions (i.e. Figure 4-2b) have been reached. Maintain the thinnest amount of hydrocarbon in the well as possible, without pumping any water.

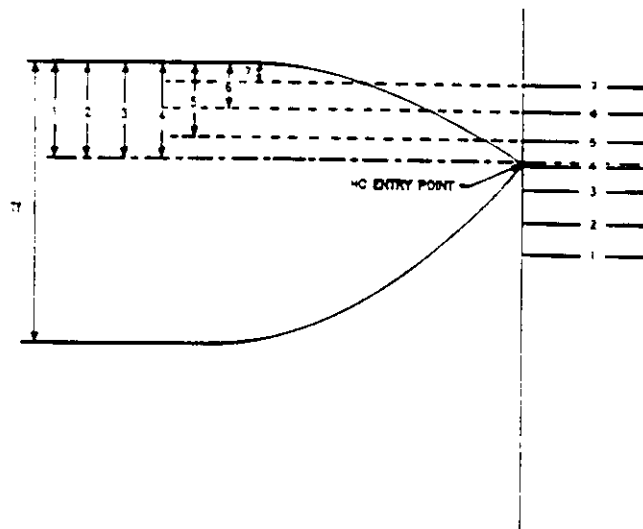


FIGURE 4-4 CHANGE IN THE PRESSURE HEAD DURING HYDROCARBON TOWARD A WELL DURING A RECHARGE TEST.

Step 2 : Shut off the pump and record the top of the liquid hydrocarbon surface (air/hydrocarbon interface) in the well as the hydrocarbon recharges. Although a hydrocarbon/water interface probe can be used, we recommend the use of a pressure transducer linked to an automatic recording device. Continue to record data until the well is fully recharged.

Step 3 : Plot the elevation of the top of the hydrocarbon surface in the well vs time.

Step 4 : Pick the point (Y), at which the recharge rate begins to decline. This corresponds to the elevation of the hydrocarbon entry point (and hence the buoyancy surface) on the curve. Scale off the distance "Z", which is equal to "Tc" in Figure 4-3. Equation 6 can then be used to calculate the actual thickness of hydrocarbon in the formation.

4.2.3 Recharge Test Results Recharge tests have been conducted in eight skimming wells. The wells all have 12-inch stainless steel, wire-wrapped screen and are constructed and developed in a similar manner. Hydrocarbon ranging from gasoline products to gas oil is produced from a highly uniform, fine to medium sand. All of the wells have been in operation at least 60 days prior to testing, and production rates and well thicknesses were held relatively constant for a minimum of four days preceding a test. Recharge tests were conducted twice in two of the wells, to assess the reproducibility of the results. In both cases, the recharge curves for the two tests were very similar.

Figure 4-5 shows 6 annotated recharge test plots. Table 4-2 shows the results of calculating Tf using these plots and equation 6. Also shown for comparison, is Tw for each well (as gauged just before the test), the ratio of Tw to Tf and the average hydrocarbon production rate, where appropriate.

Table 4-2
Well Test Results

WELL	Tw (feet)	Tf (feet)	EXAGGERATION (Tw / Tf)	AVERAGE PRODUCTION RATE (gpm)
<u>Recharge Test Results</u>				
WW- 47	6.70	2.75	2.4:1	220
WW-124	7.09	3.52	2.0:1	280
WW-126	5.41	0.88	6.2:1	60
WW-133	17.72	7.11	2.5:1	160
WW-130	5.81	1.55	3.8:1	30
WW-131	18.00	9.43	1.9:1	170
<u>Bail-Down Tests</u>				
ROW-143	4.97	0.61	8.1:1	N/A
ROW-189	12.50	0.29	43.0:1	N/A
ROW-129	0.94	0.0*	N/A	N/A

* Capillary oil only

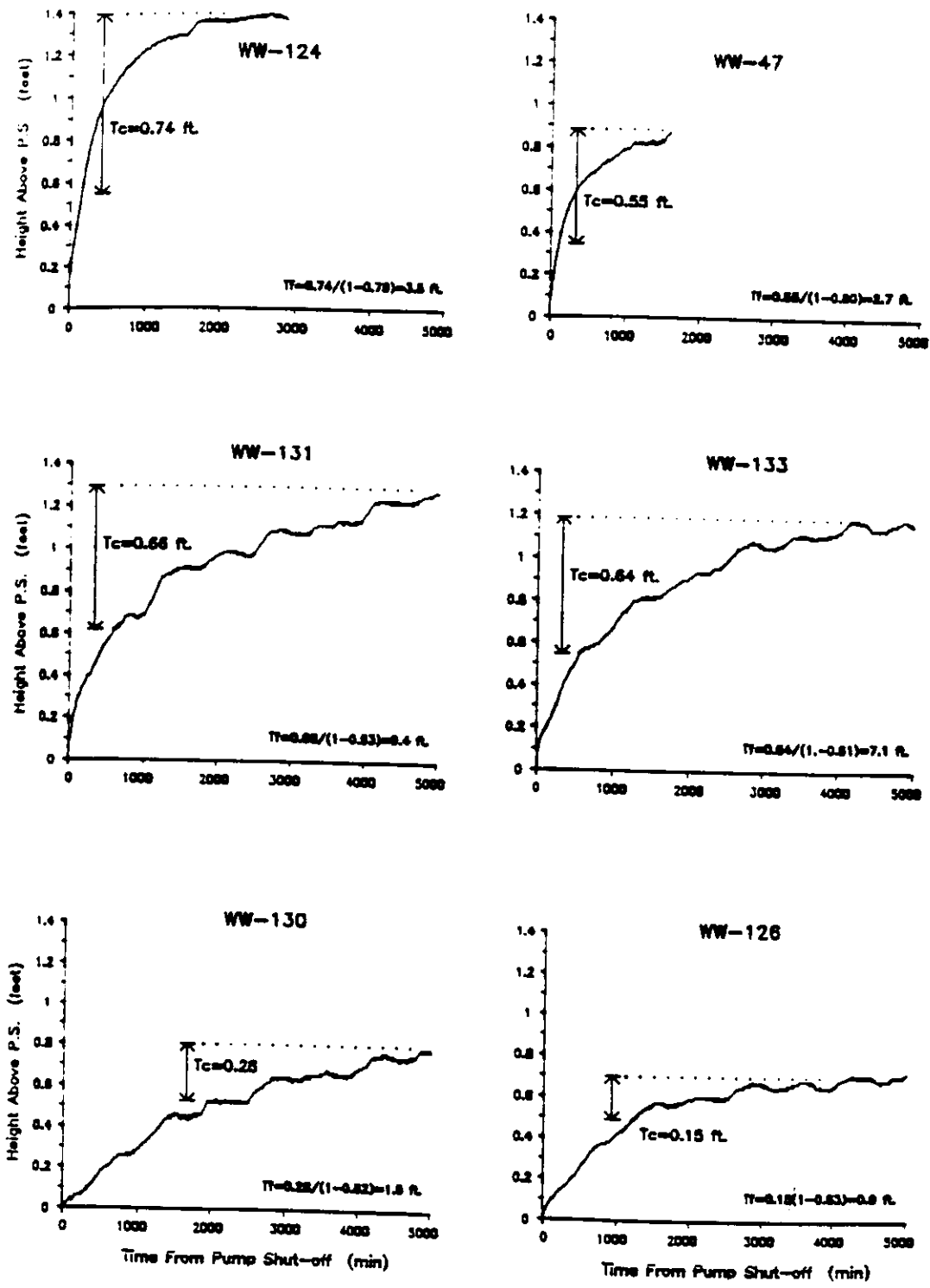


FIGURE 4-5 RESULTS OF RECHARGE TESTS IN SIX WELLS.

4.3 Bail-Down Tests

4.3.1 General Under certain circumstances, the true thickness of the mobile hydrocarbon layer in the formation can be determined by using a simple bail-down technique. The test may be used in areas whether the hydrocarbon/water interface is above the potentiometric surface, and the recharge rate of hydrocarbon into the well is slow.

The elevation data generated by the test are plotted against time and interpretations made based on the characteristics of the recharge curve. Figure 4-6 shows the "type curves" for three possible situations. If the base of the hydrocarbon in the formation is above the potentiometric surface, the well will recharge at a constant rate to that level, and then begin to recharge at a steadily decreasing rate as the well continues to fill. This is similar to what happens in a recharge test. Recall that in a recharge test the inflection point "Y" between the straight line (constant rate) and the curved (decreasing rate) portions of the plot, represented by the elevation of the buoyancy surface in the mobile hydrocarbon layer. That is because the well had been pumped sufficiently long to allow a draw-down cone to form in the hydrocarbon pool, and to allow the hydrocarbon/water interface to rebound in response to the removal of the hydrocarbon (i.e. until steady-state conditions had been reached). In a bail-down test, however, the only hydrocarbon that is removed is essentially what existed in the well. A draw-down cone is not formed in the hydrocarbon pool, consequently, the hydrocarbon/water interface does not rebound toward the buoyancy surface. The shape of the mobile hydrocarbon zone in the formation, therefore, remains as shown in figure 4-6a. Given these conditions, the inflection point "Y" represents not the elevation of the buoyancy surface, but rather the base of the mobile hydrocarbon layer in the formation. The thickness of the mobile hydrocarbon layer (Tf) is then the distance from "Y" to the top of the hydrocarbon in the well under static conditions, and may be scaled directly off the plot. This interpretation is based on the assumption that the thickness of hydrocarbon in the formation does not change during the test.

From the discussion in the previous paragraph, if the level of the hydrocarbon in the formation is below the potentiometric surface, the recharge curve produced from the bail-down test will show a steadily decreasing rate of flow into the well from the very beginning (Figure 4.6b). Given these conditions, the bail-down test will not yield any information that can be used to calculate the true mobile hydrocarbon thickness. A recharge test will yield useable results regardless of whether the hydrocarbon/water interface is located above or below the potentiometric surface. Consideration should,

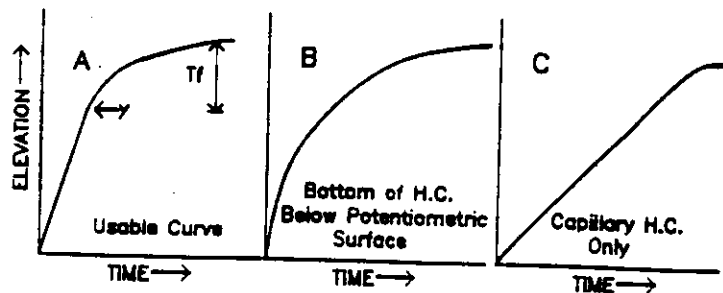


Figure 4-6. Type recharge curves for bail-down tests.

therefore, be given to conducting a recharge test at locations where the bail-down test yields the type of curve shown in Figure 4.6b.

The third type of curve that may be generated from a bail-down test (Figure 4.6c) shows a constant rate of recharge from the beginning of the test until the top static hydrocarbon level in the well is reached (i.e. during the entire test). Again based on our previous discussions, this would seem to indicate that the "head" driving the hydrocarbon into the well remained the same throughout the test. In other words, the recharging hydrocarbon surface in the well apparently reached the top of the mobile hydrocarbon zone before it reached the base of the mobile hydrocarbon zone. The solution to this apparent dilemma would seem to be that a zone of mobile hydrocarbon simply does not exist in the formation. This type of recharge could result if the filter pack around the well is allowing hydrocarbon at less than atmospheric pressure, to accumulate and enter the well (see section 2.3.2)

4.3.2 Bail-Down Test Procedure The bail-down test consists of the following steps:

Step 1 : Gauge the well and calculate the potentiometric surface.

Step 2 : Bail the hydrocarbon from the well rapidly.

Step 3 : Gauge the well again, and if the thickness of the hydrocarbon is acceptable (0.1 to 1.0 feet), calculate the potentiometric surface. It should be within approximately 0.05 feet of the first value, before beginning to record the recharging hydrocarbon elevations in the well

Step 4 : Record the top of the hydrocarbon surface in the well as it recharges. Continue until the well is fully recharged.

4.3.3 Bail-Down Test Results.. The results of three bail-down tests are summarized in Table 4-2.

4.4 Summary

The choice of which well test technique to use will depend on a number of considerations. If we compare these tests to the standard water well tests, we find that the recharge test is similar to a water pumping test, while the bail-down technique is more closely related to a "slug test". One of the main advantages of the recharge test method, therefore, is that it is more accurate than the bail-down tests. The recharge test also has the advantage of being able to yield useable results regardless of the location of the hydrocarbon/water interface in relation to the potentiometric surface. The main disadvantage of this technique, is that it is more complicated to conduct and, therefore, more time consuming and costly.

The bail-down test, on the other hand, has the advantage of being relatively cheap and quick to run since it doesn't require a pump, storage for the large volumes of hydrocarbon recovered, etc.. The bail-down test has two main disadvantages. First, since it is more like a slug test than a pumping test, the results will be less accurate than those from a recharge test. Second, the bail-down test will only work if the hydrocarbon/water interface is above the potentiometric surface. In deciding which technique to use, consideration should be given to initially trying the bail-down method. If this technique fails to yield acceptable results, then the recharge test method could be employed.

5.0 CORES

Coring through the contaminated zone is another method of obtaining a more accurate estimate of the true thickness of mobile hydrocarbon in the formation. If the cores are taken continuously (i.e. one right after another, without a break), they can be laid end to end for a close up look at a relatively undisturbed cross section of the formation. Ideally, once the approximate depth of the contaminated zone is known, any new holes would be cored from a little above the top of the air/hydrocarbon interface through the mobile hydrocarbon layer and into the water saturated section. This would allow a complete look at the zone of interest. Several things must be kept in mind when considering whether to core, how best to core, and in evaluating the results of the coring.

5.1 Lost Core

While continuous split spoon sampling (with standard sample lengths of 12 to 18 inches) is probably acceptable, as a general rule, the longer a core you can cut at a time, the more accurate the information will be. Each time you drive say an 18 inch core in front of the bit, then pull the core out, drill down 18 inches and then drive another sampler, you run the risk of losing perhaps a few inches of the section. It's very difficult for the driller to stop the whirling bit at an exact depth. In fact, an accuracy of a few inches would generally be considered quite good. Over a long coring interval those "few inches" from each sample can add up quickly. The impact of this "slop" in measurement is magnified if the actual contaminated zone is rather thin. As an example, let's say you cut three 12 inch cores in a row. Let's also say that the visibly contaminated zone starts 4 inches above the bottom of the upper core, continues through the entire middle core and extends 8 inches into the bottom core. The apparent length of the contaminated interval is, therefore, 24 inches. If we have lost (or gained) just three inches between each sample, then the actual contaminated interval could be between 18 and 30 inches long. In other words, the apparent length could be off by as much as 25%.

5.2 Dry vs Wet

A dry coring method (i.e. augers or air rotary) is preferred over a mud coring system. The presence of the mud interferes with determining the depth at which fluid is first encountered. Also, retaining the core in the sample barrel is sometimes more difficult in a mud rotary hole.

5.3 Uncontaminated Samples

Cored samples of the formation are preferable to the ground-up and mixed together cuttings obtained from conventional augering or mud/air rotary systems because the former are relatively undisturbed. Also, since they are encased in the split spoon or core barrel, the samples cannot become "contaminated" by foreign material on the way up to the surface.

5.4 Depth Control

Core samples are depth discrete while auger cuttings are not. If holes must be logged based on auger cuttings, care should be taken not to confuse the cuttings that have just arrived at the surface with what the formation looks like at the tip of the bit. Consider, for example, a case in which you are drilling a 150 foot hole. The driller has just added the last five foot flite of auger and drilled it down flush with the surface. The cuttings at the surface at that point look "clean" and so you pull out and back fill the hole, reporting that there is no contamination down to 150 feet. Since it may take several minutes for cuttings from the tip of the bit to travel that distance, you really haven't seen a sample of the formation at 150 feet to know if there is any contamination there or not. One should always continue to rotate the augers in place for awhile once the zone of interest has been reached in order to allow time for the cuttings from that interval to reach the surface. In some cases, for example in clayey soils, pieces of the formation material may still be stuck to the drill bit when the augers are removed from the boring, thereby providing additional clues to the bottom hole lithology.

5.5 Apparent Thickness vs True Thickness

The contaminated section of the core represents a thickness greater than the actual mobile hydrocarbon layer. An air/hydrocarbon capillary zone will form above the mobile hydrocarbon layer much as a air/water capillary zone forms above the water table. Since at least the lower part of the air/hydrocarbon capillary zone may be 100% saturated with hydrocarbon, it will be impossible to distinguish between this capillary zone and the mobile hydrocarbon layer just by looking at the core. The apparent contaminated zone will, therefore, be a combination of the two. Over time, the elevation of the water table and capillary zone can change in response to fluctuations in regional water levels. Pumping and injection activities that we initiate in our clean up efforts also influence water levels. The hydrocarbon saturated layer, which is supported by the capillary zone, drifts up or down along with the fluctuating potentiometric surface, potentially smearing the hydrocarbon over a large interval. This phenomenon is shown in Figure 5-1. The smeared zone can further confuse efforts to pick the true thickness of the mobile hydrocarbon layer in the formation. Table 5-1 shows the results from several cores cut recently at the refinery. Note the fairly wide range in difference between the gauged thickness and the thickness of the visibly contaminated zone in the core. In one case (Row - 175), the gauged and core thicknesses are virtually identical. In another, (Row-189), however, the thicknesses are off by a factor of 6.

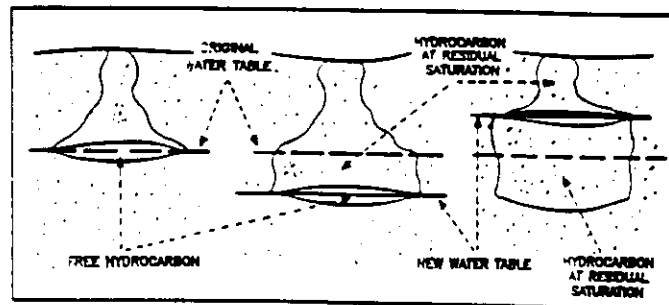


FIGURE 5-1 CONTAMINATING EFFECT ON SOIL CAUSED BY FLUCTUATING WATER TABLE (AFTER CONCAWE, 1979, FIG. 13).

Table 5-1
Comparison of the Gauged Hydrocarbon Thickness with the Hydrocarbon Thickness
Seen in Cores

Well	Gauged Product Thickness (feet)	Thickness of the Contaminated Zone in the Core (feet)
Row-133	17.72	13.00
Row-175	5.22	5.32
Row-188	12.75	4.30
Row -189	12.75	2.25

Simply using the thickness of the contaminated zone in a core will result in over estimating the true thickness of the mobile hydrocarbon layer in the formation. In all cases, though, the contaminated thickness in the core is greater than the true thickness of mobile hydrocarbon in the formation. Consequently the core thickness could be considered a conservative upper limit to the thickness of the mobile hydrocarbon layer. Note also, that in spite of the fact that the core thickness is greater than the true thickness, it is probably still closer to the actual thickness than is the thickness of hydrocarbon that you gauge in the well.

5.6 The Use of UV Fluorescence to Detect Light Products in Cores

Visual detection of hydrocarbon in cores can sometimes be tricky. If the hydrocarbon is dark brown and the core is a light tan sand, the task of identifying the contaminated zone is fairly straightforward. However, if the hydrocarbon is clear or a light golden yellow (i.e. jet fuel or typical service station products), then the hydrocarbon saturated sands may be virtually indistinguishable from the water saturated sands. On holes where respirators are being worn, odor can not be used as a method to identify hydrocarbon contaminated sands. In this situation, it is easy for the presence of hydrocarbon to be missed during field inspection of the cores. It may not be until later lab tests on the samples that the hydrocarbon is detected, perhaps leading to some false preliminary reports of "clean" sands. During the early site assessment work at the refinery we encountered this kind of problem. In comparing field descriptions of samples and later lab test results on these same samples, reports for that period occasionally contain comments along the lines of ".....elevated oil and grease levels could not generally be correlated with visible liquid hydrocarbon in the soils". In the instances when this lack of correlation occurred, later fingerprinting of the liquid hydrocarbon present in the cores generally revealed hydrocarbon in the light distillate (gasoline) and jet fuel range. In the cases where visual and lab detection of hydrocarbon correlated well, fingerprinting generally indicated hydrocarbon in the heavier range (i.e. fuel oil and gas oil). Because of this problem, we borrowed a technique that has

ong been used by oilfield geologists, the detection of liquid hydrocarbon in cores by means of ultra-violet (UV) fluorescence.

When certain substances are exposed to a UV light source, their electrons absorb the UV energy and are "kicked" into a higher or "excited" electronic level. Almost immediately, however, these "excited" electrons drop back down to their original or ground state. In the process of dropping to the lower energy level, they emit a burst of light, that we call fluorescence. Since most hydrocarbons fluoresce, including the light colored gasolines and jet fuels, we can use a UV light to detect their presence even if we can't identify them under normal (white) light. Small samples can be gathered at regular intervals along the core and placed under a UV light in a darkened room. [Special cabinets, designed to eliminate external light interference, may be purchased for use in the field.] Those samples with air or water filling the pore spaces will remain dark. Samples with hydrocarbon filling the pores will glow. All other things being equal, the 100% hydrocarbon saturated samples will glow the brightest. Lower percents of hydrocarbon saturation (i.e. above the air/hydrocarbon capillary zone and the dissolved hydrocarbon phase in water) will be identifiable but will show a duller fluorescence. A UV light, however, is not a quantitative tool. It will not tell you how much hydrocarbon is present. Rather, it is a qualitative tool - it will tell you whether or not fluorescent hydrocarbon is present. Fluorescence can be used as a "real time" screening tool to detect the presence of hydrocarbon's that might otherwise be missed by simple visual examination of the core.

5.7 Summary

Continuous coring can be a useful tool in evaluating the extent of contamination at a site. It's main drawback is probably cost, since cutting cores will take longer than simply drilling, and the fact that cores provide only a "snapshot in time" of the contamination. In other words, cores, unlike recharge tests, are not easily repeatable. If you want to see how the contaminated zone changes over time, you would have to drill a brand new hole. Continuous cores, however, provide a number of advantages over conventional drill cuttings. Because the samples are depth discrete (i.e. uncontaminated by the formation above), they provide a more accurate log of both the lithology and degree of contamination. They also provide a much better view of what the contaminated zone really looks like. The core provides a close up look at the contact between the hydrocarbon and water saturated sands. Any lithologic controls on hydrocarbon contamination (i.e. a preference for coarse sands or gravels as opposed to silts or clays) will be more easy to recognize in continuous cores. The thickness of the contaminated section indicated by the core is always greater than the "true" thickness of the mobile hydrocarbon layer in the formation. When large exaggerations exist in the hydrocarbon thicknesses gauged monitoring wells, however, the core data is often much closer to the true thickness than what the well gauging data indicates. In any case, the core data will delineate the thickness of the contaminated zone which must ultimately be dealt with during clean up - whether by pumping (for the mobile hydrocarbon layer) or by some additional technique like bioremediation.

6.0 SUMMARY

The quest to be able to measure the true thickness of the mobile hydrocarbon layer in the formation, although partly of academic interest, is really driven by some important practical considerations. Only by understanding the true thickness can we efficiently locate recovery wells, estimate volumes of hydrocarbon beneath the site and

accurately track the success of our recovery efforts over time. The authors hope that the well test and coring techniques described in this paper, can be used as tools in that effort.

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Pat Hughes received his BS degree (Engineering) from West Point in 1971 and, after a tour in the service, his MS degree (Geology) from San Diego State University. He worked for three years as a geologist with the County of San Diego's environmental group. He then joined Chevron in 1981 and worked as a corporate hydrogeologist on numerous ground water studies across the U.S.. For the last 3 years he has been the project hydrogeologist at a large petroleum refinery involved in a site assessment and hydrocarbon recovery program. Mr. Hughes is a Registered Geologist in California.

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