WORK PLAN FOR SITE CHARACTERIZATION
AREAS OF INTEREST 2 AND 3

SUNOCO PHILADELPHIA REFINERY
PHILADELPHIA, PENNSYLVANIA

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1.0 INTRODUCTION

The Current Conditions Report and Comprehensive Remedial Plan (CCR) prepared by Sunoco Inc. (R&M) (Sunoco), dated June 30, 2004, proposed Phase II site characterization and corrective action activities for Sunoco's Philadelphia Refinery (Refinery), including preparation of Site Characterization Reports for individual Areas of Interest (AOIs). The CCR presented a prioritization of all eleven AOIs based on specific risk factors. To date, site characterization activities have been completed for six AOIs at the Refinery. These include AOI 1 (Belmont Terminal, #1 and #2 Tank Farm), AOI 4 (#4 Tank Farm), AOI 5 (Girard Point South Tank Field Area), AOI 6 (Girard Point Chemicals Processing Area), AOI 8 (Point Breeze Process Area North Yard) and AOI 9 (Schuylkill River Tank Farm). Site characterization work plans and site characterization reports for these six AOIs were submitted to the Pennsylvania Department of Environmental Protection (PADEP) and the United States Environmental Protection Agency (EPA).

This site characterization work plan (work plan) has been prepared specifically for AOIs 2 and 3, the next two AOIs to be characterized in accordance with the revised Phase II Corrective Action Schedule which is included as Appendix A. A work plan for characterizing AOI 7 will be submitted in March 2010.

AOI 2, also known as the Point Breeze Processing Area, is bordered by Passyunk Avenue to the north, AOI 1 to the east, Hartranft Street to the south, and the Schuylkill River to the west (Figure 1). AOI 2 encompasses approximately 120 acres and is covered mainly with impervious surfaces except for the Short Pier area and at the eastern portion adjacent to the tank farms. Currently, AOI 2 has the only active dock (Short Pier) for loading/offloading of refined products in the Point Breeze facility. AOI 2 is primarily comprised of crude units, hydrodesulfurization units, cracking and alkylation units, sulfur recovery, maintenance facilities, wastewater treatment plant, parking areas, office buildings, and laboratories. There are no Solid Waste Management Units (SWMUs) in AOI 2 that were required to be investigated in 1992.

AOI 3 is bordered by Hartranft Street to the north, AOI 4 to the east, Penrose Avenue to the south, AOI 7 to the southwest, and the Schuylkill River to the northwest (Figure 1). AOI 3 encompasses approximately 104 acres and the majority of AOI 3 is not covered by impervious surfaces. Currently, AOI 3 is comprised of the #5 Tank Farm, Guard Basin, 4 Ponds Area, former Chevron Ballfields, contractor parking lot, operating bundle cleaning area and South Flare, contractor office trailer yard, and the Central Warehouse. The #5 Tank Farm is comprised of six aboveground storage tanks (ASTs) and is the northernmost feature within AOI 3.

The Guard Basin is an unlined stormwater retention pond located in the southeastern portion of AOI 3. The Guard Basin has been in operation since prior to 1950 as a stormwater retention basin. Channeled stormwater from the south yard of the Refinery passes to a grit chamber where under dry weather conditions the water is pumped to the Point Breeze wastewater treatment plant. During wet weather conditions, the water passes through the grit chamber to an oil-water separator before discharging to the Guard Basin. The grit chamber and oil-water separator were designed as a barrier for migration of potential contaminant releases to local surface water. Water is pumped from the pond either to the Refinery's on-site wastewater treatment plant or during emergencies, passes through the basin and is discharged to Schuylkill River. Discharge to the river is regulated by the Refinery's NPDES permit #PA0012629 A1 via outfall #004.

The Guard Basin is listed as SWMU #3 pursuant to EPA's corrective action program in the 1992 RCRA Facility Investigation (RFI) report. Several capped disposal areas are located east of the Guard Basin (RFI, 1992). These areas accepted various refinery waste including leaded and cooling tower sludges. The Guard Basin area was extensively investigated as part of the 1992 RFI investigation activities.

1.1 Objectives

The objective of the proposed activities in this work plan is to characterize current environmental conditions at AOIs 2 and 3 in accordance with the 2003 Consent Order and Agreement (CO&A) between Sunoco and the PADEP, the 2004 CCR, and the PA One Cleanup Program. Below is a list of the general site characterization activities proposed to characterize conditions at AOIs 2 and 3:

- Review of all available historical environmental reports relating to AOIs 2 and 3;
- Evaluate existing remedial systems in AOIs 2 and 3;
- Advance shallow soil borings and collect shallow soil samples for laboratory analysis of site compounds of concern (COCs);
- Install shallow/intermediate, and deep groundwater monitoring wells;
- Survey all existing and newly-installed wells and soil boring locations;
- Collect groundwater samples for laboratory analysis of site COCs from existing and newly-installed groundwater monitoring wells;

- Collect samples for characterization of light non-aqueous phase liquid (LNAPL) from select existing and/or newly-installed monitoring wells, if present;
- Complete LNAPL modeling to evaluate LNAPL specific volume and mobility, if necessary;
- Evaluate potential vapor migration pathways using the PADEP's vapor intrusion guidance and the US EPA – PA default non-residential permissible exposure levels (PELs) for volatilization into indoor air screening criteria;
- Complete fate and transport modeling of dissolved COCs in site groundwater, if necessary;
- Complete exposure and risk assessment activities, if necessary; and
- Prepare a Site Characterization Report detailing the results of the characterization activities.

The COCs for soil and groundwater are listed in Table 1 of this work plan. These COCs are the same as those listed in the CCR with the exception of two additional compounds: 1,2,4-trimethylbenze and 1,3,5-trimethylbenzene. These two compounds were added to the list of COCs based on PADEP's recent revisions to the Petroleum Short List of Compounds.

Data collected from the above activities will be evaluated as part of the AOIs 2 and 3 site characterization process. This data will be presented in the Site Characterization Reports for AOIs 2 and 3. These reports are anticipated to be submitted to PADEP and EPA by September 30, 2010 in accordance with the revised Phase II Corrective Action Schedule (Appendix A).

1.2 Overview of Investigative Framework/Remedial Approach for AOIs 2 and 3

The current remediation program for the Refinery is performed under the 2003 CO&A between PADEP and Sunoco. In April 2004, the PADEP and EPA signed an agreement entitled "One Cleanup Program Memorandum of Agreement (MOA or One-Cleanup Program)," which clarifies how sites remediated under Pennsylvania's Act 2 program may satisfy RCRA corrective action requirements through characterization and attainment of Act 2 remediation standards pursuant to Pennsylvania's Act 2. On November 22, 2005, Sunoco and its representatives met with officials of the PADEP and EPA to discuss the applicability of the Sunoco Philadelphia Refinery to the One

Cleanup Program. During the November 22, 2005 meeting, all parties agreed that the One Cleanup Program would benefit the project by merging the remediation obligations under the various programs into one streamlined approach which would be conducted under the existing 2003 CO&A.

As a follow up to the meeting, Sunoco submitted a letter dated December 2, 2005 to EPA and PADEP documenting the discussions at the meeting. Sunoco submitted a Notice of Intent to Remediate (NIR) for the Refinery, excluding the Belmont Terminal, to the PADEP on October 12, 2006 and held a public involvement meeting in South Philadelphia on September 19, 2007. On March 5, 2009, Sunoco and its representatives met again with EPA to discuss Sunoco Philadelphia Refinery's remediation progress and path forward under the One Clean-Up Program. As a follow up to the meeting, Sunoco submitted a letter dated March 11, 2009 to EPA and PADEP documenting the discussions at the meeting. The major points of this letter are below:

- EPA will provide a formal letter that acknowledges that there is a One Clean Up Program Agreement with Sunoco and it's currently operating under one EPA ID Number (PAD049791098) for Point Breeze, Girard Point and Schuylkill River Tank Farm;
- EPA will add in a Corrective Action Module to the Sunoco-submitted Draft Part B RCRA Permit. The module will reference the One Clean-Up Program agreement and the current remediation work being completed under the existing Consent Order and Agreement between PADEP and Sunoco; and
- EPA will issue a letter to Sunoco for each characterized SWMU that lists a non-leaded tank bottom designation for which no further action is required.

1.3 Overview of Existing Remediation Activities in AOIs 2 and 3

AOI 2

The Pollock Street Sewer Total Fluids Recovery System is the only active remedial system in AOI 2. The Pollock Street Sewer Total Fluids Recovery System consists of total fluids (groundwater and LNAPL) recovery from nine vertical recovery wells (RW-100, RW-101, RW-102, RW-103, RW-105, RW-106, RW-110, RW-111, and RW-112) and three horizontal recovery wells (HW-1, HW-2, and HW-3) along Pollock Street Sewer. The Pollock Street Sewer Remediation System was installed to prevent LNAPL from entering the Schuylkill River via the Pollock Street Sewer and surrounding backfill around the sewer. A sheet pile wall was installed along with the recovery system in order to minimize tidal influence in RW-105 through RW-109.

The original horizontal well (HW-1) was installed in July 2004 along the north side of the Pollock Street Sewer from RW-103 to approximately 100 feet west of RW-101. In 2006, two additional horizontal wells (HW-2 and HW-3) were installed from RW-103 to the intersection of Pollock Street and 16th Street. The totalizers were removed from HW-1, HW-2, and HW-3 because they clogged regularly preventing flow; therefore, the total fluids recovered from the horizontal wells are no longer quantified. Groundwater and LNAPL from the system discharge directly into a Benzene Waste Operations National Emission Standards for Hazardous Air Pollutants (BWON) controlled sewer and are processed through the Point Breeze Processing Area Wastewater Treatment Plant. The Pollock Street Sewer outfall is monitored manually three times per shift and field observations are recorded. Sunoco maintains spill control equipment (absorbent booms and sweeps) around the tide gate area to minimize and prevent release of fugitive LNAPL into the Schuylkill River. The presence of LNAPL inside the Pollock Street sewer outfall tide gates was observed in the third and fourth quarters of 2009.

Sunoco has established a focus group of consultants and contractors to evaluate the Pollock Street Sewer and the performance of the existing total fluids extraction system with respect to the occurrence and migration of LNAPL. Recent investigation activities completed by this group are listed below:

- Sewer video inspection;
- Survey of wells and other site features along the sewer;
- Groundwater and LNAPL data collection and trend evaluation (historic and recent data) along the sewer;
- Recovery well operation data collection; and
- Sewer cross section development.

Based on the results of the completed activities, the following areas in the vicinity of the Pollock Street Sewer were identified for further investigation and/or evaluation:

- 869 Unit Area;
- C-Header Area (NW 869 Unit);

- SW 868 Unit OBL Area;
- 14 Pumphouse Area;
- The Hill (9th and Pollock) Area;
- Former Tank 1515 / 1508 Area; and
- Short Pier Area.

This work plan includes proposed activities to characterize conditions at the above areas. The objectives of the proposed activities are to evaluate LNAPL occurrence along the sewer and to evaluate enhancement of the existing Pollock Street Sewer Total Fluids Recovery System. Specifically, proposed characterization activities will include:

- Assessing potential causes of groundwater mounding in the C-Header area that may affect LNAPL migration and accumulation in the vicinity of the sewer. Further characterizing LNAPL in the vicinity of "The Hill" (9th and Pollock) area to assess potential LNAPL sources;
- Conducting a pumping test at monitoring well S-250 to evaluate LNAPL and hydrogeologic conditions with regard to potential sources and possible remedial measures in the Short Pier area;
- Cleaning existing vertical and horizontal recovery well systems to enhance the performance of these systems in the vicinity of the sewer;
- Conducting pumping tests on horizontal wells HW-1, HW-2 and HW-3 to evaluate the specific capacity and effectiveness of each extraction system; and
- Investigating the extent and characteristics of LNAPL in the Former Tank 1515/1508 area through installation of monitoring wells.

The Short Pier total phase extraction system is an inactive remediation system located along the western boundary of AOI 2. This multi-point total phase extraction system has been out of operation since 2005 when the system was removed based on the absence of LNAPL. Since 2005, there has been no evidence of LNAPL migration to the Schuylkill River at the Short Pier area. Unless evidence of LNAPL migration to the Schuylkill River occurs, the system will remain off line.

<u>AOI 3</u>

There is one remediation system in AOI 3 which includes the RW-2 Groundwater and LNAPL Recovery System. The RW-2 Groundwater and LNAPL Recovery System is a dual pumping system consisting of separate electric submersible pumps for groundwater and LNAPL recovery. Both pumps are equipped with density-driven floats that control the respective pumps based on liquid levels in the well. Recovered groundwater is pumped to the Point Breeze Processing Area Wastewater Treatment Plant. Recovered LNAPL is stored in an 8,000-gallon holding tank that is periodically pumped out and the contents recycled by the Refinery. The RW-2 Recovery System was taken temporarily out of service on July 1, 2009 and remains offline while an evaluation of the system is completed as part of the site characterization activities.

1.4 Work Plan Support Activities

Several activities were performed to support the development of this work plan. These activities are summarized below by AOI:

<u>AOI 2</u>

- Ongoing remedial evaluation of the Pollock Street Sewer as mentioned in Section 1.3 above;
- 58 existing groundwater monitoring wells in AOI 2 were surveyed by Langan Engineering and Environmental Services (Langan) in June and August 2009 as part of the ongoing remedial evaluation for the Pollock Street Sewer. The well elevations were surveyed to the nearest 0.01 foot relative to mean sea level. All survey activities were performed by a Pennsylvania-licensed surveyor and referenced to the NAVD 88 datum;
- Aquaterra Technologies, Inc. (Aquaterra) performed a round of groundwater monitoring and sampling in AOI 2 from December 4 to December 14, 2009. All accessible wells in AOI 2 were gauged and all wells without measurable LNAPL (36 wells) were sampled for site COCs. The groundwater samples were submitted to Lancaster Laboratories of Lancaster (LLI), Pennsylvania (Act 2-certified lab) for analysis of site COCs. The results of these samples are presented in Table 2a of this work plan. 29 wells in AOI 2 contained measurable LNAPL and groundwater was not sampled from these wells.
- Available historical aerial photographs with coverage of AOI 2 were obtained from the Library of Philadelphia's Map Collection Department and reviewed to identify

specific areas for characterization and to assist in determining previous uses of AOI 2. Aerial photographs were reviewed for the following years: 1930, 1945, 1959, 1965, 1970, 1975, 1980, 1985, 1990, 1995 and 2005. A brief summary of each aerial photograph is provided in Appendix B of this work Plan.

- Available historic reports pertaining to former environmental investigations and/or remediation at AOI 2 were reviewed to evaluate and refine site characterization activities proposed in this work plan. Key reports included:

Comprehensive Remedial Plan, Sun Company, Inc., Philadelphia Refinery, Philadelphia, PA, January 1993.

Investigation of Shallow and Deep Groundwater Quality, Sunoco Inc., Philadelphia Refinery, Philadelphia, PA, ENSR Consulting and Engineering, May 1994.

Semi-Annual Groundwater Monitoring and Gauging Event July through December 1994, Sunoco Refinery Philadelphia, PA, GES, January 30, 1995.

Short Pier Initial Investigation Report, Sunoco Inc., Sunoco Philadelphia Refinery Point Breeze Processing Area, Handex, August 13, 1996.

Short Pier Area: Recovery Well Installation and Feasibility Test Report, Sunoco Inc., Sunoco Philadelphia Refinery Point Breeze Processing Area, Handex October 16, 1997.

14th Service Building/Pollock Street Sewer Naphthalene Investigation, Sunoco Inc., Sunoco Philadelphia Refinery Point Breeze Processing Area, Handex, May 2, 2001.

Site Investigation Report, Pollock Street Sewer – South Yard, Sunoco Inc., Sunoco Philadelphia Refinery, Aquaterra Technologies, Inc., October 18, 2002.

Site Characterization and Remedial Feasibility Testing Report, Short Pier Area, Sunoco Inc., Sunoco Philadelphia Refinery Point Breeze Processing Area, Aquaterra Technologies, Inc., January 30, 2003.

Subsurface Evaluation Update and Remedial Action Plan, Pollock Street Sewer, Sunoco Inc., Sunoco Philadelphia Refinery Point Breeze Processing Area, Aquaterra Technologies, Inc., August 12, 2003.

Current Conditions Report and Comprehensive Remedial Plan, Sunoco Inc., Philadelphia, PA, prepared by Langan Engineering and Environmental Services June 30, 2004.

Data collected from the above-mentioned historical investigations and reports were compiled and evaluated using the refinery's GIS. Relevant historic features and investigation areas are shown in Figure 4. In addition to the historic areas, the data obtained from the December 2009 groundwater gauging and sampling activities are summarized on this figure. The historic data, as well as the December 2009 groundwater data, were used to modify and refine the work plan for site characterization activities as shown in Figure 4, and to further refine the Site Conceptual Model for AOI 2. A summary of the proposed site characterization activities and the objective of each activity are provided in Table 3.

<u>AOI 3</u>

- 40 existing groundwater monitoring wells in AOI 3 were surveyed by Langan in December 2009 as part of the work plan activities. The well elevations were surveyed to the nearest 0.01 foot relative to mean sea level. All survey activities were performed by a Pennsylvania-licensed surveyor and referenced to the NAVD 88 datum;
- Aquaterra performed a round of groundwater monitoring and sampling in AOI 3 from November 25 to December 11, 2009. All accessible wells in AOI 3 were gauged and all wells without measurable LNAPL (30 wells) were sampled for site COCs. The groundwater samples were submitted to LLI for analysis of site COCs. The results of these samples are presented in Table 2 of this work plan. A total of 7 wells in AOI 3 contained measurable LNAPL and groundwater was not sampled from these wells. LNAPL characterization data exists for 3 of these wells.
- Available historical aerial photographs with coverage of AOI 3 were obtained from the Library of Philadelphia's Map Collection Department and reviewed to identify specific areas for characterization and to assist in determining previous uses of AOI 3. Aerial photographs were reviewed for the following years: 1930, 1945, 1959,

1965, 1970, 1975, 1980, 1985, 1990, 1995 and 2005. A brief summary of each aerial photograph is provided in Appendix B of this work Plan.

- Available historic reports pertaining to former environmental investigations and/or remediation at AOI 3 were reviewed to evaluate and refine site characterization activities proposed in this work plan. Key reports included:

  Phase I Final Progress Report, Site Assessment Investigation, Chevron-Gulf Refinery, Philadelphia, PA, Dames and Moore, May 23, 1986.

  Final Report – Volume I, Site Assessment Investigation, Chevron-Gulf Refinery, Philadelphia, PA, Dames and Moore, May 18. 1987.

  Soil Assessment for Pile A, Chevron Refinery, Philadelphia, PA, Groundwater Technologies, Inc., November 16, 1987.

  Investigation of Area A Ballfields, Chevron Refinery, Philadelphia, PA, Dames and Moore, June 10, 1988.

  Investigation of Area B Ballfields, Chevron Refinery, Philadelphia, PA, Dames and Moore, August 30, 1988.

  Final Report Soil Gas Survey Ballfields, Chevron Refinery, Philadelphia, PA, Dames and Moore, June 28, 1989.

  Results of Groundwater Sampling and Analysis, Chevron Refinery, Philadelphia, PA, Dames and Moore, March 2, 1990.

  Environmental Investigation Ballfields, Chevron Refinery, Philadelphia, PA, Dames and Moore, May 24, 1991.

  RCRA Facility Investigation Work Plan, Philadelphia Refinery, Sun Refining and Marketing Company, Philadelphia, PA, CH2MHill, May 1991.

  Addendums I and II, Investigation-Ballfields Area, Chevron Refinery, Philadelphia, PA, Dames and Moore, May 17 and July 21, 1992.

Results of RCRA Facility Investigation, Sun Company, Inc., Philadelphia Refinery, PA, ENSR Consulting and Engineering, September 1992.

Remedial Action Plan/Interim Measures Work Plan, Chevron Refinery, Philadelphia, PA, Dames and Moore, March 28, 1993.

RFI Work Plan Amendment – SWMU 3 Deep Aquifer Characterization, Sun Company, Inc., Philadelphia Refinery, Philadelphia, PA, ENSR Consulting and Engineering, May 1993.

Remedial Action Plan/Interim Measures Work Plan Implementation Ballfields Area, Chevron Refinery, Philadelphia, PA, Dames and Moore, September 28, 1993.

Southwest Tank Field: Subsurface Investigation Report and Conceptual Remedial System Design, Sunoco, Inc., Sunoco Philadelphia Refinery, Handex, September 26, 1996.

Ball Fields Study Area – Data Review and Recommendations, Sunoco Inc. (R&M), Philadelphia Refinery, PA, QES, November 8, 2000.

Ballfields Study Area – Project Phase I: Electrical Resistivity Survey and Geophysical Study, Sunoco Inc. (R&M), Philadelphia Refinery, PA, QES, August 28, 2001.

Project Phase I Work Plan Ballfields Study Area Soil Borings, Gamma Logging and Reporting, Sunoco Inc. (R&M), Philadelphia Refinery, PA, QES, September 26, 2001.

Project Phase I: Soil Borings, Gamma Logging and Ground Water Sampling, Sunoco Inc. (R&M), Philadelphia Refinery, PA, QES, June 10, 2002.

Current Conditions Report and Comprehensive Remedial Plan, Sunoco Inc., Philadelphia, PA, prepared by Langan Engineering and Environmental Services June 30, 2004.

Data collected from the above-mentioned historical investigations and reports were compiled and evaluated using the refinery's GIS. Relevant historic features and investigation areas are shown in Figure 5. In addition to the historic areas, the data obtained from the December 2009 groundwater gauging and sampling activities are summarized on this figure. The historic data, as well as the December 2009 groundwater data, were used to modify and refine the work plan for site characterization activities as shown in Figure 5, and to further refine the Site Conceptual Model for AOI 3. A summary of the proposed site characterization activities and the objective of each activity are provided in Table 3.

2.0 PROPOSED SITE CHARACTERIZATION ACTIVITIES

Based on the identified data collection needs for AOIs 2 and 3, the following site characterization tasks are proposed as part of this work plan:

Task 1: Shallow Soil Borings and Soil Sampling
Task 2: Installation of Shallow, Intermediate, and Deep Groundwater Monitoring Wells
Task 3: Groundwater Monitoring and Sampling
Task 4: Collection and Characterization of LNAPL Samples
Task 5: Aquifer Testing
Task 6: Evaluation of the Potential Vapor Intrusion Into Indoor Air Pathway
Task 7: Fate and Transport Analysis of Dissolved COCs in Groundwater
Task 8: Exposure and Risk Assessment
Task 9: Surveying
Task 10: Data Evaluation and Site Conceptual Model
Task 11: Reporting

The individual proposed site characterization tasks included in this work plan are discussed in detail in the following sections.

2.1 Task 1: Shallow Soil Borings and Soil Sampling

AOI 2

To characterize the potential direct contact to shallow soil exposure pathway in AOI 2, shallow soil samples will be collected from 0 to 2 feet beneath the ground surface at each proposed groundwater monitoring well location. Soil samples will only be collected from those areas that are not covered by impervious surfaces. Additional shallow soil samples will be collected from other unbiased locations to spatially characterize other unpaved areas of AOI 2. One soil sample collected between 0 to

2 feet beneath the ground surface will be collected from each boring for laboratory analysis of site COCs. Soil boring and sample collection procedures are outlined in Appendix C and the proposed monitoring well/boring locations are shown on Figures 2 and 4. A summary of the proposed soil sampling activities are included in Table 3.

<u>AOI 3</u>

To characterize the potential direct contact to shallow soil exposure pathway in AOI 3, shallow soil samples will be collected from 0 to 2 feet beneath the ground surface at each proposed groundwater monitoring well location. Soil samples will only be collected from those locations that are not covered by impervious surfaces. Other shallow soil samples will be collected from unbiased locations throughout AOI 3 to spatially characterize other unpaved areas of AOI 3. In addition, four shallow soil borings (BH-01-10 through BH-04-10) will be advanced in vicinity of the Guard Basin. No monitoring wells are proposed for these locations. One soil sample collected between 0 to 2 feet beneath the ground surface will be collected from each boring for laboratory analysis of site COCs. Soil boring and sample collection procedures are outlined in Appendix C and the proposed monitoring well/boring locations are shown on Figures 3 and 5. A summary of the proposed soil sampling activities are included in Table 3.

2.2 Task 2: Installation of Shallow/Intermediate, and Deep Groundwater Monitoring Wells

<u>AOI 2</u>

37 fill/alluvium/Trenton Gravel (shallow/intermediate) groundwater monitoring wells are proposed to be installed in AOI 2 as shown on Figures 2 and 4, and summarized on Table 3. The well borings will be advanced using hollow stem auger drilling methods and screened within the shallow zone (estimated depths between 15 and 30 feet beneath the ground surface). All wells will be installed so that the screened interval intercepts the shallow groundwater table, allowing for appropriate measurement of groundwater and apparent LNAPL thickness, if present. Each well will be developed subsequent to completion. All well installation, well development, and waste handling activities will be performed in accordance with the procedures described in Appendix C of this work plan.

One deep (Lower Sand) groundwater monitoring well exists in AOI 2 (S-72D). A total of three additional deep groundwater monitoring wells are proposed to be installed in AOI 2, as shown on Figures 2 and 4, and summarized on Table 3. The purpose of the additional deep wells is to obtain lithologic information beneath AOI 2 and to characterize groundwater quality of the Lower Sand.

AOI 3

12 fill/alluvium/Trenton Gravel (shallow/intermediate) groundwater monitoring wells are proposed to be installed in AOI 3 as shown on Figures 3 and 5, and summarized on Table 3. The well borings will be advanced using hollow stem auger drilling methods and screened within the shallow zone (estimated depths between 15 and 30 feet beneath the ground surface). All wells will be installed so that the screened interval intercepts the groundwater table, allowing for appropriate measurement of ground water and apparent LNAPL thickness, if present. Each well will be developed subsequent to completion. All well installation, well development, and waste handling activities will be performed in accordance with the procedures described in Appendix C of this work plan.

Five deep groundwater monitoring wells exist in AOI 3 (BF-108, S-13, S-22, S-69D, and S-8). A total of two additional deep groundwater monitoring wells will be installed in AOI 3 as shown on Figures 3 and 5, and summarized on Table 3. The purpose of the additional deep wells is to obtain lithologic information beneath AOI 3 and to characterize groundwater quality of the Lower Sand.

2.3 Task 3: Groundwater Monitoring and Sampling

2.3.1 Groundwater Monitoring

Upon completion of the monitoring well installations and well development activities in AOIs 2 and 3, a complete round of groundwater water elevation gauging will be performed from all accessible new and existing monitoring wells in AOIs 2 and 3. All well gauging activities will be performed in accordance with the liquid level gauging procedures described in Appendix C of this work plan. Monitoring well gauging data collected during this event will be used to evaluate groundwater flow conditions and the occurrence and extent of apparent LNAPL in AOIs 2 and 3.

2.3.2 Groundwater Sampling

Coincident with the groundwater gauging activities in the AOIs 2 and 3, a full round of groundwater sampling will be conducted from all accessible existing and newly installed monitoring wells that do not contain measurable LNAPL to characterize groundwater quality throughout AOIs 2 and 3. All groundwater samples will be submitted to LLI for analysis of site COCs, as listed in Table 1. Groundwater sampling will be conducted in accordance with the well sampling procedures described in Appendix C of this work plan.

2.4 Task 4: Collection and Characterization of LNAPL Samples

LNAPL characterization data exists for five wells (S-130, S-142, S-64, S-110, and S-158) in AOI 2. LNAPL from these wells was characterized in support of the CCR, historical investigations, and Pollock Street sewer investigations.

LNAPL characterization data exists for five wells (BF-106, BF-107, S-59, S-21, and S-60) located in AOI 3. LNAPL from these wells was characterized in support of the CCR and historical investigations.

If necessary, additional LNAPL samples may be collected from newly-installed monitoring wells in AOIs 2 and/or 3 that have measurable LNAPL thicknesses. LNAPL sampling activities will be completed in accordance with the procedures in Appendix C of this work plan. The LNAPL samples will be analyzed for product type characterization. The results of the LNAPL characterization analysis will be used to separate LNAPL plumes by product type and to assist in evaluating specific LNAPL volume and mobility.

2.5 Task 5: Aquifer Testing

As part of historical investigations, aquifer tests have been completed in AOIs 2 and 3. The hydrogeologic data obtained from these historical investigations may be used to derive site-specific aquifer data. The site-specific data from these tests will be evaluated and used for fate and transport analyses. If additional site-specific aquifer data is necessary, additional pumping and/or slug tests may be performed. The general procedures for these tests are outlined in Appendix C.

A long term (72-hour) pump test will be performed on S-324 as part of the ongoing Pollock Street Sewer investigation. The final work scope and detailed procedures for S-S-324 and horizontal well aquifer testing activities are still being refined by the Pollock Street Sewer remediation focus group. The objectives of the pump test are to:

- Determine true LNAPL thickness and persistence of LNAPL for long-term recovery;
- Evaluation of the pump test results may reveal the potential source of LNAPL;
- Evaluation of the pump test results will provide aquifer properties that may be utilized to determine the maximum capacities of recovery wells RW-101, 102, 103, 105, and 106. In turn, the current and future efficiencies of these wells may be estimated;
- Aquifer properties determined from the pump test coupled with the natural groundwater fluctuations recorded by the level loggers (i.e. tidal effect) may be used to evaluate the existing recovery well network to determine if it is suitable for plume control and LNAPL recovery; and
- S-324 may be turned into a recovery well or a recovery well may be installed near this location as it is on the edge of influence from the current pumping network of RW-105, and 106. The attached drawing depicts the groundwater contours from July 23, 2009.

In addition, hydraulic testing of the horizontal wells, HW-1, HW-2 and HW-3 will be performed. The objectives of these tests are to:

- Determine the maximum yield of each horizontal well;
- Determine how the yield varies along the length of each horizontal well screen;
- Determine the drawdown for each horizontal well relative to the sewer invert with regard to preventing LNAPL from infiltrating into the Pollock Street sewer; and
- The data and information obtained from the horizontal well testing will be evaluated with respect to optimizing the performance of each horizontal extraction well system.

2.6 Task 6: Evaluation of the Potential Vapor Intrusion (VI) Into Indoor Air Pathway

There are several potential indoor air receptors (occupied buildings) in AOIs 2 and 3. As part of the site characterization activities, the potential vapor intrusion into indoor air pathway will be evaluated for these occupied buildings in accordance with the PADEP

Act 2 Technical Guidance Manual – Section IV.A.4. for Vapor Intrusion into Buildings from Groundwater and Soil.

2.7 Task 7: Fate and Transport Analysis of Dissolved COCs in Groundwater

Fate and transport simulations will be prepared for groundwater in AOIs 2 and 3 to evaluate potential dissolved-phase migration pathways and potential impacts to receptors, as necessary. Fate and transport modeling will be conducted for COCs listed in Table 1 using PADEP-approved analytical models (QUICK_DOMENICO.XLS and PENTOXSD). The parameters used in the analyses will either be site-specific data obtained during previous investigations, values collected as part of future site characterization activities, and/or default parameters provided in the Act 2 regulations or guidance manual.

2.8 Task 8: Exposure and Risk Assessment

In accordance with Title 25, Chapter 250, Subchapter F, a detailed exposure assessment will be performed for AOIs 2 and 3 based on the results of the proposed site characterization activities and the known conditions. This exposure assessment will be based on an assumed non-residential current and future site use. If warranted, risk assessment activities will be completed in accordance with Act 2.

2.9 Task 9: Surveying

Sunoco surveyed all existing wells in AOIs 2 and 3 in June/August 2009 and December 2009 in support of this work plan. Following completion of the site characterization activities, the new boring and well locations will be surveyed to establish the location and elevation at each boring, and the elevations of the inner and outer casing and ground surface for wells. The well elevations will be determined to the nearest 0.01 foot relative to mean sea level. All survey activities will be performed by a Pennsylvania-licensed surveyor and referenced to the NAVD 88 datum.

2.10 Task 10: Data Evaluation and Site Conceptual Model

Data collected from the site characterization activities will be compiled and evaluated using the refinery's GIS in accordance with the objectives of the 2003 CO&A and CCR. This data will be used to modify and refine the Site Conceptual Model for AOIs 2 and 3 and for the Refinery. Site characterization activities described in this work plan will provide the following information to be used in refining the Site Conceptual Model:

- Soil data collected between 0 and 2 feet beneath the ground surface from select monitoring well/soil boring locations will further characterize the potential direct contact exposure pathway for shallow soil. Subsurface information from deeper soil borings in AOIs 2 and 3 will be used to further evaluate subsurface conditions at these areas;
- Installation, monitoring and sampling of new groundwater monitoring wells will further characterize groundwater quality and flow in shallow, intermediate, and deep zones on AOIs 2 and 3;
- New and existing LNAPL data in AOIs 2 and 3 will allow for more accurate LNAPL classification and distribution estimates;
- Fate and transport modeling of dissolved phase COCs in groundwater will further characterize the potential for migration of dissolved phase COCs in groundwater in AOIs 2 and 3;
- Updated survey data will allow for accurate depiction and evaluation of data points;
- LNAPL sampling, aquifer testing, and groundwater monitoring along the Pollock Street Sewer will further characterize LNAPL source areas and distribution and may provide data to support the enhancement of the existing total fluids recovery system; and
- Soil and groundwater sampling in the vicinity of the Guard Basin (SWMU 3) in AOI 3 will further characterize conditions at SWMU 3 to support the delisting of this feature as a SWMU.

2.11 Task 11: Reporting

Following completion of the activities listed above in Tasks 1 through 10, individual site characterization reports will be prepared for AOIs 2 and 3 documenting the results of the work plan related activities. Copies of the report will be submitted to the PADEP and EPA for review and approval. The reports will include an executive summary, description of physical site characteristics, summary of field investigation and modeling activities, supporting maps, figures and data summary tables, an exposure assessment, a risk assessment (if necessary), refinement of the site conceptual model based on field investigations, and conclusions and recommendations for future site characterization and/or remedial activities, if any.

Data gathered with respect to the deep aquifer (AOI 11), will be presented in the respective AOI reports; however, a formal characterization report for AOI 11 will be compiled at the conclusion of all other AOI site characterization efforts.

3.0 IMPLEMENTATION SCHEDULE

Site characterization activities described in this work plan are anticipated to begin in April 2010. It is anticipated that field activities for both AOIs will be completed by August 2010. The site characterization reports for AOIs 2 and 3 will be submitted to the PADEP and EPA by September 30, 2010 in accordance with the revised Phase II Corrective Action Activities Schedule which is included as Appendix A.

During the work plan implementation, if any significant deviations are required from the proposed scope of work, the PADEP and EPA will be notified prior to implementation of any changes to the work scope.

4.0 REFERENCES

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TABLES

Table 1
Constituents of Concern for Groundwater
AOIs 2 and 3 Work Plan for Site Characterization
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

METALS	CAS No.
Lead (dissolved)	7439-92-1

VOLATILE ORGANIC COMPOUNDS	CAS No.
1,2-dichloroethane	107-06-2
1,2,4-Trimethylbenzene	95-63-6
1,3,5-Trimethylbenzene	108-67-8
Benzene	71-43-2
Cumene	98-82-8
Ethylbenzene	100-41-4
Ethylene dibromide	106-93-4
Methyl tertiary butyl ether	1634-04-4
Toluene	108-88-3
Xylenes (total)	1330-20-7

SEMI-VOLATILE ORGANIC COMPOUNDS	CAS No.
Chrysene	218-01-9
Fluorene	86-73-7
Naphthalene	91-20-3
Phenanthrene	85-01-8
Pyrene	129-00-0

Notes:

1. Constituents are from Pennsylvania Corrective Action Process (CAP) Regulation Amendments effective December 1, 2001; provided in Chapter VI, Section E (pgs. 29-30) of PADEP Document, *Closure Requirements for Underground Storage Tank Systems,* effective April 1, 1998 and the March 18, 2008 revised PADEP Petroleum Short List.

Table 1 (continued)
Constituents of Concern for Soil
AOIs 2 and 3 Work Plan for Site Characterization
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

METALS	CAS No.
Lead (total)	7439-92-1

VOLATILE ORGANIC COMPOUNDS	CAS No.
1,2-dichloroethane	107-06-2
1,2,4-Trimethylbenzene	95-63-6
1,3,5-Trimethylbenzene	108-67-8
Benzene	71-43-2
Cumene	98-82-8
Ethylbenzene	100-41-4
Ethylene dibromide	106-93-4
Methyl tertiary butyl ether	1634-04-4
Toluene	108-88-3
Xylenes (total)	1330-20-7

SEMI-VOLATILE ORGANIC COMPOUNDS	CAS No.
Anthracene	120-12-7
Benzo(a)anthracene	56-55-3
Benzo (g,h,i) perylene	191-24-2
Benzo(a)pyrene	50-32-8
Benzo(b)fluoranthene	205-99-2
Chrysene	218-01-9
Fluorene	86-73-7
Naphthalene	91-20-3
Phenanthrene	85-01-8
Pyrene	129-00-0

Notes:
1. Constituents are from Pennsylvania Corrective Action Process (CAP) Regulation Amendments effective December 1, 2001; provided in Chapter VI, Section E (pgs. 29-30) of PADEP Document, *Closure Requirements for Underground Storage Tank Systems,* effective April 1, 1998 and the March 18, 2008 revised PADEP Petroleum Short List.

Table 2a
Groundwater Analytical Results
AOIs 2 and 3 Work Plan
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Analysis Name	CAS Number	PADEP Non-Residential Used Aquifer TDS <2,500 mg/L Groundwater MSCs	Location	AOI 2			AOI 2			AOI 2			AOI 2			AOI 2			AOI 2			AOI 2			AOI 2		
			Lab ID	5858663			5858664			5858665			5858666			5858667			5858668			5858670			5858671		
			Sample ID	S-133_120709			S-159_120709			S-139_120709			S-141_120709			S-251_120709			S-252_120709			S-48_120409			S-166_120409		
			Sample Date	12/7/2009			12/7/2009			12/7/2009			12/7/2009			12/7/2009			12/7/2009			12/4/2009			12/4/2009		
Volatile Organic Compounds			**Unit**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**
Benzene	71-43-2	5	ug/l	**8**	1		ND	1	U	ND	1	U	2	1		**510**	**10**		**1,600**	**25**		ND	1	U	ND	1	U
1,2-Dichloroethane	107-06-2	5	ug/l	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	3	U	ND	1	U	ND	1	U
Ethylbenzene	100-41-4	700	ug/l	ND	1	U	ND	1	U	ND	1	U	ND	1	U	240	10		120	3		ND	1	U	ND	1	U
Isopropylbenzene	98-82-8	2300	ug/l	4	2		4	2		7	2		51	2		35	2		16	5		62	2		5	2	
Methyl Tertiary Butyl Ether	1634-04-4	20	ug/l	3	1		ND	1	U	ND	1	U	6	1		4	1		6	3		13	1		13	1	
Ethylene dibromide	106-93-4	0.05	ug/l	ND	0.03	U	ND	0.03	U	ND	0.03	U	ND	0.03	U	ND	0.029	U	ND	0.03	U	ND	0.03	U	ND	0.03	U
Toluene	108-88-3	1000	ug/l	ND	1	U	ND	1	U	ND	1	U	ND	1	U	7	1		26	3		ND	1	U	ND	1	U
1,2,4-Trimethylbenzene	95-63-6	35	ug/l	ND	2	U	ND	2	U	ND	2	U	ND	2	U	**160**	2		**170**	5		ND	2	U	ND	2	U
1,3,5-Trimethylbenzene	108-67-8	35	ug/l	ND	2	U	ND	2	U	ND	2	U	ND	2	U	**68**	2		**57**	5		ND	2	U	ND	2	U
Xylene (Total)	1330-20-7	10000	ug/l	ND	1	U	ND	1	U	ND	1	U	ND	1	U	140	1		430	3		1	1		4	1	
Semivolatile Organic Compounds																											
Chrysene	218-01-9	1.9	ug/l	ND	**47**	U	ND	**500**	U	ND	**5**	U	ND	**500**	U	ND	**50**	U	ND	**50**	U	ND	**47**	U	ND	**50**	U
Fluorene	86-73-7	1900	ug/l	ND	47	U	ND	500	U	ND	5	U	ND	500	U	ND	50	U	ND	50	U	71	47		72	50	
Naphthalene	91-20-3	100	ug/l	ND	47	U	ND	**500**	U	ND	5	U	ND	**500**	U	**110**	50		87	50		ND	47	U	ND	50	U
Phenanthrene	85-01-8	1100	ug/l	ND	47	U	ND	500	U	ND	5	U	670	500		61	50		ND	50	U	170	47		97	50	
Pyrene	129-00-0	130	ug/l	ND	47	U	ND	**500**	U	5	5		ND	**500**	U	ND	50	U	ND	50	U	ND	47	U	ND	50	U
Metals																											
Lead	7439-92-1	0.005	mg/l	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U

Notes:
PADEP - Pennsylvania Department of Environmental Protection
ug/l - microgram per liter
mg/l - milligram per liter
MSC - PADEP's Medium Specific Concentration for Groundwater
RL - Reporting Limit
ND - Not Detected
NA - Not Analyzed

Qualifiers:
Q - Lab Qualifier
U - The analyte was analyzed but not detected
E - The analyte exceeded the calibration range of the instrument

Exceedance Summary:
10 - Result exceeds the PADEP Non-Residential Groundwater MSC
10 - RL exceeds the PADEP Non-Residential Groundwater MSC

Table 2a
Groundwater Analytical Results
AOIs 2 and 3 Work Plan
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Analysis Name	CAS Number	PADEP Non-Residential Used Aquifer TDS <2,500 mg/L Groundwater MSCs	Location	AOI 2			AOI 2			AOI 2			AOI 2			AOI 2			AOI 2			AOI 2			AOI 2		
			Lab ID	5858672			5858673			5858674			5858675			5858676			5858677			5861632			5861633		
			Sample ID	S-165_120409			S-167_120409			S-177_120409			S-134_120409			S-137_120409			S-132_120409			PZ-101_120809			PZ-100_120809		
			Sample Date	12/4/2009			12/4/2009			12/4/2009			12/4/2009			12/4/2009			12/4/2009			12/8/2009			12/8/2009		
Volatile Organic Compounds			**Unit**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**
Benzene	71-43-2	5	ug/l	**34**	1		ND	1	U	ND	1	U	**6**	1		1	1		ND	1	U	ND	1	U	ND	1	U
1,2-Dichloroethane	107-06-2	5	ug/l	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U
Ethylbenzene	100-41-4	700	ug/l	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U
Isopropylbenzene	98-82-8	2300	ug/l	ND	2	U	11	2		10	2		ND	2	U	6	2		55	2		2	2		22	2	
Methyl Tertiary Butyl Ether	1634-04-4	20	ug/l	**40**	1		**21**	1		ND	1	U	ND	1	U	11	1		ND	1	U	ND	1	U	2	1	
Ethylene dibromide	106-93-4	0.05	ug/l	ND	0.029	U	ND	0.03	U	ND	0.03	U	ND	0.03	U	ND	0.03	U	ND	0.03	U	ND	0.029	U	ND	0.029	U
Toluene	108-88-3	1000	ug/l	3	1		1	1		ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U
1,2,4-Trimethylbenzene	95-63-6	35	ug/l	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U
1,3,5-Trimethylbenzene	108-67-8	35	ug/l	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U
Xylene (Total)	1330-20-7	10000	ug/l	7	1		ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U
Semivolatile Organic Compounds																											
Chrysene	218-01-9	1.9	ug/l	ND	**5**	U	ND	**5**	U	ND	**5**	U	ND	**5**	U	ND	**5**	U	ND	**5**	U	ND	**5**	U	ND	**5**	U
Fluorene	86-73-7	1900	ug/l	ND	5	U	14	5		ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U
Naphthalene	91-20-3	100	ug/l	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U
Phenanthrene	85-01-8	1100	ug/l	ND	5	U	27	5		ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U
Pyrene	129-00-0	130	ug/l	ND	5	U	11	5		ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U
Metals																											
Lead	7439-92-1	0.005	mg/l	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U

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Table 2a
Groundwater Analytical Results
AOIs 2 and 3 Work Plan
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Analysis Name	CAS Number	PADEP Non-Residential Used Aquifer TDS <2,500 mg/L Groundwater MSCs	Location	AOI 2			AOI 2			AOI 2			AOI 2			AOI 2			AOI 2			AOI 2			AOI 2		
			Lab ID	5861634			5861635			5861636			5861637			5861639			5861756			5861757			5865494		
			Sample ID	S-254_120809			S-253_120809			S-140_120809			S-71_120809			S-72D_120909			RW-109_121009			RW-108_121009			S-249_121409		
			Sample Date	12/8/2009			12/8/2009			12/8/2009			12/8/2009			12/9/2009			12/10/2009			12/10/2009			12/14/2009		
Volatile Organic Compounds			**Unit**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**
Benzene	71-43-2	5	ug/l	**10**	1		1	1		ND	1	U	ND	1	U	**15**	1		ND	1	U	ND	1	U	ND	1	U
1,2-Dichloroethane	107-06-2	5	ug/l	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U
Ethylbenzene	100-41-4	700	ug/l	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U
Isopropylbenzene	98-82-8	2300	ug/l	43	2		24	2		ND	2	U	2	2		ND	2	U	ND	2	U	ND	2	U	ND	2	U
Methyl Tertiary Butyl Ether	1634-04-4	20	ug/l	7	1		14	1		3	1		**280**	1		ND	1	U	ND	1	U	ND	1	U	3	1	
Ethylene dibromide	106-93-4	0.05	ug/l	ND	0.029	U	ND	0.029	U	ND	0.029	U	ND	0.029	U	ND	0.029	U	ND	0.029	U	ND	0.029	U	ND	0.029	U
Toluene	108-88-3	1000	ug/l	ND	1	U	ND	1	U	ND	1	U	1	1		ND	1	U	ND	1	U	ND	1	U	ND	1	U
1,2,4-Trimethylbenzene	95-63-6	35	ug/l	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U
1,3,5-Trimethylbenzene	108-67-8	35	ug/l	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U
Xylene (Total)	1330-20-7	10000	ug/l	3	1		ND	1	U	ND	1	U	3	1		1	1		ND	1	U	ND	1	U	ND	1	U
Semivolatile Organic Compounds																											
Chrysene	218-01-9	1.9	ug/l	ND	**5**	U	ND	**5**	U	ND	**49**	U	ND	**5**	U	ND	**5**	U	ND	**5**	U	ND	**5**	U	ND	**5**	U
Fluorene	86-73-7	1900	ug/l	ND	5	U	ND	5	U	ND	49	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U
Naphthalene	91-20-3	100	ug/l	ND	5	U	ND	5	U	ND	49	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U
Phenanthrene	85-01-8	1100	ug/l	8	5		6	5		270	49		ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U
Pyrene	129-00-0	130	ug/l	ND	5	U	ND	5	U	54	49		ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U
Metals																											
Lead	7439-92-1	0.005	mg/l	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U

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Table 2a
Groundwater Analytical Results
AOIs 2 and 3 Work Plan
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Analysis Name	CAS Number	PADEP Non-Residential Used Aquifer TDS <2,500 mg/L Groundwater MSCs	Location	AOI 2			AOI 2			AOI 2			AOI 2			AOI 2			AOI 2			AOI 2			AOI 2		
			Lab ID	5865495			5865496			5865497			5865498			5865499			5865500			5865501			5865502		
			Sample ID	S-248_121409			S-247_121409			S-246_121409			RW-107_121409			RW-104_121409			RW-602_121109			S-108_121109			S-147_121109		
			Sample Date	12/14/2009			12/14/2009			12/14/2009			12/14/2009			12/14/2009			12/11/2009			12/11/2009			12/11/2009		
Volatile Organic Compounds			**Unit**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**
Benzene	71-43-2	5	ug/l	3	1		ND	1	U	4	1		ND	1	U	2	1		2	1		2	1		**56**	1	
1,2-Dichloroethane	107-06-2	5	ug/l	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U
Ethylbenzene	100-41-4	700	ug/l	ND	1	U	ND	1	U	2	1		ND	1	U	ND	1	U	2	1		ND	1	U	2	1	
Isopropylbenzene	98-82-8	2300	ug/l	4	2		ND	2	U	ND	2	U	ND	2	U	ND	2	U	9	2		3	2		19	2	
Methyl Tertiary Butyl Ether	1634-04-4	20	ug/l	ND	1	U	ND	1	U	ND	1	U	ND	1	U	7	1		3	1		ND	1	U	**44**	1	
Ethylene dibromide	106-93-4	0.05	ug/l	ND	0.029	U	ND	0.029	U	ND	0.029	U	ND	0.03	U	ND	0.029	U	ND	0.029	U	ND	0.03	U	ND	0.029	U
Toluene	108-88-3	1000	ug/l	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	38	1		4	1		6	1	
1,2,4-Trimethylbenzene	95-63-6	35	ug/l	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U	2	2	
1,3,5-Trimethylbenzene	108-67-8	35	ug/l	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U	5	2	
Xylene (Total)	1330-20-7	10000	ug/l	1	1		ND	1	U	6	1		ND	1	U	3	1		37	1		4	1		13	1	
Semivolatile Organic Compounds																											
Chrysene	218-01-9	1.9	ug/l	ND	**52**	U	ND	**47**	U	ND	**5**	U	ND	**200**	U	ND	**48**	U	ND	**5**	U	ND	**5**	U	**71**	**50**	
Fluorene	86-73-7	1900	ug/l	ND	52	U	ND	47	U	ND	5	U	ND	200	U	ND	48	U	ND	5	U	ND	5	U	77	50	
Naphthalene	91-20-3	100	ug/l	ND	52	U	ND	47	U	ND	5	U	ND	**200**	U	ND	48	U	ND	5	U	ND	5	U	ND	50	U
Phenanthrene	85-01-8	1100	ug/l	ND	52	U	ND	47	U	ND	5	U	ND	200	U	ND	48	U	ND	5	U	ND	5	U	110	50	
Pyrene	129-00-0	130	ug/l	ND	52	U	ND	47	U	ND	5	U	ND	**200**	U	49	48		ND	5	U	ND	5	U	**270**	50	
Metals																											
Lead	7439-92-1	0.005	mg/l	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U

Notes:
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RL - Reporting Limit
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Qualifiers:
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U - The analyte was analyzed but not detected
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Exceedance Summary:
10 - Result exceeds the PADEP Non-Residential Groundwater MSC
10 - RL exceeds the PADEP Non-Residential Groundwater MSC

Table 2a
Groundwater Analytical Results
AOIs 2 and 3 Work Plan
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Analysis Name	CAS Number	PADEP Non-Residential Used Aquifer TDS <2,500 mg/L Groundwater MSCs	Location	AOI 2			AOI 2			AOI 2			AOI 2		
			Lab ID	5865503			5865504			5865505			5865506		
			Sample ID	S-153_121109			S-154_121109			S-149_121109			S-110_121109		
			Sample Date	12/11/2009			12/11/2009			12/11/2009			12/11/2009		
Volatile Organic Compounds			**Unit**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**
Benzene	71-43-2	5	ug/l	**17**	1		**52**	1		**600**	**20**		ND	1	U
1,2-Dichloroethane	107-06-2	5	ug/l	ND	1	U	ND	1	U	ND	**20**	U	ND	1	U
Ethylbenzene	100-41-4	700	ug/l	1	1		11	1		82	20		ND	1	U
Isopropylbenzene	98-82-8	2300	ug/l	20	2		12	2		50	40		ND	2	U
Methyl Tertiary Butyl Ether	1634-04-4	20	ug/l	13	1		**45**	1		**66**	20		ND	1	U
Ethylene dibromide	106-93-4	0.05	ug/l	ND	0.03	U	ND	0.029	U	ND	0.03	U	ND	0.03	U
Toluene	108-88-3	1000	ug/l	4	1		34	1		40	20		ND	1	U
1,2,4-Trimethylbenzene	95-63-6	35	ug/l	2	2		13	2		**620**	**40**		ND	2	U
1,3,5-Trimethylbenzene	108-67-8	35	ug/l	ND	2	U	5	2		**780**	**40**		ND	2	U
Xylene (Total)	1330-20-7	10000	ug/l	11	1		99	1		560	20		ND	1	U
Semivolatile Organic Compounds															
Chrysene	218-01-9	1.9	ug/l	ND	**50**	U	ND	**50**	U	ND	**500**	U	ND	**500**	U
Fluorene	86-73-7	1900	ug/l	60	50		ND	50	U	ND	500	U	ND	500	U
Naphthalene	91-20-3	100	ug/l	ND	50	U	ND	50	U	ND	**500**	U	ND	**500**	U
Phenanthrene	85-01-8	1100	ug/l	130	50		ND	50	U	ND	500	U	ND	500	U
Pyrene	129-00-0	130	ug/l	110	50		ND	50	U	**730**	**500**		ND	**500**	U
Metals															
Lead	7439-92-1	0.005	mg/l	ND	0.001	U	ND	0.001	U	ND	0.001	U	**0.0055**	0.001	

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Exceedance Summary:
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Table 2b
Groundwater Analytical Results
AOIs 2 and 3 Work Plan
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Analysis Name	CAS Number	PADEP Non-Residential Used Aquifer TDS <2,500 mg/L Groundwater MSCs	Location	AOI 3			AOI 3			AOI 3			AOI 3			AOI 3			AOI 3			AOI 3			AOI 3		
			Lab ID	5851301			5851302			5851303			5851304			5851305			5851306			5851307			5851308		
			Sample ID	S-12_113009			S-13_113009			S-14_113009			S-17_113009			S-16_113009			S-18_113009			S-20_113009			S-22_113009		
			Sample Date	11/30/2009			11/30/2009			11/30/2009			11/30/2009			11/30/2009			11/30/2009			11/30/2009			11/30/2009		
Volatile Organic Compounds			**Unit**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**
Benzene	71-43-2	5	ug/l	**12**	1		ND	1	U	**7**	1		**13**	1		**190**	**10**		**6**	1		**9**	1		**33**	1	
1,2-Dichloroethane	107-06-2	5	ug/l	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U
Ethylbenzene	100-41-4	700	ug/l	ND	1	U	35	1		ND	1	U	1	1		290	10		3	1		3	1		4	1	
Isopropylbenzene	98-82-8	2300	ug/l	3	2		ND	2	U	ND	2	U	6	2		110	2		14	2		20	2		9	2	
Methyl Tertiary Butyl Ether	1634-04-4	20	ug/l	4	1		1	1		ND	1	U	9	1		**44**	1		ND	1	U	**98**	1		**66**	1	
Ethylene dibromide	106-93-4	0.05	ug/l	ND	0.029	U	ND	0.029	U	ND	0.029	U	ND	0.03	U	ND	0.03	U	ND	0.029	U	ND	0.029	U	ND	0.03	U
Toluene	108-88-3	1000	ug/l	ND	1	U	3	1		ND	1	U	ND	1	U	42	1		1	1		2	1		44	1	
1,2,4-Trimethylbenzene	95-63-6	35	ug/l	ND	2	U	ND	2	U	ND	2	U	ND	2	U	**430**	20		3	2		2	2		4	2	
1,3,5-Trimethylbenzene	108-67-8	35	ug/l	ND	2	U	ND	2	U	ND	2	U	ND	2	U	**150**	2		ND	2	U	ND	2	U	12	2	
Xylene (Total)	1330-20-7	10000	ug/l	1	1		140	1		1	1		2	1		420	1		6	1		7	1		110	1	
Semivolatile Organic Compounds																											
Chrysene	218-01-9	1.9	ug/l	ND	**5**	U	ND	**5**	U	ND	**5**	U	ND	**5**	U	ND	**5**	U	ND	**5**	U	ND	**5**	U	ND	**5**	U
Fluorene	86-73-7	1900	ug/l	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U
Naphthalene	91-20-3	100	ug/l	ND	5	U	ND	5	U	ND	5	U	ND	5	U	7	5		ND	5	U	ND	5	U	ND	5	U
Phenanthrene	85-01-8	1100	ug/l	ND	5	U	ND	5	U	ND	5	U	ND	5	U	10	5		ND	5	U	ND	5	U	ND	5	U
Pyrene	129-00-0	130	ug/l	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U
Metals																											
Lead	7439-92-1	0.005	mg/l	ND	0.001	U	0.0023	0.001		ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U

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Table 2b
Groundwater Analytical Results
AOIs 2 and 3 Work Plan
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Analysis Name	CAS Number	PADEP Non-Residential Used Aquifer TDS <2,500 mg/L Groundwater MSCs	Location	AOI 3			AOI 3			AOI 3			AOI 3			AOI 3			AOI 3			AOI 3			AOI 3		
			Lab ID	5851637			5851638			5851639			5851640			5851641			5854731			5854732			5854733		
			Sample ID	S-25_112509			S-8_112509			S-9_112509			S-10_112509			S-11_112509			BF-105_120209			BF-100_120209			BF-108_120209		
			Sample Date	11/25/2009			11/25/2009			11/25/2009			11/25/2009			11/25/2009			12/2/2009			12/2/2009			12/2/2009		
Volatile Organic Compounds			**Unit**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**
Benzene	71-43-2	5	ug/l	ND	1	U	61	1		7	1		26	1		11	1		ND	1	U	ND	1	U	ND	1	U
1,2-Dichloroethane	107-06-2	5	ug/l	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U
Ethylbenzene	100-41-4	700	ug/l	ND	1	U	2	1		ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U
Isopropylbenzene	98-82-8	2300	ug/l	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U
Methyl Tertiary Butyl Ether	1634-04-4	20	ug/l	ND	1	U	9	1		12	1		ND	1	U	3	1		ND	1	U	ND	1	U	100	1	
Ethylene dibromide	106-93-4	0.05	ug/l	ND	0.029	U	ND	0.03	U	ND	0.03	U	ND	0.03	U	ND	0.029	U	ND	0.029	U	ND	0.029	U	ND	0.029	U
Toluene	108-88-3	1000	ug/l	ND	1	U	2	1		ND	1	U	1	1		ND	1	U	ND	1	U	ND	1	U	ND	1	U
1,2,4-Trimethylbenzene	95-63-6	35	ug/l	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U
1,3,5-Trimethylbenzene	108-67-8	35	ug/l	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U
Xylene (Total)	1330-20-7	10000	ug/l	ND	1	U	4	1		ND	1	U	2	1		ND	1	U	ND	1	U	ND	1	U	ND	1	U
Semivolatile Organic Compounds																											
Chrysene	218-01-9	1.9	ug/l	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U
Fluorene	86-73-7	1900	ug/l	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U
Naphthalene	91-20-3	100	ug/l	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U
Phenanthrene	85-01-8	1100	ug/l	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U
Pyrene	129-00-0	130	ug/l	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U
Metals																											
Lead	7439-92-1	0.005	mg/l	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U

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Table 2b
Groundwater Analytical Results
AOIs 2 and 3 Work Plan
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Analysis Name	CAS Number	PADEP Non-Residential Used Aquifer TDS <2,500 mg/L Groundwater MSCs	Location	AOI 3			AOI 3			AOI 3			AOI 3			AOI 3			AOI 3			AOI 3			AOI 3		
			Lab ID	5854734			5854735			5854736			5854737			5854738			5854739			5854740			5854741		
			Sample ID	BF-106_120209			BF-99_120209			BF-107_120209			BF-88_120209			BF-104_120209			BF-90_120209			S-23_120109			S-3_120109		
			Sample Date	12/2/2009			12/2/2009			12/2/2009			12/2/2009			12/2/2009			12/2/2009			12/1/2009			12/1/2009		
Volatile Organic Compounds			**Unit**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**
Benzene	71-43-2	5	ug/l	**250**	2		ND	1	U	ND	1	U	ND	1	U	2	1		1	1		ND	1	U	ND	1	U
1,2-Dichloroethane	107-06-2	5	ug/l	ND	2	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U
Ethylbenzene	100-41-4	700	ug/l	55	2		ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U
Isopropylbenzene	98-82-8	2300	ug/l	59	4		7	2		60	2		ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U
Methyl Tertiary Butyl Ether	1634-04-4	20	ug/l	ND	2	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	ND	1	U	**120**	1		ND	1	U
Ethylene dibromide	106-93-4	0.05	ug/l	ND	0.03	U	ND	0.029	U	ND	0.03	U	ND	0.03	U	ND	0.03	U	ND	0.03	U	ND	0.03	U	ND	0.03	U
Toluene	108-88-3	1000	ug/l	4	2		2	1		3	1		ND	1	U	ND	1	U	1	1		ND	1	U	ND	1	U
1,2,4-Trimethylbenzene	95-63-6	35	ug/l	**220**	4		30	2		ND	2	U	ND	2	U	ND	2	U	2	2		ND	2	U	ND	2	U
1,3,5-Trimethylbenzene	108-67-8	35	ug/l	**36**	4		14	2		ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U	ND	2	U
Xylene (Total)	1330-20-7	10000	ug/l	19	2		3	1		ND	1	U	ND	1	U	ND	1	U	13	1		ND	1	U	ND	1	U
Semivolatile Organic Compounds																											
Chrysene	218-01-9	1.9	ug/l	ND	**24**	U	ND	**5**	U	ND	**24**	U	ND	**5**	U	ND	**5**	U	ND	**5**	U	ND	**5**	U	ND	**5**	U
Fluorene	86-73-7	1900	ug/l	87	24		8	5		180	24		ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U
Naphthalene	91-20-3	100	ug/l	**110**	24		16	5		ND	24	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U
Phenanthrene	85-01-8	1100	ug/l	76	24		6	5		150	24		ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U
Pyrene	129-00-0	130	ug/l	ND	24	U	ND	5	U	ND	24	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U	ND	5	U
Metals																											
Lead	7439-92-1	0.005	mg/l	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U	ND	0.001	U

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Table 2b
Groundwater Analytical Results
AOIs 2 and 3 Work Plan
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Analysis Name	CAS Number	PADEP Non-Residential Used Aquifer TDS <2,500 mg/L Groundwater MSCs	Location	AOI 3			AOI 3			AOI 3		
			Lab ID	5854742			5854743			5854744		
			Sample ID	S-1_120109			S-2_120109			BF-103R_120109		
			Sample Date	12/1/2009			12/1/2009			12/1/2009		
Volatile Organic Compounds			**Unit**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**
Benzene	71-43-2	5	ug/l	ND	1	U	ND	1	U	ND	1	U
1,2-Dichloroethane	107-06-2	5	ug/l	ND	1	U	ND	1	U	ND	1	U
Ethylbenzene	100-41-4	700	ug/l	ND	1	U	ND	1	U	ND	1	U
Isopropylbenzene	98-82-8	2300	ug/l	ND	2	U	ND	2	U	ND	2	U
Methyl Tertiary Butyl Ether	1634-04-4	20	ug/l	ND	1	U	ND	1	U	ND	1	U
Ethylene dibromide	106-93-4	0.05	ug/l	ND	0.029	U	ND	0.03	U	ND	0.029	U
Toluene	108-88-3	1000	ug/l	ND	1	U	ND	1	U	ND	1	U
1,2,4-Trimethylbenzene	95-63-6	35	ug/l	ND	2	U	ND	2	U	ND	2	U
1,3,5-Trimethylbenzene	108-67-8	35	ug/l	ND	2	U	ND	2	U	ND	2	U
Xylene (Total)	1330-20-7	10000	ug/l	ND	1	U	ND	1	U	ND	1	U
Semivolatile Organic Compounds												
Chrysene	218-01-9	1.9	ug/l	ND	**47**	U	ND	**5**	U	ND	**5**	U
Fluorene	86-73-7	1900	ug/l	ND	47	U	ND	5	U	ND	5	U
Naphthalene	91-20-3	100	ug/l	ND	47	U	ND	5	U	ND	5	U
Phenanthrene	85-01-8	1100	ug/l	ND	47	U	ND	5	U	ND	5	U
Pyrene	129-00-0	130	ug/l	ND	47	U	ND	5	U	ND	5	U
Metals												
Lead	7439-92-1	0.005	mg/l	0.0035	0.001		ND	0.001	U	0.0014	0.001	

Analysis Name	CAS Number	PADEP Non-Residential Used Aquifer TDS <2,500 mg/L Groundwater MSCs	Location	AOI 3			AOI 3			AOI 3		
			Lab ID	5854745			5854746			5854747		
			Sample ID	S-69D_120109			C-113_120109			C-49_120109		
			Sample Date	12/1/2009			12/1/2009			12/1/2009		
Volatile Organic Compounds			**Unit**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**	**Result**	**RL**	**Q**
Benzene	71-43-2	5	ug/l	ND	1	U	ND	1	U	2	1	
1,2-Dichloroethane	107-06-2	5	ug/l	ND	1	U	ND	1	U	ND	1	U
Ethylbenzene	100-41-4	700	ug/l	ND	1	U	ND	1	U	ND	1	U
Isopropylbenzene	98-82-8	2300	ug/l	ND	2	U	ND	2	U	ND	2	U
Methyl Tertiary Butyl Ether	1634-04-4	20	ug/l	ND	1	U	ND	1	U	ND	1	U
Ethylene dibromide	106-93-4	0.05	ug/l	ND	0.029	U	ND	0.029	U	ND	0.029	U
Toluene	108-88-3	1000	ug/l	ND	1	U	ND	1	U	ND	1	U
1,2,4-Trimethylbenzene	95-63-6	35	ug/l	ND	2	U	ND	2	U	ND	2	U
1,3,5-Trimethylbenzene	108-67-8	35	ug/l	ND	2	U	ND	2	U	ND	2	U
Xylene (Total)	1330-20-7	10000	ug/l	ND	1	U	ND	1	U	ND	1	U
Semivolatile Organic Compounds												
Chrysene	218-01-9	1.9	ug/l	ND	**5**	U	ND	**5**	U	ND	**5**	U
Fluorene	86-73-7	1900	ug/l	ND	5	U	ND	5	U	ND	5	U
Naphthalene	91-20-3	100	ug/l	ND	5	U	ND	5	U	ND	5	U
Phenanthrene	85-01-8	1100	ug/l	ND	5	U	ND	5	U	ND	5	U
Pyrene	129-00-0	130	ug/l	ND	5	U	ND	5	U	ND	5	U
Metals												
Lead	7439-92-1	0.005	mg/l	ND	0.001	U	ND	0.001	U	ND	0.001	U

Notes:
PADEP - Pennsylvania Department of Environmental Protection
ug/l - microgram per liter
mg/l - milligram per liter
MSC - PADEP's Medium Specific Concentration for Groundwater
RL - Reporting Limit
ND - Not Detected
NA - Not Analyzed

Qualifiers:
Q - Lab Qualifier
U - The analyte was analyzed but not detected
E - The analyte exceeded the calibration range of the instrument

Exceedance Summary:
10 - Result exceeds the PADEP Non-Residential Groundwater MSC
10 - RL exceeds the PADEP Non-Residential Groundwater MSC

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Philadelphia, Pennsylvania

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AOI 2									
C-Header	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
PZ-100	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
PZ-101	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
RW-100	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
RW-101	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
RW-102	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
RW-103	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
RW-104	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
RW-105	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
RW-106	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
RW-107	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
RW-108	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
RW-109	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
RW-600	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Short Pier Area
RW-601	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Short Pier Area
RW-602	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Short Pier Area
RW-603	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Short Pier Area
S-105	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Short Pier Area
S-106	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Short Pier Area
S-107	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Short Pier Area
S-108	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Short Pier Area
S-110	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Short Pier Area
S-130	X		Groundwater			X	X	1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-131	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-132	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-133	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-134	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-135	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-136	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-137	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-139	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-140	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-141	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-142	X		Groundwater			X	X	1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-143	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-147	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-149	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Short Pier Area
S-150	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Short Pier Area
S-153	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Short Pier Area
S-154	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Short Pier Area
S-156	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-157	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area

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AOI 2									
S-159	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-165	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-166	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-167	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-174	X		Groundwater			X		1	Characterize Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-175	X		Groundwater			X		1	Characterize Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-177	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-178	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-246A	X		Groundwater			X		1	Characterize Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-247	X		Groundwater			X		1	Characterize Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-248	X		Groundwater			X		1	Characterize Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-249	X		Groundwater			X		1	Characterize Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-250	X		Groundwater			X		1	Characterize Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-251	X		Groundwater			X		1	Characterize Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-252	X		Groundwater			X		1	Characterize Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-253	X		Groundwater			X		1	Characterize Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-254	X		Groundwater			X		1	Characterize Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-48	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-53	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-54	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-61	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-62	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-63	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-64	X		Groundwater			X	X	1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-65	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-70	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Short Pier Area
S-71	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Short Pier Area
S-72	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Office Building Area
S-72D	X		Groundwater			X		1	Characterize Deep Groundwater: Office Building Area
S-91	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-92	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
S-93	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area
SD-1	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Short Pier Area
S-292		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Former Naptha Plant, Industrial Receptor Office Building Area

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AOI 2									
S-293		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Former Batch Stills/Solvent Area, Industrial Receptor Office Building Area
S-294		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Former Batch Stills/Solvent Area, Northern Property Boundary/Industrial Receptor
S-294D		X	Soil / Groundwater	X	90 ft bgs	X		1	Characterize Soil and Deep Groundwater: Northern Property Boundary Well/Industrial Receptor
S-295		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Industrial Receptor Maintenance Building Area
S-296		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Industrial Receptor Maintenance Building Area
S-297		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Industrial Receptor/North of Short Pier Area/Adjacent to Schuylkill River
S-298		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Industrial Receptor Bio/BFW Unit Area
S-299		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Industrial Receptor Crude Unit Building Area
S-300		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Industrial Receptor HDS Area
S-301		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Industrial Receptor CAT Unit Area
S-302		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Cogen Plant Area, Pollock St. Sewer Remedial System Area
S-302D		X	Soil / Groundwater	X	90 ft bgs	X		1	Characterize Soil and Deep Groundwater: Cogen Plant Area Pollock St. Sewer Remedial System Area
S-303		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area/Solvent Area
S-304		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area, C-Header Area
S-305		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area\Eastern AOI Boundary Well
S-305D		X	Soil / Groundwater	X	90 ft bgs	X		1	Characterize Soil and Deep Groundwater: Pollock St. Sewer Remedial System Area\Eastern AOI Boundary Well
S-306		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area\S-250 Area
S-307		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Industrial Receptor North Complex Area
S-308		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Industrial Receptor, Southern AOI Boundary Well
S-309		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Industrial Receptor, Southern AOI Boundary Well
S-310		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Industrial Receptor, Southern AOI Boundary Well
S-311		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Industrial Receptor, Southern AOI Boundary
S-312		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Industrial Receptor, South East Boundary Well
S-313		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area/North Side of Sewer
S-314		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area/North Side of Sewer
S-315		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area/North Side of Sewer
S-316		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area/North Side of Sewer
S-317		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area/Barrel House & Tank 1508 Area
S-318		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area/Barrel House & Tank 1500 Area
S-319		X	Soil / Groundwater	X	20 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area\No. 3 Barrel Warehouse Area
S-320		X	Soil / Groundwater	X	20 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area\No. 3 Barrel Warehouse Area
S-321		X	Soil / Groundwater	X	20 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area\No. 3 Barrel Warehouse Area
S-322		X	Soil / Groundwater	X	20 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area\No. 3 Barrel Warehouse Area
S-323		X	Soil / Groundwater	X	20 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area\No. 3 Barrel Warehouse Area
S-324		X	Soil / Groundwater	X	20 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area\S-250 Area
S-325		X	Soil / Groundwater	X	20 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area\S-250 Area
S-326		X	Soil / Groundwater	X	20 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area\S-250 Area
S-327		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Pollock St. Sewer Remedial System Area\S-250 Area
S-328		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Heavy Oils Area

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AOI 3									
BF-100	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Ballfield Area
BF-103R	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Ballfield Area
BF-104	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Ballfield Area
BF-105	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Ballfield Area
BF-106	X		Groundwater			X	X	1	Characterize Shallow/Intermediate Groundwater: Ballfield Area
BF-107	X		Groundwater			X	X	1	Characterize Shallow/Intermediate Groundwater: Ballfield Area
BF-108	X		Groundwater			X		1	Characterize Deep Groundwater: Ballfield Area
BF-88	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Ballfield Area
BF-90	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Ballfield Area
BF-90D	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Ballfield Area
BF-99	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Ballfield Area
C-113	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Ballfield/SWMU No. 3 Area
C-49	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: SWMU No. 3 Area
RW-2	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: RW-2 Area
S-1	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: SWMU No. 3 Area
S-10	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: SWMU No. 3 Area
S-11	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: SWMU No. 3 Area
S-113	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: No. 5 Tank Farm Area
S-12	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: SWMU No. 3 Area
S-13	X		Groundwater			X		1	Characterize Deep Groundwater in AOI 3: SWMU No. 3 Area
S-14	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: SWMU No. 3 Area
S-15	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: SWMU No. 3 Area
S-16	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: SWMU No. 3 Area
S-17	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: SWMU No. 3 Area
S-18	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: SWMU No. 3 Area
S-19	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: SWMU No. 3 Area
S-2	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: SWMU No. 3 Area
S-20	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: SWMU No. 3 Area
S-21	X		Groundwater			X	X	1	Characterize Shallow/Intermediate Groundwater: SWMU No. 3 Area
S-22	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: SWMU No. 3 Area
S-23	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: SWMU No. 3 Area
S-24	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: SWMU No. 3 Area
S-25	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: SWMU No. 3 Area
S-3	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: SWMU No. 3 Area
S-5	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: SWMU No. 3 Area
S-59	X		Groundwater			X	X	1	Characterize Shallow/Intermediate Groundwater: RW-2 Area
S-60	X		Groundwater			X	X	1	Characterize Shallow/Intermediate Groundwater: RW-2 Area
S-66	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: No. 5 Tank Farm Area
S-69	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: Ballfield Area
S-69D	X		Groundwater			X		1	Characterize Deep Groundwater: Ballfield Area
S-8	X		Groundwater			X		1	Characterize Deep Groundwater: SWMU No. 3 Area

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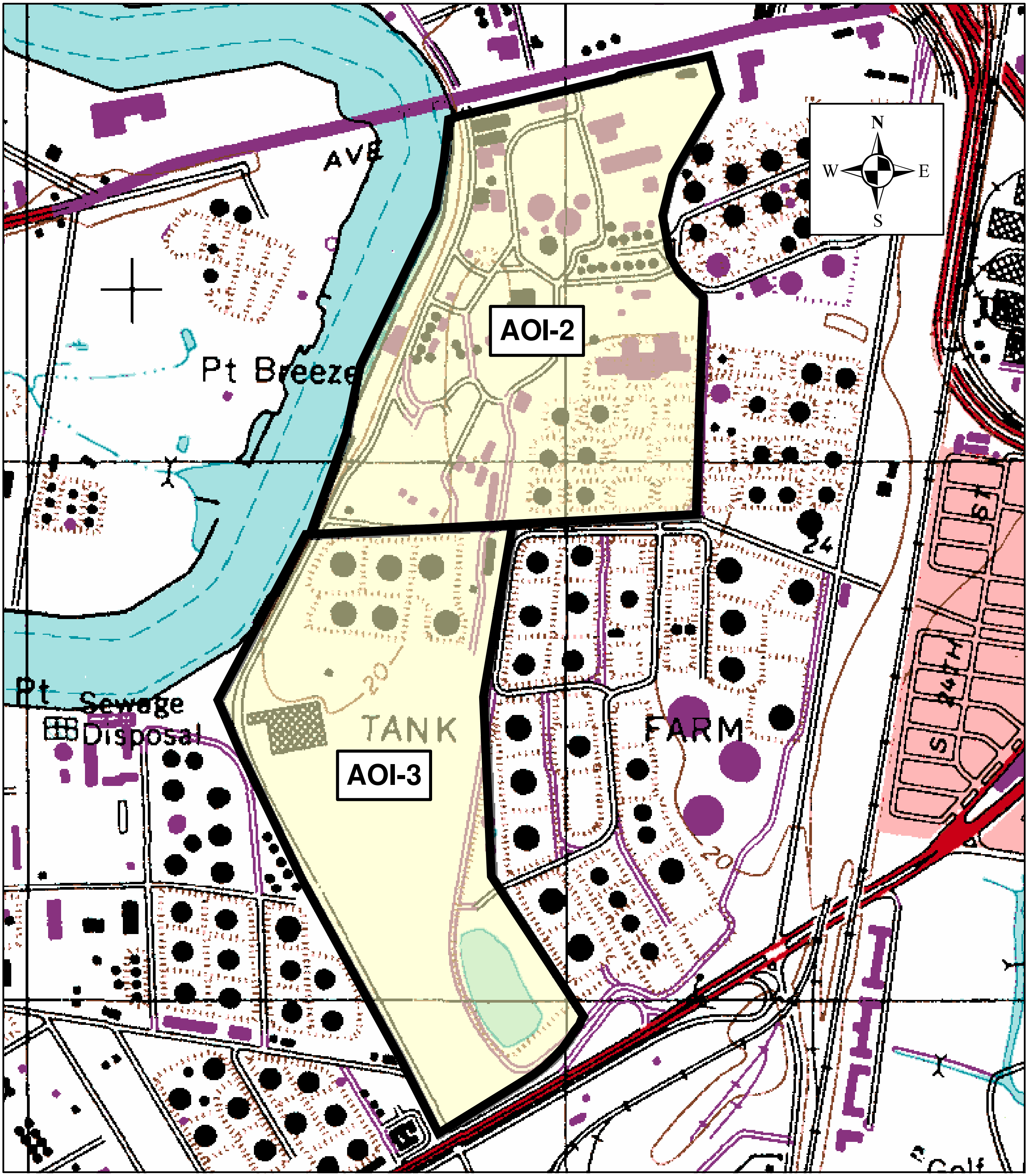
AOI 3									
S-9	X		Groundwater			X		1	Characterize Shallow/Intermediate Groundwater: SWMU No. 3 Area
S-280		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil & Shallow/Intermediate Groundwater: Industrial/Eco Receptor/No. 5 Tank Area
S-280D		X	Soil / Groundwater	X	90 ft bgs	X		1	Characterize Deep Groundwater: Industrial/Eco Receptor/No. 5 Tank Area
S-281		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil & Shallow/Intermediate Groundwater: Industrial/Eco Receptor/No. 5 Tank, RW-2 Area, LNAPL Delineation
S-282		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil & Shallow/Intermediate Groundwater: Industrial/Eco Receptor, RW-2 Area, LNAPL Delineation
S-283		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil & Shallow/Intermediate Groundwater: Industrial Receptor/Central Warehouse Area
S-284		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil & Shallow/Intermediate Groundwater: Industrial Receptor/Central Warehouse Area
S-284D		X	Soil / Groundwater	X	90 ft bgs	X		1	Characterize Deep Groundwater in AOI 3: Industrial Receptor/Central Warehouse Area
S-285		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: SWMU No. 3 Area, PDA A Area
S-286		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: SWMU No. 3 Area, PDA A Area
S-287		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Ballfield Area & Tank Car Cleaning Area
S-288		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Ballfield Area & Tank Car Cleaning Area, PDA B Area
S-289		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: Ballfield & Tank Car Cleaning Area
S-290		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: SWMU No. 3 Area, PDA A Area
S-291		X	Soil / Groundwater	X	30 ft bgs	X		1	Characterize Soil and Shallow/Intermediate Groundwater: SWMU No. 3 Area, Southern Boundary Well
BH-10-01		X	Soil	X	2 ft bgs			1	Characterize Soil: SWMU No. 3 Area,
BH-10-02		X	Soil	X	2 ft bgs			1	Characterize Soil: SWMU No. 3 Area, PDA C Area
BH-10-03		X	Soil	X	2 ft bgs			1	Characterize Soil: SWMU No. 3 Area, PDA B Area
BH-10-04		X	Soil	X	2 ft bgs			1	Characterize Soil: SWMU No. 3 Area, PDA B Area

Notes:
1. 0-2' soil samples will be collected from proposed monitoring wells where impervious surfaces are not present.
2. Final depth of well and screen placement to be determined by geologist based on field observation while completing the boring.
3. Analysis of COCs listed in Table 1 of the Work Plan.
4. Field procedures will be performed in accordance with Appendix B of the Work Plan.
ft bgs = feet below ground surface
COCs = Constituents of Concern
LNAPL = Light Non-Aqueous Phase Liquid

FIGURES



USGS Topographic Map, Philadelphia, PA. Quadrangle, USGS 1995

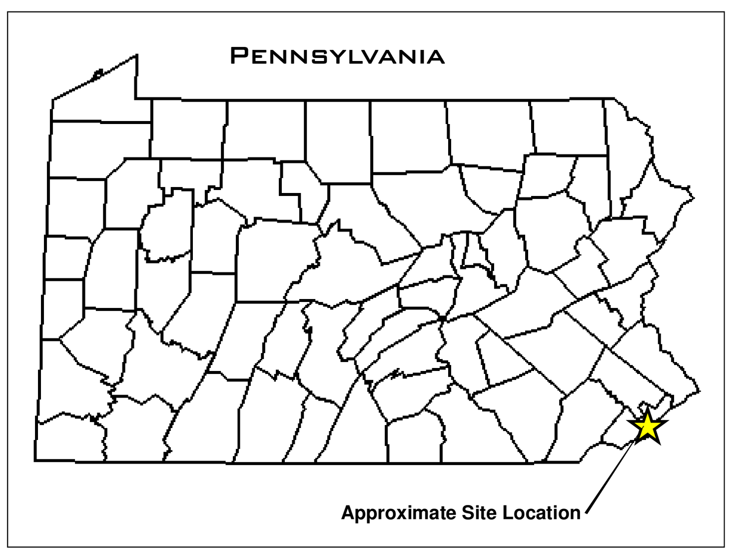
Sunoco, Inc. (R&M)
Philadelphia Refinery
3144 Passyunk Avenue
Philadelphia, PA. 19145

Figure 1: Site Location Map: AOI-2 & AOI-3
AOI-2 & AOI-3 Work Plan
Philadelphia Sunoco Philadelphia Refinery Pennsylvania

Job Number	Scale: 1" = 800'	Date
2574601	0 400 800 Feet	December 23, 2009

Q:\data6\2574601\ArcGIS\MapDocuments\AOI 2 Workplan\Figure 1- Site Location Map - AOI2 - AOI3.mxd

Notes:
1. 2005 aerial photography provided by the Delaware Valley Regional Planning Commission (DVRPC).



Legend

Proposed Activities

- Proposed Deep Monitoring Well
- Proposed Shallow/Intermediate Monitoring Well

Existing Features

- Existing Monitoring Points
- Abandoned/Damaged/Unable to Locate
- Pollock Street Sewer
- AOIs

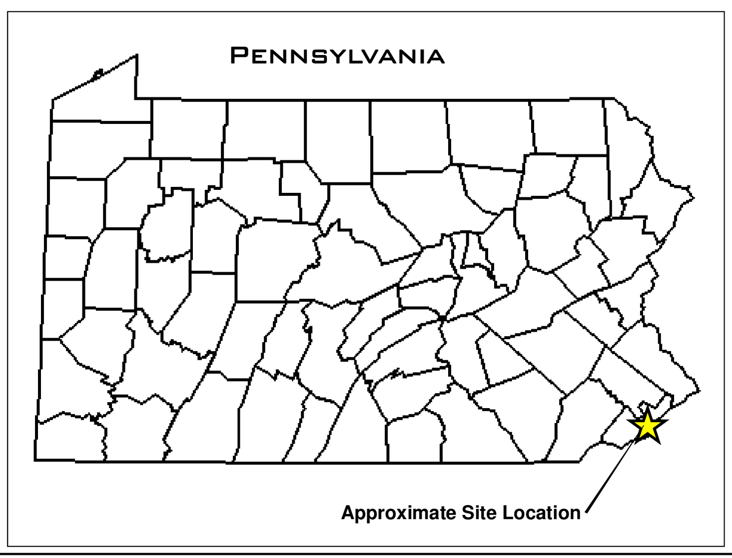
Figure 2: Summary of Proposed Site Characterization Activities for AOI-2 AOIs 2 and 3 Work Plan
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Sunoco, Inc. (R&M)
Philadelphia Refinery
3144 Passyunk Avenue
Philadelphia, PA.
19145

0 60 120 240
Feet

Q:\data\2574601\ArcGIS\MapDocuments\AOI 2 Workplan\Figure 2 - Proposed Site Characterization Activities_1-22-10.mxd

Notes:
1. 2005 aerial photography provided by the Delaware Valley Regional Planning Commission (DVRPC).



Legend

Proposed Activities

- Proposed Deep Monitoring Well
- Proposed Shallow/Intermediate Monitoring Well
- Proposed Shallow Boring Location

Existing Features

- Existing Monitoring Point
- Abandoned/Damaged/Unable to Locate
- AOIs

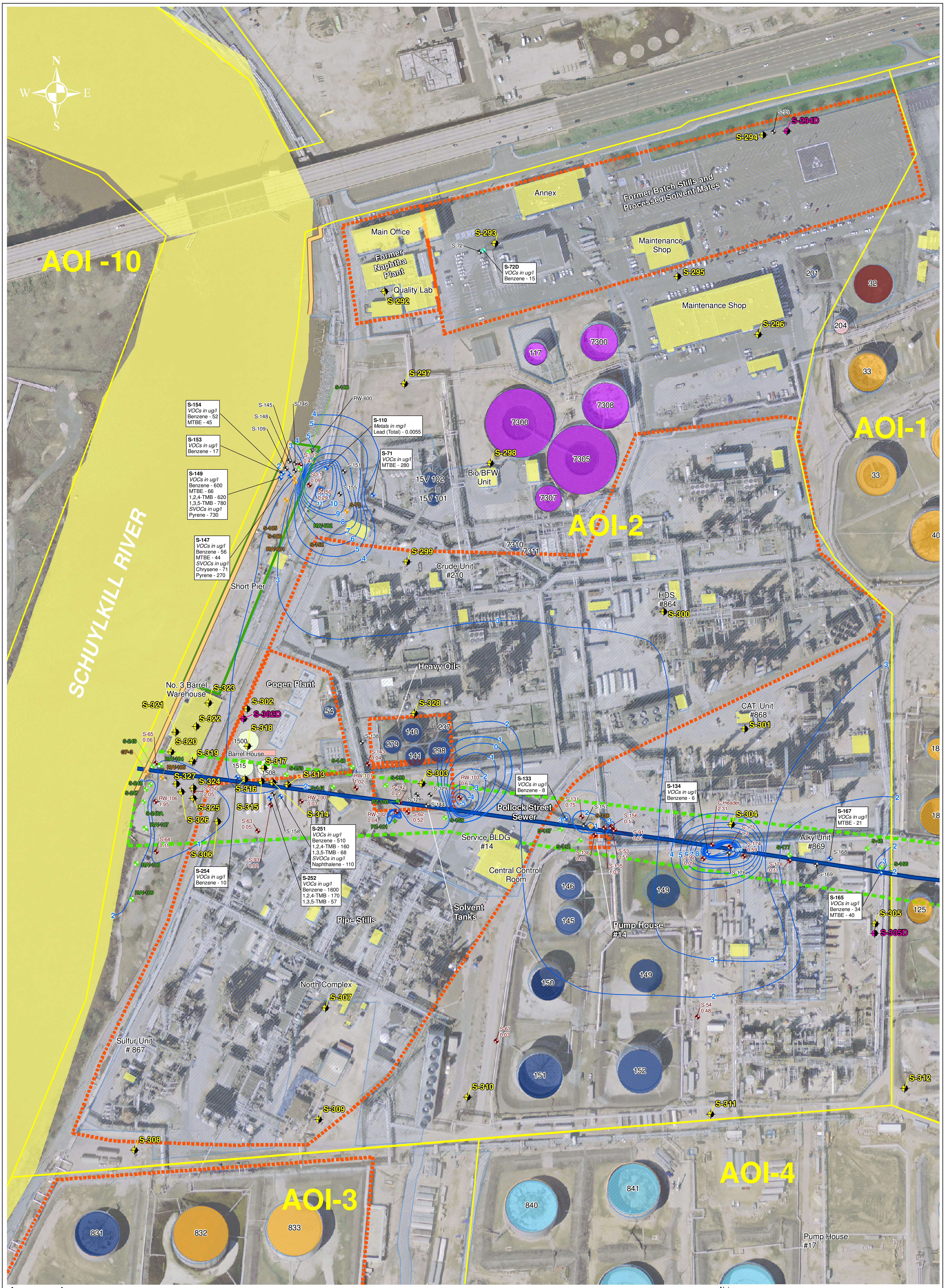
Figure 3: Summary of Proposed Site Characterization Activities for AOI-3
AOIs 2 and 3 Work Plan
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Sunoco, Inc. (R&M)
Philadelphia Refinery
3144 Passyunk Avenue
Philadelphia, PA.
19145

0 70 140 280 Feet

SCALE: 1" = 140'
DATE: January 22, 2010
DRN. BY: MH
CKD. BY: DW
JOB#: 2574601

Q:\data6\2574601\ArcGIS\MapDocuments\AOI 3 Workplan\Figure 3 - Summary of Proposed Site Characterization Activities_1-22-10.mxd



Legend

December 2009 Groundwater Data

- Fill/Alluvium/Trenton Gravel Monitoring Wells with Exceedance of PADEP MSCs (S-133, VOCs in ug/l, Benzene - 8)
- Lower Sand Monitoring Well with Exceedance of PADEP MSCs (S-72D, VOCs in ug/l, Benzene - 15)
- Fill/Alluvium/Trenton Gravel Monitoring Well with LNAPL and Apparent LNAPL Thickness (S-250, 2.05')
- Fill/Alluvium/Trenton Gravel Monitoring Well with No Exceedance of PADEP MSCs
- Fill/Alluvium Recovery Well with No Exceedance of PADEP MSCs
- Piezometer with No Exceedance of PADEP MSCs
- Monitoring Point Not Sampled
- Abandoned/Damaged (S-157)
- December 2009 Groundwater Elevation Contour (ft amsl)

Proposed Activities

- Proposed Deep Monitoring Well
- Proposed Shallow Soil Boring & Shallow\Intermediate Monitoring Well

Existing & Historical Investigation Areas, & Historic Use Areas

- Pollock Street Sewer
- AOIs
- Impervious Surfaces
- Short Pier Area
- Historic Use Areas
- Industrial/Eco Receptors
- Pollock Street Remedial System
- Bulkhead

Tank Content

- Crude Oil
- Dewatering
- Intermediate
- Light and Chemical
- Waste Water Treatment Plant (WWTP)
- Removed Tanks

Notes:
1. 2005 aerial photography provided by the Delaware Valley Regional Planning Commission (DVRPC).

Figure 4: Historical Investigation Areas and Proposed Site Characterization Activities for AOI-2
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Sunoco, Inc. (R&M)
Philadelphia Refinery
3144 Passyunk Avenue
Philadelphia, PA.
19145

0 60 120 240 Feet

SCALE: 1" = 120'
DATE: March 9, 2010
DRN. BY: MH
CKD. BY: DW
JOB#: 2574601

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Legend

December 2009 Groundwater Data

- S-9 VOCs in ug/l Benzene - 7 — Fill/Alluvium/Trenton Gravel Monitoring Well with Exceedance of PADEP MSCs
- S-8 VOCs in ug/l Benzene - 61 — Lower Sand Monitoring Well with Exceedance of PADEP MSCs
- S-2 — Fill/Alluvium/Trenton Gravel Monitoring Well with No Exceedance of PADEP MSCs
- S-69D — Lower Sand Monitoring Well with No Exceedance of PADEP MSCs
- S-21 3.24' — Fill/Alluvium/Trenton Gravel Monitoring Well with LNAPL and Apparent LNAPL Thickness
- S-19 — Monitoring Point Not Sampled
- S-7 — Abandoned/Damaged
- December 2009 Groundwater Elevation Contour (ft amsl)

Proposed Activities

- S-284D — Proposed Deep Monitoring Well
- S-80 — Proposed Shallow Soil Sample, Shallow/Intermediate Monitoring Well
- BH-01-10 — Proposed Shallow Soil Boring

Existing, Historical Investigation and Historic Use Areas

- Ballfield Historic Investigation Area
- Past Disposal Areas (PDAs)
- AOIs
- Impervious Surfaces
- RW-2 Remedial System
- Industrial/Ecological Receptors
- Historic Use Areas
- Solid Waste Management Unit (SWMU)
- Bulkhead

Tank Content

- Crude Oil
- Dewatering
- Intermediate
- Light and Chemical
- Waste Water Treatment Plant (WWTP)
- Removed Tanks

Notes:
1. 2005 aerial photography provided by the Delaware Valley Regional Planning Commission (DVRPC).

Figure 5: Historical Investigation Areas and Proposed Site Characterization Activities for AOI-3
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Sunoco, Inc. (R&M)
Philadelphia Refinery
3144 Passyunk Avenue
Philadelphia, PA.
19145

0 70 140 280 Feet

SCALE: 1" = 140'
DATE: March 9, 2010
DRN. BY: MH
CKD. BY: DW
JOB#: 2574601

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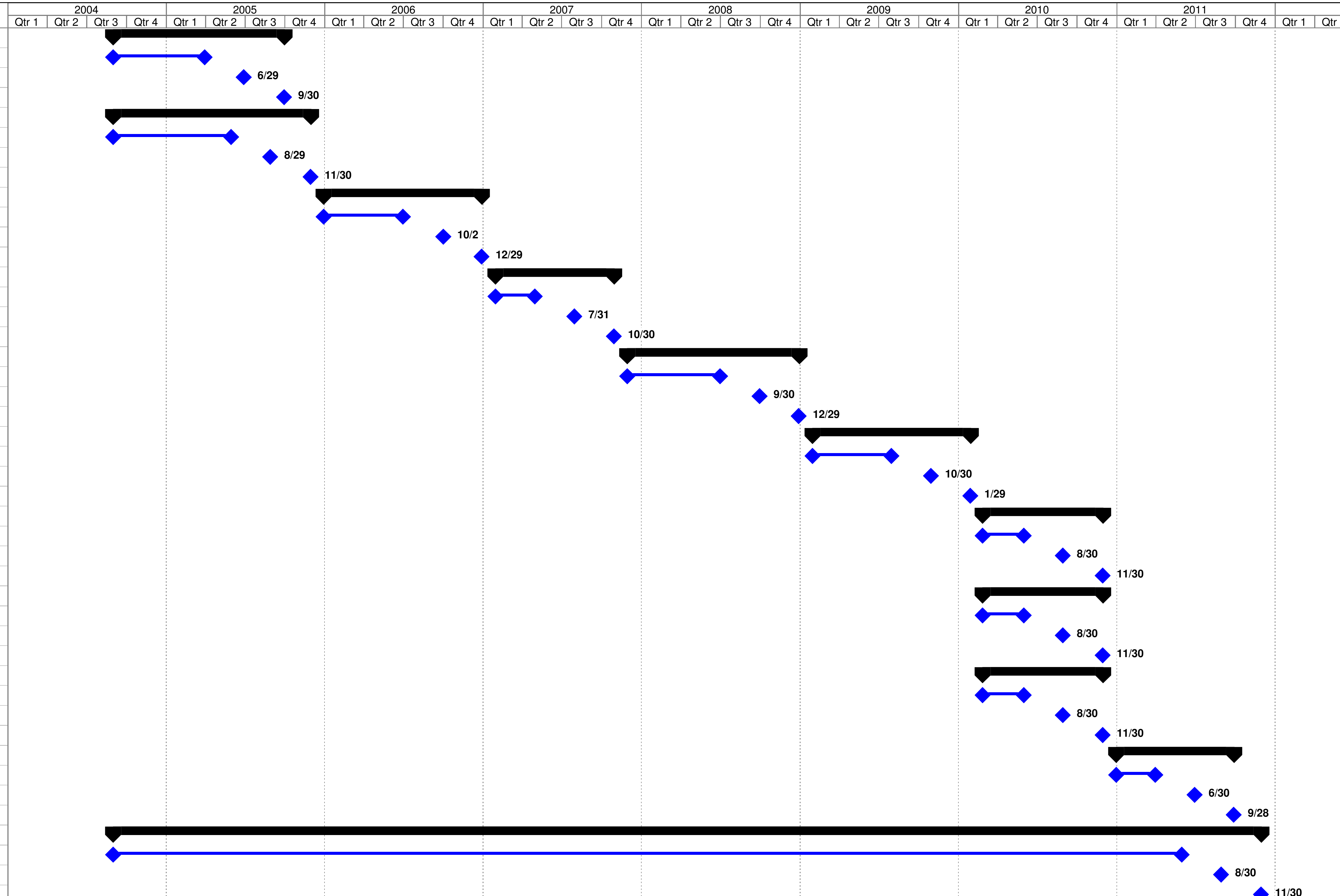
APPENDIX A

REVISED PHASE II CORRECTIVE ACTION ACTIVITIES SCHEDULE

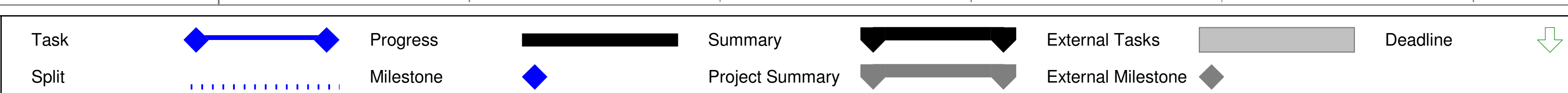
Appendix A

Revised Phase II Corrective Action Activities

ID	Task Name
1	**AOI 1**
2	Characterization
3	Submittal of Site Characterization Report
4	PADEP Comments
5	**AOI 4**
6	Characterization
7	Submittal of Site Characterization Report
8	PADEP Comments
9	**AOI 6**
10	Characterization
11	Submittal of Site Characterization Report
12	PADEP Comments
13	**AOI 5**
14	Characterization
15	Submittal of Site Characterization Report
16	PADEP Comments
17	**AOI 8**
18	Characterization
19	Submittal of Site Characterization Report
20	PADEP Comments
21	**AOI 9**
22	Characterization
23	Submittal of Site Characterization Report
24	PADEP Comments
25	**AOI 3**
26	Characterization
27	Submittal of Site Characterization Report
28	PADEP Comments
29	**AOI 2**
30	Characterization
31	Submittal of Site Characterization Report
32	PADEP Comments
33	**AOI 7**
34	Characterization
35	Submittal of Site Characterization Report
36	PADEP Comments
37	**AOI 10**
38	Characterization
39	Submittal of Site Characterization Report
40	PADEP Comments
41	**AOI 11**
42	Characterization
43	Submittal of Site Characterization Report
44	PADEP Comments



Project: Figure 19 Phase 2 Corrective
Date: Tue 4/14/09



APPENDIX B

HISTORICAL AERIAL PHOTOGRAPH REVIEW SUMMARY

APPENDIX B

HISTORICAL AERIAL PHOTOGRAPH REVIEW SUMMARY
AOIs 2 and 3 WORK PLAN FOR SITE CHARACTERIZATION
SUNOCO PHILADELPHIA REFINERY
PHILADELPHIA, PENNSYLVANIA

AOI 2 Historical Aerial Photographs

Available historical aerial photographs with coverage of AOI 2 were obtained from the Library of Philadelphia's Map Collection Department and reviewed to identify specific areas for characterization and to assist in determining previous uses of AOI 2. Aerial photographs were reviewed for the following years: 1930, 1945, 1959, 1965, 1970, 1975, 1980, 1985, 1990, 1995 and 2005. A brief summary of each aerial photograph is provided below.

- The 1930 aerial photograph depicts a series of above ground storage tanks (AST's) throughout the northern and southeastern portions of AOI 2. Railroad spurs are visible at the eastern property line of AOI 2 extending to the south-southwest portion of AOI 2. A railroad line appears to extend from the eastern property line of AOI 2 into AOI 3. Land disturbances are visible along the southwestern corner of AOI 2. Two large buildings are located in the western portion of AOI 2. Ships are visible along the Short Pier area in the Schuylkill River.

- The 1945 aerial photograph depicts an increased density of building structures located in the southwest corner of AOI 2. Ships are visible along the Short Pier area in the Schuylkill River. All other features in the aerial photograph appear to be similar to the 1930 aerial photograph.

- The 1959 and 1965 aerial photographs no longer depict railroad spurs in the northwest corner of AOI 2. A railroad line is still visible extending from the eastern property boundary of AOI 2 into AOI 3. Several ASTs have been removed in the northern portion of AOI 2.

- The 1970 aerial photograph depicts the railroad line extending into AOI 3. Additional ASTs appear to have been removed throughout AOI 2.

- The 1975 aerial photograph depicts the waste water treatment plant located in the northern portion of AOI 2. The railroad line is still visible extending south into AOI 3. Additional building structures are located in the northern portion of AOI 2 where ASTs once existed. Additional ASTs have been removed throughout AOI 2.

- 1980 and 1985 aerial photographs depict parking areas and additional building structures in the northern portion of AOI 2. The railroad line is no longer visible in AOI 2. Additional ASTs have been removed in the southeastern corner of AOI 2. Ships are docked along the Short Pier area in the Schuylkill River.

- The 1990 to 2005 aerial photographs show similar site features as depicted on the 1985 aerial photograph.

AOI 3 Historical Aerial Photographs

Available historical aerial photographs with coverage of AOI 3 were obtained from the Library of Philadelphia's Map Collection Department and reviewed to identify specific areas for characterization and to assist in determining previous uses of AOI 3. Aerial photographs were reviewed for the following years: 1930, 1945, 1959, 1965, 1970, 1975, 1980, 1985, 1990, 1995 and 2005. A brief summary of each aerial photograph is provided below.

- The 1930 aerial photograph depicts AOI 3 as unimproved land. Land disturbance is visible along the northern portion of AOI 3. A railroad line extends along the northeastern boundary of AOI 3 and extends to the southern portion of the AOI 3. A series of railroad spurs exist throughout the southwestern portion of AOI 3. Two rectangular building structures were present: one in the northeastern corner and the other in the southern portion of AOI 3.

- The 1945 aerial photograph depicts one AST in the northwest corner of AOI 3. Located immediately south of this AST appears to be a storage area. Land disturbance was visible throughout the northern portion of AOI 3. Additional railroad spurs were present throughout the central portion of AOI 3.

- The 1959 aerial photograph depicts five additional ASTs in the northern portion of AOI 3, identified as the #5 Tank Farm area. Additional smaller building structures are visible in the central portion of AOI 3. One large square building structure, identified as the Central Warehouse, is visible south of the #5 Tank Farm area. A surface water feature identified as the Guard Basin was present along the southeastern portion of AOI 3.

- The 1965 aerial photograph depicts similar features as observed in the 1959 aerial photograph. Two circular land disturbance features are visible east of the Guard Basin.

- The 1970 aerial photograph depicts the removal of railroad spurs in the southern portion of AOI 3, west of the Guard Basin. Land disturbances are visible north and east of the Central Warehouse. A drainage channel extends to the Guard Basin along the eastern boundary of AOI 3. Two circular land disturbance features are still visible east of the Guard Basin.

- The 1975 aerial photograph depicts the removal of most railroad spurs in the southern portion of AOI 3. Increased land disturbance is visible throughout the central and southern portions of AOI 3. The small building structures once located south of the Central Warehouse appear to have been removed. Two circular land disturbance features are still visible east of the Guard Basin.

- The 1980 aerial photograph depicts land disturbances in the central and southern portions of AOI 3. Ballfields are visible in the central portion of AOI 3. The two circular land features east of the Guard Basin appear to have been filled in.

- The 1985 aerial photograph depicts a road to the west and south of the Guard Basin. All other features appear to be similar to the 1980 aerial photograph.

- The 1990 aerial photograph depicts a large surface water feature west of the Guard Basin. The central portion of AOI 3 where land disturbances were once visible appears to be re-vegetated.

- The 1995 aerial photograph depicts similar features as the 1990 aerial photograph, with the exception of a parking area shown south of the Central Warehouse. The ballfields appear to have been removed.

- The 2005 aerial photograph shows similar site features as depicted on the 1995 aerial photograph.

APPENDIX C

FIELD PROCEDURES

APPENDIX C
FIELD PROCEDURES
AOIs 2 and 3 WORK PLAN FOR SITE CHARACTERIZATION
SUNOCO PHILADELPHIA REFINERY
PHILADELPHIA, PENNSYLVANIA

C.1. LIQUID LEVEL ACQUISITION

Responsible Personnel: Technicians and Geologists

Training Qualifications:

All field personnel involved in liquid level acquisition shall have, as a minimum, completed OSHA 40 HOUR HAZWOPER training and completed the 3-day minimum field training requirements as specified within the Corporate Health and Safety Plan. Prior to solo performance of liquid levels, all field personnel will have performed a minimum of three site visits under the direct supervision of experienced personnel.

Health and Safety Requirements:

Personal Protective Equipment (PPE) Required:

Level D attire including steel toe/steel shank boots. Based on previous site visits or current air monitoring results, Level C attire may be required. The PPE required to upgrade to Level C may include: nitrile gloves, disposable outerboots, Tyvek coveralls, and a respirator. Safety glasses or hard hats may also be required in certain areas.

Site Controls:

Safety cones and or caution tape should be used in high traffic areas. The "Buddy System" may also be employed in high traffic areas.

Potential Hazards:

Traffic, pinch and trip, chemical (airborne and physical contact) and biological. Additional hazards are mentioned in site-specific HASP.

Materials and Equipment Necessary for Task Completion:

Electronic oil/water interface probe or conductivity water line, decontamination supplies (Liquinox, deionized-distilled water, appropriate containers, scrub brush, and sorbent pads or paper towels), air monitoring instrument (optional, based on previous site visits).

Methodology:

The task involves the deployment of a liquid sensing probe into a well (in most cases), recording the reading, and decontaminating the probe. The recorded field readings can then be utilized for one of several applications including: well sampling, water table gradient mapping, separate-phase hydrocarbon occurrence, thickness, and or gradient mapping, and various testing procedures.

The proper procedure for liquid level acquisition from a well is as follows:

1) The wells should be gauged in order of least to most contaminated based on existing sampling data or separate-phase hydrocarbon occurrence.
2) The gauging instrument is decontaminated prior to initial deployment and after each well to prevent cross contamination between wells.
3) Decontamination procedures include the following steps:
    a) Remove gross contaminants with sorbent pad or towel.
    b) Rinse/scrub equipment with water.
    c) Scrub equipment in Liquinox®/deionized-distilled water solution.
    d) Double rinse with deionized-distilled water.
    e) Air dry.
4) The well(s) to be gauged may need to be marked off with safety cones and or caution tape in order to protect personnel from auto traffic; the "Buddy System" may also be employed.
5) The manhole cover is then lifted off of the well head. A pry bar may be needed to prevent personal injury in the case of large manhole covers.
6) The probe is lowered into the well until the instrument signals contact with liquid.
7) The corresponding reading is recorded when the instrument signals either water or product. A clear bailer may be used to verify the existence or approximate amount and appearance of product.
8) The probe is then retracted from the well and decontaminated accordingly.
9) The well is then secured appropriately.
10) Note the start and stop time for gauging round in the field book.

C.2. GROUNDWATER MONITORING PROCEDURES

Responsible Personnel: Technicians and Geologists

Health and Safety Requirements:

Site specific HASP must be completed and reviewed by field personnel. Ambient air monitoring will be performed quarterly at all treatment areas to determine the necessity of PPE upgrade. As a minimum, level "D" attire will be worn.

Training Qualifications:

All field personnel involved in groundwater monitoring shall have, as a minimum completed OSHA 40 HOUR HAZWOPER training and completed the 3 day minimum field training requirements. Prior to groundwater monitoring, all field personnel will have sampled a minimum of three sites under the direct supervision of experienced personnel. Field personnel will also have experience in vapor monitoring techniques and sampling equipment decontamination.

Materials and Equipment Necessary for Task Completion:

A list of equipment required to access, gauge, purge, and sample site monitoring wells is presented below. Also listed are materials necessary to store, label, preserve, and transport groundwater samples.

- Current site map detailing well locations;
- Field data book for recording site data;
- Liquid level gauging device (graduated, optical interface probe);
- Keys and tools to provide well access;
- Appropriate sample containers and labels: volatile samples will be collected in laboratory provided 40 milliliter (ml) glass vials with plastic caps fitted with Teflon ® lined septa; all sample bottles will be laboratory sterilized and will contain the appropriate preservative, if applicable;
- Appropriate well purging apparatus as determined by volume of groundwater to be purged and compounds to be analyzed;
- Teflon ® (or equivalent) bottom-loading bailer to extract groundwater sample;
- Clean nylon or polypropylene bailer cord;

- Disposable nitrile sampling gloves;
- Decontamination supplies;
- Calibrated five-gallon bucket and watch or stopwatch to determine discharge rate during purging;
- Blank chain-of-custody forms; and
- Cooler and ice for sample preservation.

Methodology for Three Well Volume Sampling:

Prior to actual site visitation for the groundwater sampling event, the following data will be reviewed to ensure proper preparation for field activities:

- Most recent liquid level data from all wells;
- Most recent analytical data from all wells to determine gauging and sampling sequence; and
- Well construction characteristics.

Each monitoring well to be sampled will be gauged to obtain liquid level data immediately prior to initiation of the sampling process. Refer to Liquid Level Gauging SOP for appropriate well gauging procedures. Liquid level data will be recorded in a field book. Should free-phase petroleum product be detected by the gauging process and verified through inspection in a pre-cleaned acrylic bailer, groundwater sampling will not be conducted at that location.

The sampling procedure will be initiated by purging from the well a minimum of three well volumes, except in cases where the well is pumped dry, as referenced below. Well purging is performed to remove stagnant water and to draw representative water from the aquifer into the well for subsequent sampling and analysis for the established parameters. In extreme cases where a well is pumped dry and/or shows little recharge capacity, the well will be evacuated once prior to sample procurement. Well volume calculations will be based on total well depth as determined during well installation and depth-to-water measurements obtained immediately prior to sampling.

Down hole pre-purge, post-purge, and sampling water quality readings will be collected. The parameters to be monitored and recorded will include dissolved oxygen, turbidity, pH, specific conductance, redox potential, and temperature.

Well purging is performed with various equipment including 1) a dedicated bailer for hand bailing low volumes of water, 2) a surface mounted electric centrifugal pump with dedicated polyethylene tubing, or 3) submersible pump (when the depth to water is greater than 20 feet) with dedicated polyethylene tubing. During pumping, the intake will be placed directly below the static water surface and slowly lowered during the purging process. This procedure may not prove necessary in low-yielding wells but is important in high-yielding, permeable strata where an intake initially placed deep in a well may draw laterally and have little influence in exchanging water from shallower depths within the well bore.

Flow rate during well purging will be approximated by the bucket and stop watch method. The duration of pumping required to remove three well volumes will be calculated directly from this flow rate. All fluids removed during purging will be treated on-site with activated carbon.

The sequence of obtaining site groundwater samples will be based upon available historical site data for existing wells and soil organic vapor analyzer (OVA) readings for newly installed wells. Site wells will be sampled in order from the lowest to highest concentration of water quality indicator parameters based upon the most recent available set of laboratory analyses to reduce the potential for sample cross-contamination. Groundwater samples will not be obtained for analysis from any well containing a measurable free product layer.

The following sequence of procedures will be implemented for the collection of groundwater samples from monitoring wells.

1) Establish a clean work area where sampling equipment will not come in contact with the ground or any potentially contaminated surfaces.
2) Use a laboratory, pre-cleaned Teflon® sampling bailer for each well.
3) Don an unused, clean pair of nitrile gloves.
4) Attach an appropriate length of unused, clean nylon or polypropylene cord to the designated sampling bailer.
5) Select appropriate laboratory-sterilized sample containers.
6) Slowly lower sampling bailer into well until water surface is encountered; continue to lower the sampling bailer into the standing water column to one foot below the water surface.
7) Retrieve bailer at a steady rate to avoid excess agitation.

8) Visually inspect bailed sample to ensure that no free product or organic detritus has been collected.
9) Uncap first designated sample vial and fill from bailer as rapidly as possible but minimizing agitation; secure septum and lid.
10) Inspect sealed sample for entrapped air; if air is present within sample vial. Remove lid and repeat vial filling, sealing and inspection process until no air is present.
11) Repeat Steps 9 and 10 for the second designated vial; all volatile parameter samples will be collected in duplicate.
12) Complete and attach labels to sample containers noting sample collector, date, time, and location of sample; record same data in field book.
13) Place samples in ice-filled cooler in such a manner as to avoid breakage. Samples collected for VOC analysis will be maintained at a temperature of 4°C.

Discard gloves and bailer cord and move to next sample location.

Methodology for Low-Flow Purging and Sampling:

For wells that will be Low-Flow purged and sampled, the USEPA Region III Bulletin QAD023: *Procedure for Low-Flow Purging and Sampling of Groundwater Monitoring Wells* will be followed. The following data will be reviewed for each well in order to set the pump intake for the low flow sampling:

- Soil boring (lithologic) log and continuous soil sample PID;
- Well construction log showing the screened interval;
- Identification of the most permeable zone screened by the well;
- Approximate depth to static water;
- Proposed pump intake setting; and
- Technical rationale for the pump intake setting, preferably across from the most impacted/contaminated subsurface interval.

Equipment

Adjustable rate, submersible, bladder pumps in conjunction with Teflon® or Teflon-lined polyethylene tubing for purging and sampling will be used. The tubing diameter will be between 3/16-inch to ½-inch inner diameter and the length of the tubing extended outside the well will be minimized. Flow through cells will be used to evaluate parameters during sampling. Monitoring well information, equipment specifications, water level measurements, parameter readings, and other pertinent information will be recorded during monitoring well purging and sampling.

Sampling Procedure

The following protocol details the low-flow sampling procedure that will be used for sampling the monitoring wells.

1. PID Screening of Well. A PID measurement will be collected at the rim of the well immediately after the well cap will be removed and recorded on the sampling form.
2. Depth to Water Measurement. A depth to water measurement will be collected and recorded. To avoid disturbing accumulated sediment and to prevent the inadvertent mixing of stagnant water, measuring the total depth of the well will be done at the completion of sampling on an annual basis.
3. Low Stress Purging Startup. Water pumping will commence at a rate of 100 to 400 milliliters per minute (mL/min). This pumping should cause very little drawdown in the well (less than 0.2-0.3 feet) and the water level should stabilize. Water level measurements are made continuously and will be recorded in milliliters per minute on the sampling form.
4. Low Stress Purging and Sampling. The water level and pumping rate will be monitored and recorded every five minutes during purging, and any pumping rate adjustments will be recorded. During the early phase of purging, emphasis will be placed on minimizing and stabilizing pumping stress, and recording any necessary adjustments. Adjustments, when necessary, will be made in the first 15 minutes of purging. If necessary, pumping rates will be reduced to the minimum capabilities of the pump to avoid well dewatering. If the minimal drawdown exceeds 0.3 feet, but the water level stabilizes above the pump intake setting, purging will continue until indicator field parameters stabilized, as detailed in Step 5 below. If the water level drops below the pump intake setting at the absolute minimum purge rate, the pump will remain in place and the water level will be allowed to recover repeatedly until there will be sufficient water volume in the well to permit the collection of samples.
5. Indicator Field Parameters Monitoring. During well purging, indicator field parameters (DO, turbidity, pH, specific conductance, and redox potential) will be monitored every five minutes (or less frequently, if appropriate). Purging will be considered complete and

sampling began when all the aforementioned indicator field parameters had stabilized. Stabilization will be achieved when three consecutive readings, taken at five (5) minute intervals (or less frequently, if appropriate), are within the following limits:

- DO (±10 percent);
- turbidity (±10 percent);
- specific conductance (±3 percent);
- pH (± 0.1 unit); and
- redox potential [Eh] ±10 mv).

Temperature and depth to water will be also monitored during purging. Should any of the parameter-reading components of the flow-through meter fail during sampling; the sampling team will attempt to locate a replacement flow-through meter. If none is available, the sampling team will measure that parameter with an individual criteria meter. Any other field observations relating to sample quality, such as odor, foaming, effervescence, and sheens, will also be recorded on the sampling form.

6. <u>Collection of Ground Water Samples</u>. Water samples for laboratory analyses will be collected before the groundwater had passed through the flow-through cell by either using a by-pass assembly or by temporarily disconnecting the flow-through cell. All sample containers will be filled by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence. During purging and sampling, the tubing remains filled with water in order to minimize possible changes in water chemistry upon contact with the atmosphere. Methods employed to ensure that the outlet tubing will be filled include (i) adjusting the tubing angle upward to completely fill the tubing and (ii) restricting the diameter of the tubing near the outlet of the tubing.

   The order in which samples will be collected is as follows:

   - Volatile organics;
   - Gas sensitive (e.g., Fe^{+2}, CH_4, H_2S/HS);
   - Base/Neutrals or PAHs;
   - Total Petroleum Hydrocarbons;
   - Total metals;

- Dissolved metals;
- Cyanide;
- Sulfate and chloride;
- Nitrate and ammonia;
- Preserved inorganic;
- Non-preserved inorganic; and
- Bacteria.

Decontamination Requirements:

Numerous practices are employed throughout the processes of site investigation and sampling to assure the integrity of the resulting data. Of particular significance to the procedures of groundwater measurement and sampling is the limitation, whenever possible, of materials inserted into a well bore and, even more importantly, of materials transferred from well to well.

Many items can be discarded between well sampling and/or gauging locations without significantly impacting project costs. Dedicated sampling equipment which can be discarded between well sampling locations without significantly impacting project costs, will be used whenever possible to preclude decontamination requirements. Sampling equipment included in this category are Teflon ® bailers, nitrile gloves, and bailer cord. However, other investigative and sampling equipment, including such items as liquid level probes, must be reused from well to well.

The danger in multi-well equipment applications lies in the potential of cross-contamination. While the threat of cross-contamination is always present, it can be minimized through the implementation of a consistent decontamination program during sensitive site measurement and data collection activities. The decontamination procedure is outlined below:

All site equipment used in a multi-well capacity will be decontaminated immediately prior to initial use and between each well. Standard site decontamination procedures for the optical interface probes between wells will be performed according to the following schedule:

- Initial rinse with clean tap water to remove excess residuals;
- Scrub equipment with sponge or clean, soft cloth in a distilled water/Liquinox@ (or equivalent) solution; and
- Double rinse with deionized/distilled water.

Rinse water generated during decontamination procedures will be treated on-site by passing the water through a bucket filled with activated carbon prior to disposal.

C.3. SOIL SAMPLING & WELL INSTALLATION

Responsible Personnel: Geologist

Training Qualifications: All field personnel supervising drilling activities shall have completed OSHA 40-Hour training, and three days of field training. Personnel supervising the well installation shall have observed drilling procedures for a minimum of three under the direct supervision of experienced personnel. Field personnel will have experience in operating the following field equipment: interface probe and photo-ionization detector (PID). Personnel should be able to describe soils encountered during drilling for generation of well logs.

Health and Safety Requirements:

A site specific HASP must be completed and reviewed by all field personnel. Prior to deploying a rig to the site, a utility call must be made (i.e. Pennsylvania One-Call) to allow mark-out of known subsurface utilities and associated laterals proximal to the site. Site plans, if available, should be reviewed to document and avoid the location of on-site utilities. No drilling should occur on retails sites within the exclusion zone. This zone is defined as the area between the pumps, the tank field and the station building. The area is excluded from drilling activities due to the likely occurrence of subsurface petroleum distribution lines. After review of all known mapped and marked utilities, a site reconnaissance will be performed to document the location of utility meters and storm sewer drains. In addition, the location of overhead utilities must be documented. After completing the subsurface and overhead utility review, the area to drill may be observed as clear or the location may be adjusted to a “clear” location.

Once the drilling location is established, the area must be marked with cones to alert area traffic of the work area. Other health and safety concerns include slip/trip hazards, working with heavy equipment and overhead work hazards. During drilling activities, a minimum of protective work gloves, steel toed boots, hard hats, and safety goggles must be worn.

A final health and safety requirement includes hand clearing the borehole, prior to advancing the borehole with the drill rig. To ensure the safety of workers, the borehole will be cleared by hand or air knife, to depth of 5 feet below ground surface. This will serve to clear the area of utilities, prior to drilling.

Decontamination Requirements:

All down-hole equipment must be steam cleaned prior to drilling at each boring/well location. All soil sampling equipment must be cleaned with detergent and rinsed with distilled water prior to deployment into the borehole. All well construction materials (i.e. PVC well casing, PVC well screen, sand pack, bentonite seal) should be clean and dedicated to each hole.

Methodology for Borings Outside RCRA Areas in AOIs 2 and 3:

1) Borehole Advancement

During soil sampling or well installation activities, a borehole is advanced into the unconsolidated subsurface materials or bedrock via a drill rig (or similar). Various types of drilling methods could be deployed to advance the hole. A description of each drilling method is included below:

a) Hollow Stem Auger

A spiral tool form is used to move material from the subsurface to the surface. A bit at the bottom cuts into the subsurface material. Spiral augers on outside convey the material to the surface while spinning. The center of the auger is hollow like a straw when the inner drive rods and plug are removed. During drilling or formation cutting, the center is filled with rods connected to a plug at the bottom bit. Once the desired drilling depth is reached, the center plug and rods can be pulled out, leaving the hollow augers in place. The hollow augers hold the borehole to remain open for sediment sampling and well installation.

b) Air Rotary

A drill bit at the bottom of rods is used to cut into the subsurface material. Air injected into the drill rods escapes through small holes in the drill bit and conveys the drill cuttings to the surface.

c) Geoprobe®

The geoprobe® sampling allows collection of soil by directly pushing (through hydraulic hammering) a sampling device lined with a plastic macrocore into the soil column.

d) Hand Auger

A stainless steel or aluminum hand auger will be physically advanced to the desired soil sampling depth.

2) Soil Sampling

Soil samples will be obtained for lithologic logging and laboratory analysis for chemical contaminants with one of three different sampling devices: Split barrel spoon sampler, hand auger or Geoprobe® soil sampler. For either method, the sampling devices are lowered through the hollow-stem augers or open borehole to allow sampling of the undisturbed sediments below the auger bit. Soil samples will be collected at intervals which appear to be visually impacted or from intervals which exhibit the highest deflections on the screening device (PID or similar).

a) Split barrel spoon sampler (split spoon)

The split spoon sampler will be driven into the soil column in accordance with ASTM Standard Method D1586 (Reference A6, Appendix E). Soil sampling by split barrel spoon will entail drilling a borehole with a hollow-stem auger to the desired sampling depth (standard five foot intervals). After augering to the desired depth, slowly and carefully lower the split barrel spoon sampler attached to the drill rod extension into the borehole. Drive the sampler into the soil by repeated blows from a 140 Lb. hammer with 30 inch travel. Record the blow counts required to drive the split spoon sampler each successive six inch interval. Remove sampler for borehole, split barrel open, remove soil sample utilizing a stainless steel knife to trim the top and edges of the sample and containerize sample in appropriate sample jar.

b) Geoprobe®

The geoprobe® liner is dedicated to each soil sampling interval. After retrieval of the sample, the liner may be sliced open and the soil sample can be logged and containerized in the appropriate sample jar. During shallow soil sampling from fine-grained sediments, the geoprobe® can advance the sampler directly into the ground, without the advance of an augered borehole.

c) Hand Auger

The hand auger allows for soil from the desired interval to be collected directly by removing the soil column that is contained in the auger portion of the device.

Methodology for Borings Around the Perimeter SWMU 3 and PDAs in AOI 3:

1) Borehole Advancement

During soil sampling activities at SWMU 3/PDAs, boreholes will be advanced via a geoprobe® or hand auger. Actual leaded tank bottom materials are distinguished by distinctive rust/red to black, metallic mostly oxidized scale materials. Leaded tank bottoms are also sometimes in a matrix of petroleum wax sludge. Borings will be completed around the perimeter of SWMU 3 to a depth of two feet below ground surface. If materials encountered match the physical description stated above, they will be delineated through additional borings and sampling.

2) Soil Sampling

Soil samples will be obtained for lithologic logging and laboratory analysis for chemical contaminants with one of two different sampling devices: Geoprobe® soil sampler or hand auger. Soil samples will be collected at intervals which appear to be visually impacted or from intervals which exhibit the highest deflections on the screening device (PID or similar). If soil samples are collected in the SWMU area and exhibit total lead concentrations exceeding 450 mg/kg (Act 2 non-residential MSC for lead), then the samples will be submitted for hazardous characteristic analysis under RCRA.

Methodology for Well Installations:

1) Well Construction

After drilling to the desired depth or the desired interval, permanent monitoring wells can be installed to allow groundwater sampling. In general, wells are constructed with slotted screen, which allows groundwater to flow into the well at the desired monitored interval and well casing, which restricts groundwater flow into the well from undesired interval. In most cases the well materials are constructed of PVC. In conditions where the shallowest groundwater interval is monitored, a single case construction monitoring well is installed. In conditions where multiple water bearing units occur and deep groundwater conditions are selected for monitoring, a double cased well is installed.

a) Single Casing Construction

The construction details of a monitoring well are determined by soil type, depth to groundwater and relative fluctuation of groundwater level. After drilling to the desired depth, a monitoring well is constructed for installation into the evacuated borehole. The well consists of a bottom cap, a length of screen and length of well casing. To determine the length of screen used, seasonal groundwater table or tidal fluctuations should be considered to allow the water table to intercept the well screen throughout the year. The assembled well is then inserted into the borehole.

The annular space between the well screen and subsurface is filled with a sand pack, which consists of clean, sorted sand. The sand pack allows water flow into the well but acts as a filter to prevent subsurface sediments from silting in the well. The sand pack extends one to two feet above the top of well screen. Above the sand pack, a seal is installed in the annular space between the well casing and the subsurface. The seal is comprised of hydrated bentonite and prevents surface water from infiltrating the well screen. Above the well seal, the annular space is backfilled with drill cuttings or cement. A cap is placed on the top of the well to further prevent infiltration of the surface water. The top of the well is protected with either a stand-up pipe or a locking, flush mount box.

b) Double Casing Construction

In cases where multiple water bearing zones occur, a double case well is installed to allow monitoring of the deeper water bearing zones. Construction of a double cased well is similar to that of a single case well; however, to prevent groundwater infiltration from shallower water bearing zones, a second casing is installed. This type of construction requires drilling two different diameter boreholes.

During drilling through the shallower groundwater zones, large diameter augers/bits are used to create a large diameter borehole. The borehole is advanced through the shallower water bearing area which will not be monitored. An outer casing is installed to seal the deeper monitoring well from infiltration from the shallow water bearing zones. After the outer casing is installed, the borehole is advanced deeper with smaller diameter auger/bit. The outside diameter of second augers fit within the inside diameter of the outer casing. The borehole is advanced to allow monitoring of the deeper water bearing zone. Once the desired depth is obtained, a monitoring well is installed within the outer casing, using similar methods as described in the single casing construction (3a, above). The outside casing prevents shallow groundwater infiltration into the well. The inside casing prevents surface water infiltration into the well.

2) Soil Cutting Handling

Cuttings generated from drilling will be containerized or stock-piled, undercover, until appropriate disposal is determined. In the case the soils are not impacted, the cuttings may remain on-site. Impacted soils will be removed using appropriate hazardous waste handling procedures and disposed of with an approved hazardous waste handler.

3) Well Development

After installation, monitoring wells are developed to remove residual sediments within the well and annular space. Water is pumped from the well a low flow rate (to minimize turbulence within the well and associated sand pack) until groundwater flowing from the well appears relatively free of sediments.

Documentation:

All site activities should be detailed in the site investigators fieldbook. The entry shall include the date, time, weather, address, and persons present on-site. In addition, data required to create well construction logs or boring logs (if no well is constructed) should be collected. This data includes soil type, relative moisture content, depth of water table, observed impact, soil screening measurements (if PID is used), blow counts (if split spoon samples are collected), sample recovery, depth of borehole, length of well screen, length of well casing(s), sand pack interval, well seal interval. The site investigator should identify the relative location and number.

C.4. NON-AQUEOUS PHASE LIQUID (NAPL) SAMPLING PROCEDURES

Responsible Personnel: Technicians and Geologists

Training Qualifications:

All field personnel involved NAPL sampling, as a minimum completed OSHA 40 HOUR HAZWOPER training. Prior to NAPL sampling, all field personnel will have worked a minimum of three sites under the direct supervision of experienced personnel. Field personnel will also have experience in sampling and vapor monitoring techniques and sampling equipment decontamination.

Materials and Equipment Necessary for Task Completion:

A list of equipment required to sample NAPL from a monitoring well is presented below:

- Current site map detailing well locations;
- Field data book for recording site data;
- Liquid level gauging device (graduated, optical interface probe);
- Keys and tools to provide well access;
- Appropriate sample containers and labels. NAPL samples will be collected in laboratory provided 40 milliliter (ml) glass vials with plastic caps fitted with Teflon ® lined septa; all sample bottles will be laboratory sterilized and will contain the appropriate preservative, if applicable. A minimum of 10 ml is required for laboratory analysis. In the case that sufficient volume is not obtained, a swabbing technique (described below) will be used;
- Sorbent pads (required for swabbing technique);
- Teflon ® (or equivalent) bottom-loading bailer to obtain NAPL sample;
- Clean nylon or polypropylene bailer cord;
- Decontamination supplies;
- H&S supplies (tyvek, nitrile gloves, safety goggles);
- Blank chain-of-custody forms; and
- Cooler and ice for sample preservation.

Health and Safety Requirements:

Site specific HASP must be completed and reviewed by field personnel. As a minimum, modified Level "D" attire will be worn. Individuals performing NAPL sampling are required to wear safety goggles, tyvek suit, and nitrile sampling gloves.

Decontamination Requirements:

During NAPL sampling activities, dedicated sampling equipment (i.e. Teflon ® bailers, nitrile gloves, and bailer cord) are utilized; thereby, eliminating decontamination requirements. The interface probe, used to record the presence of NAPL and relative thickness prior to sampling, does require decontamination between sampling locations.

All site equipment used in a multi-well capacity will be decontaminated immediately prior to initial use and between each well. Standard site decontamination procedures for the optical interface probes between wells will be performed according to the following schedule:

- Initial rinse with clean tap water to remove excess residuals;
- Scrub equipment with sponge or clean, soft cloth in a distilled water/Liquinox® (or equivalent) solution; and
- Double rinse with deionized/distilled water.

Methodology:

Each monitoring well to be sampled will be gauged to obtain liquid level and relative NAPL thickness immediately prior to initiation of the sampling process. Refer to SOP No. 1 for appropriate well gauging procedures. Liquid level data will be recorded in a field book.

Sampling of the NAPL will occur via two different methods: 1) direct sample or 2) swabbing.

The following sequence of procedures will be implemented for the collection of groundwater samples from monitoring wells.

1) Establish a clean work area where sampling equipment will not come in contact with the ground or any potentially contaminated surfaces.
2) Use a laboratory, pre-cleaned Teflon® sampling bailer for each well.
3) Don an unused, clean pair of nitrile gloves.
4) Attach an appropriate length of unused, clean nylon or polypropylene cord to the designated sampling bailer.
5) Select appropriate laboratory-sterilized sample containers.
6) Slowly lower sampling bailer into well until water surface is encountered; continue to lower the sampling bailer into the standing water column to one foot below the water surface.
7) Retrieve bailer at a steady rate to avoid excess agitation.
8) Visually inspect bailed sample to ensure for relative thickness of NAPL. If sufficient volume is present (>10 ml) place a direct sample of the NAPL into the laboratory vial. If less than 10 ml of NAPL is present, use a sorbent pad to absorb the NAPL from the surface of the groundwater sample. Place is swab sample into the laboratory vial.

9) Complete and attach labels to sample containers noting sample collector and date, time, and location of sample; record same data in field book.
10) Place samples in ice-filled cooler in such a manner as to avoid breakage. Samples collected for VOC analysis will be maintained at a temperature of 4°C.
11) Discard gloves and bailer cord and move to next sample location.

Documentation:

All site activities should be detailed in the site investigators fieldbook. The entry shall include the date, time, weather, address, persons present on-site, and the aforementioned parameters. Only relevant observations should be recorded. The nature of the work being performed is also appropriate.

C.5. PUMPING TESTS

Responsible Personnel: Hydrogeologists, Engineers and Technicians.

Training Qualifications: All field personnel performing pumping tests shall have completed OSHA 40-Hour training, and three days of field training. Personnel directing the pumping test shall have assisted with a minimum of three tests under the direct supervision of experienced personnel. Field personnel will have experience in operating the following field equipment: interface probe, data logger, submersible pump, related piping and fittings, flow meter and portable generator.

Health and Safety Requirements:

A site specific HASP must be completed and reviewed by all field personnel. Caution must be exercised in set up of electrical equipment, particularly the placement of pumps in a well which could be impacted by floating product. Other health and safety concerns include slip/trip hazards, and area traffic.

Decontamination Requirements:

Pump, discharge lines, hand held probes and all pressure transducers must be cleaned with Alconox and distilled water prior to installation in wells at site, and again following removal. Any water sampling activities to be incorporated during the test must be prepared and used in accordance with the Groundwater Monitoring SOP.

Methodology:

1) Pre-test Considerations:

Some site specific information regarding the geology and hydrogeology of the subject site is needed to determine the most appropriate type of pumping test and to estimate the reliability of the test results. Lithologic logs of the subject site will indicate whether the zone of interest is an unconsolidated formation or a bedrock formation. They should also give a strong indication as to whether the zone of interest is a water table formation, a confined formation or a leaky-confined formation, and whether any preferential (vertical or horizontal) transmissivity may be expected. Logs and/or slug test data will also provide indications as to what test yield is sustainable, and provide a rough indication of the areal extent pumping will influence. Additional pre-test considerations include any obvious positive or negative hydraulic barriers, any tidal effects, and /or any influence from other wells pumping in the area.

Often times, budget considerations and/or time limitations will necessitate the use of a monitoring well as the test pumping well. While this is generally acceptable, the well must be screened deep enough to allow design drawdown to be achieved and friction losses (well loss) in the pumping well must be taken into consideration when the test data are analyzed. A minimum of three monitoring wells in the vicinity of the test pumping well are needed to evaluate formation response. Ideally, the wells should all be at varying distances from the test pumping well and screened across the same zone.

Pumping tests are broken into two general classifications: step tests and constant rate tests. Step tests involve pumping a well at progressively higher rates, at set intervals of one or two hours per step. They are often used to determine the yield a well will sustain during a constant rate test and to evaluate well loss (frictional head loss between the screen/gravel pack and the formation). Constant rate tests are used primarily to evaluate aquifer coefficients for design of groundwater treatment systems and/or water supply purposes. In high sensitivity sites, where budgets permit, the best method is to do a step test first, to evaluate well loss and long term sustainable yield, allow 24 hours of recovery and then initiate the constant rate test.

The test duration is subject to site specific data requirements (i.e. sensitivity. required test goals, etc.) and to budget considerations. Optimally, a constant rate test will be run until all drawdowns have stabilized, and gravity drainage effects are curtailed; however, this is seldom practical due to time limitations. In most instances, an 8 hour constant rate test will be adequate, and a 24 hour test will be sufficient for higher sensitivity sites. Occasionally a 72 hour pumping test is warranted, though this is usually reserved for large scale water supply work. If there are any unexplained water level anomalies observed toward the scheduled end of a test, the test should be continued if at all possible.

The approximate test flow rate needs to be determined in advance for proper pump and discharge design selection. If it is not appropriate to perform a step test, sustainable yield can be estimated from slug test data or a brief (<30 minutes) pumping episode the day before the actual test. Generally, it is best to pump the well at as high a rate as is feasible order to obtain the greatest formation response data from the test. However, if floating product is present at or near the pumping well, drawdown needs to be limited so as not to impact uncontaminated soils below the water table. In these instances drawdown should be limited to less than 5 feet. In water table formations, if there is no concern regarding floating product, drawdown should not exceed two-thirds of the wetted screen depth due to the effects of friction loss.

If the test discharge is contaminated, it must either 1) treated prior to discharge or 2) containerized for off-site disposal. If it is to be discharged directly on- site and allowed to re-infiltrate (verses discharged to a catch basin) it must be routed sufficiently far enough from the test area as to avoid any artificial recharge effects. All appropriate discharge permits must be obtained and complied with. If discharge water is to be treated on-site, proper contaminant loading calculations for the test flow rate, approximate contaminant loading and test duration must be done in advance to insure treatment is completely effective. Any on-site treatment should also have at least one discharge effluent sample lab analyzed to document treatment effectiveness.

2) Pumping Test Set Up:

Prior to starting the test, all well measuring points (i.e. top of casing) should be clearly marked and vertically surveyed to the nearest 0.01 feet. The horizontal distance and orientation of all wells should be surveyed to the nearest 0.1 feet, and illustrated on the site base map. If there are any surface water bodies in the vicinity, a staff gauge should be set up and surveyed in to evaluate possible influences.

The preferred pump to be used for a pumping test is a submersible centrifugal pump ("Grundfos", or equivalent), run off either existing site power or a portable generator. These pumps are not explosion proof, so a conductivity probe must be tied into the pump controls to alleviate any possibility of product coming into contact with the pump. If the test pump is designed to pump total fluids (e.g. air operated double diaphragm pump, jack pumps, etc.)

discharge must either be containerized, or treatment must include an oil/water separator to handle any floating product. The submersible pump should be positioned just above the bottom of the well, using a handling line to support the pumps weight.

NOTE: extreme care must be taken that the power cord is neither bearing any of the pumps weight, nor damaged during installation due to the potential for sever electric shock.

Discharge piping from the pump should include a flow meter (preferably with totalizer), followed by a flow adjustment valve. The flow meter should be installed in a straight section of hard piping of sufficient length to avoid meter distortion caused by turbulence (typically about 10 pipe diameters on either side of the meter). In low flow pumping tests, flow rate can be calculated by measuring the exact time required to fill a known sized container.

Ideally, groundwater levels should be static prior to starting the test, so that pumping influences alone can be readily evaluated. Water levels in all monitoring wells and/or nearby surface waters should be gauged a minimum of two times during the 24 hours prior to starting test pumping; readings should not have varied by more than 0.10 feet. Any significant precipitation events within the previous several days will usually result in noticeable water level changes (barometric changes have significant influences in confined and semi-confined formations). If there are any major water level changes that cannot be accounted for prior to test pumping, additional investigation into possible area influences (e.g. local well pumping or construction de-watering) should be conducted.

Exact water level measurements (to the nearest 0.01 feet) and exact time denotations during the test are critical to achieving accurate test results. All personnel involved with taking measurements during the test should have watches with a second hand, and they should all be calibrated to the same time. Adequate liquid level measurements can be obtained using an interface probe ("ORS", "Solinst", etc.) for those wells with floating product. In wells clear of floating product, an electric water level detector ("Solinst", "Hazco", "M-Scope", etc.) or chalked steel tape will provide accurate measurements. All non-dedicated probes must be properly decontaminated after each level reading to prevent any possibility of cross contamination between wells.

Automatic water level recorders are typically used during pumping tests to augment hand measurements and to obtain reliable early time-drawdown data. A pressure transducer allows measure of changes in groundwater levels by measuring differences in pressure experienced by the transducer. The pressure transducers are manufactured by "In-Situ" and are available with many types of data loggers. Some data loggers are capable of connecting to several transducers (Hermits) while others collected data from one transducer (Trolls and Mini-Trolls). The measured depth data for each probe is digitally stored in the data logger as depth (in feet) at a specific elapsed time. At the conclusion of the test, the data logger is brought back to the office, and the test data is down loaded into a computer for analysis.

The transducer is installed in each well to a depth several feet lower than the greatest drawdown depth anticipated. The transducer cable is secured at this depth with duct tape or cable ties attached to the well head, and the transducer is plugged into the data logger. The transducer must not be submerged deeper than the allowable operating pressure, which is noted on each transducer cable spool in PSI. Care must be taken that the transducer cable is not damaged from rough edges at the well head, and that no vehicles run over the cable. In addition, any wells with floating product require an inner PVC stilling well to be installed to prevent the transducer cable from being damaged from contact with product. The stilling well will also eliminate the need for any water level corrections for product thickness.

In terms of prioritization, transducers should be utilized in the wells closest to the pumping well and then pumping well. Wells further from the pumping well can be successfully monitored by hand, due to the reduced likelihood that early time drawdown will be critical. Despite having transducers in given wells, back up hand readings should be taken at least hourly during the first 8 hours of the test, and then at least every 3 hours, to verify the transducer levels.

After the transducers are installed in the wells, and connected to the data logger, hand measurements are taken at each well with a transducer. These levels are then entered into the data logger as initial reference points for comparison to the depths measured by the transducers. Readings from the transducers are not completely reliable until they have been emerged for at least 30 minutes, due to the effects of probe temperature equilibrium.

3) Running the Test:

Prior to starting the pumping test, the data logger must be completely formatted for that particular test, and the operator must be completely familiar with the start up sequence. If possible, the pump discharge control valve should be pre-set to the desired flow rate prior to turning on the pump. However, depending on the test pumps performance curves, minor flow rate adjustments are generally needed during the first hour or two of the test to correct for the additional head experienced by the pump due to increasing drawdown. In addition, movement of the discharge hose after the test has been started should be avoided, since any change in the elevation of the discharge will affect the pumping rate. All changes in flow rate should be recorded with the exact time noted.

A minimum of two field personnel are needed to run a pumping test, with additional personnel required for tests with high complexity. One person should be designated to turn on the pump, adjust the flow rate, check on discharge treatment, etc. The second person should be stationed at the data logger to turn it on at the exact moment the pump is turned on. The data logger will record liquid levels very rapidly during the first part of the test, dropping off logarithmically to what ever intervals are formatted (one measurement every 20 minutes is normal). When the data logger has been activated and is running, early time drawdown measurements should be taken by hand from any wells near the pumping well that do not have transducers.

Any hand monitored wells near the pumping well should be measured frequently during the first few hours of the test, with less frequent measurements during the remainder of the test. A rough rule of thumb is one measurement every half minute during the first 5 to 10 minutes, one every 3 to 5 minutes during the first hour, and one every 10 to 20 minutes for the second hour, and then each well hourly. After the test has been running for a few hours, the transducer level readings should be compared to the hand measurements for verification, or later correction.

It is essential that some data reduction be accomplished in the field, so that major water level trends are recognized during the test. At a minimum, drawdown trends from the pumping well and two of the nearest monitoring wells need to be semi-log plotted against time so that deviations indicative of boundary conditions can be discerned before pumping is ceased. This will allow decisions to be made about whether the test should go for longer than planned.

Generally, water quality samples are taken during a test for laboratory analysis of compounds of interest. These are generally taken after the first hour of pumping and just prior to pump shutdown. If the test is of more than 24 hours duration, it is advisable to get running samples during the middle of the test as well. All samples should be obtained following sampling SOP's.

At the conclusion of the test, water level recovery data should be taken. The recovery data should plot out to an approximate inverse mirror image of the drawdown curve, with feet of recovery measured from the theoretical drawdown that would have been observed if pumping had continued. Recovery data behaves as if there were a nearby well recharging the formation, following image well theory. It has the advantage that there are no variations in the curve produced by variations in pumping rate. In water table aquifers, however, the effects of formation de-watering can cause the recovery trends to be substantially different from drawdown trends. Consequently, recovery data should be used for comparison purposes only, but not relied upon as heavily as drawdown data.

4) Data Analysis:

The data produced by pumping tests are analyzed to estimate aquifer performance characteristics, such as transmissivity, conductivity and storage, which in turn are used to predict groundwater flow under various circumstances. One of the more useful analytical products is a determination of capture zone, which is widely utilized in aquifer contamination work. Capture zone (Keely & Tsang, 1983) calculations describe the radial area (down gradient and side gradient) that a pumping well will draw groundwater in from. In the case of a contamination site, this equals to that portion of the plume a given recovery well(s) will influence, at a given pumping rate(s). Aquifer coefficients determined from a pumping test can be applied to a capture zone analysis for the determination of the best recovery system for a given plume. When the recovery system is operational, capture zone calculations can then be used to evaluate the effectiveness of the system at addressing the contamination plume, what pumping rate is optimal for controlling the plume, and the need for any additional wells. It must be noted, however, that capture zone calculations are relatively simplistic, and far from absolute. Consequently, they should be used with considerable margin for safety, and employed with a large measure of common sense.

The mathematical solutions used in pumping test analysis include many assumptions typical "real world" formations violate in one or more way (e.g., "the formation is of uniform thickness and of infinite areal extent"). In addition, some of the values incorporated into typical pumping test solutions are not actually measured, but are educated estimates (e.g. porosity based on lithology, etc.). Consequently, even the most carefully designed and executed pumping tests have severe precision limitations, and the solutions should never be considered absolute. This is why groundwater flow evaluations are generally conceded to be "a mixture of science and art", and all solutions require a strong application of common sense and experience.

Many problems associated with pumping test data evaluation are due to not recognizing, and/or correcting for, deviations from the theoretical solution employed. Some of the more common errors occur due to: partial penetration effects, formation de-watering effects, casing storage effects, poor pumping well efficiency and/or the application of incorrect equations or units. Consequently, a thorough understanding of the underlying assumptions inherent to the solution employed is required before the validity of the results can be trusted. There are numerous references that describe pumping test analyses. Some of the more recommended references include: Driscoll's "Groundwater & Wells" (1986); Lohmans "Ground-water Hydraulics" USGS Professional Paper 708 (1979) and Fetter's "Applied Hydrogeology" (1980). In addition, the USGS published "Aquifer-test Design, Observation, and Data Analysis" in 1983 by Robert W. Stallman (Applications of Hydraulics, Book 3, Chapter B 1). This is an excellent, common sense, guide to pumping test set up, measurements and data analysis.

Two of the more common pumping test equations used and their applications are listed below:

1) Cooper-Jacob (1946); time-drawdown & distance-drawdown methods: Test data is plotted on semi-log paper, and the slope is used in the solution. Both solutions assume the formation is confined; however, this distinction lessens over time as drawdown becomes stabilized. Distance-drawdown has an added advantage in that it allows water level to respond from across the site to be used, which accounts for some lithologic variations.

2) Boulton (1963), modified by Neuman (1975): This solution is used for determining aquifer coefficients in water table formations, taking gravity drainage (delayed yield) effects into account. Time- drawdown data is plotted on log-log paper and two Theis type curves are matched to get early time-drawdown and late time drawdown, respectively. While this solution most closely matches typical floating product recovery work, it is difficult to apply and often subjective, due to the inherent nature of curve matching solutions.

It is usually appropriate to analyze pumping test data by more than one solution to get a range of aquifer performance values. These values can be averaged, or the most conservative value can be used, or the best fit based on experience can be presented. The computer program "Aqtesolv", produced by Geraghty & Miller, is a very useful tool for solving pumping test solutions. Data from an Insitu data logger can be imputed to the Aqtesolv, and curve matching solutions can be produced automatically, or with some adjustments.

C.6. SLUG TESTS

Responsible Personnel: Hydrogeologists, Engineers, and Technicians

Training Qualifications:

All field personnel performing pumping tests shall have completed 40 HOUR OSHA training and 3 day field requirements. Personnel directing slug tests shall have assisted in at least 3 previous slug tests under the supervision of experienced personnel.

Materials and Equipment Necessary for Task Completion:

"Insitu" Hermit data logger, with one pressure transducer; interface tape or equivalent water level measuring device; "slug in" water displacement cylinder, or large bailer, 5 gallon pail, traffic cones and/or barricades, decontamination water and brush, alconox and decontamination pail.

Health and Safety Requirements:

A site specific HASP must be completed and reviewed by all field personnel. Caution must be exercised in test set up, particularly regarding vehicular traffic. Other concerns regard possible handling of free product, and slip/trip hazards.

Decontamination Requirements:

Any water level measuring probes, bailers and the water displacement cylinder must be cleaned with alconox and distilled water prior to use, and between uses at each well monitoring. Any groundwater and/or free product bailed must be disposed of in an approved manner, preferably in a properly installed, on-site holding tank.

Methodology:

Slug tests are utilized to obtain rough estimates of aquifer performance coefficients. They involve calculations based on the water level response of a well to the addition or subtraction of a known volume. They can be broken into two basic types of field exercises: slug-in tests and slug-out tests. As their names imply, slug-in tests involve the addition of water (volume) to the well, while slug-out tests involve the removal of water (volume). Water level response is monitored immediately following the displacement change, and for the next hour or so until the well has returned to approximately 90% of its original static level. Water level responses can be measured either rapidly by hand or with an "Insitu" Hermit data logger (or equivalent).

1) <u>Field Procedures</u>:

Exact well completion details are needed to perform slug test calculations. These include: total depth, total screened interval, depth to static water, casing diameter, screen diameter, gravel pack diameter and gravel pack interval. While these details should be documented on the well log, static water level and total depth should be field confirmed before the test. Where possible, several wells per site should be slug tested to obtain an average conductivity value for a site, or to evaluate lithologic variables across a site. Addition data comparisons are accomplished by performing both slug-in and slug-out tests on the same well, where time permits.

Slug-In Tests: The slug-in method is best accomplished by lowering a cylinder of known volume into the well, and measuring the water level response over time. The displacement volume should be sufficient to cause a several foot initial change in the water level. In the case of a typical 4 inch diameter monitoring well, a simple displacement cylinder can be constructed using a 3 inch diameter PVC casing, capped at both ends and filled with clean sand. An over all length of 5 feet provides adequate displacement volume for a typical water table well having about 10 feet of standing water. A steel eye should be bolted into one cylinder cap for attachment of a disposable lowering rope (discard lowering rope between wells to prevent any cross contamination).

If a Hermit data logger is to be used for a slug-in test, the transducer should be set in the well at least one foot below where the bottom of the displacement cylinder will rest upon insertion, but not lying on the bottom (beware of silt clogging the transducer tip). Depth to water should be measured and compared to the transducer reading for correlation. When the Hermit has been properly imputed for the slug test, the hermit should be activated and the displacement cylinder should be rapidly, but carefully, lowered into the well to below the water surface. *NOTE: Take particular care that insertion of the displacement cylinder does not damage the transducer or cable.* When activated, the Hermit will be automatically recording time and water levels, starting at 6 readings per second, and then decreasing exponentially over time. If water level changes are to be taken by hand, they must be carefully obtained at least every minute. When the well has recovered to about 90% of its original static level, the test may be concluded. If the test has proceeded for an hour and not recovered to at least 90% of the original static, additional data will be of marginal value and the test may be concluded.

2) Slug-out Tests:

Slug-out tests are performed in the same basic manner as slug-In tests, only by removing a known volume from the subject well. In wells that recharge rapidly during slug-in tests, a slug-out test can be performed by merely resetting the Hermit and extracting the displacement cylinder. The more conventional method of performing a slug-out test is to use a single long hand bailer to remove a known volume of water from the well. Typical bailers used for 4 inch diameter monitoring wells are either long steel bailers (similar to those often used by drillers to develop monitoring wells) or 2 Lexan sample bailers joined end to end to form one single long bailer. The bailer is lowered into the well prior to starting the Hermit, and the slight water level rise from the bailer is allowed to stabilize back to static. The Hermit is then activated, and the bailer is rapidly removed from the well, thereby creating the instantaneous. The test is run to 90% recovery, or one hour, like the slug-in test. If the bailed water is contaminated, it must be disposed of properly via either storage in an on site holding tank or on-site treatment with a portable carbon treatment container.

The validity of slug test values are highly field dependant. Some of the more common field oriented problems arise from:

a) Subject wells are not adequately developed prior to testing;

b) Formation slough occurred during drilling, so gravel pack volume is underestimated;

c) Water displacement is not instantaneous due to the bailer leaking during extraction;

d) The pressure transducer is jarred during water displacement; and

e) Water level changes are too rapid to get accurate measurements.

3) Data Analysis:

Field data from slug tests can be analyzed by hand or using "Geraghty & Millers" Aqtesolv computer program. If the field data was taken with the Hermit, the data can be transferred to Aqtesolv for analysis, saving considerable time over hand analysis. There are four well recognized analytical methodologies general employed. These methods and their assumptions are listed on the following table:

Application	Hvorslev	Bouwer & Rice	Cooper	Nguygen-Pinder
Confined Fm.	**X**	**X**	**X**	**X**
Unconfined Fm.	**X**	**X**		**X**
Screened across water level		**X**		
Accounts for partial penetration	**X**	**X**		**X**
Specific storage >0			**X**	**X**
Allows for anisotropy	**X**			
Assumes infinite borehole storage	**X**	**X**	**X**	**X**

As illustrated on the table above, slug tests performed in water table formations can be solved using either Hvorslev or Bouwer & Rice methods. The Bouwer & Rice method has the advantage of accounting for screening across the water table, while the Hvorslev method allows for anisotropy. Confined formation slug tests can be analyzed by any of the four methods, though the Cooper method is most often used. It is often beneficial to solve slug tests by more than one method to evaluate possible conductivity ranges.

It must be stressed that slug test data is very approximate and limited in its accuracy. It is generally conceded that conductivity' values derived from slug tests are usually within an order of magnitude of the real conductivity, and therefore are only approximations. Consequently, any judgments based on slug test values must be used with extreme caution and incorporate a large measure of common sense and experience.

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